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IN TWO PARTS—PART 2

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# PROCEEDINGS OF THE FOURTH INTERNATIONAL FISHERY CONGRESS: ORGANIZATION AND SESSIONAL BUSINESS, PAPERS AND DISCUSSIONS

HELD AT WASHINGTON, U. S. A. : : : SEPTEMBER 22 TO 26, 1908

IN TWO PARTS

PART 2

Issued August, 1910

## ANNOUNCEMENT.

The proceedings of the Fourth International Fishery Congress are published herewith in accordance with the instructions of the Congress. By authority of the Secretary of Commerce and Labor and the Commissioner of Fisheries, the Bulletin of the Bureau of Fisheries for 1908 is devoted to this purpose. In thus providing a medium for publication, the Bureau of Fisheries assumes no responsibility for any of the statements or views of the individual members or the Congress as a whole.

HUGH M. SMITH,
*Secretary-General.*

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By John W. Titcomb
*Assistant in Charge of the Division of Fish Culture*

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

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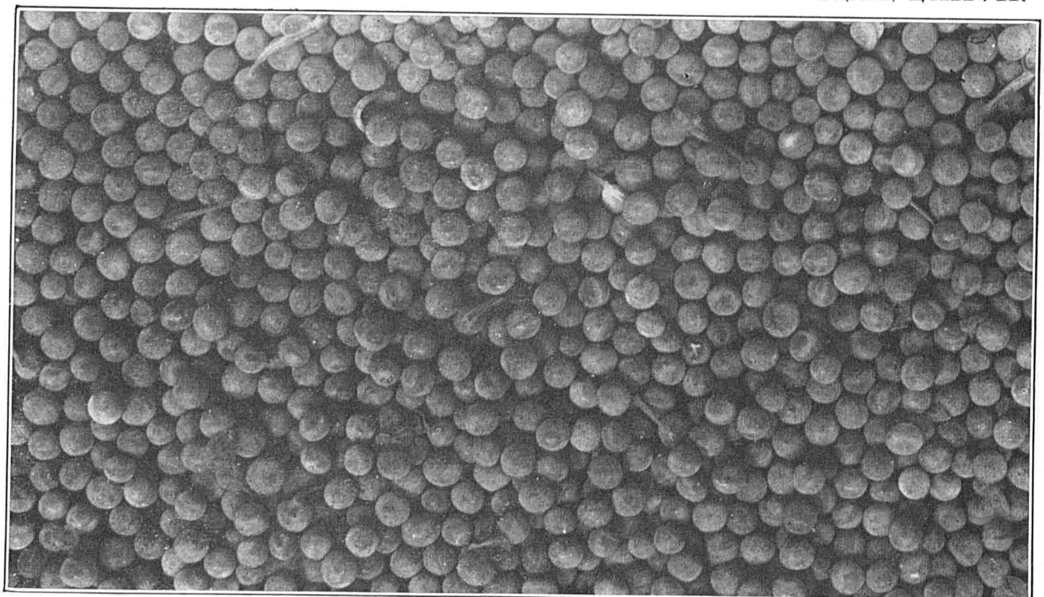

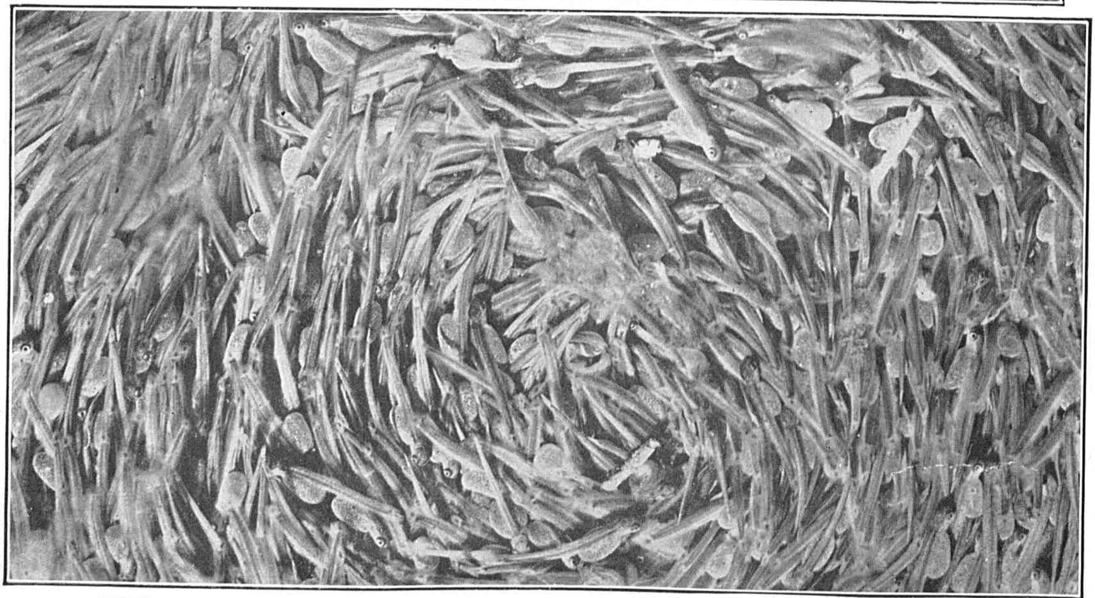

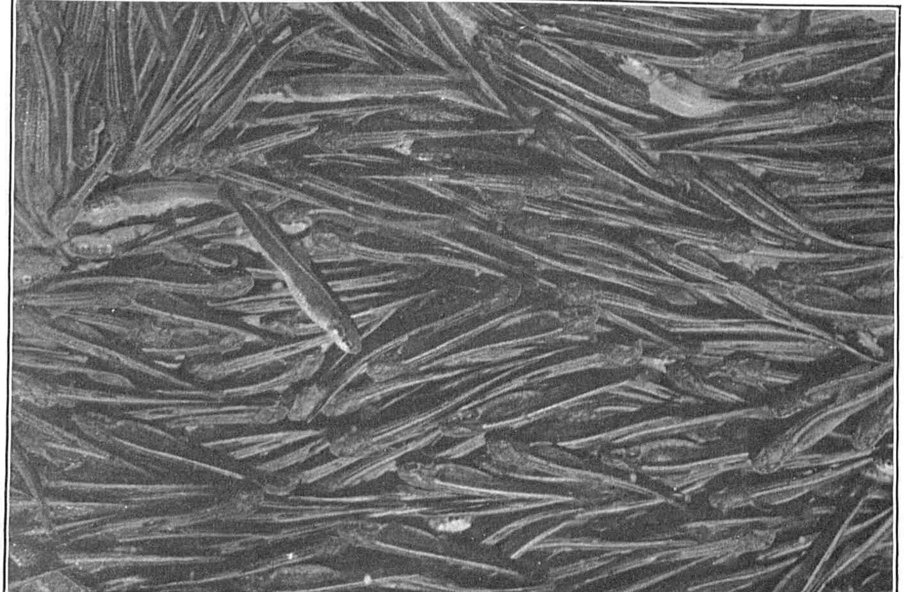

FIG. 1.—Brook trout eggs on tray, just beginning to hatch.
FIG. 2.—Brook trout fry in trough, sac stage.
FIG. 3.—Brook trout fry, sac nearly absorbed, ready to feed.
Figures about natural size. See also figure 12, plate LXXXII.

# FISH-CULTURAL PRACTICES IN THE UNITED STATES BUREAU OF FISHERIES.[a]

By JOHN W. TITCOMB,
*Assistant in Charge of the Division of Fish Culture.*

## RESOURCES OF THE BUREAU.

The fish-cultural work of the United States Bureau of Fisheries, administered from headquarters at Washington through the Division of Fish Culture, is conducted by means of numerous hatching stations located in various parts of the country, including Alaska. There are thirty-two such stations recognized for administrative purposes. Auxiliary to these are numerous field stations, some of them equipped as hatcheries and in operation throughout the year, others used only during the spawning season of the fishes they are concerned with. The land owned by the Bureau at its fish-cultural stations has an aggregate area of 12,000 acres, valued at $225,000. The improvements on this land in buildings, ponds, and special equipment represent an investment of about $1,000,000. The Division of Fish Culture has 225 civil-service employees, whose salaries aggregate approximately $200,000; while there is an annual appropriation of $275,000 for the maintenance and operation of stations, including the employment of temporary laborers and assistants in fish-cultural work.

It will be my endeavor to allude to some of the more important phases of the fish-cultural work which these resources make possible, and to explain more fully than would otherwise be permissible features of the work in which recent changes in methods or equipment have not heretofore been so fully illustrated or described.

## EXTENT AND GENERAL METHODS OF THE WORK.

During the fiscal year 1908 the Bureau distributed fish and eggs to the number of 2,871,456,280. The table accompanying gives an idea of the extent of the work for a series of years.

[a] This paper as read before the International Fishery Congress was illustrated by lantern slides, to supply the absence of which in publication the text has been amplified.

AGGREGATE OF ADULT FISHES, YEARLINGS, FRY, AND EGGS DISTRIBUTED BY THE BUREAU OF FISHERIES FROM 1872 TO 1908.

| Species. | 1872–1897. | 1898–1908. |
|---|---|---|
| Shad | 1,379,247,350 | 1,381,209,594 |
| Salmons | 168,073,769 | 1,050,738,390 |
| Trouts | 70,499,665 | 506,781,985 |
| Whitefish and cisco | 1,579,923,409 | 3,889,418,135 |
| Basses | 7,212,403 | 34,702,267 |
| Perches | 796,027,818 | 5,056,995,274 |
| Cod, haddock, pollock, etc | 520,223,000 | 2,241,063,000 |
| Flounder | 94,522,019 | 1,921,625,000 |
| Other fishes | 47,446,864 | 7,217,024 |
| Lobster | 387,989,712 | 1,182,471,440 |
| Total | 5,051,166,009 | 17,272,222,109 |

The first column represents the output of the United States Fish Commission from its inception to the beginning of the present Commissioner's administration, a period of twenty-six years. The second column represents the output for the subsequent period of eleven years. The total operating expenses of the entire eleven years, 1898 to 1908, did not exceed those of the preceding twenty-six years, while the output has been more than trebled. About 50 species of fishes are now handled.

The results of fish culture, as shown by numerous replenished waters and by actual returns in fish, might easily be made the subject of a lengthy discourse, but for present purposes will be alluded to only incidentally. A marked evidence of success may be noted in the constantly increasing demand for young fish to plant. Notwithstanding the fact that the bureau, by the increase of its facilities and by progressive methods, has steadily increased its output, the demand of the public for fish has increased therewith until in some lines of work, notably the production of the basses, crappies, other sunfishes, and the catfishes, it is greater than can be met with present means.

It is a point to be emphasized that the fish-cultural work of the Bureau is of two classes with respect to its economy. Many of the most valuable food fishes, being in their prime for market purposes just prior to the spawning season, are most extensively captured at the very time they should be spared for the perpetuation of their kind. Whenever possible, the Bureau secures the eggs of these fish from the fishermen. Fully 96 per cent of all the eggs collected and hatched by the Bureau are taken and fertilized from fishes destined to the market, and this without detracting from the value or edible qualities of the parent fish.

The collection of fish eggs under these conditions is to be distinguished from the work which utilizes the eggs of fish that have reached their spawning grounds and which it is customary to capture for the express purpose of obtaining and fertilizing their eggs. The latter is fish culture in the usual sense—extensive increase of the numbers of young by protecting the eggs and providing the most favorable conditions for hatching. The other is fish culture also, but in addition to conservation of a resource that would otherwise be unavailed of.

Some of the freshwater species, valued chiefly as game fishes although marketed also, are cultivated by confining them under conditions which will secure the maximum reproduction by natural processes. Practically all of the important commercial fishes, however, can be propagated, and much more numerously, by stripping them of eggs and milt by hand and incubating the fertilized eggs in hatcheries. It is with these that the Bureau is most largely concerned, their numbers being nearly 98 per cent of the entire output of the hatcheries.

There are some variations in the methods of spawntaking, according to species, but in general the operation consists in expelling the eggs by a gentle pressure of the thumb and forefinger along the walls of the abdomen, the strokes being continued until all ripe eggs have been secured. The fish is usually grasped near the head, and to hold it firmly may be pressed against the body of the spawntaker. The receptacle into which the eggs are expelled is usually a 6-quart milk pan which has been dipped into the water and then emptied, thus leaving it slightly moist. Other forms of receptacles, such as marbleized or porcelain-lined pans or wooden vessels are sometimes used where the eggs are especially adhesive. The milt is obtained by the same process as the eggs, and applied to the latter in the pan used to receive them from the fish.

The hatching processes are, generally speaking, of three classes with respect to equipment, determined primarily by the specific gravity of the eggs. Heavy eggs, such as those of the trouts, salmons, and the grayling, are incubated in wire-bottom trays or wire baskets set in troughs of running water. The mesh of the wire is of size to suit the size of egg and to permit the young fish as they hatch to drop through into the trough. The troughs are usually plain open boxes varying in length from 12 to 16 feet and in depth from 4 to 12 inches, to suit conditions. An arbitrary width of 14 inches, inside measure, has been adopted, uniformity in width being desirable for economy in interior equipment. For handling large quantities of eggs the troughs are frequently provided with either permanent or removable partitions to regulate the direction of the current of water through the eggs. Thus they may be converted into so-called Williamson and Clark-Williamson types of troughs.

Semibuoyant eggs, such as those of the whitefish, pike perch, shad, yellow perch, and white perch, are usually hatched in glass jars. The styles of jar are in general two—closed top and open top, the McDonald Universal hatching jar being of the former pattern, the Chase, McDonald open-top, and Downing being typically the latter.

The principles of the McDonald Universal (patented) jar are familiar.[a] By substituting foı the closed top a screw-cap rim to which has been soldered a pitcher-like spout, the Universal or automatic jar may be converted into an open-top jar and thus is the preferable equipment at hatcheries where both closed and open-top jars are required. As an open-top jar it is operated the same as the Chase and Downing jars. At hatcheries where only open-top jars are used the Downing pattern is preferred.

## RIVER FISHES OF THE EAST COAST.

### SHAD.

The most important fish of the east-coast streams, the shad, is the especial object of three hatcheries—at Havre de Grace, Md., on the Susquehanna River; at Bryans Point, Md., on the Potomac; and at Edenton, N. C., on Albemarle Sound. The steamer *Fish Hawk* is also equipped as a hatchery, and utilized at such points as may be advantageous.

As all of the eggs for the hatcheries are obtained from market fish, the shad work is primarily conservation. The exhaustive fishing at the mouths of the rivers leaves, moreover, so few fish to reach the spawning grounds that the fishery is now, in the northern streams, entirely dependent upon the hatcheries, which are themselves interfered with by the scarcity of ripe fish. Recent legislation in North Carolina has widely restricted fishing so that there has been a notable improvement of conditions in that region, and much larger collection of eggs at Edenton.

Curiously enough shad are seldom caught in ripe condition during daylight until late in the afternoon. Thus the fishermen's catch of the late morning or early afternoon is not available for the rescue work of the spawn taker. But on the approach of evening during the spawning season of the shad, the Bureau's agents may be found leaving their camps to embark preparatory to being distributed on the various fishing boats or to fishing shores where shad in ripe spawning condition are to be had.

In the collection of shad eggs the fishermen often personally manipulate the ripe fish for eggs and milt, and it is customary for the Bureau to provide all such men with the usual spawntaker's equipment of pans, buckets, etc. It is always necessary to employ a force of experienced men to go among the fishermen, to see that the eggs of all ripe fish are saved, fertilized, and properly cared for until they reach the hatchery. It may not be amiss to say that spawntakers should also be experienced boatmen, not only as a matter of safety to themselves, but because the fishermen are averse to allowing inexperienced men in their boats.

[a] Manual of Fish Culture, revised edition, 1900, p. 138. Published by U. S. Bureau of Fisheries.

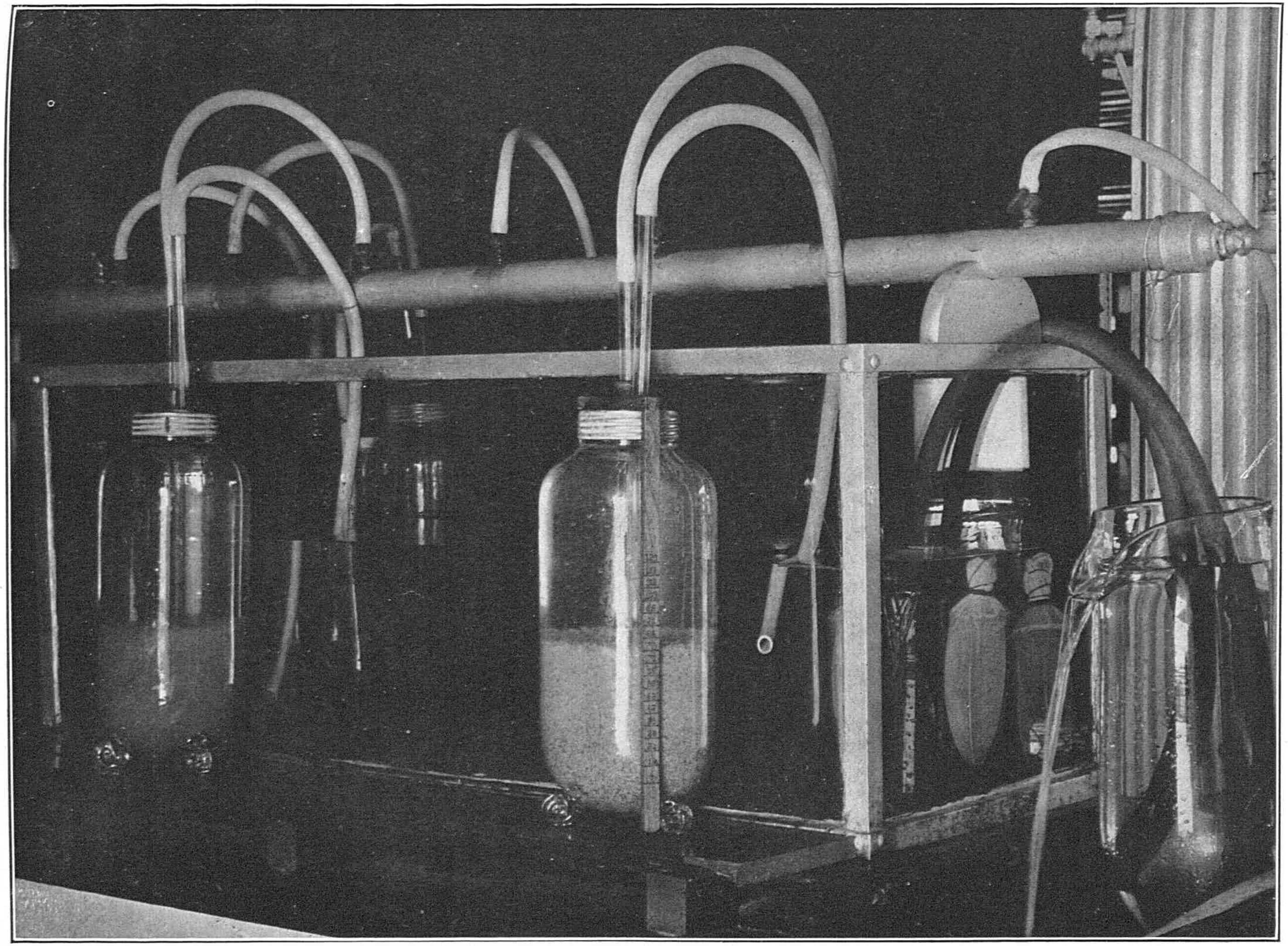

FIG. 4.—Hatching equipment for shad and other semibuoyant eggs. Over the inner ends of the tubes which serve as outlet for the aquarium is an elongate wire frame, screened with cheese cloth for white perch and other very small fry, with wire cloth for shad. (See reference on p. 705.) The jar at the right (Downing pattern) is here used, as might be any other open vessel, to maintain the desired water level in the aquarium, the outlet tubes siphoning directly into this. The scale attached to the jar (McDonald universal) in the center of the picture is the measuring device referred to on page 740.

The treatment of eggs of the shad after the milt has been applied is in substance as follows:

About half a pint of water from the river is dipped into the pan, which is then given a slow rotary motion until the milt is thoroughly mixed with the eggs. This pan with its contents is then set aside and another is used in a repetition of the process. After all the stripping has been done the milt is washed from each pan of eggs by dipping water from the river and pouring it off, repeating until the milky color of the water disappears. The pans of eggs, with about 1 pint of water in each, are then set aside; and after fifteen or twenty minutes it will be noticed that the eggs are absorbing the water. A little more water must then be added from time to time until they have fully expanded, which usually requires from forty to sixty minutes, but varies somewhat with the water temperature. When fully water-hardened, the eggs feel like shot to the touch of the fingers, and now, less sensitive to concussion, are ready to be transferred to the buckets in which it is customary to convey them to the hatchery.

En route to the hatchery it may be necessary every twenty or thirty minutes to replace the water on the eggs with water from the river in order to maintain an even temperature, the air on very cool nights affecting the water in the buckets to such degree as to injure the eggs.

The first thirty-six to forty-eight hours after arrival at the hatchery is the period of greatest mortality to the eggs, and until this has passed they are kept in open-top jars or in McDonald jars without tops, the water flowing through them being allowed to waste over the tops of the jars. The dead eggs being lighter than the live ones work toward the surface and are easily removed with a siphon of ½-inch rubber tubing. The good eggs are then measured (by means of a device which will be described later) and their number is accredited to the fisherman from whom they were obtained. They are then put up for hatching in the McDonald Universal (i. e., closed-top) hatching jars, which are arranged on specially constructed tables in connection with rectangular glass aquaria or receiving tanks and subjected to a current of about 4 or 5 pints of water per minute at 8 pounds pressure, which is sufficient slightly to elevate the eggs from the bottom of the jar, thus giving the entire mass a slow revolving or boiling motion. The number of eggs to each jar is from 85,000 to 100,000. As the young fish emerge from the eggs they rise toward the surface, where they come in contact with the suction outlet tube of the jar and pass through it with the waste water to the collecting tanks. From this they may be removed to the distributing cans by means of a ½-inch rubber siphon. Another method of removing them is to dip them from the aquaria after siphoning off a portion of the water. By this method, emptying an equal number of dippers of fry into each can, it is possible to quite equally distribute the total number to be removed.

## WHITE PERCH.

With the decadence of the valuable shad fishery there has arisen a demand for the artificial propagation of the white perch (*Morone americana*), and this work has been extensively conducted at the mouth of the Susquehanna River during the past four seasons in connection with the hatching of shad. Like shad culture, the propagation of white perch is purely the conservation of eggs which would otherwise go to market in the parent fish.

The spawning season in the latitude of the Bureau's station at Havre de Grace, Md., is from the middle of April to the latter part of May, the time varying with the character of season. The eggs are taken and fertilized by the usual dry method, the work being performed ordinarily by the fishermen. Owing to the adhesiveness of the eggs it is preferable to strip them into marbleized or porcelain-lined pans.

As with shad and other spring spawning fishes, the white perch spawns on a rising temperature, ripe fish being taken first when the temperature is about 47°. However, the eggs seem to produce better results when hatched in water of a higher temperature. At about 60° F. they hatch in forty-eight to fifty-two hours, while at 68° to 70° they hatch in twenty to twenty-four hours. They are sensitive to sudden drops in temperature, and although at 58° or 60° about 75 per cent of the eggs produce vigorous fry, at 50° or lower few if any eggs or fry survive. In one case eggs taken at 56° and held for twenty-four hours, after which the temperature dropped to 46°, finally hatched at a temperature of 54°, producing a fair percentage of fry. Observations thus far made indicate that eggs taken at mid-day or soon after mid-day produce better results than those taken earlier in the morning, although the reason has not been ascertained.

After being held for from six to twelve hours in jars without tops, white perch eggs are incubated and hatched in McDonald automatic jars on shad tables in the same manner as shad eggs. As they are especially liable to fungus, a good circulation is particularly important, and it is inadvisable to carry more than one-fourth capacity to a jar, or from 800,000 to 1,000,000. The eggs are comparatively heavy, and for this additional reason require more water circulation than is needed for shad, or 2½ to 3 quarts per minute. It is customary to reduce the flow about one-half during the last few hours before hatching, in order that fungussed masses and attached good eggs may not be carried out into the receiving tank.

When undeveloped the eggs are very white and hard, and it is difficult for the novice to tell the live ones from the dead. Some that apparently are dead suddenly eye and hatch, while, on the other hand, some apparently of good quality frequently fungus and prove a total failure. By examining in a glass tube, with which a few at a time may readily be removed from the jars, it is usually possible to distinguish the live eggs at any stage of development.

The eggs average 29 to the linear inch when first expelled and 28 to the inch after being water hardened. They are usually measured into the jars with a 1-quart apothecary's graduate, and are computed at 1,600,000 to the quart.

To guard against the escape of very small fry from the receiving aquarium the usual waste water outlet is closed, and the water is carried off by means of one or more siphons, the suction ends being provided with wire cages covered with two or three thicknesses of cheese cloth. To regulate the level of the water in the receiving tank the outlet ends of the siphons empty into an adjacent receptacle, usually a hatching jar, the rim of which is at the desired water level.

## YELLOW PERCH.

It is feasible, and under some conditions desirable, to expel and fertilize yellow perch eggs artificially, but under proper conditions practically all naturally deposited eggs are fertilized. For this reason the Bureau's work largely consists in the incubation of the naturally deposited eggs obtained from fish confined in crates for the purpose, and to some extent by collection of natural spawn in marshes where left by receding waters.

It has been found that the eggs can be hatched in almost any kind of container through which water is flowing—open troughs, open jars, shad aquaria, etc.—but careful experiments indicate that the McDonald open-top and the Downing jar are preferable to other kinds of equipment, the Downing jar possessing the advantage of greater capacity. It will hold 130,000 to 150,000 eggs, and when thus incubated the eggs are subjected to a water circulation of about 1 pint per minute.

As little has been published on the methods of culture of this fish, the data of the superintendent in charge of the yellow perch operations at Bryans Point, Md., will be given in some detail:

Here the fish are purchased from commercial fishermen, are held in crates having comparatively tight bottoms, and allowed to spawn naturally. The crates are 8 feet long, 4 feet wide, and 2½ to 3 feet deep, and are placed in the mouth of a small creek tributary to the Potomac reached by tide water from the river. A small number of fish are also kept in a large tank at the hatchery, through which there is a constant flow of river water in connection with the regular station supply.

The collecting of fish begins about the middle of March or when the water temperature ranges from 34° to 37°. The water temperature in which spawning occurs ranges from 42° to 46°. In 1908 the first eggs were obtained March

21 in a water temperature of 46°. Practically all the fish had finished spawning on April 1, at which time the water temperature was 58°. The spawn is taken daily from the crates and transferred to the hatchery in buckets.

The eggs are comparatively heavy, and are slightly adhesive when first deposited. The period of incubation in a water temperature of 47° to 54° is ten to twenty days. The absorption of the yolk sac requires a period of eight days in a mean temperature of 54°. On the Potomac River the average number of eggs from fish of one-half pound weight is about 15,000.

When measured into the jars the eggs are computed at 100,000 to the quart. Actual measurements of 10 eggs average 1.662 millimeters or 0.065 inch in diameter, but on account of the peculiar gelatinous envelope of the egg, these individual egg measurements are of no use whatever in estimating the number in a given volume.

## STRIPED BASS.

At Weldon, N. C., is a field station for the propagation of the striped bass (*Roccus lineatus*). It has been operated for a number of years with rather negative results as to the number of eggs collected, but with experience of much value as suggesting lines of improvement in methods of manipulating ripe fish and the eggs.

The chief obstacles to successful work in the propagation of this fish are the difficulties of obtaining ripe spawning females in numbers sufficient to produce large results, and of obtaining a ripe male at the time a female is available. Penning the fish has not proved successful. The delicate nature of the eggs and the limited period of incubation—1½ days—are reasons for believing that they can not be successfully transported from the source of supply.

The McDonald automatic hatching jars have been somewhat successfully used at Weldon, but the sac fry of the striped bass are more tender than those of any other fish and it was found that many were injured in their passage to the aquarium through the rubber tube of the closed top. The style of jar was then changed to open top, and has given highly satisfactory results. An elongation of the pitcher mouth by means of a trough of canvas delivers the fry from the jar to the aquarium without friction and concussion. Owing to the buoyancy of the eggs less than one quart of water per minute is supplied to each jar and at time of hatching only about one pint. When water hardened the eggs are computed at 35,000 to the liquid quart and it is customary to incubate 80,000 in each McDonald jar.

In the latitude of Weldon, striped bass spawn in a temperature of 70° to 77°, the season being from the middle of April to early in June.

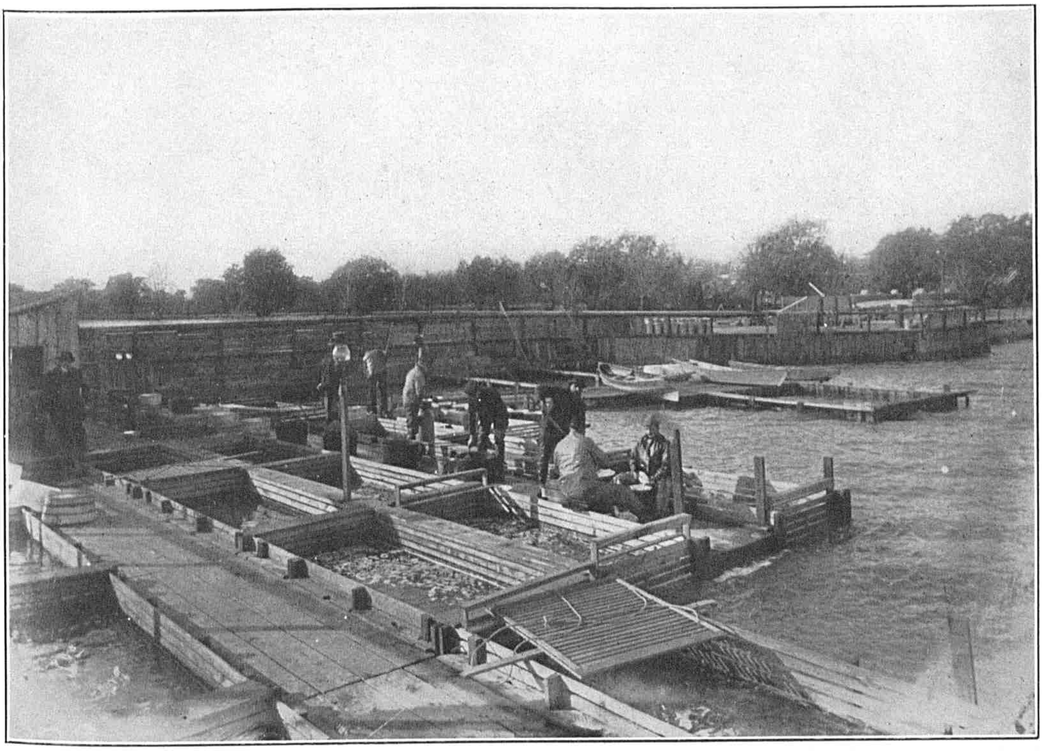

FIG. 5.—Spawntaking operations on the Detroit River, Michigan. Whitefish caught in commercial fishing are held in crates and pounds until ripe. The crates are provided with false bottoms, which may be raised for easier access to the fish.

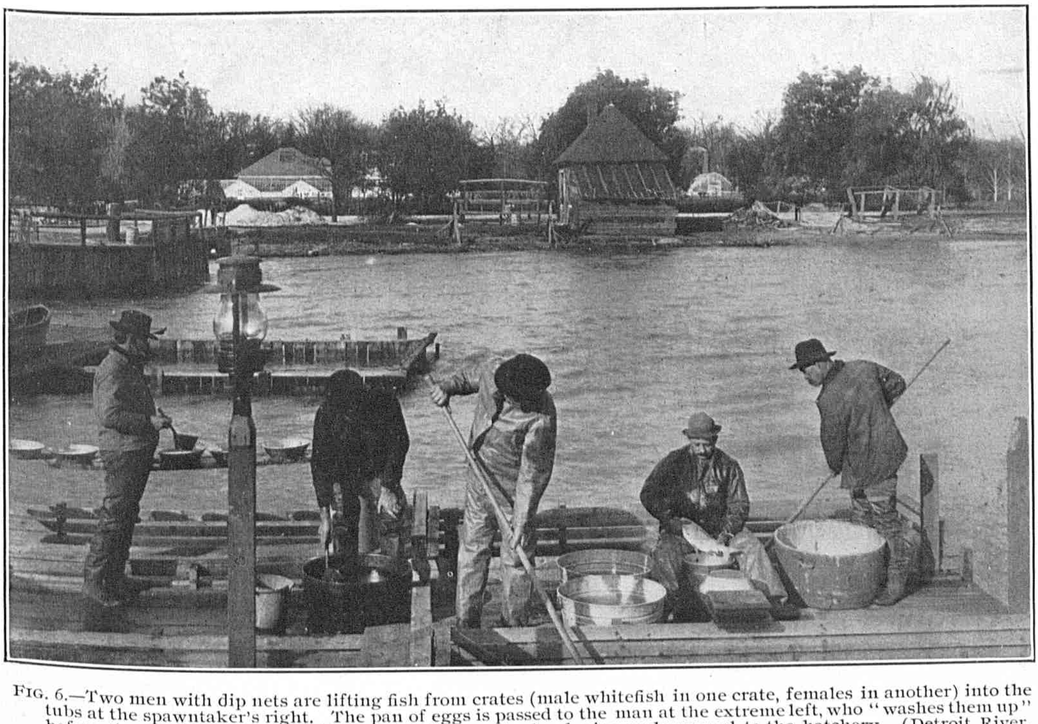

FIG. 6.—Two men with dip nets are lifting fish from crates (male whitefish in one crate, females in another) into the tubs at the spawntaker's right. The pan of eggs is passed to the man at the extreme left, who "washes them up" before they are put into the neighboring tub for water hardening and removal to the hatchery. (Detroit River, Michigan.)

## FISHES OF THE GREAT LAKES.

For the maintenance of the fisheries of the Great Lakes the Bureau operates hatcheries at Put-in Bay, Ohio, Northville, Mich., Duluth, Minn., and Cape Vincent, N. Y. At Cape Vincent the work consists largely in hatching and distributing the product of eggs received from other hatcheries, Lake Ontario not being a fruitful field for the collection of eggs.

### WHITEFISH.

At Put-in Bay station in the fall of 1907 the collections of whitefish eggs reached a total of 336,000,000, the largest on record for any station.[a] In this locality the eggs are in large part obtained by direct purchase from the fishermen, who have expelled and fertilized them as they removed the fish from the nets. In addition it is customary to pen 8,000 to 10,000 fish in crates at points convenient to the base of operations. These fish are obtained from fishermen at a nominal price for use until after spawning, when they are returned to the fishermen to be marketed. As it has not been practicable to confine the fish successfully for a very long time, this procedure is not undertaken until they are nearly ripe, the total period of confinement from the beginning of the collection to the close being about three weeks.

The crates used for penning the fish are 16 feet long by 8 feet wide by 6 feet deep, and have a partition dividing each crate into two compartments 8 feet square by 6 feet deep. Each compartment is provided with a false bottom, which may be raised at will while the fish are being manipulated, and can be shoved down against the stationary bottom afterwards. For convenience in handling the crates are made "knock down," and thus can be easily removed from the water and used year after year. While in the water they are held in position by floats 52 feet long, the crates placed between them endwise, five crates forming a raft. Only 12 inches of the crates extends above the surface of the water. The rafts are held in place by stakes driven into the bottom of the bay. Of the total number of eggs collected about 25 per cent are taken from fish confined in crates.

Another important field station for the collection of whitefish eggs is in the Detroit River, where operations are conducted from the Northville (Mich.) station. Here the eggs are derived from fish caught for fish-cultural purposes by market fishermen who operate under permits issued by the Bureau. The fishermen are willing to incur all expenses of the collections, as well as the losses from penning, for the privilege of disposing of all the marketable fish after the Bureau has taken the eggs. Penning stations are located accessible to the seining

[a] Since this writing another spawning season has passed with a record for the Put-in Bay station of over 373,000,000 whitefish eggs.

grounds, and all fish are transferred to the crates before being spawned. Spawn-taking operations are conducted daily throughout the entire period while the fish are penned. About 75 per cent of all the females confined in crates yield good eggs; the remainder either cast their eggs in the crates, become plugged, or fail to ripen.

At the Put-in Bay station the Downing jar, an open-top glass vessel with pitcher lip, devised by the superintendent, has supplanted other forms of hatching jars. In each of these jars 4½ quarts of green eggs to 5¼ quarts of eyed eggs are subjected to a flow of 4 quarts of water per minute. The jars are arranged in so-called batteries, which are described in the Manual of Fish Culture elsewhere cited. The batteries at Put-in Bay are of the type known as single batteries, each having an independent water supply. They have some new features, notably, for economy in arrangement, the alternation in position of the jars in vertical rows, thus making it possible to bring the troughs more closely together. In the batteries at this station there are 1,692 jars and the flow of water through them is so economically arranged that only 330 gallons per minute is required when all are in operation. This type of battery is the one commonly used at the Bureau's stations, called single battery to distinguish it from the double battery at Detroit.[a] The Detroit hatchery is equipped with 1,487 Chase and Downing jars, and a total of 441 gallons of water is required when the entire battery is in operation.

At Cape Vincent station the battery is a single tier, but the arrangement of the jars is not so compact and the tiers are not so well set up as to economy in water supply, 492 jars requiring a total volume per minute of 123 gallons. At Swanton station a single battery of 606 jars requires a total volume of 227 gallons per minute. The batteries at Detroit and Put-in Bay are constructed entirely of wood; the battery at Cape Vincent was originally of wood, but as the troughs began to decay galvanized iron was substituted without removing the original stand on which the wooden troughs rested. At Swanton the supply troughs in the battery are also of galvanized iron, the first cost of which is more than for wood, but taking into consideration durability of material, may be considered more economical.

## PIKE PERCH.

By methods similar to those pursued in the conservation of whitefish eggs, pike perch eggs also are extensively collected, the most important field, as with the whitefish, being within a 40-mile radius of the Put-in Bay station. Here and at other points on the Great Lakes the eggs are all obtained from ripe fish as caught, the penning of the pike perch by methods described for the whitefish having proved not feasible in the sheltered bays where such work might other-

[a] Manual of Fish Culture, p. 117.

wise be possible. The method of spawntaking at Put-in Bay is in general as follows:

On account of the adhesiveness of the eggs a wooden or fiber receptacle is used instead of the usual tin spawning pan. A liberal quantity of milt is applied, the mass is thoroughly stirred with a feather or with the bare fingers, and a little water is added. Then pan and contents are lowered into a keg, containing about 2 gallons of water, and the pan is carefully emptied. This process is repeated until the keg is about one-third full. The eggs are now left undisturbed until spawning operations are ended—not over two or three hours; then water is added, a little at a time, until the keg is nearly full. Some of the water is then poured off and more added, this process being continued until all the milt is washed off and the eggs are thoroughly water hardened.

The chief precaution during the water-hardening is this constant pouring off and addition of water. Care must be taken in pouring the water to have it fall not directly on the eggs but against the side of the keg. During this period the eggs must not be stirred, for the reason, it is said, that such motion tends to rupture them. It is also important to avoid exposure of the eggs to the air, since because of their adhesiveness they will form in a nearly solid mass. When they are sufficiently water-hardened they may be separated by gently loosening them with the bare hand. After separating them it is necessary to change the water frequently until they can be transferred to hatching jars.

The fact that pike perch spawn in the spring, while fall is the spawning season of the whitefish, makes it possible to utilize the same batteries and other hatching equipment for both species.

In order to overcome the adhesiveness of pike perch eggs and prevent their forming unwieldy masses, it was formerly considered necessary to use muck or starch in the water into which the eggs are placed immediately after fertilization. The use of muck has now been entirely abandoned and neither starch nor muck is used at Put-in Bay.

At Swanton, Vt., the pike perch is regarded as of more value as a game fish than for the maintenance of a commercial fishery. The hatchery is stocked with eggs taken from fish captured purely for fish-culture purposes from the waters of Missisquoi Bay and River. The conditions under which the eggs are taken are more favorable than those existing on the Great Lakes, it being possible to pen the unripe fish for a week or more while maturing, the penning crates being located in a current of water in the river. Delivery of the eggs at the hatchery is also more expeditious.

In the manipulation of eggs here the methods are somewhat different from those just described. After impregnation in the usual manner a little water is added and the eggs are left for five to eight minutes; then more water is added and the eggs are withdrawn carefully into half a bucket of water into which two tablespoonfuls of ordinary corn starch have been thoroughly stirred. Here they are allowed to remain ten minutes. The bucket is then filled with clear water and the washing process begins, the water being replaced until only clear water remains with the eggs. They are then stirred continuously with the hands for a period of forty-five minutes, the bucket being at the beginning about one-third full of clear water, to which more is added during this time. At the end of the continuous stirring the worst period of adhesion is over and from that time on the eggs may be stirred and fresh water added every hour until they reach the hatchery. Here they are held in a tub of running water overnight, then screened, measured, and placed in jars on the batteries.

It will be noted that the two methods of manipulating the eggs are quite at variance. There are so many factors to be considered that it has not yet been decided which procedure is best.

Pike perch eggs require more care than do the eggs of any other species handled by the Bureau. When received they are usually massed together in lumps and must first be separated with the bare hands and passed through a screen of soft bobbinet before being placed in the jars. While in the jars they require constant attention and must be frequently separated, it often being necessary to take down individual jars several times and pass the contents through the bobbinet screen.

Although pike perch are found in ripe condition in water ranging from 38° to 60°, more eggs are taken in a temperature ranging from 38° to 50° than above 50°, and the higher temperature seems to be most favorable for hatching the maximum number of fry. Unfortunately, however, the water of the hatcheries is usually of the colder temperature in which the fish spawn, and a high percentage of fry has therefore been unattainable. An average production in fry of 50 per cent of the eggs taken may be regarded as very good.

## LAKE TROUT.

The station at Northville, Mich., with its several other lines of fish culture, is also the principal center of the lake trout work, and has a record of over 58,000,000 such eggs in one season.[a] As the spawning season is short, however, and is at a period of the year when the fishermen, on account of rough weather, often can not set or take up their nets at will, the collection of eggs must necessarily vary in quantity and quality from year to year according to weather conditions.

The data for one season show the average weight per fish to have been 7.4 pounds; that 66 per cent of the catch of females yielded eggs; and that the eggs averaged two-thirds of a fluid quart per fish.

[a] Since this writing another spawning season has yielded 71,000,000 eggs at the Northville station.

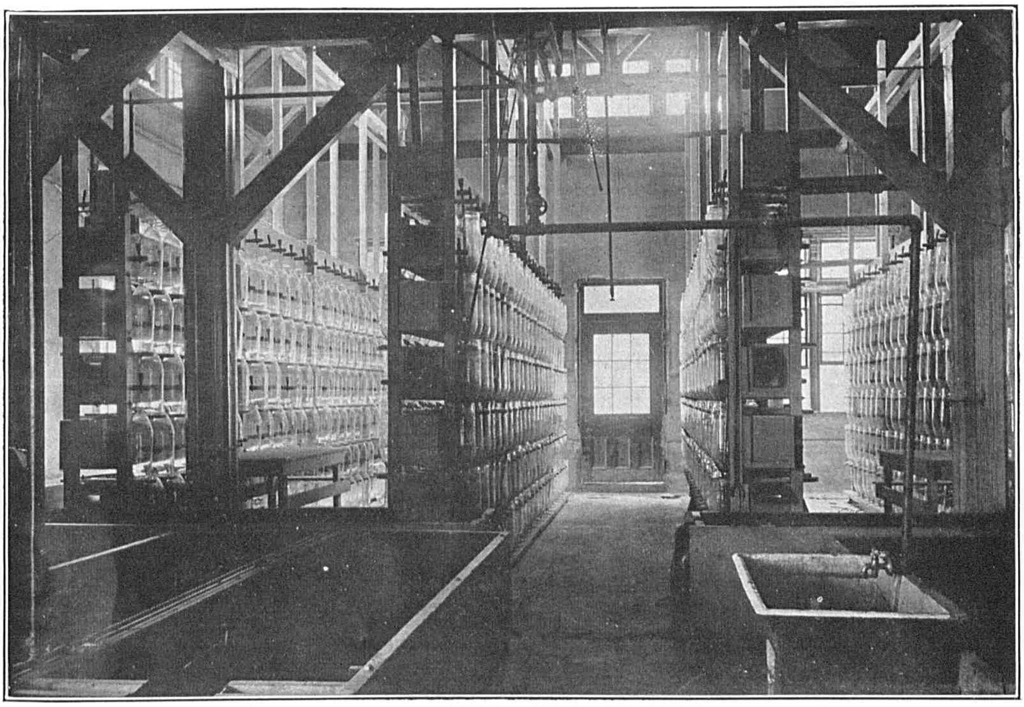

FIG. 7.—Interior of one wing of hatchery at Put-in Bay, Ohio, showing four batteries and the tanks (left foreground) into which the fry are carried by the flow from the jars.

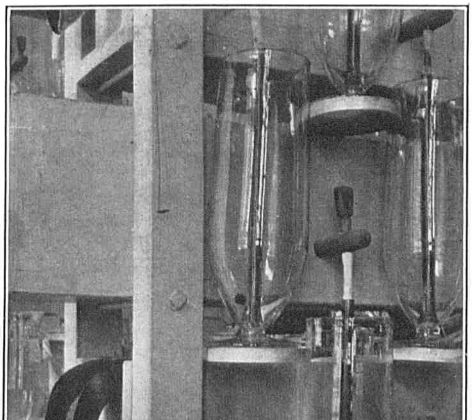

FIG. 8.—Downing jars set up for use on "battery" at Put-in Bay station, Ohio. The troughs into which the water flows from the pitcher mouth of the jars serve also to supply the jars in the next tier, by means of the wooden faucets, and there is a small overflow at alternate ends of each trough. This is the common equipment for hatching whitefish and pike perch.

The hatchery equipment for lake trout at Northville is the common form of wire tray, stacked in troughs of the Clark and Clark-Williamson types.[a] The collections in this region have increased so greatly in recent years, however, that they have outgrown the capacity of the hatchery, and it has been necessary to deepen some of the Clark-Williamson troughs to accommodate more trays during the eying period of the eggs. The deeper troughs are 15 feet long and 3½ feet wide, with a division through the center the entire length; the width therefore is that of a pair of troughs having a common bottom. The outside depth is 18 inches. Each of the deep troughs contains, besides the bulkhead, 15 compartments 19 inches by 10 inches by 16½ inches deep, with a capacity of 16 trays 18½ inches long by 9½ inches wide, on each of which may be placed, if crowded, 10,000 eggs. The total maximum capacity of each pair of

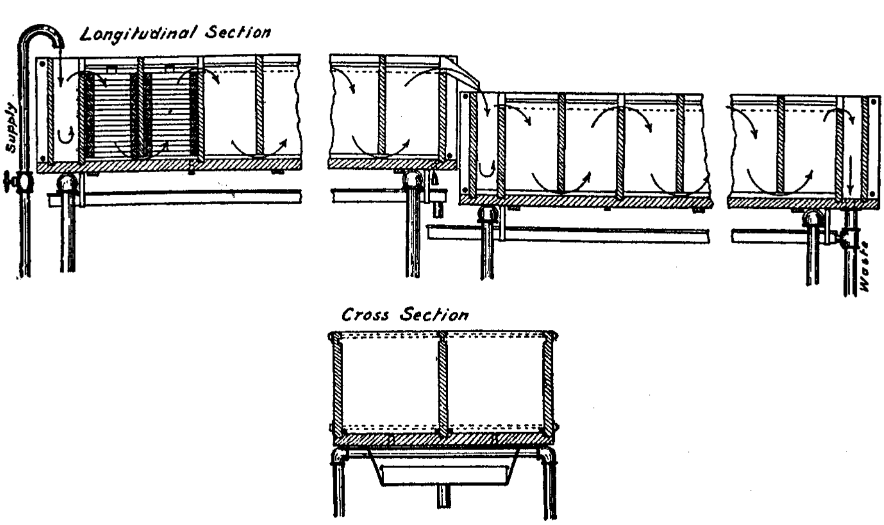


FIG. 1.—Clark-Williamson trough.

troughs is then 4,800,000. For best results, 8,000 eggs to the tray, or a total of 3,840,000 to each pair of troughs, is a proper number.

During incubation the eggs seem to do equally well in either up or down current of the Clark-Williamson troughs; at other stations where eggs are incubated in stacks of trays the Williamson type of trough is used.

As lake trout eggs are taken from fish that have been caught in nets hauled into fishing tugs by steam power, often during rough weather and frequently after the nets have been inaccessible for several days, the percentage of good eggs is not equal to that secured from most of the species manipulated. Consequently a large force of young women, who are more deft with their fingers than are men, are temporarily employed to pick over the eggs. A shallow trough with water flowing through it is provided for this work; in this trough, standing

[a] For full description of these troughs see Manual of Fish Culture, p. 97–99.

above the water on four short legs, are wire baskets, one for each egg picker, into which to throw the dead eggs. The farther side of each basket, to the picker's right, has a high back to stop the eggs as thrown from the tweezers, thus making it unnecessary for the eyes of the picker to follow each egg, and thereby facilitating the entire operation.

## THE BROOK TROUTS, CHARS, AND EASTERN SALMONS.

For brook trout eggs (*Salvelinus fontinalis*) the Bureau depends largely upon commercial trout raisers, eyed eggs being obtained from them at lower cost than it is possible to collect from wild fish at most places or from brood fish maintained only for their eggs. About 8,000,000 eggs are annually purchased from ten to eleven dealers. For the purpose of making a just comparison as to quality and final cost of fish produced from each purchased lot the eggs received from each dealer are distributed to several hatcheries, that all may be alike subject to different conditions of quality and temperature of the water supply.

At some stations, however, eggs from wild trout are more satisfactory. It has been found that eggs from the domesticated fish hatched and reared in spring water which is not subject to seasonal variations do not produce good results where the temperature of the water supplying the hatchery is below 35° or is subject to variations of several degrees. Vermont and Colorado are the only states in which eggs of the wild brook trout are collected in sufficient numbers to stock the Bureau's hatcheries in those states as well as to have a surplus for distribution to other hatcheries. It is interesting to note, further, that in Colorado, where the eastern brook trout is an introduced species, the eggs can be collected in greater numbers and at less cost than in any other state.

In Vermont[a] eggs are obtained from trout inhabiting artificial lakes on private preserves. During September and October principally, but in some localities beginning sometimes as early as July and continuing into November, the fish ascend the streams in large schools on each rise of water. The fish culturist has only to provide suitable racks and traps in anticipation of the period of migration, constructing them in the streams that have been dammed to make the lakes. The fish are dipped from the trap into adjacent pens above the rack, the pens being kept covered to guard against the escape of the fish in case of a possible flood.

A field station of this character is sometimes managed by one man, who constructs the trap, rack, and pens, cares for and strips the fish, and then cares for the eggs, which are incubated until eyed in stacks of trays in the Williamson type of troughs, then are packed and shipped to the central station at St. Johnsbury.

[a] Titcomb, J. W.: Wild trout spawn; methods of collection and utility. Proceedings of the American Fisheries Society for 1897, p. 73-86.

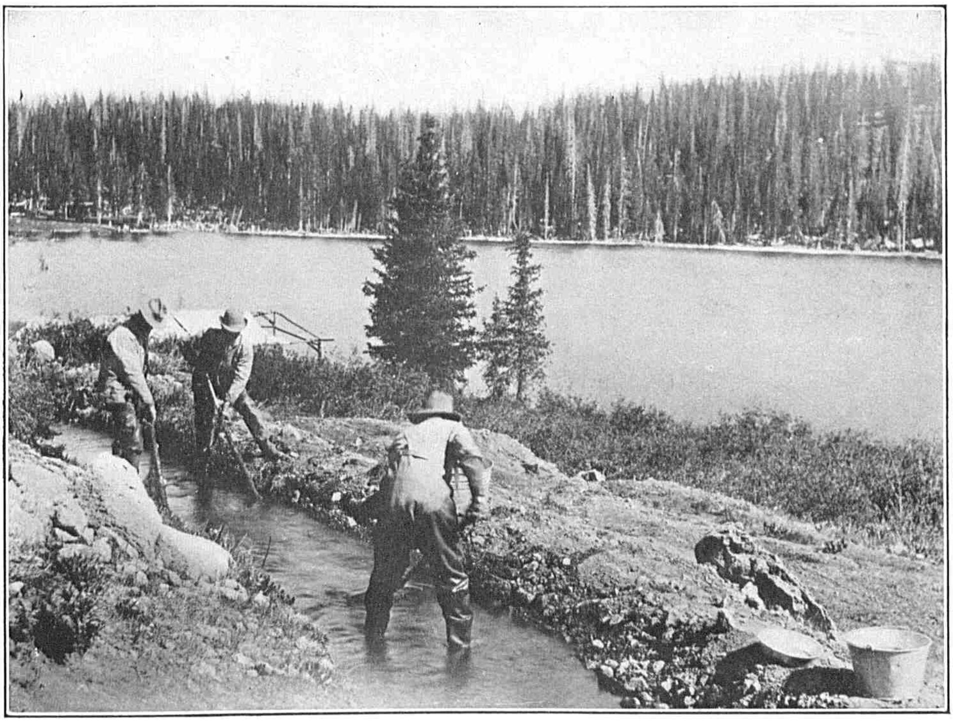

FIG. 9.—Capturing spawning blackspotted trout in small tributary of Grand Mesa Lake, Colorado.

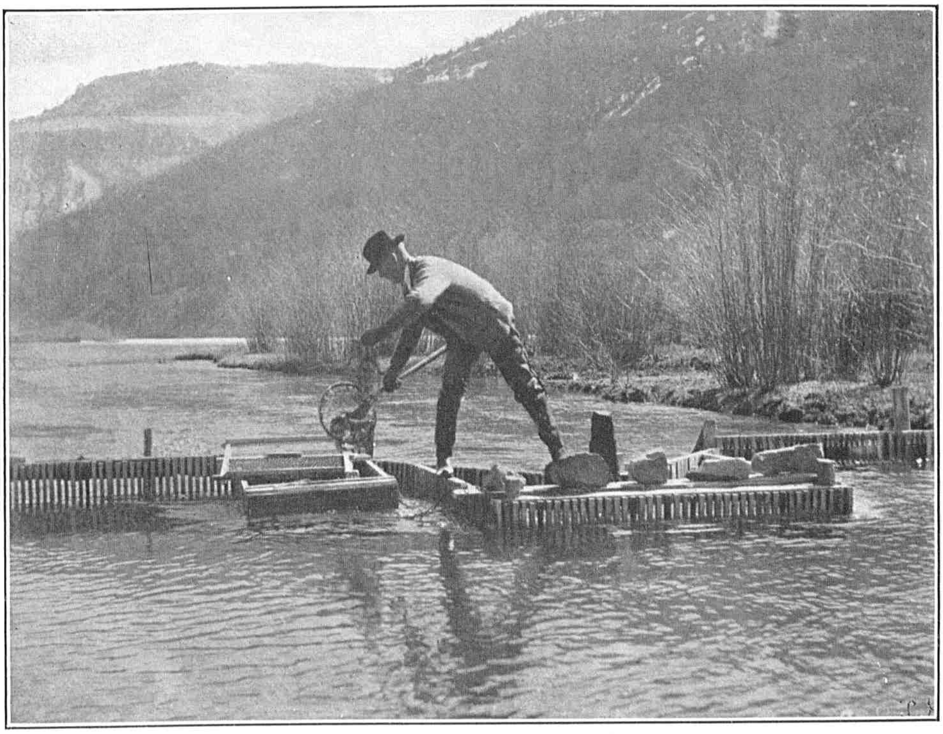

FIG. 10.—Trap for capturing spawning rainbow trout at mouth of principal tributary to Lake St. Christobal, Colorado.

The construction of the racks under the many varying conditions which are wont to prevail requires good judgment and extreme care. Such barriers must be made in anticipation of and providing for floods and must be fish-tight. One small hole large enough for the entrance of one fish may result in the escape of the entire lot.

The eying stations adjacent to these collecting stations are small inexpensive structures, a shanty 12 by 16 feet being adequate to eye a million eggs.

To compensate for the eggs taken from these waters, about 25 per cent of the fish produced therefrom are returned to them, this being an ample proportion to keep them well stocked. The parent fish are always returned to the waters from which they were captured.

Eggs of the landlocked salmon (*Salmo sebago*) are collected by methods quite similar to those pursued in the brook trout work. Although the range of this species has been extended, the field of egg-collecting operations is almost exclusively the native habitat in Maine.

Perhaps the most extensive trout-culture operations in the world are conducted from the station at Leadville, Colo., in connection with which are field stations for the collection of eggs of wild trout of three species. The output of the Leadville station for 1908 was as follows:

| Species. | Eggs. | Fry. | Fingerlings, yearlings, and adults. |
|---|---|---|---|
| Landlocked salmon |  |  | 8,400 |
| Rainbow trout | 45,000 | 100,000 | 144,000 |
| Black-spotted trout | 1,404,100 | 3,736,000 | 210,000 |
| Brook trout | 1,833,900 | 1,905,000 | 380,500 |
| Grayling |  | 50,000 |  |

SPAWNTAKING IN COLORADO.

To see the methods of work in Colorado it may be well to follow the spawntakers as they leave their camp on one of the Grand Mesa Lakes for a day's work with the native trout of the Rocky Mountains (*Salmo clarki*) at Big Island Lake, 10,000 feet above the sea level.

Each spawntaker is provided with a neck yoke and two 10-quart buckets in which to bring in the results of the day's operations. The fish have assembled in great numbers around the outlet of the lake, where as many as can be conveniently handled are caught at each haul of the seine and the ripe ones immediately stripped. Work at this point may continue all day or it may be advisable after a time to seek other spawning grounds, perhaps at the mouths of small inlets where the water from melting snow is flowing into the lake.

A most interesting phenomenon in connection with this work is the run of trout around the island from which the lake derives its name. Every two or three years, and possibly more often, at some period during the spawning season there is a procession of fish in twos, threes, and fours around this island. They follow the indentations of the shore line closely. There is no apparent break in the procession, the line being visible from any view point on the shore. It usually continues, moreover, for several days. A 200-foot Baird collecting seine run from the shore line of the island to form an obtuse angle intercepting the run for ten minutes will be full of fish. The spawntakers, standing about the bag of the seine, in two or three feet of water, proceed to strip the fish in the seine while the procession closes in, the line of trout winding in and out about the legs of the men and apparently in as large numbers as before.

The spawntakers with their full pails of spawn proceed to a station near their headquarters, where all eggs are spread on trays and the latter are stacked closely in Williamson troughs supplied with water from an adjacent lake. Here the eggs are eyed preparatory to shipping a portion of them to the Leadville and other stations. Some are hatched at the field station to replenish the waters from which they were collected, or other waters in the vicinity.

## REARING METHODS.

At most stations a portion of the fry are reared to fingerlings, and at some stations it has been found advisable to carry brood fish, both of brook trout and rainbow (*Salmo irideus*).

The latter, a native of the streams on the Pacific coast, has been domesticated and successfully propagated at stations in Missouri, Iowa, Virginia, West Virginia, and Tennessee. At stations farther north whose minimum water temperature is usually lower and subject to extreme changes, it has been cultivated with varying, but on the whole rather negative, results. It has been successfully acclimatized in some of the more northerly states, notably in Michigan; but it does not thrive in waters subject to extremely low temperatures during the winter months, and in New York and the New England States has proved in most streams a failure.

The domesticated brood fish of either species are usually the product of eggs collected from wild fish, and are reared in the usual manner. The young fish may be confined for the first four or five months, or until 3 to 5 inches in length, in the hatching troughs or in a battery of outdoor rearing troughs of dimensions and in other respects quite similar to the indoor troughs, about 12 feet long by 14 inches wide. Care must be taken, however, to guard against overcrowding as the alevins increase in growth. The actual number of young fish of a given age which can be successfully carried is dependent upon the quality of the water supply, temperature being an important factor, not only as to the number for a given space, but also as to their rapidity in growth. At the White Sulphur Springs (W. Va.) station, with a supply per trough of 10

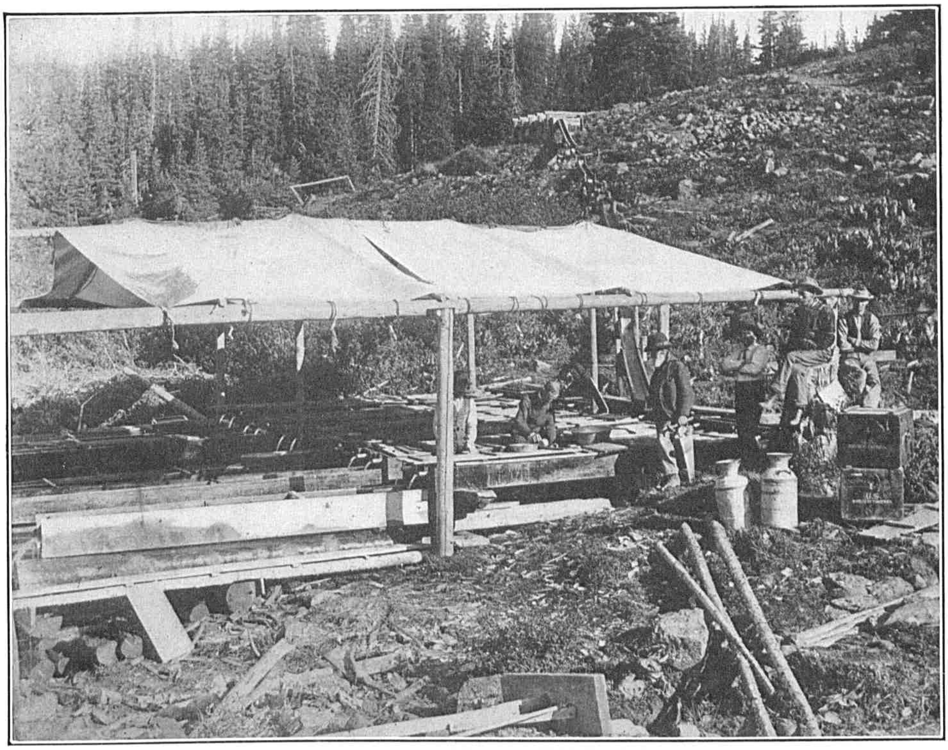

FIG. 11.—Field hatchery at Grand Mesa Lakes, Colorado. Blackspotted trout eggs to the number of 7,000,000 in one season have been developed here to the eyed stage with only a normal loss.

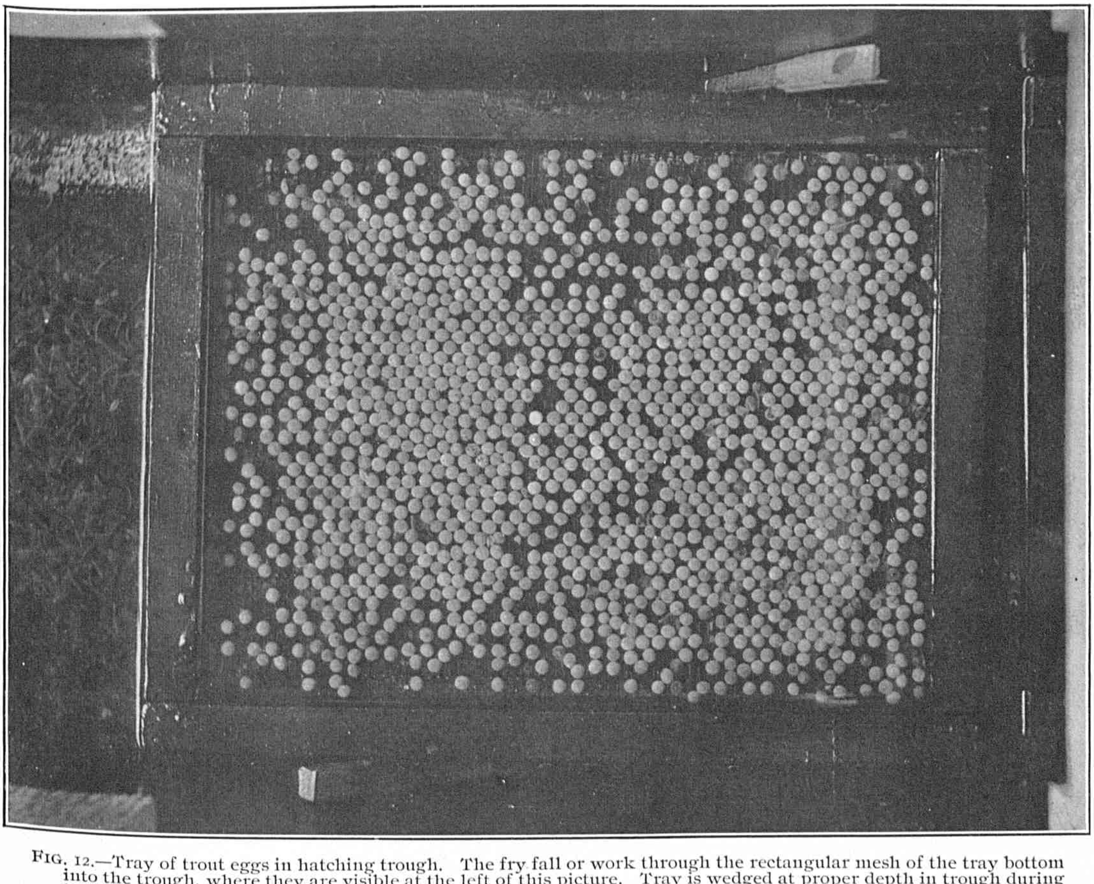

FIG. 12.—Tray of trout eggs in hatching trough. The fry fall or work through the rectangular mesh of the tray bottom into the trough, where they are visible at the left of this picture. Tray is wedged at proper depth in trough during incubation, and, for convenience in removing dead eggs from time to time, may be floated by releasing the wedges.

gallons of water per minute at a temperature of about 50°, it is customary to hatch and hold in each trough 50,000 sac fry, 25,000 advanced fry, 12,500 1¼-inch fingerlings, 4,000 1½-inch fingerlings, 2,000 1¾-inch fingerlings, and 1,000 fish 2 to 3 inches in length. Much larger numbers are often carried under similar conditions without serious loss, though often with the result that the fish prove weak in transportation.

At stations where the facilities permit, a congested condition of the hatching troughs is avoided by transferring some of the fish to outdoor ponds as soon as they have learned to take food readily, or, if weather conditions are suitable, after being fed two or three weeks. In rearing fingerlings for four to six months, concrete ponds 18 to 25 feet in length by 5 to 6 feet in width and 2½ feet deep, with a fall of 8 to 10 inches in the bottom for drainage, give good results at the Manchester (Iowa) station. The stock ponds at Manchester, 76 feet long, 17 feet wide, and 3 feet deep, supplied with 40 gallons of water per minute at a temperature of 50° to 60°, have a capacity for 3,500 rainbow trout 2 years of age; 1,800, 3 years old; 1,000, 4 years old, and 900, 5 years old. This trough and pond system is typical for rearing any species of brook trout, as well as lake trout and Atlantic and landlocked salmons, for three or four months, which is as long as it is customary to hold young fish intended for distribution. Brood fish may be obtained by selection from the fingerlings intended for distribution, which as they develop are transferred to stock ponds.

As soon as the fry swim up looking for food they are fed several times a day an emulsion of finely ground liver. This diet is continued as the young fish develop, with the difference that the liver is less finely ground and is given less frequently—two or three times a day being sufficient when the fish have attained a length of 2 or 3 inches. The kind of liver used varies at different stations, that of sheep, beeves, and hogs being extensively used, and the relative value of each being in the order named. The food for the larger fish consists of the liver, lungs, and hearts of the animals already mentioned.

At Manchester, Iowa, it has been found advantageous from an economical standpoint to mix the animal food, after it has been ground, with a mush made by cooking wheat middlings or shorts, to which a moderate amount of salt is usually added. After the mush has been thoroughly cooled the animal matter, uncooked, is stirred into it in the following proportions: For fingerlings, 1 part animal matter and 2 parts mush; for adults, 1 part animal matter and 3 parts mush. Twenty gallons of boiling water and 50 pounds of wheat middlings will make about 202 pounds of mush.

The provision of food for domesticated fish is one of the greatest problems the fish culturist encounters, and has been the subject of considerable experimentation. The intensive production of natural food has not received in the United States so much attention as in Europe nor so much as the subject deserves. The American method of raising trout precludes the economic use of natural live food, although unquestionably the edible qualities of the fish might be much improved thereby.

For several years the roe of the branch herring (*Pomolobus pseudoharengus*) has been used at several stations as a substitute for liver in feeding fry and fingerlings. It is purchased from cannery men, who preserve in tins large quantities of it for human consumption, and consequently are able to sell it at a price close to or less than the cost of liver, due allowance being made for the waste in liver and the labor involved in its preparation as a fish food. The herring roe has the advantage of always being on hand in condition ready to feed and is therefore especially desirable for isolated stations. It is not customary to feed young fishes on this food after they are 2 or 3 months old.

At Craig Brook, Me., fly larvæ,[a] used for a number of years in rearing trout and salmon to fingerlings, proved to be a very satisfactory food and the fish attained a more rapid growth than when fed on liver and other dead material. From a financial standpoint it was not as economical as freshly prepared liver or other animal foods, and this, coupled with the objectionable odor attendant on its preparation, had much to do with its discontinuance.

It is possible, however, to utilize animal refuse advantageously for the production of fly larvæ by means of a contrivance in which the material on which flies have deposited their eggs may be suspended over the water. This contrivance consists of a wooden frame, like a box without top or bottom, placed on floats and having an air-tight cover to prevent the escape of foul odors. Within the frame are two trays, the bottoms of which are made of coarse wire cloth (odds and ends of old hatching trays). Excelsior or straw is placed on the trays, and waste meat or other animal refuse is placed on top of this material. As the larvæ hatch they work through the excelsior, cleaning themselves thereby, and drop into the water. Two small trays are preferable to one of larger size, that the meat may alternately be renewed, thus insuring a more constant supply of larvæ. The noxious animals killed in the protection of fish may advantageously be disposed of in these trays.

## SPECIAL DEVICES APPLIED AT TROUT STATIONS.

Study and experience in recent years have revealed abnormal aeration as a condition existing in various water supplies at trout-culture stations, with consequent mortality among the fish. Of the methods used to correct such abnormalities, that devised by the superintendent of the station at White Sulphur Springs, W. Va., Mr. R. K. Robinson, has proved the most efficient.

[a] Atkins, Chas. G.: The live food problem, American Fisheries Society, 1903; also Food for young salmonoids, Proceedings Fourth International Fishery Congress, Bulletin Bureau of Fisheries, vol. xxviii, 1908, p. 839–851.

It consists of a series of ordinary milk pans held in a frame, one above another, in numbers to suit conditions, the bottoms of the pans perforated with a nail or other pointed instrument which will leave a ragged edge to each perforation on the underside of the pan.

This apparatus is set up at the head of the trough in such position that the supply pipe empties into the topmost pan, and the water must pass through the series before reaching the trough. By this separation into fine streams the water is thoroughly exposed to the air, thus rectifying any abnormality of air content.

At nearly all trout hatcheries it has been customary to place horizontally below the supply pipe at the head of each trough a screen consisting of a light frame, bottomed with wire cloth or perforated metal. This is designed not only to break the force of the stream entering the trough but to aerate or deaerate the water and at the same time catch foreign substances and animal life—the latter at times being quite objectionable. Such screens, however, have almost invariably caused the water to spatter over the sides of the trough, resulting in constantly wet surroundings. To overcome this objectionable feature a conical perforated screen has been devised by Mr. M. E. Merrill, of the St. Johnsbury, Vt., station. When the screen is in place the current of water falls directly on the apex of the cone, and thus is spread over the entire perforated surface, accomplishing the objects of all other styles of head screens, and avoiding the spattering of water over the sides.

A device for assorting young salmon and trout was introduced in the Bureau's operations by Mr. J. P. Snyder, an employee at one of the stations. It consists of a series of screens by means of which to separate the fingerlings into sizes.

In length the screens are slightly less than the width of the troughs, to facilitate sliding them along. There should be two screens for each size of mesh. In use one screen is carefully inserted at the foot of the trough close to the tail screen, due precaution being taken that no fish are pinched and that none are left between the foot screens and the end of the trough; midway of the trough a screen should be securely fastened in a vertical position by wedging. After the first screen is in position a similar one is inserted at the head of the trough and then moved along toward the center.

As the two screens are brought closer together the fish between them become frightened, and all that are small enough escape through the mesh of the screens. The distance of the second screen from the first should depend upon the number and size of the fish in the troughs, and also upon the number that escape through the screen. The second screen should also be fastened by wedging. Then the hand of the attendant is moved about among the fish between the screens to guard against any small ones finding a hiding place. In their efforts to escape some of the fish will be hung in the wire cloth, but it will be noticed that every trout which gets its head through the screen can pass or be assisted through without injury. The few which are caught in the mesh should be assisted by grasping the tail and pushing them. It would be well to refrain from feeding for about twenty-four hours before assorting the fish.

By using two or three sets of screens in different troughs at the same time one man can assort many thousands of fish in a day, and the sizes will be much more uniform than when assorted with a scaff net. Wire cloth, 6 bars to the inch each way, painted with asphaltum varnish, will permit all brook trout under 1 inch in length to pass through. By varying the mesh of screens brook trout may be assorted into six uniform sizes as follows:

| Number of bars to the inch: | Size of fish. |
|---|---|
| 6 | All under 1 inch. |
| 5 | All between 1 inch and 1½ inches. |
| 4 | All between 1½ and 2 inches. |
| 3 | All between 2 and 2⅜ inches. |
| 2$\frac{5}{16}$ | All between 2⅜ and 3 inches. |
| 2 | All between 3 and 3⅞ inches. |

The frames of these screens are made of half-inch wooden strips grooved and tongued at the ends. These frames are one-eighth inch less in length than the inside width of the troughs and in height equal the depth of the troughs, being rectangular in form. They are covered on one side with wire cloth held firmly by copper tacks, both the wire cloth and the frames being painted with asphaltum varnish previous to tacking the wire on the frames. This not only helps to preserve the wood and keep the wire from rusting, but smooths the latter so that there are no rough surfaces or projections to injure the fish as they work their way through.

## ATLANTIC SALMON.

Another important branch of fish culture is conducted at the Craig Brook station, near the Penobscot River, not far from Bucksport, Me. While not restricted in its work to this one species of fish, the primary object of this hatchery is the propagation of the Atlantic salmon. The decadence of this important fishery on the North Atlantic coast, due to the ruthless but natural progress of civilization, is too well understood to call for an explanation here. Suffice it to say that to-day the Bureau is maintaining a commercial fishery for the Atlantic salmon on the Penobscot River purely by artificial propagation. It is the only river in the United States where this once abundant salmon is now found in sufficient numbers to support a fishery or to warrant its artificial culture, and here, with the natural conditions so changed, it is with no little difficulty that the extinction of the species is prevented.

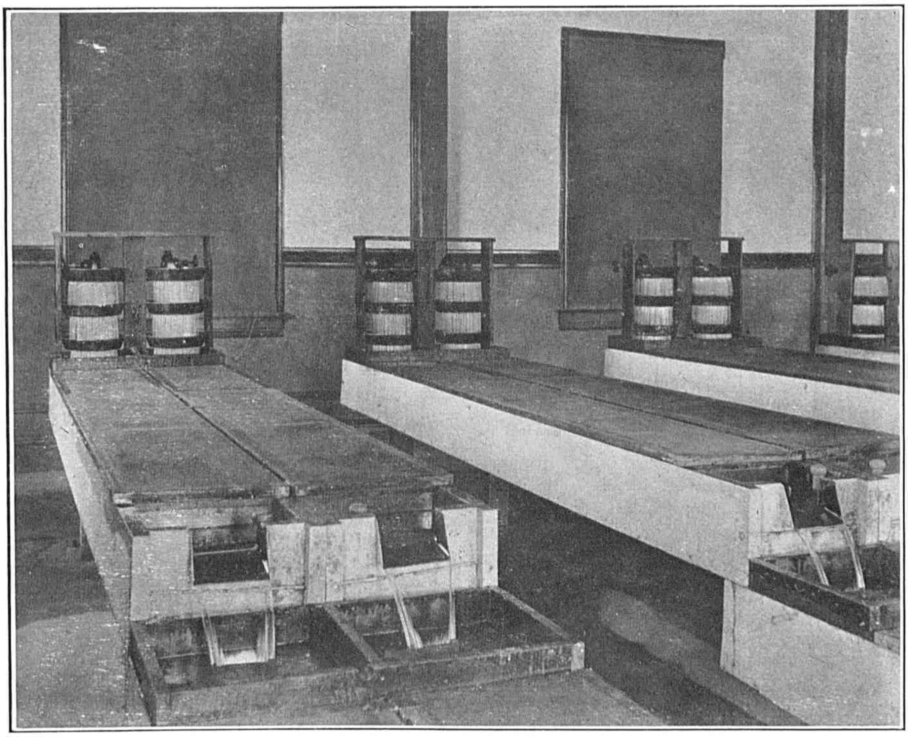

FIG. 13.—Series of covered trout-hatching troughs at White Sulphur Springs station (West Virginia) equipped with the Robinson pan aerator. (See p. 716.)

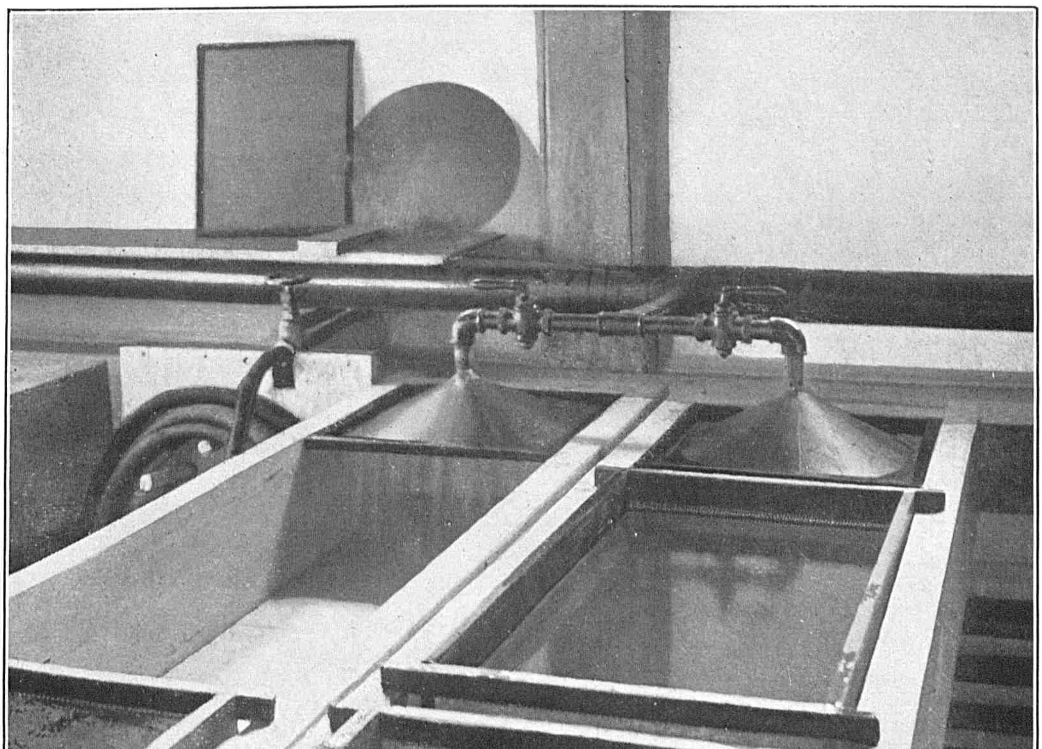

FIG. 14.—Trout-hatching troughs with Merrill aerating cone. (See p. 717.) Shows also tray basket of a pattern used at some trout stations, much deeper than ordinary tray and intended to hold fry after hatching. Left trough with tray removed to show shower of water produced by aerating cone.

The operations at this hatchery, fully described in the Manual of Fish Culture published by the Bureau of Fisheries in 1900, have undergone slight change of method and need not be dwelt upon here. The source of egg supply is the catch of the fishermen's weirs usually during the month of June, the fish being purchased and towed in live cars to the station, where they are transferred to inclosures and there retained until the spawning season, in October and November. When ripe they are stripped and the eggs placed upon wire trays, which are stacked in troughs and carefully tended until the early spring, when the eggs hatch. The young fish are distributed for the most part as fry, but a considerable number are reared to the fingerling stage.

## POND CULTURE.

Pond culture in the United States is applied only to nest-building fishes, such as the basses, sunfishes, and the common catfish (*Ameiurus nebulosus*). These species do not submit to manipulation for taking and fertilizing their eggs, but fortunately a very large percentage of the eggs are fertilized when the spawning functions are permitted to occur naturally, and the parent fish care for and protect the young until the latter are free swimmers. The cultivation of these fishes, therefore, consists in providing ponds which shall give to the maximum number of breeding fish and their young all the essential conditions of a natural environment, while at the same time protecting them from their enemies and holding them under control.

### THE PONDS.

Economy in construction usually dictates the shape and area of the ponds, but an independent water supply and drainage to each is desirable. For convenience of the fish culturist the area usually ranges from one-fourth to one acre, although some ponds of larger size are desirable. It was formerly considered essential to have at least one-fourth the area of the breeding pond not exceeding 1 foot in depth, but it has been found that the deepening of the shallower portions to a minimum depth of from 1 foot to 1½ feet has largely increased the productive area.

The presence of aquatic plants in fish ponds is a prime essential. The young of the nest-building fishes do not accept artificial food, and must therefore have their natural diet of minute animal life, the abundance of which is dependent to a large extent upon the character and abundance of plant growth. Plants are also important as oxygenators of the water and afford shelter and shade for the fish. The selection and control of aquatic vegetation, therefore, is a matter to which the fish culturist must give much attention, and experience at the various stations indicates that it offers a direct means by which the output of the ponds may be increased. The subject has not been sufficiently studied, but observations so far made suggest various practical possibilities of much interest.[a]

The supposed loss of young fish by the voracity of their parents induced the practice of partitioning the ponds in such a manner as to confine the adults in one portion while permitting the young to escape through the partitions to safety. It has been found, however, that the loss from cannibalism is due chiefly to the young fish themselves, and accordingly they are separated from their parents or not, merely as a matter of convenience. The principal precaution against cannibalism is, instead, the provision of an abundant food supply, to divert the fish from each other.

### FOOD FOR THE ADULT FISHES.

Food for the adult fishes is largely a matter of local conditions and convenience. Chopped fish is extensively used at some stations, and crawfish, so abundant in some localities, when chopped make admirable food for the adult stock. The basses, although not appearing to care for pollywogs as naturally present in the ponds, will devour frog tadpoles voraciously if the latter are seined out and thrown back by the fish culturist, but they absolutely refuse toad pollywogs when similarly served to them. Minnows are a good food, but should not be introduced into the ponds near the spawning season, as they eat not only the small forms of life upon which the fry depend but often eat the fry as well. Dead minnows thrown into the water one at a time are greedily taken by the adult basses.

Adult bass may also be advantageously fed on strips of beef liver about 2 to 3 inches long and from one-half to one-fourth inch in width or thickness; and prepared food consisting of ground liver or other animal substance mixed with a mush of cooked shorts, corn meal, or middlings has been employed in a rather limited way. It is worthy of note that for this prepared food to be attractive to bass it must ordinarily contain at least two-thirds of the animal substance, whereas prepared food containing only 10 per cent of the animal material is taken with avidity by trout.

It has been quite conclusively demonstrated that one of the principal causes of loss among brood fish is overfeeding, resulting in a fatty degeneration. This loss has been largely overcome by reducing the food supply and at the same time varying the kind of food furnished.

### ARTIFICIAL NESTS.

In the cultivation of the small-mouth bass, and to some extent the other species, it has been found profitable to provide artificial nests. These are of

[a] Titcomb, J. W.: Aquatic plants in pond culture. Bureau of Fisheries Document 643. 1909.

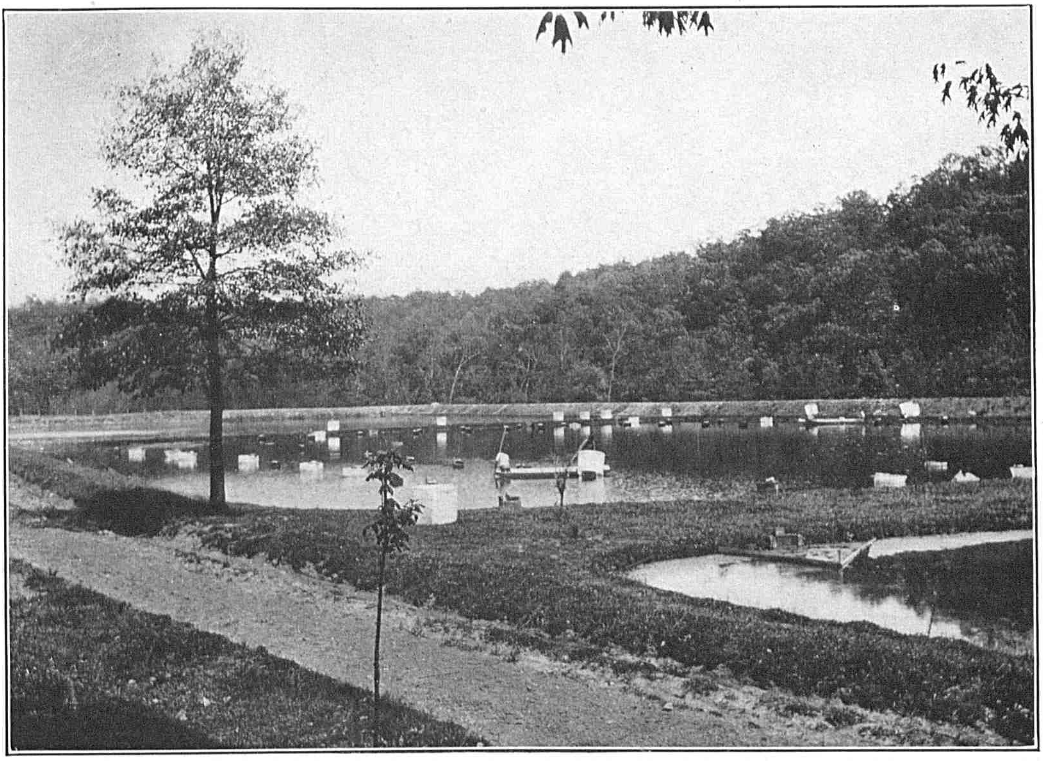

FIG. 15.—Placing cheese-cloth retainers over nests containing bass fry about ready to swim up. Most of the nests are seen covered with retainers. When a nest is occupied it is numbered and complete record kept of its different stages. The retainers are to confine the fry for convenience in transferring to other ponds to make room for following broods. (Mammoth Spring station, Arkansas.)

FIG. 16.—Pond drawn down and nest boxes placed for spawning. Area of pond, 55,000 square feet; 50 nests in pond; 150 breeding smallmouth black bass. (Mammoth Spring station, Arkansas.)

various design, but embody in general some sort of a container for the gravel the fish require, together with a shield or screen on two or three sides.[a] The primary use of screens was for the purpose of shielding the fish from view of passers-by, but the practice resulted in the discovery that the fish will accept shielded nests at more frequent intervals than when visible to each other. It is therefore of first importance that in the placing of nests the screens be arranged to meet this condition.

When shielded artificial nests are not provided it is customary to deposit here and there in the ponds mounds of coarse gravel, 18 inches to 2 feet in diameter and about 6 inches in height, that the breeders may select and prepare their nests with these.

Large-mouth black bass, though they sometimes accept gravel mounds as nests, naturally seek a weedy bottom, devoid of gravel. Peat-like sods or similar substances put into the pond prove acceptable to this species as nesting material.

The superintendent of the Cold Springs, Ga., station endeavors to imitate nature by providing "homes" for all adult fishes whether spawning or not. For the large-mouth black bass and rock bass, boards 3 feet to 10 feet in length are laid flat under the water so that by the natural contour of the bottom spaces 5 inches to 8 inches deep are formed under the boards. Catfish (*Ameiurus nebulosus*), which prefer to dig their own nests, are provided with boards either laid flat on the pond bottom or where there will be under the center of the board a depression an inch or two in depth. Where necessary, the boards are fastened by stakes at both ends, but when placed along the bank, where conditions are favorable for such a course, one end of the board may be driven a short distance into the embankment, while the other end is staked. After having been submerged a month or so the boards will remain in place without fastening. With proper precautions against projections these shelters do not materially interfere with seining operations.

For the crappie, roily water seems to be essential during the spawning season. At stations where there are no naturally roily ponds it has sometimes been found desirable to introduce a few carp, which roil the water in rooting around the bottom of the pond and do not seem to disturb the crappie.

## NUMBER OF BROOD FISH.

The desirability of maintaining a maximum number of brood fish to a given pond area has led to a comparison of experience at the different stations in an effort to arrive at some approximate average for a working basis. Conclusive

[a] One form of nest in use is the design of A. E. Fuller, described in his paper entitled "New and improved devices for fish culturists," Proceedings Fourth International Fishery Congress, Bulletin U. S. Bureau of Fisheries, vol. xxviii, 1908, p. 991–1000, pl. CIV–CVI.

determination can not be made, of course, owing to the various factors of quality and temperature of water, abundance of vegetation and of natural food, etc., but reports from the several localities are of interest.

At San Marcos, Tex., the best results are obtained with 24 to 30 large-mouth bass to the half acre; of the smaller fishes—bream, rock bass, crappie—60 to the half acre.

A 1-acre pond at Mammoth Spring, Ark., supports 100 small-mouth black bass, and an average of 2,000 fry to each productive nest has been obtained, the maximum number from one nest being 5,200.

At Cold Springs, Ga., 100 adult large-mouth black bass in a pond of three-fifths of an acre in area proved too many, and the number had to be reduced to 60 or 70 for satisfactory results. In general, 50 to 75 brood bass to three-fourths of an acre to an acre have been found the best number at this station. Of catfish (*Ameiurus nebulosus marmoratus*), 100 to the acre have been found satisfactory.

Ponds at Wytheville, Va., accommodate 75 pairs of large-mouth black bass to the acre with good results; of rock bass, 300 fish to the acre.

At Northville, Mich., in a pond three-fifths of an acre in area it has been observed that most satisfactory results were obtained with small-mouth bass to the number of 29 females and 23 males, allowance being made for the occasional polygamous tendency of the male.

At White Sulphur Springs, W. Va., 36 pairs of small-mouth black bass is considered the number for a 1-acre pond.

The maintenance of an abnormally large number of brood fish to a given area results in more or less loss according to species, the mortality among the brood fish of the small-mouth black bass being greater than with the large-mouth bass and other pond fishes. The replenishing of the stock is most advantageously accomplished by securing wild fish, preferably in the spring of the year, and they may be advantageously transferred up to within two or three weeks of the spawning season.

## COLLECTING THE YOUNG FISH.

It is often desirable to remove the surplus fry from a pond before they have left their nests, and there is now in use for this purpose a combination fry trap and retainer which is placed over the nests, taking advantage of the fact that the fry rise vertically.[a] This trap has proved of practical value in fish-cultural ponds for small-mouth bass, and, where the nest area was not too great, for large-mouth also. It has been used likewise in collecting small-mouth bass fry from natural lakes, and is believed to be applicable to fry of other nest-building fishes than the basses.

[a] See Fuller, op. cit.

Soon after the yolk sac has been absorbed, or after the fry have been feeding for two or three weeks, a portion of them are removed from the ponds and distributed to the waters they are to stock. The first crop may often be obtained by seining around the edges of the pond without the preliminary clearing away of vegetation, and for this purpose a novel casting seine has come into use at Northville, Mich. The web is rigged upon two long bamboo poles, so that the device may be operated entirely from shore, without roiling the water or unduly disturbing the fish.[a]

After the young fish have sought the deeper portions of the ponds, preliminary to drawing off the water to effect their capture, it is necessary to remove the aquatic vegetation, a process of much labor and expense, consisting in general of mowing under water, and carrying away the foliage by means of pitchforks and boats. Various methods and devices for this purpose have been evolved at the different stations, as described elsewhere.[b]

Ordinarily the assorting of young pond fishes by size is accomplished by hand manipulation with a scaff net. To some extent, however, the separation may be accomplished by regulating the size of the mesh in the nets used to effect their capture. The superintendent of the San Marcos, Tex., station suggests having an ample bag to the dip net in which quite a large lot of fish may be taken from the tub or other retainer, then passing the net gently to and fro in the water to allow the fry and smaller fish to escape, while the larger ones are retained. This method is principally used for assorting black bass, as it frequently happens there are schools of both fry and fingerlings in the ponds at the same time. Nets of one-fourth inch square mesh will permit the escape of all fish up to 1½ inches; one-half inch square mesh will permit the escape of all fish under 3 inches in length.

At the Cold Springs, Ga., station the superintendent uses a box 3 or 4 feet long by 1 foot wide and 1 foot deep, and water-tight to a depth of 2 inches. Above this 2 inches one side is covered with wire cloth instead of being closed in, the size of wire mesh being regulated for known sizes of fish. The box is partially submerged in the pond in which it is intended to place the smaller fish of a lot to be assorted. The young fish as caught are placed in the box, and then are left undisturbed for an hour or two. At the end of this time the smaller fish will have escaped from the box through the screen into the pond, when the box with the larger fish remaining in it may be transferred to another pond and emptied, or the contents may be poured into a suitable receptacle for transportation by tipping the box toward its solid side. Square-meshed galvanized cloth is used for the screen, and if the fish are given plenty of time to separate none of them are gilled, hung, or otherwise injured.

[a] Fuller, op. cit.

[b] Titcomb, J. W.: Aquatic plants in pond culture, Bureau of Fisheries Document 643. 1909.

## RESCUE OF FISHES FROM OVERFLOWED LANDS.

In the upper Mississippi and Illinois rivers there is an annual spring flood period caused by the melting of the snow in the northern forests and freshets in the local tributaries after heavy rains. The period begins with the approach of warm weather, usually about March 15, and continues until about June 1, when the crest of the high water has been reached. Soon after this date the water begins slowly to recede, and usually by July 15 the river has reached its normal stage.

Between the extreme low and high water marks there is a variation of 12 or 15 feet. There is, of course, a variation in the extremes of the water level in different seasons, but seldom, if ever, does the water fail to rise high enough to flood the lowlands. The adult fishes are thus permitted to enter the overflow basins and bayous, and invariably do so during the spawning season. After spawning most of the adult fish escape to the river before the water has receded sufficiently to cause them to be hemmed in, but immense numbers of their progeny are left in the lakes and bayous where they were hatched. These waters gradually dry up, become choked with vegetation, or overheated and unfit for fish life; some of the larger and deeper lakes and bayous, although cut off from the main river, may contain water the year around, but on account of the seepage and evaporation during the summer the depth of water in them decreases to such an extent that they freeze solid during the winter months. Sometimes the lakes from which fishes are rescued are in the hollows on farm lands, where in dry seasons crops are cultivated. Thus it will be seen that the fish imprisoned in overflow waters are doomed to destruction in one way or another.

One branch of the Bureau's operations is annually to rescue large numbers of these fishes. At present the work is confined to waters convenient of access—namely, the overflow lakes and bayous on the low islands in the rivers and on the adjacent mainland. Many of the fishes are returned to the rivers. Another portion of the more desirable species is distributed in various other waters, often far from the source of supply.

It has been found, however, that the fishes rescued from these warm waters do not bear transportation long distances without heavy losses if immediately started upon their journey. Therefore a hardening process is resorted to, which consists in holding the fish in large tanks flowing through which are streams of clear cool water. To facilitate the work the Bureau has a number of field stations—one on the Illinois River and three on the Mississippi—convenient of access to the railroad, and each equipped for holding one or more carloads of fishes for several days, or until they have become sufficiently hardened to bear transportation by cars. Adjunct to these stations are vessels, launches, and boats of various types suited to the work.

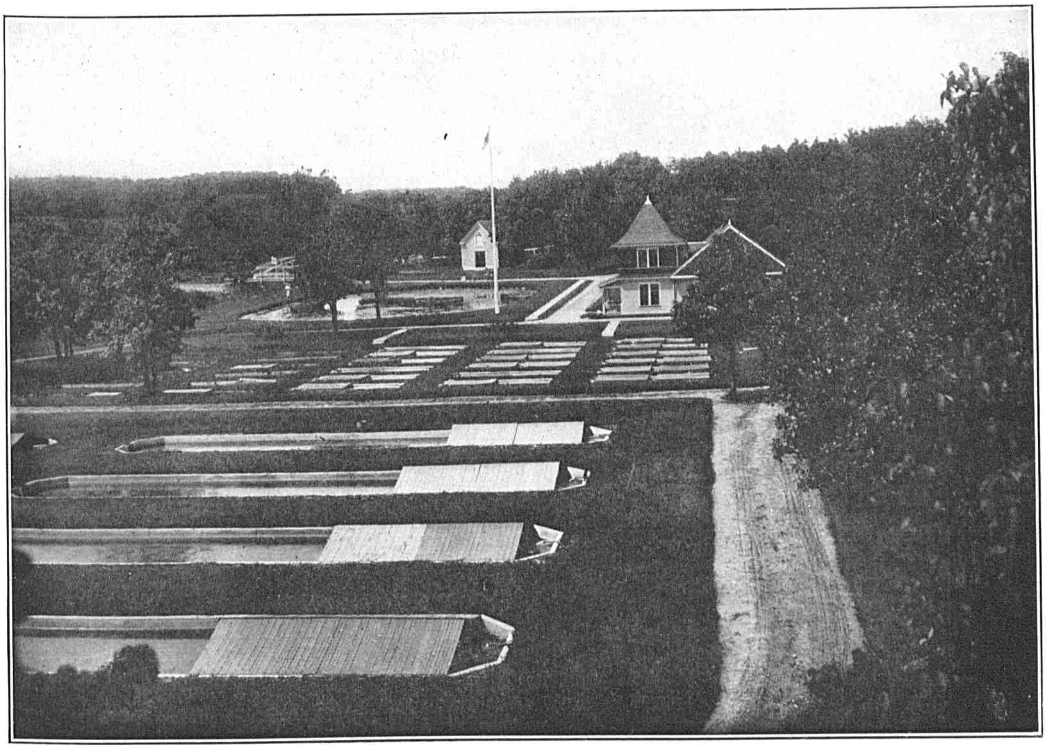

FIG. 17.—Both trout and bass are cultivated at many of the stations. This view of the station at Manchester, Iowa, shows stock ponds in foreground, then the smaller nursery ponds, all of these for trout and built of cement. Beyond, in front of the hatchery building, is a bass pond, with earth bottom and sides.

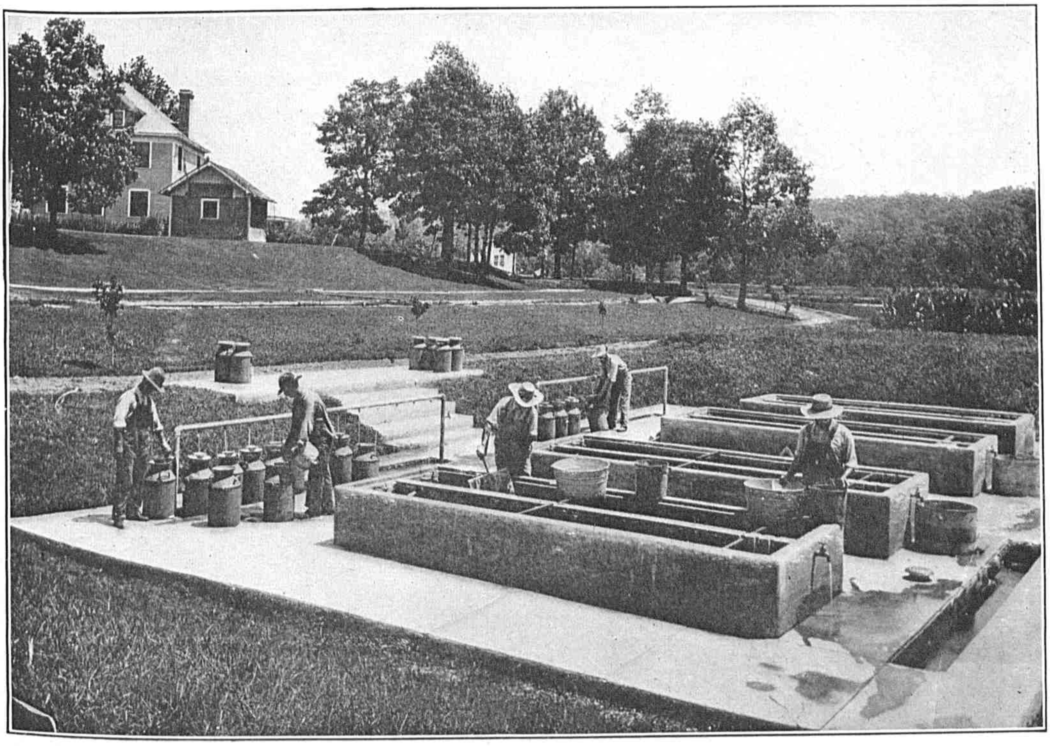

FIG. 18.—Preparing a shipment of smallmouth bass. Tanks used for hardening the young fish prior to transportation. The fingerlings are held for 12 hours in cold spring water, then dipped into tubs, counted into pails, and transferred to the transportation cans. These are then placed under a $\frac{3}{16}$-inch stream of spring water and held until train time. For an early morning shipment the fish are "canned" the evening before. (Mammoth Spring station, Arkansas.)

By this means not only is a conservation effected but the Bureau is enabled to meet the great demand of applicants for the basses, sunfishes, and perches at a less sum than it would cost to produce them at a station maintained especially for their propagation.

## THE PACIFIC SALMONS.

On the Pacific coast the Bureau has six permanent stations, including two in Alaska, all of them maintained primarily for the propagation of the Pacific salmons. Subsidiary to these there are six important field stations and other smaller ones where salmon eggs are collected and hatched. An idea of the extent of the work may be obtained from a statement of the output of these stations during the fiscal year 1908.

OUTPUT OF THE PACIFIC SALMONS IN 1908.

| Stations. | Species. | Eggs. | Fry and fingerlings. |
|---|---|---|---|
| Alaska | Sockeye | ---------- | 61,369,000 |
| California | Chinook | 64,990,550 | 4,780,855 |
| Oregon | Chinook | 3,530,000 | 19,718,996 |
| | Silver | ---------- | 215,932 |
| Washington | Chinook | ---------- | 498,309 |
| | Silver | 296,000 | 13,262,714 |
| | Sockeye | 75,000 | 8,514,305 |
| | Humpback | 502,000 | 6,764,762 |

The eggs shown in this table were transferred to state fish hatcheries and other places for incubation. In California, as will be noted, a very large proportion of the eggs taken are so distributed.

Observations at various field stations indicate that a large percentage of salmon eggs deposited naturally are fertilized but for various reasons only a small percentage hatch. Modern fish-culture methods permit of a much higher percentage of impregnation than under natural conditions, it being possible to actually hatch and distribute as fry more than 95 per cent of all eggs collected. So long, therefore, as a proper number of salmon are permitted to escape the various fishing devices in their ascent to the natural spawning grounds, and it is possible to capture them for the purpose of obtaining and impregnating their eggs, perpetuation of the salmon fishery is assured.

In the culture of the Pacific salmon it is impossible to save eggs from the commercial catch, because the latter is made before the fish are ripe, and to retain them until ripe is not feasible. By the time they have ascended the rivers to the spawning grounds and are in condition for the fish culturist the flesh has so deteriorated in quality that they are unfit for market in any form. The Bureau must therefore itself capture the fish it requires, and this is usually done by the construction of barricades to intercept the run at the most suitable point below the spawning grounds.

## BARRICADES AND TRAPS TO INTERCEPT SPAWNING RUNS.

That successful work at the salmon stations depends largely upon stable and suitable barricades, or racks, as they are more commonly called, may be instanced by the results of the work at Battle Creek, Cal., in 1903 and 1904. At the height of the season in 1903 a freshet carried away several sections of the rack grating, permitting the fish to escape upstream.[a] As a consequence only about 27,000,000 eggs were secured. The following season no flood occurred at Battle Creek until near the end of the spawning season, and the collections that year numbered over 57,000,000 eggs.

As all of the streams are subject to freshets, the water in some instances rising over 20 feet, the racks must be firmly built, and their successful operation depends not only upon ingenuity in construction but the care that is taken to guard against their becoming clogged with leaves and other débris in times of flood—work which at times is exceedingly hazardous. Methods in the construction of racks vary with local conditions, as do also the methods of capturing the salmon thus intercepted.

At the Mill Creek station, in lieu of a main or upper rack, the Bureau is able to take advantage of a mill dam 12 feet high, which effectively stops the passage of salmon. Half a mile below this dam a retaining rack with the usual traps prevents the fish from dropping down stream. Seining and spawning operations are conducted on the streams between the dam and the retaining rack.

*At Baird, Cal.*—At the Baird station on the McCloud River in California are two racks or barriers between which is formed a pool 400 feet in length. The upper rack intercepts the further passage of salmon, and the lower or retaining rack gives the fish free entrance to the pool, but effectually prevents their return. The upper rack reaches across the river, a distance of 250 feet, and is primarily supported by 10 concrete piers averaging 8 feet in height and extending 5 feet above low-water mark. The piers are properly fastened to the bed rock of the river bottom by means of heavy iron bolts. They have a flat top 4 feet wide and 6 feet long, and from top to bottom is a beveled nose extending upstream at an angle of 60 degrees, making them 4 feet wide and 10 feet long at the bottom. On either bank a small crib pier filled with rock supports the shore ends of two 10 by 10 inch stringers laid parallel from shore to shore across the tops of the piers. A 2-foot walk is built between the stringers and the whole is securely wired to eyebolts built in the pier tops.

Across the river bottom, against the nose of the piers, is a 10-inch sill. At intervals of 3 feet poles 4 inches in diameter extend at an angle of 60° from the sill at the bottom to the stringer at the top, and are securely fastened to the

[a] At Battle Creek the low-water mark is 10 feet below the top of the stringers on the rack, and during a recent flood the water was 12 feet above the top, making a 22-foot rise.

latter by large spikes. Against these poles or inclined uprights rest the gratings of the rack, which for the sake of convenience in handling are built in sections 6 feet wide and from 6 to 10 feet long to suit the varying depth of water. The gratings are made of 1½ by 3½ inch slats of dressed lumber set 1½ inches apart, their thin edge facing the current, the edge being convex to facilitate cleaning, and permit the passage of leaves. The ends of the gratings are nailed between two pieces of 1½ by 4 inch material, notched into the slats to make a flush surface. The space between the slats is gaged by nailing on 1½ by 4 inch blocks to each end. The longer gratings are braced with two strips 1½ by 4 inches nailed on 3 feet from the bottom.

In the upper rack is placed a trap 10 feet square with vertical slat sides similar to the rack gratings and having a solid board bottom. The narrow opening which allows the fish to enter is so constructed as to reduce to a minimum their chance of escape. The trap is primarily used for observing the general condition of the fish in the pool prior to the beginning of seining or spawning operations.

The retaining rack is at the lower end of the pool, where the stream narrows to about 190 feet. It is supported on 6 stone-ballasted crib piers with sides 14 feet long, made by spiking together logs 8 to 12 inches in diameter until the required height is reached. The piers are built on shore, floated into place, and filled with rock. Across the upstream end of each pier are two 10 by 10 inch stringers laid parallel and supporting a board walk, as in the upper rack. Two small temporary piers are also built, to support the shore ends of the rack. Gratings having 2-inch interstices are placed across the stream, similar to those in the upper rack, with the exception that 5 openings 2 feet wide are left between the piers nearest the center of the stream. These openings are covered by the usual traps, which extend upstream into the pool 9½ feet. The traps are 4 feet in height and 6 feet in width at the entrance, being shaped to fit the slant of the gratings. The sides are of 1¼ by 4 inch material spaced 2 inches apart, and with the broad edge toward the current. Braces are placed across the top, and at the apex of the trap is an opening 3 inches in width from the surface of the water to the bottom. The salmon pass into the pool through this opening and rarely, if ever, find their way out.

Before the installation of the retaining rack, some ten years ago, many eggs could not be collected by reason of the loss of fish from their running back downstream. This violation of the natural instinct of salmon to work ever upstream was due to fright resulting from the continual sweeping of the seine just below the upper rack. In the early days Indians were engaged to walk on either shore for a mile or so below the rack and beat the water with brush in an endeavor to drive the fish up to the seining ground. Since the installation of the retaining rack such measures have been entirely unnecessary.

*At Battle Creek, Cal.*—The main or upper rack at Battle Creek, Cal., is constructed on a comparatively soft and shifty river bottom, and is supported by piling, instead of by the log cribs anchored with rocks, more generally used. There are 12 bents of piling, each bent consisting of 3 piles driven firmly and braced with heavy timbers. The 3 piles comprising a bent are driven parallel with the current, the front one standing some 2 feet above low-water mark and the others about 8 feet above. The front and rear piles are placed about 10 feet apart. On these bents of piling and reaching across the stream are placed three 12 by 12 inch stringers, against which are secured 4 by 4 inch slanting supports, about 6 feet apart, the lower ends of which rest on a mud sill placed in the bottom of the stream. Stringers and these supports are so placed that the face of the rack will meet the current of the stream at an angle of about 60°. The gratings of the rack are built in sections of varying length but of a uniform width of 5½ feet. The slats for these gratings are of dressed lumber 1 by 3 inches, the sides set parallel with the current, the upstream edge convex. At either side of the stream, in the shallower water, single sections of gratings about 10 feet long extend from the bottom to the top stringer. In the deeper portions of the stream two 6 or 8 foot sections of the gratings are used, one above the other, with an opening between the upper and lower sections for convenience during the lower stages of water in the removal, with rakes and hooks, of rubbish and trash drifting downstream. When the water rises the closing of this aperture is easily accomplished by knocking out the blocking between the two, thus permitting the upper rack to slide down flush with the upper edge of the lower section. The length of the rack from shore to shore is about 300 feet, its vertical height above low-water mark being about 8 feet. During low water the front is submerged to a depth of from 18 inches to 2 feet, but there are holes considerably deeper behind the rack. A walk 2 feet wide is built on the top of the rack. A half mile below the barrier is a retaining rack quite similar to the one described for the Baird station.

At Battle Creek the racks are usually installed during September in time to intercept the fall run of salmon, and unless carried out by high water, remain until the close of the work in December. Gratings, stringers, etc., are then removed and stored for use another season.

*At Birdsview, Wash.*—A permanent barrier at the Birdsview station, an auxiliary of the Baker Lake station, in Washington, is of novel construction and calls for more than passing notice. This barrier is located in a portion of Phinney Creek where formerly there was a dam built for the purpose of obstructing the passage of steel-head trout. When the dam washed out, a new channel formed and the river bed was very much broadened.

The first step in the construction of the new barrier was the laying of four heavy log stringers across this new channel from the abutment on the north to

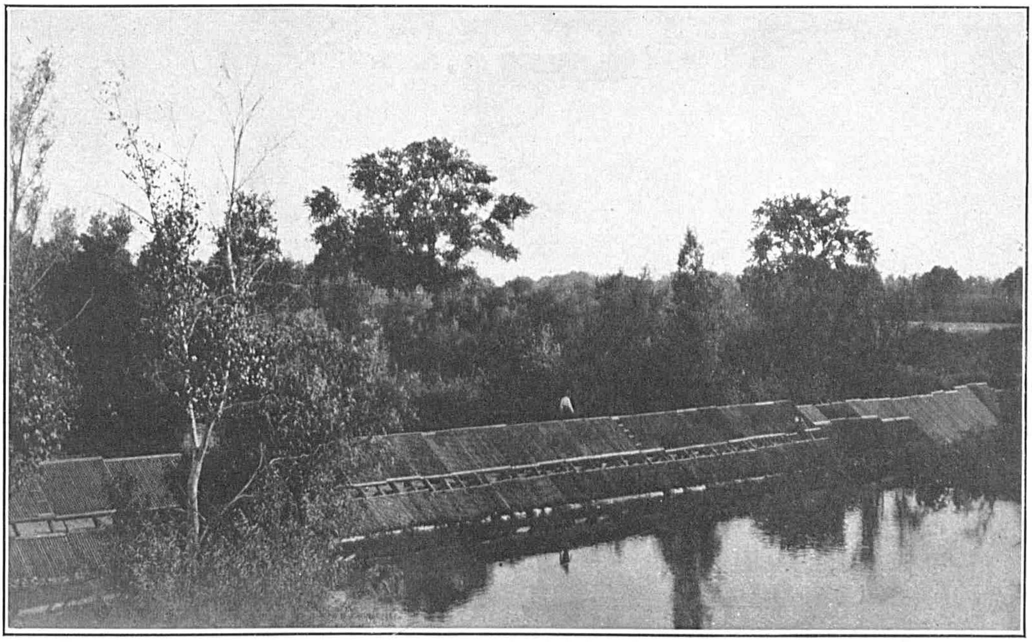

FIG. 19.—Main rack across Battle Creek near the Battle Creek station, California. Upper sections of rack raised to facilitate disposal of leaves and other débris.

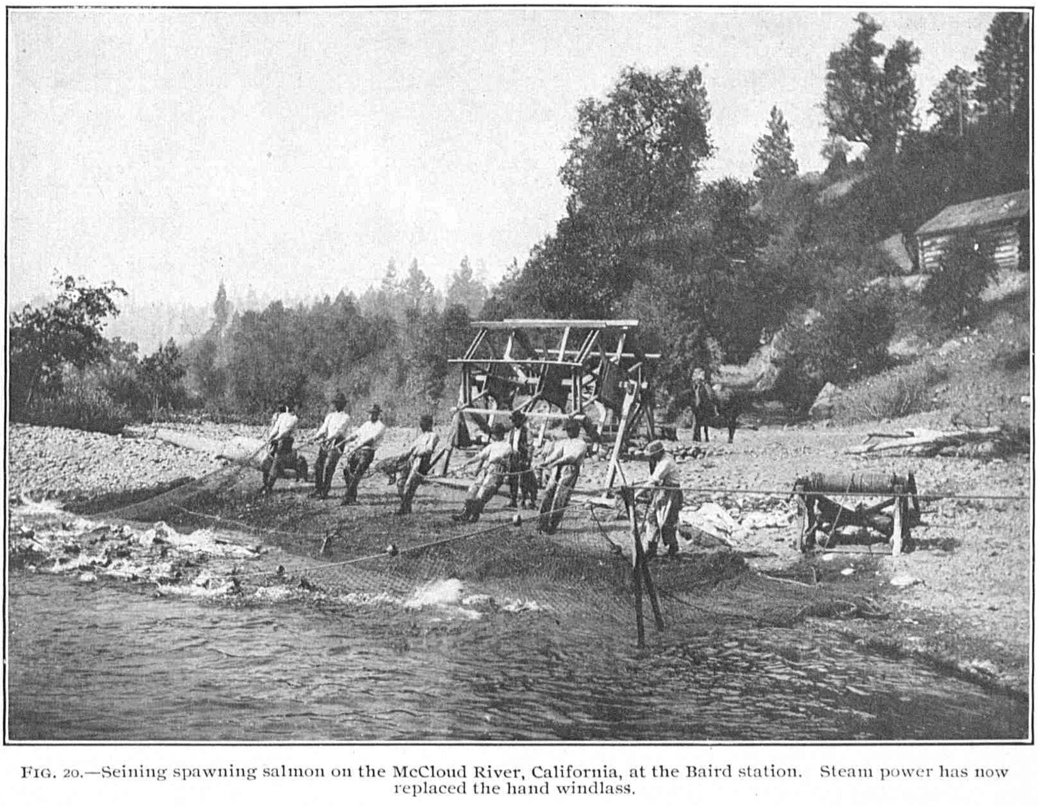

FIG. 20.—Seining spawning salmon on the McCloud River, California, at the Baird station. Steam power has now replaced the hand windlass.

the new bank on the south side of the stream. The logs were let down through the dam foundation to low-water level on the north side and the deep channel under them on the south side was filled with brush and gravel. The logs were spotted down to form a practically level bed, reaching the width of the stream. Heavy piles were then driven behind each stringer to form alternate single and double rows extending up and down stream. The log stringers were next planked over, forming a platform 18 feet wide, similar to a regular dam apron, extending from the north abutment to the final row of piles on the south side, a distance of about 140 feet.

By planking the sides of the single rows of piles and all around the double rows and filling the space with rocks, piers 4 feet high and approximately 2 feet and 4 feet wide were formed. Through each pier at the bottom, behind the upstream pile, openings 1 foot square were left, connecting the spaces between the piers. These spaces, 12 in number, are approximately 8 feet wide and are filled by swinging gates hinged to a 3 by 12 inch timber, spiked securely to the piers on either side and forming a dam or flashboard across the space above. By the insertion of other flashboards above this one a tight dam 4 feet high can be quickly formed at any time. The utility of this feature will be explained elsewhere.

The gates are made of 1 by 4 inch fir set on edge and nailed to 2 by 4 inch joist, being strengthened by 2-inch blocks set between the rack bars and nailed to them and the joists. These blocks thus determine the width of the interstices in the gates. At the upper end of each gate an auger hole is bored through the bars and blocks, to accommodate a 2-inch iron pipe, which passes through the entire upper end of the gates. Ringbolts clasp these pipes and are fastened to the 3 by 12 inch timber forming the flashboard, acting as hinges upon which the gates swing. At the lower end of each gate a wide board, 1¼ by 16 inches, is secured by means of braces, forming an angle of 45° with the lower end of the gate.

At any ordinary stage of the stream the downstream ends of the gates rest on supports which hold them a foot or more higher than the upper ends, the water passing down through them to the floor of the apron, where it runs away. The fish working up under the gates to the dam board find the cross passages through the front end of the piers and finally reach the trap. It was expected that during freshets the current acting on the flashboard would always keep the lower ends of the gates above the surface of the water, and up to a certain point this expectation was realized, but at very high stages of the stream the large quantity of gravel in the water soon clogs and sinks the gates. As the gates are only two-thirds the length of the apron, however, and rise toward the lower end, the water shoots over them with such force that it is projected some distance below the end of the apron, and fish attempting to

*B* and *C*, single and double rows of piles, respectively.
*D*, downstream end of racks.
*E*, floor under racks.
*F*, open channel to trap.
*G*, walls of V-shaped approach to trap.
*H*, trap.
*J*, screen at head of trap.
*K*, openings in pier for passage of fish to *G*.
*L*, door in north side of V-shaped approach.
*M*, abutments.

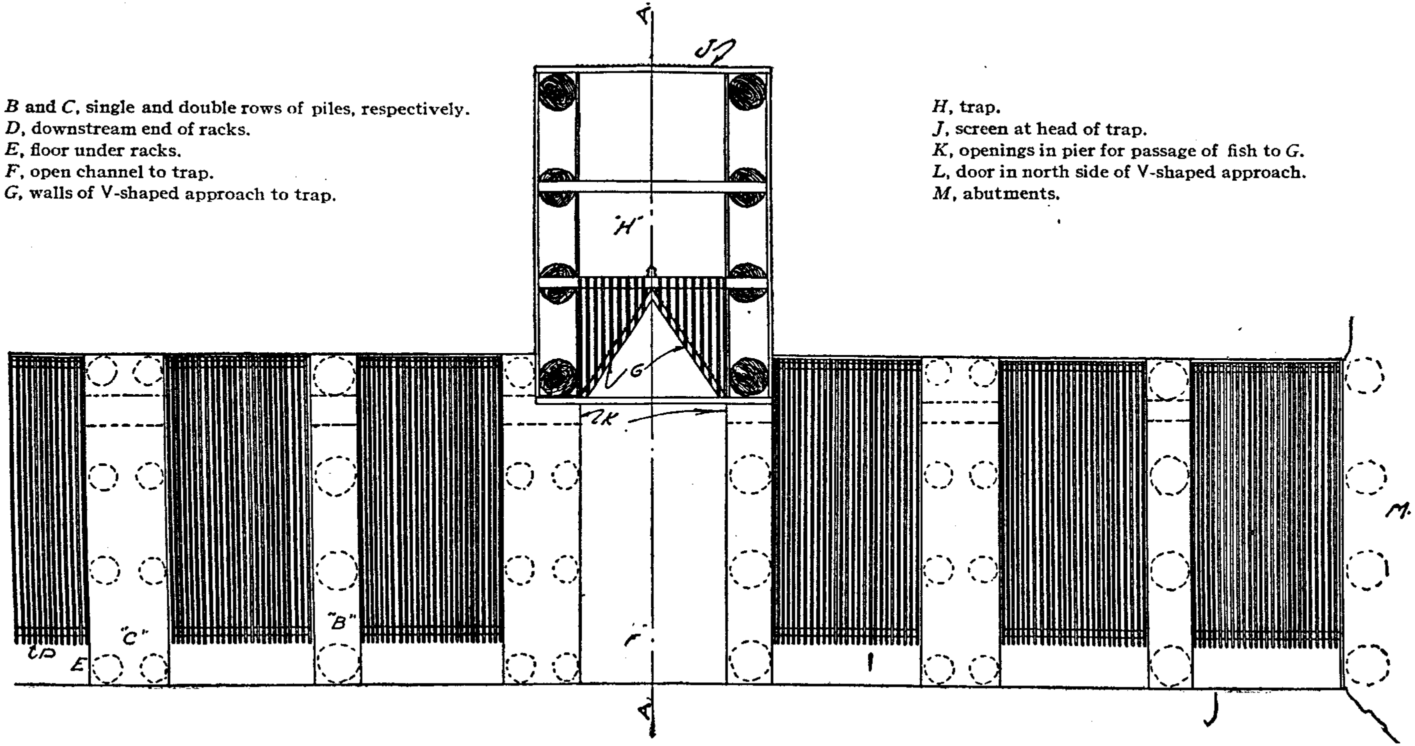


FIG. 2.—Plan of barricade in Phinney Creek, near Birdsview, Wash.

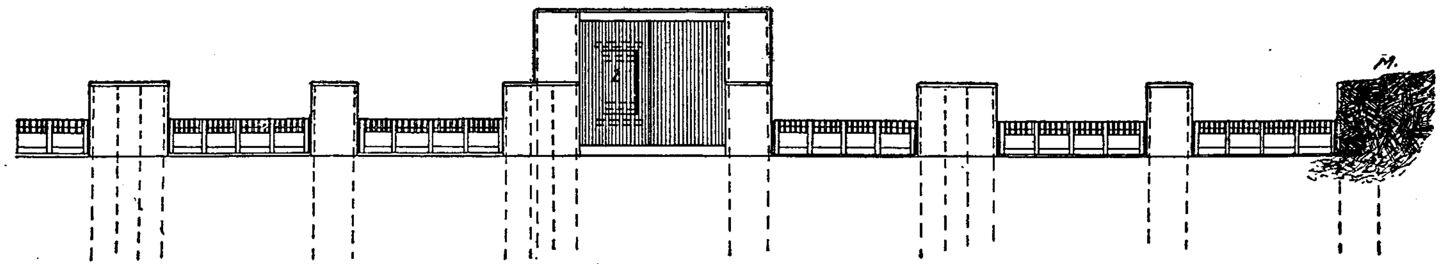


FIG. 3.—Front elevation of barricade shown in figure 2.

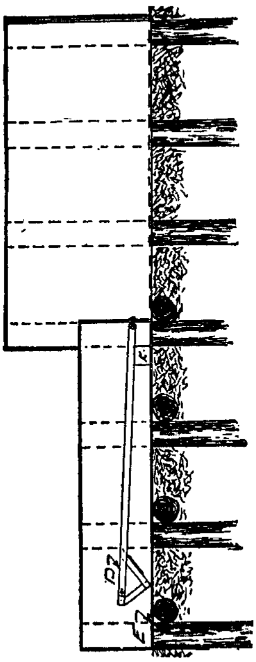

FIG. 4.—Side elevation of barricade shown in figures 2 and 3.

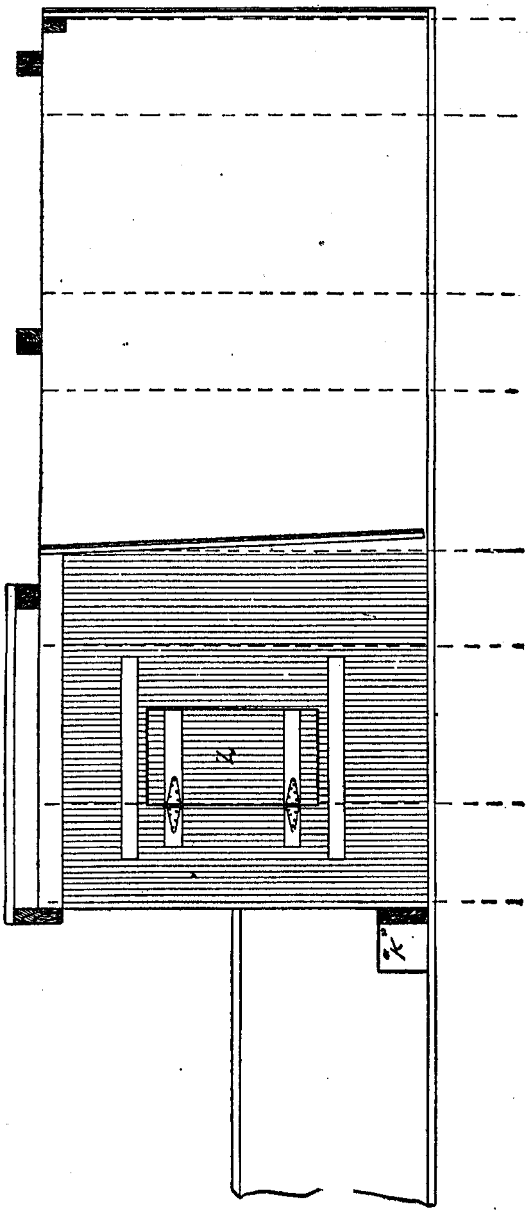

FIG. 5.—Section on line A-A of figure 2.

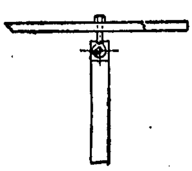

FIG. 6.—Detail showing method of fastening racks. (See figures 2 and 4, *D*.)

scale the obstruction fall far short of the ends of the gates. The barrier has been watched many times when fish were jumping and when the largest drift ran clear, and none has ever been seen to pass it.

By means of the dam boards entire control of the current can be had during ordinary stages of water and any desired quantity sent to any section of the barrier. Thus a strong current can be maintained through the trap section, leading the fish to it, and when it is desired to remove the fish from the trap the water can practically all be turned to some other section of the barrier.

One of the greatest difficulties in maintaining traps in the streams in this section is due to the tremendous quantities of gravel carried in the water during freshets, a sufficient amount being frequently deposited in front of a trap at such times to change the course of the stream. With the present form of barrier no trouble is experienced from this source, the insertion of the dam boards and the opening of one space at a time quickly clearing away the accumulated gravel.

The ninth and tenth piers were continued upstream by driving three additional piles above each. The piers form the sides of the trap. Its floor is a plank bottom, similar in construction to the apron, and the front is barred by 1¾-inch pickets placed 1¾ inches apart, the fish entering by the usual upstream V of pickets. To protect the trap from high water the two piers between which it is located were carried to a height of 8 feet. When it is desired to fish the trap, the gate at its head is closed and entrance is made from below by means of a door in the north side of the V.

The upper end of the fishway of the old dam was left in place, the narrow passage between it and the new trap protecting the spaces at the south end of the barrier from the current and from drift. These spaces have been racked above and below to form commodious pens for males and unripe females. The south end of the barrier is protected by a substantial abutment.

The maintenance of racks in Phinney Creek has been a very heavy item of expense in past years, and the trap was frequently carried away by freshets just at the height of the season, allowing large numbers of fish to escape and considerably reducing the season's take of eggs. It is believed the new barrier will stand any possible test that may be put upon it and will fish successfully in almost any stage of water. The design is to be credited to Mr. A. H. Dinsmore, superintendent of the station.

## TAKING AND HATCHING THE EGGS.

*Seining operations and spawntaking at California stations.*—At the Baird station all the salmon are caught by seine with the exception of a very few taken in the trap in the upper rack. Owing to the swift current and the formation of the river banks the seine is always landed at one place, the rope attached to the upstream end being hauled by steam engine and the lower or downstream rope by a whim operated by horsepower.

When a haul is to be made the seine is carried by boat upstream about 50 yards from the landing before it is paid out from the shore. The downstream rope is paid out automatically as the boat moves and is passed through a snatch block to keep the current from closing the ends of the seine until opposite the landing place, when both ends are drawn in at the same time. As soon as the seine has been laid out above the pool the engine is started, drawing the seine downstream toward the landing. When the last of the seine is in the water the whim is started and the lower end is also hauled down and in. A landing having been made, the ends of the seine are secured to pieces of rope fastened to pins driven into the ground. Hooks on loose ends of these ropes are slipped behind the corks of the seine. A trestle is placed under the rope to hold the cork line high above the water and thus prevent the salmon from leaping over it. The lead line is pulled upon the bank and thrown over iron pins to keep it from slipping back into the deep water.

The ends having thus been fastened, all the men are free to handle the fish, which must be quickly removed to prevent injury from crowding, this being especially true of the summer run when the water is warm. The men stand in the water and lift the fish from the net one by one until all have been looked over, handling them with the aid of heavy woolen gloves, and grasping them by the tail with the left hand while the right is placed just behind the pectoral fins. A gentle pressure of the fingers at this point forces out a few eggs if the fish is ripe; if not ripe it is thrown over the seine into the river. When a ripe female is found it is carried to the pens beneath the spawning platform a few yards distant, care being taken to hold it vent side up to prevent loss of eggs. The males are handled in a similar manner, the ripe ones being placed in pens near the females.

The seining crew are likewise the spawntakers, and after two hauls in the morning they strip the fish caught the day before. The ripe salmon of each day's catch are thus held over as a precaution against any possible immaturity of the eggs.

On the spawning platform is a frame 6 or 8 inches wide, with sides converging toward the bottom and open at one end, into which a spawning pan can be slipped. The pan is rectangular in shape, about 6 inches wide and 14 inches long, with slanting sides and flaring ends. This shape is preferable to the round pan because of facility in washing the eggs, it being possible to dip a thin stream of water into the pan the entire length of one side. The frame holds the pan secure and at the same time its slanting sides assist in guiding the eggs into the pan.

After washing, the eggs are placed in 6-gallon spawn buckets which have previously been filled with water. These buckets are made of galvanized iron, with a wire-cloth strainer inserted near the rim to permit the escape of surplus water as eggs are added; they are painted inside with asphaltum, and are provided with covers. With the eggs in them they are placed on a platform which is built under water at sufficient depth to submerge about two-thirds of the body of the bucket, and thus maintain a proper temperature during water hardening. It is an essential feature of this platform that it be entirely independent of the spawning platform in construction. The period between the washing and hardening of the eggs is a critical one, and if they are jarred or disturbed there will be consequent greater loss in the hatchery.

In the spawntaking operations five or six male fish are first dipped from the pen and dropped on the floor, where they are allowed to lie until they stop struggling and may be more easily handled. Then several females are dipped out, killed by a blow on the head with a piece of iron piping, and laid in the dead box. The bottom of this box is inclined and has a narrow slit at the lower end, through which any eggs that may escape from the fish will fall into a pan underneath, where they will be fertilized by occasional applications of milt. The dipping and killing continues until all the fish are stripped, males always being kept on the floor in order to have several ahead of the spawntakers. After being stripped the best-appearing males are returned to the pens, where they usually recuperate and are again used to supply milt.

The female fish is grasped by forcing the fingers through the gills and the thumb into the mouth, the hand being protected by a stout leather glove. The man who does this, the headholder, stands, holding the fish vertically. The spawntaker, in a kneeling position, seizes the fish by the tail, bending its body over the pan, while with a sweeping motion he makes an incision in the thin side of the belly beginning near the pectoral fins and extending to the anal. The incision is usually made with a pocketknife, the blade being held between the thumb and index finger within one-half to three-fourths inch of its extreme point to prevent cutting too deep. Most of the eggs follow the knife and fall into the pan, the remaining ripe eggs being released by running the fingers into the body cavity. As soon as the eggs begin to flow into the pan milt is forced over them and they are stirred by the spawntaker with a few movements of the hand. They are then passed to the washer. The milt of one male may serve for several pans of eggs, but it often happens early in the season that several males are required to one pan.

As soon as the washer receives the pan of eggs he dips the edge of it in the river, the inflowing water causing the eggs and milt to boil up. The eggs at once settle back and the milt is poured off over the side of the pan. Ordinarily two such dips suffice to clean the eggs, after which they are poured into spawn buckets, and at once settle to the bottom, the surplus water escaping through the wire-cloth strainer near the top. Spawning operations usually consume about an hour. After water hardening the eggs are carried to the hatchery, about 200 yards distant, and turned over to the hatchery crew.

FIG. 21.—Spawntaking operations, Baird, Cal. The fish (chinook salmon) are dipped from the pen, killed by a blow on the head, and passed to the spawntakers. The eggs are taken by opening the abdomen, and the stream of eggs may be seen in the picture following the hand making the incision.

FIG. 22.—One method of stripping steelhead trout. Since this fish normally does not die after spawning, the ripe fish are not killed as are the salmon, and they are so large, and so powerful in their struggles, that the strait-jacket here shown is sometimes resorted to.

The spawning operations at Battle Creek and Mill Creek are practically the same as those at Baird, and the seining differs only in minor details to meet local conditions.

The method of taking eggs by incision has many advantages over the older practice of expelling by hand, chief among them being the larger number of good eggs secured and the higher percentage of impregnation. There is also a great saving of time and labor, and, as all of the Pacific salmons die after once spawning, the killing of them in the process of taking the eggs merely hastens the end, and constitutes no loss of adult fish.

The eggs of the Pacific salmons are comparatively large, ranging in diameter from one-fourth inch for chinook to one-fifth inch for sockeye. Fortunately, however, these large eggs do not require the same treatment and care as do those of the other Salmonidæ, but may be placed 12 to 20 deep in wire-cloth baskets, 30,000 to 50,000 to the basket, water temperature being an important factor in deciding the quantity. The baskets, rectangular in shape, conform in width to the troughs; the latter are of the Williamson type (up-current), the flow of water to each trough varying with local conditions at the different hatcheries from 8 to 20 gallons per minute.

*Local practices in different regions.*—Experience seems to indicate, with regard to the sockeye, or red salmon, that there is an advantage in bleeding the fish before stripping, thus obviating a flow of blood with the eggs when the incision is made. It is therefore now customary at sockeye stations to decapitate or else cut off the tails of the female fish as the first step in the spawn-taking process. At Baker Lake, Washington, the practice is as follows:

The fish, which have been brought to the pens usually the day previous, are dipped out one by one, decapitated, and dropped upon a draining rack, where water is thrown over them to cleanse them for handling by the spawn-taker. The latter impales the fish on a short spike conveniently located to hold them over the pan while he makes the incision and removes the eggs. Two men are occupied in the work so far. A third fertilizes and washes the eggs, then conveys them to the hatchery. A million eggs may be secured in this manner in one forenoon by one such crew.

Although not suitable for canning or for the market, the sockeye at this period is edible and many are taken by local residents for food. Indians camp at some of the stations and preserve large numbers of the salmon. The majority of those killed, however, go to waste. At the Battle Creek station in one season it is not an unusual thing to bury during the spawning season 15,000 to 20,000 pounds of fish.

A convenient and economical method of separating dead eggs of salmon from living ones is the use of a salt solution.[a] If a basket of eggs is emptied

[a] O'Malley, Henry: Salt solution as an aid to fish culture. Transactions of the American Fisheries Society for 1905, p. 49.

into the solution, the unfertilized and dead eggs rise to the surface, where they may be quickly skimmed off. The method is not applicable in the manipulation of small quantities of eggs, but is very useful when, for some cause, there is an abnormal loss. It has not been successfully extended to the eggs of species other than the chinook, silver, and humpback salmons.

At the Baker Lake station, operated primarily for the propagation of the sockeye salmon, both sockeye and silver salmon are captured by means of a pound net as they enter the lake, but as the fish are not ripe at this stage of their upstream passage it is necessary to hold them until the spawning season. For this purpose a slough or bay at the head of the lake has been inclosed by racks and webbing to make a pound about 20 feet wide and 500 feet long, with an average depth of 6 feet. The entire bottom area is of soft mud; in it are two hollows of a maximum surface area of 300 feet and 400 feet, respectively, where the water is approximately 12 feet in depth. The water supply, from 800 to 2,400 gallons per minute, is derived from several small mountain creeks fed by glaciers and snow, and from springs.

This has proved an ideal place in which to hold salmon while their eggs are maturing. As many as 8,000 fish have thus been confined for thirty days and 6,000 for three months. After remaining in the inclosure for three or four months the fish are as clean and free from abrasion as fish that have not been penned. A noticeable fact, however, is that very few of these salmon ripen until October or November, while in previous years the spawning season has occurred during September and before October 15. The difference is attributed to the low temperature of the water in the inclosure, which remains from 6 to 8 degrees below that of the natural spawning beds of the lake. (During the summer the average water temperature on the spawning beds is about 56°.) The success of the impounding of the salmon is attributed to the low temperature of the water.

Silver salmon, as well as sockeye, have been successfully impounded at Baker Lake. A few impounded chinook, however—never more than 12 at a time—fungussed rapidly, and after three weeks usually died before the eggs were taken.

## MARINE FISH CULTURE.

### COD, POLLOCK, AND FLATFISH.

On the New England coast the Bureau maintains three stations, for the hatching of marine fishes and the lobster.

Of the fishes the cod is first in importance. Its cultivation consists principally in hatching eggs obtained from market fish, the fish being stripped either by the fishermen or by the Bureau's spawntakers. The latter are daily distributed among the fishing vessels for the double purpose of stripping ripe fish as fast as hauled aboard and of collecting and caring for all eggs the fishermen may have taken. Coming as it does during the winter months, from early December to March on the Massachusetts coast and extending through March and April on the Maine coast, the spawning season is a trying one for the spawntakers, who must share many of the dangers and hardships of the fishermen.

At the Woods Hole station advantage has been taken of the presence of a large salt-water reservoir under the hatchery to test the Norwegian method of obtaining eggs. By this process adult fish are penned and allowed to spawn naturally. The eggs float to the outlet, where they are caught in a receptacle placed for the purpose, and thence are transferred to the hatching boxes. It has been demonstrated that a larger percentage of fertilized eggs per fish can be obtained thus than by the former method of stripping penned fish. The increase is not due to a higher percentage in fertilization, but to the fact that in the case of the penned fish there is an almost unavoidable loss of eggs extruded in the crates. Both of these methods are an improvement over nature, in that the eggs are protected from the time of extrusion until they have hatched and the surviving parent fish are returned to the ocean. This is fish culture in the usual sense and not purely conservation of an otherwise waste product, as is the collection of eggs from market fish.

Prior to the spawning season for cod, or from the middle of October to the latter part of December, spawntakers are distributed among the pollock fishermen, and from the eggs thus collected many millions of pollock fry are hatched and distributed annually.

The cultivation of flatfish is conducted on a more extensive scale than any other marine fish-culture work. The adult fish are taken from the fyke nets in which captured, usually the Bureau's own, directly to the hatcheries, where they are placed in tanks and held until they have spawned, the eggs being removed daily from the tanks to the hatching apparatus. It is possible to spawn flatfish artificially, and eggs are sometimes obtained in that way.

## LOBSTERS.

Lobster culture also, as conducted by the Bureau, effects a saving of an otherwise lost resource, berried lobsters purchased from the fishermen furnishing eggs for the hatchery and being later returned to the ocean. At the Boothbay Harbor, Me., station the parent lobsters are held until the eggs are ripe in a pound similar to those used by the lobster men; and as it has been found that eggs taken late in the fall or early winter do not hatch successfully, one such pound is utilized to hold some 10,000 or 12,000 lobsters throughout the winter. The losses of lobsters during the period of confinement are only normal, and the quantity and quality of the eggs are superior to those obtained from freshly caught stock. It is noticeable also that the eggs of the impounded stock hatch almost simultaneously and somewhat earlier than those from freshly caught lobsters, undoubtedly because of the warmer, shallow, inshore water. By the middle of April the eggs are sufficiently well advanced to be removed from the parent and put up in the hatching jars; and as at this time the lobsters become quite active in a rising water temperature it is quite important that they then be removed to avoid serious losses from mutilation.

The removal of impounded lobsters is effected at low tide, the flood gates being opened and a portion of the water drawn off with care to retain enough water to protect the lobsters from exposure. Men in dories then go about the shallow portions of the pound picking up the lobsters on ordinary clam forks or hoes, the sharp teeth of which have been blunted. It was formerly the custom to use a drag seine for gathering the lobsters, but taken in such quantities they mutilate one another and it has been found preferable to remove them by hand. After a portion of the stock has been removed the water is drawn still lower, until finally only a small area of the pound is flooded, and the remaining lobsters are removed.

As it has not been possible to transport lobster eggs successfully when detached, the berried females are always taken to the hatchery to be stripped, the transfer being made in the wells of fishing smacks or the Bureau's vessels. From this time to the close of the season in July berried lobsters are collected from the fishermen and transferred to the hatchery to be stripped. Immediately after the close of the season the collection of fresh berried lobsters for stocking the pound is begun and continued into November.

It is unquestionable that the impounding of lobsters as practiced in Maine is superior to any other present method of holding the adults for a length of time. The character of the Maine coast, with its numerous natural inlets and its unusual rise and fall of tide, affords especial advantages for the use of pounds. When these conditions do not exist, however, recourse can be had to cars, although data thus far obtainable fully demonstrate that a larger number of lobsters can be held for a longer time and with a smaller percentage of loss in pounds than in cars.

Contrary to the custom of the pound fishermen, the ice on the surface of the pound operated by the Bureau of Fisheries is removed from time to time during the winter, with the result that a much larger percentage of lobsters is found in the spring. It has been observed that the rising and falling of ice with the tide frequently crushes lobsters that happen to be in the shallow water near the edges of the pound, and removal of the ice at intervals obviates this difficulty.

Experiments have been made as to the poundkeepers' practice of inserting wooden plugs in the claws of penned lobsters to prevent their mutilating one another. For lobsters intended for market the procedure seems suitable, though it results in an unsightly discoloration of the muscles. There seemed

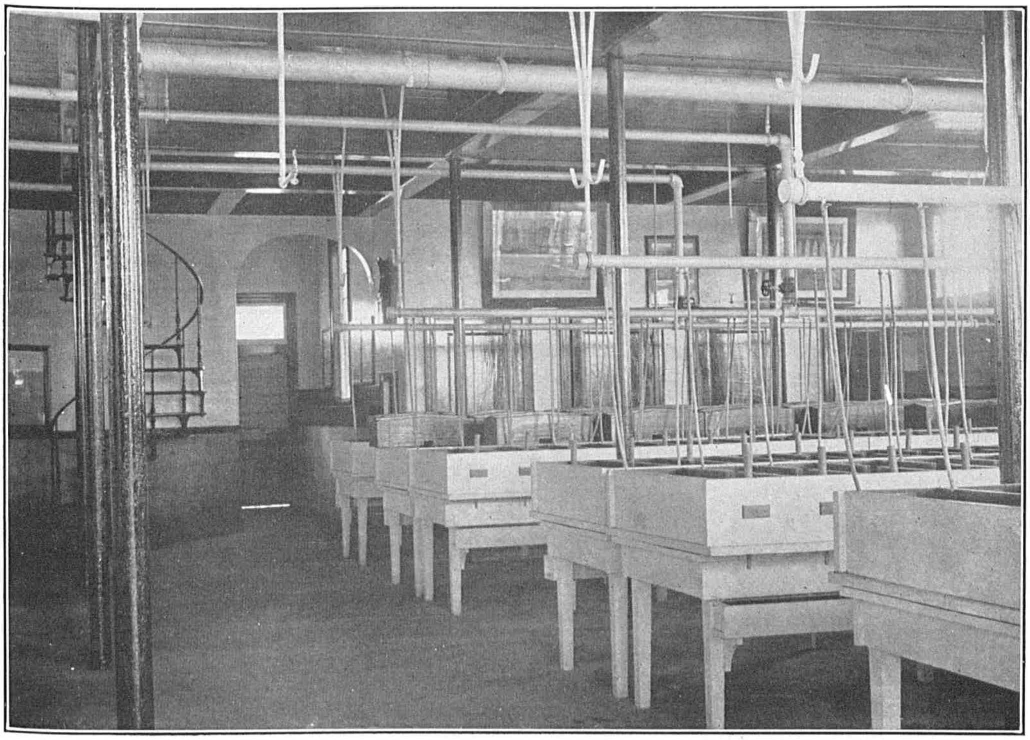

FIG. 23.—Equipment of McDonald automatic tidal boxes, for hatching cod, Boothbay Harbor, Me. Shows boxes lifted out of troughs and bottom upward on farther tables. The bottom is of scrim, and by means of cleats is held 1½ inches above the bottom of the trough at the center. By an arrangement of partitions at the head of the trough the eggs receive the supply of water through the scrim bottoms of the boxes, also through a small hole in one end of the box. The distinctive feature of the apparatus, whence it is called "tidal," is the automatic siphon outflow, by means of which the water is alternately drawn down and replenished. Standpipe with siphon cap is shown in near troughs; waste trough below.

FIG. 24.—Berried lobsters, taken from pound at Boothbay Harbor station (Maine), in course of transfer to wells of the steamer which is to convey them to the hatchery for stripping.

to be a question, however, whether it would be feasible with the impounded stock of the Bureau destined for liberation in the open waters after removal of their eggs. The experiments showed that out of 2,110 lobsters removed from the pound, all of which had been plugged when put in, 742 had lost both plugs, 563 had lost one plug, and 605 retained both. The warm weather when they are first confined, however, is their most active period, when the plugs do most good. Mutilation is thus prevented and the plugs apparently work no permanent injury to the lobsters.

It is important in the impounding of lobsters to take precautions, so far as possible, for the exclusion of eels, which have an especial liking for the eggs and will strip a female lobster in a very short time. Even with all precautions it seems impossible to exclude eels entirely; it is probable that many enter when small and grow up in the pound.

The rearing of lobster fry to the fourth molt, as practiced by the Rhode Island Fish Commission and so admirably set forth in a paper read at the congress,[a] has not as yet been taken up by the Bureau, but is doubtless feasible at the Boothbay Harbor station. Before the first experiments in this direction at Boothbay it was thought that owing to the lower temperature of the water in this more northern latitude the periods of molting would be prolonged and the feeding and care of the fry consequently attended with abnormal losses. It has since been found that this difficulty can probably be met by installing the rearing plant in a lobster pound, where the temperature is higher and more even than in the open waters. The Bureau therefore hopes to enter upon this undertaking in the near future, for the purpose of rearing a portion of the lobster output. To attempt to rear to the fourth molt the entire product of the Boothbay station would involve an expenditure far beyond present financial resources.

## MEASURING AND COUNTING FISH EGGS AND FRY.

Immediately after water hardening, for a short period varying with the species and water temperature, the careful handling of fish eggs is not injurious. During this period their numbers may be very definitely ascertained by the use of any receptacle suitable for a measure, the capacity of the receptacle having first been ascertained by counting the whole or a fractional part of its contents.

For eggs of the trouts and those of smaller size an apothecary's graduate or the ordinary graduated quart or pint measure is commonly used. For large quantities the long-handled dipper used in transferring them to the hatching apparatus may be advantageously utilized. As many eggs as possible are poured into the measure, nearly all of the water being forced out over the rim.

[a] Mead, A. D.: A method of lobster culture. Proceedings Fourth International Fishery Congress, Bulletin of the Bureau of Fisheries, vol. XXVIII, 1908, p. 219–240, pl. VII–XI.

Unless the eggs are to be transferred to a hatchery beyond the jurisdiction of the shipper, the eggs may not be measured until a more convenient time, it being possible from long familiarity with the capacity of the apparatus in actual use to estimate quite accurately the number of eggs on hand at any time. Providing they are spread uniformly, the number of eggs to a square inch is a fairly accurate basis for ascertaining how many eggs are on each tray. Some fish culturists prefer to ascertain the actual number of eggs on hand by weighing them after having determined by actual count the basis for such calculations.

These methods are especially applicable to the heavy eggs of the Salmonidæ, and may be employed not only after water hardening but also at any stage of incubation after the eggs are eyed up to a day or so before hatching, at which last stage a measurement closely approximates the number of fry that will be in the subsequent hatch.

Eggs hatched in jars are usually measured by means of a graduated scale in the form of a square made of wood, the units indicated on the long leg of the square. The square is adjusted to the jar as shown in figure 1. The scale reads from the bottom line upward, the first or bottom line being at a height corresponding to the level attained in a jar by a measured half pint of water, and each line represents the number of eggs of a given species as established by actual count from a measured half pint. The dead eggs will have been from time to time siphoned off and when the remainder are fully developed or about to hatch the scale is applied to each jar and a very careful measurement is made to ascertain their number. The number of fry available for distribution will be approximately the number of eyed eggs in the jars just before hatching, as the mortality after this stage of development is usually inappreciable.

A novel method of obtaining the number of eggs in a given lot has lately come into use, and as the work can be done without counting a large number of eggs, has proved especially valuable in dealing with eggs of small size at field stations where no measurements have been established. This method, devised by Mr. H. von Bayer, architect and engineer of the Bureau, employs a gauge which quickly gives the diameter of the eggs, knowing which it is possible by reference to a diagram to determine at once the number of eggs to the quart.[a]

In the keeping of accurate hatching records it is important that the basis for computations be ascertained immediately before any general measuring methods are applied because it is well recognized that eggs of most species vary in diameter with stock from different waters and that eggs from any given collecting station vary at different periods of the spawning season, those taken at the height of the season being larger and more uniform than those taken earlier or toward the close of the season. For instance, brook trout eggs taken at a

[a] von Bayer, H.: A method of measuring fish eggs. Proceedings Fourth International Fishery Congress, Bulletin of the Bureau of Fisheries, vol. XXVIII, 1908, p. 1009–1014.

particular station may run 250 to the fluid ounce during the height of the season, while the first take may have run 300 to the ounce and the last eggs of the season may average 400 or more to the ounce. These variations make it necessary frequently to establish a new measure for ascertaining the actual number of eggs. There is also to be taken into consideration the fact that eggs of almost all fishes increase in size from 4 per cent to 15 per cent according to the species, from the time they are water-hardened up to the time they are about to hatch.

This fact, coupled with the fact that eggs of the same species vary in size at different sources of supply and periodically at the same source of supply, is a point in favor of the von Bayer method of computing the numbers of eggs of small diameter.

Sac-absorbed fry and advanced fry of the trouts, landlocked salmon, etc., may be measured in the same manner as are the eggs—in an apothecary's graduate or other container, straight vertical sides being preferable to the flaring sides of the ordinary glass graduate. The ordinary graduated half pint or pint cup used by cooks is a very convenient measure. The fry are poured in until the measure is overflowing with them to the exclusion of practically all the water, the filling and emptying being done quickly. Actual count of the number in one measure establishes the basis for computation. The growth during this period being very rapid, however, a new unit must be determined daily.

The numbers of fingerlings are ascertained by actual count of each lot as dipped a few at a time from trough to transportation can or other receptacle by means of a small hand net of tightly stretched bobbinet.

## TRANSPORTATION OF EGGS.

To equalize and facilitate the work of the hatcheries it is customary to transport, sometimes to considerable distances, both green and eyed eggs from one station to another, thus effecting the distribution of fish through the distribution of eggs. Several auxiliary stations are maintained on the Great Lakes solely for hatching eggs received from Northville, it having been found economy to transfer to them as eyed eggs the portion of the Northville station output destined for distribution to waters in those localities. Both green and eyed eggs are also shipped to state hatcheries and the latter to foreign countries.

The methods of conveying green eggs from the field where collected vary to suit conditions. The stations at which eggs of commercial fishes are hatched in large numbers are usually located conveniently to the source of supply so that it is possible to carry the freshly fertilized eggs to them in the pans, buckets, or other receptacles which constitute the equipment of the spawn taker. It often happens, however, that the eggs must be held in the field or be in transit for two or more days, and in such cases a packing case is employed.

## USUAL STYLE OF PACKING CASE.

For ordinary purposes a packing case consists of a wooden box which will accommodate a stack of trays and an ice hopper, with 2 to 4 inches of insulation or packing on all sides and under the tray stacks. The frames of the trays are made of light, soft wood, usually white pine, 5/8 inch by 7/8 inch or 7/8 inch by 7/8 inch, over which is tightly stretched a bottom of canton flannel, nap side up, or of heavy cheese cloth, with perforations in the cloth to facilitate the passage of water.

For long-distance shipments it is customary to make the bottoms of the trays of wire cloth painted with turpentine asphaltum, over which canton flannel or cheese cloth may be spread before putting the eggs upon them, and a thin layer of moss under the cheese cloth in addition is advocated by some fish culturists. The soft spongy bed of moss prevents concussion in handling and retains moisture, while at the same time it allows a sufficient circulation of oxygen and free passage for water from melting ice, etc. For very long or warm-weather shipments it is sometimes advisable to use a case with double sides, with insulation between, the space between the inner case and stack of trays being filled with ice.

The ice hopper is about 3 or 4 inches deep, of the same length and width as the tray frames, and rests upon the top of the stack. Its bottom is perforated to allow a drip from the ice through the trays and thus keep the eggs constantly moist and cool. Double cases, the length twice the width, arranged for two stacks of trays side by side with a partition between them, are sometimes used in the Pacific salmon work.

The fish culturist often works in isolated places and must use the material which is most accessible and economical. Moss is therefore very generally used for filling the space between the stack of trays and the packing case; mineral wool, leaves, sawdust, and shavings also well serve the same purpose, though with ice in contact with the inside lining of the outside case mineral wool is objected to because when damp it has a tendency to sag. Any of these materials may be used for insulation in the long-distance cases. Cork board insulation, also, is very efficient and of lighter weight than the others, but it has not been tested so fully as have shavings, at present the material most popular with caretakers.

The cover to the case may be screwed on, but for shipments requiring the renewal of ice it is customary to provide a hinged cover fastened with hasp and staple.

## ADAPTATIONS AND VARIATIONS OF METHOD.

Eyed eggs of the Atlantic and Pacific salmon and of the steelhead trout have all been successfully shipped in the ordinary case, but the method of packing eggs of the Atlantic salmon at the Craig Brook (Me.) station has the special

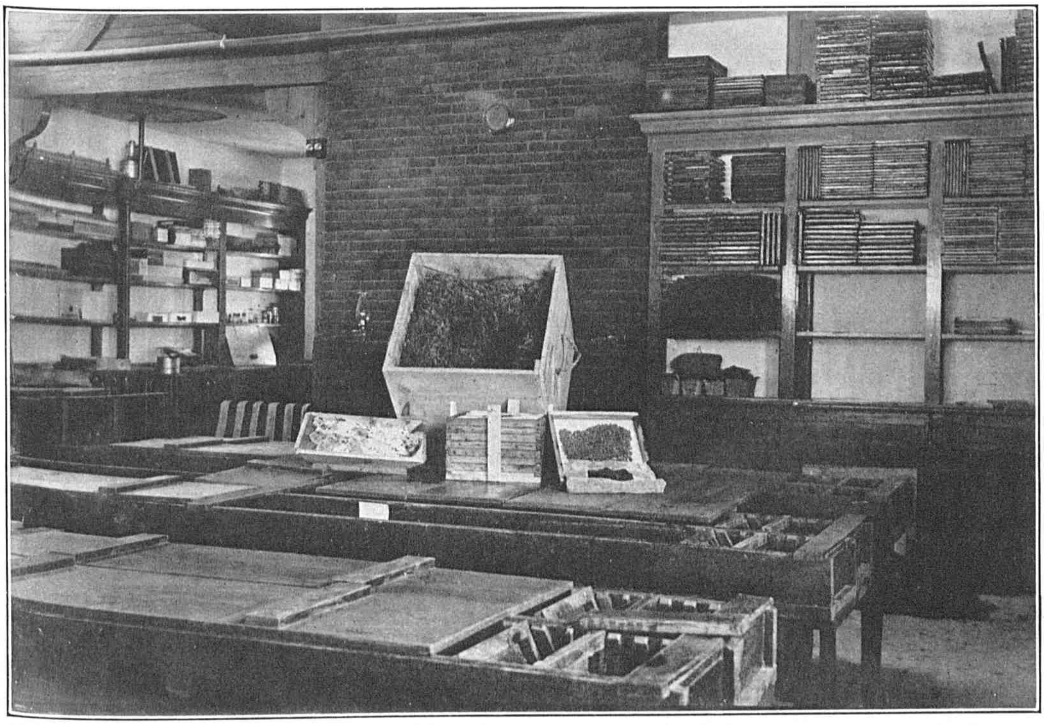

FIG. 25.—Box of trout eggs just opened. Showing ice hopper at left, stack of trays which have been taken out of the moss in center of box, and one tray with covering of mosquito net and moss removed. This is the common method of packing for ordinary shipments. (Described on p. 742.)

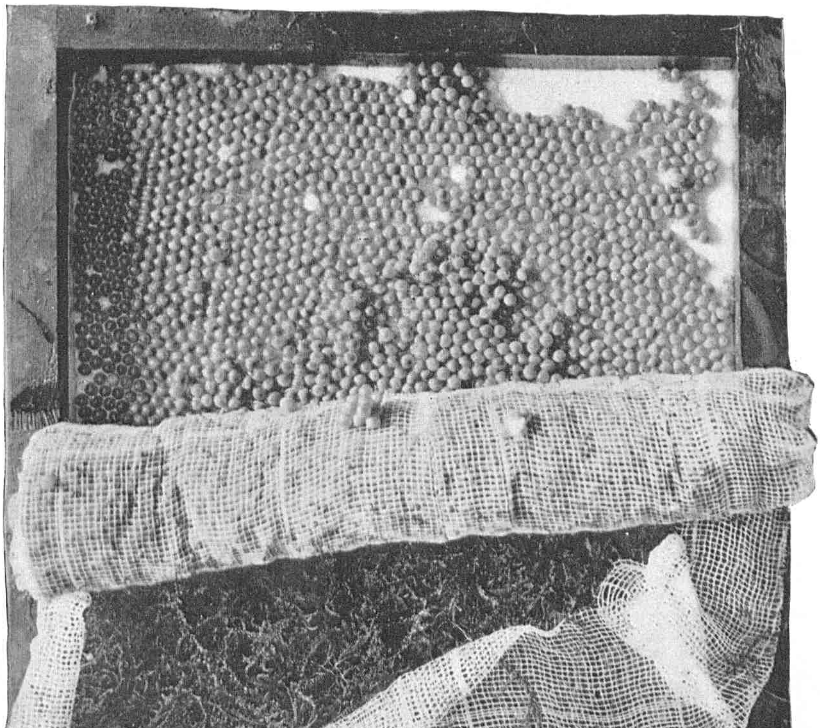

FIG. 26.—Tray of trout eggs with mosquito net and moss in which packed.

advantage of making a comparatively light package—a factor of great economic importance in transportation. The outside case may be an ordinary box of suitable dimensions. In it are packed, surrounded by moss, several boxes made of ⅜-inch boards, and usually 12 inches wide by 15 inches long by 3½ inches deep, each box containing a mass of 10,000 to 20,000 eggs in mosquito netting, with moss around all sides. No ice is used, care being taken that the packing be done in a temperature below 50°, that all packing material be kept in a place slightly below freezing point, and that the moss in which the eggs are packed be sprinkled with snow. This method of packing is an economical one for shipments of eggs of Salmonidæ during cold weather, but can not advantageously be used for eggs of spring spawning fishes unless there is available a cold-storage room in which to do the packing. Recently the superintendent of the Baker Lake (Wash.) station, who has had occasion to ship eggs of steelhead trout and Pacific salmon in warm weather, has packed them in light cases with alternate layers of moss, and then placed two tiers of these thin cases side by side in an outer case with a large hopper of ice over the whole, the drip passing down between the two tiers of inner cases. The chief advantage of this case for long-distance shipments is in the fact that less ice is required than in other forms of cases using ice, with a consequent saving in transportation charges. It can also be used in warm as well as cold weather. It is believed it will be economy to extend the use of this case in packing eggs of other species of Salmonidæ.

Green eggs of the brook trout and chars are carried in spawning pans or buckets, the spawntakers sometimes, by the use of a neck yoke, carrying two pails of trout eggs several miles. It is possible to ship the green eggs a half day's journey without serious loss, but it is preferable to eye them at places convenient to the traps where the parent fish are caught, after which they are packed by the ordinary method.

For grayling eggs cheese cloth is used for the bottoms of the trays instead of canton flannel and it is preferred by some in packing other kinds of eggs because it permits of a better circulation of air and is not so apt to hold water. No moss is used on the trays over the eggs, but only mosquito netting, as the eggs will not stand pressure. Both the hopper and the chambers around the tray stack are kept filled with ice, thus maintaining in warm weather a temperature of about 40° F.

In transferring by messenger large numbers of eggs, whether green or eyed, of any species, it is customary to omit the packing on and around the trays, ice being used to regulate the temperature.

Eggs of the shad and other species of which the period of incubation is but a few days are usually shipped within forty-eight hours after being collected. Shad eggs are seldom shipped for more than a few hours' travel. For this

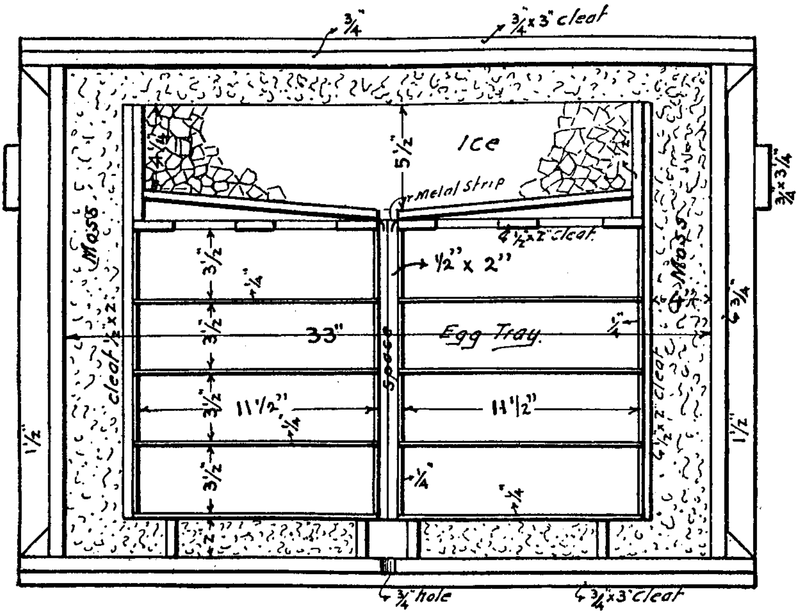


FIG. 7.—Atkins-Dinsmore shipping case. Longitudinal section.

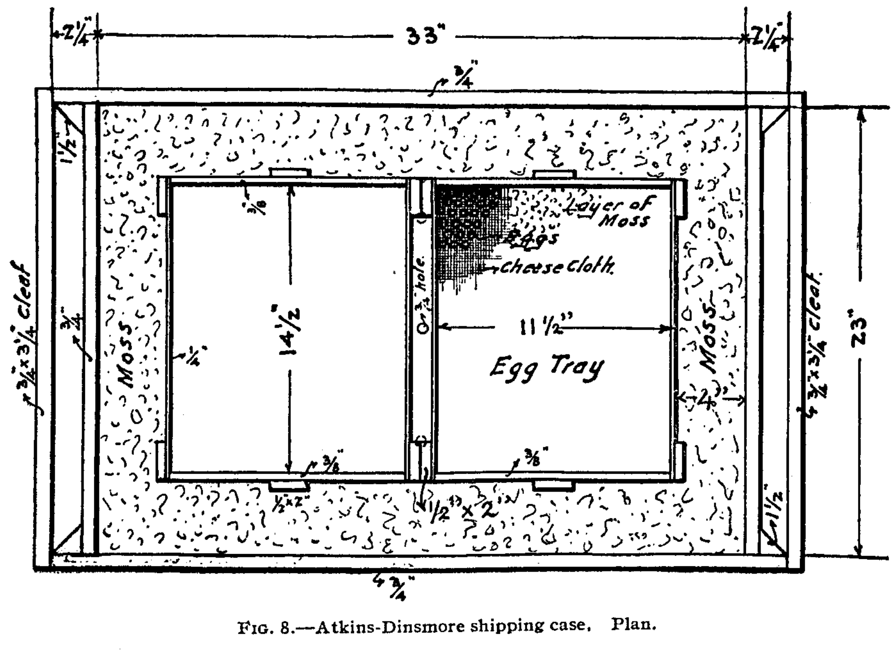


FIG. 8.—Atkins-Dinsmore shipping case. Plan.

purpose they are laid in cheese cloth on wire-bottom trays, between wooden frames also covered with wire cloth, strapped together, and shipped without further packing.

Experiments at Havre de Grace, Md., seem to demonstrate that it is practicable to pack eggs of the white perch in the ordinary trout egg case with ice hopper and ship them on journeys of thirty-six hours' duration without apparent injury. Two lots of green eggs taken at a temperature of 56° and 70°, respectively, and held in trout egg cases for twenty-four to twenty-six hours, hatched as well as eggs placed directly in the hatching jars. In the first experiment there was no change in temperature, but in the second experiment there was a fall from 70° to 64°. White perch eggs to the number of 3,000,000 have in several instances been shipped by express from Havre de Grace, Md., to Washington, D. C., a half day's travel, in four McDonald jars packed in sawdust, ice being used in the packing when the air temperature seemed to require. The jars were equipped with the usual glass tubes, which extended above the packing, but whether this provision for aeration was necessary has not been tested. To insure proper aeration, however, it would seem advisable, with present knowledge of the subject, not to ship large numbers of white perch eggs in water for travel of four or more hours without a caretaker.

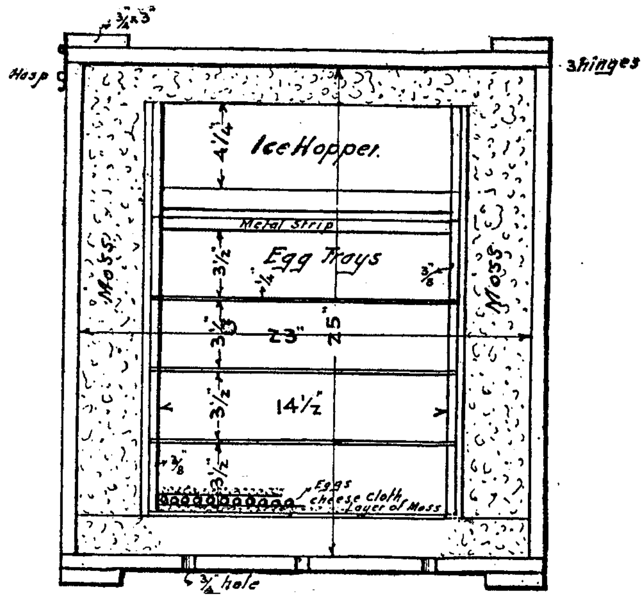

FIG. 9.—Atkins-Dinsmore shipping case. Cross section.

Attempts to transport yellow perch eggs on trays have not given satisfactory results, but it is apparently possible to carry them successfully almost any reasonable distance in the ordinary transportation cans, 1 to 2 gallons of eggs to 8 gallons of water, the proportion varying with the distance to be traveled, and care being taken to aerate and temper the water.

Green pike perch eggs may be carried from near-by collecting grounds to the hatchery in tubs or transportation cans, care being taken to renew the water frequently, to keep it well aerated, and of a proper temperature. Ice must be prevented from coming in contact with the eggs, because, unlike most other eggs, they are very sensitive to such exposure. Half-barrel fish kegs or kits with one end knocked out and iron handles attached make very good and economical vessels in which to transport pike perch eggs. It is customary to insert a wire-cloth drain in the top of the kit on one side and the kits are asphalted inside. Canvas is thrown over the top to serve as a cover. When the eggs are held over night in these kits it is expected to supply them with running water whenever possible to do so; otherwise the water must be periodically renewed or aerated. At some of the field stations a pipe arranged with pet cocks and rubber tubing for supplying water to a number of kits or transportation cans saves much labor in the matter of aerating eggs which must be held for a day or more.

Pike perch eggs collected at a distance from the hatchery are conveyed thereto in the usual transportation case on trays, a small amount of ice being placed on the top tray, which is substituted for the usual ice hopper; an inch space around the sides of the stack is also filled with ice. Ice over the stack must be used sparingly or the green eggs may be injured by the cold water where it trickles upon them. For large shipments it is customary to have a caretaker accompany the packages to regulate the temperature, etc., the use of moss on the trays as well as the insulation material then being omitted.

Since eyed pike perch eggs are usually shipped during the month of May, for safety ice is used around the stack of trays as well as in the hopper, even on a two days' journey.

Whitefish eggs are transported from the field of collection by both of the methods employed in the transfer of pike perch eggs, although they do not require quite so much attention. Eyed whitefish eggs are packed on trays in the ordinary way.

The fields for the collection of lake trout eggs being widely distributed, it sometimes happens that green eggs are held in transportation cases for several days before their arrival at the hatchery. They carry as well laid directly on the wire-cloth bottoms as on a layer of cheese cloth. No packing is necessary if they are in the care of an attendant, since the latter can regulate the temperature by the use of ice and with water of the proper temperature, the trays being removed and sprinkled at least once in twenty-four hours.

In packing lake trout eggs for short distances, say up to a thousand miles, the ice hopper is omitted. Mosquito netting and moss are put on in the usual manner and the top of the moss is slightly frosted before the trays are stacked on the baseboard. A light piece of lumber is used in place of the ice hopper and fine shavings are solidly packed under, above, and on all sides of the stack of trays. For the longer shipments the ordinary ice hopper is used, fine shavings being placed around the stack of trays for insulation.

In the handling of eggs of the cod and other marine fishes a so-called kettle, oval and with a concave top, is used to retain them on board ship in a choppy sea. The water in which they are kept must be frequently changed or aerated. The eggs are shipped to the hatchery in large fruit or butter jars, rockweed or moss, together with ice or snow, being used in packing them. It is regarded as impracticable to ship eggs of marine fishes for travel of more than two or three days.

### ARGENTINE CASE.

While the various methods above described have all been successfully employed in the transportation of eggs across the United States and also to Europe without an attendant, shipments of eggs to points south of the equator, usually leaving this country in winter and arriving at their destination in summer, have called for more than usual attention to the methods of packing them, and a caretaker is quite essential.

A highly efficient form of shipping case has been developed during the past few years for the transportation of eggs of the Salmonidæ from this country to Argentina. It is 3 feet 6 inches long, 2 feet wide, and not exceeding 30 inches high, outside measurement, and is constructed of selected tongued and grooved lumber. It has double walls, with bottom and top common to both, the 2-inch space between the walls being filled with nonconducting material, preferably tightly packed shavings. Between the inner wall and the stack of trays is a 2¾-inch space for ice, separated from the trays by perforated zinc. Between the latter and the trays, in a ¾-inch space, are the vertical supports of the zinc, viz, double corner supports, one being ½ by 1½ inches, the other being ½ by 1 inch; two intermediate supports of ½ by 1 inch material, which are provided on either side of the case and one at each end; and cross braces of ½ by 1 inch material, which extend from the uprights to the inner walls of the case.

The ice hopper, 3 inches in depth, and having the same outside dimensions as the trays, rests upon the latter and fills the space between the uppermost tray and the top of the case. It has a perforated zinc bottom, and, to facilitate handling, cleats of small ropes are attached to it. The top of the case is insulated with a 2-inch thickness of nonconductor covered with sheet zinc, this insulation fitting closely into the chest when closed, and thus covering not only the ice hopper but the ice spaces around the sides as well. In the bottom grooves lead to a ¾-inch drain hole, which is provided with a cork. Two cleats ⅞ by 3 inches are attached lengthwise to the bottom on the outside.

The trays are one-half inch deep, 27 inches long, and 9 inches wide inside measurements, the frames being of ½ by ¼ inch material. The bottom of each tray is covered with wire cloth no. 25 gauge, about 12 meshes to the inch, stretched tightly to prevent sagging and consequent uneven distribution of the drip water. A narrow binding of cloth is tacked around the bottom of each tray to prevent the wire edge from catching on the mosquito net covering of the tray beneath. On the inside ends of the trays are fastened short lifting cleats, and wedges hold the trays securely in place. The bottom tray rests on three ½-inch cleats extending lengthwise of the case, one at either side and the other in the middle. It is important to have the trays of uniform size, that they may be interchangeable.

The trays and interior of the case are coated with asphaltum. To facilitate opening from either side, four hasps are used, two on each side of the case. Two rope handles side by side are placed on each end of the case, with a cleat of three-fourth inch material just above the holes for each handle.

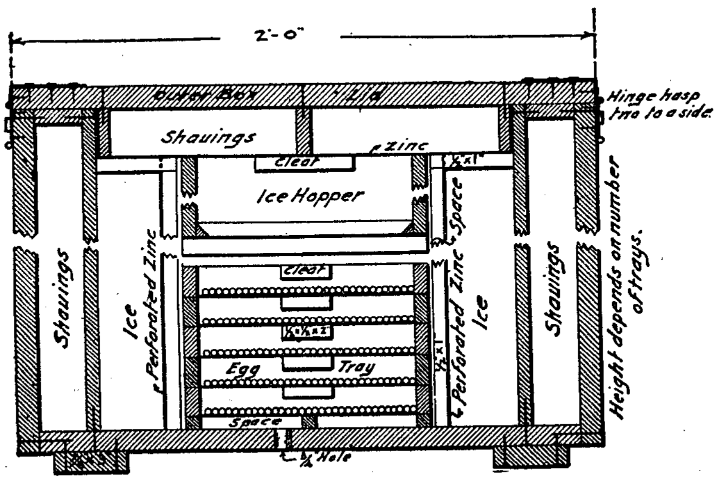


FIG. 10.—Argentine shipping case. Section.

Eggs selected for shipping should barely show the eye spots without the aid of a glass. In packing, a layer of damp moss is spread one-fourth of an inch deep as evenly as possible over the tray bottom, and upon this is placed a covering of mosquito net or bobbinet. The eggs are laid upon the netting one or two layers deep, spread to within one-half inch of the tray frame and covered with another piece of netting to keep them separate from the moss, which is sprinkled in a light layer over it, filling the tray. The netting is cut large enough to extend over the outer edges of the tray, so that the eggs may not be disturbed when a tray is lifted for examination.

On shipboard, as the greater part of the journey is made, the cases of eggs are kept in one of the fruit or cold storage rooms having a temperature of about 38° F. To this room the attendant has access, and it is his duty daily to moisten the eggs by pouring through the ice hopper water of the same temperature as the eggs, 34° to 35°. The ice compartments are frequently replenished and the eggs are picked over whenever necessary.

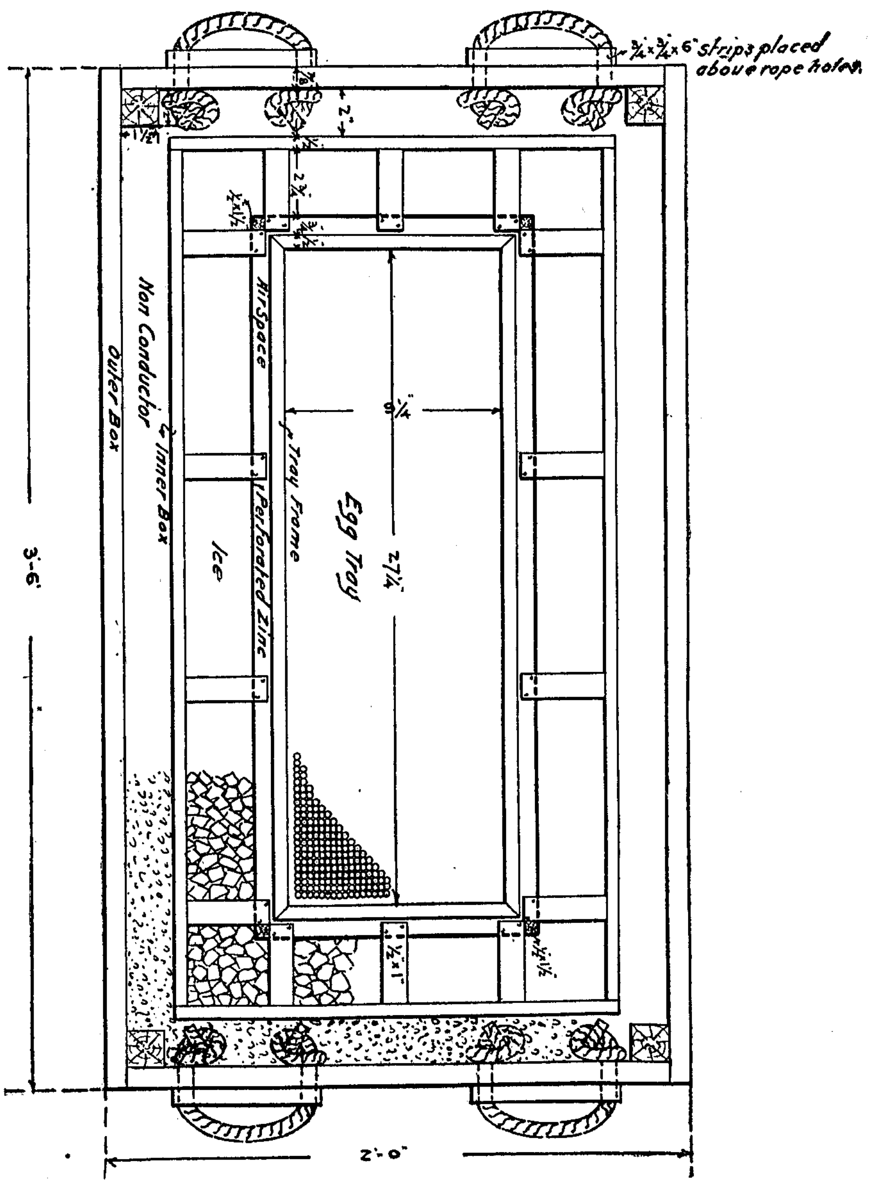


FIG. 11.—Argentine shipping case. Plan.

It will be seen that the method of caring for the eggs is not novel. The chief improvements in the case are to make it easy for the caretaker to tend the eggs in the crowded quarters of a ship's storage compartments and to facilitate handling each individual tray.

### GERMAN-CHILE CASE.

Another case used on journeys in which the care of the eggs is the same as above described is the German-Chile case, so called by reason of having first been employed by German fish culturists in shipping trout eggs from Germany to the Chilean Government. It was brought to the attention of fish culturists in this country by Mr. E. A. Tulian, chief of the section of fish culture of the Argentine Government. In 1907 and 1908 this case, somewhat modified, was used by Mr. Tulian in transporting trout and salmon eggs from the United States to Argentina with better results than had been secured with any other form of case. Owing to the absence of moss directly on the eggs, the German-Chile case is especially adapted to the handling of rainbow trout eggs, the membrane of which is more delicate than that of any other species of the Salmonidæ. From the latest observations it is undoubtedly true that the ideal form of long-distance shipping case for all species, at least when accompanied by an attendant, is the one wherein no moss or other substance is placed directly on the eggs.

The German-Chile case is constructed on the same principles as the Argentine case above described. The case proper is built of selected lumber and is 29½ inches long, 20 inches wide, and 15 inches high, outside measurements. It is so similar in construction to the Argentine case that, aside from a general description, only the differences between the two will be pointed out.

The German-Chile case accommodates two stacks of trays 7¾ by 8½ inches, in a double-chambered compartment having walls of unperforated galvanized iron, which is strengthened by a heavy wire around the top edge. A removable metal partition separates the two stacks of trays. The compartment itself is made one-fourth inch larger each way than the tray frames, to allow for swelling and the binding twine which will be placed around the trays. Next to and surrounding the tray compartment is the ice, outside of which is the dry moss or other nonconductor, within wooden walls, the same as in the Argentine case, while resting upon the top of the trays and ice compartments is an ice hopper. For purposes of insulation the ice in the hopper is covered with a cushion filled with dry moss, oilcloth being placed between the cushion and the ice. The metal bottom of the hopper has perforations only over the trays, that the eggs may receive the benefit of all drip water. Small cleats are fixed at either end of the ice hopper to facilitate handling. Under the tray compartment and coextensive with it is a perforated wooden false bottom to the case, between which and the bottom proper is a 1-inch air space. A drain hole is provided in the bottom proper. The egg trays are made a trifle deeper than the diameter of the eggs; and the latter are placed on them a single layer deep without any covering of moss. The tray frames are seven-eighths inch wide, and usually three-sixteenths inch to five-sixteenths inch thick, with a bottom either scrim

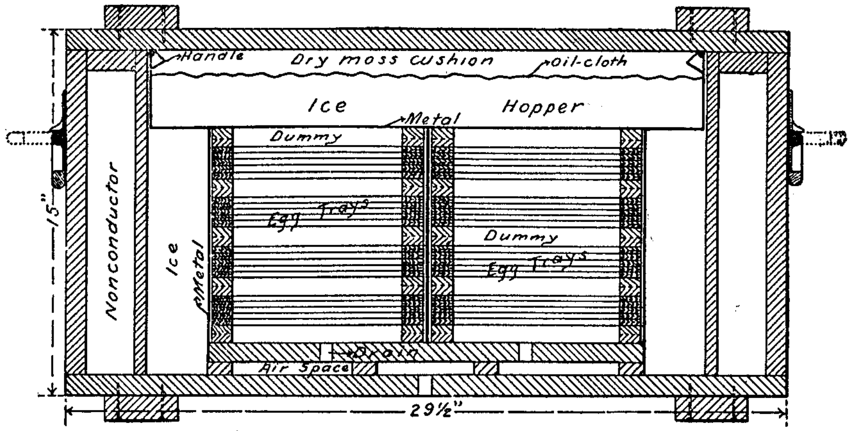


FIG. 12.—German-Chile shipping case. Longitudinal section.

or canton flannel. Instead of being made into one package for each chamber, the trays are bound together in fives, with strong twine for binding material, and alternating with each package are double-depth trays, or dummies, filled

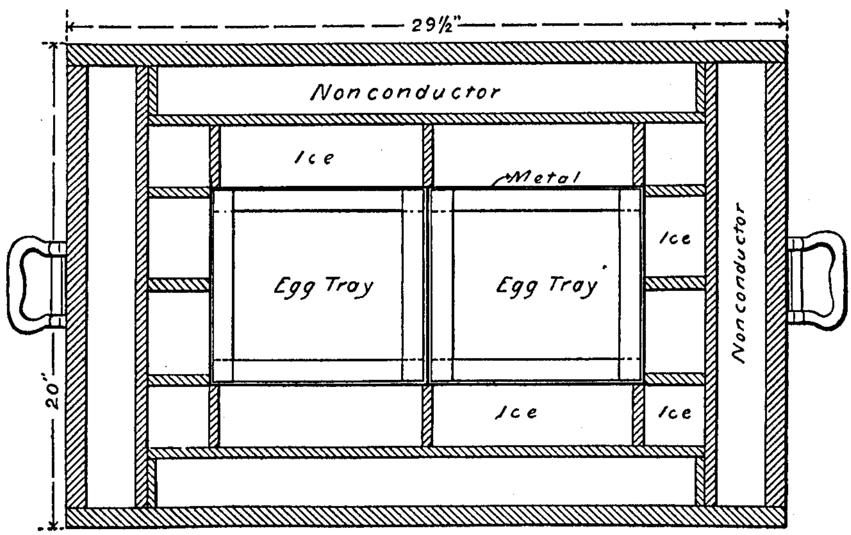


FIG. 13.—German-Chile shipping case. Plan.

with wet moss. One of these moss-filled trays is placed also in the bottom of each of the two tray chambers.

## TRANSPORTATION OF FISH.

In distributing young fish from the hatcheries to the waters they are to stock, six special cars are employed. They are equipped with all necessary apparatus for the safe carriage of young and adult fishes and each is provided with a buffet and sleeping accommodations for a crew of five men. The cars are attached to passenger trains, and many of the railroad companies, appreciating the benefits arising from stocking waters along their lines, haul the cars gratis; others make special rates for cars and crew. When plants are made off the main railroad lines, the fish are carried in baggage cars in charge of members of the car crew.

In addition, distributions are made from many stations without the aid of the special cars, the station employees caring for the fish in baggage cars. For this service the railroad companies usually charge regular fare for the attendants but transport the fish and return the empty cans gratis.

Fry and young fish are usually transported in 10-gallon round-shouldered iron cans, tinned for fresh-water work and galvanized for marine work. With fresh water galvanized iron often proves toxic, and should never be used in the transportation of fresh-water fishes. On the cars it is possible to aerate the water in each fish can by air pumped through a reservoir, from which it is taken through lines of piping along the sides of the car. The piping is equipped with pet cocks, from which the air is carried to the cans in 5/8-inch rubber tubing and forced into the water through liberators made of porous wood, preferably the American linden (*Tilia americana*), placed in hard rubber holders. For best results these liberators must not be placed in the water until air pressure is on and must be removed when air pressure is stopped.

In putting up cod fry and fry of other marine fishes for shipment it is customary to have several quarts of water in the transportation cans and then carefully dip the fry from the hatching boxes, lowering the dipper to the water in the cans before emptying it. When the box is nearly empty the remaining fry are removed from it to a can by means of a siphon. When transported on a vessel having a conveniently arranged well, linen scrim is securely fastened over the top of each can containing fry and the cans are laid horizontally in the well, the top toward a perforated supply pipe through which water is pumped into the well, thus maintaining a constant current.

Lobster fry may be carried in scrim-walled containers, or boxes, suspended in the well of a vessel, the motion of the vessel and the constant circulation of water in the well keeping the fry in good condition and preventing their settling in a mass at the bottom. The boxes are made of a framework covered on the four sides and bottom with scrim, which allows a free circulation from all sides. Each box, 42 inches by 29 inches by 29 inches, will hold from 2,000,000 to

3,000,000 fry. It is customary to take from 12 to 15 cans of fry in addition to those taken in the well, the fry in the cans being the first planted.

On vessels having no wells, aeration for all species of the marine fry, including the lobsters, is accomplished by siphoning off and dipping the water freely, as will be described for whitefish, pike perch, etc. For tempering the water ice is suspended from the cover of the can in a cylinder.

Temperature is a most important consideration in the transportation of fishes, and owing to the different conditions under which they are hatched in the various localities, is a feature that requires skilled discretion on the part of the attendant. The general rule is to keep the temperature at least as low as that of the water from which the fish were taken, and lower if the species is not sensitive to changes.

The maximum number of fishes to be carried most advantageously in a 10-gallon can is another equally important question. The distance to be traveled partly prescribes this number, but must be considered also with reference to the temperature; and these factors, interdependent as they are, go to prevent the formulation of any hard and fast rule. In the following table, however, attempt is made to generalize by means of average conditions, and show the number of fishes of specified kind and size as ordinarily transported in a 10-gallon can. The cooler period of the year in which handled accounts for the lower temperature for fry of the trouts as compared with the higher temperature of fingerlings. It also accounts for the lower temperature for landlocked salmon fingerlings as compared with fry. Ordinarily if landlocked salmon, rainbow trout, and brook trout fry from the same source should be distributed in warm weather it would be desirable to reduce the water temperature for the brook trout considerably lower than for the other two species.

NUMBER OF FISHES OF GIVEN KINDS AND SIZES TO BE TRANSPORTED IN A 10-GALLON CAN UNDER AVERAGE CONDITIONS.

| Species. | Fry. | | Advanced fry. | | Fingerlings no. 1. | | Fingerlings no. 2. | |
|---|---|---|---|---|---|---|---|---|
| | Number. | Temperature. | Number. | Temperature. | Number. | Temperature. | Number. | Temperature. |
| | | ° F. | | ° F. | | ° F. | | ° F. |
| Large-mouth and small-mouth black bass | 3,000 | 60 | 1,000 | 61 | 400 | 62 | 225 | 63 |
| Rock bass, bream, and catfish | | | | | 400 | 62 | 225 | 63 |
| Brook trout | 5,000 | 40 | 3,000 | 45 | 1,500 | 50 | 500 | 50 |
| Blackspotted trout | 5,000 | 48 | 3,000 | 48 | 1,500 | 48 | 500 | 50 |
| Rainbow trout | 5,000 | 48 | 1,500 | 50 | 1,200 | 53 | 500 | 55 |
| Lake trout | 4,000 | 40 | 3,000 | 42 | 1,500 | 44 | 500 | 50 |
| Steelhead trout | 2,000 | 45 | 1,000 | 48 | | | | |
| Landlocked salmon | 2,000 | 48 | 1,000 | 48 | | | 400 | 44 |
| Whitefish | 30,000 | 38 | | | | | | |
| Pike perch | 100,000 | 60 | | | | | | |
| Yellow perch | 125,000 | 50 | | | | | 200 | 60 |
| White perch | 200,000 | 53 | | | | | | |
| Shad | 30,000 | 68 | | | | | | |
| Cod | 300,000 | 42 | | | | | | |
| Flatfish | 1,000,000 | 43 | | | | | | |
| Pollock | 400,000 | | | | | | | |
| Lobster | 100,000 | 58 | | | | | | |

NUMBER OF FISHES OF GIVEN KINDS AND SIZES TO BE TRANSPORTED IN A 10-GALLON CAN UNDER AVERAGE CONDITIONS—Continued.

| Species. | Fingerlings no. 3. | | Fingerlings no. 4. | | Fingerlings no. 5. | | Fingerlings no. 6. | |
|---|---|---|---|---|---|---|---|---|
| | Number. | Temperature. | Number. | Temperature. | Number. | Temperature. | Number. | Temperature. |
| | | ° F. | | ° F. | | ° F. | | ° F. |
| Large-mouth and small-mouth black bass | 150 | 63 | 100 | 62 | 50 | 61 | 30 | 61 |
| Rock bass, bream, and catfish | 150 | 63 | 100 | 62 | 50 | 61 | 30 | 61 |
| Brook trout | 250 | 51 | 125 | 52 | | | | |
| Rainbow trout | 200 | 55 | 100 | 55 | 75 | 54 | | |
| Landlocked salmon | 150 | 44 | 100 | 44 | | | | |
| Yellow perch | 150 | 60 | 100 | 60 | | | | |

NOTE.—The varying usage in the classification of young fish as to size has caused such confusion and difficulty that the Bureau has adopted uniform definitions, as follows:

*Fry*=fish up to the time the yolk sac is absorbed and feeding begins.

*Advanced fry*=fish from the end of the fry period until they have reached a length of 1 inch.

*Fingerlings*=fish between the length of 1 inch and the yearling stage, the various sizes to be designated as follows: No. 1, a fish 1 inch in length and up to 2 inches; no. 2, a fish 2 inches in length and up to 3 inches; no. 3, a fish 3 inches in length and up to 4 inches, etc.

*Yearlings*=fish that are 1 year old, but less than 2 years old from the date of hatching; these may be designated no. 1, no. 2, no. 3, etc., after the plan prescribed for fingerlings.

In the care of fish away from the air circulation of the cars, aeration is usually accomplished by the use of a long-handled dipper, and this method for 10 or 15 cans, which is the usual number handled by detached messengers, if energetically operated has no equal. Several forms of aerating devices have their good points, their use is permitted, and efforts are being made to improve upon the present methods of hand aeration in order to lighten the labors of the messengers, who not infrequently care for the fish for two or three days before they arrive at a destination.

For aeration in cans containing small fry, such as the shad, pike perch, white perch, yellow perch, and whitefish, it is customary to siphon a portion of the water into a pail (the head of the siphon being in a wire cage covered with cheese cloth), aerate it with a dipper, add ice to temper it if necessary, and then pour it back through a large funnel which reaches nearly to the bottom of the can, the lower part of the funnel for about 6 inches being made of perforated tin to break the force of the water. On short trips little, if any, aeration is necessary.

Cans holding the larger fry and young fish may be aerated by dipping the water up and pouring it back again from a height of 15 or 20 inches. When transportation is by water it is customary to renew the water in the cans en route instead of resorting to hand aeration. With fishes of the Salmonidæ family, ice may be placed directly in the water in the cans.

## DISTRIBUTION AND PLANTING OF THE COMMERCIAL FISHES.

It being infeasible for various reasons to rear the young of the commercial fishes, practically all are planted as fry and the distributions are usually made by agents of the Bureau.

Fry of the marine species are often transferred to small boats in order to plant in shallow water or they are carried from the hatchery in launches. In such cases the cans are lowered into the water by two men and there slowly inverted. When planting from a vessel two lines are made fast to the can, one about the top and one about the bottom; by this means the can is lowered over the side and when partially submerged is emptied.

On the Great Lakes the distributions of lake trout, whitefish, and pike perch are usually made by means of steam vessels. In such instances the water in the cans is renewed as often as necessary by siphoning off a portion and replenishing directly from the lake. The manner of liberating the fish after the point of deposit has been reached varies in practice. In planting lake trout and whitefish the method employed by the superintendent of the Duluth, Minn., station is to pour the water and fry, one can at a time, into a large tub full of water, from which the water and fish are siphoned through a heavy 2-inch rubber hose attached to a pole or outrigger. Thus they are deposited in the lake about 8 feet from the side of the vessel, very close to if not beneath the surface of the lake, the speed of the vessel being slackened while the planting is in progress. As it is customary to transport the fry on passenger or package freight steamers, where they are necessarily stowed in a limited space and as close to one gangway as possible, the cans may be emptied into a tub sitting firmly on the deck more easily and expeditiously than they could be poured directly into the lake, and the element of danger to the men doing the work is avoided also.

The superintendent of the Northville station follows a somewhat similar procedure in planting lake trout, pike perch, and whitefish fry. If the deck of the vessel is near the water surface a piece of ordinary tin pipe is attached to a tub and arranged with elbows so as to bring the lower end near the surface of the lake. If the deck of the vessel is high above the water the tub is used with 15 or 20 feet of 2-inch fire hose instead of the tin pipe, a weight being attached to the lower end.

From the Put-in Bay station the fry are planted by pouring them over the sides of the vessel as it moves slowly along, and the superintendent of this station, from experiments he has made, believes this method preferable to the use of hose or tin conductor as just described.

None of the salmon stations on the Pacific coast is of sufficient capacity to hold more than 10 per cent of the fry until sac absorption, and in California a large portion of the product is distributed to hatcheries operated by the California Fish Commission. The portion distributed by the Bureau from the Baird station, however, is held until sac absorption. The method of distributing from Baird is as follows:

The inflow to a trough is shut off, the drain pipe removed, and the water and fry allowed to pass into a double receptacle consisting of a perforated bucket inside a regular 5-gallon spawn bucket, the inner container being about 1 inch less in diameter and raised an inch from the bottom by wooden blocks. This receptacle has been filled with water, to prevent injury to the fry as they are poured in, and the surplus water escapes through the perforations and over the rim of the outside bucket, leaving the fry in the center. If the trough is some distance from the floor a box is used to elevate the buckets to proper level, and any fry remaining in the trough after the passage of the water are brushed through the opening with a broad, flat paint brush. By this method the fry can be removed from a trough in two minutes with absolutely no loss. From the bucket the fry can be easily poured into a 10-gallon can, but frequently they are carried to the river (about 100 feet from the hatchery) and planted direct from the buckets. So far as possible the plants are made during flood water and always where there is a strong current. By this means few, if any, free swimmers are caught by the ever-present trout, as their natural tendency quickly to scatter is facilitated by swift water.

## DISTRIBUTION OF GAME FISHES.

The Bureau does not as a rule attempt to plant the game fishes produced at its hatcheries, but consigns them to individuals, anglers' clubs, protective associations, etc., by whom they are used to stock both public and private waters. It is customary to deliver the fish free of charge to the applicants at the railroad stations nearest the point of deposit.

The number of fish allotted to individual applicants is, of course, largely determined by the supply available, which depends to great extent upon the difference in methods of hatching applicable to the different species. The area and character of the water to be stocked must also be considered, of course. Moreover, the same water area that would receive a million pike perch fry would perhaps be assigned no more than 200 or 300 black bass 3 or 4 inches long, or four to eight times that many if the bass are planted as fry. The explanation is in the fact that pike perch can be propagated by the hundred million, while black bass, hatched by other methods, or collected from overflowed lands, are produced only in comparatively small numbers. The Bureau does not attempt to assign any applicant more than a liberal brood stock of the basses or sunfishes. With brook trout, which are distributed both as fry and fingerlings, assignments of fry are twenty-five to fifty times larger than assignments of fingerlings 3 to 4 inches long.

Applicants for fish are advised by mail of the approximate date on which the fish will be shipped and later by wire of the hour on which they may be expected to arrive. The advance mail notice also contains the specific instructions for the care of the fish from the time of delivery until they are planted.

# A NEW PRINCIPLE OF AQUICULTURE AND TRANSPORTATION OF LIVE FISHES

By A. D. Mead, Ph. D.

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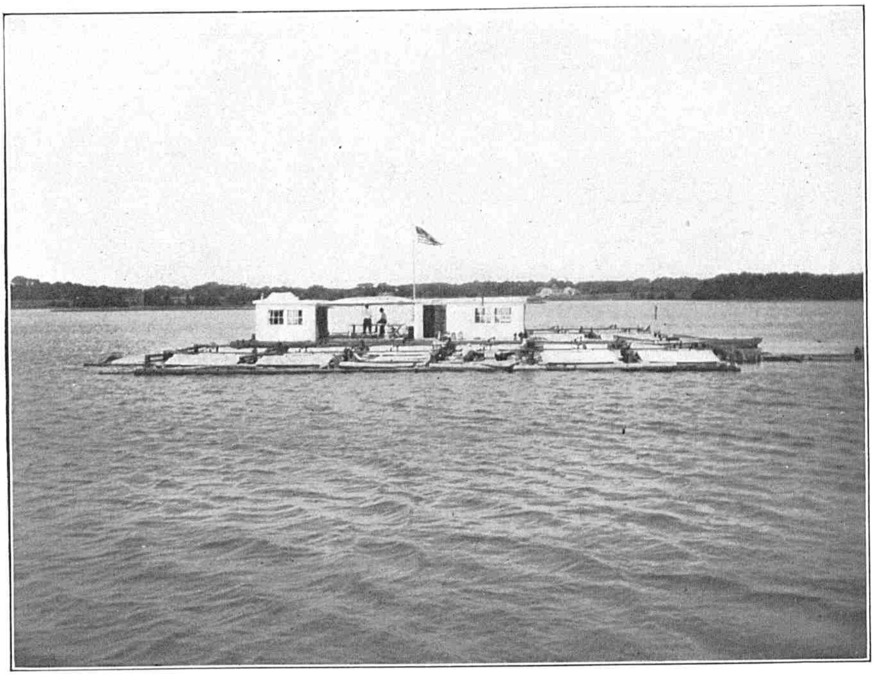

FIG. 1.—Floating laboratory and rearing plant from the port side. The forward (left) house serves as a laboratory and the after one as the engine house and tool room. Most of the rearing cars are covered with white awnings.

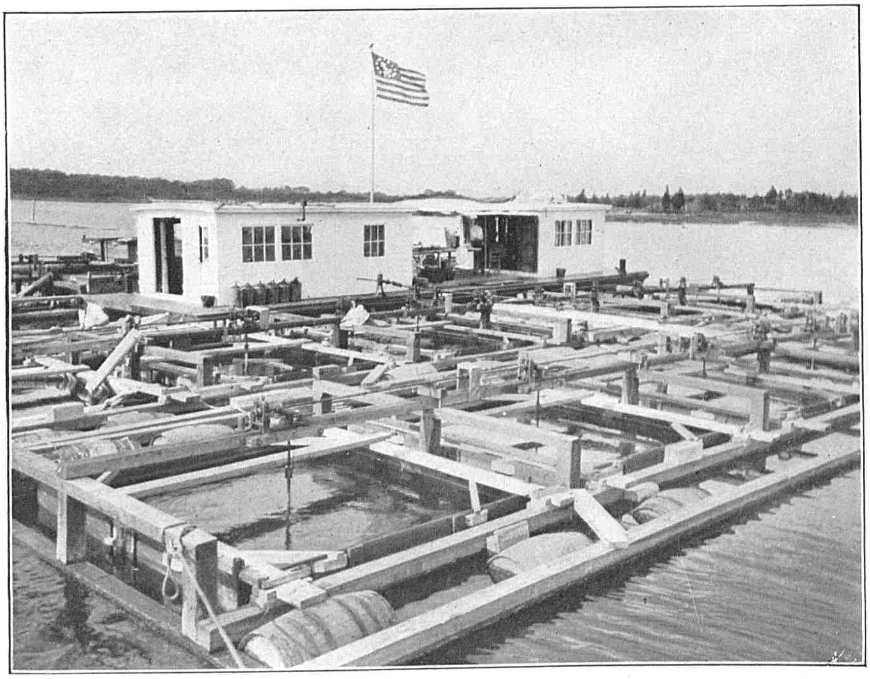

FIG. 2.—General view of the plant from the outer rear corner. In foreground one of the cars shows the propeller shaft and faint indication of propeller blades in the water.

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## ESSENTIAL FEATURES AND DEVELOPMENT OF THE METHOD.

The method and apparatus herein described as a novel and practical method of fish culture have gradually developed through eleven years of continuous experimentation at the marine station of the Rhode Island Commission of Inland Fisheries. It may be said, indeed, that the method and the station have developed together. The aim has been throughout to provide as simply as possible the essential features of the natural environment, biological and physical, for aquatic animals while kept in confinement, and to introduce as little as possible the unnatural features which are frequently considered necessary in artificial culture. Upon this principle there has been sought a feasible method of providing water agreeable to the particular species in regard to the various component salts, well aerated but not over aerated, having the proper temperature, density, and current, and containing appropriate food in available condition; while providing at the same time for the elimination of waste products of animal respiration, and avoiding the dangerous chemical and bacterial impurities almost invariably present where the water is passed through systems of piston pumps, closed conduits, and storage tanks, and is aerated by means of forced air.

The first step in the development of the method was a very direct and simple concession, namely, that of going to the ocean instead of trying to bring the ocean into a house on land. The floating laboratory and hatchery was therefore adopted as a feasible method of circumventing, if not surmounting, many difficulties.

During the first and second seasons of work it was clearly demonstrated that the starfish (*Asterias forbesii*) could be reared in the course of the summer (four months) from the larval stage to over 50 millimeters measured from mouth to tip of arm (nearly twice the length of sexually mature specimens captured in June, the breeding season, and therefore a year old), in cars of appropriate shape floating in the water between the pontoons of the houseboat. In this case living food was supplied at first in the form of small barnacles which had set on boards, and later, as the starfishes grew larger, clams, oysters, and mussels were given them to eat. The conditions in these cars were completely adequate for the healthy life of these slow-moving animals, and were abnormal only in that the young starfishes were protected from their enemies (excepting always their cannibal brethren) and were better fed than they often are under natural conditions. In many cases where they were especially well fed they far outstripped in rapidity of growth individuals found along the shore. They throve splendidly and were perfectly healthy.

This way of raising starfishes may hardly be dignified by the term "method," and yet the better condition of these specimens as compared with those usually seen in an aquarium—even in an aquarium where many fishes live for a long time—is a striking fact. It suggests also that there is often something the matter with aquarium water which, whatever the cause, makes it unsuitable for the rearing of very sensitive animals.

At the floating laboratory, animals with the burrowing habit can also be kept confined and protected and under constant observation by simply putting them into a box of sand suspended in the water. Specimens of the soft-shell clam (*Mya arenaria*) may in this way be very successfully and rapidly reared, and they give every indication of being in a perfectly normal environment. Indeed, in our experiments, when they were kept just under the surface of the water and in the tidal current, they grew more rapidly than in the most favorable shore locality I have ever seen. In one experiment with clams ranging from 5 to 17 millimeters the increase in bulk during five weeks and two days was 1,861 per cent.

In the case of sessile animals like oysters, *Crepidula*, *Anomia*, *Molgula*, *Botryllus*, sea anemones, tubiculous worms, etc., and of those which spin a byssus, like the mussel, young clams, and pectens, it is only necessary to provide the proper surface for them to set on and protection from predatory animals. In case of the hatching of such eggs as those of the flatfish, *Menidia*, *Fundulus*, and the lobster, with which we have had experience in the course of our operations, it would seem that the term "hatching" could hardly be used in a transitive sense, for, if the eggs are provided simply with water of proper constitution, temperature, and conditions for respiration, the eggs inevitably hatch themselves. These nonpelagic eggs, in fact, belong to the same category as the sessile or slow moving animals and may be treated accordingly. The method of stripping and swirling lobster eggs has been given up with us and instead the ripe-berried hen-lobsters are allowed to crawl about in the rearing cars with the result that the eggs hatch most satisfactorily. Similarly the eggs of the flatfish (*Pseudopleuronectes*) were hatched with almost no loss by placing them on a piece of scrim which formed the bottom of a box about 6 inches deep floated on the top of the water in a protected pool. The eggs of *Menidia* and *Fundulus* are hatched successfully by practically the same treatment.

## ADAPTATION TO FISHES AND OTHER PELAGIC FORMS.

### REQUIREMENTS.

In the development of the method of fish culture with which our station is identified the installation of a laboratory directly upon the water and the confining and rearing of animals in cars placed in the water marked the first step. For many animals of the types we have mentioned, the slow moving, or creeping, the burrowing, and the sessile animals, this is all that is necessary for rapid and healthy growth. For pelagic animals, however, like the young of most fishes and the larval forms of crustacea and other marine invertebrates, it is not sufficient. The very peculiarities of structure and instinct which adapt these creatures to their pelagic life make it difficult to confine them for a long time even in relatively large inclosures of the water in which they normally live.

One is baffled now by one peculiarity and now by another. The larvæ or fry are often strongly heliotropic, and in going toward or away from the light soon strike the boundary wall of their confine, and when they are numerous, as they must be in practical culture, die from the effects of crowding, if, indeed, they are spared to this fate by their cannibalistic comrades. Often in the blind struggle to go toward the light regardless of the boundary wall, they gradually work their way to the bottom and become entangled in débris or covered with silt.

If, for the sake of good circulation of water, the tidal current is allowed to pass through the car, as in the case of sessile or bottom-living forms, the pelagic fry are apt to be swept against one side, or to collect in eddies, with disastrous results. If, on the other hand, the current through the inclosure is not supplied, the water becomes stagnant and not well aerated, and since the time required to rear most animals to a considerable size is long, the stagnation under these circumstances is almost inevitable.

The minuteness of many larval animals constitutes a fourth difficulty, for perforations or meshes large enough to permit sufficient circulation frequently permit also the escape of the fry, while meshes too small for the fry to go through become clogged with silt and do not allow free circulation.

The fifth difficulty in the rearing of pelagic fry in inclosures of this kind depends upon the fact that normally they capture their prey "on the fly." A dilemma presents itself: If the fry are fed upon smaller animals or plants, these too must be pelagic, involving all the difficulties over again, while, if artificial food is used, there is no provision for keeping it in suspension, in which condition only would it be available.

### REQUIREMENTS SATISFIED.

After the first step was taken and the excellent result of rearing bottom-living animals in native water was recognized, it seemed most desirable to follow up the advantage gained in the rearing of other forms by extending and developing the procedure so that it would be applicable to pelagic fry. Fortunately we were able to hit upon a method which solved at once all the main difficulties arising from the peculiarities of pelagic existence of larvæ and other free swimming animals. This method consists essentially of creating and maintaining within an inclosure of "native" water a gentle upward swirling current. It obviates the several difficulties which we have enumerated as peculiar to pelagic fry in the following ways:

It effectually prevents the crowding of the fry to one wall of the car, for the force of the current carries them round and round continuously, nor can they work their way to the bottom, for the current has an upward as well as a rotary direction. Even the cannibalistic propensities, which are so pronounced in the larval stages of lobsters and some other animals, are rendered innocuous to a great extent by the forced separation of the fry and are mitigated by the availability of other food.

The current being wholly internal, and its main component circular in its course, it does not force the fry strongly to one side nor allow them to remain in one place as does the tidal current passing through the inclosure. The pressure of the current against the sides varies, of course, with the rapidity with which the outside water is drawn into the car, with the extent of the area through which the water can pass out, and with the rapidity of the current. Since any or all of these factors can readily be controlled there is no difficulty in obtaining a proper adjustment of current for the requirements of particular cases.

Stagnation is prevented even when no new water is admitted from the outside, for the water in the car is constantly being turned over and the lower strata brought to the top and aerated. When, therefore, the water of a car of considerable size is kept cool by being sunk into the ocean and shaded from the sun and is continuously forced to the surface so as to be relieved of waste gases as well as recuperated with oxygen, there is comparatively little need of continuous or frequent renewal. It is at least reasonable to suppose that, in what we may call (after Birge) the "respiration" of a small inclosed body of water containing a considerable quantity of animal life, the elimination of the waste or toxic gases is necessary, and that aeration which is accomplished by forcing more air into the water only partially fulfills the requirements of respiration. The analogy with the physiological process of respiration would seem to be real. In case of small, very thin, flat animals, where the ratio of surface to the bulk is large, respiration may be continuous and direct without special internal apparatus, and, likewise, shallow water with a large expanse of surface has been found by experiment to need no aeration in order to maintain animals alive for a long time. On the other hand, in bulky animals, the respiratory apparatus provides always for the elimination of gaseous products of metabolism as inevitably as it provides for the acquisition of oxygen. Therefore the bringing of the lower strata of water continuously to the surface fulfills two necessary requirements.

For keeping larval forms which are not exceedingly minute, windows covered with screens about 16 meshes to the inch in the bottom of the cars allowing for intake, and similar ones in the sides for the exit of water, are satisfactory. A much finer mesh can be used in this case than would ordinarily be practicable, because the water is drawn in through the bottom screens with considerable force by the upward tendency of the current. It is possible by means of a filter device, which will be described hereafter, to hold fry which would pass through even very fine screens.

The rotary upward current keeps the particles of food suspended in the water even when artificial food heavier than water is used. When, on the other hand, a pelagic live food is used, it is also, of course, readily available, because it is kept in motion and suspended. The important problem of the distribution of food for pelagic forms is solved by this method in a most satisfactory manner.

## ADAPTABILITY OF THE METHOD.

Before describing the apparatus as at present installed at our station, where it is applied to the hatching and rearing of young fishes and invertebrates, a word should be said to indicate its general adaptability to various requirements. In any protected body of water, whether river, lake, pond, or in the ocean itself, the apparatus can be quickly and cheaply installed. For experimental work the containing cars may be small. Dr. V. E. Emmel, by use of this method, succeeded for the first time in the difficult task of making mutilated lobsters of the first stage live to regenerate their appendages. His apparatus consisted of an ordinary "paper" bucket provided with screens and the apparatus for keeping the water in motion. On the other extreme the units in our regular installation at Wickford are square boxes measuring 10 feet on a side and 4 feet in depth, with capacity approximately 12,000 liters (fig. 4, 5, 6, pl. XCI, XCII). The capacity of a plant of this sort is capable of unlimited extension by the addition of units. At present the plant at Wickford has a capacity of 24 units of the size mentioned. The method is capable of application to aquatic animals, fresh water or marine, varying in size from those literally microscopic to those of a foot or more in length. We do not

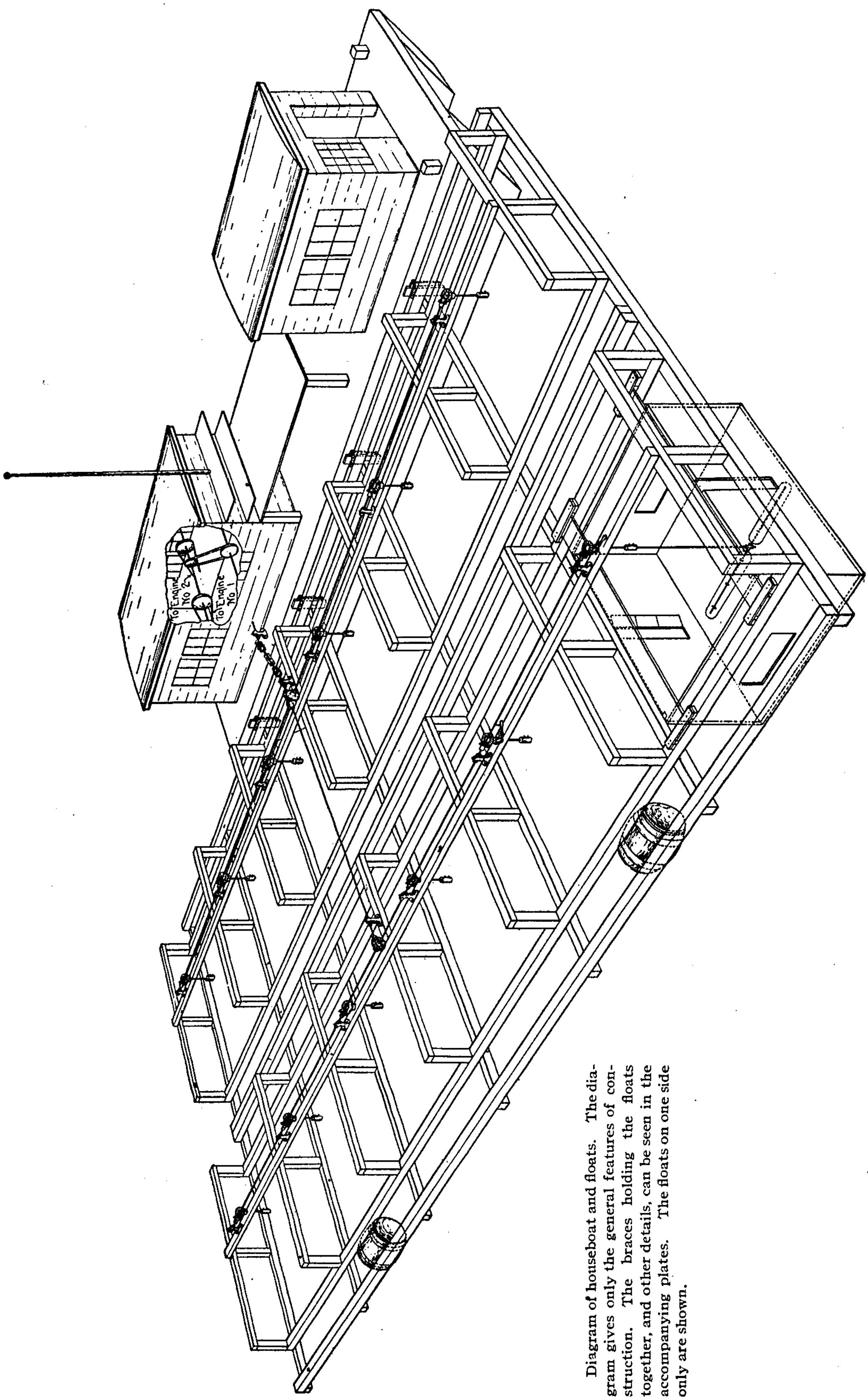


Diagram of houseboat and floats. The diagram gives only the general features of construction. The braces holding the floats together, and other details, can be seen in the accompanying plates. The floats on one side only are shown.

foresee that there are any strictly aquatic animals the requirements of whose young may not be fulfilled by means of this method.

We have developed and applied the method mainly in connection with the hatching and rearing of larval lobsters, but we may assert, without fear of contradiction by anyone familiar with the rearing of lobster fry, that we have done this not because of the comparative ease of rearing lobsters. In the case of all species of fishes which we have attempted to rear the problem is easier than in the case of lobsters.

## APPARATUS.

### GENERAL DESCRIPTION.

The apparatus as at present installed has proved capable of rearing the larval and young stages of fishes and of invertebrates belonging to several different groups. The main features are as follows: A houseboat consisting of two decked pontoons 4 by 4 feet square in section and 50 feet long held 8 feet apart, the intervening space decked and covered by two houses 10 by 10 feet square and 10 by 20 feet, respectively, flanked on either side by two floats attached to the houseboat and made of 6 by 6 inch spruce timbers bolted together and buoyed up by barrels. The spaces between the timbers of the floats are divided into areas 12 by 12 feet, to contain the hatching cars, and into alleyways about 2 feet wide, to contain the supporting barrels. (See diagram, p. 766, and fig. 1, 2, 3, pl. XC, XCI.)

The inclosures for confining the fry are in the form of 10-foot square boxes (fig. 5, pl. XCII) having two windows in the bottom and two windows in two sides, the windows screened, in the case of lobster fry and very small fishes, with fine-meshed woven bronze wire.

In each box or car a pair of propeller blades, adjustable to various angles, are horizontally placed, attached to a vertical shaft with proper bearings (fig. 4, pl. XCI; fig. 6, pl. XCII; fig. 18, pl. XCVIII). By the revolution of the propeller blades the water is kept in circular and upward motion (fig. 4). The propeller shaft carries at its top a gear which engages a similar one with half the number of teeth borne on a horizontal longitudinal driving shaft. The paddle shaft can, however, be instantly thrown out of gear by a lever (fig. 22, pl. C). The longitudinal shaft transmits the power to all the propellers in one float (fig. 2, 3, and diagram). It receives its power from a shaft running transversely across the float, the two shafts being connected by mitered gears (fig. 4). The transverse shaft of the float is connected to a similar one across the houseboat by a set of universal ball joints and an extensible shaft and sleeve device, invented for this particular purpose, which allows for several inches of variation in the length of the shafting system (fig. 17, pl. XCVIII). The transverse shaft on the houseboat runs through the side of the house and inside the latter is connected with the engine by two sets of pulleys and belts which greatly reduce the speed (diagram, p. 766).

A small gasoline engine furnishes the power. The engine speed of 324 revolutions per minute is reduced to about 36 revolutions per minute in the transverse shafting; then, by gears, to 18 revolutions in the longitudinal shafting, and to 9 revolutions per minute for the propeller blades within the boxes.

Four horizontal driving shafts running lengthwise of the float are each 63½ feet long. The transverse shafts connecting these back to the engine have a combined length of 43 feet. The four large floats are only skeletons in structure. Both they and the houseboat to which they are attached float upon the water and are subjected to considerable motion from the waves and from the swells of passing vessels. A too rigid construction, therefore, is not permissible. Indeed, a friend of the station who is familiar with mechanical construction facetiously observed that any reputable engineer to whom we might submit the plans of our apparatus would without hesitation assert that it probably would not work. However, it runs continuously with hardly an hour of interruption for three or four months at a time.

Several devices have been adopted which together make sufficient allowance for the inevitable rocking movement of the floats and for the warping of the light timbers, viz, comparatively light shafting (1 inch), which in long pieces is flexible; adjustable hangers; large-tooth cast gears; and the sliding shaft and universal joint which has been mentioned. No trouble with the running of the apparatus has ever arisen from the motion of the water, though the latter is sometimes strong enough to break out the screen windows.

## DETAILS OF STRUCTURE.

*Houseboat.*—A brief description of the houseboat with its materials and dimensions is as follows: Two pontoons 52 feet long, 4 feet wide, and 4 feet deep, of 3-inch hard pine calked, completely decked with 2-inch hard pine calked; each pontoon with 3 bulkheads and 4 water-tight compartments accessible by hatches, painted all over, copper paint below water line; pontoons placed 8 feet apart securely fastened by crossbeams and heavy knees at each end; houses 10 by 10 feet near each end of the boat, with floors of 2-inch hard pine, roofs, sides, doors, shelves, closets, of North Carolina pine, painted outside, natural-wood finish inside; roof of house 7 feet from floor and having a slight crown, covered with canvas and painted. An annex to the house (fig. 2, pl. XC) on one end, made of lighter material and of the same dimensions, has been added to give additional space for the engines and tools.

*Floats.*—The four side floats, so-called, are merely skeleton rafts, buoyed with barrels, whose construction may be seen in the diagram and on plates

XCI and XCII. Pieces of 6 by 6 inch timbers, spliced together if necessary, are bolted together to form a rectangle 19 by 75½ feet. Parallel with the long sides and 2¼ feet inside are similar timbers, running the whole length of the raft. This makes an alleyway on each side for the supporting of barrels, and the spaces between the barrels are available for small rearing boxes used in preliminary experiments. Across the inner long timbers are placed 6 by 6 inch beams at intervals of 12 feet, dividing the whole raft into six compartments 12 by 12 feet square for the reception of the rearing cars. Except for occasional spaces this completes the lower part of the raft.

Upon these beams short vertical pieces are set at the corners of the car pools to form a rest for the seven upper crossbeams which run parallel with the lower ones (p. 766, and fig. 3, 4, pl. XCI). These upper crossbeams of 4 by 6 inch stock support a longitudinal shaft beam, also 4 by 6 inches, which runs the whole length of the float through the middle and upon which are fastened the shaft hangers.

The two floats on either side of the houseboat are fastened rigidly together with bolted timbers. The inside floats are attached to the houseboat by means of D irons and eyebolts to allow about a foot of up-and-down motion. The floats are built comparatively light and of cheap wood, in view of possible future change of plan as a result of experience.

*Rearing boxes.*—The rearing boxes are square, made of ⅞-inch spruce tongued and grooved boards, nailed to a 2 by 3 inch frame with galvanized nails. The inside dimensions are 10 by 10 by 4 feet. The angles between adjacent sides and between the bottom and sides are truncated by boards 9 inches wide and beveled on the edges (fig. 6, pl. XCII; fig. 13, pl. XCVI). The vertical corner frame pieces are left projecting above the top of the box about 2 inches, to serve as corner posts for fastening the box in place. Ring bolts are put into the four lower inside corners of the box for use in raising the box for cleaning.

Window cases 9 by 36 inches are placed on two opposite sides of the box to receive the movable window frames (fig. 6, pl. XCII; fig. 10, pl. XCIV). Two similar removable window frames 22 inches square are placed in the bottom about 3 feet from the diagonally opposite corners of the box (fig. 6). The size of the mesh in these screen windows varies, according to the size of the fry under experiment, from 16 to 2 meshes to the inch. The material is usually woven bronze or copper wire or galvanized "iron."

In the middle of both sides of the box not having windows a broad slot is cut from the top to within about 8 inches from the bottom. It allows the box to be raised above the water, even though the shaft beam is low (fig. 5, 6, pl. XCII). When the box is down the doors (seen in fig. 9, pl. XCIV), which are fastened on the side of the slot referred to, are fastened shut by strong outside buttons.

It should be said here that this construction was adopted to save rebuilding the floats which had formerly held canvas bags, in which case the low shaft beam was not in the way. In the case of new construction, the shaft beams should be high enough to escape the box when the latter is raised out of the water (fig. 5, pl. XCII).

The boxes are buoyant and have to be forced down into position, where they are held fast by two planks across the top at the end of the box (fig. 4, pl. XCI). The planks are mortised into the corner posts before referred to, so as to prevent lateral movement, and are fastened down to the beams of the float by heavy adjustable cleats secured by bolts (fig. 4, pl. XCI; fig. 9, 10, pl. XCIV). The boxes are painted inside and out.

When a box is to be raised, the cleats are loosened, the planks removed, and ropes from the drums of a transportable windlass are hooked into the ring-bolts of the bottom corners (fig. 9 to 12). The doors are then opened and the hand windlass put into operation. One man has raised a box alone in fifteen minutes, and two men in five minutes. These boxes, the windlass, and many other things were designed and constructed by the superintendent, Mr. E. W. Barnes.

*Propellers.*—The size and shape of propeller blades found to be most satisfactory vary according to the requirements of different fry. The form of those most used for lobster fry is shown in figures 6, plate XCII; 8, plate XCIII; and 18, plate XCVIII. They consist of two wooden blades, each 4 feet 2 inches long and 8 inches wide at the base, tapered to 5 inches at the apex, and painted all over. Along the middle line the thickness is about 1¼ inches, but from this to either edge is a long bevel which leaves about ½ inch at the edge (fig. 8). Each blade is fastened with iron straps to a piece of galvanized gas pipe, which is screwed into a four-way cross coupling (fig. 18). The latter admits also the vertical gas-pipe shaft running upward toward the gears and a short vertical steel shaft below which sets into a socket consisting of a short piece of large gas pipe fastened to the bottom of the car by a flange. This serves as a lower bearing or guard to the propeller shaft (fig. 18).

The upper part of the propeller shaft is continued by means of couplings through the longitudinal shaft beam and carries a mitered gear at the top (fig. 14, pl. XCVI). In order easily to disconnect and take out the propeller a heavy iron sleeve coupling is inserted into the propeller shaft. The two pieces of the latter are held into the sleeve coupling by set screws (fig. 19, pl. XCIX). As the set screws would be too heavy for galvanized piping, the lower part of the propeller shaft is continued upward by means of a piece of ordinary cold-rolled steel shafting (fig. 19). This is more easily shown in the figures than described.

*Driving shafts and gears.*—The gear on the top of the vertical propeller shaft engages a similar gear with half the number of teeth on the longitudinal driving shaft (fig. 21, 22, pl. c). The latter is supported above the shaft beam by adjustable hangers. All the gears are cast instead of cut and have large teeth (fig. 20, 21, 22). For our purposes they are probably more satisfactory, and are certainly much cheaper, than cut gears. A nice adjustment is not necessary, and the speed of all the shafting is low, being 36 to 18 revolutions for the horizontal shafts and 9 for that of the propeller.

The longitudinal driving shaft connects by means of mitered gears to a transverse shaft running back toward the houseboat and engine (diagram, p. 766; fig. 4, pl. XCI; fig. 20, pl. XCIX). Between this and the transverse shaft of the houseboat is a pair of ball joints of the common type and the peculiar extension device referred to before (fig. 3, pl. XCI; fig. 17, pl. XCVIII). The latter consists of a sleeve made of two heavy castings fitting loosely over two pieces of square shafting. The two sleeve castings are provided with flanges and are held together by screws, and, to avoid their accidentally slipping off into the water, one end is made fast to the shaft with set screws. Several holes are bored through the sleeve for convenience in oiling. This device allows the square shafting to slide back and forth in the sleeve easily and it has the advantage of being very cheap. It is also very strong, because the shaft has a bearing on the sleeve on all four of its surfaces.

*Shafting, pulleys, and engine on houseboat.*—The transverse shaft on the houseboat connects with that on both pairs of side floats in the manner described, and is itself connected with the engine within the house by two sets of ordinary pulleys and belt drives in which the speed of the engine is greatly reduced. Two engines are set up ready to connect with the shaft, so that if either one gives out the other may be used. The engines are 2½ to 3 horsepower Fairbanks-Morse vertical type of gasoline explosion engines, and have proved exceedingly satisfactory.

*Boxes with filters for holding minute larvæ.*—As a modification of the usual form of box or car, to be used for rearing larvæ so small that they would go through any screen with meshes large enough to permit an adequate renewal of water, the following has been adopted: The ordinary boxes are carefully calked in all the seams, and their windows, save one of those in the bottom, are covered with canvas. A gravel and sand filter, made by putting about 4 inches of gravel and sand into a shallow box with wooden sides and heavy galvanized ¼-inch mesh wire in the bottom, is placed over the other bottom window (fig. 21, pl. C). When the car is in place, an old-fashioned bucket chain is rigged on the longitudinal shaft, and the water is thus continually lifted and poured into the hatching box through a short trough. The buckets are painted with asphalt inside and the trough is lined with canvas to prevent contamination of the water from contact with metal or wood. The new water is added, therefore, at the top of the box gradually—about 3½ gallons per minute (fig. 14, pl. XCVI; fig. 15, 16, pl. XCVII).

The amount of water passing through the bottom of the filter does not create an appreciable outward current, and, at any rate, the fry are held above the bottom by the upward trend of the current created by the propellers. Two or three cars of this type have been operated for periods of four to ten weeks at a time. Several varieties of very young fishes and larval invertebrates have been reared with highly satisfactory results. Among the many hundreds or thousands of animals only three or four dead specimens of any kind have been observed.

*Canvas lining for boxes.*—A further modification of this method has been adopted in order to prevent the escape of certain very small animals like crabs, which seek out and crawl into very narrow cracks in the wood. It consists of putting into the box a large canvas bag as a sort of lining and arranging the filter pump as usual (fig. 16, pl. XCVII). This apparatus has also proved satisfactory.

## POSSIBILITY OF VARIATION.

So detailed a description of the apparatus as at present installed and in use might without a further word leave the impression that this apparatus alone fulfills the requirements of this general method of fish culture. On the contrary, there is hardly a feature of the whole outfit that has not been represented, at one time or another during our experiments, by other materials or other forms. The present boxes, for example, have replaced bags of canvas and of scrim and bobbinet, not because the latter failed to give good results, but because they were less durable and otherwise objectionable. Three forms of power transmission have been operated successfully during the development of the plant. It is obvious that the gasoline engine might under other circumstances properly give place to a different kind of motive power, such as steam or hot-air engines or electric, spring, weight, or water motors. For use in small experiments weight or spring motors, properly governed for speed, have much to recommend them, for individual cars could be independently operated in various localities without the inevitable expense and annoyances of running the engine and the apparatus for power transmission.

## PRECAUTIONS.

There are, moreover, precautions to be taken in the construction of the cars and other devices. New wood, especially pine, and certain metals, particularly copper and galvanized iron, which are frequently used as screens, are apt to injure, and often prove fatal to young animals even when under other circumstances the circulation through the car would be ample. A very striking instance of the effect of small quantities of copper and zinc-plated screening was furnished in an experiment made a year ago at our station by Dr. V. E.

Emmel in rearing fourth-stage lobsters to the fifth stage.[a] Ninety fourth-stage lobsters were put separately into glass jars, one lobster into each jar, and the whole crate of jars submerged in the water about 2 feet below the surface. A screen of woven copper wire was placed over the wide mouth of each jar to keep the lobsters from escaping. All these lobsters were found dead twelve hours later. Galvanized copper wire screen was then substituted in a new experiment and in twenty-four hours the whole lot were dead. Finally a cloth screen of bobbinet was used, and out of 75 lobsters which were fed, only 1 died before moulting into the fifth stage. Of 15 which were not fed 4 died at the end of a month. These difficulties, if recognized, may in most cases easily be overcome.

## TESTS OF EFFICIENCY.

The method and apparatus which have been herein described have been developed, as we have said, mainly in connection with the rearing of lobsters through their pelagic larval stages. But as proficiency in this work has increased we have come to realize that the method is equally well adapted to the rearing of a great variety of fishes and aquatic invertebrates.

*Hatching and rearing lobsters.*—While the hatching of lobster eggs by this method presents no difficulties, and young lobsterlings, after reaching the fourth stage, can also be cared for without the use of special appliances, the larval lobsters, on the other hand, during the three free swimming stages of two or three weeks' duration, seem to incarnate nearly all the perverse and intractable characteristics which, from the view point of fish culture, are difficult to deal with. They are pelagic and are safe only when floating, yet in confinement they persistently tend to go to the sides and bottom of the inclosure. They are comparatively slow of movement and weak in their instincts of self-preservation and of seeking food, yet their most distressing characteristic is cannibalism. A method of artificial culture, therefore, which will successfully cope with the various difficulties involved in the rearing of larval lobsters might, *a priori*, be expected to answer the requirements of the culture of fishes, few of which, perhaps, offer so many difficulties. While the report on the special method of rearing lobsters is given in another paper, it may here be said, as indicating the general efficiency of the plant, that during the months of June and July and the first few days in August of this year we hatched and reared through their successive larval stages more than 320,000 lobsters (counted) by means of the apparatus as above described.

*Fishes incidentally reared.*—While the apparatus was occupied with the rearing of lobsters, time and car space were not available for experiments on the rearing of fishes, but incidentally it was demonstrated that the young of many fishes would thrive and grow in the cars. Upon raising cars which had been

[a] Report of Rhode Island Commissioners of Inland Fisheries for 1907, p. 104.

down for two or three weeks there were nearly always found in them a considerable number of small fishes of various species. Since all the water of the car must in these cases have entered through the screen windows of $\frac{1}{16}$ inch mesh, the fishes must have come in when they were very small. The following is an incomplete list of these fishes found in the cars.[a] It should also be mentioned that among these fishes and the other young specimens placed in the cars there was no evidence of illness or mortality.

| Species. | Size. | Dates. |
|---|---|---|
| | *Mm.* | |
| Mummichog (*Fundulus* sp.) | 5–25 | Throughout season of 1907 and 1908. |
| Silversides (*Menidia* sp.) | 4–21 | June 27 to July 8, 1908. |
| Hake (*Urophycis* sp.) | 28 | July 26, 1907. |
| Pipefish (*Siphostoma fuscum*) | 15 | July 6, 1908. |
| | 30 | Aug. 6, 1908. |
| | 114 | Aug. 7, 1908. |
| | 77 | Do. |
| | 144 | Aug. 8, 1908. |
| | 66 | Aug. 21, 1908. |
| | 73 | Do. |
| Kingfish (*Menticirrhus saxatilis*). | 41 | Aug. 4, 1908. |
| Squeteague (*Cynoscion regalis*). | 4.2 | July 23, 1908. |
| | 19 | July 30, 1908. |
| | 12.5 | July 28, 1907. |
| | 6.5 | Do. |
| | 25 | Aug. 8, 1907. |
| | 18 | Do. |
| | 20 | Aug. 9, 1907. |
| | 29 | Aug. 13, 1907. |
| | 31 | Do. |
| | 37 | Aug. 26, 1907. |

| Species. | Size. | Dates |
|---|---|---|
| | *Mm.* | |
| Puffer (*Spheroides maculata*). | 4 | (?) 1908. |
| | 3.5 | July 9, 1908. |
| | 18 | Aug. 3, 1908. |
| Flatfish (*Pseudopleuronectes americanus*). | 10–21 | From about June 15 to about July 1, 1908, from 10 to 50 were found in every car when raised |
| Tautog (*Tautoga onitis*) | 3.2 | July 8, 1908. |
| | 4.8 | July 9, 1908. |
| | 20 | July 25, 1908. |
| | 11 | July 28, 1908. |
| | 20, 18 | Aug. 3, 1908. |
| | 20, 24 | Aug. 4, 1908. |
| | 12.5 | Aug. 7, 1908. |
| | 8, 9 | Aug. 9, 1908. |
| | 23, 25 | Aug. 10, 1908. |
| | 21, 41 | Aug. 11, 1908. |
| | 8 | July 28, 1907. |
| | 5.5 | July 25, 1907. |

From July 6 to the last of August, 1908, small anchovies (*Stolephorus mitchelli*) continually entered the cars through the fine screens. In many instances hundreds of them, from 2 to 20 millimeters long, were found in these cars. In August several cars were fitted out with coarse screens, one-fourth

[a] From data collected by H. C. Tracy.

inch mesh, and several thousands of anchovies entered one of the cars in a single night. Within the cars they lived and grew. Great numbers of very small specimens between 2 and 10 millimeters in length were taken in July. Mr. Tracy points out a fact of particular significance, namely, that in the tight filter cars many specimens from 2 millimeters to 8 millimeters were found which must have been dipped up by the chain of buckets as eggs or as very small fry, since the fry of 10 millimeters are so quick and wary that they would hardly be caught in this way. There is no doubt whatever that the young anchovies of all sizes thrive perfectly well in the cars provided with screens, and also in the filter cars, and it is more than probable that the eggs of this species frequently hatched in the cars.

About 20 anchovies placed in one of the filter cars on July 28, 1908, were doing well at the date of writing (September 19, 1908), and showed a very considerable growth.

*Hatching and rearing fishes.*—Near the end of the season for rearing lobsters, during the latter part of July, when the pressure of other work was relieved, some of the large cars were reserved for definite experiments to test the practicability of the method and apparatus as applied to the hatching and rearing of fishes. Unfortunately at this time of the year there were comparatively few fishes whose eggs we could obtain, and we were unable, therefore, to exercise much choice in our material.

On July 17 a quantity of eggs of the "silverside" (*Menidia*) were obtained, and, after being fertilized, were put into a car with the filter and bucket-chain rigged as already described. A short-bladed paddle was used like that in figure 22. This was hung about 2 feet from the bottom, the lower bearing being dispensed with.

The egg masses were teased apart into small clusters and placed on a piece of cloth mosquito netting which was tacked to a piece of soaked wood, so as to form a bag, and suspended in the water. The bag thus formed was held extended and kept from collapsing by a coiled piece of insulated electric wire on the inside. (Practically the same method has been used very successfully in the hatching of the flatfish, *Pseudopleuronectes*.) The eggs hatched in about ten days with apparently no mortality. The young fishes readily escaped through the netting and seemed to thrive perfectly well in the car, where they were kept until August 21, when they were transferred to another similar car, which, however, had a canvas lining. Here they have continued to live until the date of writing (September 19, 1908). There has been no evidence of mortality of any kind during the experiment, although little attention has been given to the feeding, and the fry have had to depend upon the living pelagic food which entered with the water from the chain of buckets.

From the time of hatching to the transference of the fry to another car specimens were taken out daily and preserved. The average daily measurements are here given:

| | Mm. | | Mm. | | Mm. |
|---|---|---|---|---|---|
| July 26 | 3.85 | August 4 | 7.90 | August 11 | 8.22 |
| July 27 | 4.86 | August 5 | 7.70 | August 12 | 8.80 |
| July 29 | 5.82 | August 6 | 7.76 | August 13 | 9.20 |
| July 31 | 6.21 | August 7 | 8.32 | August 14 | 8.77 |
| August 1 | 6.90 | August 8 | 8.00 | August 15 | 9.30 |
| August 2 | 7.19 | August 9 | 7.98 | | |
| August 3 | 7.68 | August 10 | 8.23 | | |

On the afternoon of July 27 a portion of the eggs which had remained unhatched in the experiment thus described were transferred to another similarly rigged rearing car (known as S 4), and these eggs hatched within the next day or two. The measurements of specimens taken daily from this new car compare in an interesting way with those given in the previous table. Although they came from the same batch of eggs, and differed only in being slightly younger, they grew more rapidly than the first lot and soon so far outstripped those in the original car that the difference was noticeable upon casual observation.

This difference was doubtless due to the fact that the second lot had more to eat because there were fewer specimens in the car, for, as we have said, the fry had to depend for their food upon the pelagic fauna. By towing in these cars with a small bolting cloth net the absence of copepods and larval animals was conspicuous, especially when compared with the towings taken from a neighboring control car which was in all respects similarly conditioned except that it supported no young fishes. In the latter the pelagic life was abundant. It was evident that the swarm of young fry used up the supply of pelagic food as fast as it came into the car.

The following table gives the daily average length of specimens of *Menidia* in this second experiment:

| | Mm. | | Mm. | | Mm. |
|---|---|---|---|---|---|
| July 27 | 4.52 | August 3 | 7.76 | August 10 | 10.04 |
| July 28 | 4.91 | August 4 | 8.72 | August 11 | 10.34 |
| July 29 | 5.04 | August 5 | 9.00 | August 12 | 10.12 |
| July 30 | 6.06 | August 6 | 9.98 | August 13 | 10.74 |
| July 31 | 5.51 | August 7 | 9.82 | August 14 | 10.21 |
| August 1 | 6.57 | August 8 | 10.02 | August 15 | 11.72 |
| August 2 | 7.58 | August 9 | 9.25 | August 17 | 10.26 |

The regular measurements were discontinued after this date. On September 8 the average measurement was 14.83 millimeters and on September 14, 14.45 millimeters. In all of these measurements different groups of individuals were caught up, and the averages, therefore, seem to show a decrease in size rather than an increase when there is not considerable rapidity of growth.

A few eggs of *Fundulus heteroclitus* were fertilized on July 27 and were placed in the original filter car. They were floated near the surface in a shallow bag of netting somewhat similar to that described in the case of *Menidia.* The eggs hatched on August 5 and 6 and the fry all lived in healthy condition until they were taken out at intervals and preserved. The daily averages of length for the first ten days are as follows:

| | Mm. | | Mm. | | Mm. |
|---|---|---|---|---|---|
| August 5 | 4.92 | August 9 | 5.56 | August 13 | 5.98 |
| August 6 | 5.07 | August 10 | 5.37 | August 14 | 6.25 |
| August 7 | 5.40 | August 11 | 5.88 | August 15 | 6.30 |
| August 8 | 5.35 | August 12 | 5.92 | | |

Specimens of this lot have continued to live in one of the cars until the date of writing (September 19).

On July 17, 56 young toadfish, measuring from 15 to 17 millimeters, which had been raised from the eggs in a small car, were transferred to the original filter car. At more or less irregular intervals during the next four or five weeks specimens were taken out and measured. The following table of individual and average measurements indicates the rate of their growth:[a]

| | Mm. | | Mm. |
|---|---|---|---|
| July 17 (56 specimens) | 15.0–17.0 | August 11 | 26.0 |
| July 30 | 19.0 | August 14 | 26.5 |
| July 31 | 22.5 | August 21 | [b] 19.0–33.7 |
| August 1 | 18.7, 22.0 | | |

In order to test these cars with as many kinds of fishes as possible, we introduced the young of some other species in lieu of fish eggs, which could not be obtained in great variety at this season of the year. On July 17 a lot of pipefish taken from the brood pouch of a male were put directly into the original filter car. The individuals appeared to be of practically equal length and measured 10 millimeters. They apparently all lived and, like the other specimens in the cars, continued to thrive, showing no sign of disease, until they were taken out, on August 21.

The following data show the rate of growth as indicated by the average sizes at the end of irregular periods. No food was given to them except that which came in with the water by means of the chain of buckets.

| | Mm. | | Mm | | Mm. |
|---|---|---|---|---|---|
| July 17 | 10.0 | July 30 | 44.0 | August 15 | 67.2 |
| July 18 | 11.4 | July 31 | 46.1 | August 20 | 69.4 |
| July 20 | 21.8 | August 2 | 52.6 | September 8 | [c] 71.3 |
| July 23 | 24.5 | August 6 | 61.6 | September 14 | [c] 70.0 |
| July 25 | 27.5 | August 8 | 58.6 | | |
| July 27 | 26.5 | August 11 | 67.4 | | |

[a] I am indebted for these measurements to Mr. H. C. Tracy.

[b] Average, 30.21 mm. Fifty-four specimens out of 56 put into the car were recovered.

[c] Measurements taken after transference to new car.

On August 21 the remaining specimens were transferred to another filter car with canvas lining, where they remained alive and well up to September 19.

On July 21 another pipefish was caught with a brood pouch full of young which measured 10 millimeters. These young were placed, together with the second lot of *Menidia*, in a filter car rigged with a chain of buckets like the original one. These specimens lived and thrived equally well. No food was given them except on one or two occasions. The data of growth are as follows:

| | Mm. | | Mm. | | Mm. |
|---|---|---|---|---|---|
| July 23 | 10.7 | August 6 | 37.8 | September 8 | 59.0 |
| July 27 | 19.0 | August 8 | 41.8 | September 14 | 62.8 |
| July 30 | 24.0 | August 11 | 41.9 | | |
| August 3 | 31.4 | August 15 | 45.2 | | |

On August 8 and 10 a number of young bluefish were caught in the seine and were placed in one of the rearing cars which had been provided with coarse window screens of ¼ inch mesh. When put into the car there were already present in the water several thousand young anchovies, about 20 to 25 millimeters in length. These the bluefish ate during the first day. On several occasions a few *Menidia* and *Fundulus* were given them to eat. On August 12 they were given as much raw meat as they could eat, and this they devoured ravenously. They were fed on meat again on August 15 and on *Menidia* two days later. The average size of these bluefish on August 18, about ten days after they were put into the car, was 140.8 millimeters, an average increase of about 10 millimeters. On September 1 they were measured again, having been fed meantime on several occasions with *Menidia*, *Fundulus*, and other small fishes. The average length on this date, September 1, was 174 millimeters. This measurement and the two which follow were taken from the nose to the end of the fin rays, whereas the previous measurements were taken from the nose to the base of the fin rays. Between September 1 and September 8 the specimens were not fed. On September 8 they measured 175.1 millimeters, showing an increase during seven days of 1.1 millimeters.

On September 8 a quantity of live fishes was put into the car to serve as food for the bluefish, and during the next seven days the bluefish showed an average growth of about 10 millimeters, the average length being 184.3 millimeters.

The filter cars which have been described, and in which the previously mentioned eggs and young fishes were kept alive, have also proved themselves capable of maintaining a considerable variety of other fishes and invertebrates, among which are the following: Tautog, flatfish, anchovy, oysters (both old and young), scallops, anomia, crabs, barnacles, polyzoans, *Botryllus*, *Nereis* larvæ, etc.

*Crabs and scallops.*—On August 2, 1908, a very large number of zoeæ and megalops of the oyster crab were found floating at the surface of the water. A considerable number were caught with a net and transferred to one of the filter cars, in which they have remained ever since. On September 19 their average measurements were, length 8⅝ millimeters and breadth 10¼ millimeters (Mr. Sullivan).

On August 3, 13 scallops, measuring between 45 and 65 millimeters in length, were placed in the second filter car after having a deep notch filed in the shell so that the rate of their growth could be determined accurately. On September 18, 11 of these specimens were taken out of the car and were in excellent condition. The notch and the zone of new growth indicated precisely the size and shape of the shell when the scallop was placed in the box. The increase in length was about 20 per cent. The following table gives the measurements of these specimens:

| Length, Aug. 3. | Length, Sept. 18. | Length, Aug. 3. | Length, Sept. 18. |
|---|---|---|---|
| *Mm.* | *Mm.* | *Mm.* | *Mm.* |
| 50 | 60 | 51 | 60 |
| 44 | 55 | 52 | 64 |
| 47 | 60 | 46 | 56 |
| 60 | 68 | 52 | 62 |
| 45 | 55 | | |

## GENERAL APPLICATION OF THE METHOD IN AQUICULTURE.

There are two great problems in the general question of fish culture to the solution of which the method herein described contributes:

First, to the problem of hatching and rearing to an optimum size for liberation quantities of fishes of economic value for the direct purpose of stocking the waters. The comparative ease of hatching eggs of most fishes has resulted in the establishment of many prolific hatcheries; on the other hand, the number of establishments capable of rearing young fishes and the number of species so reared in confinement are few. A method of culture, therefore, which is capable not only of hatching but of rearing large numbers of fishes of widely different species marks, we hope, a new step in fish culture.

The second general problem is the ascertainment of the appearance, habits, requirements, and rate of growth of economically important fishes in their early stages of post-embryonic development. As contrasted with the vast amount of investigation of the embryonic stages of development, which has been facilitated by the abundance of readily available material in the form of eggs of all stages, the data relating to the post-embryonic development are almost entirely lacking. Even the identification of the young of many food fishes abundant in their spawning season is at present impossible. A method by which eggs of widely different species may be hatched and reared and by which the unidentified fry caught at large may be reared under observation will be able, we hope, to furnish the necessary material for the solution of this general problem.

## APPLICATION IN TRANSPORTATION OF LIVE FISHES.

In our opinion the essential principle upon which this method of fish culture is based will be found of value in solving the problem of the transportation of live fishes and, moreover, the method and even a portion of the apparatus can be modified and adapted so as to carry this principle into effect. The principle is, briefly, to provide at the start native "unmodified" water; to maintain a proper temperature and density, and in some cases current; to secure the continuous "respiration" of the water, including the egress of waste gases of the metabolism of contained fishes and often of bacteria as well as the access of oxygen, and to avoid contact with injurious metallic substances.

To carry into effect this principle we propose the following method: To use for transportation an iron tank enameled on the inside with a vitreous substance in order to prevent contact of the water with the metal; to use only water dipped from the water in which the animals have been living, in order to insure its proper constitution; to surround the tank with a jacket into which ice or warm water can be put to control the temperature (for many animals, at any rate, both among fishes and invertebrates, we have found by experience that a low temperature is a very important factor in maintaining life when the animals are crowded into a small amount of unrenewed water); to provide both the current and the continuous respiration by installing a propeller device of enameled iron kept in motion by means of a spring motor.

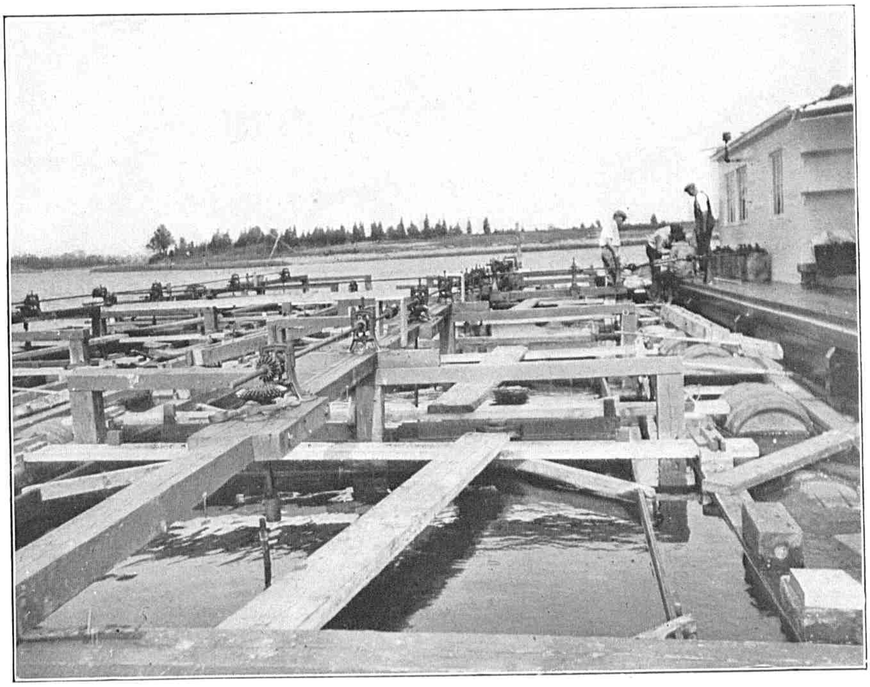

FIG. 3.—Starboard side, looking aft, inside float. Shafting system and general arrangement of cars.

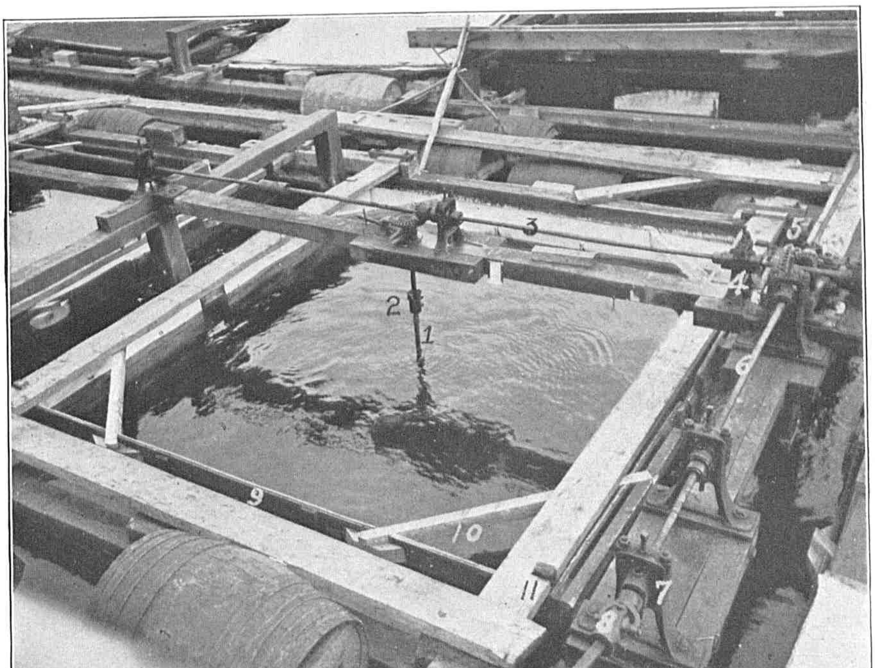


FIG. 4.—Car with propeller in motion. From propeller the shafting may be followed back (1-8) to the universal joint. 1, propeller shaft; 2, sleeve coupling; 3, longitudinal shaft; 4, adjustable shaft hanger; 5, gear trains from longitudinal to transverse shafts; 6, transverse horizontal shaft of float; 7, shaft hanger; 8, ball joint connecting shaft with that of house boat; 9, edge of rearing box; 10, brace across corner of rearing box; 11, holding-down plank mortised into corner post; 12, shaft beam.

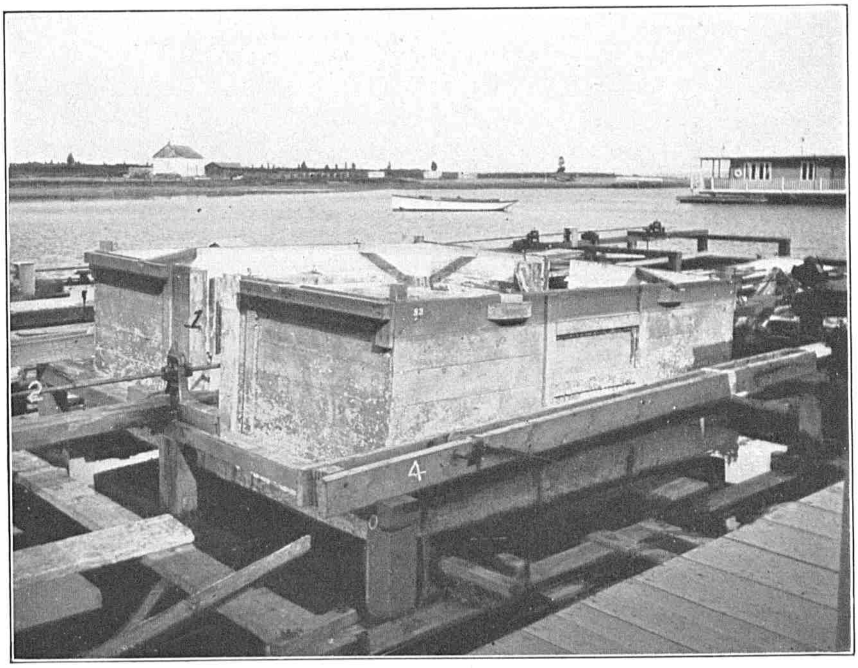


FIG. 5.—Rearing car raised and held up by portable windlass. 1, slot in end of car through which the longitudinal shaft runs when car is raised; 2, longitudinal shaft; 3, side window of car; 4, portable "horse" and windlass.

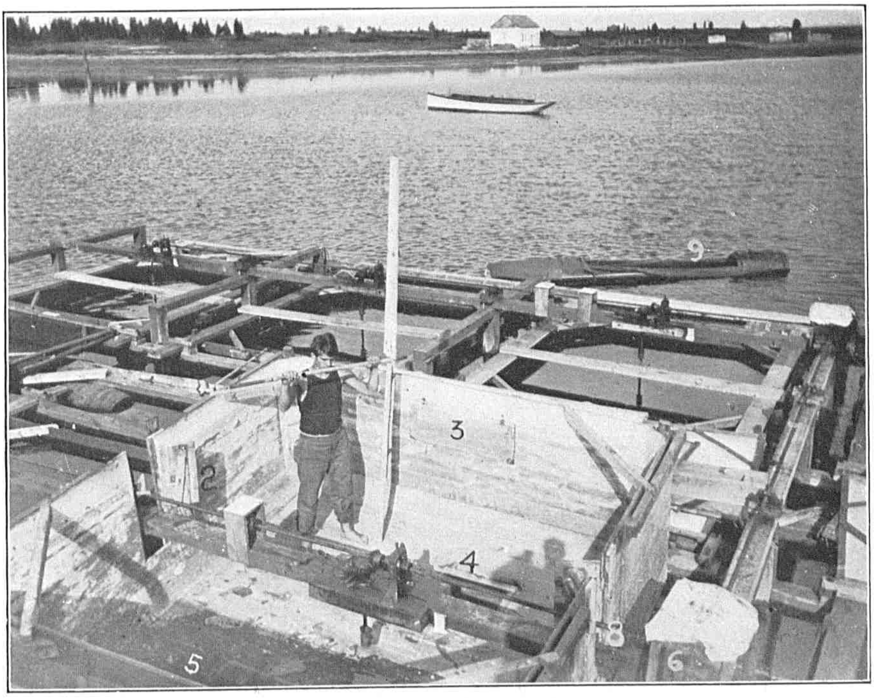


FIG. 6.—Interior of rearing car, and propeller. 1, slot in end of car; 2, doors for closing the slot; 3, side screen windows; 4 and 5, bottom windows; 6, box covering gear trains; 7, transverse shaft; 8, longitudinal shaft; 9, towing car. The arrangement of shafting on farther float can be seen.

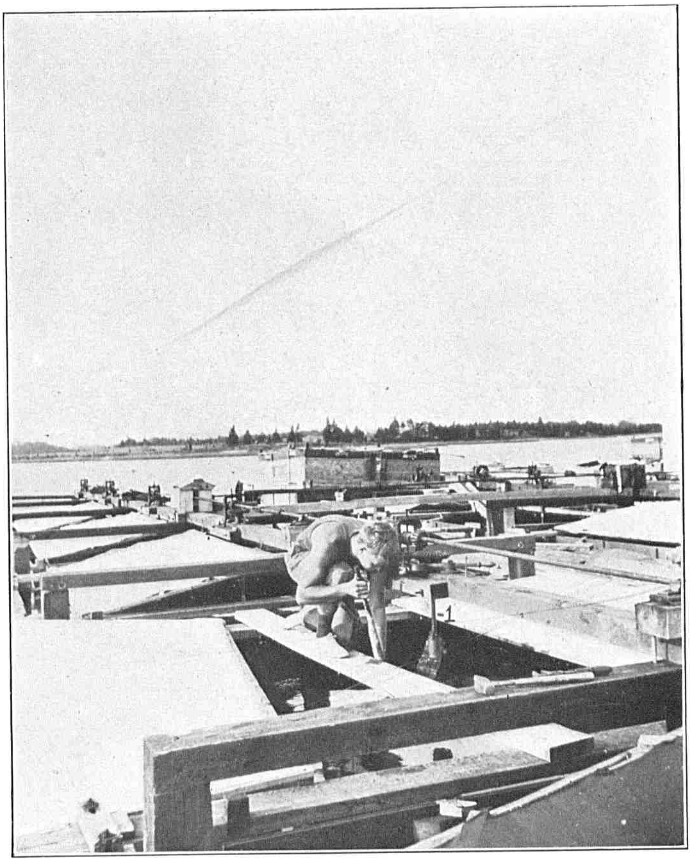

FIG. 7.—Lifting the disconnected propeller out of the water. The upper portion of the shaft with the sleeve coupling is seen at 1.

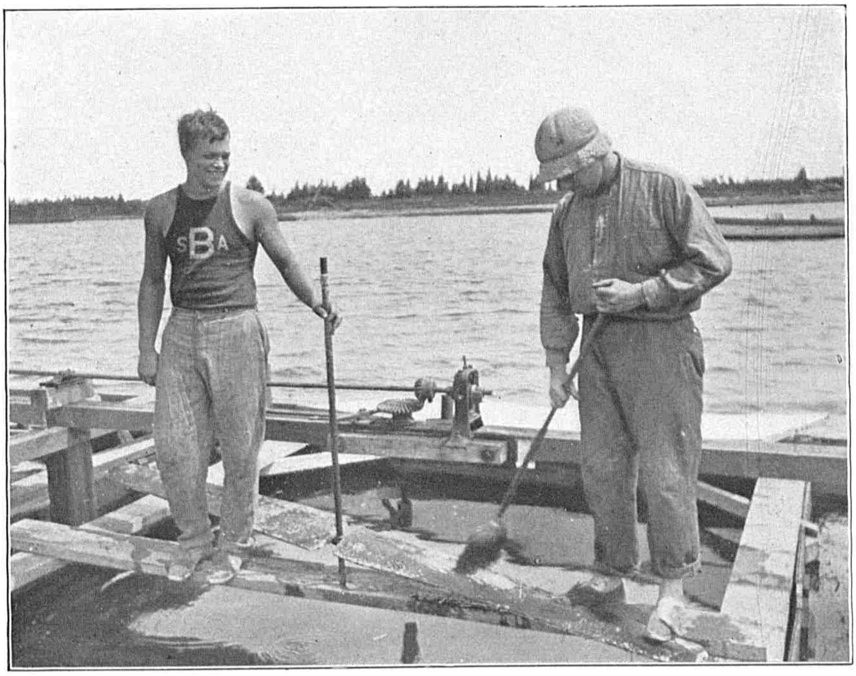


FIG. 8.—The propeller removed, showing disconnected shaft. The upper part of the shaft and the coupling are faintly visible under the shaft beam. The photograph shows well the size and shape of the propeller blades.

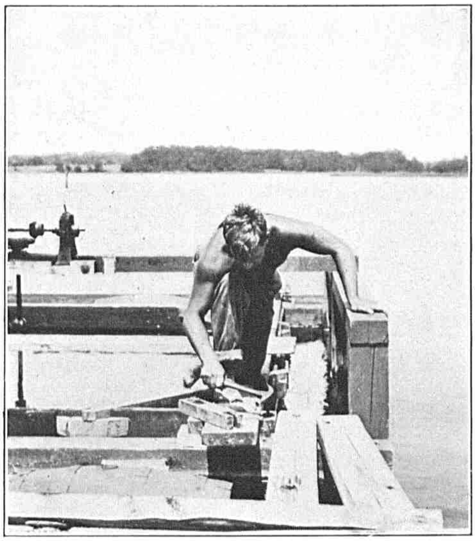

FIG. 9.—Cleat at the end of the holding-down plank, showing the detail (1).

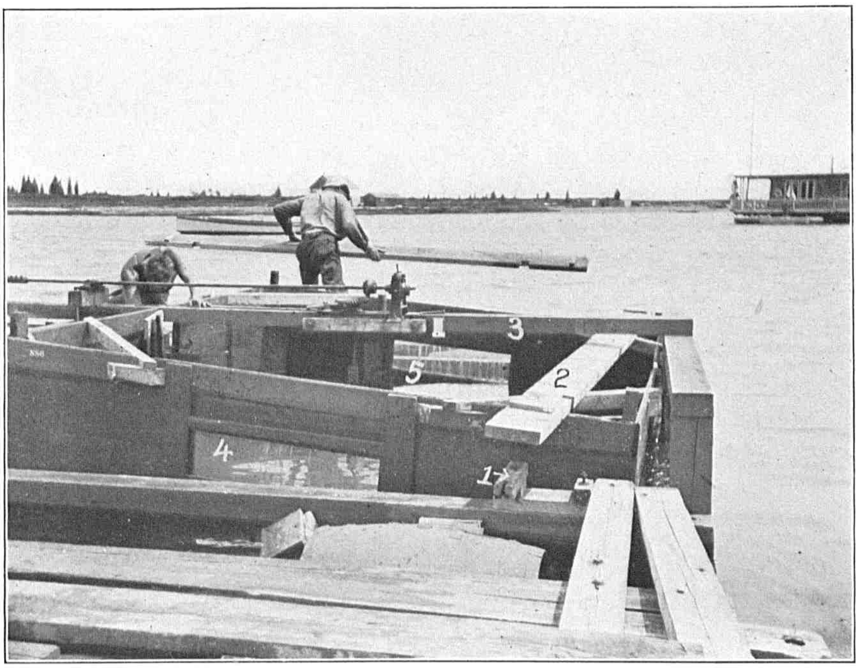


FIG. 10.—The cleats being removed, the car rises part way by its own buoyancy. Opening doors of the slot at end of car to admit the longitudinal shaft beam allows the car to be entirely raised. 1, cleat; 2, holding-down plank; 3, longitudinal shaft beam; 4 and 5, side windows.

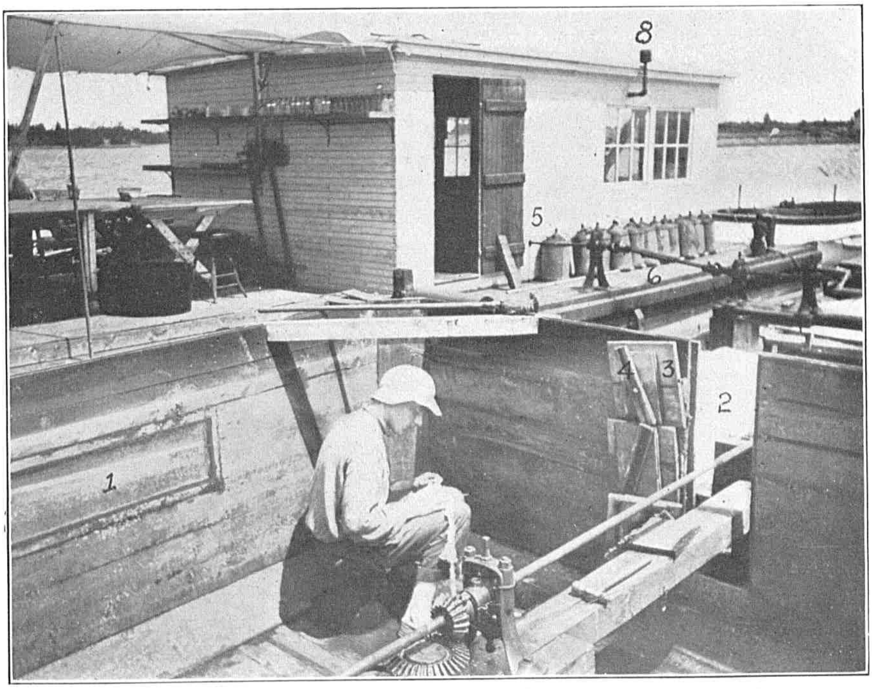


FIG. 11.—Interior of rearing car. Preparing to calk small cracks before lowering the car. 1, side window; 2, end slot; 3, doors for same; 4, buttons to hold doors shut; 5 and 6, the transverse shaft, universal joint, and sliding sleeve; 8, exhaust and muffler.

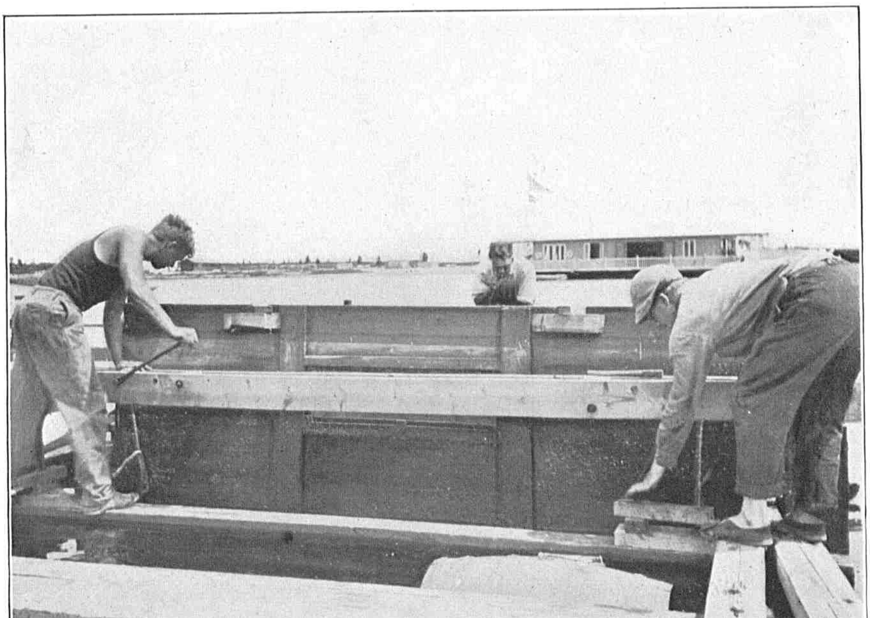

FIG. 12.—Raising the car by means of windlass. Ropes from the drums of the windlass are fastened by hooks to rings in the lower corners of the car.

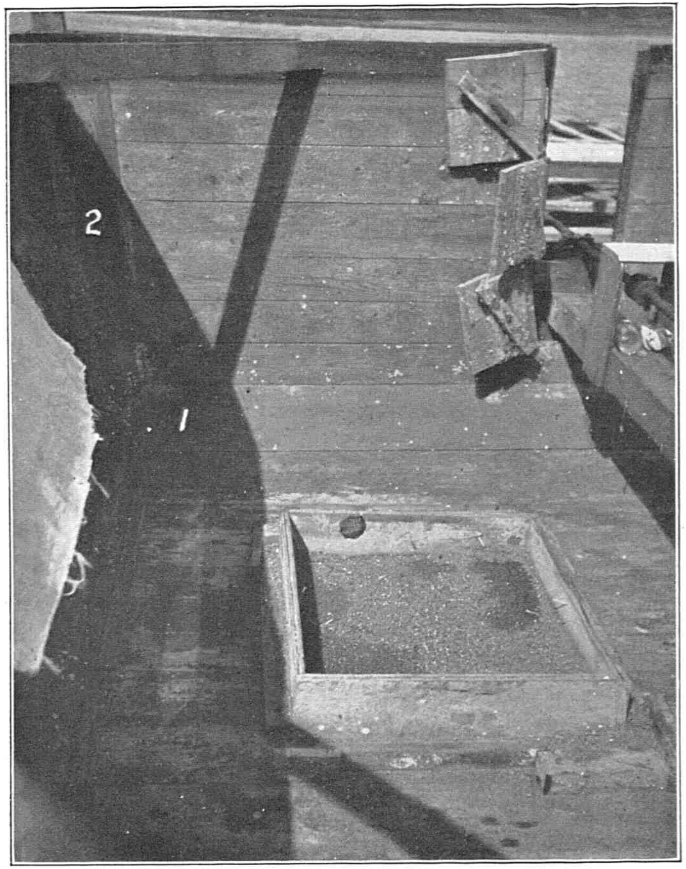


FIG. 13.—View of interior of a car, showing filter of gravel and sand placed over one of the bottom windows. Arrangement described in text for rearing very minute larvæ, or those for which screen windows are dangerous. The car is calked tight; water is poured over the top by bucket chains (see fig. 15, pl. XCVII) and its only exit is through this bottom filter.

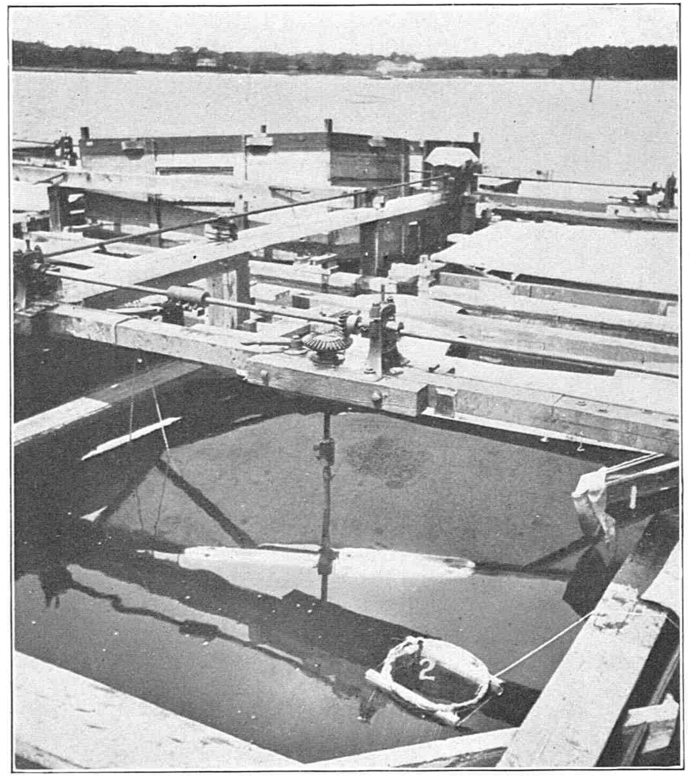


FIG. 14.—"Filter car" in operation. Short propeller hung about 18 inches below the surface. 1, trough with canvas lining for conducting incoming water; 2, floating shallow bag of scrim used in hatching certain fish eggs. The arrangement of shafts and gears shows well in the figure.

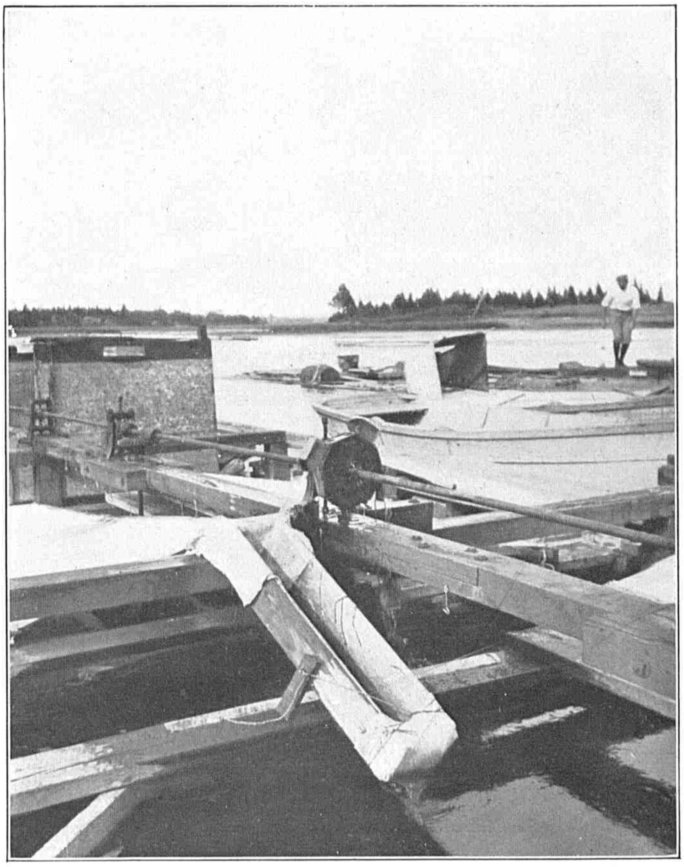

FIG. 15.—Filter car, same as figure 14, plate XCVI, showing bucket chain in operation. One of the buckets has just emptied itself and the stream of water is faintly shown running into the trough.

FIG. 16.—Filter car with canvas lining. Chain buckets on left. The propeller blades may be seen in the water.

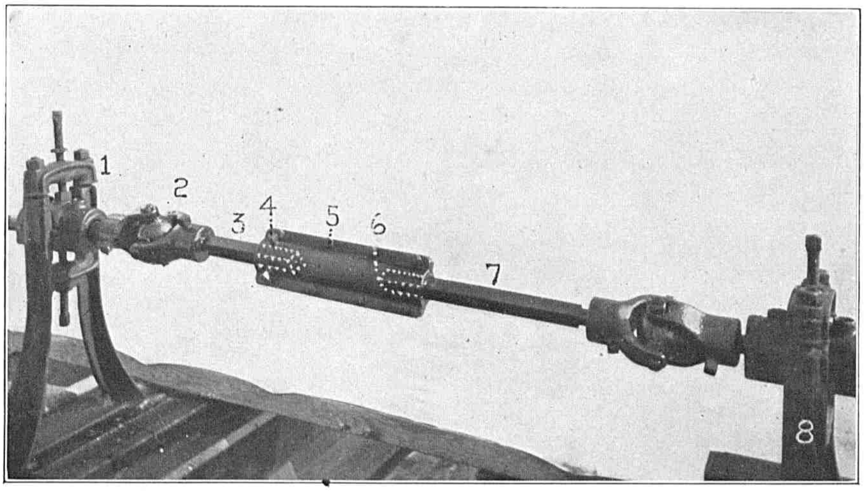


FIG. 17.—Detail of device for extension and universal movement. 1, adjustable shaft hanger on house boat; 2, ball joint; 3, square shafting, fastened by set screws into ball joint at left, and also (4) into sleeve; 4 and 5, screws through flanges of sleeve; 6, oil holes; 7, square shaft which slides in and out of sleeve; 8, shaft hanger upon side float.

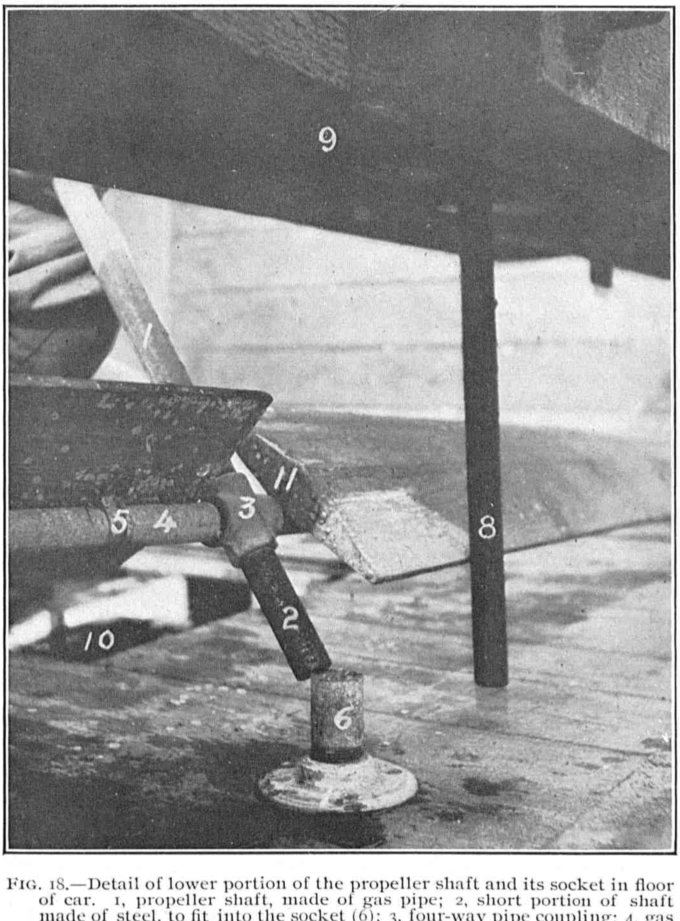


FIG. 18.—Detail of lower portion of the propeller shaft and its socket in floor of car. 1, propeller shaft, made of gas pipe; 2, short portion of shaft made of steel, to fit into the socket (6); 3, four-way pipe coupling; 4, gas pipe to which blades are strapped; 5, strap holding propeller blades; 6 and 7, socket and flange; 8, upper disconnected steel portion of the propeller shaft; 9, shaft beam; 10, window in bottom of car; 11, base of propeller blade, showing in section the shape.

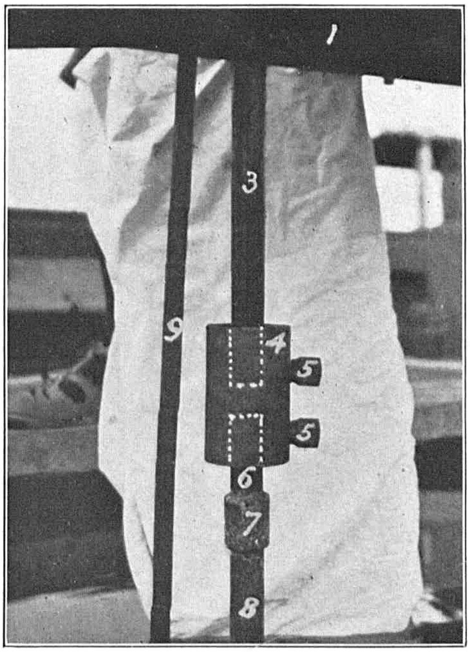


FIG. 19.—Detail of propeller shaft couplings. 1, underside of shaft beam; 3, upper steel portion of shaft, which bears gear on top and enters sleeve coupling below; 4, cast sleeve coupling; 5, set screws holding shafts in coupling; 6, short piece of steel shaft; 7, pipe coupling; 8, lower part of shaft, made of pipe; 9, measuring stick, made of sections 6 inches long.

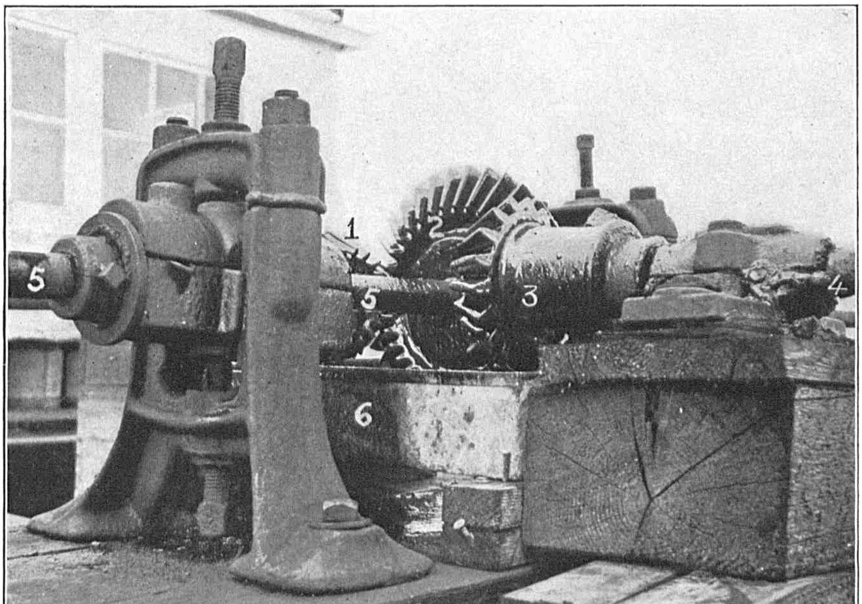


FIG. 20.—Detail of gears on float at junction of transverse and longitudinal shafts. (Compare fig. 4, pl. XCI.) 1, gear on horizontal shaft from house boat; 2, large gear on longitudinal shaft, reducing speed one-half; 3, gear on the inner end of transverse shaft (4); 4, shaft transmitting power to outer float; 5, longitudinal shaft on inner float; 6, oil box.

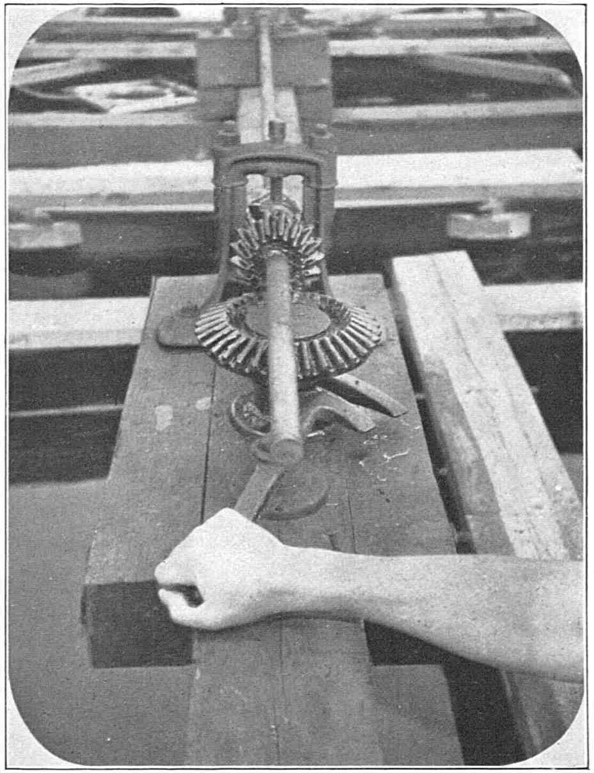

FIG. 21.—Detail of device for throwing propeller in and out of gear. By pulling the lever the propeller shaft and its gear drop as in fig. 22.

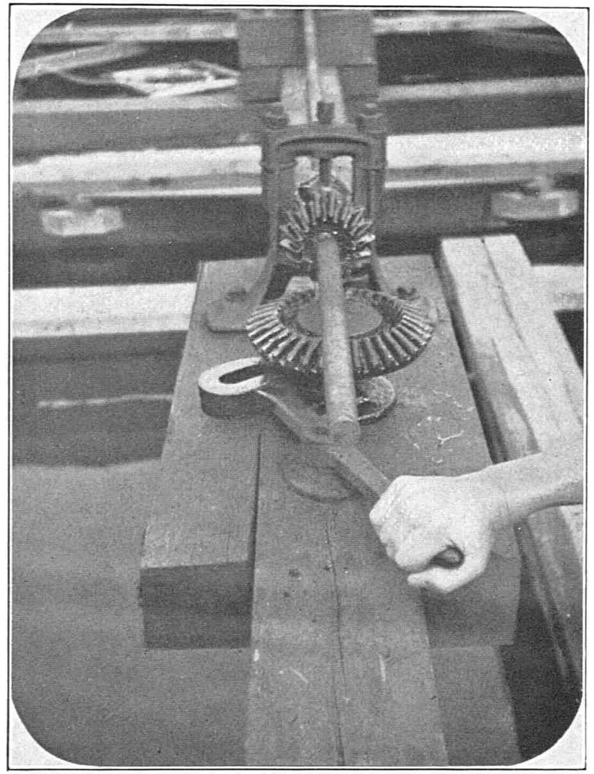

FIG. 22.—Device for throwing propeller out of gear. (Compare fig. 21.) This figure shows the propeller shaft gear dropped down so as not to engage the smaller gear on the longitudinal shaft.

# A METHOD OF CULTIVATING RAINBOW TROUT AND OTHER SALMONOIDS

By Charles L. Paige

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

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By CHARLES L. PAIGE.

## CLAIMS OF THE METHOD.

The experiments here described were conducted on Boulder Creek, in the Shasta Mountains, in Shasta County, Cal., in water to which the rainbow trout is native, under most favorable conditions for studying the fish and its habits. The experiments were made independently, with a view to determining a method for propagating trout without stripping the fish and resorting to the process of hatching the eggs artificially.

The claims established by the results of these experiments are:

1. That the rainbow trout (*Salmo irideus*, and probably nearly all the genus *Salmo*) will readily deposit their spawn in runs or races properly arranged; that after spawning the fish may be excluded from the runs or races, to prevent egg eating and cannibalism; that the water can be regulated under control while the eggs are in process of incubation where naturally deposited by the parent fish; that a high percentage of the eggs will produce hardy fry without other care than the proper regulation of the flow of water in the race and the exclusion of such fish or animals as prey upon the eggs, embryos, or young fish.

2. That when the fry appear, as they swim from the nests of the spawning beds of the race, they may be readily diverted into nursery pools connected with the race without any handling whatever, and that they may be there cared for and fed, if necessary, more advantageously than they can be in troughs or crowded colonies.

3. That pools made ready and filled with water for some months before the fry hatch will accumulate natural food for the fry, and where they are connected with an open race of running water this food supply is continued by the natural succession of aquatic and insectiverous food that is denied to fry hatched and held under artificial methods.

4. That the fry, having more water area, more varied and natural conditions in the flow of water—such as swift water, shallows, and depths—are not forced to constant struggles; that in an adequate race with side pools they have natural foraging area and may follow their instinct of independent exploration and solitary habits.

5. That the method proposed is superior in that it follows natural conditions governing the propagation and welfare of the fish, only eliminating and providing against the destructive forces, such as floods, drought, the tendency of trout to prey upon the eggs and young, and protection against such other fish and animals as prey upon the eggs, embryos, and young fish.

6. That the proposed method of causing the trouts (and probably under favoring circumstances, most of the salmon) to deposit their spawn in prepared runs or races, and the subsequent care of the nests and the young fish, may be more economically carried out than the artificial method of collecting eggs, impregnating them, and thereafter caring for them, as it is now practiced in most hatcheries, involving expensive plants and skilled attendants.

## REPORT OF EXPERIMENTS.

In support of the foregoing claims for the advantages of the system outlined, it is manifestly impossible to submit a portable model or other more tangible evidence than the sketches and particulars herewith submitted. The facts of experiments made are briefly summarized as follows, with the aid of diagrams 1, 2, and 3:

With a series of four ponds, constructed within a few yards of Boulder Creek, in which the rainbow trout are native, water sufficient to provide a flow through the ponds was diverted thereinto by way of an open trench 300 feet in length. The ponds are about 30 by 60 feet in area and range from 2 to 6 feet in depth. Several falls over weirs aerate the water sufficiently. The embankments are walled with bowlders, laid up without masonry, and in all respects the ponds comply with the natural conditions of the stream as nearly as can be devised. The temperature of the water in the ponds ranges from 40° to a maximum of 83° F., the latter high temperature occurring several days in the month of August, 1908, and lasting but a few hours in the afternoons of the warmest days. The fish suffered no ill effects from this extreme temperature, but were for the time manifestly restless and alarmed.

For two years, covering the spawning seasons of 1906 and 1907, from 40 to 100 adult rainbow trout were held in the ponds. These trout were taken from Boulder Creek with hook and line, readily became domesticated, all remained in good condition, and are at present among the largest of the breeding fish in the ponds.

The first season (October, 1905, to April, 1906), the larger of the fish spawned in beds made around the shores of the ponds, and in due time between 100 and 200 fry reached the surface. The little fish, with the exception of half a dozen, disappeared within a month. Five or six only survived.

The second year (1907), while a larger number of the parent fish spawned still fewer fry appeared, and but four of these reached the yearling stage. This season the fish were closely observed and it was ascertained that some of the smaller fish, apparently nonspawners, invaded the nests and with their noses dug into the gravel after the eggs. None of the fish was ever seen in the act of devouring fry, but the disappearance of the young could be accounted for in no other way than by the assumption that they were devoured by the adult fish.

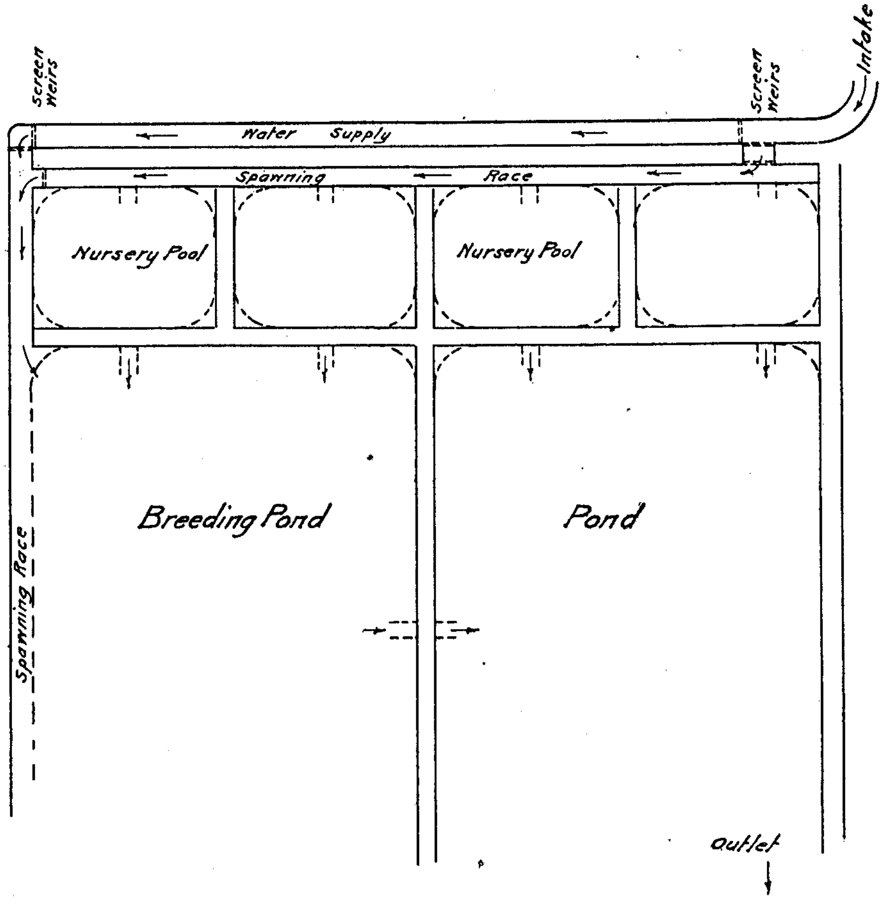


FIG. 1.—Plan of ponds and spawning race.

In September, 1907, a spawning race was constructed and connected with the ponds, substantially as shown in diagram 1, and the inflow water was diverted through the race to the ponds. The race is 2½ feet wide, 100 feet in length, and is paved with stones, loosely placed, and then covered partially with coarse sand and gravel. The race has a grade of approximately 1 in 20, and is made spiral in form, owing to limited ground area. Water affording a depth of 3 to 6 inches passed through it, the gradient giving it a rapid flow.

The fish soon accustomed themselves to the race, and at the spawning time about a dozen pairs of the larger trout conducted their spawning in it. Owing to the aggressive disposition of some of the males, the race proved to be too small for all the fish, and some of them nested in the ponds, as in previous seasons.

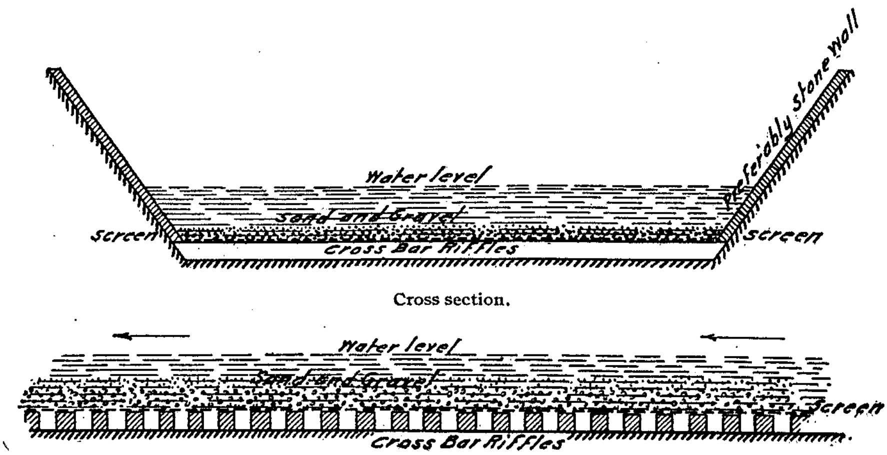


FIG. 2.—Spawning race.

NOTE.—Screen is used to prevent the clogging of the riffles, but with properly proportioned quantities of gravel and coarse sand the screen may be omitted. The eggs and milt of the fish should sink into the riffles with the finer particles of sand, to prevent fish from devouring the eggs during the spawning period.

The race was in the open air, covered at intervals with strips of burlap laid over wire netting to afford shaded portions. The spawners showed no preference as to the shaded or the open spaces, nesting in both. In some instances they

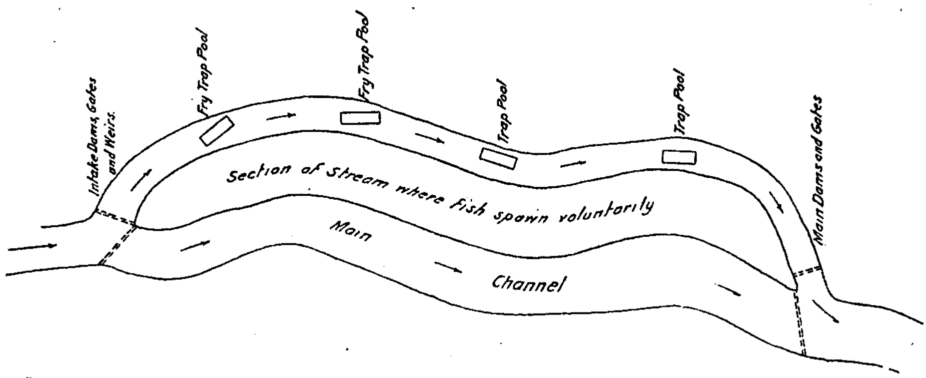


FIG. 3.—Suggested arrangement of a stream for the control of trout or salmon at the spawning season, and for the collection or rearing of the fry after the eggs have been naturally deposited and hatched. Sketch shows side channel, canal or prepared race, with flow of water regulated and controlled by dams, weirs, and gates. Under favoring conditions both channels might be available.

spawned in water too shallow to cover their backs, and in the open sunlight. Wire netting was stretched over the race to protect it from disturbance by birds and domestic animals, but it had no further attention until the fish abandoned their nests, about April 5. The run was then cleared of all fish, the water partly shut off, and screens placed at each end to exclude fish and destructive animals.

COMPARATIVE RESULTS.

About April 20 fry first appeared in the race, and fine screens were placed to prevent their escape into the ponds or out at the inflow. Two pools had been prepared for them and these were now connected with the race. By June 1 between 2,000 and 3,000 fry had hatched in the race, and these were about equally distributed in the race and the two pools. At the present writing (August 10, 1908) less than a dozen of the fry have died from any cause, and several of these perished by being caught in the screens. The fry now average nearly three months of age and are in thrifty condition, with no evidence of weakness among them.

Not above twelve pairs of the fish spawned in the race, and several of these were small females which were seen upon the nests but a few times, while the larger fish occupied the nests at intervals during six to eight weeks. It is to be considered that trout deposit but few eggs at a time, and this would appear to be a strong argument against the stripping process.

The fry appeared in the race, by careful count and removal, as follows:

| | | | |
|---|---|---|---|
| April 20 | 12 | April 25 | 10 |
| April 22 | 8 | April 26 | 10 |
| April 23 | 8 | April 27 | 18 |
| April 24 | 4 | April 29 | 11 |

Thereafter, until late in June, from 20 to 50 fry appeared daily, and the number then decreased until all had hatched. This may or may not be approximately the ratio in which the eggs were deposited, but it must be of value as proof that they are deposited but few at a time, and covering considerable time.

More than half of the spawners were kept out of the race by the pugnacious males, or elected to spawn in the ponds. Some of these were the larger fish and continued spawning throughout the season. Smaller fish, spawn-eaters, were continuously raiding the nests in the shallows of the ponds. Only about 20 fry appeared during the hatching season, and a dozen of these were saved by being dipped out with a net and placed in the fry pools. None of the others survived.

In conclusion, I desire to submit that these experiments, entailing much labor and time, and observations made under very favorable conditions and carefully recorded, have convinced me that it is not practicable to propagate trout in limited areas of inclosed water, without provision for the protection of both the spawning beds and embryos, and also the segregation of the fry until they are at least six months of age.

I do not believe a simpler, more practicable, or economical method can be devised to meet these requirements than the provision of adequate runs or races, together with nursery pools for the fry, substantially as outlined in this paper.

# POSSIBLE EXPANSION OF SHAD-HATCHERY WORK

By S. G. Worth

*Superintendent U. S. Fisheries Station, Edenton, N. C.*

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

# POSSIBLE EXPANSION OF SHAD-HATCHERY WORK.

By S. G. WORTH,

*Superintendent U. S. Fisheries Station, Edenton, N. C.*

In the past thirty years the methods of shad hatching and distribution have been carried to a high degree of excellence, and it may be said that little is left to be desired in these branches of fish-cultural work. There is an invitation to greater effectiveness, however, in the possibility of carrying the hatchery work beyond its present scope into rearing methods, so that the young fish may be planted after they have reached the fingerling stage and thus enter the open waters with greater chances of survival.

It has been exceptional to employ a gravity supply of water in any shad hatchery, the shad-spawning area being in the coastal plain region where tide water or equivalent conditions precludes the idea of dams, waterfalls, and reservoirs. If lunar tides do not exist then there are wind tides; there are no constant downward flowing streams in the spawning neighborhoods, or if any such exist the country is too low to permit the utilization of the flow. Hence nearly all shad hatching has been conducted in water supplied by steam pumps, with the expense of which it has been regarded as impracticable to undertake pond work of any kind at the shad-hatching stations. The activities have thus been concentrated upon hatching eggs and liberating the embryo fish product, attempt to carry the work beyond this point being exceptional. It was limited, in fact, to the Fish Ponds, Washington, D. C., a station now abandoned.

At that station, however, the rearing of shad was taken up in 1888, and continued until the abandonment of the establishment, in 1906, with highly satisfactory results. In the Commissioner's Report for 1888, page xxviii, appears the following statement:

Nearly 3,000,000 shad fry were placed in the west pond in May, 1888. These were held in the ponds during the summer, but were not fed; on the natural food found in the ponds they made rapid growth. In October, when the young shad were released in the Potomac River, they had attained the average length of 3 inches. It was not possible to determine by actual count the number of fish liberated, but conservative estimates placed the number at 50 per cent of the number of fry placed in the pond. These results were as satisfactory as they were unexpected, and indicated a new departure in fish-cultural work which promises important consequences.

The experience of 1888 was repeated with scarcely a variation for ten years or more. In other words, the rearing of shad fry was a success throughout. In my intimate association with the Fish Ponds and the Superintendent, the late Rudolph Hessel, and with the Central Station, which supplied the fry, I heard no suggestion of disappointment from any source. On one occasion I understood that some of the fingerling fish, on close examination, were found to be alewives, or river herring, but it may be said that any pond of a tidal or semitidal kind in the region of the river herrings is almost sure to contain some of their young. In the experimental ponds at Edenton Station the screens were kept in all the time and adult herring could not enter, but eggs were deposited on the outer surface of the wire mesh and the resultant fry, along with many others, perhaps, swam through the meshes. In fact, any screen that would allow the water to drain or waste from a pond would scarcely exclude the minute young of the river herrings. A noteworthy feature of the shad-rearing in connection with the work at the Fish Ponds, in view of the successful results, was the inferior quality of the fry supplied to the station. I personally know that, for a number of seasons, it was "the weak fry," "the early and weak fry"—fry that were of less than average vitality—that were consigned for these experiments.

Not only was the rearing of shad at the Fish Ponds a striking success, but an experiment at the more distant Neosho Station, in Missouri, under the late Superintendent William F. Page, was equally gratifying. In the commissioner's report for 1893, Superintendent Page says:

In addition, 200,000 fingerling shad were liberated in waters tributary to the Gulf of Mexico. Their number could not be ascertained except by estimate, owing to the fact that these fish can not be successfully handled. They were the product of 700,000 fry sent from Washington in the preceding June. In preparing for their release the hatchery branch was, in October, cleared of shoals, drifts, and aquatic plants for three-quarters of a mile, to a point where it empties into Hickory Creek. Early in November, when the branch was swollen by rain water, the 6-months-old fish were allowed to pass through open gates. They were some hours in escaping—a continuous silvery mass. These were the first fingerling shad planted in waters tributary to the Gulf of Mexico.

It will be well to note also what follows in Mr. Page's account, as below:

The pond which contained the shad was infested with crawfish, 1,750 pounds being removed and destroyed between August 3 and October 31. These were estimated to be 70,000 in number. By some unaccountable means black bass of the large-mouthed variety were also present. In preparing for receipt of the shad the pond had been drawn in November, 1891, and the bottom exposed for three weeks, and in the following April the process was repeated, all water connections with black bass ponds having been broken and an independent supply being established. On August 3, the intruding fish being observed, a hook and line were brought into use, and on the first day 5, averaging 1½ pounds each, were caught, and by October 31 the catch had reached a total of 152. It is believed that they burrowed in the mud, surviving the absence of water during the two periods mentioned.

The fish-cultural reputations of both Mr. Hessel and Mr. Page assure acceptance of their figures; and we know, of course, that no river herrings were among the fingerlings released from Neosho station, while the large output notwithstanding the crawfish and intruding black bass is a demonstration of the certainty of results in shad rearing where the right kind of ponds are employed.

The simplicity and the minimized cost in the rearing of shad makes it entirely practicable to entertain the idea that perhaps all of the output of the shad hatcheries might, in a short time, be subjected to the process. Deep ponds are not required, 3-feet depth being ample. Necessary conditions are to have ponds so arranged that the fingerlings require no handling—for their scales drop off at a mere touch—and to exclude as many natural enemies as possible. The first condition can be secured in either tidal or upland ponds, for the latter can be arranged in a series of two or more, each one backing the head of water against the gates of the next higher, the one nearest the stream being tidal or semitidal. The uppermost ponds could be emptied serially into the next lower down until the one next the stream contained all, when its gates could be opened. In tidal ponds there would be difficulty in excluding natural enemies, owing to the impossibility, ordinarily, of drying the bottom and keeping it exposed.

Lands available for the desired purposes are to be found throughout the shad region, and twenty years ago I pointed out the ponds used as meadows by farmers below Gloucester City, N. J., as exactly adapted to such use, they having automatic gates which turned rain water out at low tide and closed against the rising Delaware River lunar tides. Lands suitable for shad-rearing ponds would as a rule, be too low for agriculture, and their market price, or annual rental, would be inconsiderable. It has not been determined how large the ponds should be, but the one so long used for rearing at Washington contained about 5 acres. While such work should be directed intelligently, the chief cost would be the maintenance of a faithful watchman during the few months the shad were held.

In view of the extraordinary interest that attaches to the shad along so great a seaboard—Maine to Florida—by all citizens, of all degrees and conditions, and with the renown that shad culture has brought to its originators and sustainers, the work would seem to merit the bestowal of all rational culture methods that are really apparent. The rearing of the young fish can not be considered other than a strictly rational proposition, while, at the same time, it has passed all experimental stages. Welcome the day when all the shad fry produced at the shad-cultural stations shall be reared to fingerling size before being liberated in the open waters.

# THE COMPARATIVE VALUE OF FOODS FOR RAINBOW TROUT AND OTHER SALMONOIDS

By Charles L. Paige

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

# THE COMPARATIVE VALUE OF FOODS FOR RAINBOW TROUT AND OTHER SALMONOIDS.

By CHARLES L. PAIGE.

To demonstrate the comparative value of different kinds of food for young salmonoids with any degree of exactness must necessarily entail very patient and careful investigation. The fishes experimented with will have to be maintained in separate pools, under identical provisions of environment, water supply and area, temperatures, and the possible supplies of natural food carried by or existing in the water or in the pools themselves. Where there exists wide diversity of opinion as to food values for the higher orders of animals, to demonstrate the values of such atomic particles as are collected by the young fish will tax the powers of the most exact scientific analyses. Any demonstration of the maintenance of the fishes will in itself be subject to question as to specific hereditary influences, climatic or aquatic conditions, prevailing habits of the fishes, and many other circumstances for consideration.

After experiments and study covering a period of many years, supplemented by close observation of the fish in small areas of inclosed water, I can suggest no new form of food artificially prepared superior in any respect to that commonly used in most hatcheries where young salmonoids are fed. For fry I should prefer these foods in the order here named:

1. Raw beef liver, finely ground, for the first five days or week.
2. Fresh lean meat finely ground.
3. Any available fresh lean meat mixed with increasing portions of wheat middlings, fed either in the raw state or after being cooked as a mush.

In the preparation of any meat food (after five or six days feeding of raw liver alone to newly hatched fry) the fresh liver and meat should be thoroughly ground together with from one-fourth to three-fourths of its weight of wheat middlings. The middlings, in itself good food which will sustain fish indefinitely, is particularly valuable in absorbing and holding the juices of meats and makes a mixture of about the right consistency and gravity to remain in suspense or slowly sink in water, while it is easily distinguished by the fishes once they are accustomed to it. It is a cheap and generally available staple. Food prepared as described may be readily dried and preserved for emergencies where a fresh supply of meat is lacking.

That millions of trout and salmon fry have been and are being maintained in overcrowded hatching troughs upon a diet of beef liver would appear to be positive evidence of its great value, while it is commonly as easily and cheaply obtainable as any form of animal food.

The chief object of this paper, however, is to suggest that young salmons and salmonoids reared in captivity should be given the minimum quantity of artificial food and a maximum area and flow of water containing their natural food, for which they should be permitted to forage. Prepared food should supplement the natural supply where water area is overcrowded with young fish, or where drouth, cold, or other climatic conditions interfere with the normal natural supply. In support of this view is offered the following summary of well-known or readily ascertained facts and examples:

1. That along the salmon rivers and trout streams fry existing under natural provisions are commonly in excellent physical condition, mortality among them being mainly caused by abnormal disturbances of the nests, such as floods, drouths, or extraordinary climatic changes, or by the depredations of natural enemies, birds, reptiles, and other animals.

2. That salmonoids are not surface-feeding fishes exclusively, but seek food suspended in the water and on the shores and bottom surfaces accessible to them; and that of necessity they must collect more or less vegetable and sedimentary matter; in fact, that they are rather omnivorous than piscivorous or carnivorous fishes.

3. That under normal natural conditions a continuous succession of seasonable aquatic and insectiverous foods, much of which will embrace vegetable matter in some form, is supplied to the young fish.

4. That owing to the minute particles of food matter collected by newly hatched salmonoids, it is doubtless impossible to distinguish with accuracy the natural or instinctive selections made by them, or to determine nutritive values.

5. That it will appear that suitable natural food for salmonoids is abundant in the waters wherever trout and salmon spawn, and that the most available, economical, and scientific provision for young salmonoids may be made in the preparation and adaptation of sufficient water area in normal natural condition, but subject to control as regards floods, drouths, freezing to extremes, and the exclusion of destructive animals. Controlled areas of stream or prepared runs should provide for the absolute regulation of the water flow, and should contain trap pools or other devices for collecting the fish, excluding them at the end of the spawning season, and finally reducing the flow of water to a minimum for the purpose of capturing the fry or young as may be desired.

# APPARATUS AND METHODS EMPLOYED AT THE MARINE FISH HATCHERY AT FLÖDEVIG, NORWAY

By G. M. Dannevig

*Director Flödevig Hatchery*

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

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# APPARATUS AND METHODS EMPLOYED AT THE MARINE FISH HATCHERY AT FLÖDEVIG, NORWAY.

By G. M. DANNEVIG,
*Director Flödevig Hatchery.*

The main point in artificial propagation of marine fishes is to hatch the greatest possible number of fry at the least expense. To attain this end the spawning fish must be treated so that they can yield the greatest number of well-developed eggs; the fertilization must be perfect; the incubators must be able to hatch the greatest number of fry in the smallest space, must be easy of access, and easily cleaned. The following description of the Flödevig hatchery for salt-water fish will show how far the above-stated conditions have been attained.

*Main features of equipment.*—The Flödevig hatchery is situated on the seacoast near Arendal, Norway. The principal parts are a main building, having on the lower floor 42 hatching apparatus, a water wheel, and an aquarium, and on the upper floor, an office, laboratory, egg collector, etc.; an engine house with boiler and pump capable of delivering about 100,000 liters of sea water per hour; a spawning pond, dimensions 19 by 6 by 3 meters; and a larger pond 34 by 22 by 5 meters, used as a reservoir for sea water. (Fig. 1.) These several parts will be more fully described later on.

*Beginning the season's work.*—When the spawning season commences, early in February, the pump is set going and the ponds filled with sea water. To insure as far as possible a high and uniform salinity, the water is pumped up from the bottom of the bay, a depth of about 8 fathoms. If the weather has been cold, the concrete walls of the ponds will have a temperature below freezing point; and if so, the pumping must go on for several days until they have the same temperature as the water pumped in.

The spawning pond must be covered to keep out snow, rain, and to some extent, light. Direct sunlight is apt to blind the fish.

*The spawners and the spawning pond.*—When the pond is in order, the spawners are put in and may now be left to themselves. The proportion between male and female is something like 1 to 4. The fish must be fed regularly, say three or four times a week. Herring are chiefly used, but other fish containing much oily matter, as saithe, whiting, or haddock, are preferable. The pond at Flödevig will hold about 350 cubic meters of water,

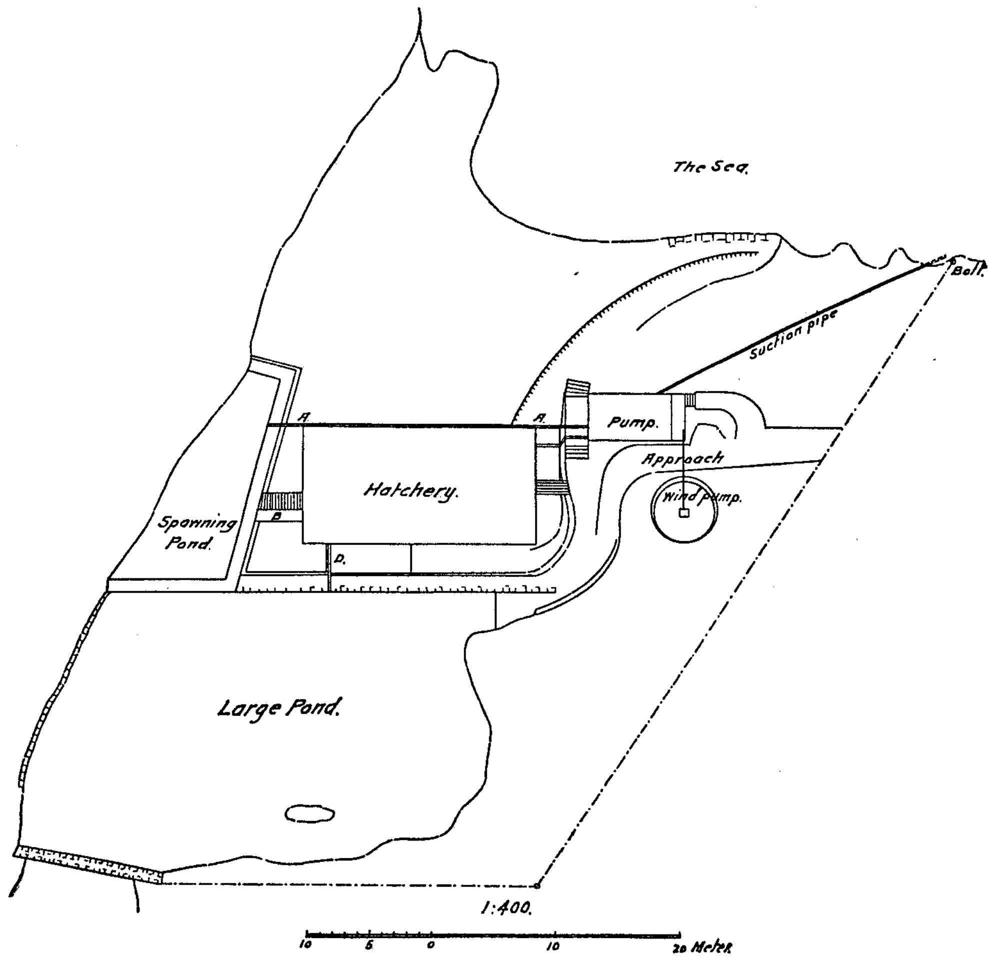


FIG. 1.—Plan of Flödevig hatching station.

sufficient for about 2,000 spawners of medium size. The water supply must be regular and proportionate to the number of fish—at Flödevig 30,000 to 50,000 liters per hour.

In feeding the fish a certain quantity of food and offal will sink to the bottom, and together with unimpregnated eggs, excrement from the fish, etc., pollute the bottom layer of the water. To prevent the spawners from coming in contact with this the pond is provided with a wooden flooring, about 1 foot over and above the highest part of the bottom, and with a

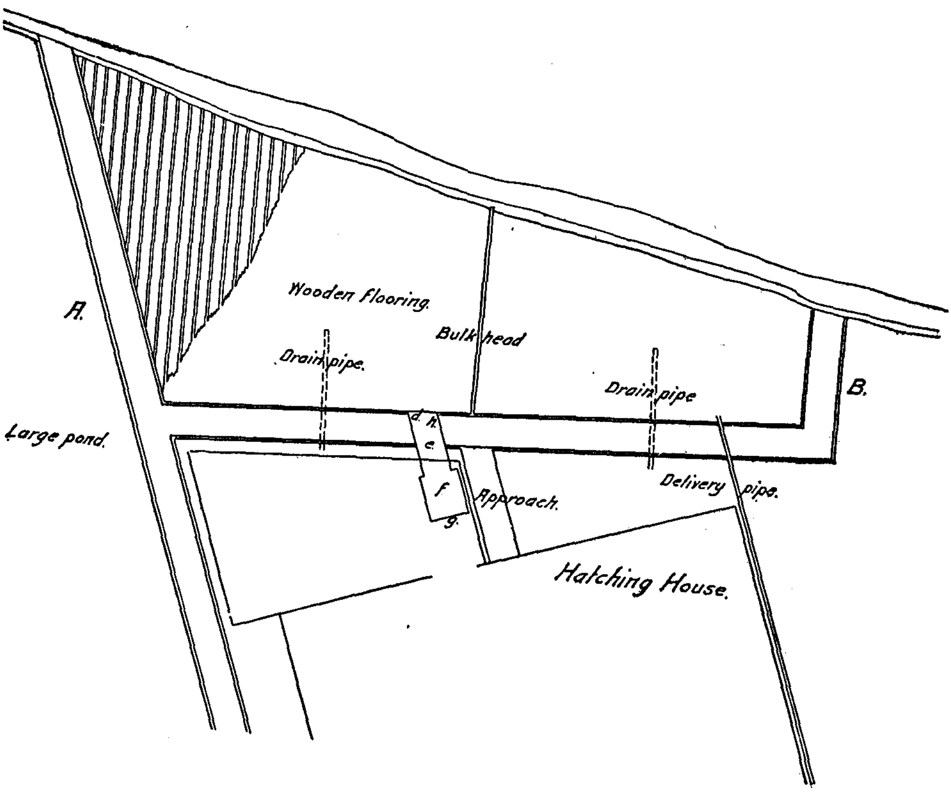


FIG. 2.—Spawning pond. (Plan.)

space between the boards of about 1½ inches. Through these openings the impurities will sink down into a sort of funnel-shaped cellars, provided with

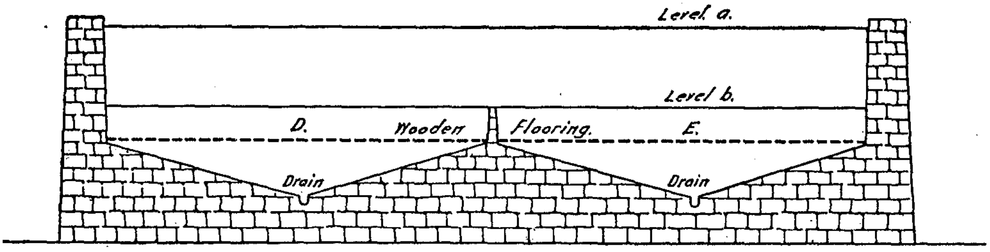


FIG. 3.—Same as figure 2, showing section A–B.

4-inch drainpipes in their lowest part. (Fig. 2 and 3.) These drains are opened about a quarter of an hour every day. In spite of these precautions, however, the bottom water will, after a time, be contaminated to a degree that becomes dangerous to the fish, and a thorough cleaning out becomes necessary. This is effected in the following manner:

The drains are opened and the water, the surface of which usually is at level *a*, is allowed to run out till it reaches level *b*. (Fig. 3.) The pond is then, by the watertight bulkhead, divided into two compartments, *D* and *E*, and with a number of fish in each compartment. Supposing *D* is to be cleaned first, the water in *E*, under continual renewal, is kept level with the top of the bulkhead, while it is lowered still more in compartment *D*, until about 1 foot above the flooring. The fish are then caught with dip nets and lifted over the bulkhead into *E*. After this is done, all the water is let out from *D*, and the place scrubbed and washed thoroughly. To facilitate the work, the middle part of the flooring ought to be made like a hatch to be lifted off, as cleaning underneath is necessary.

After cleaning, compartment *D* is filled again, the fish lifted in, and *E* cleaned out in the same manner. How often this is to be repeated depends on the number of fish in the pond, the nature of the food, and on the specific gravity and temperature of the water. I have never had occasion to do it more than three times in the season; usually once or twice.

*The spawning.*—With the exception of the necessary handling when cleaning the pond, the spawners need not be touched during the whole season. If properly fed, and with a constant renewal of the water, they soon will become accustomed to their prison life, and in a short time be so tame that they will take food out of the hand. Consequently the fish will thrive well, and the development of the reproductive organs, as well as the spawning, will proceed in the ordinary manner, just as if the fish were living under natural conditions.

The pond, however, has one great advantage. All the eggs are sure to be impregnated, as the whole volume of water, practically speaking, is filled with sperm, a result of the great number of spawners crowded together in a narrow space.

The cod generally spawn in the evening between 8 and 11 o'clock, and, provided the water has a specific gravity of 1.021 or more, the eggs will float up and form a thin layer on the surface of the pond.

*Collection of the eggs.*—I have mentioned above that the pond receives from 30,000 to 50,000 liters of water per hour. The outlet is shown at *d* (fig. 2), and is formed as a depression or cut in the front wall, 3 feet wide and 1½ feet deep. Its continuation is a wooden chute *e* of the same dimensions leading into a receiver *f* somewhat broader and deeper than the chute. From this the outflow is through an iron pipe *g*, placed so that its upper end regulates the height of the water in the pond. (See also fig. 4 and 5.)

In the receiver *f* the egg collector (fig. 1, pl. CI) is placed in such a manner that its open end fits exactly to the open end of the chute. The bottom and back end as well as both sides of the collector are covered with silk gauze no. 40. All water coming from the pond will thus have to flow into the collector, and as this will act as a strainer the eggs will be kept back, while the water continues its course through the gauze netting toward the overflow pipe *g*. As the opening in the wall as well as in the chute is deep and wide, the outflowing current would be too slow to bring all the eggs in the pond into the collector in a

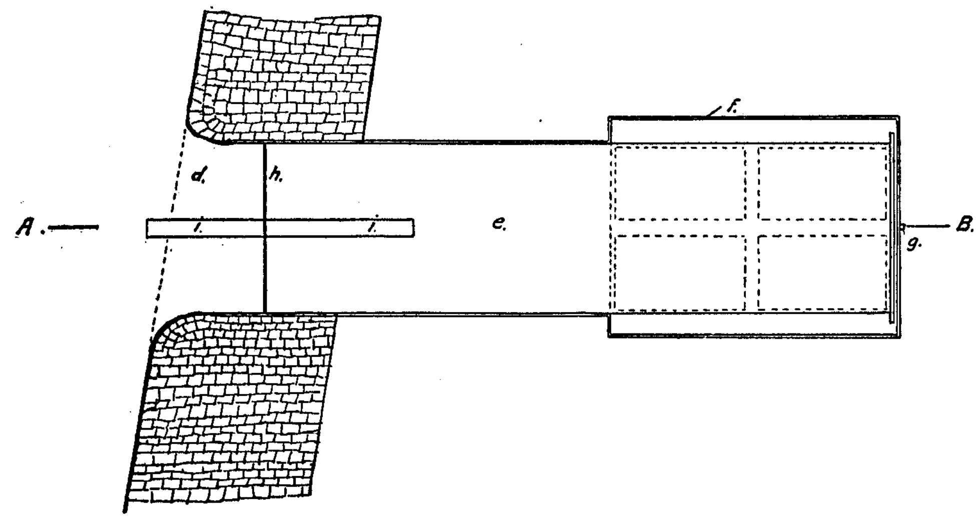


FIG. 4.—Device for installation of egg collector. (Plan.)

reasonable time. To remedy this, a partition or dam has been placed at *h* (fig. 4 and 5), and at the same height as the upper end of the overflow pipe. Instead of a slow current 18 inches deep, we will now have a strong current half an inch deep, and as the eggs float at or near the surface of the water, all of them will in a short time, say two or three hours, be drawn into the collector.

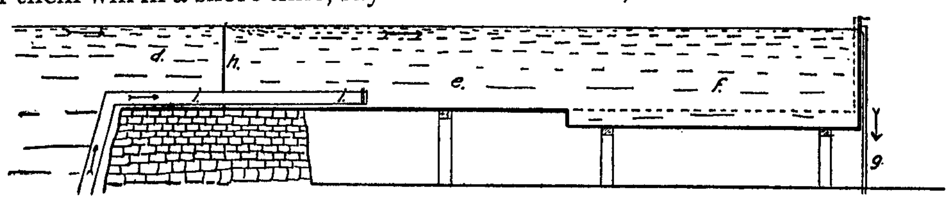


FIG. 5.—Same as figure 4, showing section A–B.

I have mentioned above that the cod spawn in the evening. Consequently all the eggs would be in the collector at about midnight, and have to remain there crowded together till the men arrive in the morning. As this is not desirable, the surface outflow is stopped in the evening and the wooden pipe (fig. 2), which draws the water from a greater depth, is opened, and thus the eggs will remain quietly at the surface of the pond till morning when the surface current is turned on again by closing the wooden pipe.

*Cleaning the eggs.*—It can not be avoided that a certain quantity of fatty matter, always floating on the surface of the pond, will be drawn into the collector along with the eggs, and form a layer on top of the water. The greater part of it can easily be removed with a stick passed horizontally along the surface, but some will always be left and have to be taken up along with the eggs, in the sort of shovel, covered with silk gauze, which is used for this purpose.

The eggs and whatever is mixed with them are put into an oval bath or a similar vessel, not too deep, and with just enough water to keep them floating. Fresh water is then poured on, which causes the eggs to sink, while the fatty matter remains at the surface. This is poured off, fresh water again added,

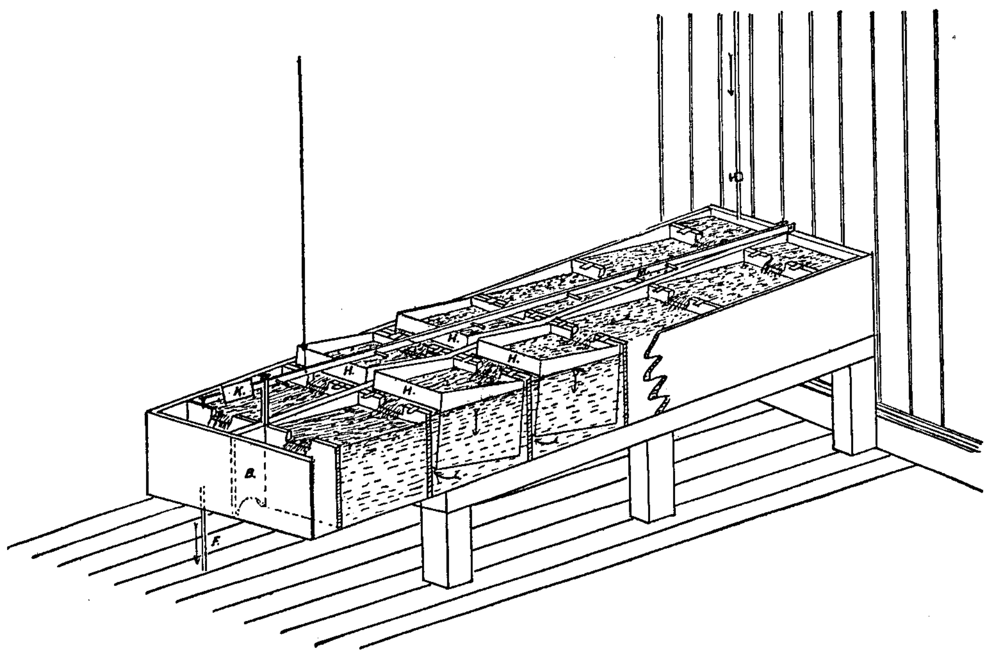


FIG. 6.—Hatching apparatus.

and when this process has been repeated two or three times, the eggs will be clean. After this the vessel is filled with sea water, and, if necessary, a little salt is added. The eggs will now float at the surface and may be taken out and measured as usual. The collector has to be taken out and cleaned one or two times a day.

*The hatching apparatus.*—If cod eggs were scarce and difficult to obtain, the main point would be to hatch the greatest possible per cent of the eggs. As this is not the case, the question must be to hatch the greatest number of fry for area of hatchery and hatching apparatus, and at the least possible expense. It is from this point of view that the methods used at Flödevig have been invented. The hatching apparatus shown in figure 6 is 7 feet 6 inches long, 2 feet 3 inches broad, and 11 inches deep inside. By a partition board in the middle it is divided lengthwise in two compartments. These are again divided crosswise in 7 compartments each, the first and last pair being 4 and the others 15 inches long. They are all watertight with the exception that the smaller ones communicate with each other through an aperture in the center-board *B*.

In the top of each of the transverse boards is a depression 1 inch deep and 3 inches wide, into which is fixed a brass spout (fig. 8).

The egg box, or incubator, shown in figure 7, is 12½ inches long, 11½ inches wide, and 10½ inches deep, and made of five-eighths inch white pine. The bottom is covered with silk gauze. It has, similar to the partition board, a depression in the upper edge, also fitted with a brass spout, just large enough to pass outside the former. The incubator is hinged to the transverse board as shown in figure 8.

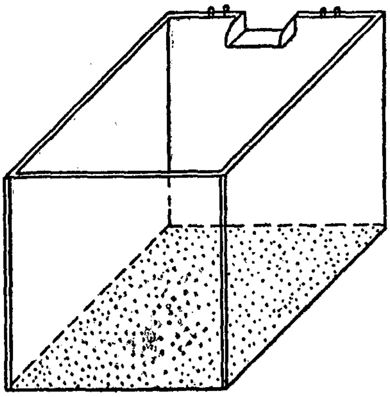

FIG. 7.—Egg box, or incubator.

When the apparatus has been placed in position—slanting 3½ inches—and the water turned on, the small compartments become filled, after which the water passes through the spouts into the next compartments, and so on until the whole of the apparatus is full and the superfluous water escapes through the drain *F*.

As the incubators are made of light wood the loose end will float up and have a position as shown at *H*, figure 6. The circulation of the water after the

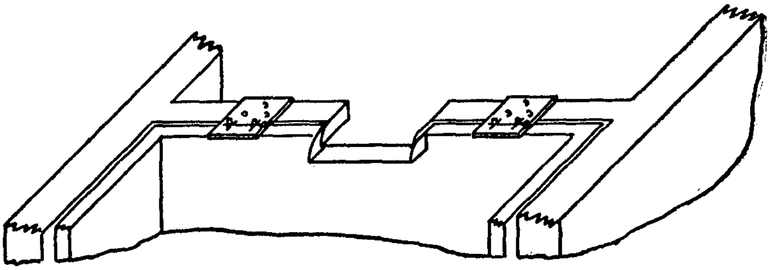

FIG. 8.—Mode of fastening incubator.

apparatus is set going is shown by arrows. As the current is regular, eddies will be formed and the eggs be crowded together in the dead corners, where a great many would die from suffocation. To avoid this an up-and-down movement of the loose end of the incubators has been contrived in the following manner:

An iron rod (*M*), a couple of inches shorter than the apparatus, is joined to this at the upper end and passes down the center between the series of boxes.

It has five transverse pins, resting on the free edges of the boxes, and is weighted sufficiently at *K* to keep the boxes down in the water. On the contrary, when the rod is raised the boxes will float up. The movement of the rod is brought about by an eccentric (fig. 2, pl. ci), which revolves about twice in a minute and is so arranged that the rise of the rod is slow, while the drop is sudden. This up-and-down movement of the free end of the incubators will make the current irregular, break up the eddies, and keep the eggs in continual motion. The eccentric wheel is driven by a waterwheel that utilizes the outflow water from the egg collector described above.

*Hatching.*—The usual quantity of cod eggs put into each of the small boxes is 1½ liters, equal to 675,000. The quantity may be raised to 2 liters, but this is rather too much if the specific gravity of the water is low, which very often is the case on this coast. To avoid difficulties in this respect, the water for the hatching boxes is never taken direct from the pumps but from the large pond, which is used as a reservoir and has its overflow pipe placed in its lower part. A temporary fall in the salinity of the water in the sea, even for several days, will by this arrangement hardly be felt. About three days after the eggs have been placed in the incubators, the dead ones will have fallen to the bottom and a cleaning out becomes necessary. This will have to be repeated at intervals as may be required and is easily done, as the incubators can be unshackled in a moment and the eggs are very hardy, so no great care is needed.

When the eggs begin to hatch, the incubators will have to be watched more closely, as the empty shells are apt to fall to the bottom and clog the netting, and a cleaning every day then becomes necessary. At this period great care is needed, as the fry are very tender. The number of days required for hatching the eggs varies according to temperature; at 3° C. to 4° C. the fry will be out in twenty to twenty-five days. The loss in the apparatus during hatching depends very much on the specific gravity of the water, and on the whole the net output of fry will vary between 60 and 65 per cent. The fry are liberated when 5 to 6 days old.

*Cost of hatching cod eggs.*—As the Flödevig hatchery has been rebuilt and altered several times, it is rather difficult to say how much money has been spent upon it. With the present prices of work and material I should say that a similar station in full working order could be put up for about $5,500. The cost of productions was for the first year about $60 per million of fry, but this price was soon reduced to one-fifth, and at present the fry can be hatched for about $6 per million. In this price everything connected with the work is included.

In 1898 the hatchery produced 412,000,000 of fry from 1,312 liters (590,000,000) of eggs, and under ordinary circumstances and with an expenditure of 12,000 kroner, or $3,150, a similar quantity could be produced every year.

*Conclusion.*—The above description refers to the Flödevig hatchery in its present state. It would be a long story to mention all the experiments, successful or otherwise, which step by step have led to the present condition of affairs. It is sufficient to say that improvements have been made from year to year and are still going on, so that the Flödevig hatchery, instead of being regarded as an old institution, rather must be looked upon as a growing concern, capable of further development. If the great expectations so justly combined with the question of artificial propagation of marine fishes shall ever be realized to their full extent, the work must be carried on upon an immense scale, and this will first be possible when the expenses have been reduced to a minimum.

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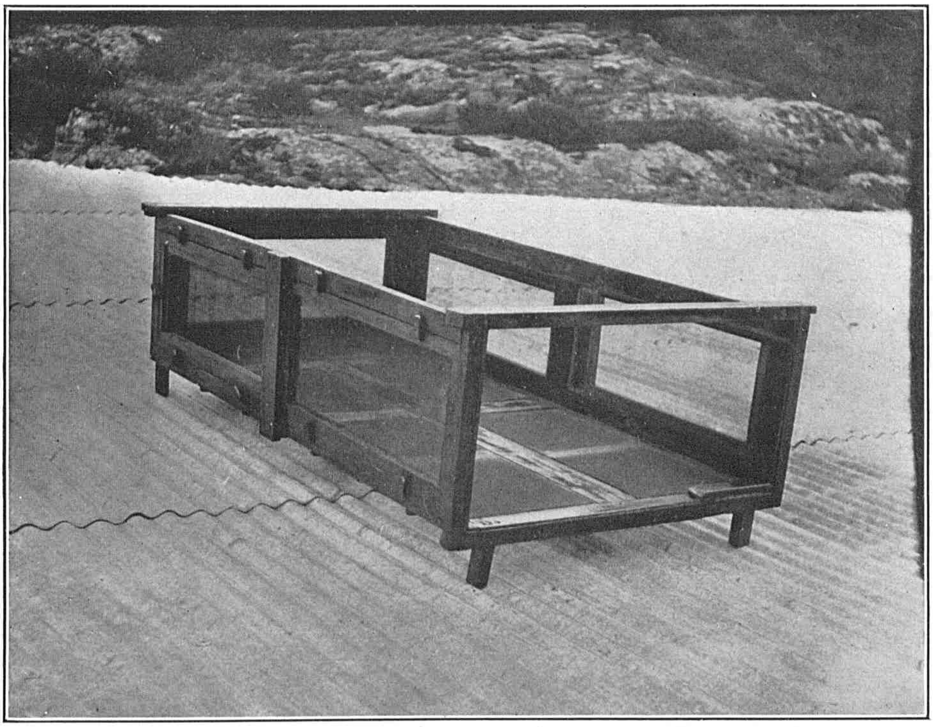

FIG. 1.—Egg collector used at Flödevig, Norway.

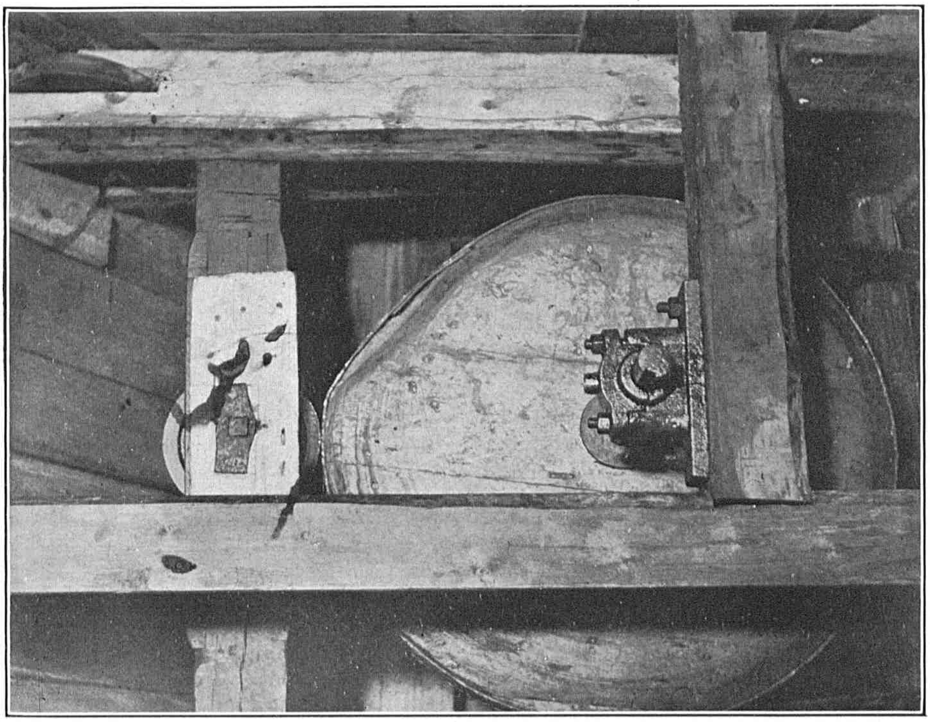

FIG. 2.—Eccentric wheel providing circulation of water in hatching boxes. Flödevig, Norway.

# THE UTILITY OF SEA-FISH HATCHING

By G. M. Dannevig

*Director of the Marine Fish Hatchery*
*at Flödevig, Norway*

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

# THE UTILITY OF SEA-FISH HATCHING.

By G. M. DANNEVIG,
*Director of the Marine Fish Hatchery at Flödevig, Norway.*

From the middle of the last century the shore fisheries on the south coast of Norway were steadily decreasing, and principally was this the case with cod and flatfish. The cause of the decline was commonly supposed to be overfishing and especially the excessive use of small ground seines, by which the bays and the small patches of clean ground adjacent to the coast were continually swept.

In the beginning of the eighties the state of things became serious. The fishermen as well as the public in general complained loudly, and several modes of protecting the fisheries were proposed. At this period the Arendal Fisheries Society was founded, and being informed that the Fish Commission of the United States had succeeded in hatching cod eggs, it was decided to try this expedient as the only one available that could be used without inconvenience to the fishermen. Consequently a small hatchery for cod was started and maintained for four years, chiefly by private contributions. As an evidence of the great interest in behalf of the enterprise, it can be mentioned that the inhabitants of Arendal, a small place with less than 5,000 souls, during the first five years contributed 24,232 kroner (equal to $6,550) toward the hatchery.

Operations began in 1884 and, as was expected, spawning fish were very scarce and difficult to obtain. The fish market at Arendal was visited almost every day from the beginning of January to the end of March, and the whole quantity of spawn collected was only 28 liters. The next year a small well-boat was provided for buying up spawners on the coast between Bisor and Homburgsund, a distance of about 40 miles, but with no great success, the whole amount of spawn for the following three years being respectively 109, 153, and 144 liters. In 1888 no fish could be had, on account of the ice blockading the coast, and in 1889 no work was done, as the station then was undergoing reconstruction, it having been found desirable to have it removed to another site and enlarged. In 1890 the new hatchery was started with 42 hatching apparatus against 9 in the preceding years, and as there was no chance of getting a full complement of spawners in Arendal or the neighborhood, a well-smack was dispatched for that purpose. In 1891 there was a marked increase in the cod fishery near Arendal, and still more so in 1892, so that a considerable part of the spawners could be bought there. In 1893 the whole number of spawners was obtained in Arendal, and the spawn collected amounted to 1,000 liters. From that year to the present time there has been no lack of spawners at the Arendal fish market, and the quantity of spawn each year has varied between 550 and 1,326 liters, not according to what could be had, but according to the sum voted by the Storthing for the hatchery. At present it would not be difficult to obtain 2,000 liters if required. It must be borne in mind, however, that natural spawning, introduced in 1890, produces at least double the quantity of spawn compared to the old method, and that consequently the number of spawners can not be calculated direct from the quantity of spawn; but on the other hand it is obvious that the cod has increased greatly in the vicinity since the hatchery was started.

As mentioned above, the hatchery was started in 1884. That year a small quantity of fry, less than 1,000,000, was planted in a small fjord about 10 miles from Arendal. In the following year the neighboring people sent me a letter with the information that a great many small cod had made their appearance, in fact more than the oldest inhabitant could remember.

In 1889 the Bergen Society for the Promotion of the Norwegian Fisheries sent one of their chief members, the president of the propagation committee, as well as the state inspector of fisheries, to the fjord in question to investigate the matter. Their report, dated March, 1889, says that there is no doubt that the number of cod in the fjord has increased and that this is the result of the planting of the fry, and, further, that there can hardly be any doubt that artificial hatching is the right course to take to improve the fisheries.

In 1895 the Storthing decided that to get further proof of the utility of sea-fish hatching fry should be planted in inclosed fjords in the same manner as before and without previous investigations. This was done, and in conformity with the plan adopted our society approached the public where fry had been planted in former years and asked their opinion as to the results. Twenty-two answers came in from parish councils, commercial marine societies, and from private parties and fishermen. The answers were unanimous, and to the effect that an unusual number of small cod made their appearance wherever fry were planted, and, further, that the fish to a great extent were of a color differing from that of the local race.[a]

These documents, however, when laid before the Storthing, caused a member opposed to sea-fish hatching to express a doubt as to their trustworthiness,

[a] The cod on the south coast of Norway vary greatly as far as color is concerned, there being light gray, dark gray, red, and yellow cod, according to race, nature of bottom, food, etc., and, generally speaking, each fjord or stretch of coast has its own peculiar variety.

and the Government ordered its adviser in fishery questions to investigate the matter. His report, dated December, 1896, contains the following particulars: He had visited the principal places where fry had been planted between Fredriksald and Arendal, a distance of about 150 miles, and had questioned fishermen and others, especially such as had not signed the documents. He had in most cases avoided making himself known, pretending to be a private individual who took an interest in the question, and thinks therefore that he got explicit and unreserved answers. Out of thirty persons with whom he had conferred, there were twenty-five who were of a decided opinion that the planting of fry had caused a more or less considerable increase in the number of cod, two who thought there was but a slight increase, and three who had observed no increase at all. In many places the people were certain that they could distinguish the broods planted in the different years and that the size corresponded with the age. The cod now were partly of a color different from what they used to be. He also found the inhabitants very eager to have more fry planted in their fjords, even if they should have to pay for it out of their own pockets.

Since then our society has received a great many testimonials of the same tenor (60 altogether) and as they have been accompanied with cash to the amount of 10,000 kroner for fry delivered, their trustworthiness can hardly be doubted.

In 1903, the Storthing, still doubtful, voted the necessary sums for the investigation of fjords where fry were to be planted. The plan was to have them thoroughly overhauled before and after fry were put in, with the objeet of ascertaining the approximate number of cod of the year's growth. A seine with very small meshes, 22 fathoms long and 2½ fathoms deep, was used, and great care was taken to have the hauls made in exactly the same places and at the same season, the latter part of September, when the fish would have a length of from 2 to 4 inches, being agreed upon. The work was conducted by me, and controlled by an assistant to the fishery board, an implacable opponent to sea-fish hatching.

Two fjords, no. 1 and no. 2, were thus overhauled in September, 1903. In no. 1 fry were planted the following spring and both fjords again overhauled in September. In 1905 fry were planted in both fjords in April, after which they were overhauled in September the same year. Fjord no. 3 was investigated by me alone, and in the following manner: First, overhauling in September, 1904, with subsequent planting of fry in April, 1905; investigated in September same year. More fry planted in April, 1906, and a final overhauling the following September. As will be seen, all the fjords mentioned have been overhauled three times each. In the first and third, fry were planted twice, in the second only once. The results were as follows:

*Fjord No. 1.*—About 10 miles long, 1 mile broad, shaped like a horseshoe. Bottom of sand, clay, and mud, the shores mostly rock, covered with algæ, while the small creeks where the hauls were made were covered with seaweed. One hundred and six hauls were made each time and with the following result: September, 1903, before planting, 426 yearlings; September, 1904, after planting, 1,523 yearlings; September, 1905, after planting, 1,133 yearlings.

*Fjord No. 2.*—About 1½ miles long by one-third of a mile broad. Bottom as in no. 1. Many of the small creeks liberally covered with sawdust. Twenty-one hauls each time, resulting as follows: September, 1903, before planting, 36 yearlings; September 1904, before planting, 133 yearlings; September, 1905, after planting, 143 yearlings.

*Fjord No. 3.*—Circular. Two and one-half miles long by 1 mile broad. Bottom as no. 1. Number of hauls 33, with following results: September, 1904, before planting, 454 yearlings; September, 1905, after planting, 756 yearlings; September, 1906, after planting, 953 yearlings.

The main results for the three fjords will be:

| Fjord. | Before planting. | After planting. |
|---|---|---|
| | *Fry.* | *Fry.* |
| No. 1 | 426 | [a] 1,328 |
| No. 2 | [a] 84 | [a] 143 |
| No. 3 | 454 | [a] 855 |
| Total | 964 | 2,326 |

[a] Average.

The increase amounts to 141 per cent.

Figures taken from the fishery statistics for the Kristianiafjord, inside of Dribak, begun in 1872, show an average catch of 75,761 cod in the period between 1872 and 1881, and of 58,476 between 1882 and 1891. In 1892, when fry first were planted, the catch was 44,013. Since then there has been a steady increase, and last year the number caught was 114,013. The number of fry planted in the Kristianiafjord since 1892 is about 170,000,000, worth about 5,000 kroner, while the increase in the catch over and above what it was in 1892 is worth about 600,000 kroner.

On the west coast of Norway, where hatching has not been conducted, the cod is gradually disappearing from the fjords.

# PROPAGATION AND PROTECTION OF THE RHINE SALMON

By P. P. C. Hoek, Ph. D.

*Scientific Fishery Adviser to the Dutch Government*

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

# PROPAGATION AND PROTECTION OF THE RHINE SALMON.

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*Scientific Fishery Adviser to the Dutch Government.*

## ENVIRONMENTAL CONDITIONS AND NATURAL HISTORY.

Wherever it is found the salmon is highly esteemed—to the most precious kinds of salmon that of the Rhine unquestionably belongs.

"Old Father Rhine," with his very important tributaries, flows through a very densely populated part of west Europe—at the same time one of the most industrious and cultivated regions of the whole world. The river itself, as you all know, comes from Switzerland, forms the frontier between that country and the Grand Duchy of Baden, passes through a great part of western Germany, then enters Holland, and in that country, with numerous outflows, finds its way to the North Sea. Of the numerous affluents, which together drain a surface of several thousands of square miles, some belong to Switzerland, many belong to Germany, a few to the Low Countries (the Netherlands) nearer the mouth of the river.

It is impossible to treat of the propagation of the salmon of the Rhine without emphasizing the important rôle the affluents play in the economy of this fish. As a rule the Rhine salmon does not propagate on the main river itself; but for that purpose enters one of the tributaries, there to spawn in the upper courses or in the mountainous rivulets and brooks which are in open communication with these upper waters. The main river itself plays only a secondary part, so to say, in the natural history of our fish; it forms the communication, the open highway, between the sea and the very extensive region where the natural propagation takes place. It is now a well-established fact that the greater part of the young salmon hatched in the higher parts of the affluents of the Rhine remain there about a year, living in that time the life of trout, and as 1-year-old fish, in springtime, migrate to the sea. They reach the mouth of the river on their way to the ocean in the month of May, their length being then from 12 to 17 centimeters. Most of these young salmon at that time have already, or at least partly, changed their trout livery (the "parr" costume), with the well-known transverse black bands, the small red spots, etc., for a more convenient traveling suit of silvery gray, and in this condition they are called "smolts."

The main river, which has served for the passage of the yearlings on their way to the ocean, a few years later conducts the grown-up fish to their spawning places; so the river itself is mainly the binding link between the sea, where the salmon grow up from 15-centimeter large trout-like fish to marketable salmon, and the upper region, where the propagation takes place and the young salmon find a living until they are about 1 year old. The food the young salmon take in the main river during their journey to the sea consists of different insects, and in the lower parts of the river and the estuaries small crustaceans. During the ascent of the larger fish coming from the sea and bound for the spawning places in the river, as a rule no food whatever is taken. The salmon caught during their ascent owe their value as food for man to the rich feeding grounds in the open sea. So it is perfectly right to consider them as a gift from the sea to the lands bordering on the river, the inhabitants of which catch them on their passage. But taking into consideration the fact that the salmon swim up the river at the expense of the fat stored in their muscles, etc., from a general economic point of view it is also evident that the fish are in finest condition on entering the river, and that therefore the lower parts of the river are most to be recommended for the catching of the salmon.

Now, keeping constantly in our mind the importance of the upper regions of the river and its tributaries for the first year of the salmons' life and that of the open sea for their growth until they shall have reached marketable size, I shall first of all point out to you that this normal course of development is not followed by those young salmon which at the end of their first year remain for a second year, and some of them longer still, at or in the neighborhood of their birthplaces. These are nearly all male fishes, and it is a well-established fact that they will be sexually mature (ripe) in the second autumn of their existence, and then even will play an active part in the propagation of the species. Their size is (October–November) from 15 to 19 centimeters, very few being smaller or larger than that size. It has been suggested by Professor Fritsch for the salmon of the river Elbe that all the young males may remain a second year in the upper parts of the river and its affluents. I have been able myself to show, however, that this by no means holds good for the Rhine. I had the opportunity of examining 365 young salmon caught in May during their descent to the sea in one of the mouths of the Rhine, and measuring from 12 to 17 centimeters, and I found that 136 (37 per cent) of these were males and 229 (63 per cent) females. Males and females were exactly of the same sizes, and it can hardly be doubted that they were all of them 1-year-old fishes. That there was a majority of females may, of course, be considered in connection with the circumstance that the salmon that remain in the river for a second year or longer are to a very large extent males.

Regarding these latter males, another suggestion has been made by myself, viz, that they will never descend to the sea, but will die after once, others twice, perhaps, having taken part in the propagation of the species. This suggestion is based on the fact that no descent of larger young salmon hitherto has been observed, though the means of making such observations have not been wanting. I have not been able, however, to prove in a direct way the exactness of my hypothesis.

Another point to which I may be permitted to call your attention. is that when I said that "grown-up" fish return from the sea and enter the river, if possible to reach the spawning places, the age and in consequence the size of these fishes, and their state of maturity as well, are extremely different. It is of course easy enough to determine the size of the salmon entering the river. Miescher-Ruesch, who did the same (in 1878 and 1879) for salmon caught near Basel and who for the first time applied the graphical method afterwards introduced into science for other fishes as the "Petersen method," found that the curve of the sizes of the salmon of the Basel market is one with three tops or maxima, making it clear at once that three different ages were represented, and showing with great evidence at the same time that the difference in age between the youngest and middle-aged salmon was about the same as that between the latter and the oldest fish caught.

To check the results arrived at by the Basel professor, I ordered to be measured for me (1893) a large number of salmon caught near the mouth of the Rhine and offered for sale at the Kralingsche Veer market. From March to December 4,653 salmon were measured, and the curve constructed with these figures corresponds in the main with that given by Miescher-Ruesch for the Basel salmon. The salmon of the Rhine (fig. 1) present themselves in three sizes: Smallest, 54 to 74 centimeters, mean 64 centimeters (2 to 4 kilograms); middle size, 74 to 98 centimeters, mean 88 centimeters (6 to 10 kilograms); largest, 98 to 134 centimeters, mean 106 centimeters (12 to 25 kilograms).

The fishes of different sizes do not enter the river together or in a haphazard way. The different sizes present themselves in different seasons, but they do in one year exactly as in any other (fig. 2).

The smallest fish (grilse) are called St. Jacob salmon in Holland. They ascend the Rhine in July and August, exceptionally few coming in June; they continue to ascend in September, though in smaller numbers than in the foregoing months, and even in October and November a few may still be taken. They are most of them males and they are all of them in so far advanced a state of maturity that they will be able to take an active part in the propagation of the species a few months or weeks or days after their arrival. This holds good also for the female grilse, though the males are by far in the majority. Of the grilse, as far as our observations go, not more than 17 per cent are females.

The middle-sized salmon (of 74–98 centimeters) are the so-called "small summer salmon" of the Dutch market. They present themselves for the first time in the river in May, and they continue to ascend until the end of the year. They are most numerous in June and July, but they form also a very important

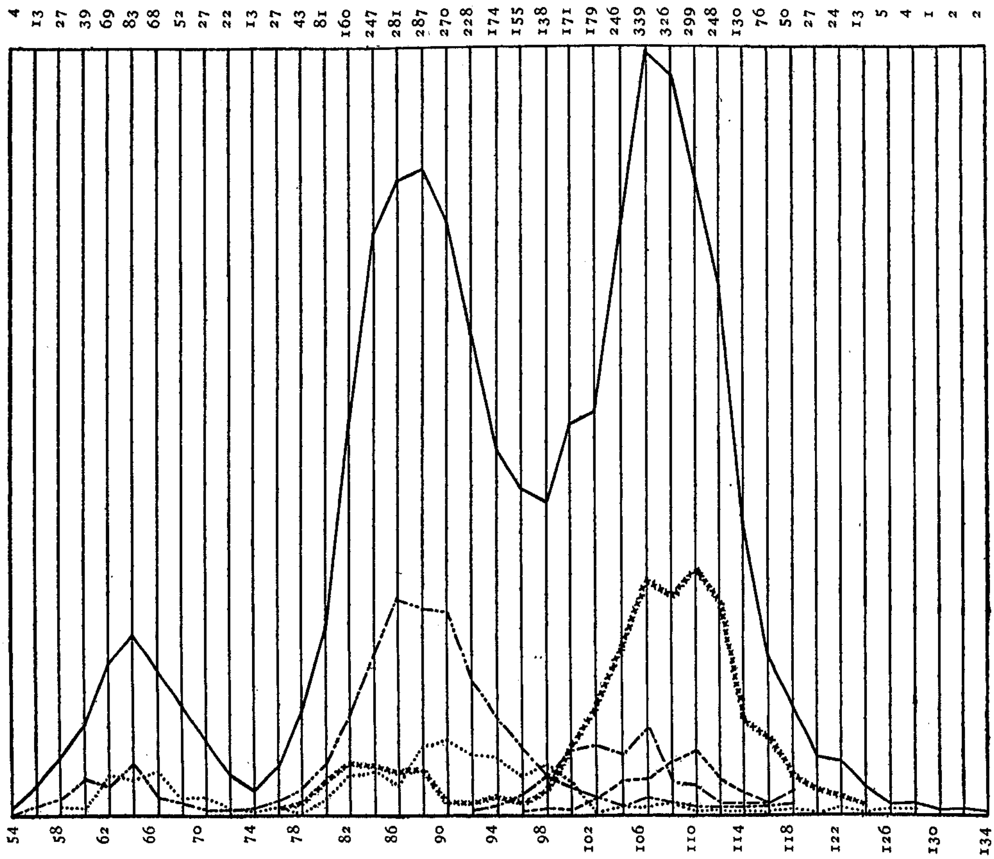


FIG. 1.—Diagram illustrating the sizes of salmon ascending the Rhine. The lengths, in centimeters, are given at the lower ends of the vertical lines. The number of specimens of each length is given at the upper end of the proper line. The total number of specimens measured was 4,653.

| | |
|---|---|
| ———— Salmon of March–December. | —..—..— Salmon of July. |
| - - - - - - - Salmon of March. | .......... Salmon of September. |
| xxxxxxxxxxxxx Salmon of May. | —.—.—.— Salmon of November. |

part of the August and September salmon. Both males and females appear among these salmon, but the females are in the majority. Though the first arrivals are far from being mature, all these small summer salmon are destined to take part in the propagation of the species toward the end of the autumn.

The large salmon (the fish of 98–134 centimeters) begin to ascend in November, though in some years a few may be taken in October. They are at that time so far from being mature that until lately they have been considered as quite sterile animals. It has been shown, however, by the investigations of Miescher-Ruesch and myself, that these salmon are by no means sterile, but only immature fish and that they will develop their sexual organs in the course of the year and during their residence in the fresh water. Some are males and some females, the latter, however, being in the majority. They are not very numerous in the winter months, but gradually their number increases; they are very fat and of the highest value as human food. They continue to ascend in spring, are most numerous from March to May, and go on ascending until the spawning time. From the beginning of their ascent until far up in spring they are called "winter salmon;" they are the same salmon, however, as those which from April or May until the spawning time in November and December are called "large summer salmon." Their sexual organs, which are in quite an undeveloped condition in November and December, are slightly more developed in the fish of February, March, and so on. In May their state of maturity is exactly the same as that of the so-called "small summer salmon," which then begin to ascend; for both categories of fishes—and the same holds good for the third category, the St. Jacob salmon, which ascend from July—the date of their entering the river is, generally speaking, a measure of the state of development of their sexual glands. The further development of these organs will take place during their stay in the river itself, and as these fish take no food during their sojourn in the fresh water, it is at the expense of the nutritive matter stored in their muscles, in the lateral muscles of the trunk especially, that the maturation takes place. From this it is clear at the same time that, the "winter salmon" of October and December being by far the most valuable fish of all, through the year the condition of the salmon deteriorates slowly but gradually until they reach maturity, with perfectly developed sexual glands (the weight of which may be over 25 per cent of that of the whole fish), but otherwise in extremely poor condition.

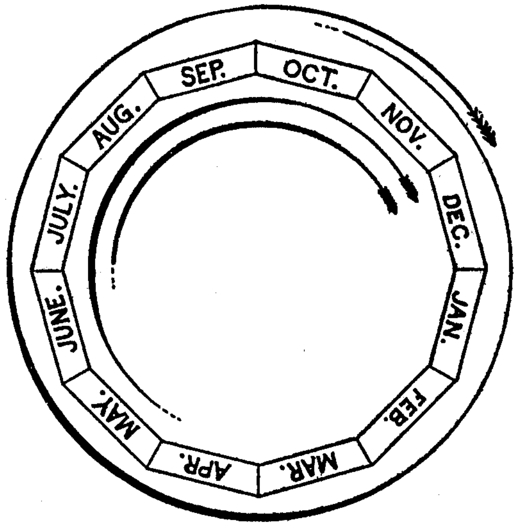


FIG. 2.—Diagram showing the ascent of the Rhine salmon in different months. The outer line, circumscribing the remainder of the figure, represents the salmon of the greatest size, which are called from October to April winter salmon and from May to December large summer salmon. The middle line represents the middle-sized salmon, which are called small summer salmon. The inner line represents the smallest salmon, which are called St. Jacob salmon (grilse). The dotted part of each line indicates when the salmon begin to ascend, the swollen part when their numbers are greatest, the feathered end part when they are ripe for spawning.

I do not wish to enter into detail upon the physiological part of this subject, however; it has been studied with great care by Professor Miescher-Ruesch, of Basel, who on the same occasion published an excellent description of the histological changes of the milt of the salmon, which changes occur during that development of the sexual organs. Later investigations (of Noël Paton and others) have in the main confirmed the results arrived at by the Swiss physiologist.

These are the headlines of the natural history of the Rhine salmon; the same fish as occuring in other European rivers has perhaps not been studied quite so carefully as the Rhine salmon, but from what we know about the other rivers, which after all is not so little, we may safely conclude that the salmon behave about the same all over Europe.

## PROPAGATION.

About the propagation of the Rhine salmon few words need be added. We saw that the natural propagation takes place in the upper parts of the tributaries, the spawning places being well known to the inhabitants and being easily distinguished from the shore, especially when the water is clear and the depth unimportant. Some of the fish, however, spawn in the main river itself, spawning beds (Laichgruben) having been observed in the Rhine between Strasburg and Basel, as also between Basel and Schaffhausen. Whether spawning in the main river takes place regularly or only accidentally has never been investigated thoroughly; in fact, even for a fish so much studied as the Rhine salmon, in some regards information is wanting which after all might perhaps not be so difficult to obtain.

The real spawning places of the Rhine salmon, it is easily understood from the foregoing, spread over a wide area situated for the greater part in Germany and for a smaller one in Switzerland. The relative richness in salmon which the Rhine even at present possesses is unquestionably to a very large extent due to the wide reaches of its tributaries, the spawning places of our fish. That richness would undoubtedly be much greater if more salmon were permitted to reach these spawning places, if these places were better protected, that the salmon might propagate undisturbed, and if all the young salmon hatched in the upper regions of the river could safely arrive in the ocean.

There can be no question that on the Rhine relatively few salmon nowadays come to spawning in the natural way. Of some of the tributaries (of the Moselle especially, but of some of the affluents in the Grand Duchy of Baden also) I studied the upper regions in this regard, and the result has not been very edifying. The fish reaching the upper region, the number of which is limited by the fishing in the lower and middle regions of the river, are sought with great eagerness. Though their value as food, especially in the very last days and weeks before the spawning, is, comparatively speaking, a small one, they represent for the fishermen of the upper regions, most of whom belong to the poorer classes of society, a precious contribution to their earnings. The higher the fish ascend, the narrower the tributaries and brooks, the easier to catch the big fish, which in their particular condition are, moreover, slow and lazy in their movements. In consequence very few fish escape; in other words, the number of those spawning in the natural way is as a rule extremely small. I I do not hesitate to say that if the keeping up of the stock of salmon depended on natural propagation only the salmon production of the Rhine by this time would be very poor.

Artificial propagation has tried, and I think not without success, to remedy this deficiency. A good many of the salmon caught in ripe condition, or nearly so, in the upper regions of the river are used for artificial hatching and from these several millions of fry have been produced annually for many years. They have been set free in the most suitable waters, that is to say, mostly in those smaller brooks and tributaries where the salmon would have spawned in the natural way if man had not interfered with their intentions. An arrangement was made, first by Baden, Switzerland, and the so-called Reichsland (Elsass-Lotharingen) and a few years later (1890) by Holland, the different German states bordering on the Rhine, and Switzerland, annually to set free a certain number of salmon fry, and quantities varying from 4 and 6 to 7 millions of young salmon accordingly were bred each year. They are planted almost immediately after the resorption of the yolk vesicle, sometimes also a little before the young salmon have developed so far. They are distributed over a large area of the upper course of the river, and, as I pointed out before, if possible at such places only as salmon are accustomed to seek to spawn in the natural way. Against this procedure an objection was raised that the distance between these spawning places and the open sea is a long one, and that numerous dangers threaten the young fish during their stay in the upper parts of the river and during their descent to the sea as well. It looks at first sight as if these dangers might be avoided by cultivating the fry near the mouth of the river and by keeping them longer in tanks or ponds at the hatchery; but as only very few ripe fish are taken in the lower parts of the river, the culturist is obliged to collect unripe salmon several weeks before the spawning and to keep them in reservoirs floating in the river until they are ripe; or, if he does not like that way of doing, to order eggs from the upper parts, which eggs, once the eyes of the embryo have become visible, endure the transportation well.

Comparing this way of proceeding with the culture at or near the spawning places, and keeping in mind that it is a well established fact that in free nature the young salmon in the upper regions of the river live at least one year the life of young trout, since studying the salmon and the salmon development I have always been convinced, and am still at the present time, that the most efficacious way of propagating the salmon artificially is to stick as closely as possible to the natural way and to plant the fry in those mountainous courses of the river where their natural home is found. This is not to shut our eyes to the dangers threatening the young salmon during their passage to the sea—in my opinion the best way to avoid this danger is not, however, to grow them in a more or less artificial way near the mouth of the river, but to stock the natural spawning places so richly that a sufficient portion remains, even if a large number of them is destroyed during their stay in the upper parts and their descent to the sea. The solid ground of nature is in this, as in so many other cases, the best to build upon.

## FISHING REGULATIONS.

Now coming to the second part of my little discourse, I prefer to give you the headlines only of the existing regulations of the Rhine salmon fishing. You know that the Rhine flows through different countries, and you understand that regulation of the fishery in such an international river based on international agreement for a long time has been considered as the best—as the only efficacious one. The first serious effort to conclude an international treaty between the countries interested in the salmon fishing of the Rhine dates from 1869, but the war of 1870 postponed for several years the conclusion of such a treaty. New negotiations were taken up about 1884, the treaty was concluded in Berlin in 1885, and has now been in force since August, 1886. Originally it was concluded for ten years, after that period each of the powers interested having the right to break off the engagement with one year's warning. Though the treaty has perhaps not quite satisfied those who expected from it great betterment of the salmon fisheries of the Rhine, there has never been seriously a question of giving it up.

As far as the Netherlands are concerned, as a good regulation of the salmon fishery existed already, important changes were caused by the treaty in two regards only—the closing of the fishery on Sunday and the closing of the fishing with big seines a fortnight earlier (on the 15th of August) than hitherto. These changes are quite in accordance with the general idea of the treaty. Those who fish in the lower parts of the river are to spare a considerable part of the ascending salmon, that those fishing higher up may profit by this and also that part of these fish may reach the upper region, there to spawn. The fishermen of the middle and higher regions, on their part, must also take into consideration the interests of the whole river. They are to spare a part of the ascending fish for natural propagation. They are to take into their custody the natural spawning places and moreover to take care that ripe or nearly ripe fish caught in spawning time are used for artificial reproduction.

Methinks the treaty, which is based on sound principles, has, taken as a whole, worked well. If nevertheless on several occasions complaints have been heard on its efficacy, we must not forget that those who find fault with it most were from the beginning too optimistic in their expectations. After all, human nature is not changed by an international treaty, and the nature of fishermen is as human as that of other people. Those who are interested in the fisheries of the middle and upper river claimed, when the treaty was being closed, a greater part of the ascending fish, and through the treaty's influence they have no doubt received that. What is more natural than that they might go further still in the same direction and should like to receive a greater share still in the future? Those who fish in the lower parts of the river, and by the treaty are compelled to spare more of the ascending fish than they were accustomed to do before, complain that the richness of the river in salmon has not augmented since the treaty was closed. They say, "We did not close the treaty only for giving a good deal of the fish we can catch ourselves to our neighbors of the middle and upper regions, but we did so that the spawning region might be better stocked with breeders. If all the fish, or too many of them, we spare are caught higher up the river, what good can come of our savings?" No wonder that they ask for measures better to protect the spawning fish.

I think, however, that it would be hardly interesting and by no means amusing for you to hear me discuss this question any longer or to go over the different articles of the treaty with you. To understand their meaning, a good deal of technical information regarding the natural condition of the river and its different parts would be necessary, and I should spare you such details. I think it will be more interesting for you to hear something about the actual condition of the salmon fishing of the Rhine.

## IMPORTANCE OF THE FISHERY.

I need hardly point out to you, who know about the fisheries of your own country, that it is very hard work for a big and precious fish like the salmon to maintain itself in a river like the Rhine, flowing through one of the most populated and flourishing parts of Europe, where all the circumstances seem to cooperate to destroy it and to prohibit its propagation. It is not only the direct influence of man, whose highly developed fishing industry is disastrous after all, that our fish has to reckon with. Indirectly, regardless of the fisheries, man, by normalization and regulation of the river and its affluents, did what he could to spoil and at several places to close the river for the ascent of the future spawning fish. Man moreover polluted the river with the sewage of his towns and with the poisonous waters of his manufactories, his mines, etc. And man, finally, by developing the river navigation, by using the water for industrial purposes, all in all did his utmost to modify the stream in a direction contrary to the interests of the ascending salmon and their propagation.

Up to the present, nevertheless, the Rhine distinguishes itself from the other rivers of North Europe (and from those of the Atlantic coast of North America as well) by the relative productivity of its salmon fishery—though I must point out at once that also for the Rhine the figures of the catches have greatly diminished from what they were, say twenty-five years ago. There exist no good statistics of the product of the salmon fisheries of the whole river; favored by special circumstances, however, those interested in the fisheries of the lower parts of the Rhine in Holland, embracing all the larger seine fisheries, have for many years been able to register carefully the figures of all the salmon caught in these waters. These are the fish landed and sold by auction at the market of Kralingsche Veer, near Rotterdam. We have these figures since 1871, and just to show you the importance of this auction, I give you the following summary:

| Period. | Total number. | Annual average. |
|---|---|---|
| 1871–1907 (37 years) | 1,822,000 | 49,200 |
| 1871–1889 (19 years) | 1,133,000 | 59,600 |
| 1890–1907 (18 years) | 689,000 | 38,300 |
| 1899–1907 (9 years) | 230,500 | 25,600 |

These figures show a very considerable diminution. We are not to forget, however, that partly in consequence of changes in the natural condition of the river, partly through the influence of the treaty, and partly through the high development of navigation in the lower parts of the river—Rotterdam harbor—the fishing of the so-called large seine fisheries, which means those selling their catches at the said market of Kralingsche Veer, is now by no means as good as it was twenty to twenty-five years ago. In consequence, the percentage of the ascending fish caught in the lower parts of the river and sold at the said market, before that period, was naturally much larger than it is at present. In other words, there is no reason to consider the decline of the Rhine salmon fishery as quite so important as might be concluded from studying the figures of the Kralingsche Veer market alone.

As, however, reliable statistics for the salmon fishing of the whole river are not available, it is impossible to calculate what part of the whole catch is represented by the fish landed at Kralingsche Veer market. It may be 50 per cent at present, it may be a little more, it may be much less. Last year at Kralingsche Veer market 31,000 salmon were offered for sale, and 9,500 more were landed at five other salmon markets in Holland. Still higher up the river in

Holland perhaps a few thousand more salmon were taken. Then comes the German part of the river, and finally that part where the river forms the boundary between Germany (Baden) and Switzerland and where important salmon fisheries are found; but as to the fish taken in the German and Swiss parts of the Rhine no reliable figures are published. Altogether an estimate of 65,000 salmon as taken in the Rhine during the year 1907 remains probably under the actual production. That year was by no means an exceptionally good one—it was slightly better only than the eight preceding years. A catch of 65,000 salmon in such a year gives us the right to say, I think, that, be its productivity no more so great as it was before, "Old Father Rhine" still is entitled to be called an important salmon river.

Now, it is my conviction, and I wish to conclude my little lecture by saying, that the Rhine to a very large extent owes to salmon culture the conservation of this production. The fact that the same river had more salmon before artificial propagation was begun does not disturb that conviction; that was at a time when natural propagation was still flourishing. Since the latter in the Rhine nearly quite belongs to history, only one way to keep up the stock remains, and that is by artificial propagation practiced in the most normal, most natural way.

## DISCUSSION.

Prof. E. E. PRINCE. There is just one question I would like to ask Doctor Hoek, and that is as to the spawned salmon or kelts. How and when are those observed migrating, and what is the view in regard to their suggested destructiveness in salmon rivers, owing to their predacity?

Doctor HOEK. Mr. President, I thank you very much for the opportunity of telling you.

Kelts return to the sea every year, but not in very large numbers. It is true that our fishing is so organized that we catch the fish coming from the sea and not so well the fish coming down; yet at least some of these fish do not come down so very fast, but remain in a certain part of the river for some time, moving perhaps with the tide. We take some kelts every year. Doubtless it will be interesting to you, in the first place, to hear that most of these kelts are taken on the Rhine in Holland in the months of March and April, and not many earlier; in the second place that the sexes are represented in the kelts about as in the ascending fish, but that the males descend earlier than the females; and, in the third place (which I think is most interesting), that very large kelts have never been taken—the largest kelts we know are of the type of the smaller, so-called summer salmon (length 75 to 93 cm.), and do not belong to the big summer salmon or winter salmon. It remains only to tell you that we made some observations on the food found in the stomachs of the kelts, and that it was found to be indeed a very poor food. From what I have seen on the Rhine I must conclude that they are not accustomed to taking food on that river.

# FISHES IN THEIR RELATION TO THE MOSQUITO PROBLEM

By William P. Seal

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# FISHES IN THEIR RELATION TO THE MOSQUITO PROBLEM.

By WILLIAM P. SEAL.

Some phases of the mosquito problem are extremely simple and easy of solution, but there are others that have not as yet attracted much attention and that, in the opinion of the writer, will not be so easily solved. The class of mosquitoes represented by the rain-barrel wigglers constitutes, with the salt-marsh species, the most of the mosquitoes, and the most pestiferous of them as mere annoyances. The problem of dealing with these is one of simple engineering, filling and draining, with the oil barrel as an auxiliary.

But the *Anopheles* mosquito is altogether in another class and will require a very different and more complex sort of treatment. It is, in fact, to a great extent a separate problem.

Though fewer in numbers than the other mosquitoes, the *Anopheles* is more to be dreaded because of its wary and insidious manner of attack and of its infectious character. It breeds in both quiet and running water, but always where there is ample protection for its eggs and larvæ, among and over masses of aquatic or semiaquatic plants, confervæ, duckweed, lily leaves, drift, floating dead leaves, and débris. And, lying and moving horizontally on the water, so completely does it assimilate with its surroundings in both color and shape that it is only discernible to the sharpest vision, generally only by its movements, which are sidewise or backward on the surface unless seriously disturbed, when it wriggles down into the water.

After a series of observations and experiments covering several years the writer is not convinced that *Anopheles* can be exterminated by any method so far advanced, or without very great difficulty and the use of every available agency. The character and magnitude of the problem are not yet understood. Several years ago, in an examination of Central Park, New York, *Anopheles* larvæ were found to be abundant, though up to that time the locality was supposed to be free from them. They were found in unsuspected places, and not where the other mosquito larvæ were found, and they were found abundantly in other unsuspected places in New York as well. Moreover, although thousands of dollars have since been spent in the attempt to destroy the breeding places, they are no doubt still occupied, within gunshot of the stately Fifth avenue homes and nearer to the beautiful playgrounds of the park. The same conditions will be found to prevail in every city.

The most prolific source of *Anopheles* supply is the ornamental plant pond, which is becoming one of the most beautiful features of landscape gardening, public and private. These aquatic gardens provide *Anopheles* with habitats closely approximating the conditions it enjoys in nature, with, however, many protective advantages. Waters of this character can not be treated with oils or chemicals without destroying their beauty. Thus it becomes a serious problem how to destroy this pest and yet preserve the beauty of the ornamental plant pond.

*Anopheles*, as well as all other mosquitoes, have numerous enemies in addition to fishes. All the aquatic beetles and their larvæ (and they are numerous), the dragon flies and their larvæ, the boat flies, the crane flies and their larvæ (and where these latter are numerous few mosquito larvæ will be found), the water skaters, and many others.

The use of fishes for the purpose of destroying mosquito larvæ is looked upon generally as an easy solution of the problem, and numbers of species have been recommended for the purpose, but so far as *Anopheles* is concerned the fishes have been generally useless. It is true that by their presence in the more open spaces they limit the areas in which mosquitoes would otherwise propagate in great numbers, and no doubt they destroy some *Anopheles*, as well as some of all other species of mosquitoes.

All small fishes, whether of the smaller species or the young of the larger kinds, will be found to eat mosquito larvæ with avidity if supplied to them. This fact alone can not be taken as evidence of usefulness in this respect in a natural condition. Nevertheless, there is no doubt that the myriads of small fishes everywhere on the salt marshes and as well in all open waters, salt and fresh, prevent by their presence such a multiplication of mosquitoes as would make life unendurable. In this respect even the most insignificant of the fishes are useful and merit our gratitude.

In considering the usefulness of fishes in this relation the natural habits and characteristics of a species are the only safe guides. That they will eat mosquito larvæ if confined in an aquarium is to be expected. But will they do so in a natural condition? Will they seek for them as food? Stagnant water, where there is an abundance of plant life, affords such a great abundance and variety of larvæ and other low forms of animal life that fishes could hardly be expected to develop epicurean tastes for particular kinds of larvæ. They appear rather to gorge themselves with whatever comes in their way. The great need is that there shall be enough mosquito eaters to consume all the other food that occurs and all the mosquitoes as well. And this means enormous numbers of fishes. What this involves is yet to be determined. We have no adequate conception of it.

While, as has been stated, all fishes have some measure of usefulness, if only in the way of deterrent effect, there are only a few species likely to be found in waters in which mosquitoes breed, and especially where *Anopheles* breeds. The most important of these are: The goldfish, which are introduced; several species of *Fundulus* (the killifishes) and allied genera; three or four species of sunfish; the roach or shiner; and one or two other small species of cyprinoids. In addition, there are a few sluggish and solitary species like the mud-minnow (*Umbra*) and the pirate perch (*Aphredoderus*), which live among plants. The sticklebacks have been mentioned in this connection, but the Atlantic coast species are undoubtedly useless for the purpose, being bottom feeders, living in the shallow tide pools and gutters, hidden among plants, or under logs and sticks at the bottom, where they find an abundance of other food.

In the salt marshes there are myriads of killifishes running in and out and over them with each tide, while countless numbers of other and smaller genera, such as *Cyprinodon* and *Lucania*, remain there at all stages of the tide. So numerous and active are all these that there is no possibility of the development of a mosquito where they have access. Of the killifishes two species, *heteroclitus* and *diaphanus*, ascend to the farthest reaches of tide flow, but it is a question as to whether they would prove desirable for the purpose of stocking landlocked waters, since they are much like the English sparrow, aggressive toward the more peaceable and desirable kinds. Even *Cyprinodon*, which would seem to be a valuable small species for the purpose, is viciously aggressive toward goldfish and no doubt all other cyprinoids. It is characteristic of all killifishes that they must be kept by themselves in aquaria. They are the wolves and jackals of the smaller fishes.

As a destroyer of *Anopheles* the writer has for several years advocated the use of *Gambusia affinis*, a small viviparous species of fish to be found on the south Atlantic coast from Delaware to Florida. A still smaller species of another genus, *Heterandria formosa*, ranging from ½ inch to ⅞ inch in length for the males to 1 inch or 1⅛ inches in length for the females, is generally to be found with *Gambusia* and is of the same general character. Both of these species are known as top minnows from their habit of being at the surface and feeding there; the conformation of the mouth, the lower jaw projecting, is evidence of such feeding habit. Both are to be found in great numbers in the South in the shallow margins of lakes, ponds, and streams in the tide-water regions wherever there is marginal grass or aquatic or semiaquatic vegetation to afford them shelter from the predaceous fishes. They are also to be found in shallow ditches and surface drains where the water is not foul, even where it is but the fraction of an inch deep. In fact, if any fishes will find their way to the remotest possible breeding places of the mosquito it will be *Gambusia* and *Heterandria*. And they are the only ones, so far as the writer's observation goes, that can be considered at all useful as destroyers of *Anopheles* larvæ.

To what extent they could be acclimated in northern waters has yet to be determined. They are to be found in the Ohio Valley as far north as southern Illinois, hundreds of miles above tide water, where the climate must be quite severe. In 1905, at the earnest request of Prof. John B. Smith, state entomologist of New Jersey, the writer planted about 10,000 *Gambusia* and *Heterandria* in New Jersey waters. Some 8,000 were planted in one locality which was thought to afford very favorable conditions. In 1907 Mr. Henry W. Fowler, ichthyologist of the Academy of Sciences of Philadelphia, and author of "Fishes of New Jersey," found considerable numbers of *Gambusia* in the vicinity of Cape May, some 90 miles from where the plant was made. This opens up a very interesting question. Mr. Fowler contends that *Gambusia* should be considered as indigenous to New Jersey. Very strong arguments to the contrary can be advanced, but the question is not of importance in connection with this paper, except that it either gives a farther northern range to the species or that, on the other hand, it shows the possibility of introducing them.

The writer has come to the conclusion, after many experiments in small ponds, that a combination of the goldfish, which is ornamental and useful in the open water, the roach or shiner, which is a very active species, two small species of sunfish, which live among plants, and the top minnow would probably prove to be more effective in preventing mosquito breeding than any other fishes. The goldfish is somewhat lethargic in habit, and is also omnivorous, but there is no doubt that it will devour any mosquito larvæ that may come in its way or that may attract its attention. The one great objection is that it grows too large and that it is cannibalistic, so that when a pond is once stocked with large goldfish the number of young to survive will be small.

The roach is probably the most widely distributed and abundant of all the small fishes except the cyprinodonts. It is a very active fish, always ranging about in search of food.

The two small species of sunfish, of the genus *Enneacanthus*, are very widely distributed. They live wholly among plants and feed upon larvæ of all kinds.

The top minnows are foragers always on the move in the search for food, skimming over the tops of plants with restless energy.

All of the above-mentioned species are among the most abundant wherever found. If the range of the top minnows can be extended north it will prove to be a valuable aid. They are quite prolific, throwing off young to the number of perhaps 10 to 20 at intervals of about a week from April to October. The young of May will be breeding by July or August the same year, thus giving a second generation in one summer.

But notwithstanding all that has been said, it is a question in the mind of the writer whether any combination of fishes will prove effective as against the *Anopheles* genus of mosquitoes under present conditions of growing ornamental aquatic plants. There must be a change in the construction and management of the water garden. As these are under the charge of intelligent men, it is only necessary that the problem should be understood and that the laws should compel the eradication of *Anopheles* and provide for an espionage over the places where it breeds. But until some organized branch of the state governments takes up an investigation of this phase of the problem in a comprehensive manner nothing will be done. The magnitude of the task is not yet comprehended. It is quite possible that all of the beautiful masses of aquatics can be grown on mud alone without destroying their ornamental character, leaving the large open ones to the water in such a way that the fishes can do their work easily. In the great wild areas of swamp and stream aloof from human abodes the problem is more serious and will tax human ingenuity, but here only the hunter and fisherman are concerned.

At present the attitude of the public mind toward suggested means of exterminating mosquitoes is good-naturedly tolerant but incredulous. And while the children are being crammed with Greek, Latin, and geometry they do not learn how to prevent the breeding of mosquitoes about their own homes or how properly to screen the houses in which they live. It is a lamentable fact that even where mosquitoes are most numerous and virulent not one house in a hundred, it is safe to say, is mosquito-proof. There is an old saying that "What is everybody's business is nobody's business." Practical work to be effective must be somebody's particular business. Local boards of any kind can not easily run counter to individual sentiments and prejudices. It is the State alone that can overcome local stumbling blocks and inspire respect, and it is for this reason that attention is called to the seriousness of this problem and the suggestion offered that it is worthy of the serious consideration of those whose interest is in the waters where mosquitoes breed and abound—the fish culturists and fishermen, represented by the fish and game commissions.

In a paper prepared for the meeting of the American Mosquito Extermination Society in 1905 the writer advanced the opinion that experimentation with and the supplying of fishes for the purpose of mosquito extermination is at least as properly the function of fish and game commissions as that of supplying them in the interests of sport and recreation, which is as much as can justly be claimed for trout culture. The mosquito problem involves both the comfort and health of all classes of citizens. The desirability of the participation of fish commissions in the work, however, appears to the writer to be a question that can only be settled by submitting it to those who would be most nearly concerned with its practical operation, those engaged in fish-cultural work and who have at their command the necessary equipment and knowledge.

It may be argued that the study of the mosquito problem should devolve exclusively upon the agricultural departments. In 1900 or 1901 this question was suggested by the writer, and the Commissioner of Fisheries then decided that the work properly belonged to the entomological division of the Agricultural Department. At first thought this seems a logical conclusion; but when we come to realize fully the magnitude of the task one is compelled to conclude that its accomplishment will require the combined efforts of all the available resources of the States and probably of the National Government.

The fish and game commissions have in their service a body of men whose duties include an espionage of both the land and waters of the States. By enlarging their powers and authority there is already available a capable organization which needs only efficient direction and support to accomplish great practical results in this direction.

There is another side to the question. The fish and game commissions do not have to the extent that they should the sympathy and support of the public in general, the prevailing idea being that they represent the interests of the sportsmen—gunners and anglers. And from this class alone there should be a vigorous support for such a development, not only because of the promise of greater comfort in their outings, but also because of the added popularity it would most surely give to the work of fish and game commissions and to legislation affecting the waters. If fish culture is to be progressive it must enlist the sympathy of all classes of citizens. It must justify itself by its usefulness. Those engaged in it and in fish and game protection should welcome every opportunity to broaden the scope of fish work. There should be a desire to extend its popularity by enthusiastic support of any line of investigation or work which will benefit the public at large. There is now a precedent in the action of the United States Bureau of Fisheries in collecting and sending fishes to Hawaii for the purpose of mosquito destruction, and there is no reason why the fish and game commissions with their trained experts should not cooperate in absolute harmony with the divisions of entomology, thus avoiding the creation of dual functions in state work.

# FOODS FOR YOUNG SALMONOID FISHES

By Charles G. Atkins

*Superintendent U. S. Fisheries Station, East Orland (Craig Brook), Me.*

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 and fifty dollars in gold offered by F. M. Johnson for the best demonstration of the comparative value of different kinds of foods for use in rearing young salmonoids, taking into consideration cheapness, availability, and potentiality

# FOODS FOR YOUNG SALMONOID FISHES.

By CHARLES G. ATKINS,
*Superintendent United States Fisheries Station, East Orland (Craig Brook), Me.*

In laying out schemes for the feeding of Salmonidæ, as well as most other fishes, it is to be borne in mind that they are by nature dependent for nourishment on living animals. Any departure, therefore, from a live-food regimen must be regarded as having the presumption against its entire suitability; and the general experience of fish culturists tends to the conclusion that even so slight a departure from nature as the substitution of the flesh of mammals for the natural food is followed by deterioration in some of the most important functions of the fish.

Perhaps the function most seriously affected is that of procreation. It has been found that fishes which have been reared on mammal flesh in artificial inclosures do not produce offspring of normal vitality and vigor, and while the possibility of there being other important factors in the case has not yet been disproved it is the consensus of opinion that the deterioration observed is due mainly to the unsuitability of the food. The view taken of this matter by the best German authorities is well expressed in the concluding chapter of a serial treatise on the feeding of salmonoids by the editor of the Allgemeine Fischerei-Zeitung, January 1, 1907, as follows:

> Assuming that the fishes grown in a wild natural state have the healthiest offspring, it follows that for breeding fishes under all circumstances live natural food is the most suitable. * * * There is a large list of fish breeders who reject wholly the feeding of breeding fish and for egg production use wild fish only. For brook trout this is beyond doubt the correct standpoint, and it would be also for the rainbow and American brook trout if we could get wild fish enough to supply the demand for eggs and fry. As, alas, we can not get them, whoever wishes to breed these fishes must of necessity resort to artificial feeding of breeders.

The experience of American fish culturists will support this view.

Under these circumstances it behooves us to look for food supplies as near to nature as possible, and a conviction that duty leads in this direction has been the inciting motive to the efforts at the Craig Brook station to produce some living insect food which could be substituted for the chopped liver and lights from slaughterhouses and the flesh of old horses, which have been the main dependence thus far.

## THE LARVÆ OF FLIES.

The experiments at Craig Brook have included a considerable list of insects and crustacea, but the most attention has been given to the larvæ of flies, especially of two species of flesh fly, the bluebottle fly (*Calliphora erythrocephalon*) and the green flesh fly (*Lucilia cæsar*). During some eight years this work was made especially prominent and on a scale sometimes equivalent to the feeding of as many as 100,000 fingerlings wholly on this food. In most cases there was a mixed ration of fly larvæ and chopped meat, but the exclusive use of the larvæ here and there affords data for definite and accurate statements of the comparative influence of the two regimens on the rate of growth, which is as far as data now available enable us to go.

The methods of the work may be thus briefly described:

Some kind of fresh animal matter, mainly slaughterhouse refuse and such parts of animals slaughtered or dressed at the station as were not available for direct feeding, were exposed to the visits of the flies, and, when well stocked with eggs, placed under the shelter of a building protected as far as practicable from marauding insects, such as carrion beetles, in specially constructed boxes, in which the larvæ assembled themselves when fully grown in masses conveniently handled. These were fed to the fish in troughs or ponds, mainly in wooden troughs about 10 feet long and 1 foot wide, sometimes in conjunction with other articles and sometimes alone, but in the latter case the fry had gone through a preparatory stage of feeding on chopped liver or similar meat for a few weeks, during which they had attained sufficient size to swallow young larvæ. The fry generally began to take food about June 1. The feeding of larvæ was generally begun early in July and was continued till some date in October, when the fish were counted, weighed, and liberated. The weighing was done in this way: A pail of water was suspended from a spring scale and its weight accurately noted. Then 200 fish or less by count were held in a soft net until the water had drained from them, when they were turned into the pail of water and the increase in weight noted. In case of very small numbers, each fish was weighed separately on a very delicate balance. The record is therefore very accurate. Sometimes the larvæ were given alternately with chopped meat, and in many other cases there were changes sufficient to forbid deductions as to the influence of the food on the growth of the fish, but here and there are cases giving positive evidence of importance.

In 1888 the record shows that lots no. 10 and 11 were fed through the season exclusively on chopped meat of various kinds (almost wholly butcher's offal), and lot no. 13 was fed on larvæ exclusively after June 2. In detail the treatment of the several lots was as follows:

Lot 10, Atlantic salmon numbering (June 7) 1,196, kept in one trough and treated as follows:

*June.*—Fed until 9th somewhat irregularly on wild live food collected from pools and other open waters; from 9th to 30th on chopped meat 2 to 4 times daily; mud baths on 5 occasions; cleaned daily.

*July.*—Fed chopped food 4 times daily the entire month; mud baths daily till 29th; cleaned daily.

*August.*—Fed chopped food 4 times daily; cleaned daily.

*September.*—Treated as in August, but on 29th transferred to a 5-foot white varnished trough outdoors.

*October.*—Treated as in September until the 17th, when they were counted.

The losses by death in lot 10 from June 18 to October 17 were 611, leaving 585[a] survivors, which were found October 20 to average in weight 30.66 grains (199 centigrams).

Lot 11, Atlantic salmon, numbering (June 7) 1,195, was treated almost exactly the same as lot 10, the points of variation being quite unimportant. Counted October 17 and weighed October 23. There were 538 survivors, and their average weight was 26.83 grains (173 centigrams).

Lot 13. Atlantic salmon, numbering (June 7) 1,864; treatment as follows:

*June.*—Kept in 2 troughs; fed on entomostracans and insects till June 9, after that chopped meat, 6 times daily; mud bath 3 times.

*July.*—Fed on liver until 3d, on which day feeding of larvæ was begun; mud bath daily until 29th; cleaned daily.

*August.*—Fed fly larvæ 6 times daily (with some irregularity); cleaned every other day.

*September.*—Treated as in August.

*October.*—Treated as in August until 23d, when counted and weighed. The 1,447 survivors weighed on the average 43.84 grains (284 centigrams).

It will thus be seen that the fish fed on butcher's offal attained a mean weight of 30.66 grains (199 centigrams) in one lot, and 26.83 grains (173 centigrams) in the other lot; while the fish fed on fly larvæ attained a mean weight of 43.84 grains (284 centigrams), a difference of 53 per cent in favor of the larvæ regimen.

A similar comparison between several lots of landlocked salmon reared the same summer shows a slight difference in favor, also, of the larvæ regimen.

The record for 1891 affords data for the following tabular statement, which exhibits the results obtained from the feeding of 39 lots of Atlantic salmon in wooden troughs of the standard size, all treated alike except in the matter of food. Butcher's offal was given to 14 lots of them through the entire season and the other 25 lots received fly larvæ exclusively from June 22 to the date of counting and weighing, which was from October 15 to October 29.

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[a] This heavy loss in numbers was the result of an epidemic that attacked the fry in June, irrespective of the food or special mode of treatment. Of the total mortality in lot 10, there were 561 deaths in June, 45 in July, 3 in August, 2 in September, and none in October.

TESTS OF FISH FOOD AT CRAIG BROOK STATION, SUMMER OF 1891.

| Fed on chopped meat the entire season. | | | | | Fed on fly larvæ from June 22 to October 29. | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Lot no. | Date of weighing | Number of fish. | Total weight. | Average weight. | Lot no. | Date of weighing. | Number of fish. | Total weight. | Average weight. |
| | 1891. | | *Lbs. oz.* | *Grains.* | | 1891. | | *Lbs. oz.* | *Grains.* |
| 283 | Oct. 15 | 1,844 | 11 3 | 42.47 | 279 | Oct. 15 | 1,387 | 10 1 | 50.78 |
| 284 | Oct. 15 | 1,833 | 10 11 | 40.81 | 280 | Oct. 15 | 1,870 | 13 13 | 51.70 |
| 285 | Oct. 15 | 1,840 | 11 2 | 42.32 | 281 | Oct. 15 | 1,855 | 11 11 | 44.10 |
| 286 | Oct. 15 | 1,707 | 11 4 | 46.13 | 282 | Oct. 15 | 1,887 | 12 15 | 47.94 |
| 287 | Oct. 15 | 1,936 | 12 4 | 44.29 | 297 | Oct. 17 | 1,719 | 12 10 | 51.41 |
| 288 | Oct. 16 | 1,897 | 10 9 | 39.98 | 298 | Oct. 19 | 994 | 8 12 | 60.60 |
| 289 | Oct. 16 | 1,472 | 10 11 | 50.82 | 299 | Oct. 19 | 1,707 | 12 13 | 53.13 |
| 290 | Oct. 16 | 1,394 | 7 13 | 39.59 | 300 | Oct. 19 | 1,864 | 13 5 | 49.99 |
| 291 | Oct. 16 | 1,815 | 10 9 | 40.74 | 301 | Oct. 19 | 1,571 | 12 0 | 53.47 |
| 292 | Oct. 16 | 1,801 | 9 14 | 38.38 | 302 | Oct. 19 | 1,629 | 12 7 | 53.48 |
| 293 | Oct. 16 | 1,813 | 10 3 | 39.33 | 303 | Oct. 19 | 1,646 | 12 13 | 54.49 |
| 294 | Oct. 16 | 1,824 | 10 15 | 41.97 | 304 | Oct. 19 | 1,767 | 12 10 | 50.01 |
| 295 | Oct. 16 | 1,798 | 9 11 | 37.72 | 305 | Oct. 19 | 1,691 | 11 9 | 47.86 |
| 296 | Oct. 16 | 1,574 | 9 9 | 42.52 | 306 | Oct. 15 | 1,284 | 10 11 | 58.27 |
| | | | | | 307 | Oct. 15 | 1,775 | 14 2 | 55.70 |
| | | | | | 308 | Oct. 15 | 1,763 | 13 6 | 53.11 |
| | | | | | 309 | Oct. 15 | 1,628 | 13 0 | 55.90 |
| | | | | | 310 | Oct. 15 | 1,664 | 13 6 | 56.26 |
| | | | | | 311 | Oct. 19 | 1,690 | 13 2 | 54.36 |
| | | | | | 312 | Oct. 29 | 2,048 | 15 0 | 51.27 |
| | | | | | 313 | Oct. 29 | 1,752 | 14 0 | 55.93 |
| | | | | | 314 | Oct. 29 | 1,754 | 14 2 | 56.38 |
| | | | | | 315 | Oct. 29 | 1,814 | 14 9 | 56.19 |
| | | | | | 316 | Oct. 29 | 1,841 | 14 10 | 55.61 |
| | | | | | 317 | Oct. 29 | 1,836 | 14 6 | 54.81 |
| Total | | 24,548 | 146 6 | 41.76 | Total | | 42,435 | 321 13 | 53.09 |

Thus the growth of the fish fed with the fly larvæ for about four months exceeded that of the meat eaters by 27 per cent.

For further illustration of the potency of fly larvæ in promoting growth, I will cite the record of 13 lots of Atlantic salmon fingerlings that were fed in 1895, 6 lots on fly larvæ exclusively after July 8 and 7 lots wholly on chopped meat of various kinds. In all other respects the treatment was very closely the same in all cases. The essential facts are embodied in the following table:

TESTS OF FISH FOOD AT CRAIG BROOK STATION, SUMMER OF 1895.

| Fed on chopped meat the entire season. | | | | | Fed on fly larvæ exclusively after July 8, inclusive. | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Lot no. | Original count. | Survivors in October. | Average weight. | | Lot no. | Original count. | Survivors in October. | Average weight. | |
| | | | Grains. | Centigrams. | | | | Grains. | Centigrams. |
| 732 | 4,500 | 3,425 | 21.17 | 137 | 724 | 4,000 | 2,592 | 62.79 | 407 |
| 733 | 4,825 | 3,510 | 27.76 | 180 | 725 | 4,000 | 2,813 | 59.41 | 385 |
| 734 | 4,825 | 2,083 | 29.06 | 188 | 727 | 4,000 | 3,164 | 50.75 | 329 |
| 735 | 4,000 | 3,001 | 25.80 | 167 | 728 | 4,000 | 3,312 | 53.50 | 347 |
| 736 | 3,000 | 2,916 | 27.91 | 180 | 729 | 4,000 | 2,929 | 49.14 | 318 |
| 737 | 4,000 | 2,242 | 34.34 | 222 | 731 | 4,500 | 2,740 | 45.51 | 295 |
| 738 | 3,500 | 3,119 | 31.14 | 202 | | | | | |
| Total | 28,650 | 20,296 | 28.17 | 182 | Total | 24,500 | 17,550 | 53.62 | 347 |

It will be noted that in this statement not only is the general average weight of the larvæ-fed fish 91 per cent higher than that of the meat-fed fish, but the best of the 7 lots of meat fish was materially below the poorest of the 6 lots of larvæ fish.

Other data might be cited, but the above will suffice to demonstrate that for increase of size of young fish, fly larvæ constitute a far superior food to chopped meat. There is reason to believe that the superiority does not end here, but extends to the quality of the growth—that it induces a more healthy condition of the tissues and functions of the fish, among other functions especially those of the reproductive organs. A demonstration of the correctness of this view must, however, wait for further experiment.

Fly larvæ are available for use during the greater part of the year. The blow-fly (*Calliphora*) was found engaged in egg laying as late as November 24. They have been actually used at Craig Brook as early as June and through the autumn and winter and as late in the spring as the month of April. For winter use, meat well stocked with very young larvæ, or even with unhatched eggs, is stored in pits or cellars where development can be retarded or hastened, as may be desired, by changes of temperature. In this way sufficient larvæ were kept during the winter of 1889–90 to feed, exclusively, nearly 10,000 young salmon to April 20, inclusive, with a loss of less than 1 per cent between December and May.

The materials which can be used in this work are sufficiently abundant and accessible in most localities. Among them may be mentioned the refuse of all sorts from slaughterhouses and fish markets, the refuse fish taken by all classes of fishermen, domestic animals dying from accident or old age, especially old horses, etc.

The cost of fly larvæ comes mainly from the labor involved. On one occasion it was found that 40 pounds of horse meat, costing 40 cents, produced 8 quarts, or 16 pounds of larvæ, the material costing thus about 3 cents for a pound of larvæ. It has been found that the mean cost of the labor through an entire season was 7.3 cents per pound of food. Both labor and materials therefore cost 10.3 cents for a pound of larvæ.

One important feature requiring mention is the evil odor generated in the process. However fresh and unobjectionable the materials may be when exposed to the flies, they become, if handled in the usual way, exceedingly malodorous before the larvæ have completed their growth. This is sufficient to forbid the location of the work near human habitations unless some means can be found to suppress the odor. It is claimed that this can be done by the use of smoke. It is also quite possible that the nuisance can be largely abated by the use of earth as a cover of the meat and the larvæ during the later stages of their growth. In Europe several methods have been brought forward which it is claimed will secure the desired result.

Before leaving the subject of fly larvæ I beg to call attention to the possibility of utilizing for fish food the larvæ of other flies, especially those of the house fly (*Musca domestica*) and of the stable flies (of the genera *Stomoxys* and *Muscina*). Their use would not be attended with the objectionable carrion odor, and it is possible that these or some other species might be grown largely on vegetable materials.

## SPRATT'S FOODS.

Several of the Spratt foods have been tried at Craig Brook station, the "fish food" in 1905, the "fibrine fish food" and the "cereal fish food" in 1907. The tests were all made in comparison with chopped hogs' liver.

In 1905, two lots of brook trout fingerlings of the same origin and character were set apart for the experiment, placed in two ponds which were also of precisely the same character, and kept under the same conditions. Each lot numbered August 1 about 20,000. These fish had been fed alike on hogs' plucks and in all respects had been treated alike until the beginning of the test, August 5, from which date one lot (no. 1736) was fed with Spratt's "fish food," while the other (no. 1738), as a control lot, was fed on hogs' plucks, mainly the heart and lights. This contrasted feeding, with otherwise identical treatment, was kept up through August 26, having thus continued twenty-two days, after which the feeding on hogs' plucks was resumed. Each morning the ponds were carefully searched, and each dead fish found was at once taken out and recorded. A few days after the test began it was noted that the mortality was increasing in the lot fed on Spratt's food (no. 1736), while in the control lot (no. 1738) it was diminishing. Thus the Spratt's food lot lost during the first ten days of the test as follows: 0, 0, 3, 4, 5, 6, 11, 11, 13, 10; total, 63; while during the same days the control lot lost 2, 6, 2, 0, 0, 0, 2, 1, 0, 0; total, 13. The disparity in losses continued to increase to the end of the test, and carrying the record forward to the second morning after the close of the feeding we have the following daily losses from August 25 to August 28, inclusive: Of the lot fed on Spratt's food, 38, 69, 76, 148; total, 331. Of the control lot, 0, 0, 0, 2; total, 2. The total mortality from the beginning of the test to the second morning after the abandonment of the Spratt's food regimen was, for the Spratt's food lot, 542, and for the control lot, 21. During the next ten days, ending on the morning of September 7, the deaths were: In the Spratt's food lot, 77, 13, 54, 24, 12, 3, 6, 13, 9, 7; total, 218; in the control lot there were no losses. By the 10th of September the mortality in the Spratt's food lot had so far subsided that from that date to the end of the month there were but 9 deaths, against 1 in the control lot. The resultant weights of these fish were not ascertained; but the record of losses seems to indicate in a very positive manner that the food tested was quite unfit for salmonoid fish to eat.

In 1907 a test was made at the same station of the merits of Spratt's "aquarium fish food" and "fibrine fish food." In submitting them for a test, the general manager of the Spratt's Patent Company said:

> Our pure-food law guaranty serial number is 1632, and I wish to reiterate the statement I have made previously, that the above-mentioned foods are purely meat, and cereal and meat, respectively, and no preservative, coloring matter, or chemical, etc., whatsoever, has been added to them.

The aquarium food, it was understood, was in part cereal, the other wholly meat. Both of them, as well as the food tested in 1905, were received directly from the company. The fishes selected for the experiment were brook trout, all derived from the same source. Six lots of 500 each were counted out to be fed with Spratt's foods, and several other lots of equal size to serve as control lots, and to be treated in various experimental ways. Three lots of 500 each were to be fed with the aquarium fish food and three with the fibrine fish food.

The experience of 1905 having indicated that it might be difficult to induce fry to take these foods well from the start, the whole six lots were as a preparatory step fed from May 20 to June 30 on finely ground hogs' liver, such as the other fry and fingerlings at the station were receiving. On June 30, therefore, the feeding of the Spratt's foods began, two of the lots receiving the aquarium food and two of them the fibrine food, while the liver regimen was continued with the other two until July 20.

Of the four lots beginning the new food June 30, one was given the fibrine food until October 19 and no other food; another lot was given the same fibrine food and liver on alternate days; a third lot received the aquarium food solely until October 19; and the fourth lot received the aquarium food and liver on alternate days. Of the two lots that continued to eat liver until July 20, one was fed from that date until October 19 on the fibrine food and the other for the same period on the aquarium food. All were fed three times daily.

Of the other lots of trout derived from the same original source, two may be regarded as control lots, numbered respectively, $1939Z^{1}$ and $1939Z^{3}$. Both of these, consisting of 1,000 fish each, began to feed May 21, and were fed three times daily through the season to October 9, hogs' liver until the end of July and hogs' plucks from that date to the close.

All of these lots were treated alike, all in troughs fed by water of the same quality, having trough room in proportion to their numbers at the start, the two control lots of 1,000 each having troughs twice as long as the lots having 500 each. Two exceptions were made in favor of two small lots, $1939K^{1}$ and $1939N^{1}$, which had much more room—each a 5-foot trough. The following table is a full exhibit of the lots in the experiment and the principal facts in their history:

EXPERIMENTS WITH SPRATT'S FOODS IN 1907.

| Lot no. | How treated—Feeding 3 times daily in all cases. | Original number of fish. | Taken out alive in August. | Close of experiment. | | |
|---|---|---|---|---|---|---|
| | | | | Date. | Fish left. | Average weight. |
| | | | | | | *Grains.* |
| 1939K | Liver to June 30; fibrine to October 19 | 500 | 15 | Oct. 19 | 4 | 24.1 |
| 1939L | Liver to July 20; fibrine to October 19 | 500 | | Oct. 19 | 14 | 21.7 |
| 1939M | Liver to June 30; then fibrine and liver on alternate days to October 19 | 500 | | Oct. 19 | 466 | 87.3 |
| 1939N | Liver to June 30; then aquarium cereal to October 19 | 500 | 100 | Oct. 19 | 4 | 29.3 |
| 1939O | Liver to July 20; aquarium cereal to October 19 | 500 | | Oct. 19 | 37 | 23.6 |
| 1939P | Liver to June 30; aquarium cereal and liver on alternate days to October 19 | 500 | | Oct. 19 | 441 | 77.4 |
| 1939K[1] | Rescued from 1939K August 16, and from that date fed on liver exclusively; kept in a 5-foot trough | 15 | | Oct. 19 | 5 | 158.5 |
| 1939N[1] | Rescued from 1939N August 16, and from that date fed on liver exclusively; kept in a 5-foot trough | 100 | | Oct. 19 | 48 | 154.9 |
| 1939Z[1] | Liver to end of July; then liver, hearts, and lights to October 9 | 1,000 | | Oct. 9 | 826 | 72.6 |
| 1939Z[2] | Liver to end of July; then liver, hearts, and lights to October 10 | 1,000 | | Oct. 10 | 768 | 82.6 |

Before the end of the first month there developed an abnormal mortality in the lot of trout fed on Spratt's fibrine, the dead picked out on the last seven mornings of the month being as follows: 4, 2, 8, 11, 14, 21, and 34; total, 94; as contrasted with the following deaths in the two large control lots,[a] namely: 2, 0, 1, 1, 2, and 1; total, 7; the rate of mortality being thus, for those seven days, forty-eight times as heavy with the fish eating fibrine as with those eating liver. The heavy mortality in this lot continued till August 16, by which time 480 of the 500 had been picked out dead, the losses in two control lots to that date being only 29 in the aggregate, out of an original 2,000.

The lot receiving liver till July 20 and fibrine for the rest of the season did not develop any excessive mortality until September, but during that month 434 out of the 500 died.

The lot fed on aquarium cereal suffered less, but they too had lost nearly four-fifths of their numbers before the end of August, in the lot taking up this food June 30, and in September an equally heavy loss befell the lot that began this food July 20.

On the 16th of August, as a sort of experimental rescue or secondary control, there were taken out of the first fibrine lot of fish (1939K) 15 of the survivors, and from the first aquarium cereal lot (1939N) 100 of the survivors. These two rescue lots were henceforth fed on liver. The object was to see whether they could, by a return to normal food, be rescued from the mortality that was fast

[a] These two control lots embraced in all four times as many fish as the fibrine-fed lot with which they are compared. The rate of mortality in these control lots was 3½ per thousand, while in the fibrine-fed lot it was 168 per thousand.

sweeping away the original lots. The result was that in the case of the fibrine fish the rescue effected essentially nothing, having apparently come too late; but in the aquarium-cereal lot 48 were saved up to October 19, out of the original 100 taken out in August, or 48 per cent; while of those left to their fate with the aquarium-cereal food only 4 were saved during the same period out of 207, or 2 per cent.

In the cases of the lots fed on Spratt's foods and liver on alternate days, the mortality was not excessive, being only 7 per cent in the fibrine lot and 12 per cent in the other.

It remains to see what effect the Spratt's foods had on the growth of the fish receiving them. As none of the dead fish picked out from time to time was weighed or measured, we can only note the weight attained by the survivors, remarking, however, that the dead fish taken out from time to time were, judging by the eye, never larger than the average of lots from which they were taken, and were generally smaller. All of these weighings were done in the usual way in water, except the smaller numbers, 14 and less, which were weighed singly on a delicate balance. The weighings showed that the 4 survivors of the lot (1939K) beginning the fibrine food June 30 weighed, October 19, on the average, 24.1 grains (155 centigrams) and the lot (1939L) that was given liver till July 20 and fibrine afterwards averaged 21.7 grains (140 centigrams). These are to be compared with the average weights of the fry of the two control lots (1939Z$^{1}$ and 1939Z$^{3}$), whose average, October 9 and 10, was 72.6 grains (470 centigrams) and 82.6 grains (535 centigrams), respectively; and it appears that the survivors of the Spratt's food regimens had made only from one-fourth to one-third of the normal growth, notwithstanding the fact that they had enjoyed from August 16 to October 19 a greatly enlarged area of trough room and a proportionably very large volume of water.

In growth the fish fed on Spratt's foods with liver on alternate days made a growth fully up to the average of liver-fed fish, the two lots attaining 87.3 grains (565 centigrams) and 77.4 grains (501.6 centigrams), respectively.

One of the most striking of the results obtained was the extraordinary growth of the two "rescue" lots mentioned above—1939K$^{1}$ and 1939N$^{1}$; the first of these, numbering at the October counting only 5 fish, had by that date acquired an average weight of 158.5 grains (1027 centigrams), and the other, numbering 48, an average weight of 154.9 grains (1003.7 centigrams). These weights are almost unparalleled in the station records of trough-reared fish. It is more than double the weight attained by the fish of the same origin fed through the season on the usual hogs' plucks, as shown in the case of lots 1939Z$^{1}$ and 1939Z$^{3}$. To what shall it be attributed? So far as the comparison is with the ordinary feeding we may safely say that the extraordinary rate of growth during this "rescue" period is the result of the increased space accorded the rescue lots. One of them (1939K$^{1}$) had, at the beginning of the rescue period, the 16th of August, when there were 15 fish, 44 square inches of trough room per fish, and at its close, October 19, when there were but 5 fish, 166 square inches, equivalent to 105 square inches for the entire period; and the other lot (1939N[1]) had in like manner the equivalent of 20.4 square inches space for each fish during the entire period; while the two control lots (1939Z[1] and 1939Z[3]) had during the same period a mean of only 1.7 square inches per fish for the first and 1.9 square inches per fish for the other.

It is interesting to note, further, that while the lots of fish that were kept on the Spratt's food regimen until the October count had a generous allowance of space, they failed utterly to receive benefit from it in the matter of growth. Thus the lot of fish fed on the aquarium cereal (1939N), although enjoying through the rescue period a mean of 12 square inches of space per fish against 9 square inches per fish accorded to the liver-fed rescued lot, attained a weight less than one-fifth that of the liver-fed fish; and in the case of the fish fed on fibrine the disparity was still greater, the fibrine fish attaining less than one-sixth the weight of the rescued fish, although the space accorded them per fish was almost exactly the same for the two.

The conclusion to be drawn from the results of these experiments can not be otherwise than this: That all of the commercial foods tried, the "fish food," the "fibrine fish food," and the "aquarium fish food," are entirely unfit for food for young salmonoid fishes. Their value for other kinds of fish is not considered here.

### FRESH FISH AND RYE MEAL.

Considerable quantities of fresh fish have been used from time to time at the Craig Brook station, both as material for the growth of fly larvæ and as direct food. In a few instances there have been made exact observations and records, which furnish limited data for demonstrations of their value. In 1907 such data were preserved of a brief trial of the use of fresh fish and rye meal. The subjects of these experiments were 18 lots of brook trout, all from the same original stock, all treated alike in respect to quarters, water, and attendance, except that 6 of the lots contained originally half as many fish as the others and were quartered in troughs half as large. All were fed on chopped hogs' liver until September 5. At that date began the experimental feeding, which continued to October 9 to 12, when the survivors in all these lots were counted and weighed. During this period 6 of these lots were fed on chopped fresh herring, 5 others on herring for ten days and then on a mixture of herring and rye meal, and 7 others, as control lots, on liver until August 1, after which hogs' hearts and lights were added to their fare. Though the period of this experiment was very short, the results seem to indicate that the continuous nourishment with hogs' plucks was the most favorable, that fresh herring came next, and that rye meal stood at the foot of the list. The 7 lots of fish fed on the plucks alone, originally consisting of 1,000 fish each, or 7,000 in all, and numbering 5,926 in October, weighed 67 pounds 5 ounces, an average of 79.5 grains (515.1 centigrams).

The 6 lots fed on herring alone, numbering originally in all 3,000 and at the close 2,579, weighed on the average 75.3 grains (488 centigrams).

The 5 lots fed on the herring and rye meal, 5,000 at the start and 4,425 at the close, attained an average weight of 68.3 grains (442.6 centigrams). Though these data indicate, as stated, the inferiority of fish and rye to plucks as promoters of growth, a final conclusion in the matter should await more extended trial.

Though in these experiments the only fish used was fresh herring, it is safe to assume that other fresh fish would be equally potential in nourishing the fish, and the cheapest kinds are no doubt for such purpose of equal value with those of higher cost. The cheapest fish that can be obtained in fresh condition is therefore probably the most desirable, provided it can be easily prepared for use. Herring are especially easy to prepare, as they can be chopped into the desired form without any dressing whatever. This fact and that of their abundance and wide distribution render them perhaps the most available of all species of fish. Their cost is also very moderate, those used at Craig Brook costing 1 cent per pound.

# FRESH-WATER SHRIMP, A NATURAL FISH FOOD

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# FRESH-WATER SHRIMP, A NATURAL FISH FOOD.

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It has been my belief for years that the greatest benefit to accrue from modern fish culture is to the individual grower, the utilizer of inland waters under control and observation. But the basic need to effect such a result is a natural food of abundance and cheapness, a food that can be grown out of the natural productiveness of the water, a food corresponding to the natural grass on which wild animals feed, to the nectar of the wild flowers which honey bees gather, conserve, and consume. If the agriculturalist reaped no return except from the fertilizer he employed, if there was nothing afforded by the natural elements of the soil, his work would be heavy, requiring pound for pound, so to speak. There is, of course, a natural fertility in the waters which is available, similarly to that of the soil, with the proper agent to take up and conserve it. In the fresh-water shrimp we have an example of such a gatherer and conservator.

*Palæmonetes exilipes* is indigenous to the coastal plain region of North Carolina. The species is not the so-called fresh-water shrimp *Gammarus*, but a true shrimp, a miniature of the salt-water shrimp and prawn. It is meaty, like those species and the American lobster. In fact, in a time of stress it would sustain man. Though small, it is incomparably larger than *Gammarus*, measuring by actual count 136 to 140 to a fluid ounce or about 2,200 per pint, as taken in the early fall, young and old, with no culling. It is a favorite bait for black bass and crappie, two abundant game fishes of the region, the crappie taking this bait when all others are refused. The angler impales several shrimps upon his hook at a time, and I have observed that they sometimes remained alive for two hours, thus displaying considerable vitality.

The exceeding abundance of fresh-water shrimp may be compared with that of house flies in summer, flying ants on their emergence from the decaying stump, or angleworms in favorable soil. They dwell in masses of water mosses and grasses, and in the region referred to such growth is practically universal on all bottom. Rarely, the shrimps swim in schools in open water, jumping entirely above the surface when suddenly alarmed by moving objects in or above the water. Ordinarily they are in hiding, to escape their legion enemy, the numerous species of fishes which abound along with them—bass, crappie, sunfish, pike, catfish, yellow perch, and many others. They are captured by a small bait or hand net operated from the bank or from a small boat, but in Sampson County the fishermen use a slat basket instead of the net, the latter clumsy mode of capture suggesting the presence of large numbers. In a place at which I had collected five days before, I dipped up 476 within a space of 4 yards square—114 per square yard. At another place I took 741 in 11 dips, at another 350 at 2 dips, and at another place I gathered 1,000 in thirty minutes' time and at the rate of 900 per square rod. With a 10-foot seine I gathered 1,250 in 3 hauls. Owing to the thick plant growth and the presence of innumerable boughs and leaves of trees, and the small size of many of the shrimps, it is obvious that I gathered but a small proportion of what was there. Hundreds of acres of water in many counties are teeming with this unrivaled natural food of fish. It exists by the millions and by the ton, but scattered, of course.

The fresh-water shrimp abounds in creeks, mill ponds, ponds or lakelets formed by river overflow, and in clay holes or borrow pits along railroad lines where earth was obtained for throwing up railway embankments. In the latter class of locality the shrimp is landlocked and dependent upon rainfall for water supply in holes but 2 to 8 inches deep, unshaded, and subjected to extremes of heat and cold, the thermometer ranging from 10 degrees to approximately 100 degrees Fahrenheit. In summer the water at times approximates or even exceeds 100 degrees, and in the severest winters it freezes several inches thick. The overflows from the Roanoke River, which afford as thick, muddy water (from a clay country) as can be imagined in a stream of its size, appear to have no decimating effect upon the engulfed shrimp. While trees grow along the sides of streams and ponds, and largely out in their waters also, their shade appears to contain no elemental saving quality, the productive borrow-pit pools being in railroad rights of way and denuded of all tall growth.

Instead of hibernating or burrowing during freezing weather, the fresh-water shrimp appears merely to seek greater water depths. Here is another similarity to the salt-water shrimp and prawn, which, in North Carolina at least, pass out to sea when cool weather reigns, seeking the deeper water and remaining in it till springtime. In Northampton County, N. C., I know an angler who annually gathers up quantities of fresh-water shrimp and, in a running, open ditch, holds them through the winter for bait.

From the foregoing it is practically certain that the species is adapted to broadcast distribution in the temperate zone of the globe, and capable of becoming a resource of incalculable value. But while I forecast the possibilities with this food of nature, it is to be considered that ponds and streams which are deluged with sand and gravel from land washing by rains to an extent to bury and obliterate the bottom-plant growth will prove disappointing. I also mention that the fresh-water shrimp can not swim against a strong current.

To determine its power of resistance in any work looking to diffusion of the species, I made experiments in 1896, as an agent of the United States, in transporting fresh-water shrimps over long distances by express, with no attention en route. The results were gratifying.

I found the species extremely slimy, and that "sliming" was a necessary prerequisite in order to hold them in tanks or transport them. The prevalence of slime aided the removal of broken bits of bark, cypress-tree leaves, twigs, and all sediment. An upright tin dipper was immersed in the center of the pan, and all the foreign matter, clinging together from the sticky slime in a coagulated mass, was easily skimmed off, the shrimp bearing off to the sides of the pan and none being caught in the dipper. Siphons and strainers and hand nets were useless, the antennæ of the shrimp, which are of wonderful length, becoming tangled and fatal injuries being inflicted. In gathering captures from the nets the fingers were the sole instrument, though slight wounds were received from the sharp needles about the head of the shrimp.

Experimental shipments were made in 4-quart tin pails, the same in which German carp were then being distributed, the covers being ventilated by means of punched holes. Ten pails were packed in an open crate composed of thin wood strips and the crate cover secured against opening. Each pail was about two-thirds filled with water and contained shrimp as follows: Ten pails contained 150 each, another ten 180 each, another ten 125 each, and yet another ten 150 each, these several lots being turned over to the express company October 7, 9, 12, and 13, respectively, at Halifax, N. C., for delivery at Washington, D. C., 200 miles distant. The water temperature of streams at Halifax was 53 to 55 degrees Fahrenheit, the railroad journey 8 hours, and the lay-over in the warehouse (at night) at Washington 11 hours, a total confinement in pails, without icing, aerating, or other attention, of 19 hours. The losses were, respectively, 2, 94, 15, and 10, or 121 out of the total of 6,050, or 2 per cent. The second lot appeared to have been overcrowded, 40 out of the 94 being dead in one pail. In two pails, containing 100 and 150 shrimp each, shipped October 15, from the same place to the Neosho, Mo., station, and en route 92 hours, there were but 2 alive at the destination; but in four pails, in the cooler weather of November 14, containing 50, 75, 100, and 150, all reached their destination alive except the 150 in one pail, all of which were dead. It was discovered early that the species is quickly responsive to overcrowding; in fact, notably so. When too thick in the pails they spring out of the water and die while clinging to the exposed surfaces of the metal sides, apparently glued by their own slime.

I have personally observed beef cattle fattened on two exclusive articles, cotton-seed meal and cotton-seed hulls, the animals haltered in the stall till slaughtering day; a profitable commercial accomplishment, doubtless, but producing a kind of beef that I would turn away from, so far removed are the two food articles employed from the usual, natural food of the beef animal. In the nourishing of fish at cultural establishments a number of articles have been utilized which were as foreign to the usual diet of the fish as the cotton-seed products to the beef animal. The angle or fish worm is universally conceded to be a natural food of fish, but the fresh-water shrimp (*Palæmonetes*) is yet a more rational one, and while the growing of angleworms in quantity by cultural methods might be a doubtful investment of time as a fish-food creative process, there can be no doubt that *Palæmonetes exilipes* is entirely capable of being easily and cheaply multiplied, requiring no better accommodations than a typical mosquito hole minus the larger natural enemies of the shrimp—i. e., the native fishes—which the hole might contain.

# THE CULTIVATION OF THE TURBOT

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# THE CULTIVATION OF THE TURBOT.

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[Translated from the French.]

The question of marine pisciculture has been for some thirty years a subject of important concern to naturalists. The present crisis in marine fisheries and the necessities involved seem to cause an increase of efforts in this direction.

The term marine pisciculture serves to designate either natural pisciculture or artificial pisciculture (piscifacture), both public and private or industrial.

The so-called natural pisciculture is the simple operation of making the young edible fishes hatched at sea enter marine ponds or artificial reservoirs communicating with the sea, there to be fattened and then captured for market when they have attained a commercial size. Practiced for centuries, its development did not demand any previous knowledge of the phenomenon of reproduction of the fishes. But it does demand the realization of natural conditions which are very special as to localities and surroundings, a thing which prevents it from becoming general.

To this pisciculture, rudimentary to a certain extent, may be opposed the so-called artificial pisciculture, or piscifacture, thus named because the eggs and larvæ are obtained in captivity.

Artificial pisciculture may pursue either of two aims: It may be a public enterprise, an undertaking of the government, as a government alone can enter upon such an operation, its aim then the repopulation of the sea; on the other hand, it may be a strictly private enterprise to inaugurate an industry which would pursue the aim of breeding certain edible sea fishes in captivity for profit.

The first attempts at artificial pisciculture were public undertakings; the aim was to attain the breeding of edible shore fishes in captivity, to have the eggs hatch, and to deposit the larvæ at a point on the coast where a decrease of these fishes had been noticed. The young fishes were released in the sea a few days after they were hatched, before the entire disappearance of the yolk sac and the beginning of feeding by external means. The Government of the United States was the first to interest itself in this question of such important general concern, by founding in 1878 at Gloucester, in the state of Massachusetts, in the vicinity of the great city of Boston, the first public establishment for marine pisciculture. The establishment at Gloucester was soon followed by one at Provincetown, one at Woods Hole, and one on the steamer *Fish Hawk*. In 1883 Norway followed the example of the United States and created the establishment of pisciculture at Flödevig. In 1889 the Government of Newfoundland founded the establishment of Dildo and, lastly, in 1894, Great Britain founded, thanks to the Fishery Board of Scotland, the establishment of Dunbar. These various establishments gave each year to the sea several thousands of cod, plaice, and even turbots, hatched in captivity; it must nevertheless be said that it was never possible to obtain at Dunbar, the only establishment where the replenishing of coastal waters with turbots was attempted, any natural hatching of this fish, and that it was always necessary to have recourse to artificial stripping and fertilization as practiced for the fresh-water fishes.

It is not our aim to discuss, after so many others have done so, the question of the real utility of marine pisciculture for the replenishment of the sea. Let us merely remember from the experiments of our predecessors this very important fact: It is due to their efforts that at the present time we have been able to obtain natural spawning in captivity and the hatching of eggs of the greater number of edible coastal fishes having pelagic eggs.

For some twelve years French naturalists seem to have devoted themselves to private or industrial artificial pisciculture. In other words, the work done to-day is an attempt at the entire process of breeding edible fishes from the egg until they reach a commercial size, to create thus a real industry which may in future become an actual source of riches. The first step in the new direction was made by Mr. Edmond Perrier, Director of the Museum of Natural History, Member of the Institute, and director of the maritime laboratory of St. Vaast-la-Hougue, who has the great merit of having been the first to appreciate the importance of the problem and to establish at his laboratory a complete equipment for industrial marine pisciculture.

It will be remembered that without any thought as to its industrial value and for purely scientific purposes, Meyer had been breeding the herring since 1878; at Flödevig young cods were bred, at Plymouth young flounders, and at Concarneau young bullheads; at Dunbar, Harald Dannevig had succeeded in breeding young plaice. In addition to the fact that the industrial point of view was entirely overlooked in these experiments, species of small or no commercial value were experimented upon.

Before attempting marine pisciculture it is necessary to ask oneself what are the fishes for which such experiments would be practically profitable. It is evident that migratory fishes, or those living in depths the natural conditions of which we can not offer them in captivity, are to be eliminated. Moreover, before attempting the breeding of nonmigratory fishes of commercial value there is a certain number of questions which ought to be answered: (1) Is the fish in question of sufficient commercial value to render its breeding profitable? (2) Is its growth in captivity sufficiently rapid, and is the cost of bringing it to its commercial size disproportionate to its market price?

In the last analysis it will appear that among the fishes inhabiting our European waters there are only four species which are profitable objects of marine pisciculture. These are the sole (*Solea vulgaris* Quensel), the turbot (*Rhombus maximus* Linnæus), the umbrina (*Labrax lupus* Cuvier), the surmullet (*Mullus surmuletus* Linnæus). According to Cunningham, the turbot at the age of two years is from 28 to 38 centimeters long, and reaches 60 centimeters at the age of four years. As to the sole, it reaches only 23 centimeters at the age of two years.

Of all these various edible fishes, the most profitable from the point of breeding is the turbot, on account of its high price, its particularly rapid growth, its prodigious fecundity (the turbot yields about 9,000,000 eggs per year) and, lastly, its hardiness and the ease with which it may be fed and fattened. Unfortunately, however, this species is the one the artificial reproduction of which presents the greatest difficulties, as was justly observed in 1905 by Fabre-Domergue and Biétrix, whose researches in this line go as far back as 1896.[a] It must be remembered that no natural hatching of turbot could be accomplished at Dunbar and recourse was had to artificial methods of stripping and fecundation, as for fresh-water fishes.

The problem of industrial marine pisciculture must necessarily traverse two stages before reaching complete realization—a preliminary and purely scientific stage, and a final and really practical stage.

The scientific success of the problem seems to consist in hatching a reasonable number of young fishes and keeping them in the laboratory beyond the critical stage. (As defined by Fabre-Domergue, the critical stage begins when the umbilical vesicle is entirely absorbed and the young fish begins to look for food among its surroundings.) Practical success consists in keeping a considerable number of fishes until they acquire such condition that the operation may be really remunerative. It is evident that before attempting the study of the second feature of this problem the first must be solved. It is only when the

[a] Fabre-Domergue and Biétrix: Le developpement de la sole, 1905. Travail du Laboratoire de Zoologie maritime de Concarneau.

first stage shall have been passed that it will be legitimate to inquire whether the results obtained in the laboratory may or may not be repeated on a larger scale, i. e., to practical purpose, with perhaps a somewhat different technique. Practical marine pisciculture, the origin of which does not date further back than twelve years, is as yet in its scientific period.

The two principal difficulties involved in the solution of the scientific problem are the following: (1) The obtaining in captivity of natural and normal hatches in as great numbers as might be desired, and the determination of the conditions of these hatches. (2) The feeding and the preservation of a reasonable number of larvæ beyond the critical period and under conditions such that the experiment may be repeated. As has been justly observed by Messrs. Fabre-Domergue and Biétrix (op. cit.), the incubation, hatching, and preservation of the larvæ until the beginning of the critical period do not present any difficulties.

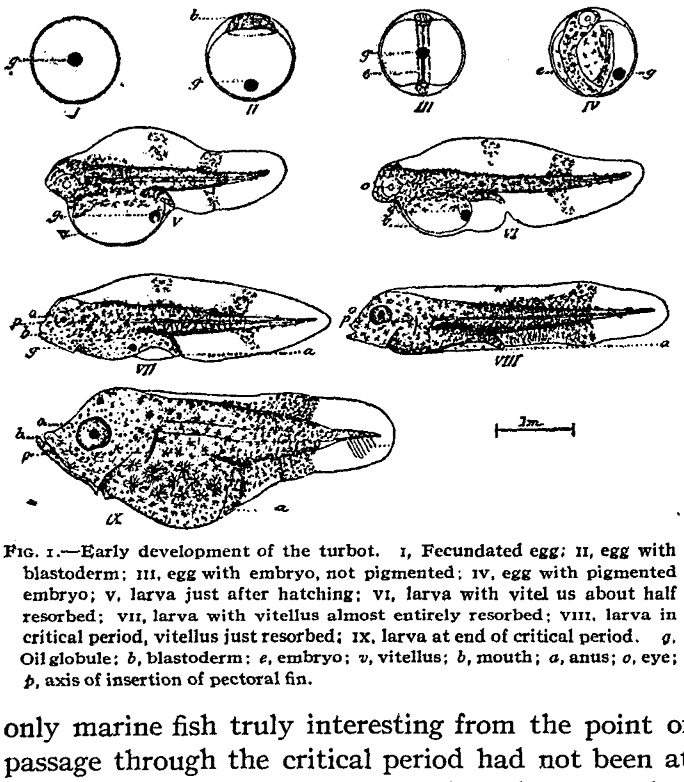

FIG. 1.—Early development of the turbot. I, Fecundated egg; II, egg with blastoderm; III, egg with embryo, not pigmented; IV, egg with pigmented embryo; V, larva just after hatching; VI, larva with vitellus about half resorbed; VII, larva with vitellus almost entirely resorbed; VIII, larva in critical period, vitellus just resorbed; IX, larva at end of critical period. *g*, Oil globule; *b*, blastoderm; *e*, embryo; *v*, vitellus; *b*, mouth; *a*, anus; *o*, eye; *p*, axis of insertion of pectoral fin.

In the laboratories of pisciculture in America, Norway, and England the question of hatching in captivity has been solved for the plaice and for the cod, but could not be solved for the turbot, the only marine fish truly interesting from the point of industrial breeding. The passage through the critical period had not been attempted for any species in laboratories here cited, because the fishes were deposited in the sea before the beginning of this period. The principal object of practical marine pisciculture in recent years, then, in Europe at least, has been to obtain normal hatches of turbots in captivity and to carry their larvæ past the critical period.

It was at the laboratory of St. Vaast-la-Hougue that numerous normal hatches of turbots were obtained for the first time by A. E. Malard in 1898.[a]

[a] Malard, A. E.: Sur le developpement et la pisciculture du turbot. Comptes rendus de l'Académie des Sciences, Paris, 17 juillet, 1899.

In 1904, L. Dantan,[a] repeating these experiments, obtained an identical result at the same laboratory. In both cases the hatching took place normally, but unfortunately all the larvæ died a few days later, not being able to survive the critical stage. Thus only the first part of the problem was solved.

In 1905 Fabre-Domergue and Biétrix (op. cit.) published their memoir on the development of the sole. No hatches of turbot or sole could be obtained in the laboratory of Concarneau where these authors operated. Fabre-Domergue and Biétrix were obliged painstakingly to collect eyed eggs of the sole in the sea. But they were able to bring a small number of individuals far beyond the critical period. For the sole, at least, the second part of the scientific problem was realized. In 1905 Malard and Dantan, who had obtained normal hatches of the turbot, had not been able to carry their larvæ past the critical period, and Fabre-Domergue and Biétrix, who had not been able to obtain hatches, had carried the sole through the critical period. With the turbot, rearing past the critical period had not been accomplished.

In the course of 1907 we were more fortunate at the laboratory of St. Vaast-la-Hougue than in 1898 and in 1904, and succeeded not only in making the larvæ live beyond the resorption of the umbilical sac, but in obtaining after this critical period a considerable increase of volume and an important modification of the shape. The conditions under which I obtained these results are the following:

During the month of February, 1907, I procured 10 adult turbots, which I placed in the large hatching basins of the laboratory. These basins, constructed according to the directions of Mr. Edmond Perrier, are three in number. The capacity of the largest is more than 300 cubic meters. They are filled by means of a pump, worked by a windmill, or a gasoline motor when the wind is not sufficiently strong. This pump brings the water to the upper part of the basin. A waste pipe is in the lower part. In the middle is an incomplete trench about the depth of a stair step, made after the design of A. E. Malard, to promote the spawning of the females, which this author found rubbed their abdomens against its acute angle. The basins are covered with a thatched roof and are amply lighted.

Let us note that so far there exists no certain external means of recognizing the sex of the turbots when alive, although many naturalists have endeavored to find it. Nevertheless, taking 12 individuals, there are great chances of having both females and males among them. The only thing to remember is that the fish should not be less than 40 centimeters in length. With smaller individuals there would be a risk of their not yet being mature.

[a] Dantan, L.: Notes ichthyologiques. Archives de Zoologie expérimentale et générale. Notes et revues, 1905.

At the end of a few weeks of captivity our prisoners began to feed. To them were distributed once a week large pieces of plaice at the rate of about half a fish the size of the hand to each turbot. This ration may seem scant, but it was purposely limited, we deeming that too great an abundance of food is not favorable to the functions of reproduction. It is probably to excess of feeding that must be attributed the failure of attempts to make the turbot spawn in captivity. In order to keep the basins free of putrefying food substances we put with our turbots a conger eel and a dogfish long since acclimated to life in captivity. These fishes, well known for their voracity, were employed as scavengers, in which capacity they did good service. Our turbots, in captivity since February, began to spawn in July.

We do not know yet whether individuals that have spawned in captivity and survived one season will spawn the following year. We will not know this until in July next. In any case it does not seem to us very important to know whether it is necessary to keep the same brood stock for one or more years, since fish captured only six months previously had ample time to get acclimated and have given excellent results. Let us add that it seems to us very imprudent to capture breeders only a few weeks before the spawning time. Not yet acclimated, they might exhibit phenomena of ovular retention, which are in most cases fatal.

The first eggs were laid on July 18, and were soon followed by four other lots. The dates of the consecutive spawnings were July 18, 21, 28, 29, and August 3. These lots of eggs numbered thousands and thousands, all normal and normally fertilized. A certain number only were carefully gathered by means of plankton nets and transferred to the incubation apparatus. An essential feature of this apparatus is continuous agitation, which is a very important thing in incubation, keeping the egg free of sediment and thus preventing asphyxiation. Dannevig, among others, at the station of Dunbar had already employed a complicated apparatus which provided continuous agitation.

The apparatus used by us was that of Fabre-Domergue and Biétrix modified, which apparatus is in itself a modification of that constructed by Browne at the laboratory of Plymouth to preserve pelagic organisms alive. It consisted of a receptacle in which a plunging disk rose and fell by means of a special contrivance. In the apparatus of Fabre-Domergue and Biétrix the somewhat violent agitation produced by the vertical motion of the disk is replaced by a helicoidal movement, the disk being obliquely fixed on a vertical rotating axis and thus working like a screw. The apparatus is composed of 4 glass barrels of 50 liters capacity, each supplied with a revolving disk, and the 4 disks are worked by a small hot-air motor of $\frac{1}{40}$ horsepower.

I thought it advisable to make a few modifications in the apparatus of Fabre-Domergue and Biétrix which seemed to me of great importance to the final success. On the thread of the vertical rod carrying the disk I attached above the level of the water, as tightly as possible, a small wad of absorbent cotton to take up and keep off the oil that might come from the wheels above it. I had observed that a small part of the oil could descend along this vertical glass rod and thus reach the water, where it formed a thin layer, the effect of which was hindrance of aeration, causing asphyxiation of the larvæ. Below this wad I placed, upside down, the disk-shaped cover of a small vessel, thus to keep dust from falling into the water, without, however, hindering the circulation of the air. This disk was secured below by a second wad of cotton. I also utilized the lower, lateral, tubular outlet of the barrel to set up a tube within terminating at the top in a funnel covered with very fine silk, to allow the passage of water but not of larvæ. The opening of this funnel was the size of a 5-franc piece, and the flare thus obtained was designed to decrease, as far as possible, the intensity of the current, which, were it too violent, would certainly have carried the larvæ with it. This possible carrying out of the larvæ constitutes a real danger, against which, however, we are still better protected in the apparatus which we have had constructed for our experiments in 1908.

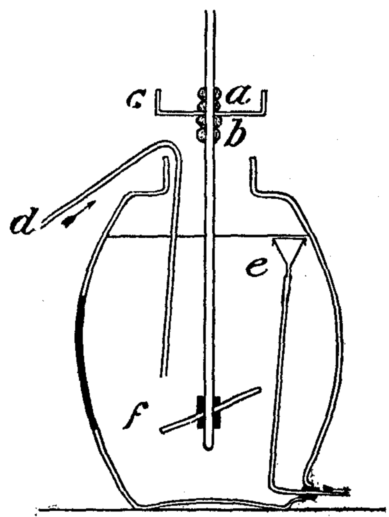

FIG. 2.—Apparatus for hatching turbot (modification of apparatus of Fabre-Domergue and Biétrix). *a* and *b*, wads of cotton; *c*, upturned cover which serves as dust shield; *d*, inflow pipe· *e*, outflow pipe with screened funnel entrance; *f*, revolving disk for agitation of the water.

Several times a day part of the water in the barrel was renewed for 10 minutes by means of a siphon, there being in the course of the supply tube a flaring inlet for the purpose of aeration. Several times a day also the bottoms of the basins were carefully siphoned to remove the dead eggs and all other matter that might pollute the water. These modifications, of details only, which we have made in the excellent apparatus in which Fabre-Domergue and Biétrix have been able to carry the sole past the critical stage ought to be considered an indication, so to speak, of more important modifications which will render possible its practical use on a larger scale than from the point of view of experiments only.

The hatching of the eggs took place without difficulty and without hindrance between the sixth and eighth days after spawning. Two or three days after the appearance of the larvæ, without waiting for the complete absorption of the yolk sac, and following in this the excellent advice given by Mr. Edmond Perrier in 1896, at the Congress of Fisheries at Sables d'Olonne, and a little later, in 1898, by Mr. Fabre-Domergue, we began the feeding of our young larvæ. Their diet was composed of live plankton collected in the open by means of fine-meshed nets, and carefully sifted upon arrival at the laboratory through very fine sifting silk, for the purpose of eliminating the organisms which might constitute a danger by their size or their nature. One distribution of plankton was made every day, and in great abundance. Moreover, the agitation of the water maintained the plankton alive, and the young fry had consequently always in reach a fresh live food as varied as under natural conditions of their life. Toward the fourteenth or fifteenth days the last trace of the sac disappeared, and about the eighteenth or twentieth day the critical period might be considered as passed. The young larvæ had at that period taken the peculiar shape characterized by the widening of the head, and they fed normally.

For the retention of the larvæ after the beginning of the resorption of the yolk sac, i. e., during the critical stage, two things are necessary: (1) Continuous agitation of the water, and (2) appropriate food. Continuous agitation of the water is incontestably very useful in the incubation of the eggs and the normal life of the larvæ up to the time when they begin to feed, but during these periods it is not, as later, absolutely indispensable.

We have, in fact, found at St. Vaast, on the one hand, that the eggs which were left in our hatching basins developed there and hatched normally, and the larvæ did very well until after the disappearance of the yolk sac; on the other hand, the same facts were observed in the hatching aquaria. But what we did not accomplish, and we can not insist too much on this point, was to make larvæ live even a few hours, though offering them plankton, under these conditions after the disappearance of their yolk sac. It is at this time, we believe, with all who have undertaken marine pisciculture, that continuous agitation of the water is absolutely necessary. Without it the young fish is never in the presence of its food, it weakens, falls to the bottom, and dies of hunger.

As to feeding, let us recall that the fry were very precocious, and began to feed even before the complete disappearance of the yolk sac. The objection might be raised that plankton as the basis of food for the larvæ can not be considered for a moment where breeding on a large scale is to be undertaken. It may be said that on certain days storms disturb the sea, and the water being full of ooze and sand, collecting is impossible. We believe that we can say that the period during which plankton will be necessary is precisely during the season of the year in which storms are most rare (from July 1 to September 15, at the latest, for the region of St. Vaast-la-Hougue). Should there be storms, however, one would always have the resource of small plankton organisms in the pools left when the sea recedes. Moreover, the continuous agitation apparatus will allow us to keep alive a small reserve of plankton to supply the needs of our larvæ for three to four days. And, lastly, one more argument, shall it be considered a priori impossible to breed certain plankton organisms, carefully selected? Continuous agitation apparatus would undoubtedly be suitable for this purpose likewise. The experiments of Bracque have almost solved this question already. I am not opposed a priori to a semiartificial food as, for example, the *Monas dunali* of marshes successfully employed by Messrs. Fabre-Domergue and Biétrix for feeding their larvæ of soles, and it is even possible that this organism might be made to render the greatest service in marine pisciculture. But it is nevertheless most true that it is in the great variety of plankton organisms that we shall find the food necessary for the normal feeding of the larvæ of teleosts with pelagic eggs. I dared not experiment with purely artificial food, advised by others (cheese, shrimp meal, etc.). I believe that rapid putrefaction would occur. I believe, in short, that during the first period the best food would be small plankton organisms, carefully selected.

Let us add that in hatching troughs the temperature of the water ought not to be above 20° C. We have operated constantly at a temperature of from 18° to 20° C. It seemed best to have it from 15° to 20° C. Let us say, further, that during the critical period we lost only 1 individual in 10, a result which might be considered excellent, it seems to me.

What is left to be done in the culture of the turbot? There remains to protect the young larvæ from the end of the critical period to the end of the metamorphosis, since we are sure, and we have often shown by experiment, that there is nothing easier than to fatten young turbots and other pleuronectids, and make them grow. For this purpose it will be sufficient to substitute for the plankton, as rapidly as possible, fish flesh mashed into a pulp, this to be consecutively replaced by larger and larger pieces of fish as the size of the turbots increases.

It remains likewise to carry marine pisciculture from the domain of science to industry, and this is not the least of the work to be done—to determine, in fact, whether the procedure applicable on a small scale in laboratories may be carried on on a larger scale. It is necessary to determine the price of the food required to fatten the fishes bred and to see if this price allows a profit, taking into consideration the market price per kilogram of the turbot.

It is possible that the waste of fishes in the vicinity of great harbors might constitute a valuable resource for industrial marine pisciculture of the future.

## RÉSUMÉ AND CONCLUSION.

The results obtained by us at the marine laboratory of St. Vaast-la-Hougue during the summer of 1907 are in brief the following:

(1) After Messrs. Malard and Dantan we obtained natural, normal, and abundant hatches of turbot, a result which had been sought for twenty years in a great number of other marine laboratories.

(2) We were the first to succeed in carrying the larvæ of this pleuronectid through the critical period, the obstacle which hitherto all the naturalists studying pisciculture had been unable to overcome, and which seemed to be the principal rock in the course of marine pisciculture.

(3) Throughout our work the mortality of the larvæ may be said to have been a negligible quantity (about 10 per cent).

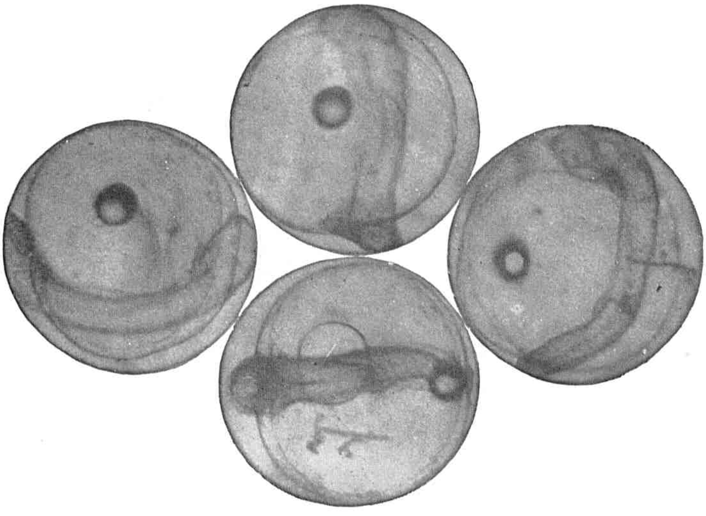

FIG. 1.—Turbot eggs with embryo. Fourth day.

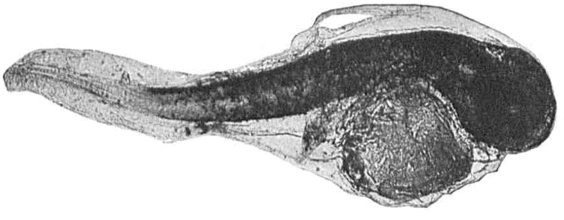

FIG. 2.—Larva with vitellus. Eighth day.

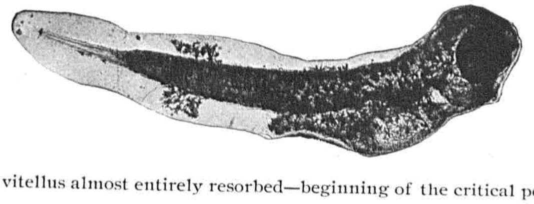

FIG. 3.—Larva with vitellus almost entirely resorbed—beginning of the critical period. Tenth day.

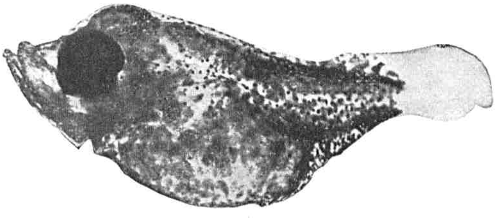

FIG. 4.—Larva a few days after end of critical period. Vitellus has disappeared, abdomen full of food. Shape of fish changed. Twenty-third day.

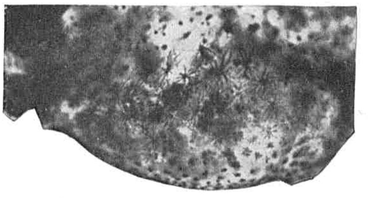

FIG. 5.—Detail of pigmentation of abdomen of above figure.

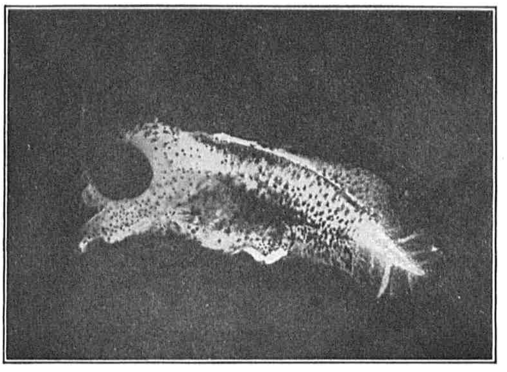

FIG. 6.—Larva after the critical period (cadaverous shape).

# THE TREATMENT OF FISH-CULTURAL WATERS FOR THE REMOVAL OF ALGÆ

By M. C. Marsh and R. K. Robinson

*United States Bureau of Fisheries*

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# THE TREATMENT OF FISH-CULTURAL WATERS FOR THE REMOVAL OF ALGÆ.

By M. C. MARSH and R. K. ROBINSON,
*United States Bureau of Fisheries.*

A great annoyance encountered at fish-cultural establishments, or in any ponds where fish are held, is the presence in the water of mossy or slimy plant growths consisting of forms known to botanists as different species of algæ. These appear usually as green or bluish green masses or strands of filaments, which clog the screens of ponds and supply canals and accumulate in the ponds themselves. The clogging of the intake screens or supply pipes endangers the life of the fish by reducing or entirely shutting off the water supply, while the clogging of the outlet screens prevents the water from escaping through the proper channel and allows the pond to fill and overflow, carrying away the young fish; in either case a loss of fish is likely to result, and the trouble of frequent cleaning of screens is inevitable. This sometimes requires the regular attention of the watchman all night or the special services of an extra laborer. The formation and accumulation of algæ within the pond containing fish, especially if there are fry or fingerlings, prevents proper feeding, greatly interferes with the operation of nets in handling fish, and occupies valuable space. The latter tends to crowding and retardation of growth, while frequently fry become entangled in the filaments and strands of the algæ in such a manner that many are lost from this cause alone.

It is true that the green filamentous algæ which are mechanically so annoying are oxygenators in sunlight and often add materially to the amount of dissolved oxygen in the water. In ponds without a rapid circulation they have been observed to superaerate the water with oxygen, and this sometimes occurs in flowing streams;[a] that is, the algæ add oxygen to water which already has absorbed its full or normal supply from the atmosphere. Under these conditions oxygen gas must have been passing slowly from the water into the atmosphere. The objectionable features of algæ, however, usually far outweigh the

[a] Marsh and Gorham: The gas disease in fishes, Report Bureau of Fisheries, 1904, p. 357. 1905.

value as an oxygenator, or as a breeding place for minute animal food for fry, if such it be. A method of eliminating this growth is therefore a great desideratum in fish culture.

Moore and Kellerman,[a] in work conducted with the object of cleansing municipal water supplies of obnoxious algæ, developed a method of treating the water with copper sulphate, finding that this salt dissolved in the water is highly toxic to algæ at a dilution so weak that it may with safety be taken into the human system. The small cost of such treatment moreover, by reason of the cheapness of commercial copper sulphate and the simple means by which it may be used, makes this remedy readily available for practical purposes, and it has for several years now been successfully applied not only for the removal of algæ from reservoirs and ponds, but also in the process of filtration as well. Its possibilities as a useful agent in fish culture have therefore invited investigation with, so far, the results set forth in this paper, concerning algæ as a mechanical annoyance to the fish culturist. Wider application is suggested in certain experiments dealing with bacterial diseases of fish, in which the treatment aims at physiological effect upon the fish themselves, but as yet no definite results in this phase can be reported.

## ESSENTIAL PRINCIPLES OF THE TREATMENT.

The efficiency of copper sulphate in the treatment of city water supplies and fish-cultural ponds or streams depends, of course, fundamentally upon the fact that it is by its nature a poison to algæ. Its use for practical purposes depends further upon the fact that it is poisonous in extremely dilute solutions, which are not injurious to most of the higher forms of life and are moreover available by reason of the cheapness of the substance. The first point of consideration in fish culture, therefore, these facts being known, is the susceptibility of the fish contained in the water that is to be treated. If, under given water conditions, the fish are more susceptible than the algæ, the remedy is not applicable. Use can be made of it only where as the proportion of copper sulphate increases the death point to algæ is reached before the death point to the fish. The larger the margin the better, but the method may be used where the margin is very small. The second and remaining consideration is an adequate method of applying the remedy.

## SUSCEPTIBILITY OF FISHES.

The chemical reactions by which copper sulphate kills fish are not known. The poison acts through the medium of the water in which it is in solution and in which the fish breathes. The water has other dissolved substances in solu-

[a] A method of destroying or preventing the growth of algæ and certain pathogenic bacteria in water supplies. Department of Agriculture, Bureau of Plant Industry, Bulletin No. 64, 1904.

tion which tend to modify the effect of the copper salt, while the physiological resistance of the fish varies with individual fish and with different broods of the same species. As a matter of fact, fish in general resist the action of copper sulphate better than algæ. The salmonoid fishes have less resistance than any group with which experiments have been made; nevertheless, it has been found in most cases thus far that the necessary margin between the death point of fish and the death point of algæ does exist. Algæ, including some species that cause annoyance, are sometimes killed by much weaker solutions than the weakest known to be fatal to the most susceptible fish, even as weak as 1 part copper sulphate to 50,000,000 parts of water.

The variation of the two important facts, however, susceptibility in individual broods of fish and in the dissolved content of the water, giving rise to wide differences in the quantity of copper sulphate that may be fatal, makes it necessary to determine in each case the susceptibility of the fishes in question in the particular water concerned. It follows that no general formulæ for the proportion of copper sulphate can be stated. Some results actually obtained will be of interest, however, and useful for comparison or to some extent in approximating the strength of the solution which must be fixed more accurately by experiment.

Moore and Kellerman give the following as the number of parts of water to one part of copper sulphate in dilutions which will not injure fish of certain species:[a]

| | | | |
|---|---|---|---|
| Trout | 7,000,000 | Catfish | 2,500,000 |
| Goldfish | 2,000,000 | Suckers | 3,000,000 |
| Sunfish | 750,000 | Black bass | 500,000 |
| Perch | 1,500,000 | Carp | 3,000,000 |

These dilutions are presumably close to the death points in the particular water used and with the particular fish experimented with.[b] The trials on which the figures for trout (*Salvelinus fontinalis*) are based show the greatest susceptibility to copper sulphate yet observed for fish. They were made at Cold Spring Harbor, N. Y., and fatal results were obtained at 1 to 6,500,000 with fingerling trout during 24-hour exposures. At Bayfield, Wis., however, adult trout resisted 1 to 500,000 during this period. These are probably extreme cases. In the former algæ probably could not be killed in the presence of the trout, and it is the only case of its kind that has come to the attention of the writers.

[a] Copper as an algicide and disinfectant in water supplies. Department of Agriculture, Bureau of Plant Industry, Bulletin No. 76, p. 11, 1905.

[b] It is of interest to note in this connection that, according to Mr. Kellerman, copper-killed fish are of little use for table purposes on account of the rapidity of decomposition, which seems to proceed more rapidly than with those killed in the ordinary ways. Moreover, the dead fish have usually an unattractive appearance, due to the distention of gills and jaws.

Some laboratory experiments were made at the Bureau of Fisheries with brook trout fry and yellow perch. The trout fry were held in shallow dishes with about one liter of water. The dishes were floated on the surface of cold water to maintain a proper temperature, which was 52° F. or under during the trials. The dilution in the dish was aerated only by contact with the air. In every dilution tested 10 fry were used in each trial; 1 to 500,000 was fatal to most of these fry within 24 hours; 1 to 1,000,000 killed no fry during 48 hours. Intermediate dilutions killed a portion of the sample of 10 during 48 hours. Potomac water was used, having at this time an alkalinity of about 53 parts per million.

Adult yellow perch (*Perca flavescens*) were tried in 10 liter samples of the dilution made with Potomac water held in tall glass jars with only air surface aeration. One perch only was used in each trial. A dilution of 1 to 1,000,000 killed the fish within 24–40 hours; 1 to 2,000,000 was fatal after 48–64 hours in one case, while in another the same dilution was safe during 5 days; 1 to 2,500,000 was fatal after 68 hours; 1 to 3,000,000 was safe during 7 days.

Fingerling large-mouth black bass (*Micropterus salmoides*) proved much more resistant than adult perch. Under the same general conditions as those above described for perch a dilution of 1 to 100,000 killed the fish within 24 hours, while 1 to 200,000, as well as several weaker dilutions, did no harm during 5 days.

Moore and Kellerman in laboratory experiments found that the eggs and fry of large-mouth black bass and very young crappie fry were not injured by 1 to 1,000,000. Carp were found usually to succumb to 1 to 500,000.

Sunfish (*Eupomotis gibbosus*) in a turbid Potomac water dilution were not killed by 1 to 400,000 during 21 hours. Mummichogs (*Fundulus heteroclitus*) were killed by 1 to 750,000, but not by 1 to 1,000,000. The temperature of the dilution in these cases was 78°–80° F.

Silver nitrate has also a very high toxicity both to algæ and to fish. It is probably its expense alone that prohibits its usefulness for some of the same purposes for which copper sulphate is used. Chinook salmon fry about three months old are killed within 48 hours by a solution of 1 part of silver nitrate to 22½ million parts of water, while 1 part to 25 million parts of water is on the border line of safety, and killed a portion only of the several fry used in the test. No substance more poisonous to fishes is known to the writers.

## METHOD OF ADMINISTERING THE TREATMENT.

In the treatment of fish-cultural waters with copper sulphate there are, of course, from the mechanical standpoint, two kinds of water to be dealt with, namely, still water and flowing water. For still water the process is comparatively simple, only a single "dose" being required. Such treatment is, however, applicable only where renewal of the water may be dispensed with for the period during which the remedy is to act. With flowing water the case is more complicated, owing to the necessity of providing a continuing and uniform inflow of the copper sulphate solution adjusted to or varying with the water flow. To do this a convenient method is to dissolve the sulphate in water and allow the solution to flow into the water that is to be treated. The requisites to this operation require some special discussion.

The strength of the admixture (otherwise termed the dilution) in the pond or stream will depend upon four factors—(1) volume of the water flow that is to be treated; (2) volume of the solution of copper sulphate that is to flow into

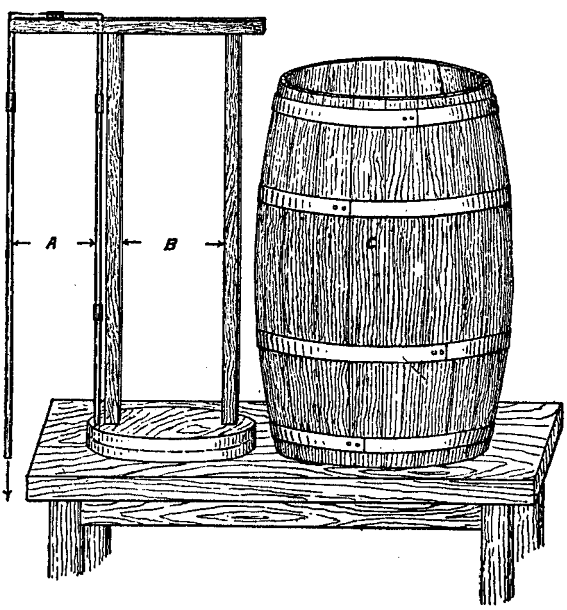


FIG. 1.


FIG. 2.

NOTE.—In each figure *A* is the siphon, *B* the frame, and *C* the container. The form of the frame is of course not essential, and should be adapted to the container. The illustrations show the glass tubing of much larger size than is necessary or practicable in small siphons. Small tubing is preferable.

it; (3) rate of flow of the solution; and (4) quantity of salt dissolved in the solution. The first factor is fixed and must be ascertained. The other three may be varied as convenient to produce the desired strength of admixture. Any two of these three being fixed, the desired result may be obtained by varying the other one. The delivery of the solution at an unvarying rate into the water flow is perhaps the greatest difficulty and is not to be accomplished by any of the ordinary means of delivering liquids from containers.

If a pipe or tube taps a reservoir containing the solution the head is constantly changing as the level of the solution in the reservoir is lowered. The flow of solution therefore gradually slows and the concentration in the water treated is constantly falling. If a fixed siphon is used the same difficulty is met. The rate of flow through the siphon depends on the head of the solution, and is therefore never constant. The simplest way to meet this difficulty is the use of a floating siphon, and this is an essential part of the method herein described. A siphon made of glass tubing with rubber connections may be mounted upon a wooden frame and the frame built upon a substantial float. The simplest carpentry suffices to adapt it to almost any shape or size of container. (See Fig. 1.) The frame holds the siphon in such fashion that one arm hangs outside the container and the other in the solution. The outer arm is made the longer, giving such head as is desired. The inner arm passes through the float, ending flush with its lower surface. The frame carrying the siphon floats on the surface of the solution, falling as the level of the latter is lowered. (Fig. 2.) The siphon always has the same relation to this level, and therefore the head is always the same and the flow constant. It is better that the frame be light in weight, relative to the base or float, so that it will float nearly upright, or else guides must be placed at the top of the container to hold the frame in position. This flow of solution may be delivered to the water flow directly or led to it by troughs or any convenient way.

## DETAILS OF THE CONTINUOUS TREATMENT.

The metric system is of such great convenience for the measurements and calculations involved that it is used throughout this description, a table for conversion to other units being given. It is worth while to calculate by the metric system, and, if measurements have to be made by other systems, to reduce them to metric units. The reason for this lies both in the advantage of decimal calculation and in the simple relationship of the metric units for weight and volume. For practical purposes 1 cubic centimeter (c. c.) of water weighs 1 gram, and 1 liter (1,000 c. c.) of water 1 kilogram, 1,000 grams, or 1,000,000 milligrams (mg.). Small metric graduates and rules are easily obtained. Weighing will more commonly be by avoirdupois, and conversion should be made. Some method of measuring small volumes should be available. A 1 cubic centimeter volumetric pipette graduated in fifths or tenths is very useful.[a]

For the actual use of fish culturists or others, the details of methods, procedure, and apparatus necessary to apply copper sulphate continuously to waters containing fish for the elimination of algæ or for other purposes, without injury to the fish, are as follows:

[a] Such pipettes, marked in tenths of a cubic centimeter, may be obtained for about 25 cents each from Eimer & Amend, 205 Third avenue, New York City; Arthur H. Thomas & Co., Twelfth and Walnut streets, Philadelphia; or Bausch & Lomb Optical Company, Rochester, N. Y.

## I. DETERMINATION OF PROPORTION OF COPPER SULPHATE.

It is first necessary to ascertain with a reasonable accuracy the amount of copper sulphate required to kill the fish which are in the water that is to be treated. Every species concerned should be tested. For this determination it will be sufficient at the beginning to make the test for 24-hour periods in standing water, with controls (i. e., extra or duplicate cans, of the same capacity, containing the same quantity of water and the same number of fish, the only difference between the two being that one holds copper sulphate dissolved in the water and the other does not). Fish cans may in most cases be used as containers for the dilution in which the fish are placed and for the control. Any receptacle large enough to hold a few individuals of the fish to be tested will answer for this. A stock solution, from which to prepare the above dilutions, should be made up in a glass bottle.

The stock solution may be made holding 10 grams of copper sulphate per liter of solution or, in other terms, approximately one-third of an avoirdupois ounce, or 146 grains, of copper sulphate, with enough water added to make 1 quart of solution, is a sufficient equivalent. Each cubic centimeter of this solution will then contain 10 mg. of copper sulphate. If the test is to be made with trout a test dilution of 1 to 1,000,000 may be made; that is, to 10 gallons (37,854 c. c., or 37,854,000 mg.) of water should be added $37,854,000 \div 1,000,000 = 37.8$ mg. of copper sulphate, or $37.8 \div 10 = 3.78$ c. c. of the stock solution. (The error in omitting to first remove 3.7 c. c. of water from the 10 gallons is negligible.) This test dilution should be thoroughly stirred. A few fishes should be introduced, not more than the water will readily support for 24 hours or more without artificial aeration, as shown by the control. The function of this extra or duplicate can or container, that of checking the result, is obvious. After a certain amount of experience it may be omitted.

If the fishes all die in the test dilution while those in the control are alive, a new trial should be made, using a weaker dilution. If they are all alive at the end of 24 hours, a new trial should be made, using a stronger dilution. When some of them live and some die during the 24 hours, the death point will have been nearly fixed. The trials should be continued until it is ascertained what is the strongest dilution of sulphate that may be used and yet leave all the fish alive at the end of 24 hours.

Having thus determined approximately the maximum amount of copper sulphate that can be safely used, the treatment may be begun with somewhat less than this amount. It is now necessary to determine the volume of water flow which it is desired to treat.

## 2. MEASUREMENT OF THE WATER FLOW.

If the flow is small and so delivered that the volume flowing during a few seconds or half a minute may be caught in containers, it may be measured directly. If the flow is too large for this or is through ground pipes, conduits, or ditches in one plane, other means must be resorted to. Technical methods, by the use of current meters, the pitometer, or weir measurements may be used where available. It is intended to discuss here only the simple methods open to anyone without the use of technical instruments.

Where the water is delivered into a pond of reasonably regular shape, it is often easy partly to draw off the water, measure the space thus drawn off, and calculate its cubic contents. The pond may then be allowed to fill up to the original mark and the time required noted. A fair estimate of the flow per minute may thus be readily obtained. If the delivery is below the surface of the water in the full pond a slight error is introduced by the change of head, which is decreasing as the water rises. This error may be minimized by lowering the pond only a few inches, or the least distance that will permit an estimate to be made. Often this estimate may be checked by the following method:

When the flow passes through a completely filled closed conduit the cubic contents of which may be measured, it is sometimes feasible to determine the speed of the flow through this conduit. This may be done by observing the time required for an object to be carried entirely through the conduit by the current, the instant of its entering and leaving this current at each end of the pipe being accurately noted. A block or ball of wood floating through the upper portion of the conduit is not a good instrument for determining the speed of the flow, being apt to scrape the inner surface of the conduit and be retarded; besides, the current is slowest next the surface and fastest in the center. A round, short-neck bottle may be weighted with shot and tightly corked, so that its specific gravity is almost exactly the same as that of water, and when completely submerged it will neither rise nor sink. It will thus remain (in shallow water) at about whatever depth it is placed, for a considerable time at least. If the bottle is of such length that it approaches the diameter of the conduit, say three-fourths of the diameter, it will, after starting properly, float submerged three-fourths of the cross section of the pipe, be thus acted upon by the currents of different rate and give a fair basis for the average speed of the water in the conduit. From this speed and the cubic contents of the conduit the volume delivered per minute is easily calculated.

Flow in open flumes or ditches can easily be measured. Simple modifications of the above method, which it is unnecessary to detail, will readily suggest themselves.

In a case where the writers applied both methods of estimating flow, the lowering and refilling a pond and measurement of speed in a closed pipe, 1,127 gallons per minute were obtained as the result by each method. The exact agreement was a mere coincidence, since these methods can not be presumed to have the degree of accuracy implied, but it indicates that flow may be estimated in a practical way by these means.

The more accurately the flow is known the more rapidly and confidently may the treatment proceed. But it is not necessary to refrain from the treatment even if no measurement of flow is possible. Any person practiced in estimating water flow with some accuracy by the eye may make a minimum estimate. Using this as a basis, a dilution of copper sulphate, much weaker than the susceptibility experiments indicate, may be assumed as safe. The treatment should then be cautiously begun with constant watching of the trout and testing them with food. As a fatal strength of copper is approached they will be thrown "off their feed." While they remain unaffected the strength may be gradually increased until the desired effect is obtained.

### 3. DETERMINATION OF VOLUME, STRENGTH, AND RATE OF INFLOWING SOLUTION.

The desired dilution and the volume of water flow per minute are now known. The volume of copper sulphate solution, the weight of copper sulphate crystals which are to be dissolved to make this solution, and the volume of flow per minute from the siphon to produce the desired dilution, are to be determined. These three may be mutually arranged in the way which is most convenient. Since it is less easy to change the siphon flow, or to make a siphon which will have exactly a given and predetermined flow, it is better to adjust the volume of solution and weight of sulphate to the fixed siphon flow whatever it is found to be after setting up and starting. The siphon may be made to deliver small amounts, even drop by drop, if desired. A flow of 20 c. c. to 100 c. c. or more per minute covers most cases. The flow should not be so large that renewal of the solution is too often required. If the siphon flow first hit upon is not within reasonable limits it may be increased by lengthening the outer arm or by increasing the diameter of the orifice in the siphon nozzle. It may be decreased by shortening the outer arm.

Having now the siphon flow determined, as well as the dilution and the water flow, the volume of the sulphate solution and the weight of sulphate to be dissolved for one filling of the container of the solution remain to be fixed. It will be natural to approximately fill the container. The volume is thus fixed and the weight of sulphate must be adjusted with reference to it. On the other hand, if only a given weight of sulphate is available, too small an amount to make the desired solution fill the container, the volume of the solution may be adjusted with reference to this weight of sulphate, instead of vice versa.

The relationships of the five factors may now be given in the shape of formularies. To use these it is better to reduce the water flow per minute to milligrams, though the figures may seem unwieldy. This is done by reducing it to liters and multiplying by 1,000,000.

The proportion (by weight) of the copper sulphate to the water is here designated for brevity and convenience as the "dilution;" e. g., a dilution of 1 to 1,000,000, or 1 : 1,000,000. In formulæ and in computing, the figure expressing the copper sulphate is omitted, as, "dilution" = 1,000,000.

If $a$ is the dilution, and $b$ the water flow in milligrams per minute, then $\frac{b}{a}$ = milligrams of copper sulphate necessary to flow through the siphon every minute.

If $c$ is the siphon flow in c. c. per minute, then $\frac{b}{a \times c}$ = milligrams of copper sulphate which each c. c. of solution must contain.

If $z$ = the number of milligrams of copper sulphate to be dissolved, and $y$ = the number of c. c. of copper sulphate solution to be in the container at the beginning; then

If $z$ milligrams of copper sulphate are to be dissolved, $\frac{z \times a \times c}{b}$ = number of c. c. of solution to be made.

Or, if $y$ c. c. of solution are to be made, then $\frac{b \times y}{a \times c}$ = number of milligrams of copper sulphate to be dissolved.

These expressions are put in words as follows:

Divide the milligrams of water flow per minute by the dilution; the result is the milligrams of copper sulphate necessary to flow through the siphon every minute.

Divide the milligrams of water flow per minute by the product of the dilution multiplied by the siphon flow in c. c. per minute; the result is the number of milligrams of copper sulphate which each c. c. of solution must contain.

Multiply together the dilution, the siphon flow in c. c. per minute, and the number of milligrams of copper sulphate to be dissolved; divide the product by the number of milligrams of water flow per minute; the result is the number of c. c. of solution to be made. But, if the latter has already been decided upon, and the number of milligrams of copper sulphate to be dissolved is unknown, then:

Multiply the number of milligrams of water flow by the number of c. c. of solution to be used; also multiply the dilution by the siphon flow in c. c. per minute; divide the former product by the latter product; the result is the number of milligrams of copper sulphate to be dissolved.

The solution should be made by dissolving the necessary weight of sulphate in a relatively small amount of water and then "making it up" to the necessary volume by the addition of more water. If this volume of water is taken at the beginning the solution will be too large, since the sulphate crystals add to its volume. In some cases the error involved is negligible.

## SINGLE-DOSE TREATMENT.

In the application of copper sulphate to large ponds which have a rather small water flow and in which the circulation is therefore sluggish and the same water remains in the pond for a considerable period, the treatment by a continuous flow of solution is not so effective as that by "single dose." The reason is that all waters that support fishes are slightly alkaline, and this alkalinity slowly precipitates the copper from solution. The writers have tried the siphon treatment twice in bass ponds with very little effect, although a much stronger dilution was used than was effective in trout ponds having a much more rapid circulation. In the case of these bass ponds the effect on the algæ was shown only about the intake to the ponds, and did not extend more than 25 or 30 feet from the point where the water entered. The reason for this restriction of the toxic action is taken to lie almost entirely in the prolongation of the time factor. To be effective the sulphate after it is dissolved must come quickly in contact with the algæ. The water moves very slowly through these ponds, and during this time the copper is being constantly precipitated from solution. In the precipitated form it does not impregnate the water uniformly, as in the case of a solution, but is gathered in minute particles which moreover do not have the intimate contact with the algal filaments which is necessary in order to exert a toxic action.

In large sluggish ponds, therefore, it is better to treat them with one dose of copper sulphate, the dilution being calculated to the whole volume of water in the pond. In other words, a given amount of sulphate is added at one time, as if the pond were a body of standing water without a current flowing through it. There is no continuous addition of the sulphate. In applying this treatment the flow may be actually cut off during the process if the fishes will endure this temporary loss of water supply; or an allowance may be made for the water entering during this period; or the inflow may be ignored if the pond is large. With a knowledge of the actual conditions, a choice may be made among these alternatives. In pond culture a constant flow of water to a pond is unusual except for supplying small-mouth black bass. The other species reared by pond culture,[a] chiefly large-mouth black bass, sunfish, and crappie, do not require a constant flow and it is customary merely to supply

[a] See Titcomb, Aquatic plants in pond culture, Bureau of Fisheries Document No. 643, p. 5.

sufficient water to compensate for evaporation, seepage, etc. If the bottom of the pond has considerable springs of water the volume delivered may be taken into account as far as it is possible to do so in calculating for the dilution, unless it is small enough to be ignored.

The first step is to determine the susceptibility of whatever fishes are held in the water to be treated. This will be done in quite the same way as already described under the siphon treatment. Pond-culture fishes will for the most part endure more copper sulphate than trout. The total volume of water in the pond must then be ascertained. The dilution to be used will be indicated by the susceptibility, allowing an ample factor of safety. The milligrams of water in the pond divided by the dilution will give the milligrams of copper sulphate to be used. This will be readily reduced to pounds or ounces or other unit and the amount weighed out. It may be placed in a bag of cheese cloth, burlap, or of other loose-meshed material, and dissolved in the pond by dragging it about at the surface from the stern of a boat.[a] The more thoroughly all parts of the pond are traversed the more uniform the distribution of the sulphate.

If the algal growth is very abundant only part of it may be killed by the first treatment. When there are large masses of algæ all the copper may be used up before the whole of the mass is destroyed. After algæ have grown unchecked in ponds for a long time the growth may mat heavily together, or where there is a current it may form long strings or ropes. These more densely massed bodies of algal growths are less susceptible to treatment. The outside strands may be killed while the inner portions remain alive, being protected by the outer. In such cases as these the dose may be repeated after an interval of time, as a few days or a week. If the pond can once be made free of algæ, it is much easier to keep it so than to kill off heavy growths. It is not always possible, however, to eliminate all growths while fish remain present. The species of algæ vary considerably in their susceptibility to copper, and some may therefore survive on account of their natural resistance to the strongest dilution the susceptibility of the fishes concerned permits to be used.

## MISCELLANEOUS DIRECTIONS AND CAUTIONS.

To make the siphon which is to be attached to the float, glass tubing with rubber connections should be used. The smaller sizes of tubing are preferable, that with an outside diameter of 4 to 6 millimeters, or five-thirty-seconds to one-fourth inches, being convenient. The tubing should be bent approximately at right angles to make the turns at the top of the float, the bending being done best by heating in the yellow flame of an ordinary gas jet. The tubing should

[a] Moore and Kellerman, op. cit., 1904.

be held to coincide flatwise with the upper edge of the flame, meanwhile turning slowly on its own axis, until it softens. The flame of a large kerosene lamp or of an alcohol lamp will answer, but will not make as good a bend.

Glass tubing may be neatly broken without cracking by slightly scarring its circumference with a file at the desired point and then, by grasping the tubing firmly with both hands, one on each side of the scar, pulling strongly in a longitudinal direction, making simultaneously a slight stress at right angles. A clean break will occur exactly at the scar.

Nozzles, which are convenient as ends to the outer arm of the siphon, may be made by drawing out in the flame several short pieces of glass tubing and breaking off at some point along the constriction. They may be attached by means of the usual rubber-tube connection. They are not necessary to deliver the flow, and the outer arm may end merely by breaking off sharp; but they give this advantage, that the length of the outer arm, or the size of its orifice, or both, may be quickly changed with their aid, and thus the siphon flow may be quickly and easily varied. For convenience a number of these nozzles may be made, differing sufficiently in length or orifice to give different flows and marked or labeled accordingly. By inserting a given nozzle a given flow may be quickly obtained or a change quickly made. In making these changes care must be taken not to change the length of the siphon arm above the point of attachment of the nozzle if the labeled flow is desired.

It is of course absolutely necessary that there be an intimate mixture between the solution flowing from the siphon and the water flow which is being treated; otherwise a uniform dilution will not obtain. The sulphate will be too strong in places and too weak in others, which may cause the loss of fish and fail to kill the algæ or accomplish the purpose desired. For this reason it is well to deliver the siphon flow at the beginning of the conduit, so that mixing may occur as the water flows. The agitation and mixing at the bulkheads of ponds usually makes a uniform distribution of the sulphate. It will not do to deliver the sulphate at a point where the water inflow to a pond enters quietly with little fall, causing no mixing swirl. It may sometimes be necessary to provide special means for stirring to obtain a mixture.

The stock solution of copper sulphate should not be kept in containers made of ordinary metals. No metals should be allowed in any way to come into contact with the solution. If the flow of sulphate solution to the water has to be conveyed by troughs they should be of wood. Galvanized iron or tin is soon eaten through, and usually can not by painting be sufficiently protected from the action of the copper sulphate. Weak dilutions, however, such as those used for testing susceptibility of trout, may be used in fish cans. The sulphate is not strong enough to attack the metal notably.

It is necessary to avoid leakage from any containers holding the solution in the vicinity of ponds containing fish, since the leak may easily find its way into the ponds.

Special care should be taken in all the calculations and they should be reviewed before the treatment is begun in order to correct mistakes and to see that all factors have been taken into account. The measuring of the water volumes in fish cans and in the solution container, and the weighing of the sulphate for this solution, need but ordinary accuracy. The volume of the stock solution and the weight of the sulphate to be contained in it, however, should be determined with special care and accuracy, since the quantities concerned are small and the error is of greater importance. The scales or balances used should weigh to fractions of ounces.

The difficulty of weighing fractions of ounces in making the stock solution where delicate scales or balances are not available may be obviated by making several times the volume stated, thus using a greater weight of sulphate; or by making the stock solution several times too strong and then properly diluting it. In much the same way portions of the stock solution may be measured in the absence of measures of small volumes. The least conveniently measurable portion should be taken, diluted accurately, the proper portion of the dilution used, and the rest thrown away.

The cost of commercial copper sulphate is about 10 cents per pound in small quantities and about 8 cents in large quantities. It is in the form of crystals, which contain five molecules of water of crystallization. This fact is expressed by the chemical formula $CuSO_4 + 5H_2O$. The weight of these crystals is therefore made up of about 36 per cent water. No account is taken in this paper of this water of crystallization. All references to copper sulphate, or to the strengths of solutions of copper sulphate, or to the dilution, are based upon the crystallized commercial substance consisting in part of water. The actual amount of the anhydrous chemical compound, copper sulphate, actually contained in the solution, in the dilution, etc., is about 64 per cent of the amounts stated. This fact interferes in no way with the calculations used for the treatment herein proposed. In quantitative chemical calculations, however, it is necessary to take account of the water of crystallization.

Clean rain water, or distilled water, is better for making the stock solution than spring or creek water.

The sulphate is best dissolved by suspending it in a burlap or loose-meshed bag near the surface of the water in the container. It then dissolves rapidly and without attention, the heavier solution tending to sink. Stir thoroughly after all crystals are dissolved. If the crystals are at the bottom of the container they dissolve very slowly unless constantly stirred.

The first effect to be seen upon the algæ when the concentration reaches the toxic point is a slight fading of the natural color. When killed the algæ filaments become gray and shrivel markedly, occupying much less space than while alive. The effectiveness of treatment is increased in warmer water.

While trout are considered the most susceptible of the species used in fish culture, there are probably some exceptions, at least under some conditions, as not all species have been tested. Several white suckers at White Sulphur Springs in one instance succumbed to a treatment which did not injure trout in the same waters. Care must be always exercised in the matter of susceptibility.

Great care should be exercised in the manipulation of the copper sulphate salt, the copper sulphate solution, and in the calculations. The substance is not a very deadly poison, yet it may have unpleasant effects upon the human system. Ordinary handling of the salt or the solution will result in no trouble. The siphon should not be started by mouth suction directly on the siphon arm, however. A moderately strong solution taken into the mouth results in a very disagreeable irritation of the mucous membrane and sometimes nausea. Attach a small rubber tube to the siphon nozzle and fill the whole siphon tube by suction; then pinch rubber tube to prevent back flow and detach it; the flow will start.

## ILLUSTRATIVE AND SUGGESTED APPLICATIONS OF THE TREATMENT.

### AT BAYFIELD, WIS.

The first experiment in the treating of water by this method on a considerable scale was made at the Bayfield station of the board of fish commissioners of the State of Wisconsin. A flow of 1,127 gallons of water per minute was treated continuously for 47 days with copper sulphate so that a dilution was maintained varying from 1:1,250,000 to 1:1,700,000. The dilution was varied at will from time to time for various reasons. Upward of 15,000 brook, brown, and rainbow trout from 2 to 3 years of age were held in this water, and during the treatment no injury was done to any of them. The immediate result of the treatment was the cessation of trouble with algæ in the ponds affected by the flow, a trouble consisting chiefly in the necessity of frequent cleaning of the screens at the outlets of the ponds. The treatment ceased on July 1. Thereafter during the summer the algæ sprang up again, and much attention was necessary to the screens to keep them free of the clogging strands of the filamentous species common in these waters.

This effect upon the algæ was not the purpose sought in this experiment at the Wisconsin station, but was incidental thereto. For several weeks of each summer the brook and other trout at this station are attacked by bacterial infection, the specific cause of which has been described under the name *Bacterium truttæ*. The ravages of this parasite are worst while the temperature ranges between 50° and 60° F. Copper sulphate even in weak dilution inhibits its action. It was therefore thought that by impregnating the water continuously with this salt, at a dilution harmless to the trout, during the few weeks while the disease usually prevailed, the loss caused by it could be prevented. On account of a break in a conduit and the loss of a large number of the experimental fish from certain ponds, the results of this trial were inconclusive. The total losses in the ponds affected, as compared with those in control ponds, so far as they are of any significance indicate a considerable inhibition of the disease among the brown trout, but the demonstration is not sufficient to set up a claim of practical prevention of the disease in question. The value of this application is for the future to determine. But the particular experiment cited is held to demonstrate the feasibility of long-continued treatment of large volumes of flowing water containing trout with dilutions of copper sulphate of sufficient strength to have an inhibitive effect upon bacterial parasites of fishes and to be at the same time harmless to trout. The expense moreover is well within the means of fish cultural operations. In the case cited it was less than $1 per day. The volume of water treated was unusually large, being more than 1,000 gallons per minute.

### AT WHITE SULPHUR SPRINGS, W. VA.

At the United States fisheries station at White Sulphur Springs, W. Va., copper sulphate was applied to the water supply of ponds containing trout for the specific purpose of eliminating troublesome algæ. A floating siphon apparatus was used, similar to that already described, but on a much smaller scale. By 24-hour trials of a few fry in fish cans with copper-sulphate solutions of different strength, the approximate strength which the species would endure for this period and in the given water was ascertained to be about 1 part of sulphate to 3,000,000 of water. The flow of water was estimated at 1,000 gallons per minute. The siphon flow was adjusted so that the above strength was applied to the whole flow. Within 24 hours a marked effect upon the algæ was visible, and a few trout in the raceway which conveyed the water to the ponds were killed. None of the trout (both fingerling and adult brook and rainbow) in the ponds were killed, but the sulphate was not without its effect upon them. It was noticed that the fry either did not feed with their accustomed readiness or refused food altogether. Like cattle and other domestic animals, they were "off their feed." On this account the strength of the solution was readjusted so that a 1 to 4,000,000 flow was maintained in the ponds. In the case of this dilution there was still a noticeable effect upon the trout, as evidenced by their refusal to take food. With young fish—fry and fingerlings—this effect was seen after about 8 hours' application of the treatment. With adult trout it was not noticeable under 20 hours, but after this period they also refused food. If the treatment was discontinued at the end of 24 hours, both fry and adults would resume feeding with their accustomed vigor within the next 24 hours.

The use of the 1 to 4,000,000 dilution, repeated about once a week for a duration of 8 hours each time, proved sufficient to keep down the algal growths without harm to the fish. The cost of the copper sulphate used in this treatment was at the rate of about 30 cents per 24 hours.

In the summer of 1907 a pond of an area of 0.68 acre and with an average depth of 18 inches, containing 28 adult large-mouthed black bass and several thousand advanced fry, was treated with 4 pounds of copper sulphate in single dose. The treatment was entirely effective in destroying the algæ and, as far as could be seen, without the loss of a fry or an adult.

### AT FISH LAKES, WASHINGTON, D. C.

As a part of some joint experiments conducted by the Bureau of Plant Industry and the Bureau of Fisheries two small ponds, each containing a few adult bass ready to spawn, were treated on April 22 with copper sulphate in a dilution of 1 to 5,000,000. The water subsequently became roily, so that observations could not be made on the nesting and spawning bass, but on May 8 a fine brood of bass fry was observed. With the disintegration of the algæ myriads of *Daphnia* appeared. On June 12 a pond of 1.55 acres, with an average depth of 20¾ inches, was treated with 1 to 5,000,000. This pond contained adults, fry, and baby fingerlings of the large-mouth black bass. Careful observations about the pond and of the young fish seined from it daily after the copper was administered showed no harmful effects upon the fish. By June 22 much of the algæ had disappeared, comparatively little remaining. Its disintegration caused the water to impart a very offensive odor when stirred.

This dilution was far weaker than any which, as far as experiments indicate, could in the least harm the species of fish concerned, but it was nevertheless strong enough to eradicate the particular growths of algæ then existing in the ponds.

### FURTHER POSSIBILITIES OF THE TREATMENT.

The success of the copper-sulphate method of treating fish-cultural waters for the removal of a mechanical nuisance indicates successful fish-cultural application of the remedy in other directions. The administration of remedies for disease in the lower animals is familiar in the case of the farmer's live stock and other domestic land animals, being the science of veterinary medicine. Upon fishes, however, medical treatment has been practiced but inconsiderably, notwithstanding the fact that they, too, have been brought under domestication and are subject to all the increased susceptibility to disease that is always consequent upon this more restricted life. The difference is due in part to the relative youth of the science of fish culture and the, so far, relative absence of disease, and in part to the difficulty of administering medicine in the presence of water, from which the fishes can not long be separated. It is obvious, however, that with a remedy that may be applied externally and a process for applying it by means of the water the fish live in, important possibilities are at hand. If copper sulphate, for instance, can be shown to be toxic to the pathogenic bacteria and external parasites of fishes in dilutions yet harmless to the fishes themselves, it will have a much wider usefulness in fish culture than its present application. The only experiments to this end so far undertaken have been inconclusive, but future experiments may be expected to show useful results in this field.

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## TABLE OF METRIC EQUIVALENTS.

| | |
|---|---|
| 1 centimeter | =10 millimeters=0.3937 inches. |
| 1 gram | =1,000 milligrams (mg.)=15.43 grains. |
| 1 avoirdupois ounce | =28.35 grams. |
| 1 apothecaries' ounce | =31.10 grams. |
| 1 avoirdupois pound | =453.6 grams. |
| 1 fluid dram | =3.70 cubic centimeters. |
| 1 gallon | =231 cubic inches=3,785.4 cubic centimeters (c. c.). |
| 1 cubic inch | =16.387 cubic centimeters (c. c.). |
| 1,000 c. c. | =1 liter. |
| 1 teaspoonful | =1 dram, or 3.7 c. c. |

1 c. c. of pure water weighs 1 gram.

Ordinary teaspoons are variable and usually hold more than 3.7 c. c. Medicine glasses graduated in teaspoonfuls (drams) may be obtained at any drug store.

# NOTES ON THE DISSOLVED CONTENT OF WATER IN ITS EFFECT UPON FISHES

By M. C. Marsh
*United States Bureau of Fisheries*

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# NOTES ON THE DISSOLVED CONTENT OF WATER IN ITS EFFECT UPON FISHES.

By M. C. MARSH,
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## NATURAL IMPURITIES IN WATER.

Since fishes are confined to water as their natural habitat, and since water strictly pure scarcely exists naturally upon the earth, they live habitually in water containing a certain amount of foreign substance in solution—in other words, in impure water. There is also nearly always some foreign matter held mechanically. Since these so-called impurities may vary greatly in kind and degree, the study of the reactions which take place between fishes and impure waters of various nature can not fail to be of both theoretical interest and practical importance.

It is profitable to inquire first whether these impurities are merely incidental to the life of the fish as they are to the water, or are essential and necessary. That air dissolved in the water is necessary to support fishes is a matter of common knowledge and observation, for they die quickly if the water is not aerated. It may likewise readily be shown by experiment that water containing dissolved air alone is not sufficient even though plenty of food is supplied. For this purpose, 5 liters of water were distilled through glass apparatus. Contrary to what seems the general impression, distilled water has considerable air dissolved, even immediately after the distillation. A portion of this water from the receiving flask was tested for oxygen during the distillation and contained, at 15° C., 5.48 c. c. of oxygen per liter. Twelve quinnat salmon fry in the sac stage were placed in the 5 liters of water in a glass jar, with a current of air in small bubbles constantly passing to the bottom of the jar and bubbling up through the water. A control was set in exactly the same way, save that Potomac tap water was used instead of distilled water. Three and one-half hours after the beginning of the experiment, the water in each jar being at 14° C., oxygen was determined. The Potomac sample held 7.25 c. c. per liter, the distilled sample 7.09 c. c., each therefore almost air-saturated with oxygen. In the distilled water, after 24 hours, 2 fry were dead, after 27 hours 3 fry, after 37½ hours all were dead. All the fry in the control remained alive. During the experiment the aeration of the control was never greater than that of the distilled sample, and was usually less.

Rain water was tried in substantially the same way and with mummichogs, sunfish, perch, and trout, with the same result. The mummichogs were the most resistant, living 41 hours.

One is led to conclude from this that foreign matter other than dissolved air is a necessary accompaniment of water that supports fish life, and that water can be too pure for fishes. The law is probably of wide application, for low forms of life are known to die readily in distilled water. It is natural to infer also that death is brought about in these cases by some osmotic reactions through the gills, which bring the blood, known to contain various salts essential to the life of the fish, into intimate relation with the water. It is an assumption open to several objections to explain the death as due to the dissolving out of salts or other substances from the blood. Certain obscure poisonous products are believed to be generated in the distillation of water and, conceivably even in rain water, these may have a toxic action on fish. If so, their toxicity is neutralized by contact with many simple substances. It is known that some toxic principles in ordinary water are thus neutralized, as will appear later.

For practical fish-cultural purposes it may be assumed that a certain minimum of dissolved solids is necessary to water before it is suitable for fishes, and no doubt there is also a maximum which should not be exceeded, though a wide adaptability must exist, as some fishes can frequent both fresh and salt water. Where either of these limits lies can not be at present stated. Of course natural waters which contain fishes furnish the safe conditions both as to quantity and quality of these necessary impurities, which are common substances—carbonates, sulphates, chlorids, in combination with calcium, magnesium, sodium, and other common metals. Potomac water had in October, 1905, 240 parts per million; the spring water at the White Sulphur Springs (W. Va.) hatchery had in February, 1906, 484 parts. Neither of these amounts is objectionable so far as known. Many waters have a total solid content below 50 parts per million, and fishes inhabit waters containing no more than 20. It is perhaps true that water with much less solid matter than this would support fishes. It would be interesting to find if possible some natural water fatal to fishes solely on account of its high purity.

It seems that these considerations about the quantity of dissolved solids may become of some practical importance when fish are transferred from one water to another, as from one high in total solids to one low in total solids. Possibly one water may differ so greatly from another in this respect alone that a gradual transfer by slowly mixing the two waters is advisable, in order that the fish may adjust itself from the one to the other. Trout, for instance, do not always thrive after transfer, even when both waters seem admirably adapted to the trout already in them.

## POISONOUS SUBSTANCES.

The substances the variations of which have been referred to are substances not harmful in themselves; that is, the action is not a poisonous one. Substances not commonly held in natural waters are usually unfavorable in their action upon fishes, and in some cases there is a poisonous action tremendously greater than with the same substance in higher animals. For instance, copper sulphate is not extremely poisonous to mammals, but 1 part to 6½ millions of water has been observed to kill domesticated brook trout within 24 hours. The fatal amount varies greatly even with the same species in different waters. At the state hatchery at Bayfield, Wis., brook trout were not killed until the concentration reached 1 to 400,000. Some waters precipitate the copper faster than others, but there was probably also a greater resistance to copper sulphate among the trout themselves. General statements of fatal concentrations of such salts must apply only to the water in which the experiments were made and to the fish adapted to that water.

Silver nitrate is even more highly toxic than the salts of copper. In experiments with Chinook salmon fingerlings three months old, one part of silver nitrate to 20 million parts of water was fatal in a few hours and 1 to 22½ million was fatal within 48 hours. With 1 to 25 million the solution is so dilute that about half the number of fish used were killed during 48 hours, the rest surviving; 1 to 30 million and weaker solutions had no recognizable effect.

Many of the metals are poisonous to fishes by lying in the same water with the fishes. Copper is the most active of the common metals in this respect. Twenty square inches in about 6 quarts of Potomac water killed 8 of 10 salmon fry within 24 hours. Ten square inches in the same amount of Potomac water killed 4 of 6 free swimming salmon fry within 2 days and 18 hours and all of them within 3 days and 2 hours. The temperature was never higher than 68° F., and the controls were good.

Zinc, lead, and aluminum are toxic in the order named. Even tin seems to have a very slight poisonous action. In vessels of any of these metals harm to fishes is nearly always prevented by even a slight flow of water. It is when the water is not changed that the injurious action is seen. Iron seems to have no effect. Galvanized iron and lead, and asphaltum and enamel paints all have more or less toxic action, but containers made of or painted with these substances become less harmful with use. Usually considerable time is required before the toxic substance becomes in sufficiently concentrated solution in standing water to have an effect, and this is the reason such containers are often used successfully for transporting fishes. They have, however, been repeatedly identified with certainty as the cause of loss of fish.

Various industrial wastes are of course injurious in sufficient concentrations, but the actual effect of some of these has been exaggerated, perhaps partly because they are sometimes highly colored and of unsavory appearance. Paper-pulp mills which use the sulphite process spend a dark-brown liquor of strongly acid reaction which contains, besides the chemicals used for extraction, the extractive matters themselves, organic compounds of comparatively complex nature. These latter are themselves often toxic to fishes, as well as the extracting agent, and the effluent containing both is presumably always quickly destructive to fish life in its undiluted condition. When discharged into streams it quickly undergoes great dilution, and it becomes of interest to know at what point it is rendered harmless. A sample from Covington, W. Va., at a dilution of 1 to 200 did not injure salmon fry during 2 days. It is evident that tremendous amounts would be required to raise the water of a stream of any size to a fatal concentration. It has been suggested that when wastes containing sulphites kill fishes the loss of dissolved oxygen due to the reducing power of the sulphite contributes to the result by tending to asphyxiation. A sample experimented with by the writer had little or no reducing action on the dissolved oxygen in the water, and it is likely that it kills by its direct action alone.

Other industrial pollutions, such as the wastes of paper-pulp mills using the soda process, tannery wastes, and dye wastes from knitting mills, will kill fishes, but the most toxic of them are made harmless to such fishes as black bass and yellow perch by the addition of a few hundred parts of water, usually 200 parts. Wastes from the manufacture of illuminating gas, however, require some hundreds of thousands parts of water to dilute them to harmlessness. The water soluble substances in bark and in the wood of some trees are capable of killing fishes, but while such products are undesirable in streams the amounts of bark and wood necessary to affect fish in flowing streams are so large that it is not likely that they do much direct damage to fishes by the substances which dissolve from them.

Tobacco ashes have been said to kill trout fry in transportation cans. After trials with salmon fry no effect whatever could be detected unless the fry were in the sac stage and lying on the bottom with the free ash, when they would suffocate from clogging of the gills. If the ash was wrapped in a cloth or if the fry were free swimming there was no effect. It is possible that the ash from other samples of tobacco would give a different result.

Fishes are very susceptible to acid water and succumb to the mineral acids in very weak solutions which scarcely taste sour. Hydrochloric acid kills mummichogs and sunfish when enough has been added to destroy the alkalinity and make about 8 parts of acid per million. Some 40 hours were required for the sunfish. The mummichog or bull minnow is more susceptible than the sunfish.

About 12 parts of sulphuric acid per million kill the same species within 24 hours. According to the degree of alkalinity of the water considerable acid may be added before the water becomes acid in reaction.

This matter of changing the reaction of water is important in connection with some industrial pollutions. An interesting case occurred during the spring of 1905 in the Potomac above Cumberland, Md. A large number of fishes, largely minnows, were found dead and dying along the shore, and still greater numbers were sick and weak and could be picked up in the hand. Twenty-nine miles above Cumberland a paper mill sewers into the river a highly alkaline waste, several tons of lime sludge passing in daily. Shortly below this point Georges Creek enters, carrying an acid waste from the coal-mine regions. It contains free sulphuric acid and salts of acid reaction. The creek water is distinctly sour to the taste and is said to contain no life of any sort. When the two wastes mix at and below the mouth of Georges Creek they neutralize each other, and besides improving the river from a sanitary standpoint permit the fishes of the river to thrive. They must be usually fairly well balanced, since fishes have usually been in some abundance. In October, 1900, on the occasion of a sudden occurrence of dead fishes in the river a sample of water was reported to contain free sulphuric acid, to which the loss of fishes was attributed. On the more recent occasion referred to the water, which was only examined as the fishes were recovering, was not acid, but the alkalinity was reduced, was very low and was rising, and therefore the probability is that the river had just been acid and was recovering its normal alkalinity. It could hardly be expected that the two extensive pollutions mentioned would be invariable in amount, and it can hardly be doubted that the acid occasionally predominates and kills fishes. The acid pollution is by far the more important in its effect upon fishes.

The courts have on occasion held that in the case of coal-mine wastes damages can not be collected nor the mine owners enjoined, since the pollution is a natural one and occurs to some extent independently of mining operations. In the instance cited it would seem that each pollution is the salvation of the river from the other; that the net result is a beneficial one, and that it would be unwise to meddle with either unless it were possible completely to remove both.

Some natural waters have been observed to acquire a selective toxicity by remaining in tin cans for some time. They become, for instance, fatal to rainbow but not to brook trout. During the spring of 1907 some results in this respect of much interest were obtained from the city water of Norfolk, Va. Samples transported in new tinned fish cans were uniformly fatal to fry of the rainbow trout, but had little effect on brook-trout fry. Samples transported in tinned fish cans which had been in use a long time and become rusty on the inside gave contradictory results but were often likewise toxic, though less markedly so, while samples carried in glass containers had no toxic quality. No toxicity was imparted to Potomac water by repeated and long-continued trials in such cans. The toxic element in the water was not identified, but it is of interest to find that it was destroyed or neutralized by some very simple means. Boiling made the water harmless, and heating to 75° C. greatly reduced the poisonous effect. It was also corrected in large part, sometimes almost completely, by the addition of a portion of either sea water, common salt, calcium sulphate, sodium carbonate, residue from the evaporation of Potomac water, or ordinary earth.

Water brought in fish cans from Newport News, Va., had a similar selective toxicity and was corrected by most of the agents mentioned above and also by the presence of fish in the water, especially by the dead bodies. Thus a sample of this water by standing with the bodies of the fry it had killed became less able to kill other fry of the same species. Shaking and soaking with bone black diminished the toxicity somewhat. These experiments suggest that for aquarium exhibits on close circulation or for the temporary holding of fish in standing water, water which it is dangerous or impossible to use may be made fit for fishes by dissolving in it some of the cheap and easily procurable substances mentioned.

## ABNORMAL GAS CONTENT.

### DISSOLVED AIR CONTENT OF WATER FROM A DRIVEN WELL.

This well was driven in May, 1906, and is 83 feet 10 inches deep. It passes for most of the distance through clays, which include two strata of water-bearing gravel and sand between the 34 and 52 foot levels, and finally takes water from fine sand and coarse sand and gravel beyond a depth of 80 feet. A 6-inch casing reaches the whole depth of the well and contains a 4-inch pipe through which the water is pumped. The casing is perforated for several feet near the 50-foot level, so that the water-bearing gravel at this level contributes to the supply of water.

The water level in the well stands about 21 feet below the surface of the ground. The electric pump installed was able to lower the level to about 28 feet, where it remained constant. The pump as ordinarily run delivered 24 gallons per minute, but could be made to deliver 32 gallons per minute. The temperature of the water was about 15° C. (60° F.).

It was intended that the water be used in the trout aquariums during the summer in order to avoid the expense of refrigerating Potomac water. On April 11, 1907, the water was turned into an aquarium containing trout. They soon showed marked distress and the water was then shut off. The next day the pump was started again and by delivering part of the flow into a glass jar it was seen that a continuous stream of minute bubbles of gas was always contained in the water issuing from the well. On dippering the water in the jar a marked white cloudiness caused by very minute bubbles appeared after a fraction of a minute. This cloudiness disappeared after a few minutes and the water became quite clear. On dippering again the same occurrence took place, and this could be repeated several times before the water ceased to cloud upon dippering.

Trout placed in a jar of the water just as it was delivered from the pump were immediately in great distress and within one minute turned over apparently suffocated. If then immediately removed to Potomac water, they revived. Trout placed in the well water after dippering it considerably lived a few hours, but then died. From the behavior of trout in the water and the release of gas from it, it was inferred that the water had a considerable excess of nitrogen or carbon dioxide, or both, and at the same time a very marked deficiency of oxygen. A determination of the oxygen alone showed only 0.2 c. c. per liter of water, while the water was probably capable of taking up from the atmosphere at least 30 times this amount of oxygen. The lack of oxygen accounted for the immediate suffocation of trout.

By various experiments in exposing the water to the atmosphere, such as allowing a slender jet of it, issuing with considerable force from a glass tube drawn out to a small orifice, to impinge upon the center of the bottom of a tall glass cylinder or battery jar laid horizontally, it was found that brook trout would live in the water thus very thoroughly exposed to air. The introduction of air into the water by means of the usual linden wood liberators accomplished the same end provided there was no renewal or flow of water. It was necessary in the case of a large aquarium full of water to let the air current flow for some time before introducing fish in order to give the water a chance to take up enough oxygen to keep the fish from immediate suffocation while the oxygen content was further increasing.

The method mentioned above of breaking up in part into spray a jet of water, even when three air liberators were delivering finely divided air into the aquarium which received the water, did not succeed in air saturating the water with oxygen. That is, it did not fill the water with as much dissolved oxygen as it was capable of absorbing from the air. It raised the oxygen content, however, from 0.2 c. c. to 4.6 c. c. per liter. By cutting off the flow of water and allowing the liberators to run air into the tank full of standing water for some 40 hours in the presence of two yearling brook trout the water then held 6 c. c. of oxygen per liter at 11.5° C.

The water was thought of such interest on account of its peculiar air content and other features that a determination of the nitrogen dissolved was desirable. Accordingly a number of samples were boiled and the constituents of the gas obtained in this way determined quantitatively by absorption. The following table gives the results for the water just as it is delivered from the well and before it has undergone any appreciable exposure to the air:

Table I.—Carbon Dioxide, Nitrogen, and Oxygen in Cubic Centimeters per Liter of the Untreated Water from the Electric Pump.

[In all tables the gases are reduced to 0° C. and 760 mm. (of mercury) pressure, and corrected for tension of aqueous vapor. These are the standard conditions for stating gas measurements.]

| No. | Date. | Temperature of water. | $CO_2$. | N. | O. |
|---|---|---|---|---|---|
| | | °C. | | | |
| 1 | April 28, 1907 | 15.5 | 52.8 | 55.2 | 0.71 |
| 2 | 1 hour later | 15.5 | 39.8 | 24.5 | 0.28 |
| 3 | April 29, 1907, 11 a. m | 15.5 | 49.0 | 24.5 | 0.45 |
| 4 | April 29, 1907, 3 p. m | 15.5 | 35.4 | 21.4 | 0.20 |
| 5 | April 30, 1907, 10 a. m | 15.5 | 37.5 | 19.1 | [illegible] |
| 6 | April 30, 1907, 3 p. m | 15.75 | 39.7 | [illegible] | 0.06 |

The carbon dioxide obtained by boiling water shows the amount dissolved in the water as gas and part of that dissolved as bicarbonate salts, since the latter decompose on boiling, liberating carbon dioxide as gas. This is not a satisfactory method of determining carbon dioxide in water, and the figures are included here only because it is necessary to obtain them in order to determine the oxygen and nitrogen. They are not of especial significance. Probably, however, a large part of this carbon dioxide is dissolved as the gas.

The first determination is much higher in each gas than any of the others. There is no satisfactory explanation for this. No. 5 and no. 6 were made after the pump had been working continuously for 24 and 29 hours, respectively, and are to be compared with no. 3 and no. 4, which were made at the beginning of this continuous run. It appears from this that the water does not improve particularly with continued pumping.

Water at 15.5° C. can take up from the atmosphere about 13.7 c. c. of nitrogen and therefore this well water has an excess of about 5 to 10 c. c. of nitrogen, or the normal and proper content has been increased 39 to 79 per cent. This is the largest nitrogen superaeration that has been determined in Fisheries station water, although at Woods Hole an excess of 5 or 6 c. c. in the sea water was experimentally induced. It is known that such an excess is fatal within a day or two at most, to many fishes, and that an excess of 2 or 3 c. c. is sufficient to make considerable trouble. In this well water, however, the effect of the excess of nitrogen upon fishes can not be observed since the deficiency of oxygen is so great that the fishes are immediately suffocated before the nitrogen has time to cause any symptoms. When the oxygen is increased by aeration, the nitrogen, of course, is at the same time decreased.

The oxygen, as shown by boiling determinations, agrees approximately with that shown by titration, in no case rises to 1 c. c. per liter, and varies from less than 0.1 c. c. to 0.45 c. c. (excluding first sample). This deficiency is probably practically as bad, as far as fishes are concerned, as if the water were absolutely lacking in dissolved oxygen.

## COMPARISON OF MEANS OF CORRECTION.

Having thus a water in which the coexisting deficiency of oxygen and the excess of nitrogen were each more extreme in degree than in any case yet met with, it was thought desirable to experiment in correcting it by exposing it to the atmosphere, and to compare methods or devices for accomplishing a thorough exposure. The question of what was the best general method was submitted to Mr. H. von Bayer, the architect and engineer of the Bureau, who recommended flow along sanded and pebbled troughs on a gentle incline as theoretically best adapted to expose and correct small or moderate volumes of water. Wooden troughs were accordingly made under his direction and when finished were substantially as follows: Total trough length 44 feet, 6 to 8 inches wide. The water flowed 22 feet through two joined troughs with a fall of 2 inches, then fell 10 inches to the second set of two troughs and returned through 22 feet, with a fall of 2 inches, and was delivered into an aquarium. The troughs were painted with asphalt and sanded on the moist asphalt. When dry, pebbles of various sizes were strewn along the bed of the troughs, thus imitating natural flow in pebbly brooks.

The troughs were suspended one set above the other near the ceiling in the aquarium grotto and the water delivered into the head of the upper from a rubber tube. Two trials were made in the sanded troughs, but without pebbles, with a flow of 2 liters per minute. The following table shows the correcting effect of such troughs.

TABLE II.—WATER FROM ELECTRIC PUMP BEFORE AND AFTER PASSING THROUGH SANDED TROUGHS WITHOUT PEBBLES.

| Date. | Sample. | Water temperature. | | $CO_2$. | N. | O. |
|---|---|---|---|---|---|---|
| | | Entering troughs. | Leaving troughs. | | | |
| | | °C. | °C. | | | |
| May 3 | Well water, untreated | 15.5 | | 38.1 | 21.0 | 0.1 |
| May 4, 12.30 p. m. | Well water, at exit of troughs | 15.5 | 17.5 | 19.2 | 14.9 | 4.5 |
| May 4, 2 p. m. | do | 15.5 | 17.5 | 13.9 | 14.1 | 4.4 |

Since the determination of May 3 on untreated water agrees approximately with the figures obtained several days earlier, it may be assumed that the water does not vary beyond the limits shown in table I. This variation, however, is considerable and as two samples could not be determined at the same time, it is not known exactly what the condition of any treated water sample was at the time it entered the troughs. It is known approximately, however, and it is apparent that the 2-liter flow water is considerably but not completely corrected for nitrogen and that much oxygen has been added but not enough to air-saturate with oxygen. At this point the pump ceased to deliver water on account of clogging with sand. No more determinations were made until May 14. In the meantime a small hydraulic pump was connected with the well and succeeded in pumping some 4 gallons per minute. This pump, however, changed the aeration of the water considerably.

The electric pump had its pumping cylinder entirely immersed and some 30 feet below the surface of water, so that all pipes were filled with water under pressure instead of suction. There was therefore no opportunity for atmospheric air to enter the pipes. The hydraulic pump on the other hand was located on the surface of the ground and had a suction pipe some 22 feet long. Though no leak was discovered, the pump delivered gas in large bubbles, much more in quantity than ever came from the electric pump. This gas, or air, must have entered the suction area at some point and though insufficient to stop the pump, modified the air content in an interesting way, as shown by comparing the "untreated" samples in table III with table I. Oxygen has been increased, while the nitrogen has not been materially changed or has even been reduced somewhat. The explanation is found in the atmospheric air which gains access to the hydraulic pump. The water having scarcely any oxygen loses little or none in the suction pipe, but takes up considerable in the pressure pipes between the pump and the point of delivery, on account of air taken in at the suction and propelled in company with the water past the pump, where it is then under pressure. The water having an excess of nitrogen must lose considerable in the suction pipe on account of the reduction of pressure. This nitrogen which comes out of solution remains within the pipe as free bubbles and together with the atmospheric air sucked in, passes on with the water past the pump when the pressure then causes nitrogen to be forced back into solution in the water. The resultant of these two opposite processes is evidently a slight diminution in the nitrogen content. This is reasonable, since the suction below the pump is greater than the pressure above it.

It is thus seen that although a leaky suction pipe in pumping systems usually injures the water from a fish-cultural point of view, in this case it improved it somewhat, by adding oxygen and subtracting nitrogen. It did so because of the great length of suction pipe, the small head pumped against, and the extreme faults of the water in the well with respect to both oxygen and nitrogen.

In addition to the troughs, tin pans with perforated bottoms were used to correct the water. Usually the water was passed through a series of 6, arranged one above the other, with a fall of 4 inches from one bottom to the next. The pans were rectangular, about 31 by 19.6 by 5 centimeters, and contained 345 circular holes 1 millimeter in diameter, regularly placed, punched from the inside with a steel punch. In table III the results with these pans may be compared with those from the troughs, on 2, 4, and 6 liter flow. The "untreated" samples were taken directly from the delivery pipe before appreciable contact with air. In comparing the results, or when considering in any case the amount of air or any gas dissolved in water, the temperature of the water must always be borne in mind, the colder water holding or being capable of holding more gas dissolved than warmer water.

TABLE III.—WELL WATER FROM HYDRAULIC PUMP, UNTREATED, AFTER PASSING THROUGH SANDED AND PEBBLED TROUGHS, AND AFTER PASSING THROUGH SIX PERFORATED PANS.

| Sample. | Date. | Flow per minute. | Temperature of water. Entering troughs. | Temperature of water. Leaving troughs. | $CO_2$. | N. | O. |
|---|---|---|---|---|---|---|---|
| | | *Liters.* | °*C.* | °*C.* | | | |
| Untreated | May 14, 3 p. m. | 6 | 17.5 | | 44.0 | 16.9 | 4.6 |
| Do | May 14, 4 p. m. | 6 | 17.0 | | 46.4 | 16.8 | 3.7 |
| Do | May 15, 9.30 a. m. | 6 | 16.5 | | 45.7 | 21.0 | 2.6 |
| Through troughs | do | 2 | 16.75 | 18.75 | 8.5 | 13.2 | 5.6 |
| Do | May 15, 5 p. m. | 4 | 16.0 | 18.0 | 12.5 | 13.7 | 5.2 |
| Do | May 16 | 6 | 15.5 | 15.0 | 15.2 | 15.1 | 5.1 |
| Through 6 pans | May 15, 3 p. m. | 2 | 16.5 | 17.5 | 7.9 | 13.3 | 5.8 |
| Do | May 16, 4 p. m. | 4 | 16.25 | 17.25 | 11.4 | 14.0 | 5.3 |
| Do | May 16, 12 noon | 6 | 15.5 | 15.5 | 13.9 | 14.8 | 5.4 |
| Untreated | May 16, 9 a. m. | | 15.5 | | 45.6 | 23.0 | 1.1 |
| Do | May 16, 1.30 p. m. | | 15.5 | | 45.8 | 22.5 | 1.2 |

Several facts of interest appear from the trials of the pans and troughs. In the first place, neither succeeds in completely correcting the water with respect to either gas. After passing either system the water could, by further exposure, take up a little more oxygen and release more nitrogen. With the 2-liter flow, however, the correction is very nearly complete for oxygen, but it must be remembered that the hydraulic pump had already added some oxygen. The correction is less complete by both troughs and pans as the flow grows larger. As between the two systems, the troughs and perforated pans, the difference is insignificant on the smallest flow (2 liters) and is in favor of the pans. As the flow increases in volume, the advantage of the pans becomes somewhat more appreciable, but even with the 6-liter flow the troughs are a practicable method of correcting water. Unfortunately, larger flows than this were not tested with the troughs. The following two determinations were made on a flow of 12.5 liters per minute, delivered May 3 by the electric pump and passed through pans each perforated by 345 holes of irregular size, but all of them considerably larger than 1 millimeter. The condition of the water before treating is shown by the "untreated" sample, and is substantially in agreement with that shown by table I.

| Sample. | Hour. | Temperature of water. | $CO_2$. | N. | O. |
|---|---|---|---|---|---|
| | | °C. | | | |
| Untreated | 2 p. m | 15.5 | 38.1 | 21.0 | 0.13 |
| Through 5 pans | 11 a. m. | 15.5 | 27.2 | 17.4 | 4.0 |
| Through 6 pans | 1 p. m. | 15.5 | 16.8 | 15.9 | 4.8 |

The water after passing 6 pans still has about 2 c. c. too much nitrogen and about 1 c. c. too little oxygen per liter. The correction is less complete than in any other case, on account of the larger flow and the larger holes in the pans.

From tables II and III it is seen that the pebbles contained in the troughs add considerably to the efficiency.

The practical application of these experiments may be found in their showing that aeration and deaeration sometimes require an extremely thorough or intimate exposure of water to the atmosphere to restore the dissolved air content to the normal. The water must be spread into very thin sheets, as in troughs, or if subdivided into streams, as by perforated pans, must be reunited and subdivided repeatedly. By increasing the lengths of trough or the number of pans, the correction can finally be made complete. Troughs have practically the efficiency of pans under the conditions of trials described herein. The objection to them lies in their warming of the water if the air temperature is high, their expense and cumbersomeness. One great advantage they possess is that they require little vertical space, and therefore they could be used where the fall from tap to trough is too short to permit the insertion of a sufficient number of pans, provided there is sufficient room laterally.

When pans are used, the diameter of the holes must be controlled largely by the volume of water, the amount of fall available, and especially by the sediment the water carries. The smaller the holes the better, as far as exposure to air is concerned, but they readily clog with suspended matter. Moreover, they do not allow the delivery of so much water as larger holes, unless the pressure is increased by deepening the pan, but this takes up vertical space. Larger holes to avoid clogging may be compensated by more pans. The size and depth of pans, number and size of holes, will be a resultant of the various factors mentioned, and may be determined by the judgment of the fish culturist for each particular case, or by trial and experiment.

Since the water from the well under consideration has a temperature of 15.5° C. or 60° F., when it arises, it can not undergo warming and remain fit for trout. Could it be passed through an efficient aerating apparatus of pans, trout could probably be maintained in it even during the heated season, since the passage through pans is rapid enough to warm the water but little. Any form of aeration, however, will seriously interfere with the clearness of this water, since it contains about four parts of iron per million dissolved as some one of the salts of iron. On exposure to air most of this iron is precipitated, and causes a marked turbidity. On standing, the particles of iron oxide settle and the water becomes clear; but for constant-flow aquariums it would require filtering before use. This would warm the water, and its use therefore would involve more trouble and expense than that which the well water was intended to obviate.

Thus this well water is of peculiar interest in having two faults, the correction of which induces a third almost as serious for exhibition aquarium purposes. The excess of nitrogen or the deficiency of oxygen are either of them singly sufficient to kill all the fishes placed in the water. Both are remedied simultaneously by one process, thorough exposure of the water to air; but this process creates, by oxidation and precipitation of dissolved iron, a turbidity which ruins the water for the purposes of aquarium exhibit.

## DETERMINATION OF SUITABILITY OF WATER FOR FISH CULTURE.

Entirely aside from any question of parasitism, and speaking only of dissolved substances, it must be admitted that there is at present no sure method of determining by chemical tests the suitability of water for fish culture. Much of course may be assumed in favor of unpolluted natural streams, as trout streams for trout culture. With spring water nothing may be assumed. Something may be learned from a chemical examination, but it must be adapted to the purposes of fish culture. Ordinarily, if a sample is submitted to a chemist he will make what is called a sanitary analysis, which determines whether water is fit for drinking and domestic uses—is healthful for human consumption. For fish culture this is almost useless. Water with a good sanitary showing may kill fishes in a short time, and on the other hand, in rivers fishes are not necessarily harmed by water which any chemist would pronounce unfit from a sanitary standpoint.

There must be established what may be called a fish-cultural analysis, and the information this will give should cover, among other things, the reaction and degree of alkalinity or acidity, hardness, total solids, sulphates, nitrates and chlorides, the carbonic acid, the dissolved oxygen, nitrogen, and carbon dioxide; and an ordinary mineral analysis with special tests for any unusual metals which there is any reason to suspect. The determinations of the atmospheric gases named should be made on the perfectly fresh sample. The dissolved air is the most important, and the nitrogen as important as or more so than the oxygen. Temperature, turbidity, color, etc., are physical characters which the chemist will note. Having obtained these results, not all of them can yet be accurately interpreted. For the atmospheric gases one can form immediately a fairly definite opinion, but as for total solids and the minerals present, we know but little of the limits of safety. Therefore it is that the final test is experience itself. A long experience with fish culture and aquarium experiments in water whose contents are accurately known will ultimately lead to the establishment of definite standards which will be useful to fish culture, just as the long-continued chemical examination of service waters in the light of the results of their usage has led to standards confessedly not well defined, but which are nevertheless useful in selecting sanitary waters.

# CAUSES OF DISEASE IN YOUNG SALMONOIDS

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

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# CAUSES OF DISEASE IN YOUNG SALMONOIDS.

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[Translated from the French.]

The common trout and its varieties are especially subject to disease of the gills, and other salmonoids likewise are not exempt from it. Such disease consequently presents great difficulty to fish culturists, who must find means of combating it. Another frequent trouble is the epidemic which may be called "staggers." The effective measures in both cases are those of prevention rather than attempt to cure; and the best means of prevention is perfect cleanliness of equipment, from the beginning of the hatching period throughout. To maintain the necessary cleanliness, however, is a question of style of apparatus as well as unremitting care.

## DISEASES OF THE GILLS.

### FAULTY HATCHING EQUIPMENT AND CONDITIONS.

As fish culturists well know, the styles of apparatus for incubating eggs of the salmon species are very numerous. In France the most common equipment is the Coste trough and its derivatives, consisting of a kind of rectangular zinc box 0.50 to 0.60 meter long, 0.25 meter wide, and 0.20 meter high, with two partitions of perforated sheet iron, the one serving to admit the water from below, the other allowing it to pass out from above. Into this box is set a glass grille of dimensions to fit.

I have heard much in praise of all varieties of apparatus, but I have heard little concerning their disadvantages and dangers. It is of these latter that I shall speak.

First of all, I consider the equipment bad which does not allow the fish culturist to see what is taking place below the grilles on which the eggs are resting or permit of cleaning without disturbing the eggs.

We are told that there are currents of water in this apparatus, which receive as much as one-half liter of water per minute. There can be no currents of water in these troughs, however, especially in those with partitions; there is, to be sure, a change of water, but there is no current which would bring about a flow throughout, and this may be easily shown by putting into the water coloring matter or thin strips of paper. And it is precisely the absence of this current which determines and creates the dangers to which the eggs and the fry are exposed—this, first, because the quantity of water supplied to the apparatus is not sufficient; second, because all obstacles, as the partitions in the apparatus, operating to prevent a current, become a hearth of infection of all kinds, by the corners they make; third, because of the very dimensions and the shape of these troughs; and fourth, the visible proof, because there are found in these troughs and in the rearing troughs fry large enough to be able to maintain an equilibrium, yet lying on their sides, with gills compressed against the bottom of the basin and in contact with the slimy ooze of the bottom. If the fish makes a movement, it is only to fall back on the other side, so that the gills are by turn infected with noxious substances from the bottom, which can not be seen and cleaned as it ought to be.

The greatest cleanliness is always necessary in fish culture, and it must be made attainable. Let us see, without being pessimistic, what the conditions most often are.

The fish-cultural apparatus found on the market has not all been invented by fish culturists having a knowledge of this science. The manufacturer sells apparatus the advantages of which he extols with the aid of so-called fish-cultural tracts (though in reality they are not such), and the inexperienced purchaser establishes his business immediately, with confidence of success.

If he buys eyed eggs, he will not have the same difficulties as the man who collects the eggs himself. Let us take the latter for example. The eggs are placed on the grilles and the grilles in the troughs, all these things being more or less well washed, but the wooden screens can not be put in the flame so as to destroy all germs. Then there may be among the eggs excretions of fishes that may have fallen in the stripping, or there may be shells of broken eggs, all of which may drop through the grille to the bottom of the trough, to be left there during the entire period of incubation, together with any dead eggs that may have slipped between the glass bars.

If the water contains sediment, this will be deposited on the bottom of the trough and will remain there. The fish culturist has been told that all he has to do is to take out the few dead eggs and await the hatching of the others before cleaning out his apparatus. Water is not the same everywhere; all has its advantages and its disadvantages; in France the incubation takes place in water the temperature of which varies during this period from 6° to 12° C. (I do not refer to the mountain region), and often the incubation period lasts from forty-five to fifty days. It is well known that some eight days before the first hatching some eggs will burst. Their contents, escaping, spread over the eggs in long filaments which attach themselves to the grill, pass through it, go to the bottom, increase the amount of sediment, and encourage the invasion of *Saprolegnia*.

The unfertile eggs are not taken out, and the first filament of fungus may not be seen on an egg that is in a corner of the grill. But later the eggs may be covered with this delicate down, and although something might still be done for the embryos whose breathing is thus interfered with, even the flow of water has not been increased since the eye spots appeared, and so the fungus establishes itself.

The hatching time is now at hand, and may last, in water having a temperature of 10°, some ten or twelve days, and sometimes more. Until it is over there is no thought of placing the fry in a cleaner place. As the fry hatch they fall, like the shells of their eggs, to the bottom of the trough, on a soft velvet composed of the flourishing *Saprolegnia.*

And these unfortunate fry, the gills of which have never ceased being in forced contact with all the impurities and disease germs which line the bottom of the trough, are now to be disturbed in this water, the sediment in which will be visible to the operator when he shakes or moves the trough. Nor is it only the breathing apparatus which suffers, but the entire fish, for its body receives shocks and wounds, inviting the fungus, and the mouth particularly becomes infected.

The disease then has secured its hold. It is not perceived, for the operator believes that he has done all that is necessary by cleaning the fry at the close of the hatching. They may have been replaced in the same trough after giving the latter a hasty cleaning, for maybe there was no other at hand. Fry from two different troughs may have been put together without thought of the imprudence of this. The lots are then of different ages by ten to twelve days, and they are a little crowded, there being 2,000 to 2,500 in those little troughs without any increase of the flow of water—for how long? They will be fed in a month, perhaps six weeks. In the meantime there is amusement in finding a few monstrosities among them. These die from day to day and the yolk sac sheds its contents, which adhere to the bottom and form white spots which occasion no alarm. The *Saprolegnia* finds again a favorable bed for development.

The oldest and most robust of the fry, endeavoring to move about a little, reach a corner of the trough, where they crowd against each other. By their swimming movements they form in this corner a small current, or more exactly, a slight motion of the water sufficient to maintain them in equilibrium on their yolk sacs facing this small partial current. As soon as the fry ceases to feel this current it can not maintain itself on its yolk sac and falls on its side. Is it no longer so strong? No; that is not the reason—it is the motion of the water which is lacking and which does not exist in the trough in any other spot except where the fry make it themselves. The proper motion of the water is created by a device of mine which I shall describe, a siphon outlet system; but for the present I say that the eggs in incubation were not given a current sufficient to wash them, facilitate the exchange of gases, and keep them from being covered with a thin layer of sediment. I maintain that thus the embryos also suffered, and I am sure that it is in this way the fry contract the disease of the gills.

Such is the origin of the disease which manifests itself in young fish in swollen gills, impregnated with dirt and bulging so much as to push out the operculum. The fish are seen to weaken and turn dark in color and then die, at first in small numbers, but increasing to an almost complete mortality. It may be justly assumed that those which escape are those which hatched last and have not been so long in contact with the deposit on the bottom of the trough. This terrible disease may not manifest itself among the young fish until the age of five to six weeks.

In addition to the cause I have named for the origin of this disease of the gills, it is sometimes due to placing too much food into the rearing troughs. The coagulated blood, spleen pulp, pulp of liver, etc., becoming diluted, render the water at times so tinted that it is impossible to see through it. The gills are impregnated with putrefiable matter, which soon gives rise to this terrible epidemic, especially if the water is not aerated and frequently changed. Lastly, a great number of fry in a small space, not receiving a sufficient quantity of water, acquire the disease of the gills by atrophy, as may be easily recognized by the small size and emaciation of the fish.

## MEASURES OF PREVENTION.

As stated at the outset, the remedy for this disease is prevention, which involves the utmost care on the part of the attendant, with also the form of equipment which shall permit of the most perfect cleanliness. I will indicate the means I have employed and consider essential.

1. Discard all apparatus that does not allow the interior to be examined. It must be possible to see under the grilles on which the eggs are placed, and, if necessary, to clean the bottom of the trough without interfering with the incubation process.

2. Use an equipment which will permit of retaining the fry therein after the hatching is over. Discard the wooden grille frame for one of metal and replace the glass tubes with solid glass rods.

3. Have an ample supply of water in proportion to the number of eggs in the trough, and create currents to reach every part. Increase the supply of water, if possible, as soon as the eye spots appear in the egg.

4. Do not crowd the eggs on the grille. Take out the dead eggs each day. Do not refill the spaces left by the removal of dead eggs. These, taken out to prevent their bursting in the trough, will now give more space to the developing eggs. Take out any eggs containing monstrosities.

5. Give a thorough cleaning both to grilles and troughs when the eggs are ready to hatch, so that the fry may fall to the bottom of the trough without danger to their gills. A hand siphon cleaner[a] should be used for the trough.

[a] Vincent E.: Devices for use in fish hatcheries and aquaria. Proceedings Fourth International Fishery Congress, Bulletin U. S. Bureau of Fisheries, vol. XXVIII, 1908, p. 1030.

6. If the hatching equipment is not adapted for retaining the fry, transfer each day's hatch, classifying by age, to thoroughly cleaned troughs, with such number to each trough as may be held for five or six weeks. In making the transfer use a syringe of 1 ¼ to 1 ½ liters capacity, with a tube of 0.017 meter diameter, so that the gills and yolk sac of the fry shall not be compressed. Do not keep the fry in darkness or obscurity; daylight is better for them. Eliminate monstrosities. Change the water every day, the siphon outlet[a] serving also as an auxiliary cleaner, since it creates currents in the troughs. Dispose the intake at a point to produce a longitudinal motion of water.

7. I feed the fry, to aid them in developing, beginning four days after hatching. This has been my practice for some six years, and I have found it good. I clean the troughs every day with a brush, called codfish tail, and take out any remnants of food which the siphon outlet has not carried off. When the fish are some five or six weeks old I put them in large troughs, the cleaning of which is simpler, and here I feed them with beef spleen placed in small wire baskets fixed at about mid depth of the trough, this to prevent the fish from seeking food at the bottom and so that less shall be wasted.

It is difficult in a large establishment to have really filtered water. No filter at all is better than a bad one.

Various devices of mine described elsewhere (op. cit.) have proved an aid to the realization of the necessary cleanliness in fish hatching. I have adopted also a combination trough, to be used both for the eggs during the incubation period and for the fry afterwards, thus avoiding the disturbance and injury of a transfer of the very young and delicate fish, while at the same time offering the advantages of the currents they need, besides facilities for perfect cleanliness. This trough is of cement and measures inside 1.5 meters long, 0.3 meter deep, and 0.35 meter wide. The shape is such as to aid in cleaning, having no angles, but curves only. The size is sufficient to accommodate two grilles and the siphon outlet apparatus already referred to. The interior is especially designed, after repeated experiment, to provide currents suitable for the eggs during incubation and later for the fry, to give the latter means of equilibrium and also supply them with food in a natural manner. The particles of food are always in motion in this trough. The model belongs to the firm of Leune, Rue Cardinal Lemoine, 28 bis, Paris.

It is important for the fry to be in equilibrium, and not lying with gills against the bottom, even though the troughs be clean, a condition which is attainable if there be a current, but not otherwise. As soon as there is the smallest motion giving the sensation of a current even the very young fry will respond to it. This may be tested by the simple experiment of using a syringe

[a] Vincent, op. cit.

in the water close to the fry. The little heads at once turn toward the current, the bodies righting themselves upon the yolk sac, and this equilibrium is maintained so long as the current continues. When it fails the fry fall back on their sides.

It is suitable currents that also make it possible to feed the very small fry without danger of disease. Even before the yolk sac has begun to diminish they will face the currents and make efforts to catch small particles of food passing some three or four centimeters above them. I have shown this very interesting and amusing sight in aquaria, and it is because of such experiments that I insist the fry shall be fed when four days old. At the end of ten or twelve days, in water having a temperature of about 10°, will be observed the occurrence above noted, and a few days later these fry, developed and strengthened by the food they have had, but still with their yolk sac, may be seen swimming progressively. The fry should not be kept in darkness. They must be able to see their food to get it.

### CURATIVE MEASURES.

With the precautions I have enumerated the fry will not be affected with the gill disease. If, however, I should find myself confronted with it I would reduce the number of fry by half; I would place them in semiobscurity and would give them no food for several days, in order not to put into the water the slightest substance for putrefaction, and keep the gills free of any organic matter due to the food or its remains. I would have well-aerated water and take care not to leave any dead fish in the troughs. Such would be the treatment to be given—a thorough cleaning from the beginning of the disease. But I do not guarantee that I could save fry which were seriously affected.

The gills are very sensitive to the disease, and their impregnation with organic matter, be it only a temporary one, causes death. I have been a professional fisherman, and all fishermen know very well that fishes caught during the first days of rising water never live, can not live, even if they are taken with the most inoffensive of fishing devices, and this is so because their gills are filled with organic matter and sediment which rising water always carries along. Three or four days after the beginning of the rise of water the gills are slowly cleaned and the fishes live.

### AN EPIDEMIC OF "STAGGERS" IN RAINBOW TROUT FRY.

The brood trout in this case weighed about four ounces and laid eggs now for the second time. The eggs were placed in filtered spring water at a temperature of 9°, 10°, and even 11°, and incubation lasted forty days. The greatest hatch took place on March 14, 1906, lasting two days. The small fry were placed in nonfiltered water, where they were kept from March 16 to April 14.

These fry were fed regularly every day, from the fourth day after hatching, with pulp of beef spleen, first crushed in a mortar, then passed through a horse-hair sieve. Somewhat later I contented myself with rubbing the spleen pulp, which was somewhat diluted, in the trough and between my hands, the fry eating this very well. On April 20, i. e., about thirty-five days after hatching, the trout, now in a pond, were eating pulp which I did not crush, but placed in a small basket suspended between two currents in the pond.

The pond was supplied with river water, of a temperature of 12½°. It was 7 meters in length, 2.5 meters in width, and 1.8 meters in depth. The flow of water was 10 liters per minute from the town supply. There were 9,000 fish. Time passed and these trout, having in only one and one-half months reached a size varying between 0.032 and 0.035 meter long, were well and healthy.

We had reached April 24 when two things happened to cause me apprehension. The allowance of food given to these trout had been gradually diminished, and on the other hand the water flowing into the basin, at the rate of 10 liters per minute, passed through a gravel filter, which did not inspire any confidence in me.

Before reaching this filter the water passed through three decantation basins, each containing about 10 cubic meters, then it rose between two walls, where it met a filter composed of medium pebbles, a layer of 0.25 meter, then a similar layer of gravel, then another layer 0.3 meter thick of finer gravel, then coarse sand 0.15 meter thick, and finally a layer of 0.15 meter of fine sand. These layers of gravel and sand were separated from each other by suitable sheets of metal.

Being able to see from the side into the interior of this filter, through glass panes 0.027 meter thick and 1 meter high, I ascertained that the filter was in reality dirty, the dirt obstructing the passage of the water through the gravel, so that the latter was kept back and rose in the basins of decantation. (It is well known that a filter made of gravel and sand does not operate well until it collects a surface layer of dirt, but on the other hand, as is not so well known, it is not necessary to wait until the surface is dirty to have the under layers cleaned.) I saw then that at hundreds of places organic matter formed with the gravel a more or less compact mass, and mold was to be found everywhere. This organic matter, this mold, consumed the oxygen contained by the water to the detriment of the welfare of the rainbow trout.

I foresaw danger in this growth of *Saprolegnia* of all kinds, and the multitudes of small animal life, some of it almost invisible to the naked eye.

The water was cut off and the upper part of the filter was partly cleaned; not thoroughly, however, as both time and space are needed for the washing of all the gravel and all the sand, the layers of which lay flat on an area of 2.4 meters by 0.6 meter.

The filter, in short, was not sufficiently cleaned, the water was turned on again, and not sufficient note was made of the fact that it was the 8th of May and the river water at a temperature of 17°, the first result of which would be a sudden mortality among the trout. This happened, too. From May 8 to May 17 the water was maintained at this temperature, and on the morning of the last day I noticed some 30 trout dead in the pond, while the others were being carried to the grating at the outlet. Most of the fish turned over and over and made pirouettes, then jumped into the mass of water as if to cross it in one movement, but they fell exhausted and dropped to the bottom. About 11 o'clock in the morning 300 trout were dead.

The fish had "the staggers." In two days they grew somewhat dark, then they began to weaken, swam with difficulty, and could no more maintain a horizontal position; their behavior was abnormal, and they finally died. All of the trout did not show the weakening, but fell to the bottom of the pond and succumbed after opening their gills convulsively two or three times.

I gathered the dead trout with a net and counted 1,200 of them. That evening there were more on the bottom of the pond, and by the evening of the next day the mortality was almost complete. The remainder living was an insignificant number. I believe that 160 were placed in spring water, and out of these 160 only about 100 were saved.

This mortality had been caused by the imperfect action of the gravel filter and by its dirtiness, by the fermentation of the organic matter which the filter had retained when from April 24 the temperature of the water, 12°, rose to 17° about May 10. The cleaning of the upper layers of fine sand of the filter gave free passage to the *Saprolegnia*, the mycelium of which abounded in the lower parts or layers of gravel, and all this infection invaded the basin, with the effect of all as just described.

In order to remedy this at least partially, if there is no spring water at one's disposition, it is better not to use any filter than to use such as this. The great quantity of water necessary in a fish-culture establishment makes it difficult to obtain a perfect filter. It might be well to use water from a river, easily aerated if the pond is lower than the river.

The best means of doing without a filter would be to keep a small fry trough very clean, so as to be susceptible only to disease or an infection coming from without, which is much at best. In order to attain this practical result, a siphon-outlet system, of a kind such as I have devised (op. cit.), should be installed.

# RADICAL PREVENTION OF COSTIA NECATRIX IN SALMONOID FRY

By Johann Franke

*Director of the Fish-Culture Establishment at Studenec and Secretary of the Fishery Committee for the District of Krain*

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

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# RADICAL PREVENTION OF COSTIA NECATRIX IN SALMONOID FRY.

By JOHANN FRANKE,
*Director of the Fish-Culture Establishment at Studenec and Secretary of the Fishery Committee for the District of Krain.*

[Translated from the German.]

## CHARACTERISTICS OF THE DISEASE.

I insist upon the limitation to "salmonoid fry," because I have not directly observed *Costia*, nor have I seen the characteristic exterior appearances of costiasis, on any adult fish with one exception. I saw four years ago in June, in the Stara Voda, in a broad place in the stream where the current was very slow, a pike some 23 centimeters in length with a whitish covering on the skin resembling a veil, very like figures 12 and 13 in Dr. Bruno Hofer's "Fischkrankheiten," in which work appears a full description of this disease.[a]

The place where my observations were made was the fish-culture establishment at Laibach, Austria.

The appearance of *Costia* was noticed among the fry some five to ten days after they had begun to feed, i. e., after the resorption of the sac—never before this period—and equally whether the fry began to feed early or late, among the early feeding *Salvelinus fontinalis* and alike the late *Salmo irideus*. About the middle of June, sometimes ten days earlier, all trace of *Costia* disappeared as mysteriously as it had come. I have no reliable criterion as to whether the fish became immune against costiasis in June or whether *Costia* in the form of a flagellate is seasonal, but I suppose the latter to be the case, since the signs of disease disappear at the same time among the younger and older fry.

No difference could be found in the susceptibility of the young fishes; the fry of the three species regularly cultivated—*Salvelinus fontinalis*, *Salmo fario*, and *Salmo irideus*, obtained from brood fishes of the establishment (among which may be included the 100 kilograms of *Salvelinus fontinalis* and *Salmo*

[a] Hofer, B.: Handbuch der Fischkrankheiten, p. 115-121. Munich, 1904.

*fario* from the excellent stream of Stara Voda)—were attacked along with the embryonated eggs obtained from elsewhere.[a] The fry that were fed nothing but live crustaceans and larvæ of mosquitoes, their natural food, were infected as much as those which, on account of temporary lack of natural food, were fed partly with substitutes, such as pig liver or beef and veal spleen.

The infection must, consequently, be of the locality. The place, the water and its near surroundings, must be infected, the shores harboring *Costia* in the shape of cysts on the dry land, whence they are scattered everywhere by the wind.

*Costia* had already established itself at Studenec before my arrival in 1891. Costiasis thus did not begin during my direction, but it spread so rapidly and at last in such manner that none of the springs were safe from it. It was first recognized in 1904 by Dr. Ivan Robida, head of the hospital for the insane in Studenec, who was fond of the sport of fishing and who in his close relations with myself studied questions which interested me. By means of his microscope (my own not powerful enough) and Dr. Hofer's book, the identity of the disease germ was fixed in 1905.

We conclude, further, that we have found the cause of the abnormal mortality of fry in previous years, there appearing the same phenomena and symptoms and course of the disease from the very beginning that had characterized those great losses for which no cause was known from 1896 until this time. I had sufficient occasion and opportunity to observe all the phenomena and symptoms minutely, and likewise to remember them, for a large part of the feeding fry were placed for one to three months in larger hatching boxes, then in floating troughs, and in September and October in large ponds in which to pass the winter, while I spent each year 180 half days and 40 to 60 entire days in this establishment.

## ACCIDENTAL DEVELOPMENT OF THE PREVENTIVE METHOD.

The radical means of preventing *Costia* was not "discovered," nor even "found," for it was not sought. It developed in the following manner:

In the one-story house occupied by Doctor Robida and other physicians of the insane asylum there is a tank under the roof with capacity of about 1,800 liters, into which was pumped water for household purposes from a spring situated in the cellar of a house about 80 meters distant, if sufficient water was coming to the ponds for the working of the pump. The spring in the cellar and the tank are well covered and the pumped water, coming in contact with the fresh air from without only by chance rifts in the cover, can not be much

[a] *Salmo fario* from Ilidze, Bosnia, 1902; *Salmo dentex* (Isonzo trout) from Idria, 1903–1907, inclusive.

contaminated by dust, etc. Doctor Robida took advantage of the vicinity of the tank to supply with water therefrom two small aquaria in his room (1905). From the main pipe, made of lead, the water passed into the aquaria through slender rubber tubes (3 millimeters in diameter at the outlet) with brass end pieces (about 1 millimeter at the opening), under pressure of about half an atmosphere. One of the aquaria consisted entirely of glass and had a bottom area of 35 by 25 and a height of 22 centimeters, while the other was somewhat larger and had a lead bottom and frame, with walls of glass. In the bottom of each was a layer of 5 to 6 centimeters of fine, white, well washed, calcareous sand, and a few shoots of water cress were planted in it. The water, falling in a slender jet, boiled up actively and sent out small bubbles in every direction, so that even in the corners they could be seen dancing in the water. In the first aquarium were placed more than 300 young *Salvelinus fontinalis* old enough to feed, while in the larger one were placed *Salmo fario* and *irideus*, also a few *fontinalis*, in all some 500 fry. More than any other fry these were fed with crustaceans exclusively, which were greedily devoured, especially by the American species, which fed until the body swelled quite out of shape and looked as if it would burst. The excrements were removed daily by means of a small suction tube, while once each week the aquarium was thoroughly cleaned, the sand washed, etc., the fishes being placed in other quarters during this proceeding. *Costia* had in the meanwhile appeared in the hatchery as in the preceding years, but there was no trace of the disease in the aquaria.

Ten diseased *Salvelinus fontinalis* were now put into the smaller aquarium. The infection had not as yet shown its full effect on them and *Costia* had established itself microscopically on other fishes looking like these. The diseased fishes differed from the fat, healthy ones, not only by the thinness of body but also by the coloring, which was more or less of a dark blackish blue hue, with a faint, almost invisible shading as compared to the light-colored and white markings of the healthy individuals, and the difference was apparent to the casual observer. The diseased fishes continued to live, seeking the bottom in the quietest places and rarely moving about, and looked at the last like a thin blackish thread with a thick knot. All died within 6 to 9 days after the fishes of the same lot and of the same appearance left in the hatchery. Expectation as to the results of this experiment was naturally great, but no effect was produced on the fishes in the aquarium.

A second experiment in the second aquarium gave the same result, and several more were made in each aquarium. Doctor Robida attempted to convey the infection by other means, i. e., by the infiltration of infected water and by the direct introduction of living *Costia*, but with no result. He changed the food freely, giving the fishes, when they had grown larger, grated meat from his own table, even chopped liver, thinking that in water so well aerated even such food could do them no harm.[a]

The abundant aeration of the water proved to be a radical prevention against *Costia*, all the fish remaining alive and healthy, not one being lost. When the action of the pump grew defective on account of scarcity of water, Doctor Robida used a small motor operated by alcohol for the purpose of obtaining a current in the aquaria. But the disadvantage increased and I put the fishes, which were from 3 to 4 centimeters long, into a rearing trough (8 meters long, 0.55 meter wide, and 20 centimeters deep), merely giving them three more salt baths, since this was the end of the critical period, in order to be safe from the danger of *Costia*.

I have never seen the white veil-like covering spreading over the skin, as shown in figures 12 and 13 in Doctor Hofer's book, except on the pike already mentioned; never on the small fry. So long as I fought *Costia* with potassium permanganate and not with cooking salt, as did Doctor Hofer, the fishes which had withstood *Costia* had white fungus spots near the gill openings, and these spots, in spite of the treatment with potassium permanganate, were in some cases fatal. Since I have begun to use common salt, I have not noticed this last phenomenon. I suppose that the fishes attacked by *Costia* are too small and consequently too weak to endure this condition until the white spots show on the skin, and die before this stage.

## EXPERIENCE OF THE SEASON OF 1906.

It was impossible to arrange an aeration of the hatchery troughs by means of water under pressure, on account of lack of fall in the supply. The only fall periodically in operation was occupied by the already mentioned pump and not available for hatchery purposes by reason of its location. Thus I could not put into practice the new experience with aeration.

Since *Costia* was again to be expected in the hatchery, however, I arranged in a pond, which had not been used for fishes for four years and the water flow of which was used only to supply two rearing troughs, a place in the open for the hatching boxes. This small pond was repeatedly dry when the water was low in the springs. The bottom was cleaned of all vegetation, raked and washed out, highly saturated with potassium permanganate, and after this washed out with salt. All the small fry able to feed and destined for rearing in the establishment were brought to this pond. The water, as may be easily understood, never grows muddy, has a constant temperature of 9.8° C., and produces many green algæ, which are very cumbersome when the currents of the water become slow with low water in the springs.

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[a] In my opinion such food can not be given long, never exclusively, and of the latter sort not even to large fish.

These measures of precaution and a careful maintenance of cleanliness in the hatching boxes, etc., as well as the sole use of live natural food, brought about only the result that in the two boxes first installed the fry did not develop the *Costia* until four or five days later than in the hatching house, and that the infection did not spring up immediately in a violent form, but crept in upon them slowly and insidiously. It may be concluded thence that after the cleaning and thorough disinfection of the pond, etc., the water was free from *Costia*, but was reinfected by the nonsaturated ground of the banks, from cysts which must have been carried into the water by the wind. But whence come these cysts? The following explanation readily presents itself:

The dirt from the rearing troughs (during the first years of my direction there were eight of them at three different places, for the most part occupied by two separate lots of fish), the excrements, debris of food, and ooze from the algæ and the grounds were washed down into the pond water; there formed in the wintering ponds during eight to nine months at the places where the water did not course so freely a thick layer of fat, black, ill-smelling ground ooze, and the ponds could not be cleaned except by flushing them out, scraping, sweeping, and washing out the ground; all this carried off into the principal pond. The latter can be emptied only down to about five-sixths of its contents, and all the springs of the local systems flow into it, through it, and off by means of one lock. From the principal spring, which is easily accessible to the village of Studenec (three or four butchers, the cattle, etc.), much organic matter comes into the pond; it continually receives manure from this source, and incidentally from the well-frequented road during rainfall. Thus a rich bottom fauna and very abundant vegetation develop. The latter must be taken out partially several times a year and thoroughly once annually. Much ooze is naturally taken out with the *Chara fragilis*, and everything taken out of the pond is piled on the banks in heaps, where it remains sometimes for two entire years. As long as the springs were full and there was a corresponding flow of water, a total of 600 to 800 second-liters in the maximum and never less than 200 second-liters up to 1896, no bad effect was noticed on the fishes from the pollution of the ground and its oxidation. And, frankly speaking, I knew nothing, as so many others, about the importance in fish rearing of ground culture and ground sanitation. When the scarcity of water and lack of currents began to be felt and had grown quite noticeable in 1904, and the well-known effects of such conditions, among others the presence of *Costia*, appeared in the fish-cultural work, I was forced to look for explanation and remedies.

Conditions for the existence of *Costia* were rendered more and more naturally favorable by the decrease of water supply in the summer of 1905, the winter following, and later down to a very few liters, and by the fish-cultural operations; and the persistence of the infection was insured by the maintenance of old and the establishment of new piles on the bank whence *Costia* cysts would be derived. I can not find any other explanation for the infection of the pond.

Cooking salt was again our resort; by this means I carried through the critical period one-fourth of the fishes in the worst cases and three-fourths of them in the less severe.

## PRECAUTIONS APPLIED IN 1907.

The same pond was again thoroughly cleaned and disinfected, then a part was partitioned off in a shallower portion by means of a wall of clay. The water for the fry flowed through a tube of rubber and lead through the dams into the distributing trough and thence through lead siphons into the hatching boxes. The covers for these were fitted better and more closely than in 1906, and supplied with glass openings in order to give the fishes both light and sun without having to take off the covers; the distributing trough was likewise kept covered as much as possible and the cover was lifted only for the cleaning of the boxes. The flow of water was increased by five, six, and eight times the ordinary amount for the cleaning of the boxes, by which means the sediment was whirled up, flooded through the closing screen, or deposited on the latter to be swept off by means of a soft brush; the whirling up and flowing off of the sediment was aided also by means of a feather.

At the end of March, some ten days later, no trace of *Costia* was found in two boxes of *Salvelinus fontinalis*; but only fourteen days later, on April 4, I saw two fishes the color of which was not quite satisfactory. On April 5, two fishes were dead and four or five had changed color. The naked eye and the microscope both testified to the unwelcome truth—it was *Costia* again. March was very dry and very windy during the latter days. I gave the fishes a salt bath of some fifteen minutes duration on April 5 and 8. Then there was no trace of the disease until the 18th, when I gave another salt bath. It again appeared necessary to give the bath on the 20th, 24th, and 28th of April, on the 1st, 3d, 19th, 24th, and 28th of May, for twenty-five minutes, and, lastly, on June 3 for thirty minutes, when the fishes were transferred to the rearing trough.

The covering of the water was not entirely useless, the infection in the two first boxes having had two long intervals, the first ten and the second twelve days. The three lots nearest to the outflow needed the salt bath most frequently, i. e., every other day without intermittence; these were *Salmo irideus* of May 3 to June 13. The explanation of this fact is the following: The cover of the trough had to be taken off every morning and every evening during cleaning time, and this admitted the dust and the cysts, caught up by the wind, which were brought by the current to the outflow in greater quantities than at the place where the water flowed in.

I carried through the critical stage about 4,000 *Salvelinus fontinalis*, which were kept in three boxes, the last 1,400 being taken by myself on August 17 to the Wocheiner Lake, a journey from 5.30 a. m. until 1 p. m., without incurring any loss; the fish were from 5 to 7 centimeters in length.

I could not detect that the salt water did any harm to the fishes. The water was of course aerated incessantly by taking it up in a 2-liter vessel and pouring it back from a height of 50 to 70 centimeters. Only the *Salmo fario* remained at the bottom during this proceeding; the *irideus* and the *fontinalis* had to be kept out of the way with a gauze hand net.

Doctor Robida did not take any part in my experiments in 1906 and 1907, and left Studenec last year.

## THE SEASON OF 1908.

The drying up of the springs, which was no longer doubtful, in addition to the spreading of the *Costia*, decided those in authority to abandon the locality near Studenec. But my desire and hope that my fish-cultural difficulties would end with the year 1907 were not fulfilled, as the spawning season of the salmonoids came round before measures for abandoning the locality could be taken.

Since I could command my time, I wished to make use of my knowledge of the effect which the introduction of atmospheric air had upon *Costia*. I sought, first, suitable cylinders, similar to those of the Hydrobion; air was pumped into these and was to rise gradually from the bottom of the fish troughs in small bubbles to the surface. Two attempts to obtain the clay cylinders met with failure.

Salt baths are good, and capable of saving the fry from entire or enormous losses; but they can not be lastingly effective if the water is continually infected anew, and they must, consequently, be repeated; and even while applying them every forty-eight hours I had to register losses which amounted in time in the most favorable cases to one-fourth of the fishes placed in the basin. They also take much time, for a man can accomplish at the same time the necessary aeration of the water in but two or three hatching boxes at the most; ten boxes would thus demand four to five hours.

## EXPERIMENTS IN THE HATCHING HOUSE.

The distributing trough in the hatching house stands some 48 centimeters above the ground and is 22 centimeters deep. I placed the hatching box on the floor and obtained thus a fall of 33 centimeters. A siphon having 8 millimeters interior diameter gives, by exact measurements, 4.2 liters per minute; the capacity of one box is 2,514 liters, and the water is changed therein in 5.98 (6) minutes with one siphon and in three minutes with two. I placed above the hatching box a basin 75 centimeters interior depth, containing 250 liters of water. The water flowed therefrom into the hatching box through a flexible rubber tube 1 centimeter interior diameter and with a conical nozzle of zinc with an opening of

2.5 to 3.5 centimeters. The pressure of the water in the basin varied between 130 centimeters at the maximum and 55 centimeters at the minimum. According to the opening of the zinc nozzle the upper basin was emptied in fifty to thirty-five minutes. The falling jet of water was so placed that the water in the hatching box began to rotate. The upper basin was filled two or three times daily for one hatching box.

I placed *Trutta lacustris* in the hatching box, fry obtained from very beautiful, large, eyed eggs, of which I received 5,000 from Schliersee in Upper Austria. The eggs were placed, on January 31, in two California hatching boxes (without the inner set of brass wire trays) between flat roof tiles. The first hatched fishes appeared on March 23 in the receiving boxes placed below. The two boxes in which the eggs had been placed were opened and 81 eggs were found thickly covered with ooze and fungus. Since the fry were very unevenly hatched, they were placed immediately in two clean and thoroughly darkened boxes, being transferred first to one and then to a second under the falling water and fed with live food. On April 28, when the fry hatched latest had exchanged their light coloring for a darker, and fed as greedily as the older fishes, they were sent to the Wocheiner Lake, which they reached "in faultless condition," according to the report of the recipient.[a]

The temperature of the water used in February was 4° to 5°, in March 5° to 8°, but rose later to 10°, then to 13° C. Until April 12 there were no losses; after this there were three in all, one fish being choked by a crumb. No *Costia* was apparent. On March 30, some seven days later, the second siphon was set flowing for the first lot, consequently 8.4 liters of water were received per minute; the same was done for the second lot.

As a control lot, on March 28, 30 fish had been placed in a small box (containing 1,362 liters of water, flow of 4.2 liters per minute) arranged as heretofore, i.e., on a level with the distributing trough without waterfall or increased pressure. On the 3d of April I noticed two weak fishes, one of which was found dead on the 4th, and I found *Costia* by a microscopic investigation of another fish showing signs of disease. After giving a salt bath to the remaining fishes I left them to their fate in a spring of the pond.

I saw *Costia* renewed between afternoon and the next morning in a control lot of *fontinalis* during the last third of April in spite of salt baths. For security and my own satisfaction I gave a salt bath of 1.5 per cent of 35 minutes' duration to a lot of *Trutta lacustris* in the morning of April 25 and 27 before shipping them away.

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[a] The transportation in two casks of 128 to 132 liters lasted 1½ to 2 hours by wagon, 2 hours and 22 minutes by rail plus 47 minutes and 13 minutes standing, a total of 6 hours and 35 minutes. The water was cooled in the hatchery and when placed in the railway carriage was of from 10° to 7.5° C. The day was warm and sunny. The dimensions of all the boxes were 52 by 33 by 22 centimeters. The depth of the water was 15 centimeters.

EXPERIMENTS IN THE POND.

It was not possible to arrange a waterfall there. I placed two barrels containing 200 liters, so that the water flowed, as in the hatchery house, through longer or shorter rubber tubes, according to necessity, and in slender jets into all the hatchery boxes. The board covering of the cut-off part of the pond had been removed in the preceding autumn and had not been renewed. The maximum of the pressure was 118 centimeters in both barrels, the minimum 33 centimeters. The filling of each of the barrels took place at least twice daily, later even as often as five times. During the first week the water had to be led up from the pond over a small scaffolding, as the spring was still too weak, but after some rainfall the water could be pumped straight from the pond.

On March 27 two boxes with *S. fontinalis* were set up. On April 4 *Costia* was noticed among them in spite of the jet of water from the barrels. The daily aeration of the water for 1½ hours to 2 hours was of too short duration and too little effective with the pressure obtaining. The outflow pipe of the barrel and the small opening of the nozzle were frequently clogged by things carried in by the wind and taken up by the pump.

There were seven boxes in all and in each of these the fry received a salt bath of 2 per cent for thirty minutes every other day. To all appearances the aeration and the streaming of the water from the barrels did not remain without effect. The boxes could be thoroughly cleaned during the whirling of the water, and it could not be denied that the fishes grew more lively in the currents, darting through the whirls after the food without paying any attention to the fact that the jet of water pressed them downward; and, the most important of all, losses were not so frequent as heretofore and amounted (by estimate) to not over one-quarter in the maximum, and in a lot of *S. irideus* it was very small, in fact inconsiderable.

This lot came from large, beautifully colored parents. I had, however, done a foolish thing with the eggs. Since it is very difficult and takes a great deal of time to place the eggs regularly on the tiles so that they will not touch each other, I had ordered flat, round depressions made in regular rows in two zinc sheets in order to facilitate the work. The placing of the eggs was effected beautifully, but think of my horror to see, after opening the breeding boxes, instead of the hoped-for 1,900 or 2,000 fry, only 378, although these were almost all large and fine. Ooze had settled in the depressions with the eggs and filled the spaces between them.

On April 14 these fry were put in the pond and were cared for more than the others in regard to food and aeration. Up to May 1 the losses amounted to 25 fishes; up to June 3 there were only three more. After June 11 there remained only three boxes to be taken care of, and the above mentioned *irideus* were treated to more frequent aeration, from eight to ten times daily. Beginning with June 24 I ventured to omit the salt baths, and since no losses resulted I decided to omit the baths entirely and confine myself solely to aeration; rightly, too, as I saw afterwards. On June 16 the fish were all sent away in a cask, fresh and healthy. The cask contained 63 liters of water without ice. Duration of transportation, 1 hour and 30 minutes by wagon, 1 hour and 30 minutes by rail, 2 hours and 30 minutes by wagon, in all 5½ hours. At the pond 3 fish were found dead, wounded by lumps of ice which were put into the water in the railway car without any ice bag.

## SUMMARY AND CONCLUSION.

I come to the following conclusion from the above-mentioned experiments: A means for the radical prevention of *Costia necatrix* in salmonoids under culture is to be found in the abundant and constant introduction of atmospheric air into the living water; in other words, abundant and constant aeration.

Can deeply infected fishes be cured and saved? I doubt it. I have never seen that surface wounds and abrasions of the skin healed; fungus invariably assailed the injured places and extended over the neighboring areas more and more until there ensued weakness, difficulty of moving, and lastly death, while deep wounds, bites, thrusts, and cuts were often found healed and leaving scars.

*Costia* lives and increases on the skin and on the gills and destroys their tissue. Cure is always possible in the beginning of the infection, and the following phenomenon may be pointed out: All the fishes presenting a suspicious appearance—i. e., showing signs of weakness and discoloration and refusing food—were taken up by me with a gauze hand net and washed out in the water flowing from the hatching troughs. There was always water around the hatching boxes 3, 5, to 10 centimeters deep, according to the height of water in the pond. Here all around the breeding troughs and in the narrow waterflow to the pond there came again and again small fishes, mostly *S. fontinalis* of the same size as in the boxes, about 50 in June, and these seemed to be quite healthy, catching greedily at the crustaceans falling from the boxes. As it was impossible for them to come through out of the boxes, either these were cured fishes or I have taken uninfected fishes out of the boxes.

It need not be mentioned that *Costia* spreads more rapidly when the fry are crowded and that the rise of temperature above 10° C. accelerates the progress of the infection and its communication.

# TREATMENT OF FUNGUS ON FISHES IN CAPTIVITY

By L. B. Spencer

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

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A large specimen of brook trout (*Salvelinus fontinalis*), which was caught with a hook in Sunapee Lake, New Hampshire, was received at the New York Aquarium in the spring of 1896. The trout had a wound on the head. A few days after being placed in an exhibition tank fungus appeared on the wound. The writer treated the disease by applying salt water from the bay, which is pumped into the aquarium. A hose was used, the end being kept near the head of the trout, so that the stream of salt water reached the wound. This operation was repeated until the fungus disappeared. The wound healed and the fungus did not again appear.

The use of salt water has been continued in the treatment of the fishes. If the water in the bay is not of sufficient saltness to cure fungus, I use enough rock salt to increase the specific gravity to near 1.028, which is about the specific gravity of ocean water. Most of our fresh-water fishes will endure this treatment for a time, but it is necessary to keep watch on some species, or they may die if the salt water is used too long.

The usual method employed is to draw the fresh water out of the tank to about 10 or 12 inches in depth, or perhaps less if the fishes are not frightened, stopping the inflow of fresh water at the time. The tank is then filled with salt water. By this method the fishes rarely, if ever, appear to suffer any inconvenience, as the change from fresh to salt water is gradual. When necessary to use rock salt, this is put into the tank before running in the salt water, as the current aids in dissolving it. The water need not be kept in circulation in the large exhibition tanks during the treatment unless one has plenty of salt water to waste; the stream may be cut off for a time, but it is necessary to keep watch on the fishes; as soon as any uneasiness is shown the fresh water should be turned on. It is often necessary to repeat this treatment each day in order to effect a cure.

In the year 1907 and the winter and early spring of 1908 the Croton water was in such condition that fungus was more prevalent, gave more trouble, was more difficult to cure, and was fatal in more cases than at any time in the history of the aquarium. Salt-water treatment did not cure as before, and the use of hydrogen dioxide was commenced. If a fish has only two or three diseased spots, it may be taken out of the tank with a net and the dioxide applied with a sponge. When the fungus is distributed over a considerable portion of the body, the fish is immersed in a solution of one part hydrogen dioxide to three or four parts of water. The length of time fishes will endure the treatment varies much with different species. It is necessary to watch them closely or some will be injured or killed.

Fungus has been killed on hundreds of fishes, of many species, in the New York Aquarium, by the application of hydrogen dioxide, and the fishes have been kept on exhibition for weeks, when they would have died in a few days without the treatment. Treatment for fungus should commence as soon as it appears; if not, it soon eats into the body and weakens the fish, making the cure more doubtful.

After treatment it is most necessary to take precautions against a recurrence of the fungus. In my experience, in many cases it is not difficult to kill fungus on fishes, but when this is done the affected place is left a sore, and the fish is more or less weakened by the disease and treatment. Therefore, when put back into the tank in the same water from which the disease was contracted, the fungus soon appears on the places formerly affected. Each recurrence reduces the strength of the fish and in many cases death occurs in time. I believe that if after treatment the fish could be put into new water practically free from fungus the sores would heal and the disease would not reappear. A human being contracts pneumonia and recovers, but is not exempt from contracting the disease again; in fact, under the same conditions, he may be more liable to a second attack.

In March, 1908, when fungus disease was so prevalent in the aquarium, there were two tanks of fishes, one of rock bass (*Ambloplites rupestris*) and the other spotted or channel catfish (*Ictalurus punctatus*), both of which species were attacked. Salt water was used, but without any beneficial effect. Hydrogen dioxide solution was used until the fishes were entirely cured. At the present time, September 10, 1908, every specimen of both species is in fine condition.

Fishes in house aquariums can be treated for fungus by taking the diseased specimen out of the aquarium and immersing it in prepared salt water, or in a solution of hydrogen dioxide. A small quantity of either preparation will be sufficient. If kept for some time, the dioxide will lose strength and become less effective.

# METHODS OF COMBATING FUNGUS DISEASE ON FISHES IN CAPTIVITY

By Charles F. Holder

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# METHODS OF COMBATING FUNGUS DISEASE ON FISHES IN CAPTIVITY.

By CHARLES F. HOLDER.

The few suggestions made in this connection are the result of observations made in several tank aquariums and a series of open-reef aquariums on the Florida coast for the study of corals and fishes.

Fishes in confinement are subject to fungus disease in a ratio as the conditions under which they are kept differ from those of their normal habitat. Such differences vary largely with the intelligence or ignorance of the keepers, or their carelessness. Fishes are handled improperly, have been injured previously or in their capture; they are overfed and food collects in the tanks; aeration is incomplete; there is an overabundance of algæ; or the cement of the tank may be poisonous. All these factors are causes of disease, as I observed in the New York Aquarium in 1873, in the Santa Catalina Zoological Station in 1903–1908, and in Florida where aquariums were built out into the reef.

It has been my experience, then, that if preventive measures are sufficient few fish are diseased or lost, and the point of my suggestions relating to fungus affecting a species of fish under cultivation is that the Chinese method of materia medica should be adopted—namely, not to cure but to keep well. A set of rules bearing on the prevention of disease should be observed by every aquarium attendant. Such rules are as follows:

I. Never take out fish with the bare hands. Lift them carefully with a large fine-mesh net. Under no circumstances touch them, as handling often produces fungus.

II. Give the fish proper and natural aeration. The surf or near-shore fishes require more or direct aeration; deep water forms require less.

III. Never allow food to collect in the tank. Have every tank supplied with an abundance of natural scavengers—crabs of various kinds, barnacles (sea water). In fact, it should be the most important qualification of an attendant to know how to equip a tank to give the fish natural surroundings. The habits of the fish should be known, its usual food given it, and the balance should be preserved in the tanks, each being supplied, so far as possible, with the conditions found in natural life.

The following are some experiments successfully tried at the Avalon Zoological Station.

1. Fungus growth developed on sculpins. Investigation showed that there were 50 per cent too many in the tank. The fish, a near-shore, rocky-bottom species, needed maximum aeration; this was increased and in a few weeks the fishes were in the best of condition.

2. Male sheepshead constantly died because attacked with a virulent fungus; swam at the surface with the head out of water; showed bruises over body, and lacerated fins. Attendant diagnosed the case as "fish sickness." The habits of the fish were carefully studied, a man watching them even at night. This watcher reported that as soon as the lights went out the largest males attacked the other males furiously and repeatedly bit and lacerated them. The next day two sheepshead tanks were arranged, each with one male to ten or twelve females. In these there was no more difficulty with fungus growth.

3. Surf-fish were attacked with malignant fungus growth. They were in a tank with air coming up through the bottom, thus receiving the minimum amount of aeration. The surf-fish in California lives near the surf and requires the rush of well aerated water. Surface aeration of a violent kind was provided and the fishes recovered at once.

4. A mysterious illness attacked rock bass. Examination of the tank showed poor sanitary conditions. The fish were invariably overfed, the débris collected at the bottom, and the underside of the rocks was covered with "white." Feeding was stopped for several days, a larger per cent of salt introduced, and scavengers—hermit crabs, mollusks of various kinds—were put into the tank. In two weeks the tanks were completely sanitary.

5. Fish in a standing tank were troubled with fungus growth. It was suspected that the evaporation (near sunlight) was too rapid, and fresh water was added, a quart at a time. The fishes recovered, apparently showing the trouble to be too much salt.

Briefly, I would advocate, instead of elaborate and expensive treatment of fishes, prevention; in other words, a study of the habits of fishes, so that each one kept in confinement may be given the conditions and environment it requires. If this is done, at least in my experience it has so proved, fungus disease need not be dreaded, as it will not appear.

As to treatment for fungus, however, if the fish is a common one and easily replaced, as trout, remove and destroy it at once and waste no time on it. If the fish is rare and treatment is necessary, remove it to a new *tried* tank and double or quadruple the aeration from overhead or direct fall. See that the tank has scavengers (crabs) sufficient to keep it perfectly pure and clean. If fungus has developed, take the fish out, using gloves, and wipe the spots with a sponge dipped in a strong solution of salt and water. Stop feeding for a few days; then give the fish its natural food, if this can be determined.

# A NEW METHOD OF COMBATING FUNGUS ON FISHES IN CAPTIVITY

By Paul Zirzow

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# A NEW METHOD OF COMBATING FUNGUS ON FISHES IN CAPTIVITY.

By PAUL ZIRZOW.

[Translated from the German.]

Several methods have already been proposed and used for combating parasites attacking fishes and for the treatment of diseased fishes. These methods consist in the application of baths of dilute watery solutions of substances which act as death-dealing agents on the micro-organisms. Greatly diluted solutions of salicyl and ammonia have been used for such baths. The use of ammonia (1:1000) for this purpose, proposed by Doctor Roth, of Zürich, proved more effective than salicyl, according to experiments made at the biological station of Munich, as this agent entirely kills off parasitic worms.

The treatment of fishes with baths of this kind has, however, the disadvantage that the fishes themselves suffer from the effects, so that the treatment can be given only with the greatest precaution and during a short period. In order to obtain a complete recovery, repeated baths have been recommended. The treatment of fishes, especially those attacked by fungus diseases, is necessarily very tedious, since the destruction of fungus growth can not be attained so quickly as the extermination of parasitic worms.

This disadvantage in the length of time required for effectual treatment with baths, as well as the injurious effect upon the diseased fish, may be overcome by a method which has been used hitherto only in the transportation of live fish. The feasibility of this method has been shown by the results of several experiments.

The new method of combating fungus diseases consists in keeping the diseased fishes in water regenerated by ozone until the disease has disappeared. The adequacy of such treatment was demonstrated by an experiment which took place in Galatz in October, 1906, during test of a method of keeping fish alive by means of water regenerated with ozone.

This experiment, in which tench, carp, and shad were used, showed that injured fishes which had fungus filaments and growths on their wounds when they were placed in the experiment tanks of a special car and treated with ozone were gradually recovering as the experiment progressed, and that at the end of the 118 hours of the experiment the fungus growths had disappeared.

The tench that had been used in the experiment were placed in the Danube in a floating inclosure and after some four weeks were again, with some carp, loaded into the special car to be carried back to Berlin. Some of the tench again showed signs of fungus. The total quantity of fish used for this experiment was 725 kilograms of tench, 1,500 kilograms of carp, and a few kilograms of pike. The saturation of the water was about 50 per cent, there being 4,500 kilograms of water. The car reached Berlin after a journey of about seventy hours, and it was found that on this occasion likewise, in spite of the abnormally high saturation of the water, the growth had again disappeared on the fishes and the wounds were healing. The fishes were in good condition, and were kept in receptacles a long time after being unloaded.

Experience gleaned during these experiments indicates that in the use of ozone for the regeneration of water it is possible to combat the invasion of fungus growth and to cure the fishes attacked by this disease.

The method may be applied by keeping the water in which the diseased fishes have to be held during their disease in constant rotation and by saturating it during its motion with ozone generated by dark electric discharges.

# EXPERIENCE IN ABATING DISEASE AMONG BROOK TROUT

By Albert Rosenberg

*Proprietor Spring Brook Trout Hatchery, Kalamazoo, Mich.*

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# EXPERIENCE IN ABATING DISEASE AMONG BROOK TROUT.

By ALBERT ROSENBERG,

*Proprietor Spring Brook Trout Hatchery, Kalamazoo, Mich.*

Mr. PRESIDENT: I shall ask your kind indulgence at the beginning of this paper to give you a brief history of my own fish-cultural operations, as this is essential to the subject.

I established the Spring Brook Trout Hatchery in 1895 without having had any practical experience. The site on which operations were commenced was a basin of about 4¼ acres surrounded by high hills. The water supply originates at the north end of the basin at the foot of the hills, where is a number of what are called in this part of the country (Michigan) spring holes. The land was covered with tamarack, elm, ash, etc. These were all cut off and a dam 209 feet long was built across the site, flooding about three-fourths of an acre. Eight ponds were excavated by hand labor, as the soil was muck, and ditches were dug to carry the water from springs that were uncovered. I took about 20,000 eggs in the fall of 1895 from wild fish and hatched a good percentage; also bought 25,000 fry in the spring of 1896.

It soon appeared that conditions were not right for extensive fish-cultural operations, as I had started too near the head of the supply and the water became too warm and stagnant. Some of the ponds contained a number of bottom springs which supported a limited number of fish. By 1897 the reservoir had grown up to a dense mass of moss, which, although it was raked out by the boat load, could not be suppressed.

In February, 1899, there were three weeks of intensely cold weather, which heaved all the raceways and put the ponds out of commission. Early in the spring the remainder of the farm was purchased and a large reservoir constructed at the head of the valley. Here was a water supply of 453 gallons a minute. The reservoir was 277 feet long, had an average width of 58 feet, and an average depth of 3½ feet, and was full of small bottom springs.

In 1900 the pond built in 1895 went out during a severe storm. Meanwhile fry of 1899 had grown to good size and 1,500,000 eggs were taken that fall. Losses during the spawning season were normal.

Early in the spring of 1901 an epidemic broke out among these fish. We could pick up from 40 to 50 dead fish early in the morning, and by evening there would be just as many more. Most of them showed no marks of any kind; a few were fungused. The ponds were thoroughly cleaned and the fish shifted, but there was no abatement of the disease.

About the middle of June the fish were netted and given their liberty in the reservoir and the mortality ceased at once, only seven fish being lost. Here there was plenty of natural food and the fish were not supplied with artificial food. In the early fall they were netted and trapped for breeding purposes and placed in a clean pond, but they commenced to die in large numbers before they had ripened their spawn. It was apparent that they had the boil or ulcer disease, as they were covered with purplish blotches and boils.

The hatch of 1900–1901 proved almost a total loss, caused by water pollutions. Early in 1902 I started to build a new system of ponds down the valley. All the brook trout on hand were disposed of. Two hundred and fifty thousand eggs were purchased from eastern sources that season, a number of flowing wells were installed, and it looked as if the troubles were over. But the sequel proved there were worse. Heretofore the fish had not been attacked by disease until 18 to 24 months old, but now the trouble commenced in the fall following their hatching and continued all winter, culminating in the spring with losses of from 90 to 95 per cent. None of these young fish showed any symptoms of boil disease, but most of them had fungus on the gills and head. Not knowing exactly what the trouble was, I continued to hatch fry from eggs taken from wild fish, but the result always proved the same.

I became thoroughly convinced early in 1904 that brook trout could not be reared on an intensive scale under existing conditions, and so reported to persons interested with me, but after these continual losses they were discouraged and would not take any steps to better conditions.

In 1903, 1904, 1905, and 1906 I lost on an average 50,000 to 75,000 yearlings each season, and as no changes were made in methods matters went from bad to worse. In the spring of 1906 there were left only some 40,000 brook trout fry, and as I was unable through severe illness to give the work personal supervision these shrank by September 1 to 10,000. I then determined not to waste any more time and labor on brook trout until the existing conditions could be altered.

I neglected to state that I had taken on rainbow trout in 1898, and had become by 1906 very successful with these fish.

The reservoir built in 1899 had become more or less filled with liquid muck and decaying vegetation. Tons of algae were taken off each year in the early spring and the water could be seen to work and boil. This would continue until about June 1, when all the trees had leaved and water cress had grown to good size, then losses in fry would cease until fall.

In the fall of 1906 I secured complete possession of the plant and at once cut out this reservoir, laying dry the ponds it fed, disposed of all brook trout fingerlings on hand and contracted all eggs taken excepting 18,000 eyed eggs from wild stock.

In the spring of 1907 I ordered made a galvanized iron raceway 277 feet long, 18 inches wide, and 5 inches deep. This was put in place about June 10, and fry were placed in the pond about June 15. The water entering the raceway comes some 700 feet across the marsh, through a solid bed of water cress, and is very cold.

The loss in brook trout fry before they left the hatchery had been very slight, and the still smaller losses outdoors were agreeably surprising. In fact, from June 15 to September 15 the total loss was 152 fry. This pond was drawn once a week and thoroughly cleaned. The fish were fed sheep's liver, always absolutely fresh, and the pond was literally alive with water fleas and pond snails. About this time we became so busy with other work that this pond was not cleaned for about four weeks and the result was a loss of 110 fish, which had become fungused, confirming my theories that unsanitary conditions had been the cause of all this waste of fish and time.

These fish were moved and sorted into two ponds farther down and estimated, by counting a series, at 14,000 in number. A finer lot of fry it would be hard to find. They were of a good size and color. I looked forward eagerly to spring, as I was not satisfied that this would be a permanent success. They were again moved and reassorted into larger ponds about April 22, 1908. As a matter of course there is some loss in these fish—kingfishers, herons, snakes, etc., destroying some, and a few dying of disease.

In addition to the above I have about 450 two, three, and four year old fish. The losses in these have been about two fish per month since spawning, last fall. I have kept all of the hatch of brook trout, this season some 75,000. I am thoroughly convinced that they can be reared successfully. In order to accomplish this desirable result the water must be pure and cold, the ponds kept absolutely clean, and the food perfectly fresh and sweet.

I believe that if conditions permit of changing the application of the water supply these results can be obtained at other stations that have had this trouble, provided the water is suitable to start with. At stations which derive their water supply from brooks or ponds that heat and dry up in summer and freeze hard in winter, it will be obvious that the case is hopeless.

In conclusion, I will state that I will be pleased to give personally any further information that may be desired.

# AMERICAN FISHES IN ITALY

By Giuseppe Besana

*President Lariana Section, Lombardy Society of Fisheries and Aquiculture*

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

# AMERICAN FISHES IN ITALY.

By GIUSEPPE BESANA,
*President Lariana Section, Lombardy Society of Fisheries and Aquiculture.*

[Translated from the German.]

## REARING IN ARTIFICIAL PONDS.

In the small ponds of the Piscicoltura Borghi at Varano-Borghi, opened in 1907, were produced at first mostly fry and yearling fishes for stocking purposes. But as the plants were without results, the ponds were increased in number and the rearing of table fishes was undertaken, including attempts to cultivate American trouts and salmon, namely, *Salmo irideus*, *Oncorhynchus tschawytscha*, and *Salvelinus fontinalis*. Experiments were made also with *Salmo clarkii*, crossing it with the rainbow trout.

Of these fishes, at the present time only the rainbow trout is being cultivated. The quinnat grew extraordinarily fast during the first year and without losses, reaching a size for table use during that one year; but the flesh was not yet firm nor of good flavor. The growth was still good during the second year, but in the third year there remained but very few of the fish, and they were thin and for the most part died during the period of spawning. The quinnat presented another disadvantage during the second year, being so delicate that when fished out to be transferred to other ponds, in spite of the great care taken, a great number of them died. The brook trout grew very well during the first year, markedly less during the second year, still less during the third, while the mortality continually increased. Compared with the European salmonoids the best results were obtained with the rainbow trout. In the second summer these trout reached the size of table fishes, weighing 150 to 200 grams, and the flesh had a good flavor. They endure transportation well, and readily take artificial food. We know of no other salmonoids so well adapted to culture in ponds. The few experiments in crossing the *irideus* with the *clarkii* trout did not encourge further effort, as the growth of the hybrid is far inferior to that of *irideus*.

## PLANTS IN LAKE MANATE.

The area of this lake is 240 hectares; greatest depth, 37 meters; plankton abundant; vegetation scant; maximum temperature of water, 8° C. at the bottom, 24° C. at the surface; minimum temperature, 8° C. at the bottom, 0° C. at the surface. The native fishes of this lake are, in the order of their abundance, river perch, tench, roach, pike, bleak, eel, and burbot. Tables I, II, III, and IV show the plants of the introduced fishes and the catch. Table V gives the catch for 1907.

TABLE I.—RAINBOW TROUT (SALMO IRIDEUS).

| Year. | Size or age of fish planted. | Number planted. | Number caught. | Weight of catch. |
|---|---|---|---|---|
| | | | | *Kilograms.* |
| 1897 | Fishes 2 years old | 800 | | |
| 1898 | Small fry | 4,130 | | |
| 1899 | Yearlings | 8,618 | | |
| 1899 | Fry 2 months old | 676 | 5 | 9.700 |
| 1900 | Fry 2 months old | 1,400 | | |
| 1901 | Yearlings | 300 | 7 | 9.800 |
| 1901 | Fishes weighing 400 grams each | 21 | | |
| 1902 | Fry 2 months old | 4,500 | | |
| 1903 | Small fry | 10,000 | | |
| 1904 | Small fry | 10,000 | | |
| | Total | 40,445 | 12 | 19.500 |

TABLE II.—BROOK TROUT (SALVELINUS FONTINALIS).

| Year. | Size or age of fish planted. | Number planted. | Number caught. | Weight of catch. |
|---|---|---|---|---|
| | | | | *Kilograms.* |
| 1903 | Fry 2 months old | 2,240 | | |
| 1903 | Yearlings | 80 | | |
| 1903 | Fish weighing 200 grams each | 150 | | |
| 1904 | Small fry | 2,500 | 19 | 5.200 |
| 1905 | Yearlings | 518 | | |
| | Total | 5,488 | 19 | 5.200 |

TABLE III.—BLACK BASS (MICROPTERUS SALMOIDES).

| Year. | Size or age of fish planted. | Number planted. | Number caught. | Weight of catch. |
|---|---|---|---|---|
| | | | | *Kilograms.* |
| 1897 | Yearlings | 500 | | |
| 1897 | Fish 2 years old | 86 | | |
| 1897 | Fish 3 years old | 6 | | |
| 1899 | | | 30 | 11.80 |
| 1901 | | | 76 | 78.20 |
| 1902 | | | 226 | 217.10 |
| 1903 | | | 163 | 196.70 |
| 1904 | | | 372 | 284.50 |
| 1905 | | | 343 | 246.80 |
| 1906 | | | 803 | 368.20 |
| 1907 | | | 241 | 147.40 |
| | Total | 592 | 2,254 | 1,550.70 |

TABLE IV.—SUNFISH (LEPOMIS AURITUS).

| Year. | Number of fish planted. | Average weight when planted. | Weight of catch. |
|---|---|---|---|
| | | *Grams.* | *Kilograms.* |
| 1901 | 140 | 30 | |
| 1901 | 66 | 45 | |
| 1902 | 91 | 50 | |
| 1903 | | | 120.80 |
| 1904 | | | 164.60 |
| 1905 | | | 249.20 |
| 1906 | | | 300.10 |
| 1907 | | | 302.70 |
| Total | 297 | | 1,137.40 |

TABLE V.—TOTAL CATCH IN LAKE MANATE IN 1907.

| Species. | Number. | Weight. |
|---|---|---|
| | | *Kilograms.* |
| Tench (Tinca vulgaris) | 618 | 706.70 |
| River perch (Perca fluviatilis) | | 562.80 |
| Small eels (Anguilla vulgaris) | 107 | 22.60 |
| Large eels (Anguilla vulgaris) | 24 | 14.70 |
| Pike (Esox lucius) | 53 | 46.50 |
| Bleak (Alburnus alborella) | | 302.70 |
| Sunfish (Lepomis auritus) | | 302.70 |
| Black bass (Micropterus salmoides) | 241 | 147.40 |
| Burbot (Lota vulgaris) | 4 | 1.10 |
| Total | | 2,107.20 |

Failures were noticeable with the salmonoids. I must add, however, that I have had similarly negative results with European salmonoids. It was only in the beginning of this year that there were caught 100 *Coregonus marœne*, weighing from 0.50 to 2 kilograms. Fry of this species had been introduced, and a large individual was seen only here and there. No fry had been planted in the lake for four years, and the smaller fishes which were caught, weighing 800 grams, must have been bred from fishes that had spawned in the lake.

The sunfish did not increase greatly in this lake; the catches are insignificant and have never exceeded 300 kilograms yearly, i. e., somewhat over 1 kilogram per hectare.

I had built great hope on the black bass. Young *Micropterus* were seen everywhere during the first years. The first catch was made only four years after their introduction, and it increased to 368 kilograms. During the last year, however, it fell to one-half of this quantity, and the present year will show still poorer results. When the black bass was introduced there were quantities of bleak in the lake, and this fish was not caught at all. At the present time it has entirely disappeared.

Lake Manate yields at present, as formerly, 3,000 to 5,000 kilograms of fish yearly. No benefit was derived from the introduction of new species of fishes, but perhaps even some disadvantage. *Micropterus*, which bring a higher price, have disappeared, as have also the river perch and the pike, probably on account of a lack of small fishes for food. The tench and the roach (*Leuciscus erythrophtalmus*) are the only ones that remain.

How to provide new food is the present difficult problem, which, after the failure with the sunfish, will scarcely find easy solution with present experience.

## PLANTS IN LAKE VARANO.

Area of this lake, 360 hectares; greatest depth, 7 meters; much plankton, very rich vegetation; maximum temperature of the water, 24° C. at the surface, 24° C. at the bottom; minimum temperature, 0° C. at the surface, 6° C. at the bottom.

The species of fish contained in the lake are, in the order of their abundance, sunfish, river perch, tench, bleak, black bass, eel, zander, mirror carp, and pike. The sunfish and black bass, also the zander and the carp, were introduced in this lake.

The results obtained with the American fishes here are marvelous, especially with the sunfish, as two other lakes communicating with Lake Varano are overstocked with sunfish. It is scarcely possible to notice any effect on the other kinds of fishes, except that the pike has grown scarcer and the bleak has disappeared. The river perch is much fatter and grows much more rapidly than before.

The plants of introduced fishes, together with subsequent catches, are shown in tables VI and VII. The yearly output of fish of all kinds, amounting, formerly to 170 tons, has increased to 300 and more tons. Table VIII gives the total catch for 1907, which is exceedingly good, amounting to almost 90 kilograms per hectare.

TABLE VI.—SUNFISH (LEPOMIS AURITUS).

[Eighty-three 3-year old brood fishes introduced in 1900.]

| Year. | Weight of catch. |
|---|---|
| | *Kilograms.* |
| 1901 | 682.5 |
| 1902 | 1,919.5 |
| 1903 | 5,845.9 |
| 1904 | 5,958.4 |
| 1905 | 7,456.9 |
| 1906 | 5,990.7 |
| 1907 | 12,811.4 |
| Total | 40,665.3 |

TABLE VII.—BLACK BASS (MICROPTERUS SALMOIDES).

| Year. | Fish introduced. | | | Number caught. | Weight of catch. |
|---|---|---|---|---|---|
| | Number. | Size or age. | Average weight. | | |
| | | | *Grams.* | | *Kilograms.* |
| 1900 | 8 | Brood fish | 560 | | |
| 1900 | 1,000 | Small fry | | | |
| 1901 | 21 | Brood fish | 860 | | |
| 1902 | 6 | Brood fish | 500 | | |
| 1903 | | | | 859 | 657.50 |
| 1904 | | | | 3,193 | 2,204.90 |
| 1905 | | | | 2,183 | 1,387.30 |
| 1906 | | | | 8,941 | 2,987.20 |
| 1907 | | | | 5,896 | 2,345.70 |
| Total | | | | 21,872 | 9,582.60 |

TABLE VIII.—TOTAL CATCH IN LAKE VARANO IN 1907.

| Species. | Number. | Weight. |
|---|---|---|
| | | *Kilograms.* |
| Tench (Tinca vulgaris) | 2,801 | 3,634.70 |
| River perch (Perca fluviatilis) | | 7,568.10 |
| Small eels (Anguilla vulgaris) | 1,066 | 280.50 |
| Large eels (Anguilla vulgaris) | 894 | 457.30 |
| Pike (Esox lucius) | 224 | 232.10 |
| Bleak (Alburnus alborella) | | 2,626.60 |
| Sunfish (Lepomis auritus) | | 12,811.40 |
| Black bass (Micropterus salmoides) | 5,896 | 2,345.70 |
| Carp (Cyprinus carpio) | 52 | 280.30 |
| Zander (Lucioperca sandra) | 219 | 407.70 |
| Total | | 30,644.40 |

I was criticised for introducing the sunfish, but I believe that I do not deserve it. The sunfish is of much better flavor than the ordinary bleak. Delicious steaks can be cut out of the larger of them, and the fish bring a good price where better known. They are also a very good food for the carnivorous fishes in the lake. They increase in an extraordinary manner in shallow lakes and must be fished out diligently. They do not reach any importance in deeper lakes and in consequence can not have any effect. In lakes where there are no salmonoids the sunfish should be an excellent item of popular food. The average weight of the fish caught is 100 grams, which is reached in three years, but we have caught individuals weighing 400 grams. Another advantage is that except when the lake is frozen it is always possible to catch more or less sunfish, a thing which is of great importance to the fisherman. The long spawning season, lasting from May until the middle of August, offers the advantage that, as the sunfish do not grow during the winter, there is present through almost the entire year a quantity of small fishes to constitute a food for the predatory species. If the sunfish now and then eats other small fry, it does not consume dangerously great quantities. That it does not eat spawn is well established. The fish should be of great value in Italy in swampy waters, where it thrives very well and can stand great heat and great cold. While Lake Manate, which is of far greater depth, produced only a little more than 1 kilogram per hectare, the shallow Lake Varano with its swampy bottom produced 35 kilograms of sunfish per hectare during the past year.

The black bass also flourished in this lake (table VII), yielding somewhat less than 10 kilograms per hectare. The fishing is very irregular and uncertain, however, some 100 kilograms being caught one day, while on the next not one fish may be found. The black bass can be transported safely alive. Its flesh is boneless and very palatable, but its plump shape and big head make its sale difficult. There is much around the head that can be eaten, but most people prefer the zander. The growth of the black bass is markedly greater than that of the river perch. While the latter seldom reaches 1 kilogram and this in some eight or nine years, the black bass reaches this weight in three years. It increased in number considerably during the first years, but later, when there were many large individuals, these ate up many of the smaller of their species. It has no effect whatever on the other fishes in the lake, except *Alburnus alborella*, which it has eaten up entirely. I certainly prefer the zander, but it can not be introduced into all waters, while the black bass will thrive anywhere.

I have also introduced the black bass in small lakes with great success and at a small cost. In order to make this success lasting, however, it is necessary to introduce the sunfish at the same time. The small bleak is soon eaten up by the black bass, the sunfish alone, on account of its enormously prolific propagation, being able to withstand and keep ahead of this terrible devourer.

On account of the defective organization on the part of our government in respect to fisheries, it is impossible for me to report on the introduction of rainbow trout in public waters, or on catfish, black bass, and sunfish in other lakes. It may be seen, however, from the above reports, that great advantages may be reaped from the introduction of these and other American fishes.

# ACCLIMATIZATION OF AMERICAN FISHES IN ARGENTINA

By E. A. Tulian

*Chief of the Section of Fish Culture, Ministry of Agriculture, Argentina*

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

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# ACCLIMATIZATION OF AMERICAN FISHES IN ARGENTINA.

By E. A. TULIAN,
*Chief of the Section of Fish Culture, Ministry of Agriculture, Argentina.*

During the latter part of 1903 the Government of Argentina, having determined upon investigations as to the possibilities of practical fish culture in that country, employed Mr. John W. Titcomb, chief of the division of fish culture in the United States Bureau of Fisheries, to inaugurate the undertaking. Mr. Titcomb was engaged in the work some eight or nine months, and during this period arranged for the introduction of several species of fish from the United States. He also chose the site for the first hatchery at Lago Nahuel Huapi, situated in the Andes Mountains, within 2 or 3 miles of the Chilean boundary.

Actual fish cultural work was begun in Argentina March 4, 1904, with the arrival at Lago Nahuel Huapí of a consignment of fish eggs with which I had left New York January 19. From Buenos Aires I brought also the necessary equipment for a small temporary hatchery, the latter having been planned by Mr. Titcomb and nearly finished under his direction before he left the lake. The first part of the journey, from Buenos Aires to Neuquen, was made by train, the time occupied being two nights and one day. From Neuquen to Lago Nahuel Huapí, a distance of 300 miles, the eggs and hatchery equipment were carried in wagons, the members of the party accompanying on horseback.

The consignment of eggs consisted, in New York, of the following: One million whitefish (*Coregonus clupeiformis*), 100,000 brook trout (*Salvelinus fontinalis*), 53,000 lake trout (*Cristivomer namaycush*), and 50,000 landlocked salmon (*Salmo salar sebago*). The loss in the entire lot of eggs, from the time they left New York until their hatching was completed, was less than 10 per cent. The loss in the lake trout was only about 5 per cent, and the same in one lot of brook trout, while the other 50,000 lot of this species began hatching before reaching their destination, thereby causing a loss of about 30 per cent. The loss of landlocked salmon was about 10 per cent, while the loss of whitefish to the day their distribution was concluded had been only 10 per cent. This consignment of eggs produced a great many more fry than we expected, and it became necessary to move the hatching troughs and fish immediately to a site about 3 miles away, where were found springs from which would flow at least ten times more water than those at the first location. The hatchery on this site has since been pulled down and rebuilt on a much larger scale.

We liberated 900,000 strong, healthy whitefish fry in Lago Nahuel Huapí within a month after the arrival of the eggs at the hatchery. Up to the present time, however, no specimens of the whitefish have been secured for unmistakable identification, owing, probably, to the fact that we have not yet been able to fish systematically for them with suitable boats and nets. A supposed whitefish was caught in a small seine about a year ago by an "estanciero" living on the shore of the lake.

The majority of the lake trout, as also the greater number of the landlocked salmon, were planted in the lakes Nahuel Huapí, Traful, Gutierrez, and Correntosa. Lago Traful is about 45 miles from Lago Nahuel Huapí, and is about 30 miles long, but probably not more than 5 wide at greatest width, and very narrow at other points. Lago Gutierrez and Lago Correntosa are connected with Lago Nahuel Huapí by short streams. Both lakes are about 10 miles long, with an average of 2 to 4 miles in width. The larger proportion of the brook trout were planted in a number of small rivers and streams flowing into these lakes, as well as in tributaries to the Rio Limay and Rio Traful. The Rio Limay flows out of Lago Nahuel Huapí, and the Rio Traful out of Lago Traful, and empties into the Rio Limay.

Lake trout have been found in Lago Traful and Lago Correntosa, and landlocked salmon in Lago Gutierrez, while brook trout have been found in nearly all of the rivers and brooks stocked. In many of these the brook trout are very numerous and are increasing rapidly. The superintendent and assistants of the Nahuel Huapí hatchery took, both last year and this, thousands of fingerlings from irrigating ditches which receive their water from these streams, and replanted them in the brooks. Only last April 860 brook trout fingerlings were taken from a small garden-irrigating ditch heading in the "arroyo de Jones," and 2,300 from another heading in the "arroyo de Newbery." These were undoubtedly fingerlings hatched in September or October, 1907.

On March 1, 1905, the fish in the ponds at the Nahuel Huapí hatchery were counted, and there were found to be 8,500 brook trout, 3,800 lake trout, and 1,800 landlocked salmon. They measured from 6 to 8 inches in length. A large number were accidentally lost during the latter part of the year, but in May, 1906, we had a considerable number of each of these species in the ponds. The death rate in all three from the time hatched, in March, 1904, until now was as low as would have been found at any one of the more successful trout hatcheries in the United States. During this month (May) about 50,000 brook trout eggs were collected from stock fish, and the loss on the lot during the hatching period was but 4 per cent. The alevins hatched were strong and healthy, and later turned out a robust lot of fry, the loss being less than 5 per cent during the next four months.

During May and June, 1907, 270,000 brook trout eggs were collected at the Nahuel Huapí hatchery. They were hatched with an average loss of 15 per cent. On June 21 140,000 of these eggs were eyed and started down the Rio Limay to Neuquen in a small boat, and brought from Neuquen to La Cumbre, in the Province of Córdoba, via Buenos Aires, by rail. They arrived at the La Cumbre hatchery July 7, with a loss en route of 2 per cent, and were hatched with a further loss of 4 per cent. The fry loss was not large, not taking into account the killing of a large number by accident. Plants of fry were made during the latter part of August and all of September, in various bodies of water in the provinces of Córdoba, Buenos Aires, Tucuman, Salta, and San Luis.

La Cumbre is in the Córdoba Mountains, an inland range, and about eighteen hours from Buenos Aires by train. The elevation is about 4,100 feet.

I have not yet had time to make a systematic investigation of the waters stocked with the fish hatched from the 40,000 brook trout eggs at La Cumbre, but have been told that trout do exist in several of these bodies of water; and I know that splendid results have been obtained from a plant of 200, made the last of September, in what is known as the Lumsdaine "dique." This is a small pond from 130 to 150 feet in diameter, nearly round, with a maximum depth of 10 feet in its deepest part when full, which is seldom. The water for filling this pond is brought from a very small mountain stream in an open ditch, which is from one-half to three-fourths of a mile long and into which the sun shines all day. The minimum flow of this stream is 35 gallons of water per minute, and the ponds receive it all during the first ten days in each month, but only 5 gallons per minute during the rest of the month. The maximum temperature of the water in this stream is 75° to 77° F. at noon on a hot summer's day, but usually drops back to from 60° to 65° F. at night. I do not know the temperature of the water in the ditch where it empties into the pond at midday in summer, but judge it reaches a temperature as high as 80° to 85° F. I presume the temperature of the water in the bottom of the pond is about 74° to 78° F. at this time.

On July 31, 1908, about one year after these trout were hatched, there were in this pond from 125 to 150 as fine and healthy brook trout as I have ever seen. The only artificial food they have ever had was during about one month when held in the rearing troughs. Since being liberated they have had only the natural food found in this pond; notwithstanding which all are now from 7 to 10 inches in length.

It is hoped that about one-half million of brook trout eggs and a few thousand of landlocked salmon eggs will be collected at the Nahuel Huapí hatchery this season. By May 31 a total of 255,600 brook-trout eggs had been secured. About the first of June 63,000 eyed eggs of this lot were sent to Buenos Aires, and from this city 23,000 were sent to the La Cumbre hatchery, and 40,000 to a small temporary hatching plant only recently located near Ledesma, in the Province of Jujuy, the most northerly province of Argentina. A few days later another lot of 25,000 brook trout eggs were shipped from the Nahuel Huapí hatchery to Santiago, Chile, by request of the Chilean Government, to be hatched in a small hatchery belonging to that Government, located in the Andes Mountains, on the railroad which crosses from Buenos Aires to Valparaiso, not far from the Argentine boundary. The eggs shipped to La Cumbre and Ledesma, via Buenos Aires, reached their respective destinations with a loss of less than 3 per cent. Those shipped to La Cumbre were hatched with a very small loss (less than 4 per cent), and the alevins are strong and robust and fast reaching the feeding stage, with a very small percentage of loss. The loss of eggs hatched at Ledesma was larger, owing to the high temperature of the water we were compelled to use for hatching, which was 55° to 60° F., and 8° to 10° F. warmer than at La Cumbre. The loss of alevins at Ledesma has also been rather large to date, owing probably to the same cause; in neither case, however, has the loss been unexpectedly great.

From what we have accomplished with the brook trout at Nahuel Huapí and La Cumbre, I am led to believe that, by gradually breeding them up to it over a period of two or three years, these fish can be successfully reared in very warm water.

The following table shows the small loss of stock fish at the Nahuel Huapí hatchery for the five months ended March 31, 1908:

STATEMENT OF LOSSES OF ADULT FISH AT NAHUEL HUAPÍ HATCHERY FOR FIVE MONTHS ENDED MARCH 31, 1908.

| Species. | On hand Oct. 30, 1907. | Deaths from Oct. 30, 1907, to Mar. 31, 1908. | On hand Mar. 31, 1908. |
|---|---|---|---|
| Brook trout (2 to 4 years) | 4,902 | 53 | 4,849 |
| Landlocked salmon (4 years) | 70 | 3 | 67 |
| Rainbow trout (3 years) | 4 | | 4 |
| Total | 4,976 | 56 | 4,920 |

Of fingerling and yearling brook trout there were on hand October 30, 1907, 60,950; distributed November 1, 1907, to March 31, 1908, 49,700; loss November 1, 1907, to March 31, 1908, 3,350; on hand March 31, 1908, 8,900.[a]

The second shipment of eggs of American fishes to the Argentine Republic resulted rather disastrously. One of the superintendents of this section left New

[a] It is in the summer months—December, January, and February—covered by these figures, that the greatest losses occur.

York early in June, 1904, with 20,000 eggs of steelhead trout (*Salmo gairdneri*) and 50,000 rainbow trout (*Salmo irideus*) eggs. Off the coast of Brazil the steelhead eggs commenced hatching rapidly and before reaching Rio Janeiro these had all to be put overboard. The rainbow trout eggs carried very badly, and nearly all were lost by July 23. On this date the few remaining live eggs were planted in Laguna La Grande, as it was deemed impossible to reach the Nahuel Huapí hatchery with any alive.

The third shipment was more successful, although far from satisfactory. Early in January, 1905, one of our superintendents left New York with 300,000 brook trout (*Salvelinus fontinalis*) eggs, 224,000 lake trout (*Cristivomer namaycush*), 100,000 quinnat salmon (*Oncorhynchus tschawytscha*), 92,000 rainbow trout (*Salmo irideus*), and 30,000 landlocked salmon (*Salmo salar sebago*), arriving in Buenos Aires February 4. On arrival in the city, the quinnat salmon eggs were found to be practically all dead, while the larger portion of rainbows were either dead or dying. The landlocked salmon, brook and lake trout were in much better condition, the percentage of loss en route having been comparatively small. The greater portion of the live eggs were taken to the Nahuel Huapí hatchery, where they were hatched with fair success. An attempt was made, however, to hatch a few landlocked salmon, brook and lake trout eggs in a temporary hatching plant erected at Alta Gracia, in the Province of Córdoba. The water to be used was from a small mountain stream, it being hoped that the weather would be sufficiently cold at this time—the latter part of March—to reduce the water temperature here to about 55° F. Unfortunately, however, the weather proved to be as warm as at any time during the entire summer, and consequently the water temperature in this stream would rise to about 75° F. at midday, although usually falling to about 60° F. each night. The hatching plant had been located where there were two small springs whose waters came out of the ground at 62½° F. This water was to be given a trial in case the water in the stream was higher, but water at 62½° F. was found to be entirely too warm for hatching and rearing eggs which had been in refrigerator cases at a temperature of 35° to 38° F. for nearly eighty days. A few thousand fish of each variety were hatched, but had to be planted soon after coming out. It has been reported that some of the trout and landlocked salmon planted here have been caught from time to time, but I have never been able to obtain a specimen of either.

The fourth shipment yielded even better results than the first. On February 10, 1906, I left New York, en route to Argentina via England, with 300,000 quinnat salmon (*Oncorhynchus tschawytscha*) eggs, 122,500 sockeye salmon (*Oncorhynchus nerka*), 98,200 silver salmon (*Oncorhynchus kisutch*), 80,000 lake trout (*Cristivomer namaycush*), 60,000 brook trout (*Salvelinus fontinalis*), 30,000 landlocked salmon (*Salmo salar sebago*), and 25,000 rainbow trout (*Salmo *irideus*). At Southampton, England, on February 23, I received 25,000 Atlantic salmon (*Salmo salar*) eggs from the Earl of Denbigh's fisheries in North Wales. On March 17 I arrived at Buenos Aires, but I was unavoidably delayed here for 10 days. The losses from the time the eggs were packed at the hatcheries in the United States and North Wales until reshipped on March 27, en route to the Santa Cruz hatchery, in southern Argentina, were as follows: Quinnat and sockeye salmon, 1 per cent each; brook and lake trout, the same; silver and landlocked salmon, 2 per cent each; Atlantic salmon, only 5 per cent, while it was 20 per cent on one lot of rainbow and 60 per cent on another. From this time until all of the eggs were hatched, April 30, the losses of eggs and alevins were as follows: Quinnat and silver salmon, only 2 per cent; sockeye salmon, 4 per cent; lake trout and landlocked salmon, only 5 per cent; brook trout, 20 per cent (mostly fish hatched en route because of the delay in Buenos Aires), and Atlantic salmon and rainbow trout, about 50 per cent.

The following table shows the number of each species on hand at the Santa Cruz hatchery May 1, 1906, and again on November 1, 1906, with losses, plants made, etc., during this period (6 months):

RECORD OF SANTA CRUZ HATCHERY, MAY 1 TO NOVEMBER 1, 1906.

| Species. | On hand May 1. | Deaths May 1 to Nov 1. | Per cent of loss. | Distributed May 1 to Nov. 1. | On hand Nov. 1. |
|---|---|---|---|---|---|
| Quinnat salmon | 291,000 | 8,730 | 3 | 270,470 | 11,800 |
| Sockeye salmon | 116,400 | 2,330 | 2 | 110,470 | 3,600 |
| Silver salmon | 94,300 | 4,715 | 5 | 85,185 | 4,400 |
| Lake trout | 75,200 | 2,250 | 3 | 68,550 | 4,400 |
| Brook trout | 47,500 | 2,850 | 6 | 40,050 | 4,600 |
| Landlocked salmon | 27,90c | 3,070 | 11 | 24,040 | 790 |
| Rainbow trout | 9,400 | 750 | 8 | 8,400 | 250 |
| Atlantic salmon | 11,900 | 5,900 | 50 | 6,000 | ------------ |
| Total | 673,600 | 30,595 | ------------ | 613,165 | 29,840 |

The following table shows the number of each species on hand at the Santa Cruz hatchery on November 1, 1906, and again on March 1, 1907, with losses, plants made, etc., during this period (4 months):

RECORD OF SANTA CRUZ HATCHERY, NOVEMBER 1, 1906, TO MARCH 1, 1907.

| Species. | On hand Nov. 1. | Deaths Nov. 1 to Mar. 1. | Per cent of loss. | Distributed Nov. 1 to Mar. 1. | On hand Mar. 1. |
|---|---|---|---|---|---|
| Quinnat salmon | 11,800 | 165 | 1.4 | 7,000 | 4,635 |
| Silver salmon | 4,400 | 22 | .5 | 1,300 | 3,078 |
| Sockeye salmon | 3,600 | 20 | .56 | ------------ | 3,580 |
| Brook trout | 4,600 | 65 | 1.4 | ------------ | 4,535 |
| Lake trout | 4,400 | 36 | .8 | ------------ | 4,364 |
| Landlocked salmon | 790 | 87 | 11.0 | ------------ | 703 |
| Rainbow trout | 250 | 13 | 5.0 | ------------ | 237 |
| Total | 29,840 | 408 | ------------ | 8,300 | 21,132 |

The following table shows the number of each species on hand on March 1, 1907, and again on October 1, 1907, with losses and plants made during this period (7 months):

RECORD OF SANTA CRUZ HATCHERY, MARCH 1 TO OCTOBER 1, 1907.

| Species. | On hand Mar. 1. | Deaths Mar. 1 to Oct. 1. | Distributed Mar. 1 to June 1. | On hand Oct. 1. |
|---|---|---|---|---|
| Quinnat salmon | 4,635 | 4 | 4,135 | 496 |
| Silver salmon | 3,078 | 8 | 2,578 | 492 |
| Sockeye salmon | 3,580 | 47 | 3,078 | 455 |
| Brook trout | 4,535 | 25 | 693 | 3,817 |
| Lake trout | 4,364 | 57 | 983 | 3,324 |
| Landlocked salmon | 703 | 64 | 499 | 140 |
| Rainbow trout | 237 | 15 | | 222 |
| Total | 21,132 | 220 | 11,966 | 8,946 |

The Santa Cruz hatchery is supplied with water from two springs, which do not run more than 125 gallons of water per minute, at a temperature of 48° F. When the shortage of this water supply is considered, it is little less than remarkable that we were able to hold the large numbers of 6 months old fish (about 30,000, the greater number being Pacific coast salmon) which we had on hand November 1, 1906 (see first table), and have them in a perfect state of health on this date. In fact they were as healthy as possible on October 1, 1907, one year and six months after they were hatched. The very low death rate from November 1, 1906, to October 1, 1907, will be found by referring to the last two tables. The water supply of the Santa Cruz hatchery decreased greatly during the summer of 1907–8 (months of December, January, and February), and the fish on hand showing signs of disease, a number of each species were planted during these months.

On January 18, 1908, the fifth lot of eggs brought from the United States to Argentina left New York, numbering as follows: 300,000 quinnat salmon (*Oncorhynchus tschawytscha*), 104,000 sockeye salmon (*Oncorhynchus nerka*), 90,000 silver salmon (*Oncorhynchus kisutch*), 75,000 lake trout (*Cristivomer namaycush*), 75,000 brook trout (*Salvelinus fontinalis*), 30,000 rainbow trout (*Salmo irideus*), 15,000 landlocked salmon (*Salmo salar sebago*), and 3,000,000 cod (*Gadus callarias*). I personally had charge of this consignment of eggs to Southampton, England, being accompanied by Mr. Frank Brophy. The loss of the cod eggs was almost complete when we arrived in England, hence I determined not to attempt to take any of these farther. The loss of other eggs was very small indeed, having been less than one-half of 1 per cent from the time they were packed until put on board the steamship *Thames* on January 30, en route to Buenos Aires. The eggs were given over to Mr. Brophy's charge when this ship left her dock on January 1, and in addition to those already mentioned he was given 20,000 Atlantic salmon eggs which were secured from the Earl of Denbigh's fisheries in North Wales. Mr. Brophy arrived with the eggs at the hatchery in Santa Cruz on March 1. The loss from the time of leaving Southampton until the eggs were unpacked at the hatchery was as follows: Quinnat salmon, a little over three-fourths of 1 per cent; sockeye salmon, a little over $1\frac{7}{10}$ per cent; silver salmon, a little less than nine-tenths of 1 per cent; lake trout, something over three-fifths of 1 per cent; brook trout, somewhat over two-fifths of 1 per cent; landlocked salmon, a trifle over $1\frac{1}{2}$ per cent; rainbows (youngest packed without moss) about $30\frac{2}{5}$ per cent; rainbows (youngest packed in moss), a little less than 64 per cent; rainbows (oldest packed without moss), $5\frac{3}{5}$ per cent; rainbows (oldest packed in moss), a trifle over $6\frac{1}{5}$ per cent; and Atlantic salmon 100 per cent. The total loss of the Atlantic salmon was due to imperfect packing, which was not discovered until after the eggs were all injured.

While the eggs that reached the hatchery alive appeared to be good, they were not as strong as a similar lot brought out for this hatchery from the United States and England two years previously, as will be seen by a comparison of the records. The death rate from the time the eggs were put into the hatching trays until they had finished hatching was in most cases rather high, as was also the death rate of fry during the month of March. The losses of eggs during the hatching period were as follows: Quinnat salmon, −9 per cent; blueback (sockeye), 30+ per cent; silver salmon, −14 per cent; landlocked salmon, 4+ per cent; brook trout, 34+ per cent; lake trout, 17+ per cent; and rainbow trout, −44 per cent. The losses of alevins during the month of March was as follows: Quinnat salmon, 5+ per cent; sockeye salmon −9 per cent; silver salmon 18+ per cent; landlocked salmon −63 per cent; brook trout, 10+ per cent; lake trout, −27 per cent; and rainbow trout, 100 per cent.

The lake trout from this hatchery and also the landlocked and sockeye salmon are planted in Lago Argentino and other bodies of water near by. The other salmon are usually planted in the Rio Santa Cruz and tributaries and Rio Gallegos and tributaries. The brook trout are planted in tributaries to the rivers mentioned, also in the tributaries of Lago Argentino and Lago San Martin. The rainbows (first lot of eggs) were planted in tributaries to the Rio Santa Cruz. Lago Argentino is supplied by several small rivers and streams which rise in the Andes Mountains, where there is ice and snow the entire year. The Rio Santa Cruz rises in Lago Argentino, which itself is situated in the Andes Mountains at an elevation of 2,500 to 3,000 feet above sea level, and is very deep. This lake has not yet been accurately surveyed, but is supposed to be 25 to 30 miles long at its greatest length and from 6 to 8 miles wide. It is in the Territory of Santa Cruz, which is the most southerly but one of Argentina.

On May 6 of this year I left New York with about 300,000 steelhead trout (*Salmo gairdneri*), these being the sixth lot of eggs to leave the United States for the Argentine National Government. These eggs were taken to Southampton, England, where 50,000 rainbow eggs from Germany were added to the consignment. They left England May 15, arriving in Buenos Aires on June 7, and at the La Cumbre hatchery on the 13th of the same month. The loss of eggs en route from the United States was very small, and not over 10 per cent on the rainbow eggs from Germany, this latter loss being entirely due to rough handling between Germany and England in the absence of any attendant. From England to the La Cumbre hatchery the loss was less than one-half of 1 per cent. The loss of the oldest steelhead eggs during the hatching was $6\frac{3}{5}$ per cent, mostly due to these eggs being a trifle too far advanced when shipped. The loss of the second oldest steelhead eggs during the same period was about $15\frac{1}{2}$ per cent, due greatly to the eggs being a trifle young when packed. The loss of the youngest of this lot of eggs while hatching was $18\frac{4}{5}$ per cent, due also, no doubt, mostly to the fact that the eggs were rather young for packing. There is, however, no way to avoid these losses on journeys of this length, as some eggs must be shipped when younger than others to guard against the possibility of the older eggs hatching en route. The loss of steelhead fry until they were six weeks old was 4 per cent. At this age they were as strong and healthy a lot of young trout as I have ever seen. All were feeding at this time.

The loss of the rainbows during the hatching period was about $10\frac{1}{2}$ per cent, and the loss of fry until six weeks old was $2\frac{3}{5}$ per cent. At six weeks of age these were all taking food, and were very healthy and strong.

# INTRODUCTION OF AMERICAN FISHES INTO NEW ZEALAND

By L. F. Ayson

*Chief Inspector of Fisheries for New Zealand*

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

# INTRODUCTION OF AMERICAN FISHES INTO NEW ZEALAND.

By L. F. AYSON,
*Chief Inspector of Fisheries for New Zealand.*

At the commencement it is, I think, appropriate to say something about the geographical position and physical features of this little country in the far away South Pacific, which is doing much valuable work for its people by the introduction into its waters of a number of the best sport and commercial fishes from the Northern Hemisphere.

New Zealand, situated between latitudes 34 and 47 degrees south, in the Pacific Ocean, consists of three main islands, the total area of which is about 104,000 square miles. A large extent of the country is mountainous, particularly in the Middle Island, which is intersected along almost its entire length (about 500 miles) by a range of mountains known as the Southern Alps, the highest peak, Mount Cook (the Maori or native name is "Aorangi," meaning "cloud piercer"), being 12,400 feet. The summer snow line on these mountains is about 7,000 feet above sea level.

As would be expected from a country with such physical characteristics, New Zealand possesses a very fine system of rivers and lakes. In the South Island the larger rivers all originate among snow-clad mountains of hard rock formations; in a good many instances their tributaries flow into mountain lakes and from there down through the low country into the sea. Over 20 rivers, taking their rise among the glaciers of the Southern Alp range, flow down into the Pacific Ocean on either coast. In parts of the North Island the same formations prevail to a large extent, but many of the rivers run for the greater length of their course through low country.

This country, with its unique flora and fauna, has also the extraordinary peculiarity that with its magnificent water system it has no indigenous fresh-water fishes of any sporting or commercial value. Eels (*Anguilla australis*) are found everywhere, also a few inferior fishes, such as the kokopu (*Galaxias fasciatus*); but the only representative of the Salmonidæ is the little smelt (*Retropinna richardsoni*) and the native grayling (*Prototroctes oxyrhynchus*), called by the natives "upokororo." This interesting fish, however, seems to be on the verge of extermination, owing to the introduction of trout into the rivers it inhabits, to mining, and to clearing of the vegetation from the banks of the rivers for farming purposes.

The early colonists who emigrated to New Zealand from Great Britain were very much surprised to find a country with such fine rivers, lakes, and streams, but with no fish of any value in them. In a few years the question of introducing some of the British Salmonidæ was considered, and in 1864 the matter assumed definite shape when the Otago Provincial Council took it up and voted a sum of money for the importation of Atlantic salmon eggs (*Salmo salar*), and in 1868 the first lot of English brown trout (*Salmo fario*) eggs arrived in the colony. Since that time the English brown trout and the Loch Leven trout (*Salmo levenensis*) have been successfully acclimatized, and the brown trout now abounds in many of the rivers, particularly those in the South Island.

Of American fishes the following species have been brought into New Zealand: Rainbow trout (*Salmo irideus*), eastern brook trout (*Salvelinus fontinalis*), whitefish (*Coregonus clupeiformis*), chinook salmon (*Oncorhynchus tschawytscha*), sockeye salmon (*O. nerka*), landlocked salmon (*Salmo sebago*), Mackinaw trout (*Cristivomer namaycush*), lake herring (*Argyrosomus artedi*), and catfish (*Ameiurus vulgaris*). Of these we have successfully acclimatized the rainbow trout, brook trout, and the catfish, and as the chinook and sockeye salmon have now returned from the sea to spawn three seasons in succession, I think that we can fairly claim that they are established as well.

The following account of the introduction of the fishes mentioned above may be of interest:

*Rainbow trout.*—Three consignments of eggs were obtained from California by the Auckland Acclimatization Society in 1883 and 1884. These, I believe, were the only rainbow eggs which have been brought to this country. A considerable percentage were lost on the voyage down, but sufficient were saved to provide a stock of brood fish for the hatcheries, and a number to plant in some of the northern rivers. It took some years to work up a stock of spawners at the hatcheries, and as the young fish were produced they were planted in streams all over the Auckland province. It is about fifteen years since rainbow trout commenced to be caught by anglers, and now they exist in immense numbers in almost all the rivers, lakes, and streams in that part of the country.

These fish grow to a great size in this country. While the most common weight caught by anglers is from 2 to 8 pounds, specimens are frequently taken ranging from 10 to 18 pounds, and occasionally over 20 pounds. On the walls of my office I have six mounted specimens taken in the spawning season from a stream flowing into Lake Tarawera; the smallest of these is 12 pounds and the largest 18 pounds. Heavier specimens could have been procured, but these were chosen on account of their elegant shape. They are most plentiful in the streams flowing into and in Lakes Rotorua and Rotoiti. By angling (and anglers are restricted to 30 pounds weight a day) over 20 tons of trout have been taken out of these two small lakes this season. Rainbow-trout fishing has now become one of the chief attractions for tourists to the Rotorua district, and the value of this fish to the country, both for sport and food, is immense.

*Eastern brook trout.*—The first brook-trout eggs brought to this country were imported by a Mr. Johnson, of Christchurch, in the South Island, about 1882, and from Mr. Johnson's importation various acclimatization societies obtained eggs from which they subsequently raised stock fish for their hatcheries. From these hatcheries large numbers of young fish of various sizes have been planted in streams both in the north and south. They made a good showing in a few streams for a time, but since the introduction of the rainbow and English brown trout into these streams the brook trout in some instances have wholly disappeared and in others have been greatly reduced in numbers. Our people think highly of this beautiful fish and are much disappointed because better success has not attended the efforts made to thoroughly establish them in our waters.

*Chinook salmon.*—The first importation of eggs was made in 1875 and from that date to 1880 several shipments were made, some by the Government and some by acclimatization societies. On arrival the salmon eggs were parceled out to different acclimatization societies and the young fish when hatched were planted in rivers from the north of Auckland to the far south. Through want of experience, unsuitable water at the hatcheries, and planting the young fish in rivers when the conditions were entirely unsuitable for them, no results were obtained from these shipments.

In 1900 the government decided to make a vigorous and systematic effort to acclimatize this fish. A site for a salmon station was chosen on the Hakataramea River, a tributary stream of the Waitaki, and the erection of the hatching shed was commenced in November of that year. The government decided to confine its efforts to one of the rivers considered to be the most suitable for these fish, and the Waitaki was chosen, as in its general characteristics it bears a considerable resemblance to the rivers on the Pacific coast of America which the chinook salmon frequent in the spawning season.

In January, 1901, the first shipment of chinook eggs for the government salmon station arrived. They were supplied by the United States Bureau of Fisheries, from its station at Baird, California, on the McCloud River. The shipment came over in charge of Mr. G. H. Lambson, superintendent of the Baird station, and arrived in excellent condition.

From 1901 to 1907 five importations of eggs were made, invariably arriving in splendid condition, the loss in most of the shipments not amounting to more than one-half per cent, i. e., 99½ per cent of good eggs were unpacked into the hatching-boxes at Hakataramea. The total number of eggs in the five shipments reached about 2,000,000, and from these fully 1,700,000 young fish have been turned out. They were planted at various ages from fry to 2-year-old fish, but about 90 per cent were planted just after the sac was absorbed.

Now, as regards the definite results obtained from the young salmon planted. In 1905 salmon were reported as having been caught by anglers in the tideway near the mouth of the Waitaki River, and a specimen of these fish was identified by the late Sir James Hector as a male of the genus *Oncorhynchus*. In May and June, 1906, salmon were found spawning in the Hakataramea River, and specimens were identified by Sir James Hector and myself as chinook. In April and May last year (1907) quite a run of salmon came up the Waitaki River and spawned in several of its main tributary rivers. In the Hakataramea from 300 to 400 salmon spawned in the 2 miles of river before it joins the Waitaki, and a number of these fish were caught and stripped and about 30,000 eggs put down to hatch. The eggs hatched out well, and a number of the young fish are now being reared at the salmon station for experimental purposes. This season the run of spawning salmon in the Waitaki is similar to last year as to quantity, but on an average the fish are considerably heavier, and they seem to have run higher up the main tributary rivers of the Waitaki. Several dead and "spent" fish measured from 3 feet to 3 feet 10 inches in length. Owing to floods when the best run was on, we were able to collect only about 50,000 eggs this season. From the knowledge now acquired with regard to the run of fish in rivers farther inland, arrangements will be made to collect eggs on several streams next season. A point which will be interesting to salmon authorities is that as far as we have gone we have had no "summer" run of salmon; they have always come in April, May, and June—months which correspond, as regards season, with November, December, and January in the northern hemisphere, and the months when the "winter" run of chinook salmon takes place in the Sacramento. Now, I understand that the five shipments of eggs imported to this country from 1900 to 1907 were all from "winter" run fish, and so far we have only had a "winter" run of spawning salmon here.

*Sockeye salmon.*—Only one importation of sockeye eggs was made to this country. A shipment of 300,000 was presented to the New Zealand government by the Canadian fisheries department in 1902. Most of the young fish were planted in streams flowing into Lake Ohau, a lake fed by rivers flowing down from the snowy Southern Alp Range. In 1905 and 1906 reports were received of salmon spawning in the rivers at the head of Lake Ohau, but we were not able to procure specimens until the "run" which took place in April last year.

The officer who visited the locality reported having seen a large number of dead salmon. He netted a number of fish and brought six specimens, the examination of which by experts proved them to be sockeye.

*Whitefish.*—The first shipment of eggs was brought from America in 1877, and from that year to 1904 several shipments were brought over. Owing to the want of expert attention on the voyage, these shipments generally arrived in indifferent condition, and as none of the hatcheries had proper appliances for hatching the eggs I am afraid that most of them were killed. In 1904 the New Zealand government determined to make a systematic effort to acclimatize this fish and erected hatcheries, equipped with the proper whitefish hatching jars, on Lakes Te Kapo and Kanieri. Four shipments of eggs were brought over from 1904 to 1907, and as they were carefully packed and selected for the journey and came over in charge of an expert they all arrived in perfect condition. The loss from the time they left the hatchery at Northville, Mich., until put in jars in the hatcheries in New Zealand was under 3 per cent. The total number of eggs in these four shipments was about 6,000,000. The young fish were all planted in the lakes as soon as the sac was absorbed. As there is no netting for fish in these lakes no reliable information has yet come to hand as to whether they have done well or not, but we intend to net them early in the summer this year, for the purpose of proving whether or not they have taken a hold there.

*Landlocked salmon.*—One shipment of the eggs of these fish was brought to this country in 1906 and arrived in good condition. A number of the young fish have been planted in one of our lakes, and some are now being reared at two hatcheries for the purpose of procuring eggs from them when they mature. There is little doubt but what a good many of our lakes should be suitable for this fish.

*Mackinaw trout.*—A shipment of Mackinaw eggs was brought over from America in 1906 and they hatched out well. The young fish were planted in lakes in Canterbury and the west coast of the South Island.

*Catfish.*—A number of these fish were brought over from America by Mr. T. Russell, of Auckland, in 1877. They were placed in St. Johns Lake and are reported as being numerous in that lake at the present time.

The value of the introduction of these foreign fresh-water fishes into New Zealand waters can not be estimated. Formerly it was a country whose rivers and lakes were devoid of fresh-water fish of any value, now they are teeming with fish of the finest quality for sport and food. All this has been attained partly by the perseverance of our own people and by the generous assistance given to our Government by the United States Bureau of Fisheries and its officers in supplying any fish eggs required.

## DISCUSSION.

Mr. H. STEPHENSON SMITH. I would like to add, with your permission, sir, as New Zealand is a country very remote from this, and as many, perhaps, of my hearers do not know much about its geographical and topographical features, that the country covers approximately 15° of latitude, almost due north and south. It has over 5,000 miles of seaboard; it is interspersed with water courses. In a large portion of that country you will find a mountain stream every mile. We have also some arterial rivers, running 400, 500, 600, and 700 miles, in some cases navigable short distances from the mouth, and they are all tidal rivers. The majority of the smaller streams which run into the eastern and western streams are not tidal rivers, but are fed by glaciers from the mountains. The whole seaboard is indented with bays and harbors, the rivers coming down on each side; and the lakes extend from one side of the islands to the other. Some of the rivers are of considerable size for a country of that extent; and we have chains of lakes running for hundreds and hundreds of miles.

It would seem to me, as a man who knows little about fish except to eat them, that that country should afford facilities for producing fish of the very best kind and of almost any quantity. It also seems to me that there is plenty of food for the fish. The surface of the lakes and streams is covered with flies and many varieties of little insects all the year around; and the rivers never run dry, but are everlasting streams, winter and summer. I thank you very much for your kind attention.

Mr. JOHN W. TITCOMB. One thought suggests itself to me: The results from the acclimatization of the chinook salmon perhaps are the most remarkable thing in the paper; but it is said that the rainbow trout, so-called, which is so very generally distributed now in New Zealand, is not the rainbow trout (*Salmo irideus*), but the steelhead trout (*Salmo gairdneri*).

Prof. EDWARD E. PRINCE. My name was down, I believe, for a communication a day or two ago, but my engagements officially have been so very pressing that I have with difficulty arrived even at this late hour. If you will permit me, I wish to bring a fraternal message from Canada to this important gathering, and I take this first opportunity of doing so.

One important reason why I would like to say a few words in regard to Mr. Ayson's paper is because I have been personally interested in this work of Mr. Ayson in New Zealand. He has several times visited Canada, and I have spent a good deal of time with him on those visits. I arranged for supplies of salmon eggs to be shipped to that distant part of the world, and I have always felt, as every fish culturist on this continent has, a very warm regard for him and his fishery work.

To sum up the great success of these efforts in New Zealand: Its rivers correspond in many features with those of the Pacific coast; many of them are glacial and have abundance of snow water, and there are other features which Mr. Smith referred to in the few remarks he made which correspond to the waters on this continent. But it seems that on the whole the planting of salmon has not been so successful as the trout, and it has always seemed to me one reason was in the lack of proper feeding grounds. There may be abundant food for them in the streams where they were planted as fry, but when out at sea they are literally "at sea;" they do not know where to go to get the appropriate food which the salmon gets in the sea. When the salmon get out to sea they do not apparently find their way back again. Whether they find feeding grounds I do not know. The conditions are not the same off the coasts in the seas of New Zealand as off our own coast or the coast of Europe. But the trout do not wander far on the coast, and numbers remain in the rivers and lakes. They have really succeeded marvelously, so that fish whose original parents were only one or two pounds when adult, now reach twenty or thirty pounds in New Zealand (which is a size that would be almost incredible had we not abundant proof of it) under the favorable conditions provided in antipodean waters.

I have had a communication from Mr. Ayson, jr., within the last few days, in which he expresses hope that the sockeye salmon will be a success. If so, and these Pacific sockeyes breed, then I think the trouble for New Zealand salmon is solved.

I have listened with great interest to this paper, and have only to apologize for troubling the meeting with these remarks at this late stage of the discussion.

# NATURALIZATION OF AMERICAN FISHES IN AUSTRIAN WATERS

By Franz von Pirko

*President of the Imperial and Royal Austrian Fishery Society*

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

# NATURALIZATION OF AMERICAN FISHES IN AUSTRIAN WATERS.

By FRANZ VON PIRKO,
*President of the Imperial and Royal Austrian Fishery Society*

In the belief that it might greatly interest American fish breeders to know what experiences and observations have been made by Austrian pisciculturists in regard to fish imported from America for breeding purposes, and in compliance with a special invitation from the committee of the Fourth International Fishery Congress, Washington, 1908, the Imperial and Royal Austrian Fishery Society has called upon the prominent fish breeders to furnish their observations regarding the results obtained with such American fish. These results, which are briefly set forth here, warrant the conclusion that of all the Salmonidæ which can be taken into account for breeding purposes the American rainbow trout must be regarded as the most important. This trout, which has now been in Austrian waters for a quarter of a century, despite manifold opposition has gained, so to say, the rights of citizenship there. Owing to its excellent qualities it has been quickly introduced into all pond fisheries and is really a first-class salmonid. In consequence of its ability to endure deep water, the number of ponds in which it can grow is quite considerable, and pond-fish owners would be well advised to allow plenty of room for the rainbow trout, without forgetting, however, that after all it is a salmonid. Its capacity to stand high temperatures enables it to replace the pike in carp ponds, the more so as it does not possess the dangerous qualities of the latter.

The *irideus* is just as indifferent to high temperatures as to cold. Therefore at a time when the *Salmo fontinalis*, or brook char, and the native brook trout have long ceased to take food the *irideus* still comes to its meals, and the advantage offered to the breeder by its appetite, displayed even when the pond is covered with ice, must not be underestimated. In addition to this its power of resistance against diseases is amazing. It is not only—perhaps owing to its perceptibly thicker skin—far less exposed to the attacks of the malignant Saprolegniaceæ than all the other Salmonidæ, and therefore very rarely seized with fungus, but it also appears to possess immunity from the most dangerous bacterial diseases, such as furunculosis. Its indifference to polluted waters enables it to live in water courses where no other salmonid could thrive. Even in the immediate neighborhood of factories discharging waste water and refuse, where both the brook trout and the char could certainly not exist, the *irideus* flourishes and grows fat. It appears to be specially valuable for exclusively or partially populating the numerous cold ponds in the forests of lower Austria, which in consequence of their low temperature, severe climate, and exposed situation are less adapted for carp breeding. Altogether it must be said that the *irideus* has fully come up to all that has been expected from it in nearly every instance.

Thus until very recently all breeders joined in a panegyric of the *irideus*. But things have now changed. The sad discovery has been made that the much-praised power of resistance of the rainbow trout in ponds against disease rapidly decreases and that this fish if strongly fed nowadays suddenly shows a remarkable frailty, nay an exotic weakness, which had been entirely unforeseen. The most unpleasant phenomenon for the breeder is the increasing spread of anæmia, which frequently causes great losses. The extraordinary weakness becomes manifest in the death of numerous fish through simple sorting operations, the clearing out of ponds, or short transportation. Quite frequently examination of the dead fish reveals no other symptoms but those of a greater or less poorness of blood. The fish are pale, particularly in the gills, the regular color of which ought to be a very bright red. The internal organs are also pale, and the liver yellow. This organ frequently shows fatty degeneration and is interspersed with hemorrhages, as the result of ruptures of the sides of the vessels. Searches for any other causes, such as bacteria and parasites, have proved unsuccessful. Consequently anæmia must be regarded as a symptom of general deterioration of the breed. As a rule these symptoms become visible in the second year, and it may be that frequently the death of the fry as well as the outbreak of dropsy of the yolk sacs is due to this circumstance. As a matter of course such fish are not very well qualified to act later as mother fish, as they give bad eggs and sometimes remain sterile because of degeneration of the sexual organs. Undoubtedly the unfitness of the rainbow trout for acclimatization here is the cause of this degeneration. The conditions in which the fish lives in its native country, where it migrates even at the spawning time, are it appears different from those in Austria. It may therefore be truly said that the rainbow trout is decreasing at a rapid rate and before long will disappear from our ponds, unless there is a speedy introduction of fresh blood by the importation of eggs from America. In the unfortunately somewhat limited number of brooks and small rivers which for some time have been stocked with *irideus* in a regular and rational manner, a good stock has developed which spawn in open water and multiply in a natural way although not in great numbers. These do not show any of the symptoms of degeneration of the pond and fattened fish of this species.

Not less valued than the rainbow trout was the American brook char, *Salvelinus fontinalis*. It is true it was less utilized than the *irideus*, as it can only live in spring water; its breeding gave very satisfactory results, however, in the first years after its introduction. Not inferior to the *irideus* as regards early growth, it behaved excellently even in ponds watered exclusively by precipitation of the atmosphere and it appeared as though the brook char might be qualified to replace our brook trout, whose breeding offers far greater difficulties. In the course of time, however, these sanguine expectations gave place to bitter disappointment, and it became obvious that all the hopes entertained were chimerical.

Even before birth the char causes great trouble. The losses in eggs are enormous, as despite scrupulous attention at spawning time the number of sterile eggs is great beyond measure, and miscarriages are far more frequent than with other fish. On the other hand, it is true that the bringing-up of the brood gives very little trouble. The small fish take artificial food very early and in autumn the pond is alive with fry. But soon an unpleasant feature becomes visible, viz, premature growth, which attribute is the more unfortunate as the char indulges in cannibalism more than any other fish. In this respect it comes very near the pike. Its voracity very greatly promotes its growth in the first and second years, but later it suddenly stops growing and fine large fish are seldom seen.

Its capacity to resist disease, which quality we value so highly in the *irideus*, is extremely small. Bacterial infections, fungus, and intestinal disorders often kill whole stocks, and it is also much more liable to furunculosis than is its American brother. Besides, the char suffers from a peculiarly special form of petechial affection. This manifests itself in irregularly shaped flat defects of the surface skin, dull gray spots with byssus, the origin of which has not yet been definitely ascertained. This disease has discouraged many pisciculturists from continuing to breed the *fontinalis*.

Another circumstance must be mentioned which makes the cultivation of the brook char in the second year very unprofitable, namely, degeneration of the eggs caused by overfeeding. That the brood product of such fish as are artificially fed is entirely worthless would be a lesser evil were it not also that the fish themselves perish in great numbers at the spawning time through over-fattening of the internal organs. It is chiefly the spawners that die, as they can not deposit their spawn, which is not thoroughly and normally matured. The char, moreover, requires special qualities and temperature of water. It only thrives in hard, clear spring water of even temperature ranging from 42° to 54° F. The risk connected with its fattening rapidly increases with rising temperature of water, whilst if this is much below the above-mentioned degrees the food taken no longer affords proper nourishment. It has often been proposed to rear the char in running water, but to this the objection must be made that the char would immediately become too formidable a competitor of our brook trout with regard to feeding, and in all likelihood there is hardly a pisciculturist who would be prepared to substitute the brook char, which can not be disposed of so easily here, for the popular brook trout. For these reasons the breeding of the brook char has been generally neglected in Austria for the last few years, and in some fisheries has even been abandoned altogether.

A promising future appears to lie before the *purpurata*. In growth it develops as rapidly as the *irideus* and it thrives under the same conditions. Its brilliant exterior and slender body, similar to that of the brook trout, are advantages which must not be underestimated. So far, however, the *purpurata* is bred in Austria only in isolated fisheries, and it would be premature to-day to pronounce a definitive decision regarding the value of this beautiful fish to breeders.

The American black bass, *Micropterus salmoides*, is being bred in several pond fisheries side by side with carp. The conditions of growth are favorable. The objections raised against this fish are that it is a great truant and extremely sensitive to the effects of muddy water, which latter occasions great losses in the clearing out of ponds. There is also no great demand for the fish, though it is fleshy and palatable, for the public show a certain aversion to the disproportionate size of the head, which, in fact, equals a quarter of the weight of the whole fish. As the fish is tenacious of life, however, can be easily transported, and is not very dainty in feeding, it may be that in time it will become more popular, especially if breeders succeed in producing it with a smaller head. In the tributaries of the Danube and in pools and stagnant water it could not exist at all.

The tiny California sheatfish is not yet well known in Austria, and as its many good qualities are much underestimated it is not very popular. It is a harmless fish, extremely tenacious of life, and, like the black bass, is often bred in carp ponds. As it is a decided mud fish, attempts have been made to introduce it in waters in which our finer fish have been destroyed through the discharge of factory refuse, river regulating works, and exploitation of water power. The tiny sheatfish has fulfilled all the hopes placed in it and thrives splendidly even in strongly polluted waters. Though it offers only an inferior substitute for our better kinds of fish, it may yet perhaps be destined to play an important part in Austrian pisciculture.

From all this it follows that our most precious acquisition from America is the rainbow trout, as we do not yet sufficiently know the *purpurata*, provided that we shall be able to renew the breed by the speedy importation of eggs from America, and in this conviction we heartily join the Austrian pisciculturist who writes at the close of his observations, "May our friends in America add a new gift to that which they have made us already in the *irideus*, and give us a little from their superabundance. The fish breeders of Austria would be very grateful to them."

# CAUSES OF DEGENERATION OF AMERICAN TROUTS IN AUSTRIA

By Johann Franke

*Director of the Fish-Culture Establishment at Studenec and Secretary of the Fishery Committee for the District of Krain*

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# CAUSES OF DEGENERATION OF AMERICAN TROUTS IN AUSTRIA.

By JOHANN FRANKE,

*Director of the Fish-Culture Establishment at Studenec and Secretary of the Fishery Commission for the Province of Krain.*

[Translated from the German.]

I have had to do with the feeding of rainbow and brook trout in ponds and inclosures for seventeen years. I have had experience with rainbow trout in clear running water for thirteen years, and much more thoroughly and in detail with brook trout for eight years.

The two species are excellent as breeders, first class and far superior to the native trout (*Salmo fario*). They can consume an astonishing amount of food, their appetite is extraordinarily persistent, and they repay the voracious feeding by astoundingly rapid growth; they remain well, keep their beautiful vivid coloring, and yield excellent spawn, even "red eggs" when in the proper condition and in surroundings suitable to salmonoids. The view that the degeneration of this fish, wherever it has occurred, is a result of natural tendencies and the qualities of our water, and that the degeneration was to be expected in the nature of things, I entirely repudiate, for I am convinced that the degeneration is the effect of artificial conditions unsuitable to salmonoids.

The true reason for the degeneration of these fishes is in faulty methods on the part of the fish culturists. The brook trout especially has been greatly discredited in Vienna and in other places, being pronounced very weak, its flesh distasteful, etc. This may have been true, as it is being bred in a most irresponsible way, the fish being given all kinds of impossible food in order to produce it quickly and cheaply. There is great competition in the sale of spawn, small producers selling not directly to the users but to agents who advertise not only hundreds of thousands but even a million or two as being their own product. The producer does not obtain even 3 crowns (60 cents) per thousand in many cases. Much of this has already been published in German special papers discussing the subject of degeneration, and many astonishing facts have been brought out. Good eggs are cheap even at 5 crowns (or $1), and a breeding establishment can be maintained properly and on a businesslike footing only when the eggs bring 10 crowns. At present the fishes are bred down into a wretched condition. The much desired eggs from America will degenerate in the same way if the method of breeding for reproduction is not henceforth different from that which has prevailed.

The unfavorable conditions surrounding the American trouts in this country, brought to my knowledge through experience during the long period I have mentioned, I have found to be due partly to inadequate insight into many essentials of fish culture, and partly also to things which could not be changed. I have been able, however, to acquaint myself with some of the phenomena of degeneration and their causes, and some of them I have successfully combated.

I consider the principal causes of degeneration to be:

1. Unhealthy pond bottom, i. e., bottom on which ooze and remnants of food as well as excretions accumulate for months at a time. The slower the current and the longer required for the water to run off, the more dangerous grow the conditions even at a low temperature of from 10° to 13° centigrade. The planting of water cress on the bottom and the introduction of carps and perches is not sufficient by any means, as these fish do not wallow in the ooze at temperatures of 10° to 13°. For example: A spring pond having an area of 140 square meters and a depth of from 60 to 100 centimeters was stocked about the end of August with 1,500 rainbow trout of the same year, and disease appeared in January, 1897; it was impossible to drain the basin without lowering the level of the water in the principal pond and disturbing the entire establishment. The ooze was taken out by means of a strong pump and a rubber hose; in some places it was black and bad smelling. The disease disappeared entirely a few days later. After this I succeeded in saving the one-year-old fishes in low-water ponds with weak currents by means of frequent pumping out of the ooze and by keeping the bottom clean.

2. Substitutes for the natural food. Fresh flesh of fishes (I had only fresh-water fishes) must be considered as natural by the effect produced, even if it is cooked. I never succeeded in keeping the trout healthy for a long period when using substitutes (a mixture of fresh blood cooked with shrimp meal, or the spawn of sea fishes, or fish meal—Ideal brand—and flour as a binding material) without an abundant addition of fresh fish. Within two and at the latest within three months there were traces of change of color to a darker, dimmer hue with a bluish tinge, more noticeable in the many-colored brook than in the darker rainbow trout. If they reached the blackish-hue stage they could not be saved. In such cases live natural food without any adulteration proved the best of remedies.

Latest example from the current year: Spring pond of 90 square meters, good depth, and slow current of the water at a temperature of 10° C.; there were in the middle of February 400 beautiful rainbows from a lot of the previous year, of which 950 had been taken out in apprehension of lack of water in winter and sent to other places in November. The suspicious looking bluish tinge was already awakening our anxiety; there was danger in delay, but the best remedy was natural food. A broad flat pool with spring water flowing through it, all covered with vegetation and algæ, had become free of ice. Here were caught by means of a fine dip net a mass of various small animal life, small and large larvæ of mosquitoes, crawfish, woodlice, small fishes, and even bullheads. The small animal forms came slowly to the surface from the thick forest of vegetation and dirt and were caught up. The entire mixture was then taken to the shallow water near the bank of the pond, where the trout themselves took the food out of this mixture. The pool supplied ample food year after year, thus saving the fishes more than once, though diminishing in abundance each year toward the month of May. Seven of these rainbows died, but all the remaining seemed well and acquired within three months their normal aspect, which they kept. To be sure, they were given no more food substitutes. The last 75 fishes were sent away in July; they weighed each 13 kilograms and stood very well the transportation of 6½ hours, as did also those which were sent away earlier.

As long as the materials for the diet of the small fry and young fishes contained crustaceans and fresh fish, the breeding and rearing went on exceedingly well, but in winter, with the forced use of substitutes, or in proportion to the lack of fresh fishes, the trouble began.

3. Insufficient flow of water through the ponds. The two large ponds have an old accumulation of ooze at the bottom some 20 to 100 centimeters deep; can be emptied only down to five-sixths of their contents at best, as the entire system of springs of the establishment flows through these. This, which it is impossible to correct, is surely an evil, but it had no apparent bad effect upon the larger salmonoids and the breeding fishes so long as the flow was abundant. When the supply grew less, in 1897–98, there appeared again the exophthalmia and the "staggers" now and then. With the decrease of springs these phenomena grew more frequent, several of the native trout (*fario*) became miserably thin, and several rainbow trout yielded spawn that could not be used. In 1904 the establishment went through two or three months without the flow of the springs, and in summer the surface water of the principal ponds at a certain distance from the inflow of the water had a temperature of 18° and near the exit a temperature of 21.2° C. At that time the water was calm, for what current could be expected from a couple of second liters in an area of 1¾ hectares? The water near the bottom was cooler by some 2° to 4°, and the trout lay there

in lethargy and without appetite; only the roaches and a few carp swam slowly about. Good spawn was obtained only in ponds where there was an outflow of springs; there were but few brood fish in the places where formerly could be found some 100 kilograms; and good roe fishes were in still smaller number. In addition to this symptom of degeneration there were others in an increased degree. Anæmia, however, did not appear in the rainbow or brook trout.

No food substitute whatever was given to the fish in the principal pond, in order to forestall a beginning of degeneration. This, however, was without avail. The regulation of the course of the principal river of the country gradually drained away the living water supply of the establishment; the springs coming from the great subterranean stream of the Laibach field went dry, and we were forced to abandon the locality in July of this year.

It is impossible to demonstrate in a more striking way than this the necessity of a good flow of water, *one* of the three conditions—infected bottom of ponds, continuous use of substitute foods, and insufficient flow of water—which brings about phenomena of degeneration, the more rapidly and in so much the higher degree if two or all three causes are operating at the same time.

And what about native trout? I would ask only when and where has there been observed in this fish any greater power of resistance against the above-mentioned causes of degeneration? It is not less sensitive than the brook trout and considerably more so than the rainbow.

As to the American trouts in running streams I know of only one drawback to the rainbow, namely, that there is no reason to suppose that it will remain and make a constant abode in particular waters, or that it will immediately leave the abode of its youth; water seemingly of the same character was in reality quite different. In two cases the fry developed in four years into mature fishes. The lingering of the rainbow in certain waters has astonished us as often as its disappearance from the same localities.

The brook trout shows more tendency to remain. In waters where food is abundant this fish surpasses even the rainbow in rapid growth. Contrary to the general opinion that it must have cool water, I saw this fish thrive one summer in water having a temperature of 18° to 20° C. In small creeks, poor in food, it scarcely thrives as well as the native *fario*. In the Stara Voda, which stream I had under my control from 1901 to 1908, it grew to be the principal fish after the first introduction as small fry, while only a few of the rainbow trout had remained there. The native *fario*, which was already there and did well, remained far behind the *fontinalis* in numbers and in rapidity of growth. Only during the last two years, when the stream suffered, like the establishment of Studenec, from lack of water and of current, the *fario* stood it better than the *fontinalis* and appeared in greater numbers than the latter.

Up to the time when I began to control this stream I knew nothing about the possibilities of the brook trout. Introduced into the stream in March, 1901, as small fry which had not yet been fed, several fishes were caught by me in August weighing from 0.3 to 0.5 kilogram, while the largest weighed 0.65 kilogram; they were fat and round, beautifully tinted, and their flesh was exquisite. The spawn (spawning season from November 7 to December 15) proved good in the hatchery, although the eggs were smaller than those of older fishes. Three-year-old fishes weighed 0.75 kilogram. I never dared to let them grow older through fear of their being stolen.

My regret over the drainage of this stream is greater than for the ruin of the fish-culture establishment.

# NEW AND IMPROVED DEVICES FOR FISH CULTURISTS

By Alfred E. Fuller

*U. S. Fisheries Station, Northville, Mich.*

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

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# NEW AND IMPROVED DEVICES FOR FISH CULTURISTS.

By ALFRED E. FULLER,
*U. S. Fisheries Station, Northville, Mich.*

## ARTIFICIAL BASS NEST.

[Exhibit 1. Fig. 1, pl. CIV.]

This form of bass nest, like others in use, consists primarily of a container for the gravel, constituting the nest proper, and a shield to furnish the seclusion required by the nesting fish. Both container and shield, however, are of distinctive design, and the shield, which is detachable, is provided with a waterproof record holder and indicator projecting above the water.

The nest proper is an iron hoop 2 feet in diameter, made of 1½-inch by ⅛-inch band iron. This hoop, placed in the pond and filled with gravel, holds the latter within its circumference without the necessity of any bottom and may be left in position permanently. Riveted at each of 3 quartering points on the outside of the hoop is an iron socket or slot, of size to accommodate a standard 1 inch wide and ⅛ inch thick. By means of these slots the removable shield is adjusted to the hoop.

The shield, 2 feet high and semicircular to fit one side of the hoop, is made of ordinary galvanized sheet iron riveted to three iron standards. The standards, which are 1 inch wide by ⅛ inch thick, extend 2 inches below the sheet of iron they support, and are pointed at the lower end for ready adjustment to the sockets in the hoop. The two end standards are 26 inches in height and flush with the top edge of the shield. The middle standard is higher, projecting above the shield to hold the indicator and record case. The height of the projection is determined by the depth of the water in which the nest is used, the indicator to be always visible above the surface of the pond. The shield and container are coated with paint.

The record holder consists of a waterproof case to contain cards or small sheets of paper and has a number and an indicator on its face. The case is made of 2 rectangular pieces of thin sheet metal, preferably copper, 2½ by 5 inches, with rolled edges to permit one side of the case to slide upon the other. Into the back are slipped the cards or sheets of paper containing detailed records of the nest. The nest number is stamped or painted on the upper half of the face of the case; in the lower half is fixed a metal pointer, in a dial upon which appear symbols which will indicate to the fish culturist whether the nest is "cleaned up" or contains eggs or fry. A metal pocket is soldered upon the back of the case, by means of which to fit it to the tall standard of the shield.

The especial advantages of this nest are as follows:

1. The shield can be removed to permit placing the retaining screen around the nest without roiling the water or disturbing the nest proper, thereby avoiding injury to the fry by the rolling of the gravel.

2. The nest proper, remaining permanently in the pond, is always in readiness for use without the expenditure of labor to renew each year, and when once installed requires only attaching of the shield, which can be done in the space of a moment.

3. The nest, being of heavy metal, will remain stationary in the pond without being weighted down to prevent floating.

4. A separate and complete record of each nest can be kept as its product advances to different stages, while its condition can be determined from the shore at a glance without disturbing the fish by entering the water or going to the nest in a boat.

5. Nest and shield are easily stored. Fifty of the shields require a space but 2 feet wide, 2 feet high, and 26 inches long.

## BASS FRY RETAINING SCREEN AND TRAP.

[Exhibit 2. Fig. 2, pl. CIV.]

The retaining screen and trap exhibited is intended for use in connection with the bass nest just described. It combines with the ordinary cylindrical retainer a device by means of which the fry are entrapped and may be readily lifted from the nest. Certain improvements in the construction of the retainer are also important features.

The retaining screen is made of a piece of 14-mesh galvanized wire cloth 3 feet in width, stretched around a frame consisting of two iron hoops and 4 iron standards. The hoops are made of ⅛ by 1 inch iron bands and are 3 feet in diameter; the standards are 3 feet high. The joinings are everywhere made with stove bolts, which also secure the wire cloth to the frame. At the seam the wire cloth is lapped directly over one standard and an extra upright 3½ feet long is bolted over the lap. The circular inclosure thus built is readily "knockdown" for storage purposes. Upon the projecting upright is fitted the record holder, which was attached to the nest shield described in exhibit 1 and is now to be transferred to carry on the record for the fry. All metallic parts are painted.

The trap is within the retainer. It consists of a hoop fitted over the bottom hoop of the retainer and securing about its circumference a piece of bobbinet so shaped and seamed as to form a blunt cone about 2 feet high when held in place within the wire-cloth screen. The top of this cone is open, the bobbinet here fitted and secured to an iron ring 4 inches in diameter. To hold the cone in position, two cords attached on opposite sides of the opening are carried to the upper rim of the retainer and there fastened by means of bent-wire hooks at the ends of the cords.

As the bass fry ascend from the nest their natural tendency is to follow the inside of the cone upward to the 4-inch opening, through which they pass to the upper section of the retaining screen. After they have all ascended, this opening is closed with a tight-fitting cap made of a circular piece of bobbinet held in at the edge by an elastic gathering string. The fish are then in captivity. To remove them from the pond, the apparatus is lifted to the surface of the water, the cords holding the cone are released, and the cone telescopes, forming a scaff net, which is then detached from the bottom hoop of the retainer, placed over the collecting tub, and the fish liberated therein.

The advantages of this combined retaining screen and trap are as follows:

1. All the fry that are able to rise from the nest can be captured.

2. They can be taken from the trap at any time desired without regard to roiliness of the water or low temperature.

3. The device is useful in the capture of bass fry in inland lakes which have become overstocked and from which it is desirable to transfer the fish to barren waters or waters more accessible to sportsmen

### COLLECTING TUB.

[Exhibit 3. Fig. 3, pl. CIV.]

This tub is convenient for use in connection with the trap described in exhibit 2. It is constructed of ordinary galvanized iron, is 3 feet in diameter, 14 inches deep, and has a 2-inch flaring rim with outer circumference to fit the hoop of the cone-shaped trap. At each of two opposite points in the side is inserted a piece of perforated tin, 7 by 10 inches, extending to within 4 inches of the bottom. Two handles are attached below the rim on the sides transverse to the perforated inserts, and the tub is painted inside and out.

When in use the tub is placed in a wood float 4 feet square, which permits it to be easily towed from nest to nest as the collections are made. In emptying the tub its contents are poured out over the solid side rather than the perforated.

This tub has the advantage of allowing the fish a free circulation of fresh water during the process of collecting, a condition very essential during warm weather. Necessity for changing the water is thus obviated, and handling of the fish, which should always be avoided as much as possible during warm weather, is minimized.

## FISH RETAINER.

[Exhibit 4. Fig. 4, pl. cv.]

This article is a convenient means of temporarily confining fish awaiting shipment. It is made of ordinary galvanized iron, and is in effect a taller and slenderer form of the collecting tub described in exhibit 3, with the addition of a combined cover and bail. It is 10 inches in diameter and 20 inches high, with a 2-inch flaring rim and with two perforated strips of tin inserted opposite each other in the sides. The perforated inserts are 6 inches wide by 14 inches in height, reaching from the lower edge of the rim to within 4 inches of the bottom of the receptacle. A stiff wire bail, to which the cover is fastened, is attached on the perforated sides, and the receptacle is painted.

When in use this retainer is set in a wooden float to prevent its sinking. Such floats may be constructed any length, to accommodate any number of retainers, but sections 26 inches wide and 7 feet long, which will accommodate 10 retainers, are found to be most convenient. The apparatus is placed in fresh or running water, and the fish to be carried in one transportation can are placed in one retainer. In emptying the retainer its contents should be poured out over the solid sides instead of the perforated, to prevent injury to the fish.

This device has the advantage of allowing shipments of fish to be prepared in advance of the time of departure, as a free circulation of water is permitted at all times and the fish can be held any reasonable number of days. It obviates extra handling of the fish, which is to be avoided as much as possible, and also enables one man to prepare the shipment without assistance, which is of great convenience for night departures.

## FISH ATTENDANT'S OUTFIT.

[Exhibit 5. Fig. 5, pl. cv.]

This outfit comprises an aerating device and a combination ice pick and net, for use in the transportation of fish. The aerator consists of a cylindrical screen made of perforated zinc or tin, and a perforated funnel-shaped plunger with long handle. The screen is 6½ inches in diameter, 21 inches high, with a 2-inch slightly flaring collar at the top, has a perforated bottom, and is fitted with a wire bail. Two heavy wires, crossing each other at right angles, are soldered 2 inches from the bottom to prevent the plunger from striking the latter. The slender dimensions of the screen permit it to be inserted into the ordinary transportation can.

The plunger may be made of an ordinary tin funnel of 6 inches mouth diameter, a shallow tin pan of the same diameter, and a ¼-inch rod bent to form a loop at one end. The funnel is perforated with nail holes, as is also the bottom of the pan, and the latter, inverted, is soldered over the mouth of the funnel. The rod is inserted into the tube of the funnel, giving the plunger a total length of 18 inches.

To operate the aerator, the plunger is churned up and down in the screen. The screen filled with ice may be used also in cooling the water in which the fish are held.

Both as aerator and cooler this device is especially useful in transporting fry which are the more susceptible to injury in handling, such as shad, pike perch, and whitefish. With these means, moreover, the attendant can give proper attention to a large number of fish in a short space of time and with a minimum amount of labor.

The combined net and ice pick consists of a semicircular frame of 10 inches long dimension, made of no. 6 wire and covered with soft net of any desired mesh. This is fitted into a wooden handle, the opposite end of which holds a disappearing point 3 inches long, made of ¼-inch spring steel.

The net is of use in pouring water from transportation cans in order to replenish with a fresh supply, or for purposes of "doubling up" the contents of two cans, as may be necessary just before delivering from the train. It also takes the place of the siphon and scaff net usually carried by attendants in charge of shipments of fish, and since these and the ice pick are usually carried separately, the combination device reduces the number of articles from 3 to 1.

### SEINE FOR COLLECTING FINGERLING BASS.

[Exhibit 6. Fig. 6, pl. CVI.]

This seine, made of heavy bobbinet, is rigged upon two handles consisting of bamboo poles 14 feet in length. The web is 16 feet long and 4 feet wide, corked and leaded, and is attached at each end to a 4-foot steel brail ¼ inch in diameter. The brails are fastened to the bamboo handles by strap-iron hinges, which allow the brails to break but one way. A heavy cord attached to the lower end of each brail passes through a screw eye in the handle at a point the brail's length distant from the hinge. In operation the seine is projected over the water with the brails extended, the back of the hinges downward. The handles are then given a half turn, allowing the brails to drop at the hinges, beyond the school of fish. The seine falls into the water and as soon as the leads touch the bottom of the pond the cords are tightened. Pulling from the lower end of the brails with the hinges bent, the cords draw upon the bottom of the seine, and it is easily hauled ashore.

The use of this seine, since it can be operated from shore, avoids the roiling of the water which occurs when the operators wade into the pond, and it makes possible the capture of fish at any desired time without drawing off the water. The seine is of advantage, among other purposes, in thinning out the fish from time to time to avoid exhaustion of the food supply and consequent cannibalism.

## SHIPPING CASE FOR FISH EGGS.

[Exhibit 7. Fig. 7, pl. CVI.]

This case is designed for shipping fish eggs either to foreign countries or points at any distance throughout the United States. It can be constructed of any sound lumber ⅞ inch thick. The outer case is 2 feet wide, 2 feet high, and 3 feet long, with corners halved together to permit of nailing both sides and ends. Its sides are lined with asbestos packing paper, and the bottom with rubberoid roofing paper. The inner case is made of any light ½-inch lumber and is 19 inches high, 20 inches wide, and 32 inches long. The bottom is made of ordinary galvanized iron and has a slope of 2 inches toward the center to a waste pipe. The outside of this inner case is covered with rubberoid roofing paper.

Cleats in the ends in the bottom of the outer case support the inner one and make an air space below it, at the same time raising it so that it projects 1½ inches above the upper edge of the outer case. Between the walls of the outer and inner cases is a 1-inch air space, and this is closed at the top by means of a strip of lumber 2 inches wide inserted edgewise and flush with the inner wall, making the space airtight. This projection fits into the top of the case when the latter is closed.

The inside case is divided into five compartments, one at each end and in the middle for ice, the two others for trays, the partitions all flush with the inner case. The ice compartments are 3 inches wide and of the full width and depth of the inner case. The middle compartment is removable. The partitions are made of ½-inch mesh galvanized-wire cloth and are held in place with 1-inch cleats nailed upright to the sides of the inner case. These cleats also hold the tray stacks in vertical position, and the space they make allows for air circulation and the dripping of the ice hoppers which are to be placed above. It also allows easy access to the trays and permits of inspecting them at all times without disturbing the ice.

The case holds 24 trays for eggs, 12 in each compartment. The trays are made of ½-inch lumber and are 8½ inches wide, 18½ inches long, and 1 inch deep. The bottoms are of fine-mesh wire cloth. Each side of each tray is perforated with five equally spaced ½-inch holes to allow air circulation.

Over each tray stack, resting upon the ends of the vertical cleats, is an ice hopper 10½ inches wide, 18½ inches long, and 2 inches deep, made of ordinary galvanized-iron bottom and sides, with wooden ends. The bottoms of the hoppers are perforated near the sides with ½-inch holes to allow the water to escape. Over the lower end of the waste pipe to prevent the cool air from escaping is a bowl-shaped cap which is always filled with water.

The top of the case, which is hinged, fits tightly over the rabbet formed by the projecting edge of the inner wall, making an air-tight chest. It is provided with two hasps in front, and is lined with a single sheet of asbestos, a layer of ½-inch lumber, and over these a covering of rubberoid roofing.

The empty case weighs 88 pounds. The space devoted to ice will hold 60 pounds. Allowing 20 pounds for eggs and moss, the whole shipping weight would be 168 pounds. The case is designed to hold about 80,000 steelhead trout eggs, 120,000 lake trout eggs, 250,000 brook trout eggs, or 1,000,000 whitefish eggs.

This case has the advantage of allowing easy access to the eggs for inspection at any point en route. It permits of free circulation of air, thereby producing an even moisture and even temperature for all of the trays. For local shipments or field work the stacks of small trays, ice hoppers, and central ice compartment may be removed and large trays substituted, making a combination case, and avoiding the necessity for three separate styles, as usually required for different distances. The present case has also the advantage of carrying a maximum number of eggs at a minimum weight.

Coating the case inside with paraffin wax will prevent odors, or moisture from swelling the box.

The following tables record a 36-day test given a roughly constructed case of this type, beginning January 29 and ending March 5, 1906. During the first 26 days the case contained 53,000 eyed lake trout eggs. It was not filled, only 10 of the 24 trays being used. Nine of them contained 5,000 eggs each and one had 8,000.

RECORD OF FIRST 26 DAYS OF TEST.

| Test day. | Temperature of room. | Temperature on egg trays. | Ice used. | Test day. | Temperature of room. | Temperature on egg trays. | Ice used. |
|---|---|---|---|---|---|---|---|
| | °F. | °F. | Pounds. | | °F. | °F. | Pounds. |
| 1 | 75 | 34 | 80 | 15 | 90 | 35½ | 25 |
| 2 | 64 | 34 | | 16 | 84 | 35 | 20 |
| 3 | 82 | 35 | | 17 | 85 | 35½ | 20 |
| 4 | 71 | 36 | 30 | 18 | 90 | 36 | 20 |
| 5 | 76 | 34½ | | 19 | 87 | 36 | 20 |
| 6 | 70 | 35 | | 20 | 80 | 36 | 20 |
| 7 | 60 | 35 | | 21 | 81 | 36 | 20 |
| 8 | 69 | 37 | 76 | 22 | 80 | 36 | 20 |
| 9 | 74 | 34½ | | 23 | 70 | 36 | 20 |
| 10 | 85 | 35 | 20 | 24 | 82 | 36 | 20 |
| 11 | 85 | 36 | | 25 | 84 | 36 | 20 |
| 12 | 82 | 39 | 48 | 26 | 85 | 35½ | |
| 13 | 85 | 35½ | 16 | | | | |
| 14 | 84 | 35 | 20 | Total | | | 515 |

The eggs were looked over on the seventh day and 44 dead eggs were removed; on the sixteenth day 121 dead eggs were removed; on the twenty-sixth day 168.

On the sixteenth day the moss placed over the eggs was removed, the water squeezed out, and the moss then replaced.

The above test was made in the boiler room, and on the ninth day the case was moved nearer the boiler, which accounts for the rise in outside temperature.

On the twenty-seventh day the eggs were all removed from the case, the latter thoroughly cleaned, and the tray containing 8,000 eggs was replaced for a further test of ten days. During the first five of these days the case was outside in a temperature ranging from 14° to 50° F., the last five it was inside the hatching room at a temperature of 50° F.

RECORD OF LAST 10 DAYS OF TEST.

| Test day. | Air temperature. | | Egg temperature, noon. | Test day. | Air temperature. | | Egg temperature, noon. |
|---|---|---|---|---|---|---|---|
| | Noon. | Midnight. | | | Noon. | Midnight. | |
| | °F. | °F. | °F. | | °F. | °F. | °F. |
| 27 | 50 | 43 | 34 | 32 | 50 | 50 | 33 |
| 28 | 35 | 31 | 34 | 33 | 50 | 50 | 34 |
| 29 | 34 | 19 | 34 | 34 | 50 | 50 | 35 |
| 30 | 23 | 14 | 33 | 35 | 50 | 50 | 35 |
| 31 | 30 | 25 | 32 | 36 | 50 | 50 | 36 |

These eggs were then removed to Clark hatching troughs and at the end of one week hatched, producing good strong healthy fry. The fry were held until the sac was nearly absorbed, and then planted.

The tray containing the 8,000 eggs stood the test for the entire thirty-six days, and at this rate would give the capacity of the case as 192,000 lake trout eggs, thus demonstrating that a much larger number of eggs than claimed for it can be safely transported in this case should occasion demand. During the above 10-day test but 20 pounds of ice was consumed.

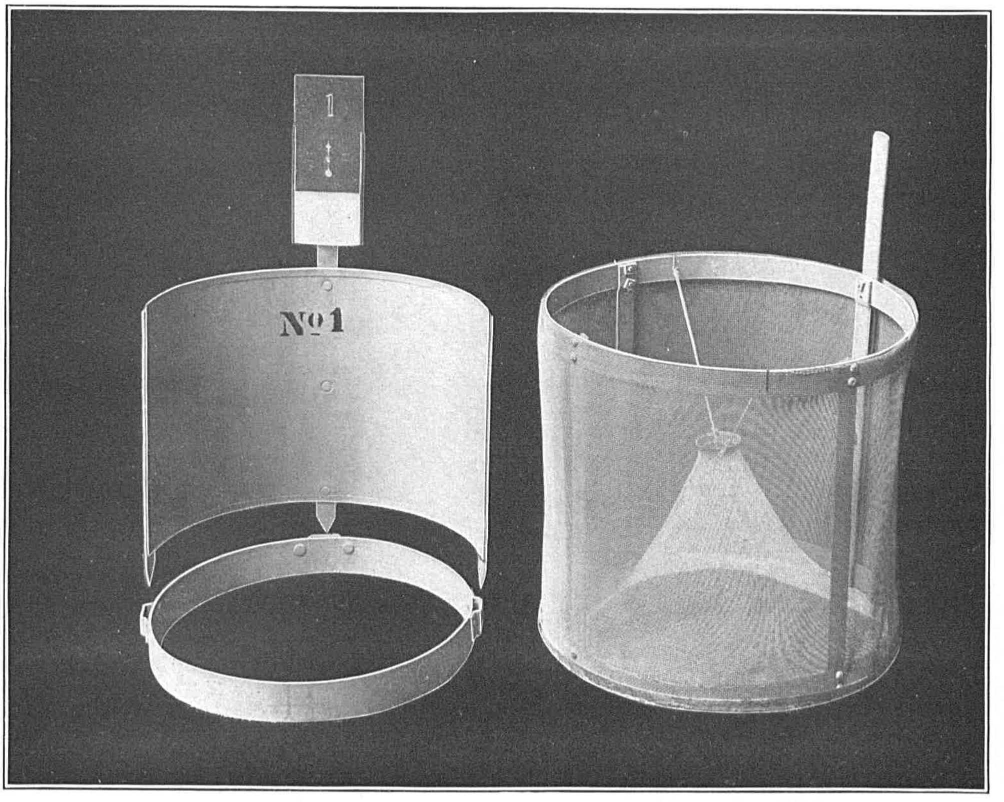



FIG. 1.—Artificial bass nest. FIG. 2.—Bass fry retaining screen and trap.
(Photographed from models, which were not built to scale.)

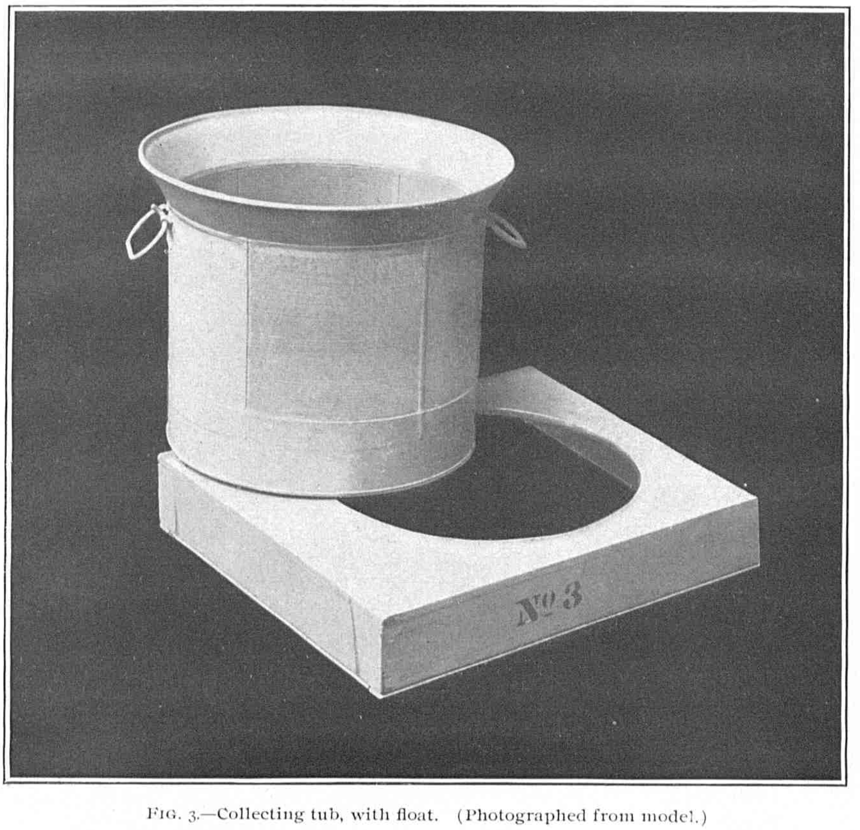



FIG. 3.—Collecting tub, with float. (Photographed from model.)

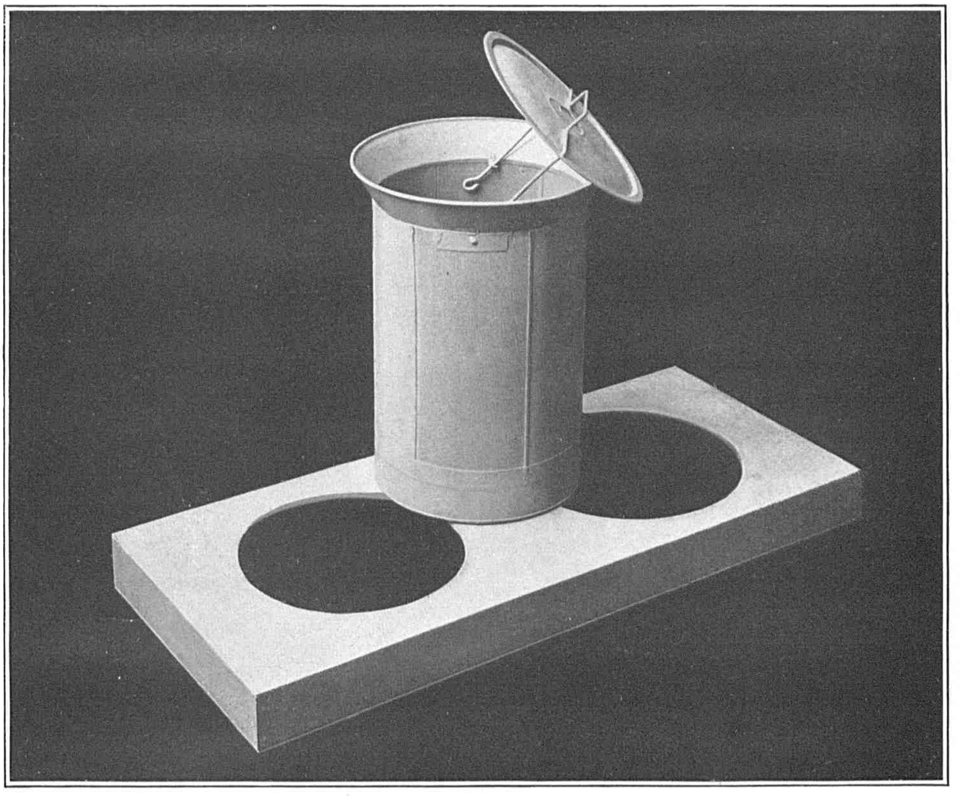


FIG. 4.—Fish retainer, with float. (Photographed from model.)

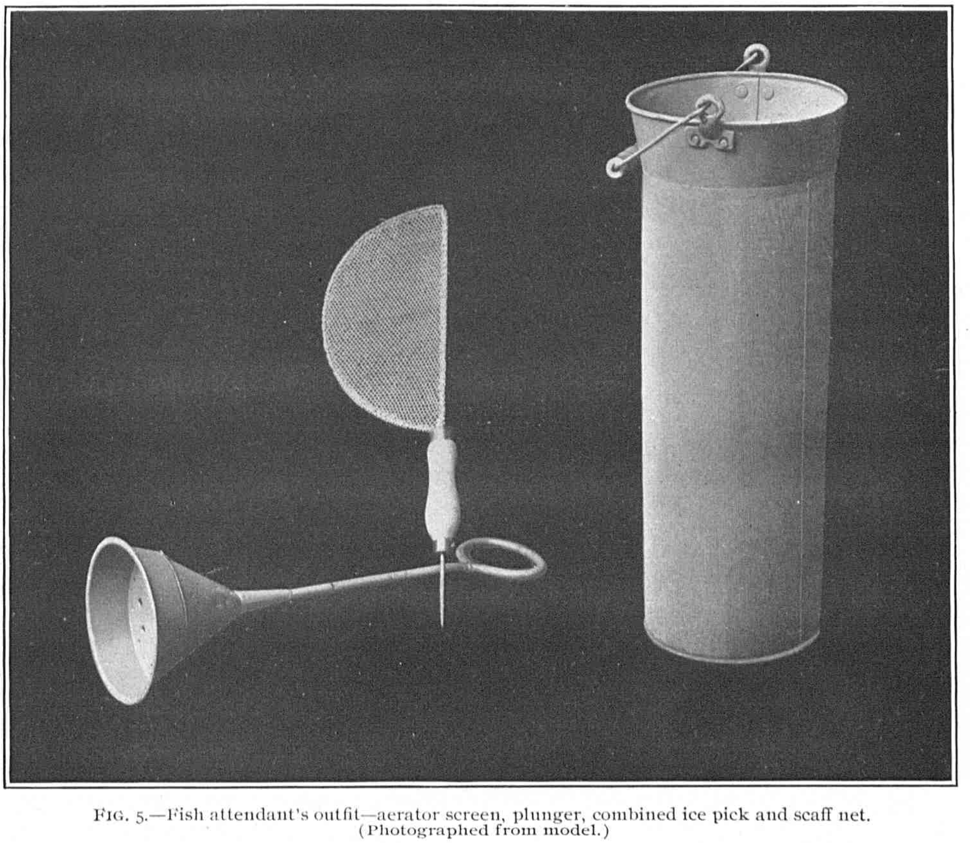


FIG. 5.—Fish attendant's outfit—aerator screen, plunger, combined ice pick and scaff net. (Photographed from model.)

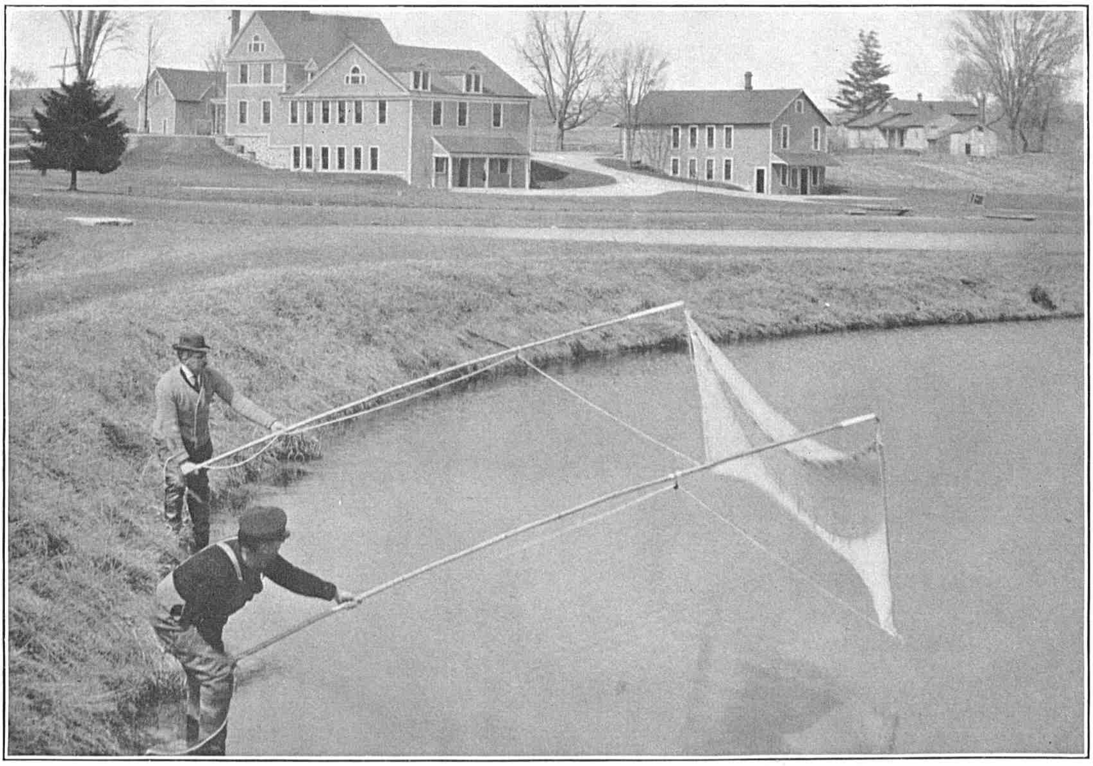


FIG. 6.—Seine for collecting fingerling bass.

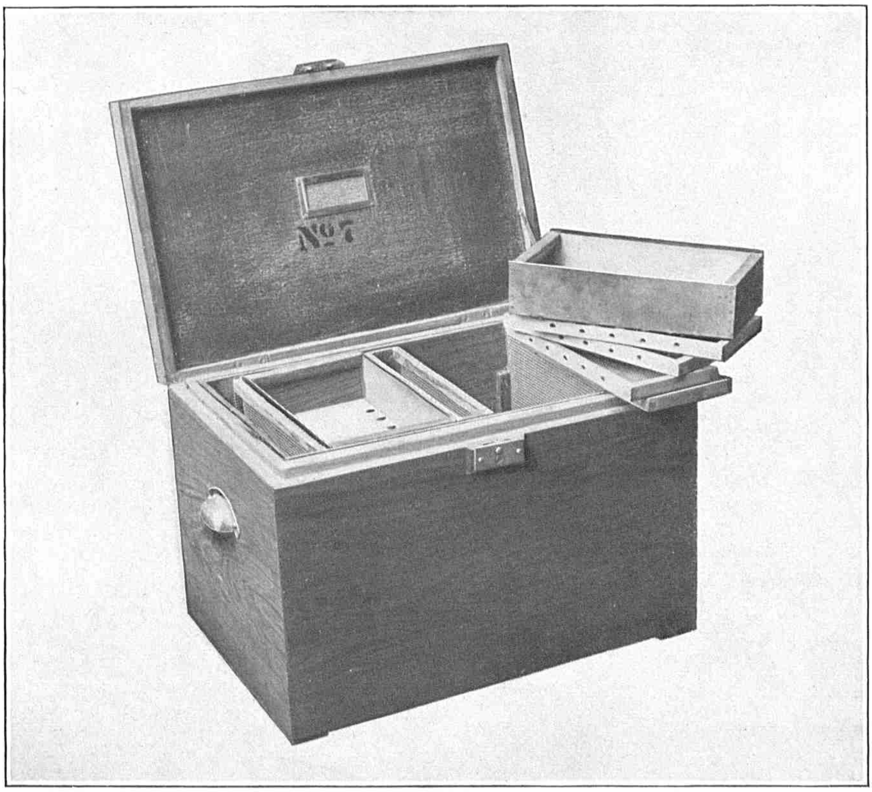



FIG. 7.—Shipping case for fish eggs. (Photographed from model, which was not built to scale.)

# A DEVICE FOR COUNTING YOUNG FISH

By Robert K. Robinson

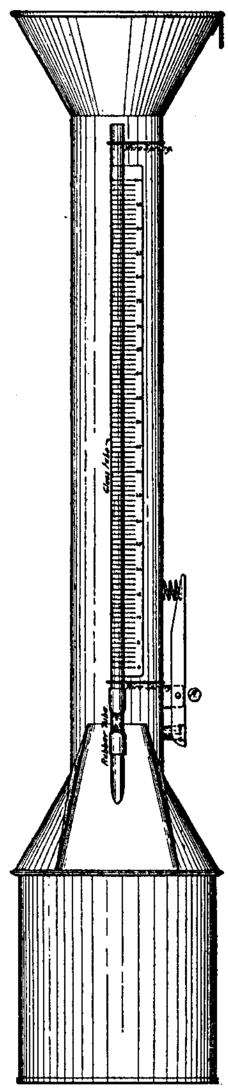
*Superintendent U. S. Fisheries Station, White Sulphur Springs, W. Va.*

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

# A DEVICE FOR COUNTING YOUNG FISH.

By ROBERT K. ROBINSON,
*Superintendent U. S. Fisheries Station, White Sulphur Springs, W. Va.*

This device is intended as a means of measuring or counting young fish of a size from the fry stage up to the length of $1\frac{1}{4}$ inches. The instrument is made of thin brass, nickel plated, and weighs about 1 pound. The cylindrical base is 4 inches in diameter and 4 inches high, with a top or neck which tapers to a diameter of $1\frac{1}{2}$ inches, at which point is joined an upright tube of this diameter and 15 inches long. The tube is enlarged at its upper end to form a funnel mouth. Immediately above the base, upon the sloping neck, is fastened a small metal tube, and to this is attached, by means of a short piece of small rubber tubing, a glass tube $\frac{3}{8}$ inch in diameter which extends up to the base of the funnel at the top and is held in place by wire clamps. Behind the glass tube, on the main tube of the apparatus, is engraved a 10-inch scale, graduated 10 points to the inch, beginning at zero at the bottom, and each fifth point above numbered consecutively to the top, or to 100 points. The lower end of the small metal tube is set in a shield of metal, which is soldered to the sloping neck of the base of the vessel, this covered area of the latter being perforated to permit the entrance of water into the small tube while screening out the fish. Immediately below the zero point, and to the side of the scale, there is a small vent or valve, which is controlled by a spring lever and serves conveniently to adjust the water level in the apparatus to the zero point on the scale. The mode of using the apparatus may be understood by the following directions:



Measure by means of which to count young fish.

Fill the measure with water until the latter appears in the glass tube slightly above the zero point on the scale. By pressing the upper end of the valve lever the water may be allowed to escape and thus be easily adjusted to the zero point.

Count out from any given lot of fish to be measured 300 to 500 of average size. Put the counted fish into the measure as free of water as possible; this may be done by putting them into a quart graduate and, holding a small hand net tightly over the top of the graduate, draining the water off quickly by inverting the graduate. A perforated dipper may serve in place of the hand net.

The displacement made by the counted fish will be shown by a rise of water in the glass tube above the zero point; then by reading the number of points to which the water rises the average number of fish per point may be easily ascertained. To find the number of fish in an entire given lot, empty the measure, replace the water to the zero point, put the fish in by the operation above described, again read the number of points above zero, then multiply the latter by the number of fish per point, previously ascertained.

The measure should be held perpendicular, which may be accomplished by suspending it between the thumb and index finger placed at the base of the funnel.

# A METHOD OF TRANSPORTING LIVE FISHES

By Charles F. Holder

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

# A METHOD OF TRANSPORTING LIVE FISHES.

By CHARLES F. HOLDER.

In my somewhat extended experience in handling and transporting live fishes the following has proved the most satisfactory method, as illustrated on a particular occasion:

Large numbers of fish of different kinds were to be collected, upon contract, from fishermen along the Hudson River, from the mouth as far up as Fishkill. My boat, chartered for the purpose, was a water boat, or large tug, with her tanks filled with fresh water and her decks covered with galvanized-iron tanks for salt water. The fishermen came alongside with their fish in live cars, or the tug steamed up to the big nets; cans were sunk beside the cars or the nets, and the fish were transferred without being touched by hand.

A few hours later the tug landed in New York, where big drays, loaded with cans, were in readiness. The insides of the cans were covered with sponges wired into wire fencing and pressed against the interior of the can; the sponges swelling when wet and forming a perfectly soft pad for the fishes. These cans were lowered by a derrick into the tanks of the tug, where men standing in the water transferred the fish to them by means of very wide fine-mesh nets, never touching the fish with their hands. As each can was filled, which was done with great rapidity, it was hoisted to the deck and covered with a tin cap which had an inner false bottom perforated with small holes. With this, at the slightest tip from the horizontal, water flowed into the perforations and dropped back in a shower, thus aerating itself. The moment a dray was loaded it was driven away, not carefully but at a run or fast trot, to the aquarium, the rapid motion being less dangerous to the fish than a long swing.

The original and distinctive features of this method of transporting live fishes are the sponge-lined tanks and the self-aerating device. The latter can not be exclusively depended upon—I found it necessary to make the round of the tanks with a large syringe—but the false lining of the tops reduced the hand labor 50 per cent; and on shipboard, for instance, when the motion is sufficient, it is my belief that fishes might live a week with this automatic aeration of the water in the cans.

I used this method of transporting fishes first in 1876, and on numerous occasions since have found it successful. A chief feature is the care in handling, not a fish being touched by hand, and thus, with the cushioned tanks, not a fish being injured. The sponges also prevent the loss of water.

# A METHOD OF MEASURING FISH EGGS

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

# A METHOD OF MEASURING FISH EGGS.

By H. VON BAYER, C. E.,

*Architect and Engineer, United States Bureau of Fisheries.*

In a well-regulated fish hatchery it becomes at times necessary to count the eggs of fishes, so as to know the quantity on hand and prepare for certain shipments of eggs as well as for the future care of the fry. The methods thus

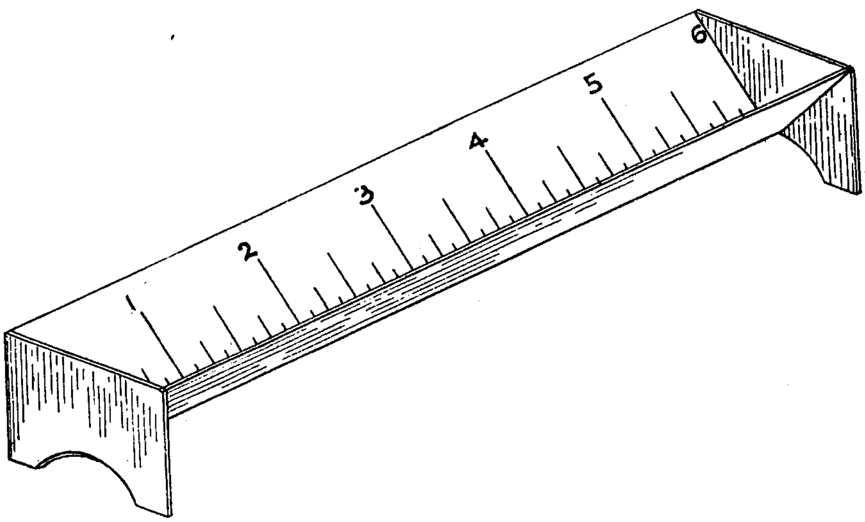



FIG. 1.—Metal trough for use in determining diameter of fish eggs.

far employed have been to determine by actual count the number of eggs contained in one liquid quart measure, and then to multiply said number by the number of quarts of eggs on hand; or to weigh one liquid quart of counted eggs, next to weigh all the eggs on hand, and then by simple proportion to determine the number of all the eggs.

The new method proposed by the writer is first to determine the diameter [a] of one egg, and then to enter with the value of said diameter a table or diagram

[a] By diameter is here understood the diameter of the egg including its surrounding matrix, if any.

in which the corresponding number of eggs per liquid quart or other unit measure is found by inspection.

To determine the diameter of one egg of a certain species of fish, a V-shaped metal trough with scale engraved thereon is used, in which a certain number of eggs is placed one egg deep in a row, the eggs touching each other; the space occupied by the eggs is then read on the scale; this reading, when divided by the number of eggs in the trough, will give the diameter of one egg.

The accompanying table and diagram are self-explaining. They are based on a series of actual counts of eggs contained in a liquid quart measure, these counts fairly agreeing with each other and the theoretical value, and being extended by computation according to the law that solids increase as the third power of their diameters.

Example:

$d = 0.127''$, diameter of whitefish egg (determined).

$n = 33{,}036$, number of whitefish eggs per quart (actually counted).

$d_1 = 0.1406''$, diameter of shad egg (determined).

$n_1$ = Number of shad eggs per quart (sought).

$$d^3 : d_1^3 = n_1 : n$$

$$\therefore n_1 = \frac{d^3 n}{d_1^3}, \text{ or}$$

$$0.127^3 : 0.1406^3 = n_1 : 33{,}036$$

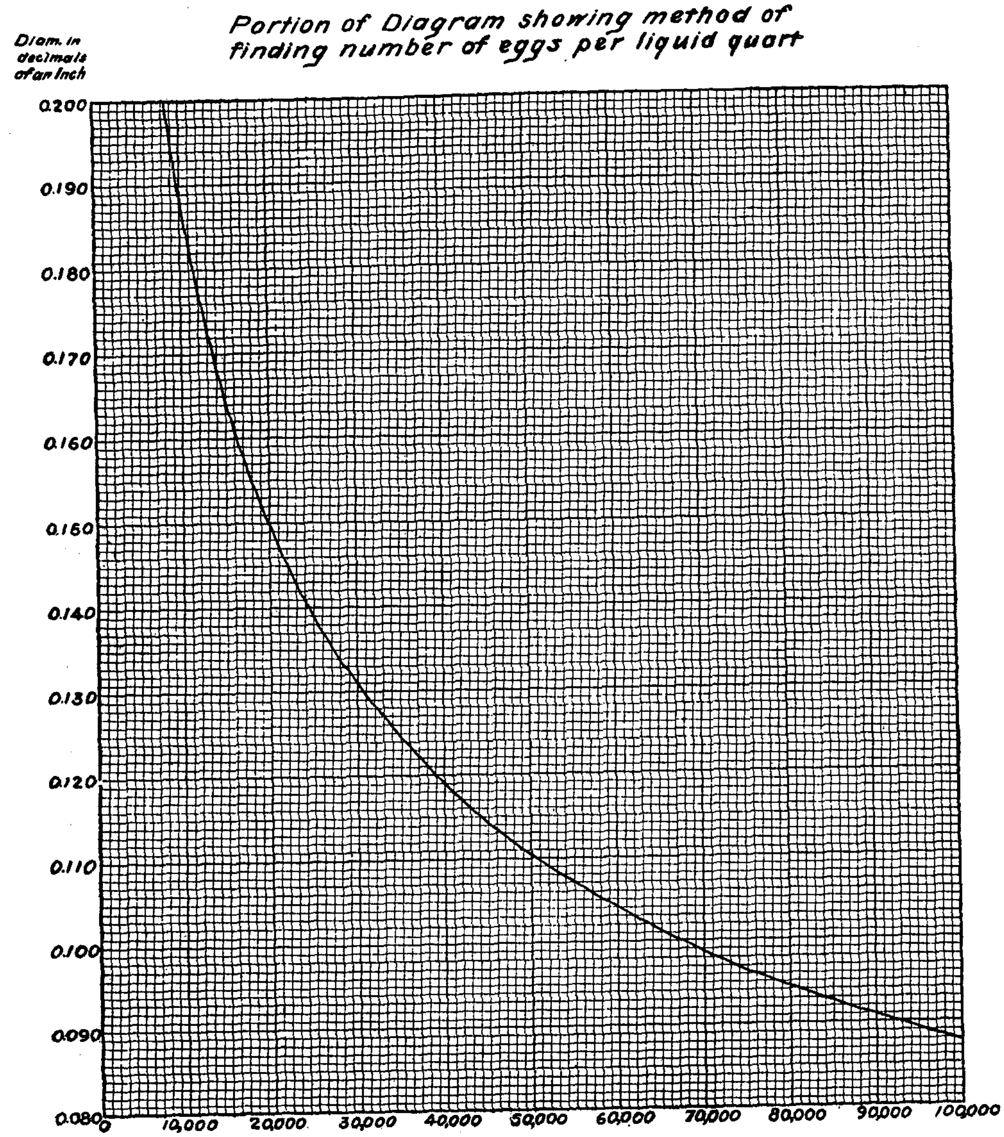
$$n_1 = \frac{0.127^3 \times 33{,}036}{0.1406^3} = 24{,}345, \text{ answer.}$$

TABLE FOR FINDING NUMBER OF FISH EGGS OF GIVEN DIAMETER PER LIQUID QUART.

| Diameter. | Number. | Diameter. | Number. | Diameter. | Number. | Diameter. | Number. |
|---|---|---|---|---|---|---|---|
| *Inch.* | | *Inch.* | | *Inch.* | | *Inch.* | |
| 0.300 | 2,506 | 0.230 | 5,562 | 0.160 | 16,521 | 0.090 | 92,826 |
| | 2,531 | | 5,635 | | 16,835 | | 95,990 |
| | 2,557 | | 5,709 | | 17,157 | | 99,297 |
| | 2,583 | | 5,785 | | 17,487 | | 102,762 |
| | 2,609 | | 5,862 | | 17,825 | | 106,390 |
| 0.295 | 2,636 | 0.225 | 5,941 | 0.155 | 18,172 | 0.085 | 110,190 |
| | 2,663 | | 6,021 | | 18,528 | | 114,172 |
| | 2,690 | | 6,102 | | 18,894 | | 118,346 |
| | 2,718 | | 6,185 | | 19,270 | | 122,730 |
| | 2,746 | | 6,269 | 0.151 | 19,655 | | 127,333 |
| 0.290 | 2,775 | 0.220 | 6,355 | 0.150 | 20,050 | 0.080 | 132,170 |
| | 2,804 | | 6,442 | | 20,456 | | 137,251 |
| | 2,833 | | 6,531 | | 20,874 | | 142,600 |
| | 2,863 | | 6,622 | | 21,303 | | 148,220 |
| | 2,893 | | 6,715 | | 21,744 | | 154,155 |
| 0.285 | 2,923 | 0.215 | 6,809 | 0.145 | 22,197 | 0.075 | 160,400 |
| | 2,954 | | 6,905 | | 22,662 | | 166,995 |
| | 2,985 | | 7,002 | | 23,140 | | 173,950 |
| | 3,017 | | 7,102 | | 23,633 | | 181,300 |
| | 3,050 | | 7,204 | | 24,140 | | 189,070 |
| 0.280 | 3,083 | 0.210 | 7,307 | 0.140 | 24,661 | 0.070 | 197,290 |
| | 3,116 | | 7,412 | | 25,197 | | 205,992 |
| | 3,150 | | 7,520 | | 25,748 | | 215,204 |
| | 3,184 | | 7,629 | | 26,316 | | 224,995 |
| | 3,219 | | 7,741 | | 26,901 | | 235,377 |
| 0.275 | 3,254 | 0.205 | 7,855 | 0.135 | 27,504 | 0.065 | 246,410 |
| | 3,290 | | 7,971 | | 28,125 | | 258,141 |
| | 3,326 | | 8,089 | | 28,764 | | 270,631 |
| | 3,363 | | 8,210 | | 29,422 | | 283,936 |
| | 3,400 | 0.201 | 8,333 | | 30,101 | | 298,132 |
| 0.270 | 3,438 | 0.200 | 8,459 | 0.130 | 30,801 | 0.060 | 313,289 |
| | 3,476 | | 8,587 | | 31,523 | | 329,490 |
| | 3,515 | | 8,717 | | 32,268 | | 346,828 |
| | 3,555 | | 8,851 | | 33,036 | | 365,405 |
| | 3,595 | | 8,987 | | 33,829 | | 385,331 |
| 0.265 | 3,636 | 0.195 | 9,126 | 0.125 | 34,647 | 0.055 | 406,733 |
| | 3,677 | | 9,268 | | 35,492 | | 429,750 |
| | 3,719 | | 9,413 | | 36,364 | | 454,539 |
| | 3,762 | | 9,561 | | 37,265 | | 481,270 |
| | 3,806 | | 9,712 | | 38,198 | | 510,139 |
| 0.260 | 3,850 | 0.190 | 9,866 | 0.120 | 39,161 | 0.050 | 541,362 |
| | 3,895 | | 10,023 | | 40,156 | | 575,173 |
| | 3,940 | | 10,184 | | 41,186 | | 611,893 |
| | 3,986 | | 10,348 | | 42,251 | | 651,776 |
| | 4,033 | | 10,516 | | 43,354 | | 695,223 |
| 0.255 | 4,081 | 0.185 | 10,688 | 0.115 | 44,494 | 0.045 | 742,613 |
| | 4,129 | | 10,863 | | 45,676 | | 794,400 |
| | 4,178 | | 11,042 | | 46,899 | | 851,128 |
| | 4,228 | | 11,225 | | 48,166 | | 913,380 |
| 0.251 | 4,279 | | 11,412 | | 49,480 | | 981,852 |
| 0.250 | 4,331 | 0.180 | 11,603 | 0.110 | 50,841 | 0.040 | 1,057,350 |
| | 4,383 | | 11,799 | | 52,254 | | 1,140,780 |
| | 4,436 | | 11,999 | | 53,720 | | 1,233,250 |
| | 4,490 | | 12,203 | | 55,239 | | 1,335,960 |
| | 4,545 | | 12,412 | | 56,817 | | 1,450,406 |
| 0.245 | 4,601 | 0.175 | 12,627 | 0.105 | 58,456 | 0.035 | 1,578,320 |
| | 4,658 | | 12,846 | | 60,159 | | 1,721,630 |
| | 4,716 | | 13,069 | | 61,925 | | 1,883,020 |
| | 4,776 | | 13,298 | | 63,766 | | 2,065,130 |
| | 4,835 | | 13,533 | 0.101 | 65,680 | | 2,271,500 |
| 0.240 | 4,895 | 0.170 | 13,774 | 0.100 | 67,670 | 0.030 | 2,506,310 |
| | 4,956 | | 14,020 | | 69,741 | | |
| | 5,019 | | 14,272 | | 71,899 | | |
| | 5,083 | | 14,529 | | 74,146 | | |
| | 5,148 | | 14,793 | | 76,486 | | |
| 0.235 | 5,214 | 0.165 | 15,064 | 0.095 | 78,927 | | |
| | 5,281 | | 15,341 | | 81,473 | | |
| | 5,350 | | 15,625 | | 84,130 | | |
| | 5,419 | | 15,916 | | 86,904 | | |
| | 5,490 | | 16,215 | | 89,800 | | |

CONVERSION TABLE.

1 inch = 25.4 millimeters.
1 millimeter = 0.03937 inch.
1 quart = 57.75 cubic inches.
1 quart = 0.9464 liter.
1 liter = 61.0234 cubic inches.
1 liter = 1.0567 quarts.
1 pound = 0.4536 kilogram.
1 kilogram = 2.2046 pounds.
Fahrenheit = 9/5 centigrade ± 32°.
Centigrade = 5/9 Fahrenheit ± 32°.




Directions: Find the line on the left margin corresponding to the given diameter; follow said line to the right until it intersects the curve; from this intersection proceed at right angles to the lower marginal line of figures and there read the required number of eggs per quart.

If diameter is given in millimeters multiply by 0.03937 to reduce to inches.

# AN IMPROVEMENT IN HATCHING AND REARING BOXES; WITH NOTES ON THE CONTINUOUS FEEDING OF THE FRY OF SALMONIDÆ

By G. E. Simms

*Ex-Curator of the Brighton Aquarium, Brighton, England*

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

# AN IMPROVEMENT IN HATCHING AND REARING BOXES; WITH NOTES ON THE CONTINUOUS FEEDING OF THE FRY OF SALMONIDÆ.

By G. E. SIMMS,
*Ex-Curator of the Brighton Aquarium, Brighton, England.*

It will, I think, be admitted by even the most conservative exponent of modern pisciculture that there is ample scope for improvement in the type of box now used for hatching and rearing, *inter alia*, the eggs and fry of salmonoids. Speaking broadly, it appears to me that it would be impossible to conceive and, having conceived it, to design an appliance which so thoroughly combines in a small compass the minimum of utility and the maximum of imperfection characterizing the square cornered, oblong pattern of wooden box on which pisciculturists, for lack of a better form of apparatus, are forced to depend for carrying out one of the most important sections of their work. It is not improbable that this may be regarded as a too sweeping indictment of an old and valued servant—if I may be permitted so to describe an inanimate object—but, at the risk of differing from those of my hearers who later on will be my critics, I venture to maintain that, apart from the fact that by its agency fish ova can be brought to maturity, the rectangular wooden hatching box has not a single redeeming quality attached to its name. Indeed, so much so is this the case that I will advance a step further and assert that any utility it may possess in this connection is altogether nullified by the facilities it provides for the unchecked production of fungus, which render it a constant menace and danger to eggs, alevins, and fry alike, so long as they are confined within its sphere of influence.

Three factors are responsible for this unsatisfactory state of affairs. These are the material of which the box is built, its rectangular form, and, last but not least, the position at which the waste-water outlet is situated. A moment's consideration will convince anyone with a practical knowledge of the interior of a hatchery of the correctness of my statement. From either a practical or a scientific point of view, wooden appliances leave more to be desired than they give. Not only are they heavy, unwieldy, and liable to leakage at odd and inconvenient moments, but they have the additional disadvantage of becoming water sodden and readily receptive to the spores of fungus. With the object of preventing any possibility of attack from this, the pisciculturist's most insidious enemy, the services of the charring iron are brought into requisition to antisepticize the interior of the box by superficial carbonization. A more brilliant method of holding in check an ever-present evil of any kind has seldom or never been devised. The only fault that can be found with it is that when those parts of the box which have undergone carbonization are subjected to the action of water any antiseptic properties they may have possessed while dry rapidly disappear, and in a short time the last state of that box as a fungus-fighting appliance is worse than its first. The mischief does not, however, end here. In the course of a few days the inside of the box up to water level—assuming, of course, that it is in use—becomes covered with a viscid slime, and this, in conjunction with the roughened, semispongy substance of the carbonized wood, forms a secure resting place on which particles of excrement and of unconsumed food, as the case may be, can decompose and generate a more or less plentiful crop of fungus.

Turning to the form of the box, what do we find there? The supply, whether it falls in from above or is so arranged that it enters from below, has to force itself against the whole volume of the contents of the box, and consequently its force is expended and ceases to make itself felt before it has, at the outside, reached more than 3 inches from its point of entry. In other words, it is absorbed into and assimilates with the water into which it is poured instead of forming, as it should, a gentle current running over the eggs from end to end of the box. This raises a question as interesting as it is important scientifically and commercially, viz, are the eggs under conditions such as these, which in no wise conform to natural conditions, properly oxygenated by the water in its upward progress toward the outlet? Furthermore, is the passage of the water from the inlet to the outlet equal or intermittent? In regard to each I hold an opinion which is not an affirmative one, but I leave the definite solution of this very interesting problem to those who have more time and opportunities at their disposal than I have for carrying out the necessary experiments.

No doubt many of you have watched a pair of trout making preparations for spawning, and as you have watched you have wondered at the marvelous instinct which prompts the male fish to select a point above the redd, i. e., the spawning bed, with just sufficient stream to carry the milt as he discharges it in a milky cloud over the eggs which have been deposited by his mate. But the two fish—and to the lady must be accorded her fair share of credit in their joint undertaking—have a much deeper purpose in view than the efficient impregnation of the eggs alone. Their instinct also teaches them that the eggs, without an adequate supply of oxygen, will not come to unimpaired maturity, but will produce weakly alevins, and that unless a current of water passes over the eggs while incubation is proceeding they will not obtain a requisite amount of oxygen. Here it appears to me that the dumb instinct of the fish is far superior to the reasoning power of man, as exemplified by the latter's idea of a suitable form of box for the artificial hatching of fish eggs. You will therefore see why I asked, a short way back, whether eggs incubated in a rectangular hatching box are properly oxygenated by the water in its upward progress toward the outlet.

On this side of the Atlantic, wherever in the country districts there occur diverging roads, a handing post to indicate the direction and distance of adjacent villages and towns is erected by the local authorities. Among our rural folk, whose sense of humor is not of a wildly extravagant character, it is a standing joke that their spiritual guides are like handing posts because they point the way to all and sundry and never follow it themselves. But the piscicultural writers of my acquaintance can not be held altogether free from something of the same reproach. To a man they impress on their readers the necessity of extreme cleanliness as an absolute essential to success in pisciculture. No one will be inclined to dispute the soundness of this advice until he attempts to put it into application. Then he will be compelled, probably with some reluctance, to confess he has attempted an impossible task. Leaving "extreme" cleanliness out of the question, it will be found that even ordinary cleanliness can not be observed, and for this reason: The rectangular hatching box is, de facto, merely a pocket of water which can admit, but which, owing to the position of the outlet, can not eject, extraneous matter that may enter it. It therefore follows that when the alevins have arrived at the fry stage and require feeding, any particles of food that they happen to miss must in the natural order of things gravitate to the bottom of the box, where they become saturated with water, decompose, and generate fungus. In this connection it must not be forgotten that animal tissue, however carefully it is treated in converting it into fish food, can never lose its identity as animal tissue. Its juices may be dissipated and dried up by the application of heat and its substance by hard pounding reduced to the finest powder, but its tendency to decompose is only dormant and will actively assert itself immediately the powder or any portion of it is brought under the influence of moisture. The filthy and insanitary condition of the interior of a rectangular box after fry have been hand fed in it for a few days can therefore be better imagined than described. My remarks on this head are of course dictated by the assumption that the methods followed by American and English pisciculturists are identical, viz, that the fry are retained in the hatching boxes and fed until they are ready to be transferred into the rearing ponds.

The shortcomings of the rectangular type of hatching and rearing box have, I regret to say, occupied more space than I originally intended to devote to them. I am, however, assured that the interest and importance of the subject to pisciculturists will be its own apology, if an apology be needed, for the tax I have been compelled to impose on your patience and good nature before dealing with the principles in construction which should be observed in making a hatching and rearing box which will combine thorough efficiency with effective sanitation. These are three in number and are as follows: (1) The material of which the box is constructed must not only be impervious to water, but must have a smooth, hard surface which will act as a preventive against the lodgment of the spores of fungus; (2) the box must be shaped so that the water is kept in constant circulation so long as the supply is running; (3) the outlet must be placed at a point which will enable it to maintain a direct current over the eggs during their period of incubation and at the same time, when the fry have to be fed, act automatically to remove any small particles of unconsumed food.

As regards material, I have met with nothing equal to highly glazed earthenware, and were I in a position which would enable me to indulge in the luxury of an experimental hatchery the whole of its equipment would be of china or delft. These materials are, however, too fragile for the requirements of a hatchery in which from 150,000 to 250,000 eggs are laid down each season, and consequently we shall have to cast about for a material which will make an effective substitute. Thin enameled iron, such as is used in the manufacture of basins, pie dishes, and other domestic utensils, will answer the purpose admirably. To me personally it is a matter of surprise that it has not already been generally adopted for piscicultural work in preference to wood, seeing that of the two materials it is, size for size, relatively the lighter. Moreover, it has the additional advantage of being cheaper, is easier to keep clean, and possesses far greater durability.

Coming to the second principle of construction, I have endeavored to show that any approach to the conditions under which eggs are incubated in a natural state is not attainable with a rectangular hatching box. It will, therefore, be necessary to abolish straight lines in favor of curves, as indicated in the accompanying sketches. Perhaps, however, you may grasp my meaning more readily if, in imagination, you take a length of piping of fairly large dimensions and divide it lengthways into equal halves. At each end of one of these halves affix a circular head and you will then have an exact representation of the type of box I am endeavoring to describe, but as yet minus the outlet. This consists of a circular opening of at least 3 inches in diameter, cut at one end of the box, its lower edge being exactly flush with the bottom of the box (fig. 1). The orifice to which I refer opens into a pipe which is joined to it and runs upward to within an inch of the top of the box, where it turns outward and acts as a spout (fig. 2). The pipe must be of the same dimensions as the circular orifice. In order to prevent the escape of alevins and fry, the orifice where the pipe is fixed into the box should be covered with a grating of fine parallel wires at spaces of about $\frac{1}{16}$ inch apart. The grating may be a little larger, but must on no account be smaller, than the opening of the pipe on which it rests, or the ring to which the wires are soldered will obstruct the passage of any light particles that are being carried away by the outfall. To support the box two semicircularly cut-out boards, placed on edge, will be required when it is placed in the hatchery. These, I should say, are detachable, the box being held in position by its own weight. Figure 1 will explain the action of the box. It will be seen that the supply falls in at B and, so far as the surface is concerned, follows the course marked by the arrows, while a current extending from B to C is caused by the outfall picking up and ejecting any light particles that happen to gravitate within its influence. It is needless for me to add that the box must be fitted with a cover, so that the eggs may be protected from the effects of the light during their period of incubation.

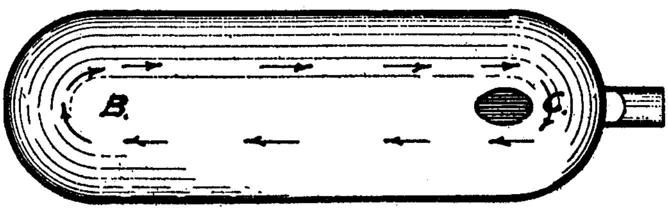


FIG. 1.—Plan.

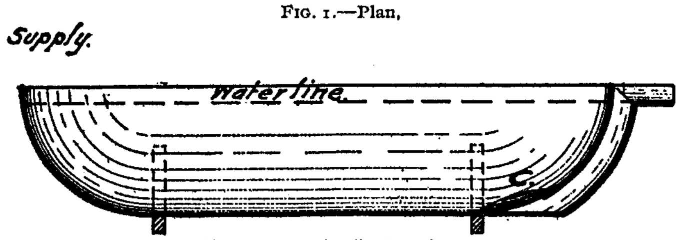


FIG. 2.—Longitudinal section.

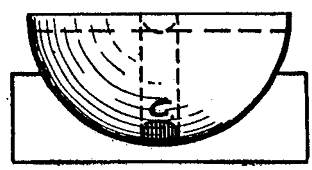


FIG. 3.—Cross section.

DESIGN OF PROPOSED HATCHING AND REARING BOX.

The furnishing of the box with baskets or with grills, as the case may be, is a matter which must be left to the discretion of the pisciculturist who has to use it. If baskets are decided upon they can be fixed in position exactly as they are in the rectangular hatching box. If, on the other hand, grilles are employed, they can be held in a light iron frame resting on a series of studs projecting from the sides of the box. Next season I hope to have one of these boxes fitted with a set of wire baskets, not more than an inch in height and divided by longitudinal slips into compartments which will take five rows of eggs side by side. The baskets will be shaped to the curve of the walls and will be in contact with the bottom. By this means I think it will be possible for the eggs to receive the full benefit of the current caused by the outlet.

The practice of feeding fry with artificial food while they are in the hatchery appeals to me as being about as obsolete and out of date as the type of box in which they are hatched. Not only does the preparation of the food and its subsequent administration involve time and trouble, but there is attached to it the danger of fungoid outbreaks from the particles which have escaped the notice of the fry and are decomposing on the bottom of the box. It is within the knowledge of every pisciculturist that fish raised from the same batch of eggs and reared under artificial conditions always exhibit a considerable diversity of growth; that is to say, there is an ascending scale of sizes running from what may be described as ordinary fish to medium and large. In a natural state of life, fry can and do feed whenever they are assailed by the pangs of hunger; but in a hatchery they must perforce wait until the time fixed for the attendant to come round and give them their food. My experience teaches me that the divergence in growth to which I have referred is accentuated, if it is not increased, by this intermittent feeding during the fry stage. For some time past I have been using a curious little gregarious worm, the *Tubifex rivulorum*, which is more generally known as the summer worm or mud worm, and I find that it makes a magnificent food for fry from the moment they have absorbed the umbilical sac until they are ready to go into the rearing pond. These little worms are found in masses along the alluvial soil at the edges of ditches and ponds. They vary in length from an inch to 3 inches and resemble in appearance animated threads of floss silk. If the water above them is disturbed they will immediately disappear by withdrawing themselves into their burrows in the soft mud. They soon, however, recover from their fright, come out again, and at once recommence the restless movements with which their numbers and bright color attracted the passer-by. It is the tail end of the animal which is protruded out of the mud. The skin of these worms is so fine and transparent that not only can the blood be seen through it, but under an ordinary magnifying glass the internal arrangements of the creatures may be plainly observed. When taken from the water these worms resemble to the touch a piece of very soft jelly, but their full beauty is not apparent until the lump is placed in a clear glass vessel filled with water, when it assumes the appearance of a magnificent scarlet zoophyte, with a multitude of waving tentacles constantly in motion.

In using these worms for feeding fry all that is necessary is to distribute three or four pieces, about an ounce each in weight, at different parts of the rearing box, and the fry will commence feeding upon them and will require no further attention. Fry so reared make better blood and better bone than those brought up on artificial food in the usual fashion, and, unlike the latter, they never become tame. They also rise readily to floating particles, and consequently I do not think that the slightest fear need be entertained that the use of these worms as a primary food will train the fry to become ground feeders at a later stage of their existence. *T. rivulorum* is pretty widely distributed throughout England and the continent of Europe, but I have no idea whether it extends to America. In regard to its introduction into the latter country, it is such a fragile, insignificant creature that I do not think it could, under the influence of an altered environment, do the slightest harm; and if any enterprising pisciculturist in the United States wishes to give it a trial I shall be very happy to extend to him any assistance that lies in my power. Given a nice, soft stretch of mud, covered by an inch or so of water, and an equitable climate, the mud worm will flourish apace and multiply with a truly surprising rapidity. It has been tried on trout fry in several of the leading hatcheries in England, and the reports I have received concerning it have been of a most favorable character, the only fault to be found with it being that it is an exceedingly expensive food. As the hatcheries mentioned above have had to purchase their supplies from London at the rate of 3 shillings 6 pence per quart, this complaint is quite justified, but if the pisciculturists who make it will only go to the small amount of trouble necessary for laying out a worm bed, they will find that *T. rivulorum* is a cheap and invaluable food for their fry.

# DEVICES FOR USE IN FISH HATCHERIES AND AQUARIA

By Eugene Vincent

*Fish Culturist, Aquarium of the Trocadero, Paris*

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

## CONTENTS.

# DEVICES FOR USE IN FISH HATCHERIES AND AQUARIA.

By EUGENE VINCENT,
*Fish Culturist, Aquarium of the Trocadero, Paris.*

[Translated from the French.]

## ARTIFICIAL POND WITH SIPHOID OUTLET FOR REGULATION OF HEIGHT OF WATER.

This pond is made of cement, the bottom having a layer 0.05 meter in thickness and a lining of 0.02 meter, the sides being 0.08 meter in thickness. The dimensions are 12 to 15 meters by 3 meters, with any desired depth, and the ends are rounded. Crosswise the bottom slopes from the middle upward at the degree of 0.05 meter per meter, which equals 0.75 meter for a side of 1.50 meter. With this slope the pond may be cleaned by simply sweeping toward the center or by means of a few buckets of water thrown against the sides. It is fed by one or more troughs which empty into it with a stream of 0.20.

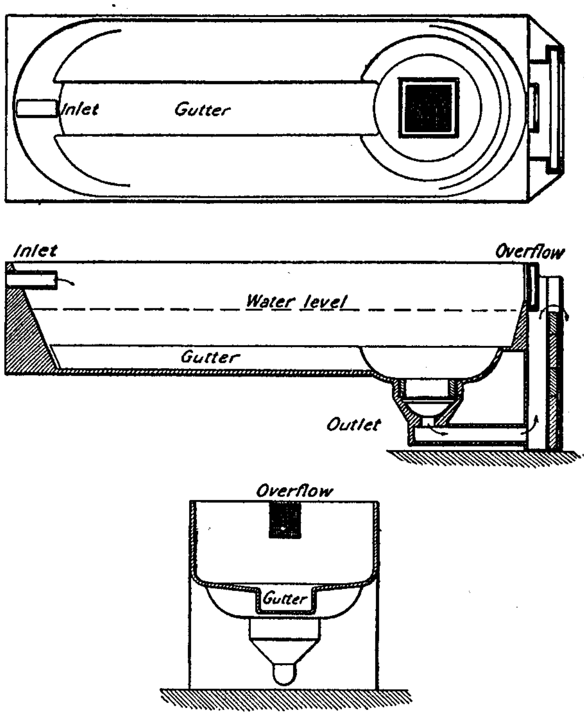



FIG. 1.—Design for artificial pond with siphoid outlet.

The pond must be level in lengthwise direction, in order to preclude danger of leaving any dry area below a given height. In the middle of the bottom of the pond, beginning at the intake end and terminating in a circular basin which occupies the opposite end, is a gutter at least 0.50 meter in width and 0.12 to 0.15 meter in depth. The circular basin is from 1.50 to 1.80 meters in diameter, and 0.20 to 0.30 meter in depth. With the gutter it serves to hold the fish when the water is drawn out of the rest of the pond for cleaning. The cleaning process itself is simplified, since a man may enter for the purpose and walk about on the bottom of the pond.

So far the pond is not provided with any outlet. In the wall opposite the intake, 0.15 or 0.20 meter above the gutter in the bottom of the pond, is an aperture 0.50 to 0.60 meter square, covered with wire netting. This, however, is not an outlet but an overflow. The outlet proper is in the bottom of the large circular basin and consists first of an opening 0.60 meter square and 0.10 to 0.12 meter deep. Into this square is set a wooden box with a wire mesh bottom, and this box, filled with coarse gravel, rests upon an iron grating 0.60 by 0.60 meter. Below the grating is a circular basin 0.50 meter in diameter and 0.15 meter in depth, with an opening in the center which leads into an outflow pipe.

The outlet provided, the regulation of the water level in the pond remains to be accomplished. This is done by carrying the outflow into a tank or other receptacle outside the pond, in which any desired level may be maintained by regulation of its overflow. The latter is controlled by a board wall or dam constructed of removable sections.

In addition to the convenience of this construction in regulating the height of water in the ponds, there is afforded every protection against loss of the small fish, since the water in leaving must pass through gravel the size of hazel nuts; the cleaning of the pond may be accomplished without injury or shock to the fish; all impurities fall into the gutter and are carried off through the circular basin, while the fish, seeking the incoming current, are in the upper strata of water and away from all such impurities as do not pass through the screened outlet; the fish are provided with desirable currents derived from the action of the siphon, and the pond is continuously self-cleaning. When the fish are larger the gravel may be removed, and still later the screen itself may be discarded.

Fish culturists will appreciate the importance of perfect control of their rearing ponds. A construction such as this described is possible wherever there is a fall of at least 1 meter in the water supply, since it is not necessary to take the siphon apparatus into account. There is but one thing absolutely necessary to provide against—namely, the possibility of emptying the pond entirely, down to the screen with the gravel. It is of little importance that the outflow pipe is not emptied; the water will always flow off, on account of the difference of level.

The design has been adopted with satisfactory results in several fish culture establishments in France.

A SIPHOID OUTLET FOR HATCHING AND REARING TROUGHS.

The various systems of outlet in most fish-cultural equipment are defective in several ways, as I have had occasion to observe on visits to different establishments. The young fish escape in the outflow, perhaps, due to its faulty construction or installation; many of them are caught in the perforations of the sheet-iron cap and die there; many others are killed or injured by the fingers that try to rescue them; overflows are caused by the clogging of the perforations; the water is not thoroughly renewed and the trough becomes infected with germs of disease. All this is too familiar to need to be dwelt upon. I have sought to overcome various difficulties by the following device.

I have provided a large cylindrical wire screen or cage, which is set over the outlet and incloses the outlet apparatus which I shall describe. The large surface of the screen gives free course to the water without attracting the young fish and thus becoming a means of their destruction.

In the daily procedure of changing the water in the rearing troughs, I desire to be able to lower the level to a given point without the necessity of losing time waiting beside the trough. To accomplish this I have made, first, for the orifice in the bottom of the trough, a water-tight collar of two pieces screwed together with a leather washer between. The lower piece is supplied with lugs extending downward, and into this collar is inserted a tube, making an ordinary standpipe. With this form of outlet, however, the water is renewed only at the surface, the bottom water, with remnants of food, refuse substances, etc., being left unchanged. I have accordingly elaborated the standpipe into a form which constitutes an unfailing cleaning device. It carries off all the solid matter

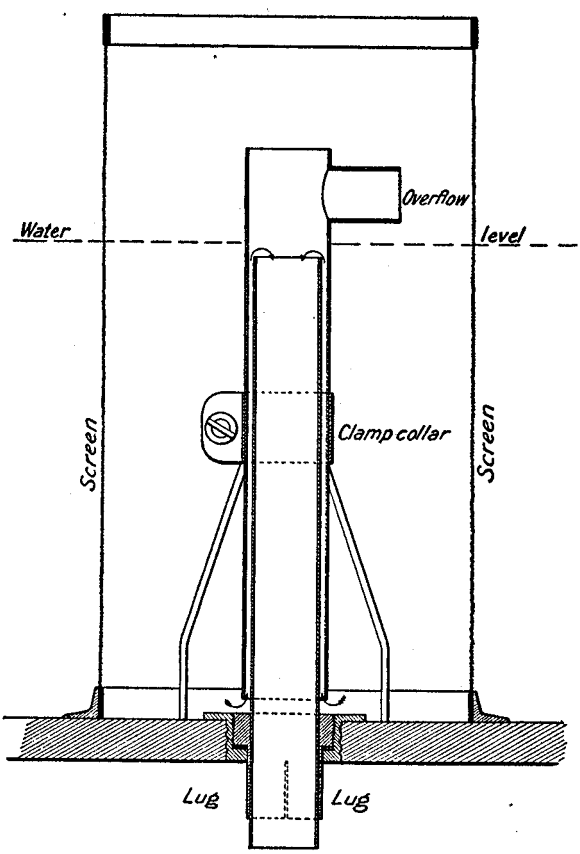



FIG. 2.—A siphoid outlet for hatching and rearing troughs.

that passes through the screen, and affords a desired current for the young fish, which do not like to be inactive.

For this purpose a second slightly larger tube is slipped over the standpipe and, by means of a clamp collar supported on three legs, is held with its lower end just above the bottom. The current thus produced can be regulated, greater force being obtained when desired by lowering the outer tube and thus preventing the full outflow of water. This raises the level in the trough, and the difference between the level in the trough and the stream which can escape—namely, the height of the inner standpipe—makes the pressure to force the water up from the bottom and carry with it the refuse matter in the trough. It is not in a trough such as this that there will be ill-smelling bottom water.

The apparatus does not, as one might think, act merely as do communicating vessels. With a flow of 2 to 3 liters per minute I obtain a difference of level of 3 to 4 centimeters, according to the elevation of the outer tube. By regulation of this tube, which is very simple, both surface and bottom water will be renewed. If only the lower water were emptied an oily layer would form at the surface and act as an insulator between the air and the water.

As the aquarium of the Trocadero is supplied by sluices, in the flow of which there might be the same fluctuations as in the river, I have provided an emergency overflow to balance any sudden rush of water.

When it is desired to remove some of the fish from the trough the whole apparatus may be removed, the mouth of the outlet in the bottom of the trough being closed with an ordinary cap or plug.

## A SUCTION APPARATUS FOR CLEANING HATCHING AND REARING TROUGHS.

This device is designed for use in the removal of dead eggs or fry, remnants of food, or any undesirable substance that may be found in the troughs. The use of the usual metal or wooden tweezers, or perhaps long pins, too often causes the eggs to burst, thus spreading infection from their decomposed contents. Little glass pipettes are used, taking one egg at a time. But this often escapes and, falling to the bottom of the trays, is left to give rise to *Saprolegnia.*

To meet these difficulties I have used a pipette with a rubber bulb attached. The tubes vary in diameter, according to the sizes of the different species of eggs, and are 0.25 meter long, being slightly bent at the entrance to the bulb. At the outer end is a ring of blue glass to guide the eye of the operator. With the aid of this form of pipette 15 or 20 eggs may be taken up to be thrown out of the trough at one motion of the operator.

Upon this appliance as a basis I subsequently devised a second means of cleaning by combination with the siphon principle. The later apparatus consists of a long rubber tube attached, with metal handle and connections, to a blue-tipped pipette on one side and to a rubber bulb on the other. The bulb normally receives its air supply through a small rubber tube which is connected with a metal piston valve inserted in the large tube some 0.60 meter below the bulb. An auxiliary air valve in the handle is controlled by a little piston within reach of the index finger of the right hand.

To use this apparatus have the lower end of the large tube and also the lower piston valve below the water level existing in the trough. Squeeze the bulb with the right hand, press the lower piston with the left, and then, putting the end of the glass tube in the water, release the bulb. Then release the piston and the siphon will have started. The glass tube may be directed at will. If the suction is too strong it may be regulated by the piston in the left hand.

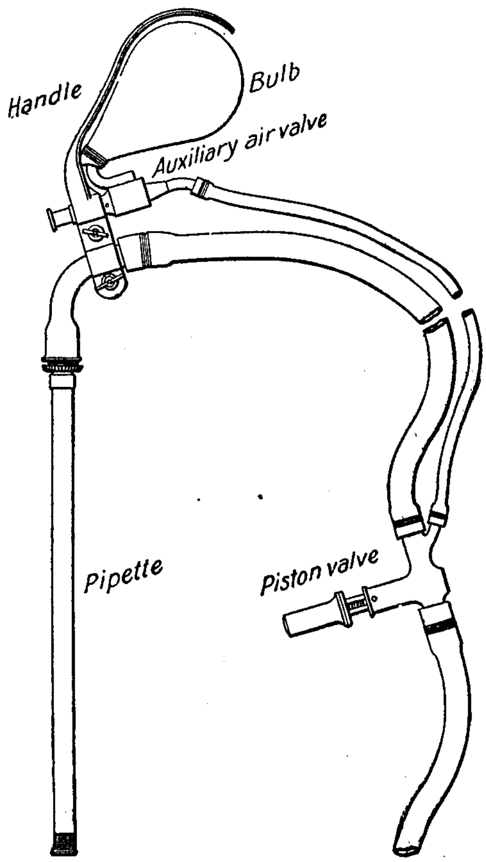



FIG. 3.—Apparatus for cleaning hatching or rearing troughs.

Should a good egg be picked up by mistake it may be readily replaced without waiting for it to discharge at the lower end of the rubber tube. Stop the flow of water by closing the lower piston with the left hand; then press the bulb to expel the air from the small tube upward into the larger, the mouth of the glass tube being meanwhile under water. If this does not force the egg out of the glass tube continue to hold the piston closed, squeeze the bulb with the right hand, and then with the index finger press the little auxiliary piston at the end of the handle. If now the bulb is released it will fill. Removing then the pressure from the little piston on the handle there can be no escape of air at this point when the bulb is compressed, but only backward in the main tube, for the discharge outward is cut off by the closed lower piston valve. The egg will thus be forced out of the glass tube.

Care should be taken to avoid drawing water into the bulb, but in such event a discharge may be effected by proceeding as just described except that the lower piston valve is in this case left open.

This apparatus has proved most successful and obviates the necessity of putting the hands in cold water to do the work of picking the eggs.

A CLEANING DEVICE FOR PONDS OR AQUARIA.

The imperfect construction of some ponds, not permitting them to be entirely emptied, necessitates the use of various means and implements, such as dip nets and even shovels, for cleaning. With even the greatest care it is difficult to maintain the cleanliness necessary to avoid mortality among the fish.

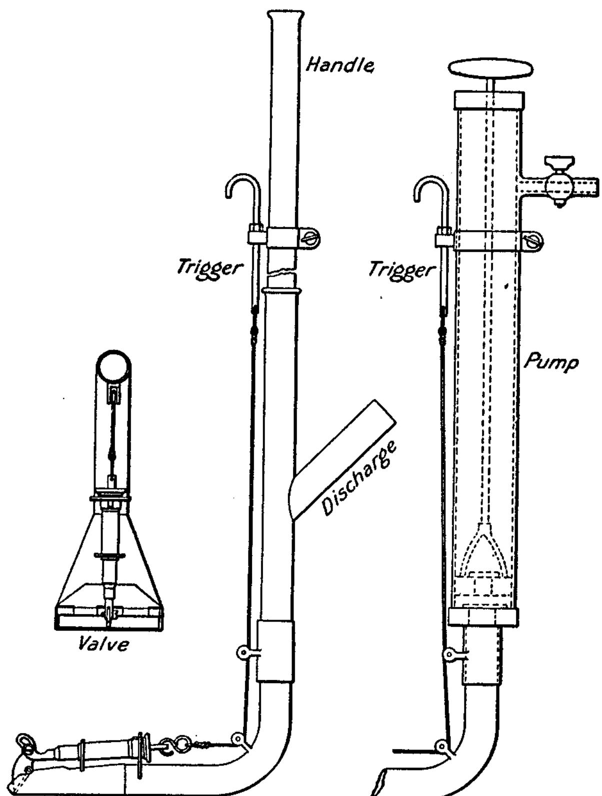


FIG. 4.—Cleaning device for ponds and aquaria.

The present device enables the fish culturist to prevent disease by more thorough cleaning, and also by avoiding the bruises inflicted upon the fish in the course of the ordinary cleaning process if the water is muddy. It also prevents the disagreeable taste of fish reared in muddy and ill-cleaned ponds.

The apparatus is constructed upon the principle of the foregoing rubber siphon and glass tube. Being for larger work, however, it is made of brass pipe with rubber or canvas connections. It consists of a main arm terminating in an elbow joint which is expanded into a flat triangular cavity with an entrance valve. This valve, opening upward, is controlled by a lever attached by a cord to a trigger on the handle of the apparatus. The handle, which is of wood and inserted in the upper end of the main tube, may be of any desired length. Branching off the main tube a short distance below the handle is an arm for connection with the discharge pipe.

In operation the discharge arm may be attached to rubber or canvas hose, with outlet below the level in the pond or tank, and the apparatus guided about over the bottom by means of the handle, the suction being regulated by the cord attached to the valve. In cases where the pond may not be emptied, and the siphon therefore is not feasible, the handle is removed from the cleaning apparatus and a pump attached. A small suction pump, such as used in gardens, is very suitable. If for any cause convenient, the apparatus may be left in the pond, for with the valve closed the suction can not act.

## OXYGENATION AND VACUUM-PRODUCING APPARATUS.

This apparatus is in effect a section which may be introduced into a supply pipe, and consists of an exhaust chamber and an air-supply tube, with the essential feature of a movable jet. The differences of water pressure and sizes of supply pipes render a stationary jet ineffective or even useless at times.

The model here represented has a jet of 5 to 6 millimeters diameter, adjustable by means of a screw on the outside, and sends air into the water to a depth of about 4 meters, from an opening of 20 millimeters. It may be mounted with openings varying from 20 to 26 millimeters. The lower part of the apparatus is provided with a movable tube having a conical entrance, to divide the water better and make the vacuum stronger.

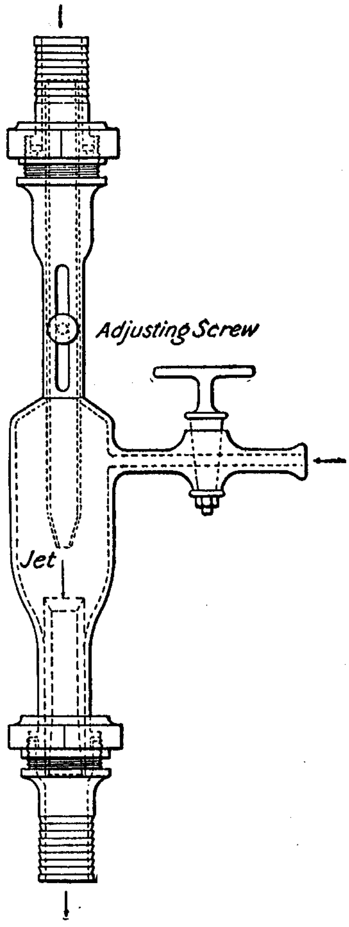



FIG. 5.—Oxygenator and vacuum producer.

The pressure of the water of the Vanne is diminished in the sluices of the Trocadero Aquarium by the many separate outflows, and to provide the desired currents, 13 of these oxygenators have been installed. The fishes playing in the numerous silvery bubbles which rise from the bottom arouse much admiration from the public, and it will be readily believed that the fish are clean and never sluggish. Small or large, they thrive with this kind of aeration, which brings them artificial currents of water which they did not find in these same ponds before. These currents, moreover, do not allow the food given to fall to the bottom when it is sprinkled in. The young fish, some 5 or 6 weeks old, may be seen to catch in passing the small particles of food which the water brings them. The ponds are from 2 to 3 meters deep, from 7 to 8 meters long, and from 2 to 3 meters wide. These oxygenators render great service; it is a hygienic method which ought to be used wherever possible.

This apparatus may be used without disarrangement for the purpose of producing a vacuum in boxes specially prepared for the preservation of food for fishes and even for the shipment of fishes destined for market. It may be of various sizes and may be placed at the base of a reservoir or even in a receptacle in an automobile for the transportation of fishes alive. In this case the motor will turn a small pump in the apparatus and this even during stops, with the exception of cases when the motor itself does not work.

I have a small oxygenator at the extremity of a small hand pump, to serve me for long transportations. This is more practical than an air pump, the globules from which are too large and must be divided. By means of its water jet, which carries the air along, the oxygenator divides its globules, and these rising less rapidly to the surface, aerate the water much better than the large globules.

The discharge pipe of the oxygenator must be sufficiently large to contain at the same time the air and the water which must pass through it together. Thus if it should be found necessary, as for instance, if the ponds need to be cleaned by flushing, it is possible to attach at the connection of the air pipe a joint identical with the water pipe and use this double water supply in spite of the presence of the oxygenator which might seem to intercept it. Or the spigot of the air pipe may be closed and the flow of water is then normal.

Some three years ago I placed with a manufacturer a design for an oxygenator, but feeling some distrust withheld the feature of the sliding jet, though I mentioned it. It was well that I did withhold it, for not only did I lose my apparatus but the idea was stolen, though I retained the secret of the true mode of operation. The sliding jet is indispensable to success. In a locality in the north of France a system of oxygenators installed at great expense afterwards necessitated the modification of a great part of the plumbing and changes in the size of jets, all of which is obviated by the sliding jet.

## SCRAPER FOR PREPARING FISH FOOD.

Fish culturists know that it is not a very agreeable or easy task to extract the pulp from the spleen of horses or beeves, and that it is, moreover, a very long and fatiguing operation if a knife, spoon, or any such instrument is used. For my part, having some 15 kilograms and sometimes more of spleen to scrape, I endeavored to find a readier means.

My device somewhat resembles a block plane in shape, with 5 blades protruding their full depth. I had to seek a long time for blades of requisite flexibility, shape, and size, and to fit them in proper place and at proper inclination. It will be seen that these blades have not all the same shape. This is because each has its definite place of contact, none scraping directly on the spot which the preceding blade has scraped. Otherwise the pulp would be immediately torn at the first stroke of the scraper. I have likewise overcome the other difficulties encountered at the beginning of the attempt at this device.

The following is the mode of proceeding:

To a board, 1 meter long and 0.30 meter wide, edged with a strip 0.02 meter high to keep the pulp of the spleen from falling over the sides, is affixed at each end a transverse support to raise it above the surface of the table on which the scraper is used. One support should be sufficiently high to permit a small receptacle to be placed somewhat under the board, at a height of 0.10 meter approximately, while for the other support a height of 0.03 meter would be sufficient. The board will thus be inclined.

At the lower end a narrow board is attached flat by means of a hinge at the farther side. This small board is 0.05 to 0.06 meter wide, of the same thickness as the big board, and in it are fixed 10 to 12 sharp points 0.02 meter long, spaced 0.015 meter apart. This board swung back, the spleen is placed flat on the larger board, some 0.03 or 0.04 meter of it falling over the end. The small board is then swung forward and its points, piercing the spleen, will keep the latter in place during the scraping. A small hook at the end holds the small board in position to keep the spleen from slipping. The thin skin around the spleen is taken off with a knife and the spleen is cut longitudinally several times.

The scraper is manipulated in the manner of a plane. The spleen should be turned end for end, if need be, to scrape the part which had been held under the toothed board.

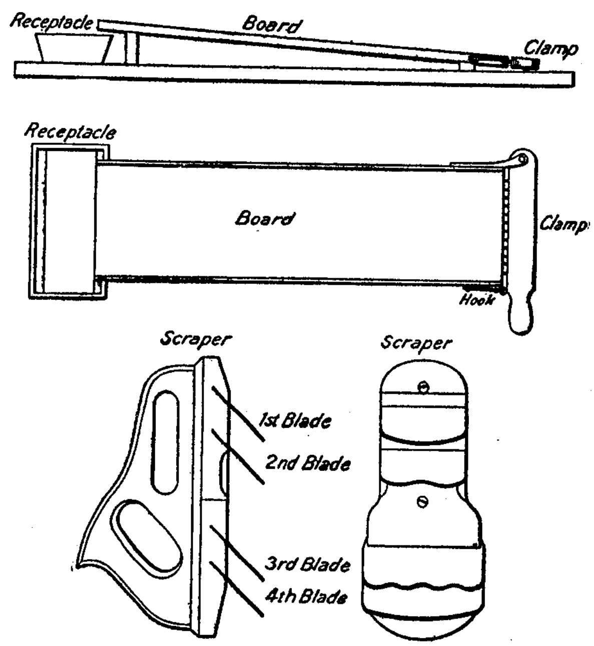



FIG. 6.—Scraper for preparing fish food.

This implement may seem an odd device, but it is remarkable how rapidly the spleen pulp is extracted. Two to three minutes are sufficient for the operation, with a spleen weighing 0.80 kilogram. It should be added that this pulp does not contain any remnants of spleen cells, as might be supposed.

If the spleen is frozen in winter and it is not feared that the nutritive qualities of the raw flesh or the spleen pulp might be decreased, it may be immersed for a few minutes in hot water before being scraped and the operation will be still more rapid.

Several establishments make use of this scraper because their proprietors have seen me use mine. I have ordered several from a manufacturing firm.