XV.—EXPERIMENTS UPON RETARDING THE DEVELOPMENT OF EGGS OF THE SHAD, MADE IN 1879, AT THE UNITED STATES SHAD-HATCHING STATION AT HAVRE DE GRACE, MD.

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The report hereby submitted gives somewhat in detail the methods and results of the experiments in retarding the development of impregnated shad-spawn which were carried on by Mr. F. N. Clark and myself during the month of June, 1879, at the United States Fish Commission barges, near Havre de Grace, Md. These investigations were instituted principally for the purpose of ascertaining the possibility and practicability of transporting shad-spawn across the ocean, with a view to introducing American fish into European waters, and all of our efforts were made with that end in view. Normally, as is well known, or as is generally considered at the present time, shad-spawn requires for its development a constant although slight motion, and a continuous exchange of fresh water. Under these conditions, whether produced naturally or artificially, the spawn after impregnation will proceed in its development, and the young shad come to maturity, quickly or slowly according to the temperature of the water in which they are placed. With a temperature of 68° to 74° the ova will hatch out in from three to five days. If the water is of a lower temperature, or about 56°, the development will be much prolonged and the hatching take place in about eleven days. Upon an ocean voyage the great difficulty to be surmounted would be the lack of fresh water. Motion can be given to the eggs, and the temperature can be kept at any point which may be desired by means of ice, but all the water used with the eggs must be such as can be taken on board at the beginning of the trip.

The questions to be answered, then, in regard to a shipment of the kind proposed were, "Can shad ova be carried, and will they go on in their development, in stagnant water, or in water which, although changed as often as thought necessary, is not absolutely fresh; or can they be carried in some other manner, as for instance in an ice-chest, as is done with some other kinds of fish-spawn, as that of the white-fish of the Great Lakes for example?" It is quite evident that if it could be shown to be possible, even with considerable care, to carry shad-ova in either of these ways, it would not be very difficult to transport any quantity which might be desired to the other side of the Atlantic, and

thus introduce there a species of fish which upon this side of the water is considered one of the table delicacies of the season. We began our experiments by endeavoring to solve the second question first. For this purpose an ice-chest was constructed under the supervision of Mr. Clark. It consisted of a covered wooden box (Fig. 1, *a*) about 3 feet in each dimension, within which was a second box or well, *b*, of about one-half the size of the outer one. This well opened upon one side of the chest by a box-door, *c*, about 5 inches in thickness, and so arranged with slats, 1, 2, 3, 4, upon the inside that a large or small quantity of ice could be packed in it. The well was free from the other sides of the chest all around and on top by a space of about 8 inches, and beneath it was a drawer *d*, of about 6 inches in depth. The well could thus be entirely surrounded with ice, and the temperature regulated by the amount of ice placed in the chest, and by more or less completely closing the door of the well and the cover of the chest. In practice it was found that with a small amount of ice around the sides of the well and in the drawer and door, and a large cake upon the top of the well, an even and moist temperature could be maintained throughout the chest with very little trouble.

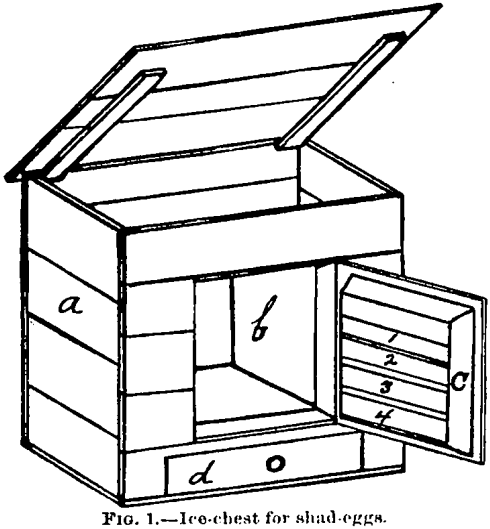

FIG. 1.—Ice-chest for shad-eggs.

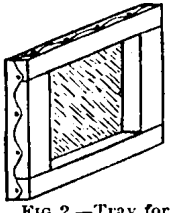

FIG. 2.—Tray for ice-chest.

Within the well a series of trays (Fig. 2) were placed one above the other. They were made with wooden frames about 1 inch in thickness, and were covered upon the bottom with cotton-flannel. When wanted for use the cotton-flannel bottom of the tray was thoroughly moistened, and about 7,000 to 8,000 freshly impregnated eggs placed upon it and carefully spread out with a feather. The temperature of the eggs was then lowered very gradually until it was the same as that of the well of the chest, the chest having previously been partially filled with ice. The tray was then placed in the chest and kept at a uniform temperature during the time of the experiment. The first lot of eggs was placed in the chest on the evening of the 7th of June. This lot consisted of about 25,000 eggs which were taken fresh from the spawners and distributed upon three or four trays. The temperature was reduced very gradually to 37° when they were placed in the well, and kept at 37° and 38° until about 8 o'clock p. m. of the 9th of June. At this time they appear to be all dead, and the temperature was allowed to

rise to 55° which was about 10 o'clock p. m. same date, when a second lot of freshly-taken eggs, of about the same number as the first, was placed in the chest.

The temperature was then allowed to sink to 48°, and kept there, not running below 47° nor above 49°. About 10 a. m. of the 12th the eggs of the first lot were found to be all dead and were thrown away, but those of the second lot appeared to contain some good ones, and one trayful was placed in a cone of fresh running water at a temperature of about 75°. On the third day after, or on the 15th of June, about 20 or 30 young fish hatched from this lot.

At 12 m. of the 12th, after the trayful of eggs had been transferred to the cone, a third lot of eggs was placed in the chest. These eggs had been taken on the night of the 11th and kept in a cone of fresh running water until the segmentation cap had entirely covered the yelk and the young fish could be seen as a dark band along the side of the vitellus. The temperature was now allowed to sink to 43°, and kept at about 45° until 6 p. m. of the 14th, when all the eggs of both second and third lots were found to be dead. Forty three degrees is thus undoubtedly too low a temperature for shad-spawn; otherwise we ought to have had some live eggs in either the second lot, which furnished live ones at 48°, or in the third lot, which had been subjected to the low temperature for only about two days. On June 17th, 10 p. m., a fourth lot of freshly-taken eggs was placed in the chest, where the temperature showed 64°, and on the 20th a fifth lot was consigned to the well. In these latter ova the young fish were so far advanced as to show the eyes, protovertebræ, ear-cavity, and the heart as a single-chambered pulsatile organ. When these were placed in the chest the temperature was 55°, and it was kept at this point until the 23d, when both eggs and young fish were found to be dead. In order to keep the temperature at 55° or 56° very little ice was necessary, and it is possible that the eggs did not have moisture enough to maintain them in good condition, since they appeared to melt down into a mat-like mass after being in the chest for a day or so. This was not noticed, or but very slightly, in the other cases. Our only success, or partial success, with the ice-chest, then, was with that portion of the second lot of eggs which was kept at a temperature of 48°. The young fish which were hatched from these eggs were exceedingly vigorous and hearty, and when we broke camp on the 24th, or nine days after they had escaped from the eggs, they were about five-eighths of an inch in length, with the rays of the dorsal, anal, and caudal fins well advanced, the end of the notochord turned up very prominently, and the caudal fin slightly forked. They were about one-third larger than some older fish which were in another cone and which had been hatched out in the ordinary manner. In the stomachs of all of these young fish I found a great many shells and remains of daphniæ and other small animals, and saw them, and especially the older ones above mentioned, eat the dead of their own species.

The trials which we have thus made seem to indicate that it is impracticable to carry shad-spawn in an ice-chest, as can be done with many kinds of spawn, especially such as is laid in the fall or winter season. But it is possible that more trials and greater precautions are necessary before we can be positive in this respect, particularly as I am informed that Mr. Welcher, now of the Michigan fish commission, has kept shad-spawn in an ice-chest for a considerable time, and afterwards hatched out

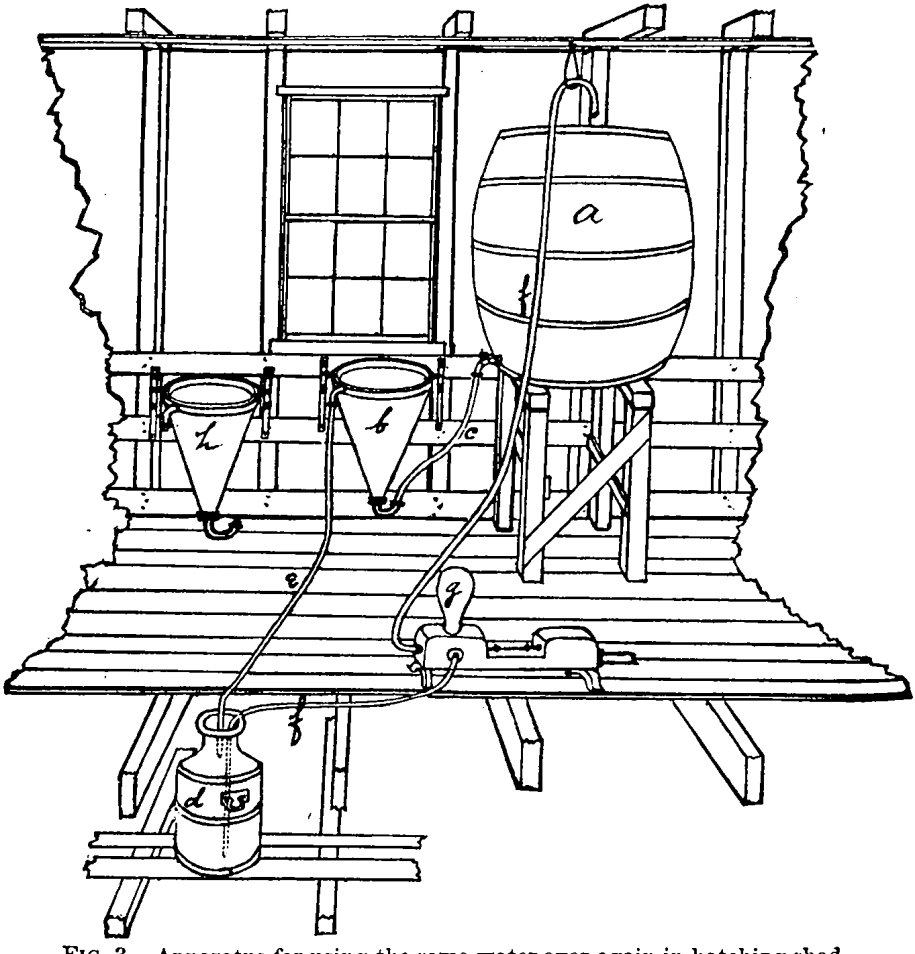

FIG. 3.—Apparatus for using the same water over again in hatching shad.

young shad from such spawn. I am not conversant, however, with his method, nor do I know to what extent he was successful in such experiments. But judging alone from our efforts, the results seem to show that an ice-chest is seriously detrimental to the integrity of shad-ova. So far, then, as our experiments have been carried, and as regards the ice-chest, the question would have to be answered in the negative.

Our second set of experiments were then begun for the purpose of test-

ing the feasibility of using the same water over and over again when its temperature is kept below the normal condition.

Our apparatus, Fig. 3, as arranged for these experiments, consisted of two reservoirs, a hatching-cone, and a steam-pump, and their connections. The first or supply reservoir (Fig. 3, *a*), was a small hogshead elevated about three feet above the floor or just above the level of the hatching-cone *b*, which was of the ordinary pattern, with a rim of wire sieving around the inside at the top with a gateway in it for the purpose of letting dead eggs pass off into the gutter, which ran around the top of the cone outside of the sieve rim and so into the escape-pipe. The cone was swung on braces attached to the side of the wall, and was connected with the supply tank by means of a rubber pipe, *c*, passing from the bottom of the reservoir to the bottom of the cone. The second reservoir, *d*, was smaller than the first, and was placed under the floor and below the hatching-cone with which it communicated by means of an escape-pipe, *e*, passing from one side of the gutter at the top of the cone down and over the edge of the reservoir can.

The apparatus was completed by placing the two reservoirs in communication by means of a long tube, *f*, passing through the steam-pump *g* and entering the top of the first reservoir. Water being placed in the large reservoir a flow would take place into the cone, and the cone when full, would overflow into the second reservoir, from whence the once-used water could be pumped back by the pump into the supply-tank, again to run its circuit through the cone. In this manner we had a constant flow of water in our cone, and as the end of the escape-pipe from the cone into the lower reservoir and that of the supply-pipe from the pump into the supply-tank were considerably above the level of the water in their respective reservoirs, there was also a slight amount of aëration from the falling water.

The temperature of the water was regulated by keeping ice in greater or less quantity in the supply-reservoir. Our first trial of this apparatus was begun on the evening of June 8. The supply-reservoir and cone were filled with water from the bay and 50,000 freshly-taken eggs placed in the cone. The temperature of the water was reduced to 45°, then allowed to rise to 52°, and kept at that temperature until the morning of the 11th, when the eggs were found to be dead and were thrown away, and the apparatus thoroughly cleaned. It is probable that the low temperature of the water had its effect in destroying this lot. At 10 a. m. of the 12th the reservoir and cone were refilled and a second lot of eggs placed in the cone. The temperature was 67°, and was gradually reduced to 56°, and kept for the most part at that point, although on the 15th it rose to 64°, for lack of ice, consequent upon our change of locality, but was brought back to 56° on the 16th. These eggs had been taken on the night of the 11th and kept until 10 a. m. of the 12th in fresh running water, at 77°, before being placed in the cone. When placed in the cone the segmentation cap entirely covered the yelk, and the young fish, as was the case with lot No. 3 which was

placed in the ice-chest, could be seen as a dark band around one side of the yelk. These eggs continued their development, or at least a goodly proportion of them did, up to the middle of the fourth day, when they were well developed, showing eyes, protovertebræ, ear-cavity, and the heart as a single-chambered pulsatile organ. They appeared to be healthy and in good condition; but gradually the water became filled with sloughs and decomposing animal matter, and early in the fifth day, or by the morning of the 17th of June, the fish were all dead. The eggs were accordingly thrown away and the apparatus again cleaned and placed in readiness for a third trial.

It had become pretty evident that the trouble was in the water, and we determined to try the next time the effect of more thorough aëration upon it. Accordingly at 10 p. m. of June 17 a third lot of about 50,000 eggs was placed in the cone, with the water in the supply-reservoir at 72°. By 7 a. m. of the 18th the temperature had been brought down to 64°, and by 12 a. m. to 53°. It was kept thereafter during the trial at an average of 54°. At intervals of two to three hours after the water had commenced running, the water in the supply reservoir and that in a second cone, Fig. 3, *h*, which had been arranged to receive the outflow of the first before the water passed into the second reservoir, was thoroughly agitated for five to ten minutes. This was accomplished by the use of a dipper, running the dipper down deep in the vessels and getting the water from near the bottom, then lifting the dipper high above the vessels before pouring it back, so as to give the water as much of a fall as possible. In addition to this method of purifying the water a certain quantity was taken two or three times each day from the surface of the hatching-cone. In this manner it was intended to take of that water which had just passed over the eggs about the same quantity that would be added to the supply-tank as fresh water by the melting of the ice, and in taking it from the hatching-cone any sloughs or dirt which had accumulated around the top of the cone could be included. Under this treatment the eggs progressed in their development and appeared in fine condition up to the middle of the fifth day, or one day longer than those of the second lot. At this time they were at the same stage of development as the second lot upon the fourth day; but it is to be borne in mind that the second lot was started in warmer and fresh water before being placed in the cone, while these passed through their entire development in the stale water. On the afternoon of the fifth day the water, despite the constant aëration, began to have a rank, fishy odor and to foam slightly in the supply-reservoir. Notwithstanding this the eggs appeared in a good and healthy condition. On the morning of the sixth day, however, or the 23d of June, the foam on the water was very considerable in amount and the eggs were quite noticeably affected. As much of the water as could possibly be spared was then taken off through the hatching-cone, together with as much of the slough and dead material as could be separated from the good eggs, and a filter of charcoal placed under the supply-tube of the supply-

reservoir. But this did not seem to stop the death of the eggs, and in order to save the remainder they were transferred at noon of the sixth day to a cone of fresh water at a temperature of about 73°. The stale water had, however, apparently been too injurious to them and they all finally died. It appeared to be pretty evident from this trial that while artificial aëration would increase to a certain extent the time during which the water could sustain the eggs in good condition, yet four and a half or five days were about the utmost limit of time the same water could be used over and over again. When used for this length of time the entire vitality appeared to be taken from it. This was probably from the using up of the oxygen contained in it, although the decaying organic material, sloughs, and dead eggs, of which there are always more or less mixed with good eggs, may have played a very important part in rendering the water unfit for sustaining life.

The end of the season was now at hand and good spawn was very difficult to obtain. We were thus prevented from trying other methods of using the water. The next method would have been to take enough water on board at the beginning of the experiment, in addition to that in the reservoir and cone, to enable us to give the eggs a complete change of water, drawing off the old and putting the other in its place once every three days.

If unused water—water which contains its normal amount of oxygen and which has not passed over the eggs so as to become tainted with decaying organic material—is all that is required to replace the used or partially exhausted water of the cone, then there would be no difficulty in keeping the eggs in good condition for a voyage of twelve or fifteen days, for it would be an easy matter to carry sufficient water in extra casks to make complete changes every three days for this length of time, or even longer. But as a trip can be made in from eight to nine days, or as that would be the length of time which would elapse before fresh water could be obtained, it would hardly be required to make over two, or perhaps three, changes. From our experience this year it seems highly probable that such an attempt would be entirely successful, and that a good proportion of eggs thus treated could be hatched out and the young fish distributed wherever it was desired to take them. In such an experiment the larger the amount of water passing over the eggs the longer the time required to exhaust it or render it foul. If the experiment should be tried again and for the same purpose, that is, transportation across the ocean, the apparatus should be just such as would be employed on ship board, and with the supply-reservoir made as large as could be conveniently carried. Then, by changing the water, aëration, and the use of a filter for the used water before it re-entered the supply-tank, it would seem as if success could be assured. At least, if this method cannot be made to answer the purpose it is very questionable whether any can. Several cones instead of one could be used, if desired, by simply connecting one cone with the next, each cone taking the outflow from the one preceding. In this case it would be neces-

sary to have the cones arranged in a series, each one with its top or outlet considerably higher than the one into which it flowed, as in Fig. 3 with the two cones, so that there should be sufficient motion in the water to keep the eggs stirring.

It may not be out of place to notice the fact that the eggs kept in the stale water were almost entirely free from any fungoid growth. Why these eggs should be favored in this manner is hard to say, and may be a question worthy of farther research. As regards the influence upon the development of the germ, there was a very marked difference in the two methods employed. In the ice-chest, in the case of freshly impregnated ova, segmentation would go on until the "mulberry" stage had been reached, or until a small limb or protuberance of small cells had been formed upon one side of the vitellus. After this there appeared to be an entire cessation of all development as long as the egg remained in the chest or until the vitellus disintegrated.

In most cases disintegration or death did not take place for two or three days, and up to this time the eggs had every appearance (otherwise than that they did not develop) of being alive and in fair condition. In the cone, however, development went on regularly and slowly from the very first, and continued until the water became of such a nature as to fail to longer nourish the embryos.

This development was such that in about two hours the "mulberry" stage had been reached; in sixty hours the segmentation cap entirely surrounded the yelk, and the young fish formed a prominent welt along one side of the vitellus; in seventy-two hours the eyes commenced to show; and in one hundred and eight hours, or four and one-half days, the tail portion, or that part free from the yelk, was as long as the portion attached to the yelk, the eyes very prominent, with the crystalline lens formed, the ear-cavity forming a semi-circular depression upon the side of the body above the yelk, the protovertebræ numerous, and the heart a small, single-chambered body, situated just back of the head, between the yelk and anterior end of the central canal, and just beginning to exhibit regular although somewhat spasmodic beats. In an embryo developed in fresh running water, at a temperature of 68° to 74°, those stages would be passed through, respectively, in four, ten, twelve, twenty, to twenty-six hours, showing a retardation in the case of the embryo kept in water at 56° of from three to three and one-half days. At this rate the young fish in the colder water ought to hatch out in about eleven to twelve days, and would probably, from their slower growth, be more hardy than those hatched in three to three and one-half days. It is to be regretted that these experiments could not have been begun earlier in the season, thus giving plenty of time for thoroughly studying the questions and arriving at some definite results, for although it would appear as if the method last suggested might be successful, yet a trial seems to be absolutely necessary before undertaking an ocean voyage.

WASHINGTON, D. C., *July* 3, 1879.