XIX.—ON THE TRANSPORTATION OF SHAD FOR LONG DISTANCES.

A—EXPERIMENTS WITH A VIEW TO TRANSPORTING SHAD IN SEA-WATER.*

By James W. Milner.

In order to discover the best methods for transporting shad by sea-going steamers, a series of experiments was made at Noank, Conn., at the close of the spawning season.

Twelve glazed earthen-jars, with a capacity of little more than four gallons each, were provided to contain a certain number of shad, and a formula for the treatment of each jar written out.

The tests thought to be desirable were the endurance of young shad in sea-water, in mixtures of fresh water and sea-water, and in fresh water at different temperatures, and with fresh supplies at varying prolonged intervals.

The young fish used were the very last of the season's hatchings. The fish began to make their appearance freed from the eggs on the morning of the 14th of August. Early on the morning of the 15th, about 45,000 were put into five cans. The train left Holyoke, Mass., at 6.23 a. m. The water on the fish was 71°. Fresh-water supplies were given them at 7.30, at 9.30, and 11.30 a. m., and at 1.30, at 3.30, and 6 p. m.

On arriving at Noank, Conn., on Fisher's Island Sound, a small building was fitted with shelves, at a convenient height, and the twelve jars were arranged on two sides of the room. Jars Nos. 1, 2, 3, and 4 were to be devoted to experiments with definite mixtures of fresh and sea-water, the latter gradually increased; Nos. 5, 6, 7, and 8 to experiments on temperature; Nos. 9 and 10 to experiments as to the effect of ordinary changes of temperature; No. 11 to pure sea-water; and No. 12 to surface-water from the bay at low ebb of tide, in which was a mingling of the fresh water from the drainage of the land.

At 9 p. m. the series of experiments was begun, the jars having been supplied with a rather full quantity of fishes; by estimate, in accordance with our usual judgment from their thickness in the water, about 4,000 to each jar, Nos. 7, 8, 9, 10 having somewhat less. The temperature of the water in the jars was 70°. It required about one-half hour to apply the

* Having been called away from these experiments soon after inaugurating them, I have to thank Mr. C. D. Griswold, Commander L. A. Beardslee, United States Navy, and Mr. G. Brown Goode, for their interest in carrying them through to their results.—J. W. Milner.

varying treatment to the series of jars, but as it was always begun with No. 1, and carried through with the same order, the interval for each jar was always the same, and in recording, the hours of 9, 12, 3, and 6 were used for convenience sake, though strictly they would apply only to No. 1.

The purpose of the tests with 1, 2, 3, and 4 was to try if gradually increasing proportions of sea-water would enable the young shad to become accustomed in time to supplies of pure or nearly pure sea-water without diminishing their vigor and vitality.

No. 1, at 9 p. m. August 15, had 128 gills of fresh water at a temperature of 71° Fahrenheit. Two quarts of the water were drawn off, and this was replaced by two quarts of a mixture, 15 gills of which were fresh water and 1 gill was sea-water. Three hours later, at 12 midnight, two quarts were again removed from jar No. 1 and two quarts of a mixture of 14 gills fresh water and 2 gills sea-water poured in. At 3 a. m. of the 16th two quarts were again removed and a mixture supplied of 13 gills of fresh water and 3 of sea-water.

This supply of a mixture amounting to one-eighth the contents of the jar, with a continually increasing proportion of sea-water, was afforded every three hours. At the end of 45 hours the two quarts of supply, having the sea-water proportion increased one gill each time, would be all sea-water. After the 45 hours, at 6 p. m. on the 17th, or the fifteenth supply of water to the jar, two quarts of sea-water were afforded every 3 hours, a like quantity being at the same time removed. At this rate the water upon the fish at the end of 24 hours, or 9 p. m. of the 16th, would be about 25.6 per centum sea-water.

At the end of 48 hours, or 9 p. m. of the 17th, the jar would contain a mixture with 66.2 per centum sea-water. At the end of 72 hours, or 9 p. m. the 18th, the mixture would become 88½ per centum sea-water.

The temperature remained very even until noon of the 17th, when it fell to about 67°, 3° less than at 9 a. m. The 18th, at 6 p. m., it had again risen 4°.

The shad seemed to retain vigor and health until the 18th. They showed weakness in the morning, the per centum of sea-water having reached 80⅓, and at 6 p. m. they were all lying on the bottom of the jar, the per centum of sea-water being 86.8. A few of these were taken out and put into a glass jar which contained a mixture of one quart fresh water and one quart sea-water; in this the most of them revived and lived from 6 p. m. August 18 to 6 p. m. August 22—96 hours longer than those left in the jar.

In the jar No. 1 they were soon after all dead. They were about 102 hours old, and had been kept about 17 hours in the hatching boxes, about 16 hours in the cans, and 69 hours in the jars with the sea-water mixtures. Those revived in the glass jar were 198 hours or eight and one-fourth days from the egg at the time of death.

The treatment of No. 2 began at near the same hour as No. 1, the temperature being the same. In this jar the one-eighth supply of mixture every three hours had a more slowly-increasing proportion of sea water. The first supply at 9 p. m., August 15, was ½ gill of sea-water and 15½ gills of fresh water. At 12, midnight, the mixture was one gill of sea-water and 15 gills of fresh water, and at 3 a. m. of the 16th it was 1½ gills sea-water and 14½ gills fresh water. At this rate of increase the supplies would become all sea-water after 93 hours.

In this much more gradual increase of sea-water the young shad began to show weakness on the 19th, the contents of the jar having reached a per centum of about 75 sea-water. At 9 p. m. of that date, three hours after the first supply of all sea-water, they were observed to be dying. At this time the sea-water was 81 per centum of the whole contents. At 6 a. m. of the 20th, there were considered to be one-half of them dead, and on the 22d, at 9 a. m., the last of them died. The jar contained a solution of sea-water, 98.8 per centum sea-water and 1.2 fresh water.

The temperature had varied from 66° to 78°. The latter, occurring on the 20th, no doubt had some effect in reducing their vigor. They were, at the time the last of them succumbed, 189 hours from the egg, and had been in the jar 156 hours.

The increasing proportion of sea-water in the supplies to No. 3 was at the same rate as No. 2. It was continued until the mixture became half sea-water and half fresh, and the supplies from that time, the 17th at 6 p. m., forward, were in this proportion. The fish began dying at 9 a. m. of the 22d, the per centum of sea-water being 49.86, and at 3 a. m. of the 23d all were dead, the last ones being about 207 hours old, and having been in the jar 174 hours. The water had become 49.93 sea-water.

Jar No. 4 proved the most enduring of any of the experiments with sea-water. Beginning approximately at the same time, and with temperature the same as the others, in this jar the addition of sea-water to the supplies was at the same rate as in that of Nos. 2 and 3. The addition of ½ gill of sea-water at each interval of three hours to the mixture, with a corresponding decrease of fresh water, made the proportions of fresh and salt water in the supply, at the end of 30 hours, about one-third of the latter and two-thirds of the former. This proportion was thereafter retained. The fish began dying at 6 a. m. of the 23d, when the per centum of sea-water was 34.35. At 6 p. m. of the 23d about seven-eighths were dead, the water having attained a per centum of 34.36 sea-water. At 7 p. m. of the 25th the last one died having attained the age of 271 hours, and having been in the mixture about 238 hours. The sea-water had reached the percentage of 34.37.

These were all the experiments made with proportions of sea-water. Others were made with pure sea-water and with surface-water from the bay in which the fresh-water drainage had more or less diluted the salt.

A jar was filled with sea-water several times and a quantity of shad placed in it. They invariably died within three hours.

Jar No. 12 was filled with surface-water from the bay; the recent rains had diluted this to a considerable extent. The treatment of the jar was to afford a supply of this water every three hours. At 8 a. m. of the 16th they were put in the jar, and at noon of the 21st they were all dead, having been in the jar 124 hours.

An experiment was made by removing fish, nearly exhausted in sea-water, to fresh spring-water. The fish survived those left in the jar about 28 hours.

Nos. 5, 6, 7, 8, 9, and 10 were experiments to test the effect of different temperatures, and 70°, 65°, 60°, 55°, and 50° were prescribed for these jars. The temperatures were not, however, controlled with the facilities at hand. No. 5 was intended to retain a temperature of 65°, which it did quite regularly for about 175 hours. The last of the fish were dead at 3 a. m. of the 23d, being then 207 hours old and 174 hours in the jar.

The record for No. 6 was almost identical with No. 5.

No. 7, with a temperature of 64°, kept the fish alive until they were 225 hours old, 192 hours in the jar. This is the longest period of life among them; the No. 4 sea-water test, however, exceeded it some 13 hours. It had slightly fewer fish than Nos. 5 and 6, which was of course an advantage.

In Nos. 9 and 10 the water remained at the temperatures of the room without any care to decrease or regulate them in any way. The waters varied from 66° to 78°. The fish retained life 219 hours, 186 hours in the jar.

No. 8 it was intended to keep at 50°, but, instead, it remained for the most of the time at 64°. It was placed about the time the fish were six days old in the refrigerator, which reduced the temperature to 48°, at which the fish died rather rapidly. They were seven hours in the ice-chest, and were dead within three hours after the mercury stood at 50°.

It will be at once seen, by those who have followed the published experiences of men who have carried young shad long distances, that the longest periods recorded for transportation of shad by rail (as in Seth Green's trip with shad to California in 1871, 184 hours,) or by steamer (as in Mather's and Anderson's trip to Bremen, 240 hours,) are not much different from the longest period in which shad endured the treatment with sea-water, (as in No. 4, 238 hours,) or a low temperature, (as in No. 7, 192 hours.)

The movement of the car or steamer in producing a moderate agitation in the water is known by all who have carried shad to be a very large advantage in favor of the life of the fish. With this advantage the fishes in the jars would undoubtedly have prolonged their existence considerably, as the use of water from the same source continually is an advantage not at command when traveling, and the facilities for cleansing the jars and keeping the temperature regular are also much greater.

In the fresh-water temperature tests, the fish did not endure as long as in the sea-water test, No. 4.

There is ample evidence in the experiences in the treatment of shad that they are in need of food when about six or seven days old, and if not supplied will starve to death in from 70 to 80 hours, so that it is not possible to say that the presence of the sea-water in the last test killed the shad. No practicable methods for feeding embryo-shad and white-fish (*Coregonus albus*) have been discovered, though river-water seems to afford them some supplies of nourishment.* The intestines of many of the embryo-shad from the jars, when examined under the microscope, failed to discover any food.

The problem of the transportation of embryo-fishes like those of the shad and white-fish (*Coregonus albus*) long distances, which occupy a period of time longer than a week, requires study and experiment. The probability is that the great need is some method for feeding them *en route*.

To devise a method for feeding them will require the services of a microscopist familiar with the lower forms of invertebrates and the eggs and larvæ of higher groups, which are the principal minute organic forms available as food in the waters where the fish breed naturally. The only investigations which I am aware of are the observations of Mr. S. A. Briggs, of Chicago, published on page 57 of the report of 1872–3, and those observations just referred to in these experiments.

The experiment may also be carried out empirically by trying young fishes with the different forms of the groups just referred to. If food can be found among these forms, experiments as to the feasibility of breeding them *en route* will be in order. Many of them have been developed in numbers by naturalists for purposes of study, and with some it is very easily accomplished.

Another, and probably the most feasible method to obviate starvation, is, in the case of the shad, to retard the eggs by cold, and devise a process of hatching *en route*. If this can be accomplished so that the fish can emerge from the egg when six days out from land, they will be likely to arrive at their destination with vigor and strength.

These facts and experiences in regard to keeping shad alive seem to indicate that the application of sea-water with a very gradual increase and in small proportions has not a sensibly injurious effect. Where fresh water has been used, no greater periods of life have been attained when the fish were confined in small vessels. Still, the series of experiments indicates that in proportion as the quantity of sea-water increases the endurance of the fish diminishes; and, inversely, the less and more gradually the sea-water is applied, the longer the fish endure. A parallel instance would be that a little overplus of oxygen in the atmosphere

* See report of United States Commissioner of Fisheries, 1872–'73, p. 57; and fourth annual report of commissioners of New York, 1872, p. 20.

of a room exhilarates and even benefits a man, while a greater increase rapidly becomes injurious and fatal.

Pure sea-water, in repeated experiments, proved fatal in 3 hours. A rapid increase of the salt, in which the supplies became all sea-water in 45 hours, (jar No. 1,) and the contents of the jar became $80\frac{1}{3}$ per centum sea-water in 60 hours, the fish showed distress and weakness, and in 69 hours all were dead or dying at the bottom of the jar, the water having become 86.8 per centum sea-water.

In a more slowly increasing proportion, in which the supply became all sea-water in 93 hours, (jar No. 2,) after 96 hours the water having become $81\frac{1}{8}$ per centum sea-water, the fish began dying. After 156 hours all were dead, the sea-water being $.98\frac{6}{7}$ of the whole.

In a mixture where the supply was one-half sea-water after 45 hours, (jar No. 3,) and retained at that, the fish began dying when the water had become $49\frac{7}{8}$ sea-water, or in 156 hours. In 174 hours they were all dead, the mixture having become one-half (49.9 per centum) sea-water.

In the most slowly increasing proportion the supply became one-third sea-water after 30 hours, (jar No. 4,) and was retained at that. The fish did not begin dying until 177 hours, the contents of the jar being one-third sea-water. After 189 hours all were dead, the per centum of sea-water being 34.3.

There seems to be sufficient in the results of these experiments to deter any one from attempting to move shad across the ocean, depending upon the use of sea-water for large proportion of supplies; though small quantities could be cautiously used for improving the stale fresh water.

The temperature experiments were not very satisfactory, as the intended reductions were not readily reached and controlled with the appliances at hand. In the case of No. 8, it was produced by placing the jar in a refrigerator and reducing it very rapidly. The fish were already six days old, and probably somewhat reduced in strength. They succumbed at once to the rapid reduction of temperature, though to have completed the experiment an effort should have been made to revive them by gradually raising the temperature.

No. 7 had the advantage of having fewer fish in the jar, the advantage of a larger supply of water sustaining them beyond the expiration of 5 and 6, which had about the same temperature. The indications in the temperature tests are scarcely worth determining, as the devices and facilities for the necessary reductions of temperatures according to the plan laid down were not available, and the rapid reduction of No. 8 in the refrigerator would not afford a fair comparison of endurance of low temperatures with Nos. 5, 6, 7, 9, and 10.

The main purpose of the series of experiments, that of testing the value of sea-water, was well carried through, and I believe will be a final decision against its use, except perhaps in the slight quantity indicated.

Table showing comparative results of experiments in keeping embryo-shad alive in mixtures of fresh and sea water.

[Supply every three hours two quarts (one-eight contents of jar) of a mixture of fresh and sea water.]

Date, (to apply to all.)	Hour, (to apply to all.)	No. 1.—The proportion of sea-water in supply increased one gill each time until all sea-water.					No. 2.—The proportion of sea-water in supply increased one-half gill each time until all sea-water.					No. 3.—The proportion of sea-water in supply increased one-half gill each time until one-half sea-water, and retained at that.					No. 4.—The proportion of sea-water in supply increased one-half gill each time until one-third sea-water, and retained at that.				
		Temperature.	Per cent. sea-water.	Age, (in hours.)	Period in jar, (in hours.)	Remarks.	Temperature.	Per cent. sea-water.	Age, (in hours.)	Period in jar, (in hours.)	Remarks.	Temperature.	Per cent. sea-water.	Age, (in hours.)	Period in jar, (in hours.)	Remarks.	Temperature.	Per cent. sea-water.	Age, (in hours.)	Period in jar, (in hours.)	Remarks.
1874.		°					°					°					°				
Aug. 15	9 p. m.	71	......	33	....	Treatment begins	70	......	33	....	Treatment begins.	68	......	33	....	Treatment begins	69	......	33	....	Treatment begins.
*17	3 a. m.	69	......	....	....	....	69	......	....	....	....	68	......	....	....	....	69	......	....	30	Supply becomes $\frac{1}{3}$ sea-water.
	6 p. m.	67	......	....	45	Supply becomes all sea-water.	68	......	....	....	....	66	......	....	45	Supply becomes $\frac{1}{2}$ sea-water.	68	......	....	....	
18	9 a. m	67	80.34	....	60	Fish show weakness.	66	......	....	....	....	....	......	....	....	....	....	......	....	....	
	6 p. m	71	86.8	102	69	†Fish dying at bottom of jar.	....	......	....	....	....	....	......	....	....	....	....	......	....	....	
*19	6 p. m	....	......	....	....	....	69	......	...	93	Supply becomes all sea-water.	73	......	....	....	....	....	......	....	....	
	9 p. m	....	......	....	....	....	...	81.12	...	96	Fish begin dying..	...	......	....	....	....	...	......	....	....	
20	6 a. m	....	......	....	....	....	70	87.35	...	105	About one-half dead.	70	......	....	....	....	71	......	....	....	
	6 p. m	....	......	....	....	....	78	......	...	....	....	74	......	....	....	....	75	......	....	....	
*22	9 a. m	...	......	....	....	....	68	98.84	189	156	All die............	...	49.86	....	156	Fish begin dying.	....	......	....	....	
	6 p. m.	....	......	....	....	....	....	......	....	....	....	....	......	....	....	....	75	......	....	....	
23	3 a. m	....	......	....	....	....	....	......	....	....	....	....	49.93	207	174	All die............	....	......	....	....	
	6 a. m	...	......	....	....	....	....	......	....	....	....	....	......	....	....	....	....	34.35	....	177	Fish begin dying.
	12 m...	....	......	....	....	....	....	......	....	....	....	....	......	....	....	....	....	34.355	....	183	About one-half dead.
	6 p. m.	....	......	....	....	....	....	......	....	....	....	....	......	....	....	....	....	34.36	....	189	Ab't seven-eighths dead.
25	7 p. m	....	......	....	....	....	....	......	....	....	....	...	......	....	....	....	....	34.37	271	238	All die.

* Jars emptied and cleansed.

† A considerable number of these from the bottom of the jar (No. 1) were placed in a small two-quart jar containing a mixture one-half fresh and one half sea water, supplies of like character being afforded, and lived 96 hours longer than those in the jar.

B—EXPERIMENTS WITH A VIEW TO TRANSPORTING SHAD A FEW MONTHS OLD.

By Charles D. Griswold.

After returning from Noank, Conn., at the close of the experiments with embryo-shad, I began an experiment with fish of greater age and development. The shad were obtained from the Connecticut River with a fine-mesh seine. The experiments were made with a view of testing the endurance of fish of a larger growth than the newly-hatched embryos which we had before tried.

Great care was taken in their capture to prevent their injuring themselves before they were placed in the jars. They were dipped from the water, before the net was drawn entirely out, with a tin dipper and immediately put into pails of fresh water, with but few in each pail.

There was some difference observed in the color of the young shad, the pale, lighter-tinted ones proving generally the weaker, and enduring much less than the others.

The shad procured measured from 1½ inches to 4 inches in length; those of about 2½ inches being rather more numerous. They were taken in the evening, the net-hauls in the early part of the day taking nothing. They were kept in the transportation-cans, in stone jars, with and without gravel in the bottom, and with river and spring water.

The first experiment was made on September 5. The shad were put in a twelve-gallon tin can. Supplies of fresh water were afforded every two hours, the supply being about one-eighth the contents of the can or jar in which the fish were placed. The air temperature was 65° and the water (spring-water) 64° at the beginning of the experiment, and the variation from this was very slight. The last was dead after six hours.

The second experiment was made September 7. On this date two day-time hauls resulted in no captures. In the evening better success attended the effort. The shad were put into the twelve-gallon cans. The temperature of the water was 64°, the air 65°, at 5 p. m. At 11 p. m. the water showed a temperature of 60°, and in one hour afterward they were all dead, having lived seven hours.

The 8th of September shad were put into the cans at 6 p. m. The spring-water supplies were made less frequently. The temperature at 10 p. m. was for the air 66°, for the water 66°. At 1 a. m. the air was 55°, the water 60°. At 4 a. m., air 52°, water 59°, and the fish rapidly died. They lived ten hours.

On September 11 a number of shad were again taken and placed in a four-gallon stone jar. The temperature of the air was 66°, of the water 64°. They were supplied every two hours with river-water fresh from the river each time. The water grew colder in the night. Three died after seven hours, a few lived about thirteen, and one died after twenty-one hours.

On the 14th, a cloudy day, the smallest shad during the season were obtained. Their length varied from 1½ inches to 2 inches. A comparative experiment was made with spring and river water. Four shad were put into the jar with the river-water. The water of the river at the time of capture was 70°. A supply of one-eighth was afforded every two hours until the 17th, when the time was increased to three hours, but a larger supply of water afforded. The temperature remained quite even, the variation being between 67° and 70°.

Of the four fish put in the jar with the river-water, two died at 12 p. m., having lived about seven hours; the remaining two lived forty-nine hours.

In the spring-water test the fish were placed in the jar after the river-water fish had all died, or after sixty hours. Three had died in the can the first day. Two more died after one hundred and thirty-six hours. One of those remaining died after one hundred and fifty-seven hours, and one after one hundred and sixty-eight hours. The air-temperatures ranged from 62° to 70°, and the water from 64° to 67°.

The next capture of shad was made on the 17th of September, at 5 p. m. Four were put into a four-gallon jar, and three put into a three-gallon jar. The former were supplied with spring-water, the latter with river-water. After sixty-one hours one was dead in the spring-water and two in the river-water. The temperature at this time for air and water both had varied between 59° and 66°.

The subsequent variation was greater. The air ranged from 46° to 89° and the water from 50° to 65°. The high temperatures of the air were during short periods of the day, so that the water did not attain the high degrees of heat which the atmosphere did. The fluctuations in one day, however, amounted to from 50° to 65°. After 136 hours there had been one death more in each. After 160 hours there was another death in the spring-water, and one lived 253 hours, or 10 days and 13 hours.

An experiment was made in keeping five or six fish at a time in the hatching-boxes, where the current kept a good change of water continually. The fish lived from two to three days.

A dozen fish were put in a forty-gallon can, and the water was renewed from a hose continually. They varied in size from 2 to 3½ inches. The temperature remained quite evenly at 60°. A few lived three days.

On the 28th an experiment was made with shad, the water-supply being afforded every three hours. Nine fish were put into the forty-gallon can. The temperatures ranged from, for the air, 46° to 66°, and the water, 50° to 60°. Six fish died after 33 hours, one after 51 hours, one after 66 hours, and one after 87 hours.

The use of gravel in the bottom of the jars evidently provided food to some extent. Shad retained in a jar until quite weak worked busily awhile among it, and revived so as to outlive the others about 15 hours.

In the stomach of a shad about 2½ inches long I took fourteen small black flies. The contents of other stomachs were of a reddish hue.

These are the results of the series of experiments which, I think, show less advantage in an attempt to transport shad of these sizes, from $1\frac{1}{2}$ to 4 inches, than in the little three-eighths-of-an-inch-long embryos. Besides the longer endurance of artificial confinement of the embroy-shad in a mass of thousands instead of four or five, as in these experiments, the larger shad have the disadvantage of not being obtainable in anything near the same numbers, and also that the proportion of fish to the quantity of water used in transportation must be very many times less. There may be something of value in the fact that our experience proved the glazed-stone jars better for the fishes than tin; and the observation that the lighter-tinted pale fishes invariably succumb first, proves that in each year's stock of shad there is a considerable variation of vigor and constitution in different individuals.

C—APPARATUS FOR HATCHING SHAD-OVA WHILE EN ROUTE TO NEW WATERS.

By Fred Mather.

Honeoye Falls, N. Y., *September* 16, 1875.

I send report of shad-hatching at Point Pleasant. I also send you a drawing of the improved hatcher.

I believe, notwithstanding that the second German expedition has failed, that I can get fry across, and that running water is superior to the use of an air-pump. I cannot conceive of a more perfect approach to the river-boxes than this can, and was glad to show you its perfect working at Holyoke this summer, (July 20 to 25.) Simple as it seems, it took some time to get it to its present perfection. The original idea as tried at the Smithsonian worked well on paper; but this one will bear trial and favorable comparison with anything of the kind.

Very truly, yours,

FRED MATHER.

Mr. James W. Milner,
Smithsonian Institution.

According to instructions, I went to Point Pleasant, Bucks County, Pennsylvania, to observe the development of shad-eggs in the hatching-can, which I suggested after my failure to transport live fish to Germany last year.

I had one made with a diameter of 15 inches, containing a screen or tray of 13 inches diameter; and after searching for something better for reservoirs, we obtained three oak whisky-barrels which had been used once, and, taking out one head, thoroughly charred the inside by burning straw in them; after this, they were soaked in water twenty-four hours, when they still had an odor of alcohol.

I had used whisky-barrels similarly treated for the transportation of fish, and once carried a quantity of adult grayling on a journey of thirty-four hours in them with but trifling loss, none of which seemed to be due to the slight trace of alcohol perceptible to the sense of smell.

Therefore, with a slight misgiving that so delicate a creature as an embryo shad might possibly be affected by the homœopathic amount of alcohol still present, I set up my apparatus on the shaded piazza of the hotel. One barrel was used for ice-water and the other two as reservoir and receiver.

The first trial was made with 3,000 eggs, which were taken from the fish at 10 p. m. June 20, and were put in the river-boxes, where the water was from 76° to 80°. On the following day, at 4 p. m., they were brought to the hotel, and the temperature gradually lowered to 68° by 8 p. m., when they were placed in the hatching-can, and the spigot set to flow twenty gallons per hour. The following table gives the temperatures and results:

Date.	6 a. m.	Noon.	6 p. m.	Midnight.	Mean.	Remarks.
	°	°	°	°	°	
June 20	....	....	....	80	80	
21	....	....	68	64	66	Water tastes of whisky.
22	62	72	74	74	70.5	Gave an entire change of water.
23	74	74	76	78	75.5	Fish visible in the eggs; motion at daybreak; fungus on dead eggs.
24	76	76	....	....	76	First fish hatched at 8 a. m.; 1,000 at noon; they appeared very weak, and there was no deposit of pigment in the eye; put them in box in the river and cleaned the barrels.
Average mean............					73.6	
Time 86 hours.						

In this experiment, nearly the same results were attained as in one that I conducted in the Smithsonian Institution some two weeks before, viz, the fish hatched, without any perceptible color in the eye, and had little vitality.

In the former trial referred to, this lack of vital power was attributed to the bad air in the basement where the hatcher was located, arising from the absorption of gases from a portion of a whale that had just arrived in bad condition. This theory, whether correct or not, was the only one that presented itself to account for the fact that the fish lived but a few hours after hatching, as it was the opinion of several experts that, as the flow of water was sufficient to supply all the oxygen required, and that a movement of the egg was not necessary, therefore when I attained the same result in the open air I concluded that a flavor of whisky in the water produced the same effects as the deleterious gases before referred to, or that a lack of motion was the cause.

To test the latter point, I had a new can made, with a diameter of six inches, and screen of five, which, with sixty gallons of water per hour flowing through it, gave a slight movement to the eggs. While this trial was in progress, the weather was very hot, at midday on several occasions reaching 96° in the shade, causing a great consumption of ice. The following table gives the results:

Date.	6 a. m.	Noon.	6 p. m.	Midnight.	Mean.	Remarks.
	°	°	°	°	°	
June 25	....	....	....	82	82	Eggs taken from fish 10 p. m. on the 25th; put 2,000 in hatcher at 10 a. m.; water in river 85°.
26	....	80	65	71	72	
27	70	66	60	64	65	Motion at daybreak.
28	63	63	....	....	63	Fish livelier than any former ones; still no color in the eyes; turned into the river at noon, 28th.
Average					70.5	
Time 92 hours.						

As the increase in vitality could only be attributed to the increased motion due to flowing three times the quantity of water through a screen of less diameter than on the former trials, it appeared evident that the failure of previous experiments was due to lack of motion, and as all water had to be dipped from the receiving-barrel standing on the floor into the reservoir-cask standing on the table, with a pail, that it would require too much labor for one man to handle double the quantity, and so would require at least four men to attend it, running night and day, and another objection was the limited capacity of this small can.

Here a valuable suggestion was made by my assistant, Mr. Charles Bell, and a hatcher was made after his plan, which did its work perfectly. (See illustration.) It was in the shape of a funnel, with a tube below like the others to connect the rubber supply-pipe. It had a depth of ten inches and a diameter of twelve at the top, to which was soldered a rim of wire-cloth one inch and a half high; outside of this rim was a flange with a tin rim, which had an outlet-pipe on one side.

Near the bottom, where the cone was two inches in diameter, a screen of fine brass wire was fastened. This passed all the water through a screen of two inches, on which an egg could not rest. They were sent up with a gentle motion in the center of the can, and separating equally in all directions toward the wire rim, through which the flow was so gentle that the eggs began to drop before they reached it, and, falling on the sloping sides, gently settled toward the center, to be again lifted before reaching the bottom.

We exchanged our whisky-barrels for old casks that had been used for catching rain-water, and moved from the hot piazza into the cellar, where the temperature of the air averaged about 70°, making the experiment without the use of ice, the temperature variation being very slight.

The following table exhibits the results:

Date.	6 a. m.	Noon.	6 p. m.	Midnight.	Mean.	Remarks.
	°	°	°	°	°	
July 1	......	......	......	......	......	Eggs from fish at 9 p. m.; put in hatcher at 10 a. m.; water in river 82°; found a flow of twenty gallons per hour sufficient.
2	......	66	65	64	65	
3	64	65	66	65	65	
4	65	66	66	68	66. 25	Eyes showed black at midnight; fish lively in egg.
5	68	68	68	70	68. 5	A few hatched at noon, and swimming at night.
6	68	70	72	......	70	About half hatched at noon; all hatched at 9 p. m.; very strong and lively; put them in the river next morning (7th).
Average mean					66. 95	
Time 120 hours (5 days).						

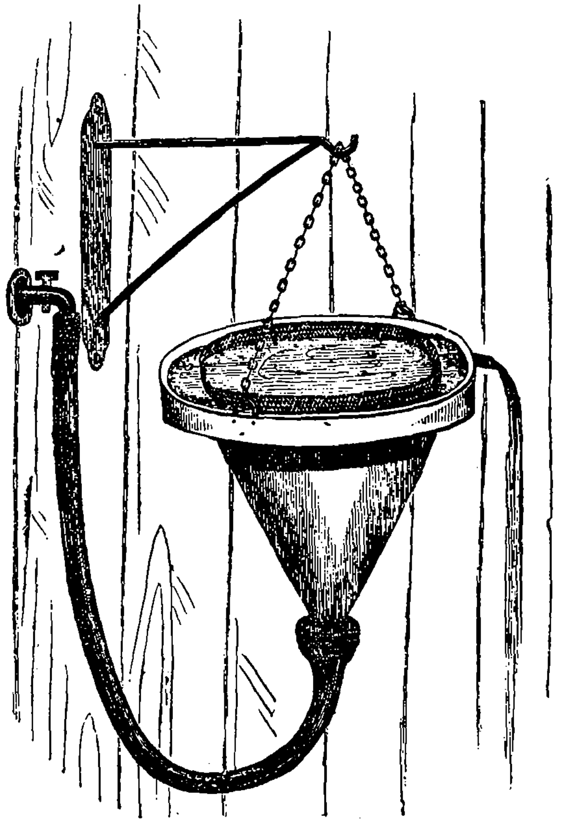
These trials have, I think, proved two things: first, that a flow of water that does not give motion to the egg sufficient to hold it in suspension will not hatch strong shad; and, secondly, that it is possible to hatch them in transit with a limited supply of water. The same water was used two to three days, and was well aërated in its fall from the hatcher into the barrel and by pouring from a pail from there into the reservoir.

As I found in my attempt to carry young shad already hatched to Germany for the Commission last year that the thermometer varied little from 62°, I think it possible that at that temperature the hatching will be delayed from six to seven days, and the fry delivered on the other side before they have suffered much, if any, from lack of food.

In order to test the endurance of shad-eggs, I made the following trial of 4,000 spawn with the same flow of water as before, using ice.

Date.	6 a. m.	Noon.	6 p. m.	Midnight.	Mean.	Remarks.
	°	°	°	°	°	
July 8	......	70	65	60	65	Spawn from fish at 9 p. m. 7th; water in river 82° at 8 a. m. 8th.
9	58	58	58	56	57. 5	
10	55	56	58	60	57. 25	Motion in morning.
11	58	56	54	54	55. 5	Eyes visible, but embryo small.
12	54	54	58	60	56. 5	No ice from noon till 6 p. m.; fish not lively.
13	58	59	60	62	59. 75	Am afraid that when hatched, they will not have vitality enough to live; let temperature go up to see if possible to revive them.
14	61	62	65	66	63. 5	All dead at 6 a. m.
Average mean					59. 52	
Time 7 days 9 hours.						

I do not consider the average mean temperature to be a fair test in this trial, as it was probably the *lowest* point that did the damage; and if the temperature of the river for the twelve hours they were in it had been figured in, the mean would have been much higher. As it is, the mean was only about 5½° below the former trial, which was so successful, and in my opinion a steady temperature of 59° to 60° would have given far different results.



Mather and Bell's apparatus.

The above tables are accurately copied from the record-sheet, and it is proper to add a word about the thermometers used. In the first two trials made upon the piazza, we had a small pocket-thermometer, only graduated to two degrees, and which registers two degrees higher than the one used in the cellar in the two last trials; but having no opportunity to correct the instruments, I give the record as it appeared at the time; but if the pocket-instrument was correct, then the records of the last two trials should read two degrees lower than shown in the tables.

In conclusion I will say, I believe that shad-fry can be taken across the Atlantic by hatching the eggs in transit in the can last described; and as the record of my trip last season showed the temperature of the water in the cans at sea without ice to be about 62°, that would seem, according to the above tables, to be about the proper point. It could probably be kept from 60° to 64° without the use of much, if any, ice, by opening or closing the hatches.