XXV.—BIOLOGICAL OBSERVATIONS MADE DURING THE ARTIFICIAL RAISING OF HERRINGS IN THE WESTERN BALTIC.

By Dr. H. A. Meyer.*

PREFACE.

I have published my observations on the spawning-season of the herring, on its growth, the influence of the temperature of the water on the spawn, as well as some other facts relating to the mode of life of the herring, in the Annual Report of the Commission for a scientific investigation of the German seas for 1874–'76, Berlin, 1878.

These investigations I have continued during the years 1877 and 1878, in the direction pointed out in that report. As it will be some time before the next report of the commission is published, and as from a practical point of view it will be of interest to make the newly acquired experience quickly known, I publish the following preliminary report, containing the more important results of the last two years' observations of the development of the herring.

I.—INFLUENCE OF THE TEMPERATURE ON THE DEVELOPMENT OF THE EGGS OF THE HERRING IN SPRING.

In the above-mentioned report of the commission, the various experiments are given, which go to prove that very cold water will considerably delay the hatching of the eggs of the autumn herring. It was still an open question whether the same applied to the eggs of those herring which spawn in spring, which could only be settled by making the necessary experiments. This seemed all the more desirable, as it was a question not only of scientific but also of practical interest. If impregnated eggs of those fish of the herring kind which spawn in spring and summer can be preserved in a healthy state for a longer time by keeping them cold, the artificial raising of fish will thereby be benefited, because then it will become possible to send such eggs to distant countries. As the time which it takes the summer spawn to develop under ordinary circumstances is but short, the attempts to import the spawn of valuable American summer fish have so far not been successful.

* *Biologische Beobachtungen bei Künstlicher Aufzucht des Herings der westlichen Ostsee.* Von Dr. H. A. Meyer, Berlin, 1878. Translated by Herman Jacobson.

I therefore examined the condition of spring spawn when kept in very cold water with the following results:

For this year's experiments I used full-grown fish which had been caught with hook and line near Bappeln, on the Schlei (Duchy of Schleswig), on the 26th of April. Milt and roe were ejected by these fish into porcelain dishes the very moment they were taken out of the water, without exercising any pressure. The temperature of the water at the time these fish were caught was 8°.4 C. (47.12° F.), the saltness midway between the surface and the bottom 1 per cent. (specific gravity=1.0076 at 17°.5 C.=63.5° F.). The artificial impregnation was, as in former cases, accomplished in porcelain dishes, which during the journey to Kiel were often supplied with fresh sea-water, which was kept at the above-mentioned temperature.

The diameter of the eggs, altough they came from different fish, only varied between 1.22 and 1.37 millimeters. On closer examination it was found that nearly every egg had been impregnated and that their normal development had begun.

The following experiments were made with these impregnated eggs:

1. A number of eggs were placed in the open water of the Bay of Kiel, whose temperature at this time was 11–12° C. (51.8°–53.6° F.), and whose saltness near the surface was 1.40 per cent. These eggs were left in the water till the young fish were hatched.

2. Some eggs were likewise hatched in the open water of the Bay of Kiel, but after having been impregnated, they were from the 2d to the 5th day after this had taken place put in water whose temperature was only 2° C. (35.6° F.), in order to learn the influence of cold water on scarcely developed eggs, and likewise to see what would be the result of suddenly placing them in colder water.

3. Eggs which for eight days had been in the water of the Bay of Kiel with a temperature of 11–12° (51.8°–53.6° F.), and whose development had almost been completed, were suddenly placed in water whose temperature was only 2° (35.6° F.), in order to ascertain the power of resistance to cold of eggs which were near being hatched.

4. One-fourth of all the eggs were, immediately on their arrival at Keil, placed in water whose temperature was only 2° (35.6° F.), where they were left, to retard their development as much as possible.

5. Finally, some eggs were placed in still colder water, in order to ascertain the degree of cold which becomes destructive to herring-eggs.

A uniform temperature suitable for these purposes can easily be obtained by using wooden boxes similar to refrigerators, especially if these boxes are carefully surrounded by non-conductors of heat. The water used in these experiments was salt water from the Bay of Kiel. In all the experiments the water was changed once a day and fresh water put in the vessels after being reduced to the desired degree of coolness.

At as low a temperature as 2° C. (35.6° F.) it seems quite easy, even without taking any special precautionary measures, to keep herring-eggs

fresh and healthy for a month. Only where a number of eggs had become pasted together did they begin to mold or rot. Wherever the eggs lay at the bottom of the vessel in a single layer it would not even have been necessary to change the water once a day during the normal period of development.

In artificial hatching special care should therefore be taken to distribute the eggs evenly over the vessel. If this is done their sticking to the bottom is no hinderance, but rather an advantage, as the fine sediment which forms at the bottom can easily be removed without injuring the eggs.

In the following review of the results of my five experiments I have omitted many details, because I would only have to repeat what I have communicated in former publications.

Experiment 1.

From the eggs kept in the open water of the Bay of Kiel young fish were hatched in 10 to 11 days.

This agrees with my former statement (Report of the Commission for 1877, p. 240) as regards the time required for the development of autumn eggs in water of the same temperature. These required 11 days at a temperature of 10° to 11° C. (50°–51.8° F., and spring eggs, which formed the subject of my present investigation, required about the same time, having during the first day been in water having a temperature of 8.4° (47.12° F.), which afterwards was changed to 11° to 12° (51.8°–53.6° F.).

The young fish after having left the eggs only differed from those hatched in autumn in being somewhat smaller. Two of the larger ones were measured with the following results (given in millimeters):

Total length.	From the end of the head to the umbilical bag.	Length of the umbilical bag.	From the lower end of the umbilical bag to the "sphincter ani."	From the "sphincter ani" to the point of the tail.
6.6mm	0.84mm	1.10mm	3.17mm	1.48mm
6.4mm	0.46mm	1.08mm	3.17mm	1.37mm

Experiment 2.

Placing eggs at the beginning of their development for three days in water having a temperature of 1° to 2° C. (33.8°–35.6° F.), did not injure them in the least, but retarded the hatching about four to five days. This process of development was therefore not stopped, but merely retarded. This slower development must have continued after the eggs had been replaced in water having a temperature of 11° to 12° (51.8°–53.6 F.).

In this experiment the time from the impregnation of the eggs till the young fish escaped was fourteen to fifteen days.

Experiment 3.

Placing nearly developed eggs from water having a temperature of 12° (53.6° F.), into water having a temperature of only 1° to 2° (33.8°–35–6° F.), does not injure them.

For this experiment eggs were selected whose embryo if left in water having a temperature of 11° to 12° (51.8°–53.6° F.) would have been hatched after two days, whilst now, in water having a temperature of only 2° (35.6° F.) they required twelve days. In comparing this result with that of the preceding experiment, it appears that further developed eggs are more retarded by the influence of cold than those whose development has not advanced quite so far. In the second experiment the hatching was only delayed four to five days in spite of their being exposed to cold water for fully three days; whilst in this third experiment they were delayed twelve days, although the eggs were only exposed to the cold for two days. The whole time consumed from impregnation to hatching was, in this experiment, about twenty days.

Experiment 4.

Those eggs which immediately upon their arrival at Kiel were placed in water having a temperature of 1° to 2° C. (33.8°–35.6 F.) did not develop as evenly as during the first three experiments.

The first young fish left the eggs on the twenty-eighth day after impregnation, the majority between the twenty-ninth and thirty-third day, and a few even later. If we take into consideration, that during the first day these eggs had been in warmer water (8°.4 to 12°=47.12°–53.6° F.) and that if immediately on being impregnated they had been placed in water having a temperature of 1° to 2° (33.8°–35.6° F.) their development would have been a few days slower, it may well be supposed that in that case they would have required thirty-three to forty days.

In my former experiments with autumn-eggs a similar delay occurred at a temperature of 3°.5 C. (38.3° F.). It seems, therefore, that the eggs of the spring fish differ somewhat in this respect from those of the autumn-fish. This difference, however, is not marked enough to draw special conclusions from it. It must be granted that there is a similar delay caused by cold in both cases.

Experiment 5.

The period of development was by this experiment shown to increase in length if still colder water was applied. At first, water was used having a temperature of 0° (32° F.); with this temperature, the first young fish were not hatched till the forty-seventh day, and if we count in the first day spent in warmer water, still later.

The young fish, however, did not seem to be quite healthy, although some of them swam about for days in a lively manner. Many retained a very noticeable deformity of the back. It could not be ascertained

whether this was solely caused by the lower temperature; for it is probable that other causes aided in bringing about this result, for example, keeping the eggs for more than one and one-half months in small vessels which could not be thoroughly cleaned; the impossibility of keeping the temperature exactly at 0° (32° F.); and, finally, the change of water, which could only be effected once a day. I do not maintain that it is utterly impossible to produce perfectly healthy fish at a temperature of 0° (32° F.), for, in repeating the experiment with better apparatus, some of the mistakes of the first experiment might be rectified; but a renewed experiment would scarcely seem profitable, because it has been ascertained as a fixed fact that at a temperature of + 1° C. (33.8° F.) the eggs of the herring develop in a perfectly normal manner, whilst repeated experiments have shown that this is impossible at a temperature of only —0°.8 C. (30.56° F.). At this temperature the yolk becomes opaque, expands, and finally bursts the shell of the egg.

In the water of the Baltic, which is not very salty, the dividing line lies between + 1° (33.8° F.) and —0°.8 C. (30.56° F.); at any rate, very near to zero.

I have so far not been able to ascertain whether this condition would remain the same in the water of the North Sea, which has a greater degree of saltness, and whose freezing-point is lower.

The fact that the spawn of the herring can stand such a low temperature sufficiently explains why young herrings sometimes make their appearance in the Schlei immediately after the breaking up of the ice. They can, without any risk, lay their eggs even in very shallow water, as no thick cover of ice, which alone might prove dangerous, forms in spring. Even those eggs which have been laid earliest do not fully develop until the water has become somewhat warmer. The autumn herring never spawns in shallow water, but only where there is a current. In the Western Baltic, therefore, the young herrings will scarcely be destroyed by cold. On the other hand, it might be of interest to investigate whether currents coming from the Polar Sea during the spawning-season of the herring could strike the spawn in northern waters, for instance, on the coast of Norway. This would furnish an answer to the mysterious problem why the herrings leave certain coasts which they had been in the habit of visiting for many years. The surface temperature cannot decide the question, but the temperature of the water at the depth at which the eggs are found.

In the above-mentioned report of the commission (p. 241), I have mentioned the fact that in the eggs of the autumn fish the yolk diminishes in size if the season of development is extended on account of the cold. But as the autumn eggs used in former experiments differed in size, and the young fish hatched from them in length, it was impossible to decide whether those embryos whose time of development had been prolonged by the cold had already increased in length whilst in the egg. As the spring eggs used in this year's experiments were all of the same

size, it could be proved that the decrease of the yolk is invariably accompanied by an increase of the embryo. The young fish were measured, with the following result:

	Millimeters.
After 7 to 8 days from the time they left the egg	4.7 to 6.0
After 11 to 12 days from the time they left the egg	5.2 to 6.6
After 20 days from the time they left the egg	6.0 to 6.9
After 28 to 35 days from the time they left the egg	6.1 to 7.2

If these results are compared with those which are given in the report of the commission, for young fish hatched from autumn eggs from Korsoer (Denmark), it will be found that these last-mentioned fish were considerably longer. Their length varied between 5.4 millimeters, when the time of development was shortest, and 8.8 millimeters, when it was longest.

II.—INFLUENCE OF NORTH SEA WATER ON HERRINGS' EGGS FROM THE BALTIC.

In order to ascertain the influence of the water of the North Sea—which contains more salt than that of the Baltic—on the eggs of the Baltic herring, I took some eggs which had been impregnated, on the 26th of April, at Cappeln, on the Schlei (a fiord of the Baltic), on the following day to the aquarium of the zoological garden in Hamburg. The North Sea water used in this aquarium at this time only contained 3.25 per cent. salt, and its temperature was 12° C. (53.6° F.). Here the Baltic water was gradually mixed with the North Sea water, so that the eggs were not exposed to the full degree of saltness till after forty-eight hours. On the 7th of May the first young fish were observed swimming about freely, and during the succeeding days they were followed by others. The time of development was therefore very nearly the same as in Baltic water of the same temperature. The day when the eggs were taken to Hamburg was unfortunately very hot, and as the eggs were not evenly distributed, but were placed several layers deep at the bottom of the vessel, the larger number of them spoiled. But the fact that the remaining ones reached their full development about as fast in the North Sea water as in that of the Baltic, shows that the saltness of the water does not exercise any very marked influence. There were no arrangements in the Hamburg aquarium for raising the fish, and this first experiment therefore only proves that the eggs of the Baltic spring-herring can develop in the North Sea, leaving it an open question whether the young fish hatched from these eggs can live and grow to maturity in the North Sea.

III.—RAISING YOUNG HERRINGS FROM ARTIFICIALLY-IMPREGNATED EGGS.

As far as I know, no one has succeeded in artificially raising young herrings. My own numerous experiments in this direction invariably failed, because the eggs began to mold, and because no suitable food

for the young fish could be found. They died, if not sooner, at any rate after the yolk had been consumed. The growth of the fish could, therefore, not be observed in one and the same individual, but had to be estimated approximately from a series of measurements made on different fish, which only kept fresh for a short time, and then had to be replaced by freshly-caught fish of the same size.

In the spring of 1878 I at length succeeded in raising young fish, reaching a length of 72 millimeters, from eggs which had been used in the above-mentioned second experiment. My observations confirm, as a general rule, the data regarding the growth of the herring given in the report of the commission. There were, however, some differences in the details which will justify me in giving in this place a full report of this experiment.

As has been mentioned before, the eggs were impregnated at Cappeln, on the Schlei, on the 26th of April. The second, third, and fourth day after impregnation they were kept in water having a temperature of only 2° C. (35.6° F.); the remaining time they were kept in the open water of the Bay of Kiel, having a temperature of 11–12° (51.8°–53.6° F.). The entire season of development lasted 14–15 days. A short time before the young fish escaped from the eggs the dish containing the eggs was placed in an oval wooden vessel, measuring 135 centimeters in length, 95 in breadth, and 77 in height, and holding about 0.7 cubic meter of water. Half of this water was every day replaced by fresh water from the bay, which could flow off slowly, but continuously, through a sponge firmly pressed in a round opening at the bottom of the vessel. This sponge served as a filter, hindering the animalcules which serve as food for the larvæ of the herring from escaping. During the course of the summer the temperature of the water on the surface of the bay increased to 25° C. (77° F.), and in the wooden vessel, which was generally protected from the light and heat by a wooden lid, to about 20° (68° F.). The saltness varied between 1.15 and 2.20 per cent.

When within two days the greater portion of the eggs had been hatched, I did not wait any longer for the remaining ones to be hatched. The number of young fish was anyway very considerable. They always kept together like a swarm of bees, and when the sun was allowed to shine on the water they often came to the surface.

After one to two days many of these young fish already showed a considerable increase in length, the largest measuring 9.2 to 9.3 millimeters. After three days many had lost the umbilical bag entirely and showed a widely opened mouth. After five days food could be recognized in the intestinal tract. In some it consisted of a fine-grained greenish matter, whilst in most it was composed of embryos of gasteropods and bivalves of the smallest kinds of *Rissoa*, *Ulvæ*, *Lacuna*, *Tellina*, *Cardium*, *Mya*, which at this season of the year fill the water of the Bay of Kiel near the shore. These embryos can easily be distinguished by their small shell, and swim about in the water in a very lively manner. Those which were found in the intestinal tract of the larvæ of the herrings had

a length of 0.11 to 0.16 millimeter. Sometimes 20 were found in one and the same larva resembling a string of fine beads and filling the whole space from the mouth to the "sphincter ani." The copepods, at first of the Nauplius kind, were not quite so frequent among the contents of the intestinal tube.

When Professor Hensen and I examined some of these larvæ on the 10th day after being hatched, we found a small number of colorless and scarcely visible particles of blood.

After the 10th day the number of our young fish, which had so far enjoyed excellent health, began to diminish in a very noticeable degree. Finally their number dwindled down so rapidly that I was afraid my experiment would be brought to a premature close. The fish did not seem to grow much more in length, although some progress could be noticed in its transformation from a larva to a definite fish shape. But the length of the largest one on the 47th day after impregnation was only 12 millimeters, whilst, according to my observations of young herrings raised in the open water of the Schlei, it ought to have been about 17 millimeters. An increase of only 3 millimeters during a whole month could certainly not be called a normal development. The intestinal tube was nevertheless filled nearly all the time.

Hitherto fresh water had been poured into the oval vessel through a thick cloth, so as to keep out any enemies of the herring. I now made a change in this respect, by pouring the fresh water direct into the vessel, hoping thereby to give to the young fish more and more varied food. I can of course not decide whether the favorable turn which matters took was owing to this change, but I know of only one cause of the sudden growth of the fish, namely, the largely increased number of copepods.

By this increased growth during the third and following months the artificially hatched fish at the end of the fifth month reached exactly the same size as the herrings of the same age living in the open water of the Schlei—which I have mentioned in a former report. This was further corroborated by a number of young herrings raised in the Schlei simultaneously with those kept in confinement.

Age, counted from the impregnation of the egg.	Measurements of herrings living in the open water of the Schlei.	Measurements of herrings raised artificially from Schlei eggs during the spring of 1875.	Growth of the artificially raised herrings per month.
	mm.	*mm.*	*mm.*
One month	17–18	10–11	.....
Two months	34–36	17–19	7– 8
Three months	45–50	30–35	13–16
Four months	55–61	48–54	18–19
Five months	65–72	65–70	17–16

Probably it was only the want of suitable food, brought about by filtering the water through a cloth, which detained a large number of fish from their normal growth. The few, however, which passed this ordeal successfully showed in the most unmistakable manner that they knew how to make up for their involuntary fasting. This is an interesting observation, because it shows how much the growth of the herring depends on the quantity of food. A still more striking example of rapid growth was exhibited by a few small sprats which were sent to me from Cappeln on the 20th of August, 1878.*

These fish, measuring 30 to 35 millimeters in length, reached a length of 66^{mm} in thirty-five days, whilst they were confined. We, therefore, observe in a small fish closely resembling the herring a growth of 25^{mm} in thirty-five days, or 22^{mm} during one month. It is well known that the growth of all fresh-water food-fish varies very much. But the fact, proved by actual experience, that salt-water fish, like herrings and sprats, are not only retarded in their growth by want of sufficient food, but will make up for lost time as soon as food is more plentiful, must be considered as another proof that fish of different size may have the same age. This will be a welcome statement to those who could not make the occurrence of herrings of all sizes at every season of the year agree with the supposition of two, or at most three, spawning-seasons. There is at the present time scarcely any doubt that the best-fed fish of the autumn spawning are fully equal in size to fish of the spring spawning—therefore 6 months older—which have been retarded in their growth, but that these last-mentioned fish can at a later time reach the size which belongs to their age.

It is likewise certain that the food of the herring is, as a rule, more plentiful during some months of the year than during the rest; that, for example with us, on the shores of the Bay of Kiel, there is a very noticeable lack of pelagian animals towards the end of winter. Our herrings, therefore, probably grow slower at certain seasons of the year than at others.

All that can be aimed at is, therefore, to ascertain the average growth, more especially as one year may not resemble the other in this respect.

Although this treatise was to be confined to the growth of the embryo, I also made a few observations on the growth of the fins, which may find a place here.

On the 25th day after the fish had left the egg, the dorsal fins began to appear, and on the 33d day 11 distinct rays could be seen. Six weeks after the fish had left the egg, the dorsal and caudal fins in fish measuring 15-19 ^{mm} had assumed their complete shape; but in the former some rays were still wanting, whilst in the latter the smaller half of the rays was wanting. The anal fin likewise showed a form resembling its definite form very closely. The number of rays in different fish of the same age varied very considerably. The shape of the pectoral fins had not changed much, and did not by any means resemble

*Large numbers of these fish appeared about the same time in the Bay of Kiel.

the adult shape. Of the ventral fins there were only very indistinct indications. After ten days more had elapsed—therefore 7 to 8 weeks after the fish had left the egg—many of the larvæ entered the transition period. They now measured 25 to 28^{mm} in length. This is the same length as that of the smallest larvæ, of the same age, living in the open water of the Schlei, whilst with the autumn herring the transition period does not set in until the fish have reached a much larger size. The fish which had been artificially raised in the Bay of Kiel had, therefore, preserved the character of the Schlei spring fish.

The young herrings of the same size which can now be caught in large numbers in the Bay of Kiel differ somewhat from the above-mentioned herrings in the position of their fins, and to some extent resemble the autumn herring. They are, therefore, certainly not hatched from Schlei eggs, but are probably natives of the Bay of Kiel. In my former reports I had to leave it undecided whether the Bay of Kiel contained spawning-places; but now I can answer this question in the affirmative.

On the 5th of May, 1878, and during the following days, there was excellent herring-fishing at the mouth of the river Schwentine.

On the 5th and 6th of May only fully-matured fish containing spawn were caught; on the 7th of May some were caught which had spawned, and from day to day the number of spent fish increased, until no other were caught.

Also at the mouth of the canal, near Holtenau, the same large and full fish were caught.

This confirms a supposition, which I have expressed in another place, that the spring or coast fish have numerous spawning-places in the Western Baltic, although none of these spawning-places are of great importance.

KIEL, *September*, 1878.