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38.—HATCHING COD IN NORWAY.*

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[Report of the codfish hatchery at Flodevig, Norway, for the year 1886.]

The unusual low temperature of the sea-water has this year put several new obstacles in the way of the work, so that the results, although better than those of preceding years, have not come up to what might have been expected, when we take into consideration the advantages of the accumulated experience of many years.

The greatest obstacle to the work was caused by the ice, which prevented parent fish from being obtained at the most important time, namely, from the 26th of February to the 30th of March. After that date it is always very uncertain and difficult to get fish which are not either too far advanced in spawning or have not already spawned.

When, nevertheless, a larger number of eggs was incubated than in previous years, it must be ascribed to the method of keeping the parent fish swimming in a special place in the hatching-house, instead of, as formerly, in an open vessel by the wharf.

In further explanation I may say that already in 1884 I noticed that a very large portion of the roe we received was dead when taken from the fish, and consequently useless for incubation to such an extent that three-quarters had to be discarded. It became of the greatest necessity to find out the reason for such a great loss and how it could be prevented or at least minimized. To assist me in this matter I applied for information to several persons of experience, but even with their assistance the problem could not be satisfactorily solved. The only way open to me was to proceed with the necessary investigation myself, and after a long time my labor was at last crowned with success.

The specific gravity of the roe is the surest sign of its being dead or alive. When alive, it floats easily in water with a specific gravity of 1.024; whereas if dead, it sinks and lies on the bottom, even when the specific weight of the water is increased by the addition of salt solution to 1.030. This fact is taken advantage of to remove the dead and useless roe when the apparatus is cleaned. When the roe is taken from the fish, fecundated, washed, and put in a large glass cylinder with water of a specific gravity of 1.022 to 1.024, a difference will at once be noticed between the good and useless. The living roe will after a few minutes float up to the under part of the surface, and the dead sink to the bottom, leaving a space of clear water between the two.

* Translated from the Norwegian by N. OHMAN.

The difference with regard to color begins now also to be noticed. The living roe is more or less of a yellowish-red color, whereas the dead is of a gray color, with a regular white spot on the under side of each egg. That the healthy color was lost with life was so natural that I passed it without any further investigation; but my whole attention was directed to the examination of the above-mentioned white spot, which was invariably found in all dead eggs, when taken directly from the fish, as well as when they had been in the hatching apparatus any time. They all presented, under the microscope, a cloudy apppearance, as if a white membrane lay on the bottom of each egg. Later on, I became convinced that such was the case; for the white spot was simply the membrane bag which contains the yolk (vital fluid), and sinks to the bottom of the egg after being broken and its contents mixed with the white of the egg.

It appeared as if outside violence to the fish was the cause of the eggs being thus destroyed (as, for example, pressure on the belly of the fish); and I began to feel so sure on that point that I came to the conclusion that to handle the parent fish with care would be the surest way to prevent its occurence, when an incident came to my assistance and led my researches in another direction. Among the fish procured was a splendid pair of light-gray deep-sea cod, one a roe and the other a milt fish. All the roe from time to time obtained from these fishes was, to my great regret, useless, and at last I gave up all hope of getting any hatchable roe from them; but as they were fine specimens and of a very large size, I decided to keep them in the hatchery basin, for the benefit of visitors and spectators. The water in which they were kept was often renewed with fresh sea-water, taken from a depth of 9 fathoms. Some time afterwards I happened by chance to catch one of them, and to my surprise I got exclusively good roe from it, and in considerable quantities.

Experiments were commenced with a greater number of fish which had given more or less bad roe, and when the result in all cases was the same it was considered clear proof that the saltness of the water must be taken largely into consideration. It may be remarked that the water pumped into the hatchery from a depth of 9 fathoms contains twice the quantity of salt as that on the surface.

It still remained to be explained why some fishes gave only useless roe, while all of them lived under exactly the same conditions and in the same place. I noticed that, as a rule, small-sized fish, of a dark color, gave the best roe for hatching, and, on the contrary, the light ones gave bad. Now the fish of light color live outside the coast in deep water; and the darker live closer to the shore, and are commonly called fiord fish, bay or shore fish. I was convinced that it was not the greater or less amount of salt the water contained that made the difference, but the sudden change from the deep-sea to the fresher water on the surface. This was also further proved by some deep-sea cod that were

held captive by the shore from one year to the other, and were then found to give roe perfectly good for hatching. In consequence of these observations, all the parent fish for this year were kept in a reservoir in the hatchery; and from them was got a manifold greater quantity of roe. This can be easily understood when I mention that, during the breeding season this year, notwithstanding the low temperature of the water by which more roe was lost than in any previous year, we had only 150 fish, against 400 to 500 the previous year, from which roe were obtained. The loss in the apparatus this year amounted to 52.8 per cent., against 39.3 per cent. in 1885.

We must not conclude from this fact that the coldness of the water has a directly killing effect on either the roe or young fish. Such is not the case; but the hatching period is so much prolonged, and necessitates the keeping of the roe for a longer time in the apparatus, where it is subjected to injury and loss.

The time required for hatching cod eggs this year was forty-two days, whereas the longest time, in any previous year, was twenty-six days; the difference in the mean temperature was only 2.5° Réaumur. At a temperature of 4° R. [41° F.] it takes as a rule twenty-two or twenty-four days to bring out the young fish; and as they then appear to be strongest and most vigorous, we may suppose this to be the temperature best adapted to their nature. If the water is warmer, as for example, 6° R. [45½° F.], the hatching will be done in fifteen or eighteen days; but then the young fish are very frail and weak. The same is the case if the temperature is as low as 2° R. [36½° F.] or lower.

When the doubt regarding the possibility of hatching cod roe artificially was clearly removed, another question was brought forward, namely, had the young fish, hatched in this manner, energy and power enough for further growth and development in the natural element?

It was useless to explain that the conditions were the same as for those hatched naturally; that the temperature and saltness of the water, &c., were the same as in the sea; that the fecundation of the eggs and the progress of hatching must absolutely be the same as nature's arrangement, or else would have failed. The public wanted proof; and as the same public kept the institution going by their subscriptions, there was no choice but to set to work and bring such proofs.

A number of propositions were brought forward regarding the best course to adopt, and all had taken the economical question most strongly into consideration. That the same question had a prominent place in my calculations was natural; but the main point with me was to guard against anything being done or adopted that would in any way endanger the complete success of the work. I looked upon the question from the standpoint that a failure in this case would place too strong a weapon in the hands of skeptics, and our fish-breeding institutions would come to an end.

I had from time to time been experimenting on a small scale with young cod, and found that the water must have, besides the proper temperature, a specific gravity of 1.022, which is absolutely necessary in order to keep them from sinking to the bottom. If the specific weight of the young fish is more than that of the water they have too great a tendency to sink; and as their swimming power in their early stage is very small, they will touch the bottom at last, no matter how they struggle against it, and then their destruction is certain.

In view of these facts, it was considered necessary to construct a basin in such a place and in such a manner that the saltness of the water and its renewing would be under absolute control. I therefore proposed one entirely separate from the sea, which could be filled with proper sea-water by aid of a steam pump. A good place for such a basin was easily found. A plan of such was sent to the branch directors, which they accepted, and the work was commenced and finished during the fall of 1885. The dimensions of the basin are: Greatest length, 43 meters; greatest breadth, 20 meters; greatest depth, 5 meters [about 140 by 66 by 16 feet].

The capacity is about 2,500 cubic meters [about 88,000 cubic feet], and its overflow lies about 8 meters [26¼ feet] above sea-level. It is situated in a natural indentation in the cliffs and has a wall 40 meters [131¼ feet] long to the south, and one 15 meters [49¼ feet] to the northeast. The pumping is done by a small steam-engine and a windmill, erected in the neighborhood; but they are found rather too weak to perform the work satisfactorily, especially as a hill to the southeastward shelters the windmill from that direction.

During the month of April the basin was cleaned out and filling it was commenced, during which several kinds of sea-plants were put in. On the 3d of May about 500,000 young cod, hatched on the 27th of April, were put into it; the pumping continued steadily until the basin was filled, and afterwards at certain intervals.

With regard to the further progress of the young cod, I copy from my day-book as follows:

May 3–8.—Saw the fry every day, most of them at the eastern side. They never swim in schools, always by themselves.

May 9.—Development goes on. In the most of those I examined was seen a yellow content.

May 10.—The greatest number were seen about the mouth of the pipe through which the water was pumped in, probably because the water was fresher there than elsewhere in the basin.

May 11.—Continue to grow. Yellow spots are seen on the head and backs. Great numbers of crab larvæ (zoea stage) are found in the basin, and are very lively, swimming about near the waste-water overflow.

May 13.—About 5,000 young fry were put in the basin. Cod fry grow steadily, and, as mentioned before, are in greatest numbers about

the filling pipe. The length is about 7 millimeters [¼ inch]. The intestine has begun to form a bend. The ground color is more yellowish. Temperature, 8° R. [50° F.]; specific gravity of water, 1.021.

May 18.—Cloudy and rain. Saw a number of cod fry of 8 millimeters length.

May 20.—Clear weather; fry all over the basin.

May 21.—Towards the evening, they gather to the west side of the basin. Length of fry, 10 millimeters.

Places of taking temperature, &c.	Temperature.		Specific gravity.
	°R.	°F.	
At overflow	10	54.5	1.0227
At 1 meter depth	10	54.5	1.0227
At 2 meters depth	9.7	53.8	1.0227
At 3 meters depth	0.5	53.4	1.0227
At bottom	9.5	53.4	1.0230

May 23.—The fry prefer to keep themselves in the shade, consequently they are at the east side in the morning and west side in the evening. The difference in the size is considerable, but the development is nearly the same. The distinction between the different kinds has already commenced to be noticeable.

May 31.—From last date the weather has been cold and rainy and observations insufficient. To-day are seen a great number of them. Caught one 15 millimeters long [a little over ½ inch]. They still like the shade.

June 1.—Saw a young flat-fish among the cod, all in the shade.

June 3.—It is a month to-day since they were put into the basin. Caught and preserved 50 of them in spirits of wine. They are now from 9 to 16 millimeters long. The smaller do not seem to have the same degree of development as the larger.

June 6.—Temperature in the basin 12½° R. [60° F.]; temperature in overflow, 10½° R. [55½ F.]; temperature in filling pipe, 6° R. [45½ F.]. That the water was so much colder in the filling pipe was because it was pumped from a greater depth. The fry are growing and are found over the whole basin. Tried to feed them to-day with fine-cut mussels and fish, etc., but it was no use; they fled in great haste from it.

June 8.—During the last days they seem to have disappeared in great numbers from the upper part of the basin, and keep closer towards the bottom. Caught one at two fathoms of water.

June 10.—After carefully studying the life and habits of the cod fry from early morning and during the whole day (a clear, calm, and sunny day), I have found that they attack, kill, and eat each other in considerable numbers, whereas the crab larvæ (now both in the zoea and megalops stage) were seldom pursued, and, as far as I could see, were never caught by the young cod; not that they seemed to lack the desire to catch them, but the larvæ are such splendid swimmers, and understand

so well how to avoid the attack. On the other hand, I never saw a crab larva attacking the cod, so they may grow and develop peaceably together, for a time at least. That the larvæ at last succumb to the voracious cod is certain, but not until his size is considerably larger than the crab. As the cod, when larger, very seldom attack and eat each other, we may conclude that the greediness which they at present have is because the basin is new, and only a few sea-plants are yet growing there, so that there is not sufficient food in it for such a number of fish. Tried to feed them and succeeded in getting some of them to swallow pieces of finely-powdered mackerel.

June 19.—During the course of the last nine days numbers of cod have been examined, and their stomachs were filled with several kinds of animalculæ, such as mosquito larvæ and pupas, of which there is an incredible number in the basin. There were also found in them part of the food daily thrown into the basin for them. Some were found dead by the overflow, and marks of outside violence were visible, their hind-parts bloodshot and the skin injured.

When the young cod leave the egg they have a length of 3 millimeters. During the first eight days, while the yolk sac is able to give sufficient nourishment, they grow 2 millimeters, so that when taken out of the apparatus they have a length of 5 millimeters. [It takes a trifle over 25 millimeters to make 1 inch, so 5 millimeters equal about $\frac{1}{5}$ inch.]

Their future growth is varying indeed, and depends more perhaps on the difference in race kinds than on the greater or less quantity of food they succeed in obtaining; and when in the following table I give their length, it must be understood to be the average:

Date.	Age.	Length in millimeters.	Length in inches.
	Days.		
April 26	0	3	.12
May 3	6	5	.20
May 16	19	7	.28
May 18	21	8	.31
May 21	24	9	.35
May 31	35	10	.39
June 3	38	12	.47
June 6	41	15	.59
July 12	77	55	2.17
August 12	108	70	2.76
September 12	139	85	3.35
October 12	169	*115	4.53

* The largest one caught at this time was 157 millimeters [or 6.18 inches] long.

Between the 6th of June and the 12th of July there is a very large step in the development, as the table shows; but the reason is that at this time the young cod begin to eat the food given them twice a day, and in considerable quantities.

From the middle of October until now (middle of February) their growth has been very slow, the causes of which may be easily ex-

plained. I will here mention, first, that young cod, in their natural element, betake themselves to the deep waters when the upper waters begin to be cold, which usually takes place in the month of November. That at the same time they go, as it were, into the mouths of their many enemies, and the largest number of them are thus destroyed, has nothing to do with the present question. Those who escape all danger, no doubt, have a very comfortable existence in the deep waters, where they are able to procure for themselves a sufficient quantity of food in addition to the congenial temperature. That such a migration could not take place in the basin was evident; and all they could do was to search out the deepest holes, where they keep themselves as well as they can. That this is hindering their growth is easy to see, and especially as they during the cold weather eat almost nothing.

I may also mention, in this connection, that the water has not been renewed in the basin as often as might have been necessary, and may not have been so healthy for the young cod to live and thrive in. I have, nevertheless, seen only one dead in the basin during the winter, but that there may be more of them dead is quite possible, in the deeper holes, where the bottom cannot be seen.

Had this experiment been carried out to its fullest extent, the steam pump should have been kept going at least two whole days in each week, but the means at our disposal would not allow that.

The principal question is, however, satisfactorily settled: That the cod fry artificially hatched have the power and energy to live, grow, and develop when set at liberty and left to care for themselves in their natural element, the sea.

We must thus leave this question to rest for the present, especially as so many others of great importance in this connection are yet before us for solution. I shall again refer to the progress of the young cod in my early report for 1887. As the basin is now and has been covered with ice since the middle of December, I cannot venture to say how many are alive there yet, but I should suppose they still amount to several thousands.

Table showing the work during three winters.

Year.	Eggs taken.	Young cod let out into the sea.	Loss, per cent.
1884	12, 575, 000	5, 095, 000	59. 5
1885	48, 760, 000	29, 620, 000	39. 3
1886	68, 880, 000	32, 510, 000	52. 8

AREndal, NORWAY, *January* 1, 1887.