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103.—ON THE NATURAL AND ARTIFICIAL FERTILIZATION OF SEA HERRING EGGS.*

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In 1862 Professor Huxley arrived at the conclusion that herring visit our shores twice a year in order to spawn, some schools arriving during the autumn, while others make their appearance during the winter. The herring which spawn during the autumn chiefly frequent banks on the east coast, while those which spawn during winter are most abundant on the west coast. A report of the Scottish Fishery Board referring to the east coast spawning-beds was published in Nature on November 29 last. The present paper deals chiefly with the Ballantrae spawning-bed, which lies off the coast of Ayrshire.

In 1862 Professor Allman made some investigations for the Scottish Fishery Board, and succeeded in dredging and hatching what was considered herring ova; but since then, although important results have been obtained by the German and American Commissioners of Fisheries, little or nothing has been done in this country.

When examining the Ballantrae bank the author of this paper succeeded in dredging several specimens of herring ova attached to stones, sea-weed, and sea-firs. These stones coated with eggs varied from 6 inches to 1½ inches in length, and from 4 inches to 1 inch in breadth, but in all cases the eggs were attached to a comparatively smooth surface, and they were arranged either in low cones or in comparatively thin layers one or two eggs deep. The eggs on the sea-firs were always attached in small clusters about half an inch in diameter around the stems. On examining the spawn found on the stones and sea-weed, embryos at various stages of development were at once visible, some of them apparently only three days old, while others had distinct eyes, and from their violent movements and their size seemed almost ready for hatching. Some of the egg-coated stones were taken to the University at Edinburgh, where the eggs hatched on March 15, eight days after their removal from the spawning-ground, and to-day (March 17) they are three-eighths of an inch in length, extremely active, and swimming freely about in the water.

By taking soundings over the Ballantrae bank in various directions it was ascertained that it consisted of rock, stones, shells, and coarse sand, and that the depths varied from 7 to 13 fathoms. The outer edge of the bank shelved at most points rapidly until a depth of 17 fathoms

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was reached, and at this depth the bottom consisted of fine, soft mud. While on the east coast spawning-grounds, examined during the autumn, the surface temperature in most cases varied from 53° F. to 55° F. and the bottom temperature from 52° F. to 54° F., even at a depth of 40 fathoms; the temperature at the Ballantrae bank varied from 42°.8 to 43°.8 F. at the surface, and from 42°.8 to 43°.5 F. at the bottom. The corresponding surface temperature, however, on the east coast during the week ending March 8 was from 2° to 3° F. lower than at Ballantrae.

According to previous observers:

"When spawning takes place naturally the eggs fall to the bottom and attach themselves. But at this time the assembled fish dart wildly about and the water becomes cloudy with the shed fluid of the milt. The eggs thus become fecundated as they fall, and the development of the young ova sticking to the bottom commences at once."

Mr. Mitchell, in his book on "The Herring," referring to the once famous spawning-bed off Dunbar, states that—

"About August 30 the shoals began to deposit their spawn a short distance from the harbor, and on September 3 the fishermen found that a very large body of herrings remained fixed to the ground in the progress of spawning, the ground being of a rocky or stony nature."

While many fishermen believe that herring spawn on hard ground, some believe that they also spawn on a clayey bottom; and while some think that they spawn near the bottom, others affirm that they spawn near the surface. Having secured at Ballantrae a large number of live herring, some of the largest and ripest males and females were placed in a large wooden tank into which a number of stones and a quantity of sea-weed had been previously introduced. After the fish had been about two hours in this tank the stones and sea-weed were examined. Although a few eggs were attached to both stones and sea-weed it was quite evident that the eggs had not been deposited in the same way as those found on the stones dredged on the previous day; but we were not surprised that only a few isolated eggs were found on the stones, because the fish had been disturbed every few minutes by the pouring of water into the tank.

On reaching Rothesay the hatching-boxes and live herring were at once transferred from H. M. S. Jackal to the tanks—a tank into which comparatively little light entered having been selected for the ripest and most vigorous herring. In about half an hour after they were introduced a large, full herring was seen moving slowly about the bottom of the tank, with four other fish making circles around her at some distance from the bottom. Appearing satisfied with a particular stone which she had evidently been examining, she halted over it and remained stationary for a few minutes about half an inch from its surface, the tail being in a straight line with the tank and the pectoral fins near or resting on the bottom. While in this position a thin, beaded ribbon was seen to escape from the genital opening and fall in graceful curves on the surface of

the stone, so as to form a slightly conical mass almost identical with a cluster on one of the stones dredged at Ballantrae. As this little heap of eggs increased—some falling to the left side one moment, while others fell to the right the next, according to the currents in the water—the males continued circling round her at various distances, while the other females in the tank remained apart. The males remained from 8 to 10 inches above the bottom of the tank, and formed circles varying from 18 inches to 2 feet 6 inches in diameter. Some of the males were swimming from right to left, others from left to right, and although there was no darting about, no struggling among themselves, there was a peculiar jerking of the tail as they performed their revolutions. Soon the object of this peculiar movement was sufficiently evident. Three or four times during each revolution each fish expelled a small white ribbon of milt, which varied from half an inch to three-quarters of an inch in length, and was nearly a line in breadth across the center, but pointed at both ends, and somewhat thinner than it was broad. These delicate ribbons slowly fell through the water, sometimes reaching the bottom almost undiminished in size, but in most instances they had almost completely dispersed before the bottom was reached. In this way the whole of the water about the female became of a very faint milky color, and practically every drop of it was charged with sperms, as was afterwards ascertained. It will thus be seen that there is no attempt whatever on the part of the males to fertilize the eggs as they escape from the female. While the female is depositing the eggs at the bottom, the males concern themselves with fertilizing the water in the neighborhood, and it will be observed that the males are careful to guard against the influence of currents by forming circles around the female and shedding milt on the way. It matters little how the currents are running, they are bound to carry some of the milt towards the eggs, the milt, like the eggs, sinking though not adhering to the bottom.

This then is the natural process of depositing and fertilizing the ova of the herring in comparatively still water. When the female had deposited a certain number of eggs at any given spot, she moved forward in a somewhat jerky fashion without rising from the bottom, and as she changed her position the males changed theirs, so that the female was always surrounded by a fine rain of short sperm ribbons. A specimen of *Hydrallmannia* sent from Eyemouth seems to indicate that the female moves about among sea-firs and sea-weeds in exactly the same way as she does among stones. On each stem of the colony there is a cluster of ova about the size of a small grape, and all the clusters had reached on arrival the same stage of development as if they had been deposited about the same time and by the same fish.

This method of depositing and fertilizing the eggs accounts, I think, for all the eggs, or at least for a very large percentage of those found attached to sea-firs, sea-weeds, and stones, containing developing embryos.

When a female was depositing her eggs she was very easily disturbed; whenever anything was introduced into the tank she at once darted off. When strong currents were made, she at first seemed to apply herself nearer to the bottom, to make sure, as it were, that the spawn would get fixed before it could be carried away; but when the currents were further intensified she at once changed her position, and arrested the escape of the spawn. A spawning female was held immediately under the surface of the water so as to cause the spawn to escape. When this was done the spawn escaped in long ribbons consisting of a single row of eggs. So firmly do the eggs adhere to each other that in perfectly still water the ribbon was sometimes over a foot in length before it broke. When it had only about 2 feet of water to travel through, it fell in wide loops at the bottom, but when it had to fall over 3 feet the chain broke up into numerous segments which formed an irregular pattern on the bottom. From experiments made, it seems the further the eggs have to fall and the longer they are in contact with the water before they reach the bottom, they are more widely dispersed, and have all the less adhesive power. When the eggs are expressed in water moving rapidly in various directions, the chains soon break into short segments, and the individual eggs and the small groups are often carried a considerable distance before they reach the bottom.

A number of flat stones and pieces of sea-weed were obtained, and a spawning female held over them at different distances in still water, in water with gentle currents, and in water with strong currents. In this way we obtained groups of eggs which mimicked in a very striking manner all the arrangements of the eggs on the stones and sea-weeds dredged on the Ballantrae bank. When gently pressed, a beaded ribbon, consisting of a single row of eggs, always escaped; when there were no currents, it formed a conical heap; when in a gentle current, the ribbon fell in irregular loops, the elements of which rearranged themselves so as to form a flattened cone; but when strong currents acted on it the ribbon was broken into fragments and only a few eggs succeeded in fixing themselves to the objects introduced. When the currents were strong, the males were seen not only to swim nearer the bottom but to expel longer ribbons of milt, which reached the bottom before getting dispersed, and remained visible sometimes for ten minutes. On gently expressing a male under the water it was never possible to expel so fine or so short portions of milt as escaped naturally, but it was extremely easy expelling a ribbon from 18 inches to 3 feet in length, measuring 2 lines across and 1 line in thickness. Such ribbons fell to the bottom and remained almost unchanged for nearly two hours. They then assumed a segmental appearance, and in about three hours and a half had all but disappeared.

Eggs were allowed to escape into a vessel containing fine sand, and into another containing mud. The eggs after being fertilized underwent the early stages of development, but either owing to their moving

freely about with the sand particles or owing to their getting coated over with the sand and mud their development was arrested. I have not yet determined finally if the development is arrested when the eggs are detached while development is proceeding, but this seems extremely probable.

When at Ballantrae I noticed that the trammel-nets secured often more males than females. Mr. Wilson, fishery officer at Girvan, informs me that the ripest fish are caught in the trammel-nets, while most of the unripe fish are obtained in the drift-nets, and that at the end of the fishing season there are about three males taken for every two females, indicating not necessarily that the males are more abundant than the females, but rather that the males remain longer on the spawning-ground; and Mr. Wilson believes that herring prefer quiet water free from strong currents when spawning, and that when the weather is fine the herring remain long upon the bank and deposit their spawn leisurely, but when there are strong currents they either hurry the spawning process or disappear into deep water.

As to artificial fertilization and hatching I found, after many experiments at Ballantrae, that the best results were obtained when both the male and female were held under water while the milt and ova escaped, *i. e.*, when the natural process of spawning is followed.

An ordinary wooden tub was obtained and filled with sea-water. Into this a small quantity of milt was expressed, the male being held completely under water while the milt escaped. A glass plate was then held about 4 inches beneath the surface of the water, and, the female herring being held about 1 inch beneath the surface, by gentle pressure the eggs readily escaped in the characteristic narrow beaded ribbon, and, by moving the fish over the surface of the glass, either a close or an open net-work could be formed. At first, where one loop crossed another, the eggs were two or more layers thick, but, either owing to the weight of the eggs or the gentle currents set up in the water, before a few minutes had elapsed the eggs formed a single and almost continuous layer, the net-work arrangement having disappeared. The plate was then allowed to rest for two or three minutes at the bottom of the tub, and a few short ribbons of milt were again introduced. After moving the plate once or twice across the top of the tub in order to wash off any scales that were adhering, it was placed either in a hatching or a carrying box. Many thousands of ova treated in this way contain extremely active embryos, which are expected to hatch on March 22 or 23.

(Professor Ewart exhibited a number of specimens showing herring eggs attached to stones, sea-weeds, and sea-firs, and some of the herring fry hatched on March 24 from the eggs artificially fertilized on March 8.)

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