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On the Size and Number of the Ova of Irish Herrings.

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FOR some time past it has been the practice, when a sample of Irish herrings was examined by the staff of the Fisheries Branch, to measure the diameter of the eggs of a small number of females, in order to obtain data which might be useful in checking the estimates of maturity made by the generally accepted scale of I to VII.

It soon became evident that the size of the ova when compared with the weight of the gonad relative to the length of the fish, using the formula $K_G = \frac{\text{weight of gonad} \times 10000}{L^3}$, showed such wide variations

that the diameter of the ova could not be used directly to give an effective diagnosis of the stage of maturity.

On a recent attempt to investigate this variation further it became evident that there were two definite size-groups amongst the eggs, and that all herrings known to be spring spawners had the larger eggs, while the eggs of the autumn spawners were distinctly smaller. Samples whose time of spawning was not certainly known belonged definitely to one or other size-group and it has been assumed that they were respectively spring or autumn spawners.

If this observed difference should be found to hold good for other localities it may furnish a convenient method of distinguishing between different stocks of herrings at any stage of maturity, less troublesome than vertebral counts, since smaller numbers of fish are required; and for this reason attention is called to it here without waiting for the accumulation of data which a full investigation of its implications would demand.

The difference in size of the eggs of herrings from different places has often been alluded to, and as early as 1878 Kupffer pointed out that the eggs of Norwegian herrings were much larger than those

from the Baltic, but I have not seen any references to a difference between the eggs of spring and autumn spawners from the same locality. The routine adopted in making the measurements was to measure the total length of the fish to the nearest millimetre from the snout to the tip of the longest tail-ray bent up or down, to weigh the gonad to the nearest gramme, or, if small, to the half-gramme, and to tease out a small portion of the ovary in 10 per cent. formalin for subsequent measurement. The eggs were measured under the microscope with a squared eyepiece, to the nearest .01 mm., twenty of the most nearly spherical ova being selected at random and the average diameter taken.

There are some small sources of error in ascertaining the value of K_G . The most serious is shrinkage in length of the fish, which may amount to 4 mm.; in addition to this, errors of measurement might amount to 2 mm., giving a range of error for a fish of 25 cm., of 24.4–25.2 cm. The gonad might possibly be referred to the gramme weight above or below the true weight, e.g., 18 gm. might be recorded as 17 or 19. Consequently a fish of 25 cm., gonad 18 gm., might be recorded as 24.4 cm. gonad 19 gm., K_G 13.1, or 25.2 cm. gonad 17 gm., K_G 10.6.

These errors, though insufficient to account for the whole variation, may help to account for some of the wide divergences from the averages.

The diagram (Fig. 1) shows the measurements of the ova plotted against the values of K_G for all the fish measured. It shows plainly the difference in size of the eggs in the two size-groups. The broken lines in the diagram are not the means of the two groups but are

equivalent to $\sqrt[3]{K_G}$ in units corresponding to the diameters of the eggs. The observed sizes of ripe, i.e., running, ova are shown on the right of the diagram. The K_G for these, owing to the loss of ova, is irrelevant.

This method of tabulating the measurements and weights is only justified on two assumptions, one that the specific gravity of the ova remains more or less constant during development, and the other that the weight of the ovary at any given stage of ripeness is proportional to L^3 for all sizes of fish. This latter assumption, as will be shown later, is not correct, but it is sufficiently accurate within the general run of sizes met with to allow of its use as a preliminary diagnosis of the type. It will be noticed that no ripe ova of autumn spawners were obtained, but it is clear that they can never attain the size of those of spring spawners for in that case the weight of the ovary would amount to about 50 per cent. of the total weight of the fish.

The following are the particulars of the samples from which the measurements were taken, and in the table which follows, the average diameters of the ova in the various samples are given for successive values of K_G , the number of fish on which the values are based being given in brackets.

Fig. 1. Diameters of ova of spring and autumn spawning herrings compared with K_G of ovaries.

Fig. 3. Weights of ovaries of autumn spawning herrings compared with length of fish, for ova of different diameters.

Table 2.

Autumn Spawners.

Sample No.	Average Diameter of Ova at Successive Values of K_G .							
	1	2	3	4	5	6	7	8
$K_G = 1.5$	.62(3)	—	.43(1)	.44(6)	.52(14)	.52(2)	—	.36(1)
2.5	—	—	—	.48(15)	.59(9)	.72(1)	—	—
3.5	—	.79(1)	.66(3)	.51(1)	.70(5)	.75(2)	—	—
4.5	—	.75(1)	.65(4)	—	.66(9)	.78(2)	—	—
5.5	.78(2)	—	.67(4)	—	.68(3)	.76(1)	—	—
6.5	.79(1)	.82(1)	.78(2)	—	.76(2)	.85(3)	—	.75(3)
7.5	.81(1)	.86(2)	.74(4)	—	.75(2)	.84(1)	—	.78(7)
8.5	.81(3)	—	—	—	.79(1)	.92(4)	—	.84(6)
9.9	—	.98(1)	—	—	.83(2)	.93(4)	—	.83(6)
10.5	.88(3)	—	—	—	—	.95(9)	—	.93(6)
11.5	.95(1)	.94(3)	.87(1)	—	.82(1)	.90(3)	.94(1)	.96(7)
12.5	.96(1)	—	—	—	—	1.01(3)	—	.90(1)
13.5	—	1.00(1)	—	—	—	.93(2)	1.05(1)	.96(3)
14.5	—	—	—	—	—	1.00(5)	—	.92(2)
15.5	—	—	—	—	—	1.01(2)	.97(1)	.94(3)
16.5	—	—	—	—	—	1.07(3)	.94(1)	.95(1)
17.5	—	—	—	—	—	1.08(1)	1.08(1)	.99(1)
18.5	—	—	—	—	—	1.02(1)	—	.99(2)
19.5	—	—	—	—	—	—	1.08(1)	—
20.5	—	—	—	—	—	1.13(1)	—	—
21.5	—	—	—	—	—	1.06(1)	—	—
22.5	—	—	—	—	—	—	1.15(2)	—
23.5	—	—	—	—	—	—	—	1.02(1)
24.5	—	—	—	—	—	—	1.00(1)	—
25.5	—	—	—	—	—	—	—	—
26.5	—	—	—	—	—	—	1.05(1)	—

The measurements can be considered from another point of view. Taking the distinction between the eggs of spring and autumn spawners as proved, we may for each class plot, for ova of a given diameter, the weight of the gonad against the length of the fish, assuming in this case that, in each group, the size of the ovum represents a definite stage in development. In the graphs (Figs. 2 and 3) this has been done for selected sizes of eggs.

It is evident from these graphs that the relationship $\frac{\text{weight of ovary}}{L^3}$ is not a constant value for any definite stage of maturity, but that the weight of the ovary increases more rapidly than L^3 or, in other words, than the size of the fish.

As a preliminary estimate it is suggested that the weight of the ovary at any given stage of maturity is proportional to $L^{4.5}$, and the broken lines shown on the graphs represent that proportion expressed in units corresponding to the size of the ova, the units at any length being directly proportional to the diameter of the ova; or, more concisely, they represent $\frac{cL^{4.5} \times d^3}{10,000,000}$ where d is the diameter of the ova and c is a constant, = 52 in the case of spring spawners and = 110 in the case of autumn spawners, the length being given in centimetres, the diameter of ova in millimetres and the weight in grammes. These figures were taken, without mathematical proof, as giving a satisfactory agreement with the distribution of the points on the graphs.

It will be noticed that although the samples of both spring and autumn spawners come from widely separated sources they all fall into position more or less accurately in their respective diagrams.

Any marked divergence of the points on the graph from the broken lines should indicate that the assumptions that have been made are not accurate. The most noticeable divergence is in the case of the largest fish whose ovaries in the advanced stages drop below the line, i.e., show a falling off in weight. It is suggested that this is because very large fish do actually show a smaller increase in the size of their ovaries than is indicated by $L^{4.5}$.

The data may be considered in a third way. Assuming that the weight of the ovary for fish of any particular length represents a definite stage of ripeness, it has been shown that the spring spawners have consistently larger eggs, i.e., for a fish of the same size and weight of ovary the eggs of a spring spawner are approximately 25 per cent. larger in diameter. It follows that, if the specific gravity of the eggs is the same, the volume of an egg in the spring spawner is almost twice as great, i.e., 195 : 100 and consequently the number must be about half as large, i.e., $\frac{10}{19.5}$. From the fact that all the ripening eggs in an ovary are approximately of equal size it may be inferred that the numbers destined to ripen in any breeding cycle are fixed from the time that the storage of yolk has begun. Consequently if the

specific gravity of the eggs, or, in other words, the weight of a given number at a given size, is known we can ascertain the actual number of eggs in an ovary if the weight of the ovary and the diameter of the eggs are known. An actual count of a carefully weighed fraction, about $\frac{1}{20}$, of three ovaries of Howth herrings, taken 16th September 1937, gave the following results:—

	Length	Weight of Ovary	Diam. of Ova	Estimated Number of Eggs
(a)	25.4 cm.	16.60 gm.	.991 mm.	36530
(b)	28.4 cm.	23.65 gm.	.991 mm.	52570
(c)	29.0 cm.	47.50 gm.	1.132 mm.	70120

These counts gave the following values for X in the equation

$$\text{Number of eggs} = \frac{\text{wt. of ovary} \times X}{\text{diameter}^3} : -$$

(a) 2162.9

(b) 2143.5

(c) 2141.2

An average value for X of 2150 has been taken, and this value has been applied to fish from selected samples from those mentioned above, for the purpose of estimating the total numbers of ova. Fish with ripe ova or with very small ovaries have been omitted. In the diagram (Fig. 4) the numbers of ova so obtained have been plotted against the length of the fish. The broken lines shown in the diagram correspond to $L^{4.5}$.

It should be noted that in this procedure no new data have been introduced other than the approximate value for the specific gravity of the ova, which is assumed to apply to all stages of maturity of any fish.

This diagram brings out more clearly what was deduced from the figures given earlier in the paper, namely, that the number of eggs in the autumn spawners is almost twice as great as in the spring spawners, and also that the rate of increase in number in fish over 32 cm. in length ceases to correspond to the increase in length and either falls off considerably or ceases altogether.

It will be noticed that there are small discrepancies between the results obtained from these three methods of treatment. In Fig. 1 the comparative diameters of the ova of spring and autumn spawners are shown as having the ratio of 405 to 510, which is equivalent to a difference in size of 1 to 2. In Figs. 2 and 3 the most satisfactory expression of the ratio of the weights of the ovaries appears to be 10 to 21, and in Fig. 4 the difference in numbers of ova was as 25 to 58. Most, if not all, these discrepancies are no doubt due to the rule-of-thumb methods used in dealing with the data.

It follows from the figures which have been given that, taking both spring and autumn spawners together, the size of the eggs is not a measure of the stage of ripeness, but for each group separately the choice is open between the size of the eggs and the weight of the ovary

Fig. 4. Numbers of active ova (thousands) in spring and autumn spawning herrings at successive lengths.

as an indicator of ripeness, the data available up to the present being insufficient to decide between them; for we cannot yet say, as between two herrings of the same size, one with more numerous ova than the other, whether the ripe eggs of the former will be smaller than or of the same size as those of the latter or whether size and number both vary independently round a mean.

The primary cause of the difference between the spring and the autumn spawners must surely be looked for in a genetic difference which induces a difference in habit, but it seems possible that the conditions under which development of the ova commences and is carried on may have some effect on their number and size. The recovery of the ovary and development of the new crop of eggs appears to take place very shortly after spawning, and in the case of the spring spawners this usually occurs when the temperature of the sea is at its minimum or is just beginning to rise, while the autumn spawning occurs while the temperature is still high but has begun to fall after its summer maximum.

Summary.

The spring and autumn spawning Irish herrings, so far as they have been examined, can be separated at any stage of maturity by the size of the ova in relation to the weight of the gonad.

For fish of the same size the ova in an ovary of any given weight are approximately 25 per cent. larger in spring spawners than in autumn spawners and about half as numerous.

The weight of the ovary for ova of the same size is approximately proportional to $L^{4.5}$ for both spring and autumn spawners.

The number of ova is proportional to $L^{4.5}$ for both spring and autumn spawners.

There are indications that there is a falling off in the numbers of ova in proportion to the length of the fish in fish of above 32 cm. in length.