REPORT

ON THE

RESULTS OF THE FISH-EGG CRUISE MADE BY THE S.S. "HUXLEY" IN JUNE, 1909,

BY

H. J. BUCHANAN-WOLLASTON.

With Tables I. to III.; Figures 1.–13. in the Text; Plates I. and II., and Two Appendices.

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CONTENTS

	Page.
METHODS OF RESEARCH	209
TABLE I.—Showing Number and Species of Fish Eggs and Fish Larvæ caught by the Hensen Net (Voyage 109 s.s. "Huxley")	211
SYSTEMATIC DISCUSSION OF THE SPECIES OF EGGS TAKEN	214
APPENDIX I.—On the Constant of the Hensen Net used by the "Huxley" in June, 1909 ...	225
TABLE III.—Showing Value in Millimetres of Divisions of the Micrometer Eyepiece with which the Eggs were measured...	226
APPENDIX II.—On Mathematical Methods of representing Groups of Fish Eggs and of separating Compound Groups into their Constituent Species	226
LIST OF LITERATURE	234

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ON THE

RESULTS OF THE FISH-EGG CRUISE MADE BY THE S.S. "HUXLEY" IN JUNE, 1909,

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The cruise of the "Huxley" in June, 1909, (voyage 109) was the first to be made by an English ship with the express purpose of making observations on the spawning of fishes by means of samples of eggs taken with a "quantitative" net. Hauls were also made with the Petersen Young Fish-Trawl at most of the stations, in order to catch larval and post-larval stages of fishes, but the examination of these has had to be postponed for a while. The present paper deals only with the results of the Hensen-Net hauls, the large catches of eggs made by the Petersen-Net being occasionally made use of in order to explain methods of obtaining standard sizes, &c., for different species of eggs. It is most important in examining Hensen-Net catches to have access to larger catches of eggs taken at nearly the same time.

With the exception of the samples taken on the voyage at present under discussion, those of voyage 110, and those taken in June, 1904 (voyage 32), all the collections we have are too much scattered over different years and various localities to be of much help in forming conclusions. The catches made in June, 1904, were examined and reported upon by Boeke (1). Where it seemed useful references have been made to these catches and others taken by the Dutch and German workers.

Appendix I. is a short discussion on the question of the constant for the Hensen-Net, and in Appendix II. are described methods for separating species of eggs which overlap as regards size. These should prove useful, as the methods at present in use for separating compound groups into their constituents are either somewhat rough, as Heincke's method ((2) pp. 194 et seq. and p. 201) or, very laborious, as that of Karl Pearson. That it is often extremely important to be able to separate one species of egg from another, which overlaps it in size, is obvious, when it is remembered in how many cases one of the overlapping species is of great value to the fisheries, while the other is comparatively unimportant. Such overlapping occurs, for instance, between the eggs of brill and gurnard, mackerel and gurnard, turbot and greater weever, and greater weever and mackerel, to mention those only which have come under our own observation in dealing with one month's catches. There has not been time to test the above methods except in one case, a somewhat difficult one, given as an example in Appendix II., but it was thought advisable to give a full description thereof in order that other workers might test them in practice.

Methods of Research.

The collections discussed here were made by vertical hauls from bottom to surface, with a large conical net constructed on the pattern of Hensen's quantitative Egg-net. The dimensions are given in Appendix I. The catches were preserved at once in one per cent. Formaldehyde solution in sea water (one part 40 per cent. Formaldehyde to 39 parts sea water), and examined ashore. A chart of standard sizes of eggs was made for reference, from large numbers of eggs caught by the Petersen Trawl on the same voyage, and another chart was made in the same way for the oil-globules of the eggs. These proved most useful for identifying eggs in the Hensen gatherings in stages before the development of pigment in the embryos. However, better charts could probably be formed by combining the sizes of eggs and oil-globules in the manner described in Appendix II., as has been done in the charts given for brill, mackerel and gurnard. The numbers of the various species of eggs taken were found by the use of the microscope, and tabulated for the stations. At all the stations two hauls were made, one immediately after the other. The numbers of eggs "per square metre surface" is therefore found by mutiplying the sum of the eggs in the two catches by $\frac{3}{2}$ (See Appendix I.). It was found that a most useful method for showing the pigment in difficult cases was to clear the eggs in Carbolic acid (saturated solution in absolute Alcohol). All that is necessary is to transfer them direct from the Formalin solution to 80 per cent. Alcohol, leave them in the Alcohol for two or three hours, then transfer them to the Carbolic acid. They very often collapse in the Alcohol, and also at first in the acid, but after a few hours in the latter, they regain their normal shape and *more than their normal size.* On the latter account, measurements, if wanted, must be made before clearing. By this method, the eggs become almost as clear as when living, the pigment stands out sharp and intense, that in the oil-globule appearing particularly clear. The difficulty of distinguishing turbot's from greater weever's eggs, or grey gurnard's from those of mackerel, disappears, except in the case of very young stages.

Photographs are given at the end of this report of different stages of various eggs as they appear after clearing. They were taken with a ½-inch objective without using an eyepiece. Using Imperial Ordinary plates, the correct exposure was found to be about three minutes, by the light of an incandescent gas burner placed about a foot from the mirror of the miscroscope. The concave side of the latter was used, and in order to obtain sufficient depth of focus, the aperture of the objective was decreased to an eighth of its ordinary diameter, by means of a Davis shutter.

As the slide used for counting and measuring the eggs was of a somewhat novel form, a description may be of use. The slide was designed by Mr. Todd, of the Lowestoft Laboratory, and the one actually used was made by the writer. The construction is very simple (Fig. 1). On an ordinary 3 in. by 1 in. microscope slide (*a*) a rim is made, either by

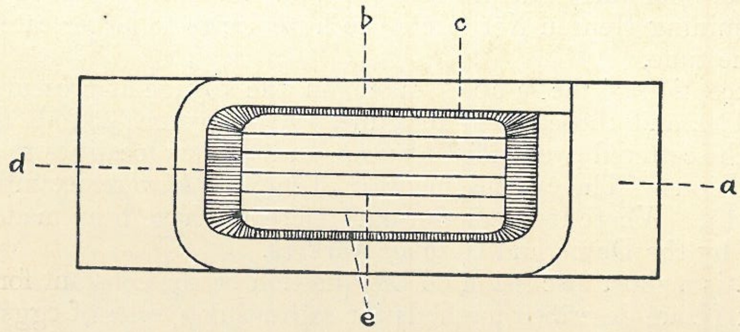

FIG. 1.—The slide used at Lowestoft Laboratory for measuring and counting Fish eggs.

pieces of glass cemented on, or by bending a glass rod (*b*) in a flame, so as to enclose a rectangular space, and cementing this to the slide with balsam. The spaces under the rod are filled in with paraffin-wax (*c*), in order to make smooth walls to the centre space. Two small pieces of paraffin-wax (*d*) are warmed and pressed on to the slide at the ends of this space, and in these are imbedded fine glass rods (*e*) about ½ mm. in diameter, made by drawing out ordinary rod in a flame. It was found more serviceable to have two ½ mm. rods cemented one above the other than a single 1 mm. rod. These pairs of rods are placed at such a distance apart that eggs put on to the slide form rows and cannot pass each other. This slide does away with the chance of an egg being accidentally measured or counted twice, and allows of a large number of eggs being examined at a time. The rods do not interfere with measurement of the eggs, as the diameters to be measured can be taken at an angle of 45° to the direction of the rods.

In most cases the eggs and oil-globules were measured twice each, the measurements being taken approximately at right angles, as advised by Prof. Ehrenbaum. This does away to a certain extent with the error due to the lack of symmetry of the egg. The following tables show the actual numbers of eggs taken at the stations with the Hensen-Net, as well as the "number per square metre surface of water," the latter being printed in heavy type. After the tables follows a systematic discussion of the species of eggs taken. I must here take the opportunity of thanking Prof. Ehrenbaum for his most kind help during my stay at Heligoland, and Miss Lee, of Lowestoft Laboratory, who most kindly put her mathematical knowledge at my service, and without whose help I should have found considerable difficulty in developing the methods given in Appendix 2. My thanks are due also to Mr. Todd and Mr. Goodchild for kindly lending me the necessary photographic apparatus, and for other valuable help, and finally to Mr. Potter, who has spared no pains in preparing the plates and charts for press. The skill and dispatch with which these were made from my rough drawings has saved much time, and added greatly to the pleasure of the work.

TABLE I.—Showing NUMBER and SPECIES of FISH-EGGS and FISH-LARVÆ caught by the HENSEN-NET (Voyage 109).

Number of Eggs " per Square Metre " is given in heavy type.

Date.	No. of Station.	Position of Station.	Depth (Fathoms).	Species of Eggs.								Larvæ.
				Mackerel.	Horse Mackerel.	Sole.	Solenette.	Rockling and Scaldback.	Dragonet.	Sprat.	Other Species.	All Species.
6/6/09	5 (1)	52° 57′ N.	22	0	0	0	20	1	2	10	Dab, 1; Brill or Gurnard, 1.	None.
		2° 56′ E.		**0**	**0**	**0**	**76**	**1**	**16**	**31**		
	5 (2)	"	"	0	0	1	31	0	9	11	Dab, 2; Whiting, 2	None.
6/6/09	6 (1)	52° 56′ N.	16	1	0	0	8	1	0	1	Turbot, 1	None.
		3° 17′ E.		**1**	**0**	**0**	**46**	**9**	**3**	**7**		
	6 (2)	"	"	0	0	0	23	5	2	4	Lemon-sole, 1; Grey Gurnard, 1.	Dab, 1.
7/6/09	7 (1)	52° 57′ N.	16	4	1	1	33	1	5	2	None	Solenette, 1; Gobius sp., 1; Unknown, 1.
		3° 37′ E.		**6**	**1**	**1**	**79**	**3**	**10**	**18**		
	7 (2)	"	"	0	0	0	20	1	2	10	Dab, 1; Brill or Gurnard, 1.	None.
7/6/09	8 (1)*	52° 58′ N.	15	10	10	0	25	1	1	36	Whiting, 2; Dab, 1	Dab, 3.
		3° 56½′ E.		**30**	**30**	**0**	**75**	**3**	**3**	**108**		
7/6/09	9 (1)	52° 58′ N.	13	81	15	3	21	1	3	0	Dab, 1	Dab, 1.
		4° 16′ E.		**214**	**42**	**7**	**43**	**1**	**4**	**1**		
	9 (2)	"	"	62	13	2	8	0	0	1	Gurnard, 1 ...	Solea sp., 1; Dab, 1; Herring, 1; Gobius sp., 2.
8/6/09	10 (1)	52° 55′ N.	15	0	1	1	22	1	1	44	Dab, 1; Turbot, 1; Brill, 1; Lesser Weever, 1; Whiting, 3; Raniceps?, 1; Lemon-sole?, 1; Flounder?, 1.	Dab, 5; Globius sp., 3; Solenette, 2; Dragonet, 2; Unknown, 1.
		4° 2′ E.		**4**	**3**	**3**	**66**	**1**	**3**	**118**		
	10 (2)	"	"	3	1	1	22	0	1	35	None	None.
8/6/09	11 (1)	52° 51¾′ N.	14	3	0	5	59	1	9	2	Turbot, 2; Dab, 2...	Sole, 1; Solenette, 4; Dab, 1; Solea sp., 1; Dragonet, 4; Gobius sp., 1.
		3° 47′ E.		**6**	**0**	**7**	**166**	**4**	**25**	**10**		
	11 (2)	"	"	1	0	0	52	2	8	5	Dab, 1; Turbot, 1; Whiting, 1.	Solenette, 2; Sole, 1; Solea sp., 3; Dab, 1; Caranx, 1; Dragonet, 2; Gobius sp., 1.
8/6/09	12 (1)*	52° 48¼′ N.	15	0	0	0	30	0	4	6	Lemon-sole, 1 ...	Clupea sp., 2; Dab, 2; Dragonet, 6; Gobius sp., 1; Solea sp., 1; Solenette, 2.
		3° 31½′ E.		**0**	**0**	**0**	**90**	**0**	**12**	**18**		
8/6/09	13 (1)	52° 44½′ N.	16	0	0	1	40	4	1	13	Brill, 1	Solenette, 1; Dab, 3; Dragonet, 2.
		3° 15¾′ E.		**0**	**0**	**1**	**94**	**6**	**7**	**30**		
	13 (2)	"	"	0	0	0	23	0	4	7	Brill, 1; Turbot, 1	Dab, 6; Solenette, 1; Clupea sp., 2; Scaldback, 1; Dragonet, 1.
8/6/09	14 (1)	52° 41′ N.	20	0	0	2	6	0	10	27	Dab, 2; Turbot, 1; Brill, 2.	Whiting, 1; Dab, 1.
		3° 0′ E.		**0**	**0**	**3**	**22**	**0**	**27**	**60**		
	14 (2)	"	"	0	0	0	9	0	8	13	Gurnard, 1; Turbot, 1.	None.
8/6/09	15 (1)	52° 37½′ N.	23	1	0	0	4	0	5	145	Brill or Gurnard, 1; Turbot, 1; Dab, 1; Whiting, 1.	None.
		2° 44′ E.		**3**	**0**	**0**	**10**	**0**	**9**	**333**		
	15 (2)	"	"	1	0	0	3	0	1	77	None	Whiting, 1.
8/6/09	16 (1)	52° 34′ N.	26	1	0	0	0	0	0	18	None	None.
		2° 29′ E.		**4**	**0**	**0**	**1**	**0**	**0**	**48**		
	16 (2)	"	"	2	0	0	1	0	0	14	None	None.
8/6/09	17 (1)	52° 30½′ N.	22	0	0	0	0	1	0	13	Dead, 3	None.
		2° 13′ E.		**3**	**0**	**0**	**1**	**1**	**0**	**40**		
	17 (2)	"	"	2	0	0	1	0	0	14	None	None.
8/6/09	18 (1)	52° 27′ N.	18	0	0	0	0	0	0	0	None	None.
		1° 58′ E.		**0**	**0**	**0**	**0**	**0**	**0**	**4**		
	18 (2)	"	"	0	0	0	0	0	0	3	None	None.
8/6/09	19 (1)	52° 30½′ N.	16	1	0	0	0	0	0	2	Brill or Gurnard, 1	None.
		1° 53′ E.		**1**	**0**	**0**	**0**	**0**	**0**	**7**		
	19 (2)	"	"	0	0	0	0	0	0	3	None	None.
11/6/09	20 (1)*	52° 19½′ N.	12	1	0	0	0	0	0	0	Turbot, 1	None.
		1° 48′ E.		**3**	**0**	**0**	**0**	**0**	**0**	**0**		

* No. 2 haul lost.

Date.	No. of Station.	Position of Station.	Depth (Fathoms).	Species of Eggs.								Larvæ.
				Mackerel.	Horse Mackerel.	Sole.	Solenette.	Rockling and Scaldback.	Dragonet.	Sprat.	Other Species.	All Species.
11/6/09	21 (1)	52° 17′ N. 2° 4¾′ E.	20	1 **1**	0 **0**	0 **0**	0 **0**	0 **0**	0 **0**	14 **39**	None	None.
	21 (2)	,,	,,	0	0	0	0	0	0	12	None	None.
11/6/09	22 (1)	52° 15′ N. 2° 20¾′ E.	27	0 **0**	0 **0**	0 **0**	0 **0**	0 **0**	0 **0**	2 **16**	None	None.
	22 (2)	,,	,,	0	0	0	0	0	0	9	Dab, 1	Motella sp., 1; Clupea sp., 5.
11/6/09	23 (1)	52° 13′ N. 2° 37′ E.	22	0 **0**	0 **0**	0 **0**	0 **0**	0 **0**	1 **3**	0 **1**	None	Sole, 1; Clupea sp., 2.
	23 (2)	,,	,,	0	0	0	0	0	1	1	Turbot, 1; Whiting, 1; Lesser Weever, 1.	Clupea sp., 1.
11/6/09	24 (1)	52° 10½′ N. 2° 53′ E.	23	1 **1**	0 **0**	0 **1**	2 **6**	3 **9**	4 **12**	2 **7**	Dab, 1; Lesser Weever, 1.	Clupea sp., 5; Dragonet, 5; Whiting, 1; Dab, 2.
	24 (2)	,,	,,	0	0	1	2	3	4	3	Lesser Weever, 1; Flounder, 1.	Clupea sp., 5; Dragonet, 2; Solea sp., 1; Dab, 1; Pout, 1.
12/6/09	26 (1)	52° 9′ N. 3° 7′ E.	20	1 **6**	0 **1**	0 **6**	4 **10**	1 **4**	5 **16**	1 **1**	Gurnard, 2 (1?); Lesser Weever, 1; Whiting, 1.	Clupea sp., 2; Solea sp., 2; Dragonet, 2.
	26 (2)	,,	,,	3	1	4	3	2	6	0	Turbot, 1; Gurnard, 1.	Sandlaunce, 1; Solea sp., 3; Solenette, 1; Scaldback, 1; Dab, 2; Dragonet, 8.
12/6/09	27 (1)	52° 6½′ N. 3° 23′ E.	17	5 **10**	16 **63**	0 **0**	4 **34**	0 **3**	0 **3**	0 **0**	Turbot, 1; Mackerel or Gurnard, 1; Brill, 1; Whiting, 1.	Solea sp., 2; Solenette, 1.
	27 (2)	,,	,,	2	26	0	19	2	2	0	Gurnard, 1; Whiting, 1; Turbot, 2; Lemon-Sole, 1; Dab, 1; Lesser Weever, 1; Unknown, 1.	Gurnard, 1; Horse-Mackerel, 1; Solea sp., 5.
12/6/09	28 (1)	52° 4′ N. 3° 39′ E.	14	12 **37**	79 **217**	4 **9**	37 **97**	7 **15**	5 **15**	12 **40**	Gurnard, 1; Turbot, 2; Dab, 2; Whiting, 1.	Whiting, 1; Dragonet, 1; Solea sp., 2.
	28 (2)	,,	,,	13	66	2	28	3	5	15	Whiting, 1; Turbot, 1.	Solea sp., 2; Whiting, 1; Dragonet, 1; Horse-mackerel, 10; Unknown, 1.
15/6/09	29 (1)	52° 2½′ N. 3° 53′ E.	13	0 **0**	0 **0**	0 **0**	20 **73**	9 **37**	5 **12**	16 **70**	Turbot, 1; Dab, 3.	Whiting, 1; Solea sp., 2; Solenette, 1; Gobius sp., 2; Dragonet, 1; Unknown, 1.
	29 (2)	,,	,,	0	0	0	29	16	3	31	Brill, 1; Turbot, 1; Whiting ?, 1.	Dab, 1; Scaldback, 1; Horse-mackerel, 1; Dragonet, 2; Gobius sp., 2; Unknown, 2.
15/6/09	30 (1)	51° 49′ N. 3° 38′ E.	15	2 **9**	130 **406**	0 **3**	28 **64**	9 **21**	8 **18**	10 **28**	Brill, 1; Turbot, 1; Mackerel or Gurnard, 1; Gurnard, 1; Brill or Gurnard, 1; Dab, 1.	Solenette, 1; Horse-mackerel, 1.
	30 (2)	,,	,,	4	141	2	15	5	4	9	Anchovy, 1 ...	Horse - mackerel, 17; Solea sp.,* 1; Solea sp., 1; Whiting, 1.
15/6/09	31 (1)	51° 56′ N. 3° 22′ E.	16	3 **10**	35 **99**	0 **0**	9 **13**	7 **15**	6 **10**	0 **0**	Scomber or caranx, 1; Lesser Weever, 1.	Horse-mackerel, 4; Dragonet, 2; Solea sp., 3.
	31 (2)	,,	,,	4	31	0	0	3	1	0	Brill, 1; Gurnard, 1; Turbot, 1; Mackerel or Gurnard, 1.	Solenette, 1; Whiting or Poor-cod, 1; Clupea sp., 2; Gobius sp., 1.

* Apparently *Solea variegata* or *S. lascaris*.

Date.	No. of Station.	Position of Station.	Depth (Fathoms).	Species of Eggs.								Larvæ.
				Mackerel.	Horse Mackerel.	Sole.	Solenette.	Rockling and Scaldback.	Dragonet.	Sprat.	Other Species.	All Species.
16/6/09	33 (1)	51° 53′ N. 3° 7′ E.	17	4 13	23 43	0 0	4 10	2 4	2 7	0 0	Turbot, 1; Gurnard, 1; Lesser Weever, 1; Whiting, 4.	Horse-mackerel, 28; Dragonet, 5; Mackerel, 1; Solea lutea (?), 6.
	33 (2)	„	„	5	6	0	3	1	3	0	Turbot, 1; Gurnard, 1; Brill or Gurnard, 1; Lesser Weever, 2; Whiting, 1.	Horse-mackerel, 38; Dragonet, 4; Mackerel, 1; Solea sp., 2; Solenette, 1; Scaldback, 1; Sandlaunce, 1; Whiting, 1.
16/6/09	34 (1)	51° 49′ N. 2° 52′ E.	17	8 21	46 157	0 0	0 1	3 6	5 9	0 0	Whiting, 1; Lesser Weever, 1.	Horse-mackerel, 9; Dragonet, 3; Sole, 1; Solenette, 1; Sandlaunce, 1.
	34 (2)	„	„	6	59	0	1	1	1	0	Brill, 1, Dab, 1 ...	Caranx, 7; Dragonet, 2; Sandlaunce, 1.
16/6/09	35 (1)	51° 48′ N. 2° 35′ E.	23	3 7	0 0	0 0	0 0	0 3	7 21	2 10	Turbot, 1; Lesser Weever, 1; Gurnard, 1.	Dragonet, 5; Clupea sp., 18; Solea sp., 1; Scaldback, 1; Sandlaunce, 1.
	35 (2)	„	„	2	0	0	0	2	7	5	Lesser Weever, 1...	Dragonet, 5; Clupea sp., 14; Solea sp., 1; Mackerel, 1; Horse-mackerel, 1; Gobius sp., 1; Unknown, 1.
16/6/09	36 (1)	51° 47′ N. 2° 18½′ E.	23	0 0	0 0	0 0	0 0	0 0	0 0	1 1	Whiting, 1; Dab, 1	Clupea sp., 5.
	36 (2)	„	„	0	0	0	0	0	0	0	Whiting (?), 1 ...	Clupea sp., 3.
17/6/09	37 (1)	51° 45¾′ N. 2° 0′ E.	18	0 0	0 0	0 0	0 0	0 1	0 1	6 18	Lesser Weever, 2...	Solea sp., 1; Gobius sp., 1; Onos mustela, 1; Clupea sp., 1; Sandlaunce, 1.
	37 (2)	„	„	0	0	0	0	1	1	6	Gurnard, 1 ...	Solea sp., 1; Onos mustela, 1; Gobius sp., 2; Clupea sp., 2.
17/6/09	38 (1)	51° 37′ N. 2° 9′ E.	27	0 0	0 0	0 0	0 0	1 3	4 6	2 4	Unknown, 1 ...	Dragonet, 2; Clupea sp., 1.
	38 (2)	„	„	0	0	0	0	1	0	1	None	Dragonet, 2; Dab, 1; Gobius sp., 1.
17/6/09	39 (1)	51° 29½′ N. 2° 18′ E.	19	4 7	2 9	0 0	0 1	4 9	7 24	0 0	Lesser Leever, 1; Brill, 1; Greater Weever (?), 1.	Dragonet, 2; Horse-mackerel, 2; Clupea sp., 1; Pout, 1; Whiting, 1.
	39 (2)	„	„	1	4	0	1	2	9	0	Lesser Weever, 1; Turbot, 1.	Dragonet, 4; Horse-Mackerel, 3; Sandlaunce, 2; Gobius sp., 2.
17/6/09	40 (1)	51° 22′ N. 2° 27′ E.	17	1 9	115 459	0 0	0 1	2 9	1 13	0 0	Brill or Gurnard, 1; Mackerel or Gurnard, 1.	None.
	40 (2)	„	„	5	191	0	1	4	8	0	Brill or Gurnard, 2; Brill, 1; Unknown, 1.	None.
17/6/09	43 (1)	51° 18½′ N. 2° 8′ E.	17	1 6	41 103	0 0	0 0	3 6	5 15	0 0	Pilchard, 2; Lesser Weever, 3; Gurnard, 1.	Horse-mackerel, 1; Dragonet, 4; Sandlaunce, 1.
	43 (2)	„	„	3	28	0	0	1	5	0	Pilchard, 2; Brill, 1; Turbot 1.	None.
17/6/09	44 (1 & 2)	51° 13½′ N. 1° 51′ E.	21	4 6	25 37	0 0	0 0	3 4	1 1	0 0	Pilchard, 6; Lesser Weever, 1; Turbot, 1; Whiting, 1.	Dragonet, 1; Solea sp., 1; Horse-mackerel, 1; Gobius sp., 1.

It will be seen from the tables that the only species of eggs occurring in considerable quantities were those of Mackerel, Horse-mackerel, Sprat, and Solenette. The hauls with the Petersen Young Fish-Trawl, indeed, sometimes contained fairly large numbers of other species, such as Pilchard, Red Gurnard, Whiting, Grey Gurnard, Sole, Greater and Lesser Weaver, &c., but these hauls have not as yet been systematically examined and, even had they been, the value of the results from a quantitative point of view would be open to question. One useful result has come from them, however : they have afforded an excellent opportunity of obtaining a clear view of the differences between similar species, both as regards pigment and size, which would have been impossible with the very limited numbers of eggs caught by the Hensen-Net. It is hoped that the notes on these differences, in the case of Brill and Gurnard and Mackerel, and Turbot and *Trachinus draco*, together with the photographs, will render the identification of preserved eggs of these species somewhat easier. The identification and distribution of the eggs may be now systematically treated. The species are taken in the order of Boulenger's classification ; Fig. 2 is a chart showing the stations of voyage 109 at which the Hensen-Net and Petersen-Trawl were used, with the exception of Stations 1, 3, and 4, at which the sea was too rough for the former net to be employed.

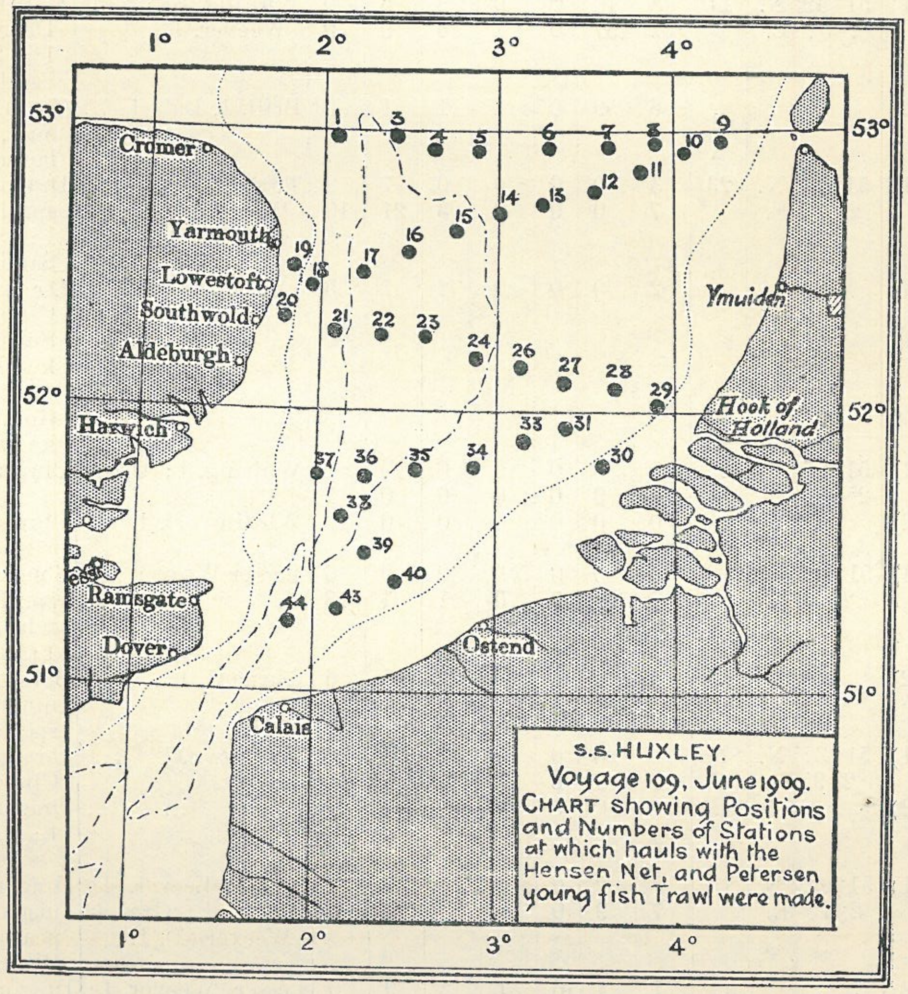

FIG. 2.

WHITING. (*Gadus merlangus.*)

One or two gadoid eggs occurred in a great many of the hauls. They possessed a curiously dark, vacuolated yolk, which, as Dr. Ehrenbaum informs me, is characteristic of whiting eggs. The following are measurements of a group of these eggs taken by the Petersen-Trawl at Station 28 :—

Eggs.

Micro-Divisions ...	31	32	33	34	35	36	37	38	39	Total
No. of eggs	1	1	2	9	23	23	14	2	1	76

Mean size 35·54 = 1·084 mm.

Ehrenbaum (2) gives 1·1 mm. as the average size of 36 Whiting eggs taken in the Plankton in May, and in (3) he gives two groups of measurements of 52 and 26 eggs respectively, with means of 1·048 and 1·043. The average size of the group given above is considerably greater, but probably within the range of annual variation. As June is very near the end of the spawning season for whiting, great numbers of eggs are not to be expected in the catches. The greatest number occurred at Station 33, off the Dutch coast, at about the middle of the 20–40 metre zone, where seven eggs per square metre were present. One or two eggs occurred at most of the stations. This is quite in accordance with what has been found by other workers, viz., that the spawning region of whiting in the North Sea is very extensive, and not limited to any particular part of the sea.

SPRAT. (*Clupea sprattus.*)

The eggs of the Sprat can be recognised in nearly all cases by the segmentation of the yolk, by the size (which, however, I have never found it necessary to measure), and by the fact that they usually show a somewhat marked deviation from the truly spherical form.

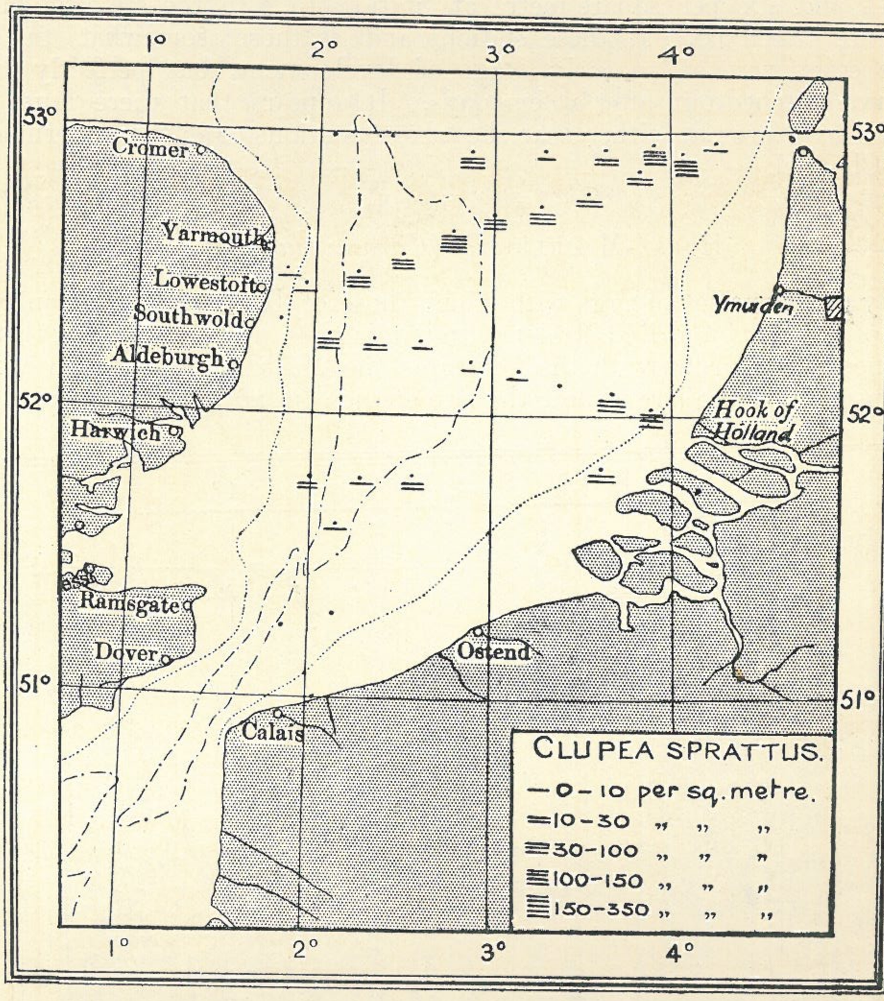

FIG. 3.

Sprat eggs occurred at nearly all the more northerly stations, even where the depth of water was great. The greatest number of eggs (viz. 333 per square metre) was taken at Station 15, where the depth was 22 fathoms (40 metres), and the next two greatest, 118 and 108 per square metre, at Stations 10 and 8 respectively, the depth at each being 15 fathoms (27 metres). However, at the three shallow stations, 28, 29 and 30, sprats' eggs also occurred in considerable quantities, so that we are not justified in saying that the sprat, at least in this part of the North Sea, prefers the deeper water to the shallower for spawning, or the reverse. Boeke (1) found great numbers of Sprats' eggs in the samples collected by the "Huxley," in June, 1904, in the neighbourhood of the Wash and off the coasts of Norfolk and Lincoln, and also in catches made far out to sea. Our observations, then, confirm the conclusions of Boeke and the other Dutch workers, that in the southern part at least of the North Sea, excepting perhaps the most southerly part—that south of the Mouth of the Thames—the Sprat is a ubiquitous spawner. Further north, off the East Friesian Islands, the eggs of the Sprat are also very abundant—indeed Ehrenbaum states (Ehrenbaum (3)), that in June, the eggs of the sprat are overshot by no other species in that region, as regards abundance. The absence of this species of egg from the catches made at Stations 27, 31, 33 and 34, while so abundant at neighbouring stations, is curious. It does not appear, however, from an examination of the salinities of the water samples taken, that this is due to the presence of a tongue of water of high salinity, extending from the mouth of the Channel over this region, as would at first sight be supposed.

Pilchard. (*Clupea pilchardus.*)

The eggs of the Pilchard are very easy to identify. They are very large, the yolk is segmented, the oil-globule minute, and the perivitelline space of extraordinary size, so that there is no other species of egg with which they can possibly be confused.

Pilchard eggs must have been present in considerable quantities in the most southerly part of the Flemish Bight in June, 1909, as nine per square metre were taken at Station 44, and six per square metre at Station 43. In the Petersen Trawl, large quantities were taken both at these stations and at those somewhat further north. Most of the eggs were at an early stage of development, but perfectly healthy, as numerous larvæ hatched out after a few days. It appears that there must have been spawning pilchards present either near the above stations or in the easternmost part of the English Channel.

Horse-Mackerel. (*Caranx trachurus.*)

The only other species of eggs with which those of Horse-mackerel can be confused, are the eggs of Mackerel and Red Mullet. In our catches, however, I think there is practically no chance of confusion with the former as the Mackerel eggs taken were without exception considerably the larger, and the two species did not, when measured in groups,

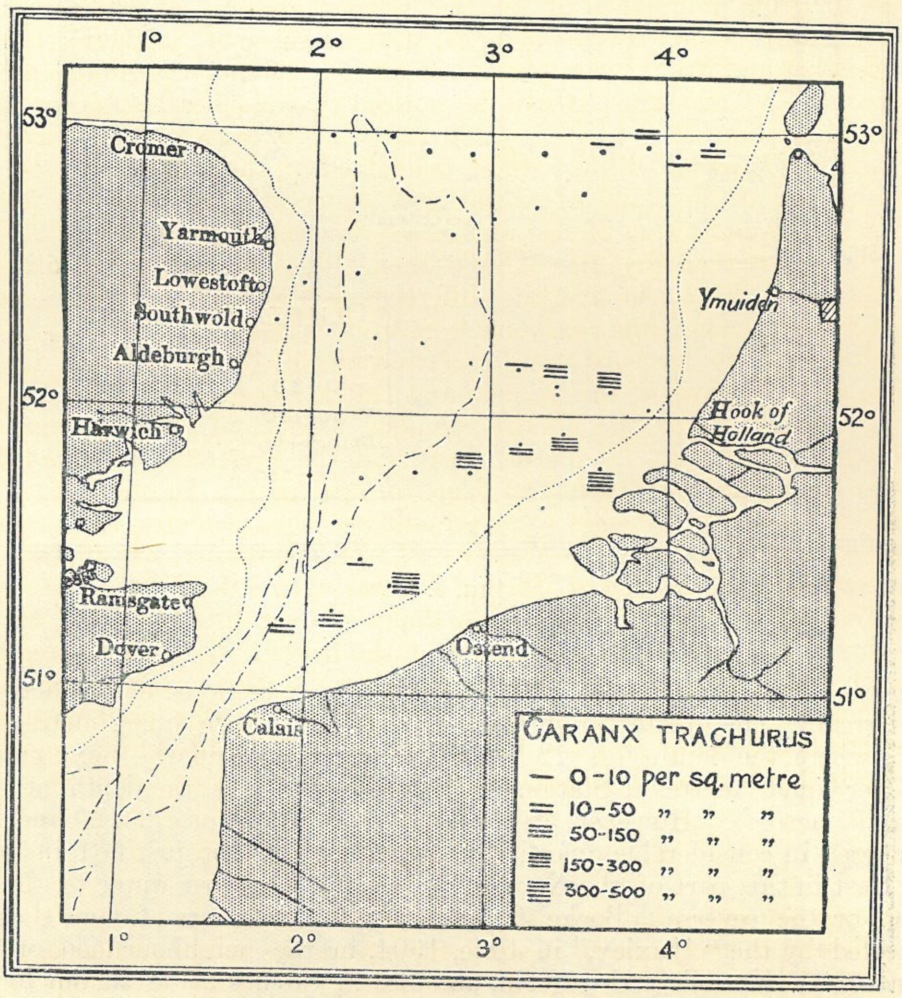

Fig. 4.

overlap at all. Horse-mackerel eggs, too, very often show a very marked segmentation of the yolk, even in preserved material, but not invariably. The measurements, when grouped, fitted the normal curve of error so closely, that it is not possible that any other species, even differing only slightly in size, can be mixed with the horse-mackerel eggs. Were those of *Mullus* present in any but insignificant numbers, this could not fail to be indicated by the skewness, or bimodal form of the resulting curve of measurements.

The following are series of measurements of *Caranx* eggs and the contained oil-globules. The eggs were taken in the Petersen Trawl at Station 28. The corresponding areas of the Curve of Error ($\sigma = \cdot 91$) for eggs, and that for oil-globules ($\sigma = \cdot 508$) are also given :—

Eggs.

Micro-Divisions ...	26	27	28	29	30	31	32	33	34	Total.
No. of Eggs	0	2	2	13	72	101	42	4	0	236
By Curve of Error ...	0	0	1	17	75	99	39	5	0	236

Oil-Globules.

Micro-Divisions ...	7 ...	8 ...	9 ...	10 ...	11 ...	Total.
No. of Eggs	0 ...	12 ...	25 ...	1 ...	0 ...	38
By Curve of Error ...	0 + ...	11 + ...	25 + ...	1 + ...	0 + ...	38 +

The eggs of *Caranx* occurred abundantly at all the eastern stations, particularly at those nearest to the Southern Dutch and the Belgian coasts. The greatest quantities taken were 406 per square metre at Station 30, and 459 per square metre at Station 40. They were quite absent from the catches at all the western and central stations.

We may say quite definitely from these results that the spawning ground of the Horse-mackerel in this part of the North Sea is off the Dutch and Belgian coasts, in shallowish water (20 to 40 metres).

The absence of *Caranx* eggs from the hauls at Station 29 is most extraordinary. They occurred in great abundance at the two nearest stations, at which the depth was only slightly greater. Other species of eggs, such as those of Solenette, Rockling and Scaldback, Dragonet and Sprat, were present at Station 29 in proportions approximating to those at Stations 30 and 28. It will be noticed that Mackerel eggs are also absent from the hauls at Station 29. Is it possible that this is caused by a heavy outflow of fresh water from the Maas and Rhine, which is avoided by these fish ?

On examination of the table of salinities of water-samples taken on the voyage, it was found that that from Station 29 had remarkably low salinity, namely $32 \cdot 23 °/_{oo}$; this is more than $1 \cdot 0 °/_{oo}$ lower than any other sample taken. The salinity at Station 28 was 33·49, and that at Station 30, 33·28, so that the difference is probably sufficient to account for the absence of horse-mackerel and mackerel eggs from Station 29.

Our results as to the depth of water preferred by the Horse-mackerel for spawning do not quite agree with those of the German and Dutch researches. Both Tesch (4) and Ehrenbaum (3) lay stress on the almost complete absence of *Caranx* eggs at stations where the water is more than 30 metres deep, and the preference of this fish for even much shallower water, down to 10 metres deep, for spawning. In our case, at the eleven stations at which more than 50 eggs were present per square metre, the depths were as follows, taken in numerical order :—Metres : 27, 24, 31, 38, 31, 31, 26, 29, 31, 27, 31, and the greatest catch of all, that at Station 40, was with a depth of 31 metres. True, *Caranx* eggs are absent from stations with a depth of over 40 metres, but we cannot be certain that this is not due to the preference of the fish for the easterly regions of the Southern North Sea. The fact that the south-eastern stations nearest the coast yielded the greatest numbers of this species of eggs, proves, however, the preference of this fish for coastal waters as spawning grounds, but it appears that the spawning region is not so limited as regards depth as has been previously supposed.

MACKEREL. (*Scomber scomber.*)

Mackerel-eggs are somewhat troublesome to identify. In our catches, their size was found quite sufficient in every case to separate them from the rather similar eggs of Horse-mackerel, but this does not hold as regards Gurnard-eggs. In the later stages of Mackerel the pigment is very characteristic, particularly that on the head, and that on the sides of the body of the embryo ; and the pigment over the oil-globule may be included. In intermediate stages the body-pigment is in the form of two double rows of chromatophores, which later coalesce to form diagonal lateral bars. (Plate II., Fig. 2.) These may be the beginnings of the bars of the adult fish. The head-pigment consists of a continuous ring of anastomosing chromatophores, which completely surround the optic region, and two

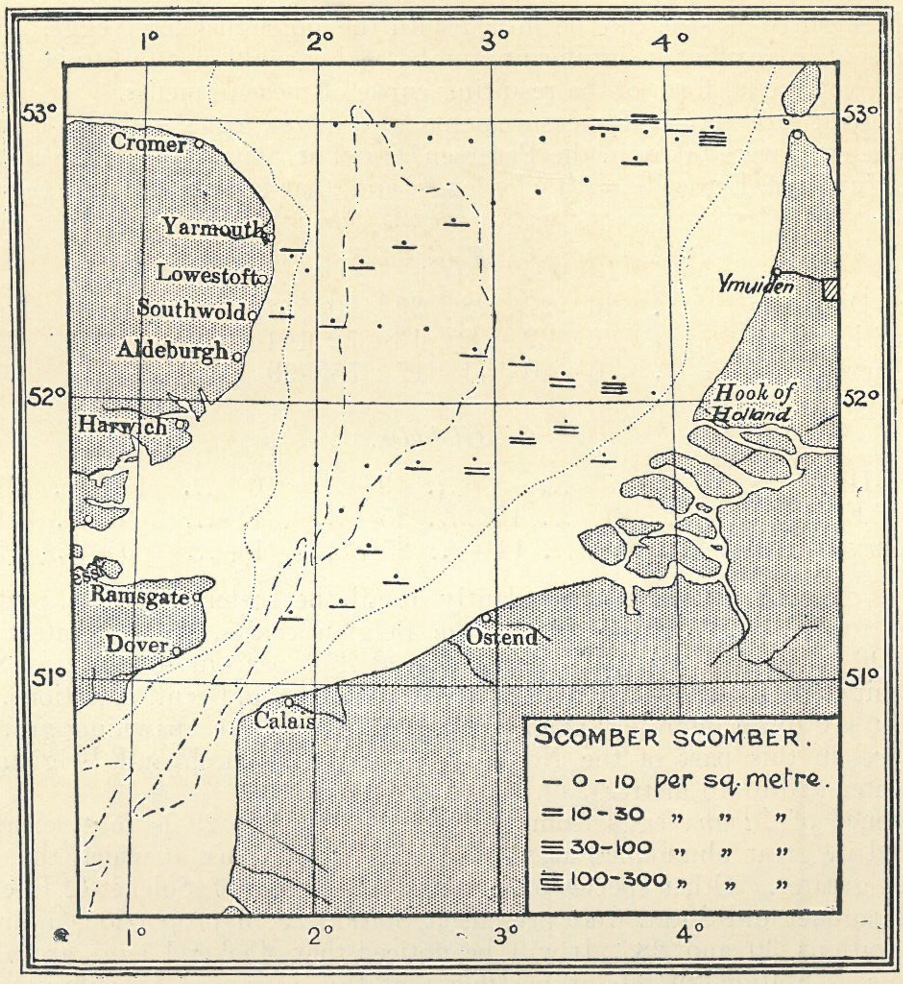

FIG. 5.

rows of similar chromatophores which extend down the sides of the occipital region and almost enclose it. The centre of the occipital region is practically free from pigment. (Plate II., Fig. 1.) The pigment-spots over the oil-globule are usually limited to one half. (Plate II., Fig. 2.)

Mackerel and Gurnard eggs in the earlier stages may be separated by the methods given in Appendix 2. I tested the methods on a mixed group of these two species—84 Mackerel and 36 Gurnard, and found that they gave a result very near the truth.

The average diameter of 200 Mackerel eggs from Station 9 was found to be 38·88 Micro-Divisions (1·1857 mm.) and that of the oil-globules 10·4575 Micro-Divisions (·319 mm.). The co-efficient of correlation between diameters of the eggs and oil-globules was ·58. In Appendix 2 is given an elliptical chart (Fig. 9) of these measurements, as well as another chart (Fig. 12) showing the amount of overlapping between Mackerel and Gurnard eggs measured. The distribution of Mackerel eggs in June 1909 is shown in the chart, Fig. 5. It appears that, as regards the Flemish Bight, the region between the 20 and 40 metre lines on the eastern side is preferred as a spawning-ground by this fish. The most southerly stations as well as those with deep water, and those on the English side, yielded but few Mackerel eggs. The Dutch and German workers obtained their greatest catches of these eggs further north, Ehrenbaum (*see* 3) north-west of Heligoland, and Tesch (*see* 4) near the Great Fisher Bank. The numbers, however, are considerably less than in our greatest, namely, that from Station 9, near the Haaks Lightship, where 214 per square metre were present. The spawning-region is thus shown to extend further south than has been previously supposed.

SOLE. (*Solea vulgaris.*)

Sole-eggs are easily recognisable from their size, the segmentation of the yolk surface and the arrangement of the oil-globules, which are very numerous and minute, and distributed in "clumps" throughout the yolk. After preservation the oil-globules sometimes coalesce to form larger globules, but in nearly all cases some minute ones remain, which serve to distinguish the eggs from those of Lesser Weever, when the segmentation of the yolk is not easily visible.

The following is a group of measurements of Sole-eggs taken at Station 30 in the Petersen Trawl.

Micro-Divisions ...	34	35	36	37	38	39	40	41	Total
No. of Eggs ...	1	1	3	8	8·5	5·5	1·5	·5	29

Mean = 37·621 = 1·147 mm.

Very few Sole-eggs were taken on voyage 109. The only stations at which they occurred in the Hensen-net, are the following, the "number per square metre" being given in brackets, namely, Station 9 (7) ; 10 (3) ; 11 (7) ; 13 (1) ; 14 (3) ; 24 (1) ; 26 (6) ; 28 (9) ; 30 (3). All these stations lie between the 20-metre and 40-metre lines on the eastern side of the Flemish Bight. The small size of the eggs, and the great quantity of postlarval stages taken in the Petersen Trawl, combine to show that the time of most intensive spawning had passed when the voyage was undertaken.

It was suggested to me by a passage in Boeke (1) (p. 31), that a comparison of the hauls made from the "Huxley," in June, 1904, in the neighbourhood of the Wash, with tow-nets—those hauls examined by Boeke—and of neighbouring hauls with large gear, would be instructive. Table 2 is a list of these. Unfortunately there are many hauls with the tow-nets with which there are none made with the shrimp and beam trawls to compare, but even the scanty records we have clearly indicate the Wash and neighbourhood as a spawning-ground for Soles. A cruise undertaken on a larger scale than the above in April, May or June, in this neighbourhood, on which parallel hauls with the large and small gear were made, would probably give very interesting results.

It will be seen from Table 2 that, on all occasions on which more than two Sole-eggs were taken in the tow-nets, except one, ripe or nearly ripe Soles also occurred in neighbouring hauls with the large gear.

In Table 2 the following abbreviations are used :—

SMALL GEAR.

Hor. Cl. N. (2) = Two Horizontal Closing Nets.
F. & C.S.T. = Fine and Coarse Surface Tow-nets.
F.S.T. = Fine Surface Tow-net.
C.S.T. = Coarse Surface Tow-net.

LARGE GEAR.

S.T. = Shrimp Trawl.
B.T. = Beam-Trawl.

TABLE 2.—Spawning of Soles in the Wash and neighbourhood. Showing the Hauls made with Tow-nets in June, 1904, in which Sole-Eggs were taken, compared with Neighbouring Hauls with the Shrimp-Trawl and Beam-Trawl.

Hauls with Tow-nets in which more than Two Sole-Eggs were taken.					Neighbouring Hauls with Shrimp-Trawl and Beam-Trawl.				
Date.	Gear.	Position.	Depth (Metres).	No. of Sole-Eggs.	Date.	Gear.	Position.	Depth (Metres).	Soles.
8/6/04	Hor. Cl. N. (2).	52° 59′ N. 0° 19′ E.	21	4	10/6/04	B.T.	53° 0⅛′ N. 0° 22′ E.	27	3 nearly ripe.
8/6/04	F. & C.S.T.	52° 54½′ N. 0° 16¾′ E.	13	5	10/6/04	S.T.	52° 54⅜′ N. 0° 16⅜′ E.	13	1 nearly ripe.
					"	S.T.	52° 56⅜′ N. 0° 18′ E.	13	2 nearly ripe.
					"	S.T.	52° 55⅝′ N. 0° 17¼′ E.	13	2 nearly ripe.
					"	S.T.	52° 55¼′ N. 0° 17⅛′ E.	13	1 nearly ripe, 1 spent.
8/6/04	F.S.T.	52° 59¼′ N. 0° 16′ E.	8	3	9/6/04	S.T.	52° 58′ N. 0° 18⅜′ E.	18	3 nearly ripe, 2 spent.
8/6/04	F. & C.S.T.	52° 59¾′ N. 0° 12⅜′ E.	9	3	8/6/04	S.T.	52° 59¼′ N. 0° 11¼′ E.	13	No Soles.
10/6/04	F. & C.S.T.	53° 1¾′ N. 0° 26¼′ E.	29	3	10/6/04	B.T.	53° 0⅛′ N. 0° 22′ E.	26	3 nearly ripe.
17/6/04	C.S.T.	53° 19½′ N. 0° 27′ E.	15	11	17/6/04	B.T.	53° 22½′ N. 0° 23¼′ E.	17	4 nearly ripe, 5 ripe, 7 spent.

SOLENETTE. (*Solea lutea.*)

The eggs of the Solenette are very easily recognized.

They were found to be very generally distributed over the eastern region of the Flemish Bight, being more abundant, however, at the more northerly stations. On the western side of the deep water they did not occur. The greatest number, 166 per square

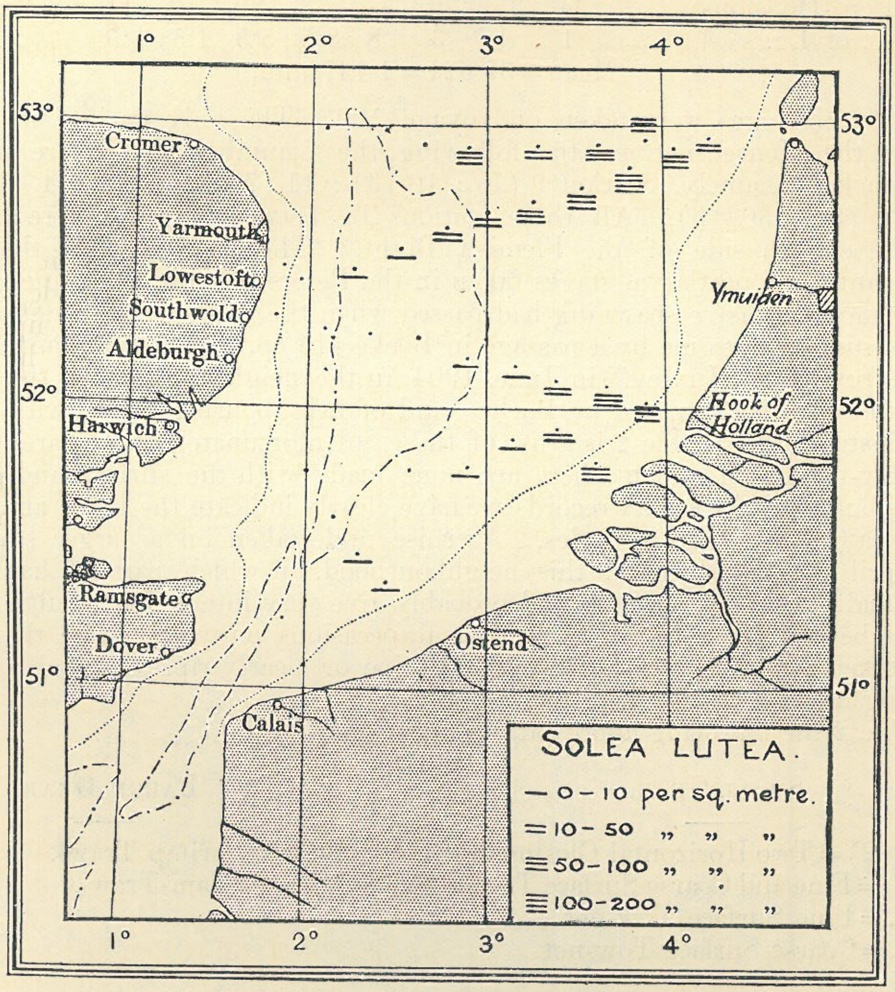

FIG. 6.

metre, was found at Station 11. It will be noticed that these eggs occurred plentifully at Station 29, proving that water of low salinity is not avoided by the Solenette for spawning. Our results agree well with those of the German and Dutch researches on the spawning of this fish.

DAB. (*Pleuronectes limanda.*)

The egg of the Dab is recognized by its being the smallest of those without oil-globules. Though overlapped in size by the Flounder's egg, the spawning time of the latter fish is probably quite past by June, so that all of these very small eggs found in that month, can be fairly safely ascribed to the Dab.

It will be seen from Table 1 that Dabs' eggs occurred in ones and twos at a great many of the stations, but it is obvious that the culminating point of the spawning-season of this species was long past when the voyage was undertaken. It is, of course, useless to attempt to draw conclusions from such small catches.

LEMON-SOLE or LEMON-DAB. (*Pleuronectes microcephalus.*)

Very few eggs of the Lemon-Sole occurred in the tow-nettings. The spawning-season had probably hardly begun as early as June, since, later on, in August, enormous numbers of Lemon-Soles were taken by the Lowestoft smacks on the Leman Banks and neighbouring region, most of them either ripe or spent.

TURBOT. (*Bothus maximus*) and GREATER WEEVER. (*Trachinus draco.*)

Though the eggs of the Turbot were taken in but small numbers in the Hensen-net—the greatest number being four per square metre—yet they occurred in greater quantity in many of the hauls with the Petersen trawl. Sufficient numbers were taken in the latter, in all stages of development, to render it possible to do something towards clearing up the important question—how to distinguish between Turbot eggs and Greater Weever eggs in different stages, when dealing with preserved material. Photographs are given (Plate I.) showing the differences between the pigmentation of the two species, beginning with that stage of development at which the first signs of dark pigment appear. In living eggs it is probable that pigment may be discerned in still earlier stages. The following are notes on the pigmentation, drawn up with the view of emphasizing the differences.

Stage 1.

Turbot (Fig. 1, Plate I.).—The whole of the dorsal surface, except the fore-part of the head and hinder part of the tail, is dotted with small circular dark-brown chromatophores.

T. draco.—No pigment is discernible.

Stage 2.

Turbot (Fig. 2, Plate I.).—The pigment is very similar to that of the first stage, but more intense, and extending now over the head and tail of the embryo.

T. draco.—The first signs of pigment begin to appear, in the form of two rows of irregular black chromatophores, extending, one along each side of the dorsal surface of the body from the eyes to a point nearly midway between the snout and the tail (as in Fig. 5, but more faint).

Stage 3.

Turbot.—As in Stage 2, but the chromatophores are now larger and less numerous, and have extended over the sides of the embryo.

T. draco (Fig. 5, Plate I.).—As in 2nd Stage, but some chromatophores are also present between the two rows, about midway between snout and tail.

Stage 4.

Turbot.—Form of pigment intermediate between that of Stages 3 and 5. The pigment-cells are now somewhat branched, particularly on the head.

T. draco (Fig. 6, Plate I.).—The lateral rows have broken up. A few scattered black chromatophores are now present on the head and gill-region and others form an irregular bar midway between snout and tail. One or two spots—one in photograph—are visible on the tail.

Stage 5 (probably shortly before hatching).

Turbot (Figs. 3 and 4, Plate I.).—Pigment is generally distributed over the embryo in the form of anastomosing stellate chromatophores, those on the head being larger and more markedly stellate. On the tail they are smaller and less intense.

T. draco (Figs. 7 and 8, Plate I.).—Scattered pigment-spots are present on the body from the snout to a point distant from the end of the tail about one-third of the length of the embryo. The remainder of the tail-region is free from pigment with the exception of one or two spots at the base of the embryonic fin near the caudal extremity. The head-pigment consists of two large irregular chromatophores *behind* and one or two *between* the eyes, also a group of large ones on the snout. The pigment over the oil-globule is very characteristic. All the chromatophores are intensely black.

The differences in pigment may be summarised for all stages as follows:—

Turbot.—Pigment in the form of *numerous almost radially symmetrical chromatophores* covering nearly the whole dorsal surface of the embryo and *extending over the tail region*, except in very young stages. In the oil-globule the chromatophores are of a fairly regular *stellate* form.

T. draco.—Pigment in the form of a *few scattered irregular chromatophores*—in the youngest stages forming a single row on each side of the body—*not extending beyond a point distant from the caudal extremity about one-third of the length of the embryo*, with the exception of one or two chromatophores at the base of the embryonic fin-membrane: Tail free from pigment with the exception of these last. Pigment in oil-globule consisting of *irregularly shaped chromatophores*, resembling the spots on the eggs of some birds—the Buntings, for instance.

As will be seen from the above notes, there is no difficulty in distinguishing by means of the pigmentation between the species in question, from that stage of development in which the tail of the embryo is almost free from the yolk, until hatching. In advanced stages neither the diameter of the egg nor that of the oil-globule are criteria, *since the oil-globule in Greater Weevers' eggs is gradually absorbed during development*, as in the eggs of the Lesser Weever. This renders it impossible, in the absence of a pure group of the

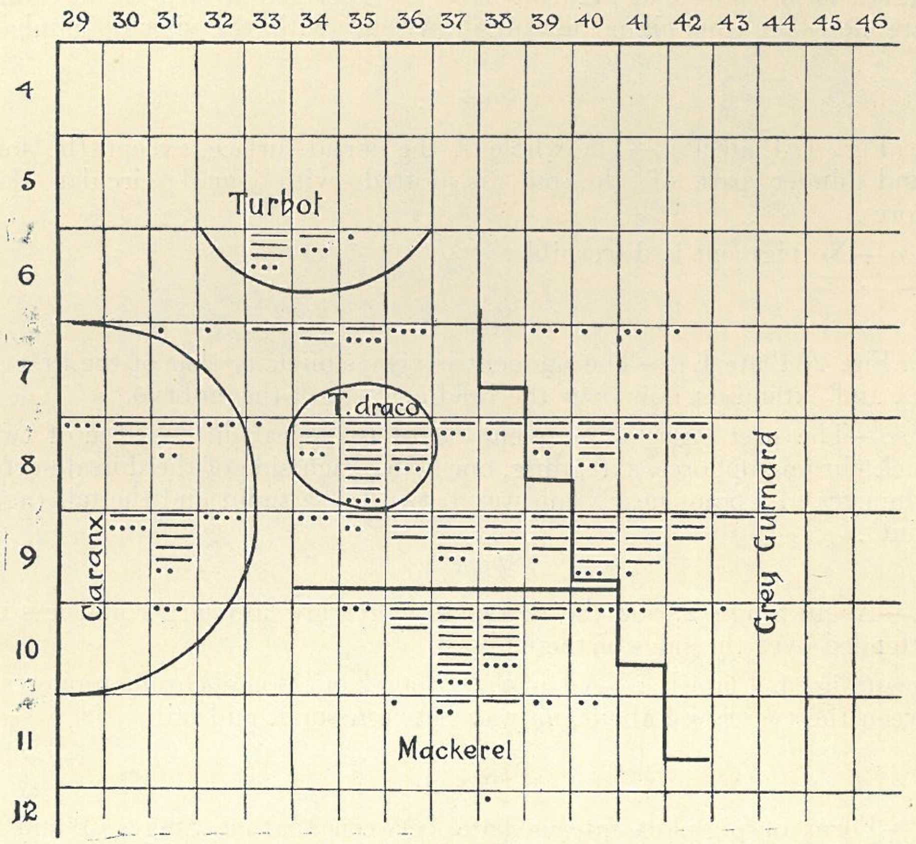

FIG. 7.

species, ever to obtain an absolutely correct standard size for the oil-globule. The average diameters of the two species of egg are not very different, though that of Weever eggs is slightly greater. In all our catches in which a considerable number of Greater Weever eggs occurred, they were overlapped in size on all sides, namely, by groups of Turbot, Mackerel, and Grey Gurnards' eggs, both as regards egg-diameter and O.-G. diameter.* The only way possible to disentangle the group in question would be to complete the other three by some mathematical method, such as those given in Appendix II. This is somewhat laborious, as it necessitates the evaluation of four or five curves of error. These evaluations have not been attempted in the case of our catches, as it is very probable that a purer group will be obtained in the future from which a better standard can be derived.

Tesch (4) gives 1·060 mm. as the mean diameter of a group of 37 *T. draco* eggs taken in July, 1908, and states that the oil-globules had diameters of from ·20 to ·23 mm. The stage of development is not noted.

The following are the measurements of a group of these eggs in advanced stages of development, taken in the Petersen trawl at Station 18, Voyage 110 (near the Haaks Lightship, 28/6/09).

Egg Diameters.

Micro-Divisions	33	34	35	36	37	Total
Eggs	0	3·5	10·5	5·0	0	19

Mean = 35·08 M.D. = 1·07 mm.

O.-G. Diameters.

Micro-Divisions	5	6	7	8	9	10	Total
Eggs	0	1·5	7·5	9·5	·5	0	19

Mean = 7·47 M.D. = ·22 mm.

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* *See* Fig. 7, which is a Table of measurements showing this overlapping. For an explanation of the way in which the figure is constructed, compare the account of Fig. 13 on p. 231.

It will be noticed that diameters of 7 M.D. and 8 M.D. are here about equally common among the oil-globules. But in the case of little-developed eggs from the same catch there is a very distinct mode at 8·0 M.D. (*see* Fig. 7), and the frequencies at 7 M.D. are small; it is obvious that the oil-globules have been gradually absorbed during development. This question needs further treatment. An elliptical chart was drawn up for a group of Turbot eggs from Stations 27, 30, 31, and 40 of Voyage 109, but it was found that the micro-divisions were too large for the method to give a satisfactory picture in the case of a group of eggs with such slight variability as those of Turbot. The measurements, taken separately for egg-diameter and O-G diameter, are as follows :—

Egg-Diameter.

Micro-Divisions	32	33	34	35	36	37	Total
Eggs...	0	16	20·5	6·5	1	0	44

Mean = 33·83 M.D. = 1·03 mm.

OG-Diameter.

Micro-Divisions	4	5	6	7	8	Total
Eggs	0	2	27	15	0	44

Mean = 6·3 M.D. = ·19 mm.

A group of 27 certainly identified eggs from a haul with the Petersen Trawl at Station 18, Voyage 110,—the haul for which Fig. 7 shows the measurements of unidentified eggs—gives a mean egg-diameter of 33·63 M.D., and a mean OG-diameter of 6·185, both being thus slightly smaller than in the case of eggs taken on Voyage 109.

Finally another difference, between the two species dealt with, may be noticed—that in the colour of the yolk. Turbot eggs, that is of course preserved ones, usually have a very clear and colourless yolk, while Weever eggs possess a yolk of a distinct yellow colour. In some Turbot eggs the yolk is also yellowish, but I have never seen Weever eggs with the other character.

Brill (*Rhombus laevis*) and Grey Gurnard (*Trigla gurnardus*).

Though the eggs of the Brill and Grey Gurnard were very rarely taken in the quantitative hauls they occurred in considerable numbers in the qualitative ones. At Station 29, for instance, over 100 Brill eggs were taken in the Petersen Trawl. An elliptical chart of the measurements of these eggs (Fig. 10) is given in Appendix 2. The mean diameter of the eggs was 43·525 M.D. (1·227 mm.) and that of oil-globules 7·22 M.D. (·22 mm.). Though in many cases the large size of the egg and the small size of the O.G. is sufficient to distinguish them from those of Grey Gurnard, yet the overlap is considerable (*see* Fig 12). The pigment, too, is in some stages very similar, in the two species. In advanced stages of development, there are characteristic differences. The Brill egg is much the more intensely pigmented on the head, and on the yolk near the gill-region, and the chromatophores are much smaller, more numerous, and less branched (Fig. 7, Plate II.). The pigment on the yolk in the Gurnard egg appears very early, and is at first intense, but it soon becomes faint, the chromatophores send off long processes (Fig. 3, Plate II.), and finally become almost invisible. The opposite is the case with the egg of Brill, that is to say, the pigment becomes continually more intense with development of the embryo. Figs. 4, 5, and 6 of Plate II., show well the pigmentation of a Gurnard egg in an advanced stage of development. The following characteristics may be noticed, (1) the large branched chromatophores on the head, (2) the faint pigmentation of the yolk, and (3) a very distinct row of pigment-spots on the dorsal fin-membrane, quite absent from the Brill-embryo. In still further advanced stages, just before hatching, all the pigment is almost invisible, and the pectoral-fins become very conspicuous; they are quite separate from the yolk and samewhat curled upwards. From the characteristics here noticed, it is usually possible in the case of a moderate number of eggs, to obtain a standard size for distinguishing eggs of this species in a less-developed state, from those of Mackerel and Brill. It will be seen that the curves formed from the Gurnard group in Appendix 2 have not the appearance of compound curves, and thus probably belong, mainly at least, to one species only. That this species is Grey Gurnard is highly probable, as the other species of *Trigla* are not nearly so common in the North Sea.

The mean diameters in the *Trigla* eggs measured were 40·86 M.D. (1·24 mm.) and 8·863 M.D. (·26 mm.) for eggs and O.G.'s respectively. These eggs, used to form the ellipse for Gurnards (Fig. 11), were taken at Stations 27, 28, 30, 31, 33, 35, and 40 of Voyage 109 in the Petersen Trawl.

SCALDBACK (*Platophrys laterna*) and ROCKLING (*Onos sp.*).

The eggs of the above species are difficult to distinguish except in advanced stages. They have therefore been entered in the same column in Table (1), though, in some cases, separation was possible by means of pigmentation. In cases where this was possible, it appeared that the groups consisted mostly of Scaldback eggs, since, as a rule, no pigment was visible. (*See* Ehrenbaum (3), pp. 237 *et seq.*) Scaldback and Rockling eggs occurred in nearly all the Hensen-Nettings taken between the 20 and 40 metre lines on the Dutch Coast; the two stations nearest shore, namely, 29 and 30, yielded the largest numbers, 37 and 21 per square metre respectively, the next largest being given by the neighbouring stations, 28 and 31. It is useless, however, to attempt to draw conclusions from such small catches, in the case of eggs which are not certainly identified.

As a rule, none of these little eggs were taken in the Petersen-Trawl, probably owing to the coarseness of the material of which it is made. It would be useful to obtain large catches by means of a finer-meshed Petersen-Trawl in order to obtain good standards, which might then be applied to the separation of the groups taken in the Hensen-Net.

RED GURNARD. (*Trigla cuculus.*)

Some large eggs very similar in pigmentation and general appearance to those of Grey Gurnard occurred in the Petersen-Trawl, four at Station 38 and five at Station 36, of Voyage 109; also 27 at Station 10 of Voyage 110 (between Stations 15 and 16, Voyage 109). The measurements were as follows:—

Egg-Diameters.

M.D.	46	47	48	49	50	51	52	Total
Eggs	1	5·5	8	8	7	3·5	3	36

Mean = 48·86 M.D. = 1·49 mm.

O.G.-Diameters (*omitting very irregular O.G.'s*).

M.D.	10	11	12	13	Total
Eggs	5	18·5	7	·5	31

Mean = 11·097 M.D. = ·339 mm.

The large size and coppery colour of the oil-globule render it probable that these eggs belong to Red Gurnard (*see* McIntosh and Masterman (5), pp. 134 and 462). The embryos, where present, show peculiar lobes, one on each side of the snout (Fig. 8, Plate II.), and the chromatophores on the yolk are large, faint and much branched, as in Grey Gurnard eggs, but to a greater degree. No pigment is visible on the embryo itself, but it is probable that, even if faint pigment had been present in the living egg, this would have become invisible after preservation. Though the above measurements showed distinct correlation between egg-diameter and O.G.-diameter, the number of specimens is not sufficient to warrant quantitative treatment.

GREATER WEEVER. *Trachinus draco* (*see* under Turbot).

LESSER WEEVER. (*Trachinus vipera.*)

The spawning season of this fish fell rather later than the first half of June in 1909. The Petersen-Trawl catches at some of the stations of voyage 110 (latter half of June 1909), and two or three hauls taken on the Knoll Flat on July 22, 1909, contain enormous numbers of Lesser Weever eggs.

DRAGONET. (*Callionymus lyra.*)

The eggs of the Dragonet are the most easily recognizable of all fish-eggs, by their peculiar honey-comb-like markings. These eggs may be divided into two groups as a rule—those with "cells" of large diameter on the capsule, and those with small "cells." It was formerly supposed that the small-celled eggs belonged to *C. maculatus*, but Prof. Ehrenbaum* informs me that this is very doubtful, if not improbable. Eggs with

* For possible explanation, *see* Ehrenbaum (3).

both sorts of markings were about equally common in our catches, and it seems probable that they both belong to *C. lyra*, as *C. maculatus* is a very rare fish in the Southern North Sea.

Dragonet eggs were taken at all the more easterly stations, though not in great quantities, the greatest catch being 35 per square metre at station (11), voyage 109. There is not apparently any preference shown by this fish for coastal waters. If a straight line is drawn from a point half-way between stations 4 and 5 to a point half-way between the Sandettie and Bergues Lightships, it will be seen that these eggs are fairly common at all stations to the Eastward of the line, and absent or rare at those to the Westward. These results agree, as to the depth of water preferred, with those of the German and Dutch workers.

APPENDIX I.

Note on the Constant of the Hensen Net used by the "Huxley" in June, 1909.

Two hauls were made with the above net at each station. The speed of hauling of the second differed somewhat in most cases from that of the first. Except in three cases only, viz., Stations 6, 29 and 40, it was found that the greater number of eggs was caught either (1) by the first haul, whether the quicker or slower, or (2) by the second haul when this was the quicker.

Omitting Stations 6, 29 and 40 and Station 22 as an extreme case (the greater catch was here four times as great as the lesser), also Station 9 at which the hauls were made at the same speed and Station 17 in which the numbers of eggs in the two catches were equal; finally omitting those hauls in which the total number of eggs caught was too small to give reliable results, there remain 18 pairs of hauls for comparison. The results are as follows :—

In 12 cases out of 18 the first haul gives the greater catch by an average excess of 37 per cent.
In 12 cases out of 18 the quicker haul gives the greater catch by an average excess of 44 per cent.
In 6 cases the first haul is the quicker and gives the greater catch by an average excess of 51 per cent.

In 6 cases the first haul is the slower and gives the greater catch by an average excess of 23·5 per cent.

In 6 cases the second haul is the quicker and gives the greater catch by an average excess of 37 per cent.

From these figures it is obvious that too much reliance must not be placed on the constant for the net as calculated from the speed of hauling. It is probable that the fact of the first haul's being often greater than the second, even when the latter is hauled more quickly, is due to the net's becoming somewhat shrunk and clogged by organisms such as *Phaeocystis* or *Noctiluca*. These organisms were present in great abundance at some of the stations, but unfortunately the estimation of the comparative numbers present is a matter of great difficulty, particularly as regards *Phaeocystis*.

I have thought it best in the circumstances to calculate a constant for the net from the *average* speed of hauling and to use this for all the catches. The calculation was carried out by means of Hensen's Tables (6) with the help of Dakin's paper (Dakin (7)).

The average speed of hauling was found to be ·3 metres per second; and the constant is therefore 1·182.

To reduce to "amount per square metre" the number of eggs must be multiplied by the above constant and by the factor $= \frac{\text{Area of net opening}}{\text{1 square metre}}$, *i.e.*, by $1{\cdot}182 \times 2{\cdot}598 = 3{\cdot}07$. As the net is made of material with 22 meshes per cm. instead of 23 per cm., as in No. 3 Müllergaze (the material used by Hensen in his calculation), the constant will be somewhat lower than 1·182, and the number of eggs per square metre will be given to a sufficient approximation by simply multiplying the catch by 3. This has accordingly been done to form the row in dark type in the Tables of Eggs in the present paper.

I append a list of measurements of the egg-net used at Lowestoft Laboratory. The measurements are of internal dimensions.

MEASUREMENTS OF THE HENSEN FISH-EGG NET USED AT LOWESTOFT LABORATORY.

Diameter of opening	70 cm.
„ of upper ring to which the net is attached	97 cm.
„ of lower ring joining net and bucket	19 cm.
Length of side of net (frustum of cone)	136 cm.
Half-angle at apex of net-cone (a)	16° 40′
Area of net opening	3848·5 q. cm.
Area of silk in net (N′)	26152·2 q. cm.
Area of silk in bucket (C.)	944 q. cm.
Total conical area of silk (N′ + C. cos. a)	=27056·5 q. cm.
No. of bolting-cloth ... ... Staniar's Quality I., No. 2.	
No. of meshes in silk per cm.	22

TABLE III.—Showing VALUE in MILLIMETRES of DIVISIONS of the MICROMETER EYEPIECE, by which the Eggs were Measured.

Number of Divisions.	Millimetres.	Number of Divisions.	Millimetres.	—	
1	·030497	31	·945407	Value of Fractions of a Division.	
2	·060994	32	·975904		
3	·091491	33	1·00640		
4	·121988	34	1·03690	Divisions.	Millimetres.
5	·152485	35	1·06739	——	——
6	·182982	36	1·09789	·05 ...	... ·00152
7	·213479	37	1·12839	·10 ...	... ·00305
8	·243976	38	1·15889	·15 ...	... ·00457
9	·274473	39	1·18938	·20 ...	... ·00610
10	·304970	40	1·21988	·25 ...	... ·00762
11	·335467	41	1·25038	·30 ...	... ·00915
12	·365964	42	1·28087	·35 ...	... ·01067
13	·396461	43	1·31137	·40 ...	... ·01220
14	·426958	44	1·34187	·45 ...	... ·01372
15	·457455	45	1·37236	·50 ...	... ·01525
16	·487952	46	1·40286	·55 ...	... ·01677
17	·518449	47	1·43336	·60 ...	... ·01830
18	·548946	48	1·46386	·65 ...	... ·01982
19	·579443	49	1·49435	·70 ...	... ·02135
20	·609940	50	1·52485	·75 ...	... ·02287
21	·640437	51	1·55535	·80 ...	... ·02440
22	·670934	52	1·58584	·85 ...	... ·02592
23	·701431	53	1·61634	·90 ...	... 02745
24	·731928	54	1·64684	·95 ...	.. ·02897
25	·762425	55	1·67733		
26	·792922	56	1·70783	NOTE.—Where no unit is mentioned in the measurements, the unit is the Micro-Division (M-D), or ·030497 mm.	
27	·823419	57	1·73833		
28	·853916	58	1·76883		
29	·884413	59	1·79932		
30	·914910	60	1·82982		

APPENDIX II.

On Mathematical Methods of representing groups of Fish Eggs and of separating compound groups into their Constituent Species.

It is often of very great importance, in the case of a catch of fish eggs, to be able to separate out two or more species of eggs which overlap in size. As a rule there are no morphological characters which enable us to do this before the embryos are far developed, and the pigment has begun to show specific characters. In the case of early stages we have to depend solely on mathematical methods applied to measurements taken under the microscope.

Heincke and Ehrenbaum (1. pp. 194 *et seq.*) give methods for roughly determining the positions of the *maxima* or modes for overlapping species and also a method (loc. cit. p. 201) for showing how many of each species are present in a compound group. The latter method was applied by the authors mentioned to distinguish between the eggs of Dab and Flounder, and in other cases, and has done very useful work ; it obviously, however, only gives correct results in cases where the component species are present in equal or nearly equal quantities, and where the modes are quite distinct. This is indeed pointed out by the above authors themselves. It is proposed here to give an account of a method which should give more exact results, and which may often be applied in cases where the maxima fall close together. It is, in the form in which it is developed here, only applicable to species of eggs with oil-globules, but the fundamental idea can be easily applied to the other case, though, possibly, with not quite such correct results.

In the case of eggs with oil-globules, the method depends on the assumption that the numbers of eggs measured with regard to their diameters and that of the contained oil-globules fit approximately a normal correlation surface. As the cases dealt with are purely biometrical, there is surely justification for the use of biometrical methods, and the above assumption is made by all biometricians who make use of the coefficient of correlation. The following method takes into consideration all the measurable characters of the eggs, that is to say, not only the actual diameters of eggs and oil-globules, but the relation between them. As an instance, consider an egg of 41 divisions, with an oil-globule of 9 divisions. Now an egg of 41 divisions may belong to either Grey Gurnard or Mackerel; similarly with an oil-globule of 9 divisions. But an egg of 41 divisions *with an oil-globule of 9 divisions* is most unlikely to be a Mackerel egg, or anything but a Gurnard egg. This, of course, only applies to eggs taken at the same time of year as those here considered, but the idea may easily be extended to fit other cases.

In the development of the methods the following symbols are used :—

$x_0\ y_0$=centre of correlation surface, *i.e.* centre also of all horizontal sections of the surface.
σ_1=standard deviation of all x's (egg-diameters) from mean of whole surface.
σ_2=standard deviation of all y's (O.G. diameters) from mean of whole surface.
r=coefficient of correlation between x's and y's.
k=any constant.

Method for representing Groups.

A good picture of a species of fish-egg as regards measurable characters (diameters of eggs and oil-globules) is given by a horizontal section of the correlation surface from which the frequencies at different measurements arise with least improbability. The values of σ_1, σ_2, and r are obtained in the usual way from the measurements, and these values, together with N, the total number of eggs in the group, fix the form and size of the correlation surface. The position of the centre is fixed by the positions of the means of the two characters measured. We must decide on a horizontal section of this surface, within which fall very nearly all the frequencies. As an example may be taken a horizontal section of the surface extending from $x_0\ y_0$ to $x_0\ y_0 \pm 3\ \sigma_1$, and from $x_0\ y_0$ to $x_0\ y_0 \pm 3\ \sigma_2$. This will probably contain the great majority of frequencies, but the limits may easily be extended if necessary. Nothing, however, would be gained in a case such as those considered here by including all extreme frequencies. The equation to the correlation surface is

$$Z=\frac{N}{2\ \pi\ \sigma_1\ \sigma_2\ \sqrt{1-r^2}}.\ e^{-\frac{1}{2}\left\{\frac{x^2}{\sigma_1^{\,2}\,(1-r^2)} - \frac{2\ xyr}{\sigma_1\sigma_2\,(1-r^2)} + \frac{y^2}{\sigma_2^{\,2}\,(1-r^2)}\right\}} \quad \ldots \quad \ldots \quad (a.)$$

where N is the total frequency ;
so that the equation of any horizontal section is :—

$$\frac{x^2}{\sigma_1^{\,2}} - \frac{2\ xyr}{\sigma_1\ \sigma_2} + \frac{y^2}{\sigma_2^{\,2}} + 2\ k(1 - r^2) = o, \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (b.)$$

which is the equation of an ellipse with centre $x_0\ y_0$. Equation (b) is obtained by putting $Z = a$ constant in (a).

The problem to be solved then is as follows :—" To draw an ellipse of the form of equation (b), touching the straight lines $x = \pm 3\ \sigma_1$ and $y = \pm 3\ \sigma_2$." Substituting $3\ \sigma_1$ for x, equation (b) becomes

$$\frac{1}{\sigma_2^{\,2}}(y^2) - \frac{6\ r}{\sigma_2}(y) + \left\{2\ k\,(1 - r^2) + 9\right\} = o. \quad \ldots \quad \ldots \quad \ldots \quad (c.)$$

For the condition that the ellipse given by equation (c) touches but does not cut the straight line $x = 3\ \sigma_1$, the roots of equation (c) must be equal, that is :—

$$\frac{36\ r^2}{\sigma_2^{\,2}} - \frac{4}{\sigma_2^{\,2}}\left\{2\ k\,(1 - r^2) + 9\right\} = o \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (d.)$$

$$\therefore 2 \quad (1 - r^2) = 9\ (r^2 - 1)$$

$$\therefore k = -\frac{9}{2}$$

Equation (b) then becomes

$$\frac{x^2}{\sigma_1^{\,2}} - \frac{2\ rxy}{\sigma_1\ \sigma_2} + \frac{y^2}{\sigma_2^{\,2}} + 9\ (r^2 - 1) = o. \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (e.)$$

Substituting the values $\pm 3\ \sigma_1$ for x, or $\pm 3\ \sigma_2$ for y, the points of contact are found to be

$$x = \pm 3\ \sigma_1,\ y = \pm 3\ r\sigma_2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (f.)$$
$$y = \pm 3\ \sigma_2,\ x = \pm 3\ r\sigma_1.$$

These points lie on the " Regression Lines "

$$y = \frac{\sigma_2}{\sigma_1}.\ r.\ x.$$

$$x = \frac{\sigma_1}{\sigma_2}.\ r.\ y.$$

that is, the Regression Lines pass through the points of contact between the ellipse and the straight lines $x = \pm 3\ \sigma_1$ and $y = \pm 3\ \sigma_2$.

In general, if the limiting values for x and y are taken as $\pm t\ \sigma_1$ and $\pm t\ \sigma_2$ respectively, the points of contact are

$$x = \pm t\ \sigma_1,\ y = \pm tr\ \sigma_2$$
$$y = \pm t\ \sigma_2,\ x = \pm tr\ \sigma_1$$

and the equation (e) becomes

$$\frac{x^2}{\sigma_1^{\,2}} - \frac{2\ rxy}{\sigma_1\ \sigma_2} + \frac{y^2}{\sigma_2^{\,2}} + t^2\,(r^2 - 1) = o \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (g.)$$

In Fig. 8 are given the equations of all the straight lines mentioned, as well as the co-ordinates of the points of contact and points obtained by putting $x = o$, $y = o$ in equation (e) in the particular

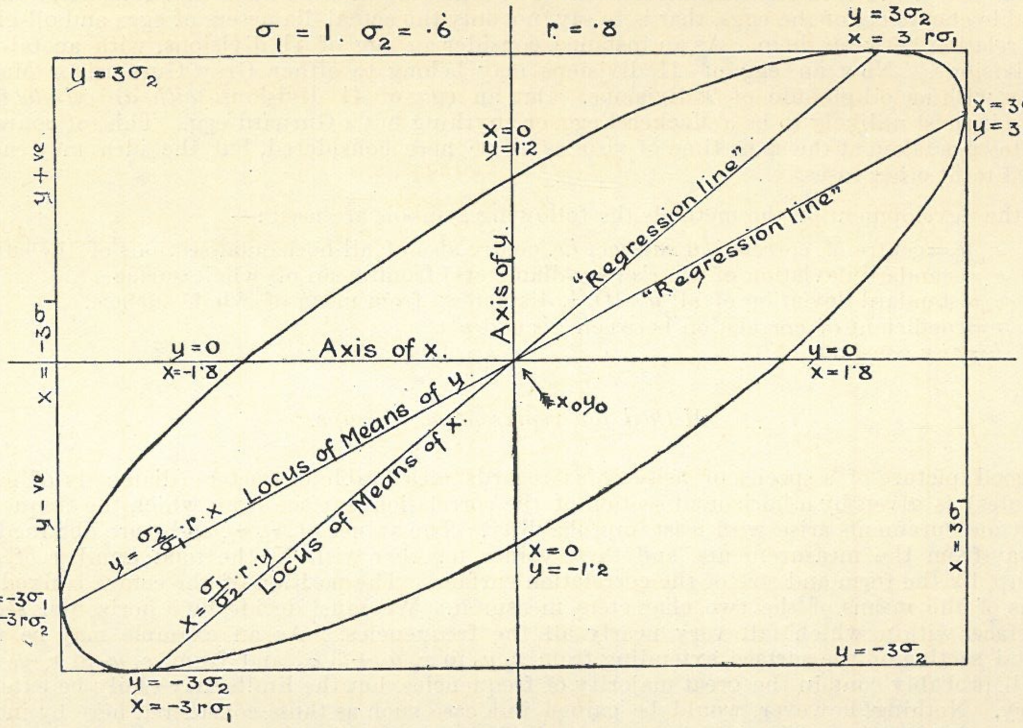


FIG. 8.

case when $\sigma_1^1 = 1$, $\sigma_3 = \cdot 6$, $r = \cdot 8$, and the limiting values for x and y have been taken respectively as $\pm\ 3\ \sigma_1$, and $\pm\ 3\ \sigma_2$. From these eight points the ellipse is easily drawn freehand.

The following shows the calculation needed to draw the ellipse for mackerel (Fig. 9). It will be noticed that the smaller ellipse, obtained by putting $x = \pm\ 3\ \sigma_1$, &c., includes nearly all the frequencies, while the larger, obtained by putting $x = \pm\ 4\ \sigma_1$, &c., includes them all.

Now

$$\sigma_1 = 1{\cdot}085,\ \sigma_2 = {\cdot}612,\ r = {\cdot}58.$$

All measurements are from the means (38·88 and 10·4575)

If

$$x = \pm\ 3\sigma_1,\ y = \pm\ 3\ r\ \sigma_2$$
$$x = \pm\ 3{\cdot}255,\ y = \ \pm\ 1{\cdot}065$$

$$2 \text{ points of contact are at } \frac{38{\cdot}88 + 3{\cdot}255}{10{\cdot}4575 + 1{\cdot}065} \text{ or } \frac{42{\cdot}135}{11{\cdot}522}.*$$

$$\text{and } \frac{38{\cdot}88 - 3{\cdot}255}{10{\cdot}4575 - 1{\cdot}026} \text{ or } \frac{35{\cdot}625}{9{\cdot}392}$$

If

$$y = \pm\ 3\ \sigma_2,\ x = \pm\ 3\ r\ \sigma_1$$

$$2 \text{ points of contact are at } \frac{40{\cdot}77}{12{\cdot}2935} \text{ and } \frac{36{\cdot}99}{8{\cdot}6215}.$$

Putting $x = o$ in equation (e) on page (227)

Then

$$\frac{y^2}{\sigma_2^2} = -\ 9\ (r^2 - 1) = 9\ (1 - r^2)$$

$$\frac{y}{\sigma} = \sqrt{9\ (1 - r^2)} = 3\ \sqrt{1 - r^2}$$

$$\therefore\ y = 3\ \sigma_2\ \sqrt{1 - r^2}$$

$$= 3 \times {\cdot}612 \times \sqrt{{\cdot}6636} = \pm\ 1{\cdot}49.$$

∴ Two points on ellipse are at mean of x's and at distances $\pm$ 1·49 from mean of y's or at $\frac{38{\cdot}88}{11{\cdot}95}$ and $\frac{38{\cdot}88}{8{\cdot}97}$.

Putting $y = o$ in equation (e)

$$x = 3\ \sigma_1\ \sqrt{1 - r^2} = \pm\ 2{\cdot}65$$

$$\therefore\ 2 \text{ points on ellipse are at } \frac{41{\cdot}53}{10{\cdot}4575} \text{ and } \frac{36{\cdot}23}{10{\cdot}4575}.$$

* This expression and similar ones below are not fractions ; the upper numbers indicate the values of x, and the lower those of y, at which the points in question fell.

From these eight points the ellipse was drawn freehand.
The points on the larger ellipse are given by

$$x = \pm 4\,\sigma_1,\ y = \pm 4\,r\,\sigma_2 \text{ (two points)}\ ;\ y = \pm 4\,\sigma_2,\ x = \pm 4\,r\,\sigma_1 \text{ (2 points)}$$
$$x = o,\ y = 4\,\sigma_2\sqrt{1 - r^2} \text{ (2 points)}\ ;\ y = o,\ x = 4\,\sigma_1\sqrt{1 - r^2} \text{ (2 points).}$$

Figs. 10 and 11 are similar ellipses for brill and grey gurnard, while Fig. 12 is a chart, showing the amount of overlap in the three species considered.

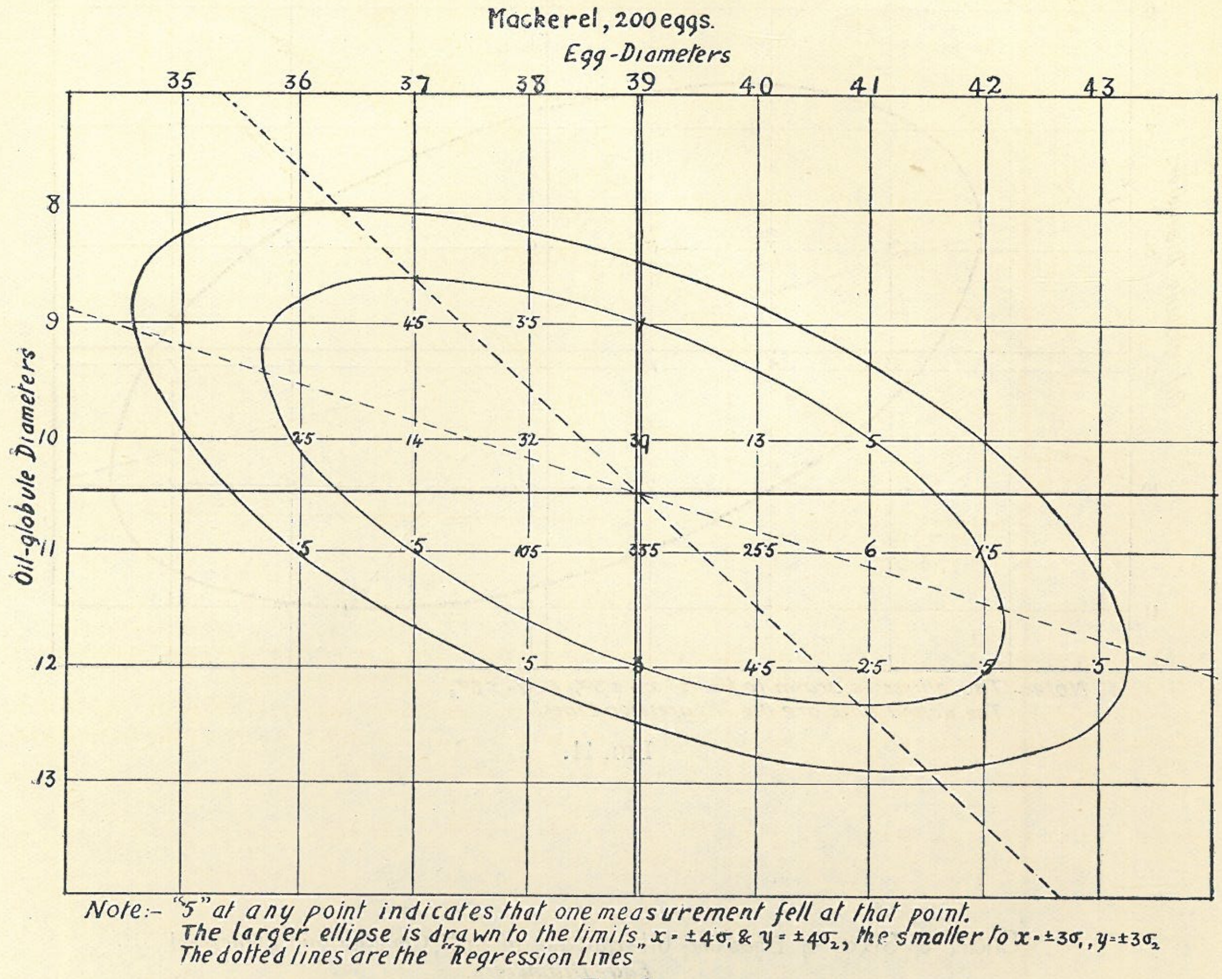


FIG. 9.

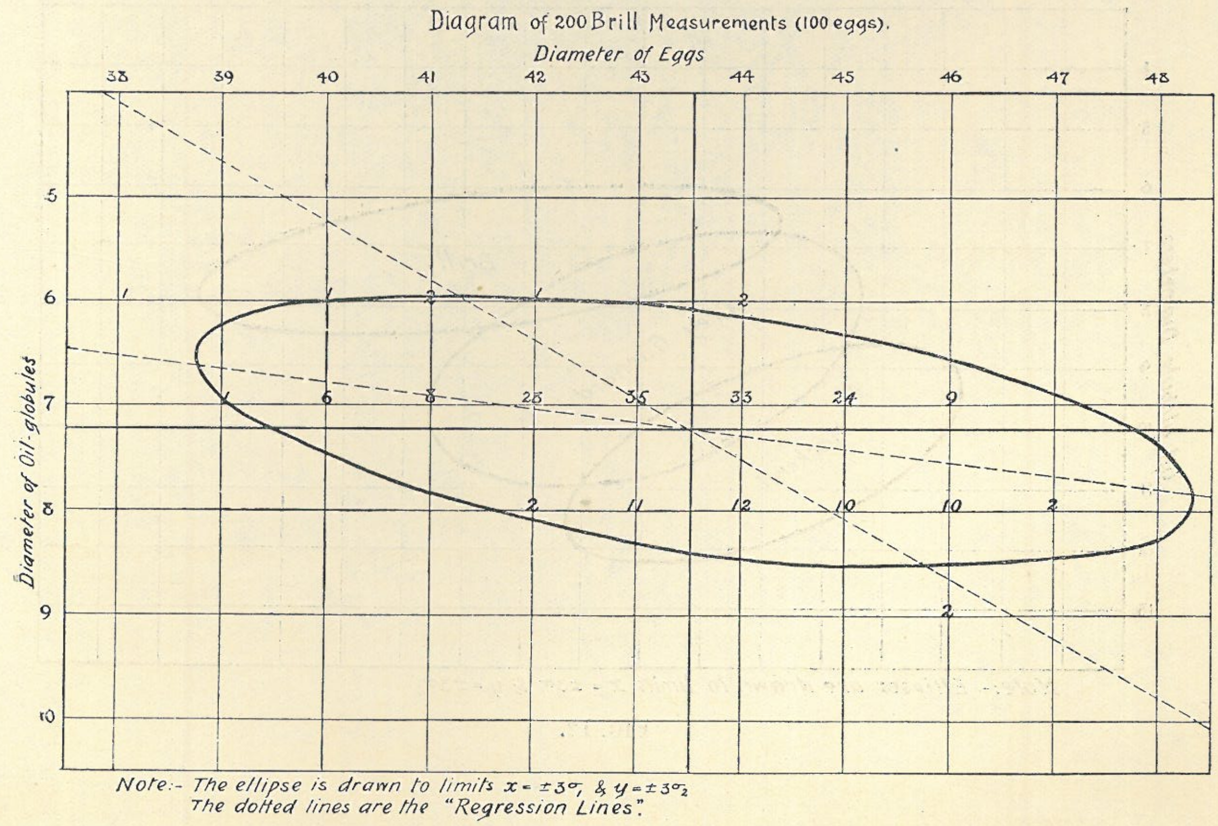


FIG. 10.

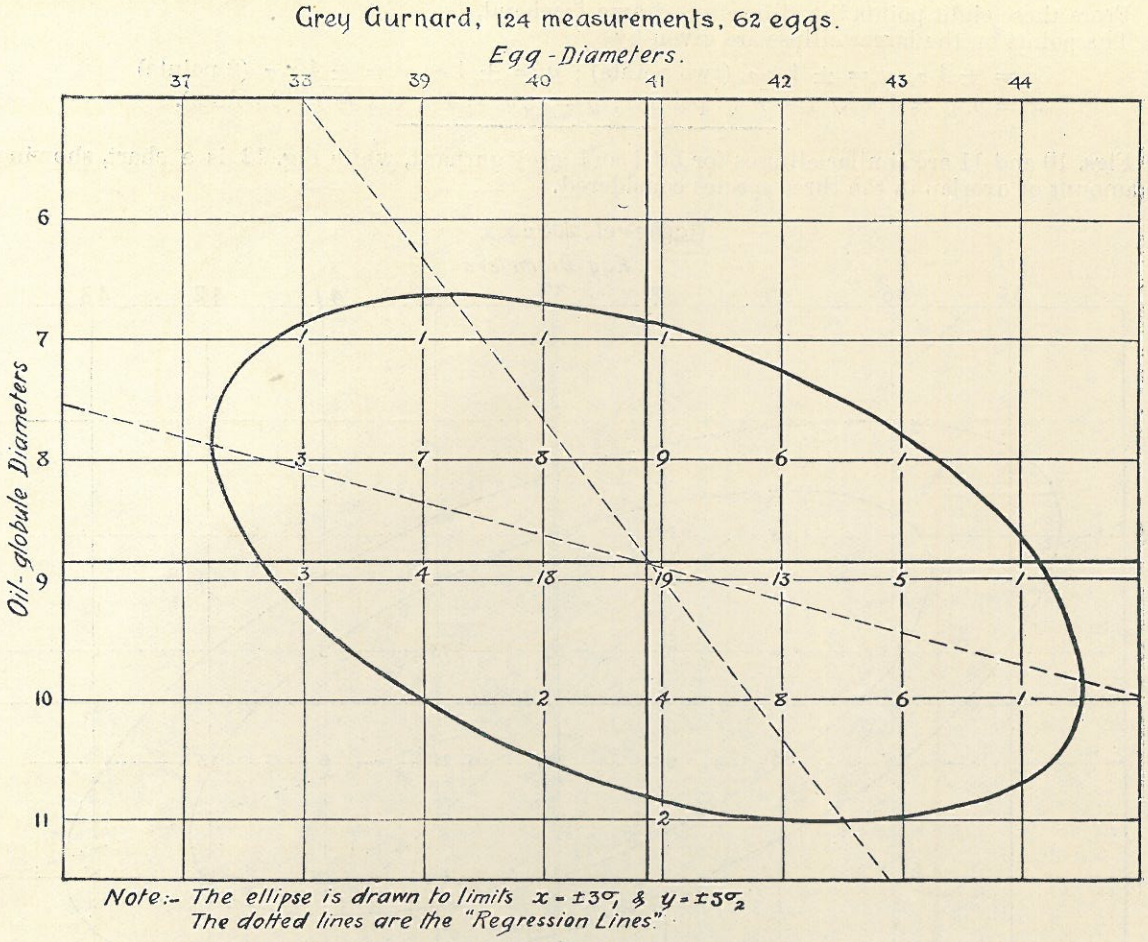

Grey Gurnard, 124 measurements, 62 eggs.
Egg-Diameters.
37
38
39
40
41
42
43
44
Oil-globule Diameters
6
7
8
9
10
11
Note:- The ellipse is drawn to limits $x = \pm 3\sigma_1$ & $y = \pm 3\sigma_2$
The dotted lines are the "Regression Lines."

FIG. 11.

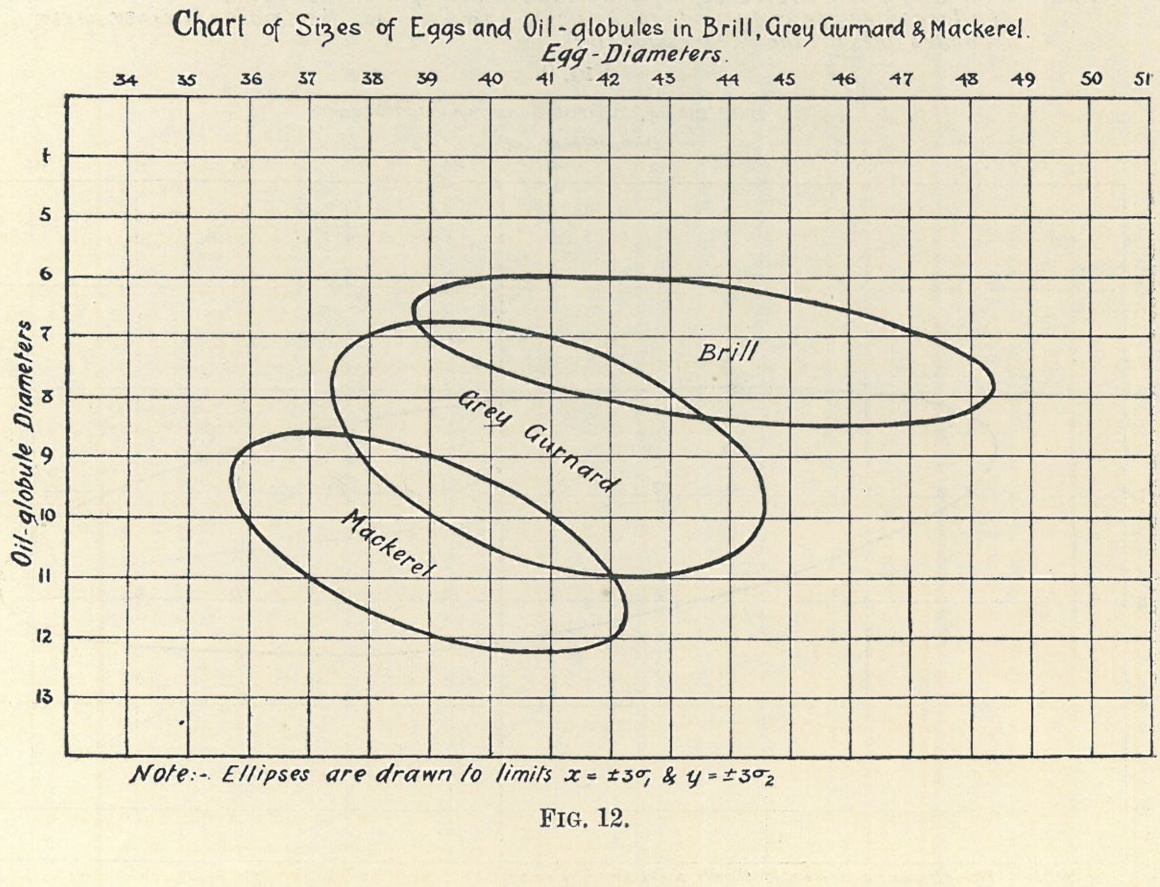


Chart of Sizes of Eggs and Oil-globules in Brill, Grey Gurnard & Mackerel.
Egg-Diameters.
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
Oil-globule Diameters
4
5
6
7
8
9
10
11
12
13
Brill
Grey Gurnard
Mackerel
Note:- Ellipses are drawn to limits $x = \pm 3\sigma_1$ & $y = \pm 3\sigma_2$

FIG. 12.

Methods of separating Compound Groups of Eggs into the True Numbers of their Constituent Species.

The methods may be most easily explained by means of an example.

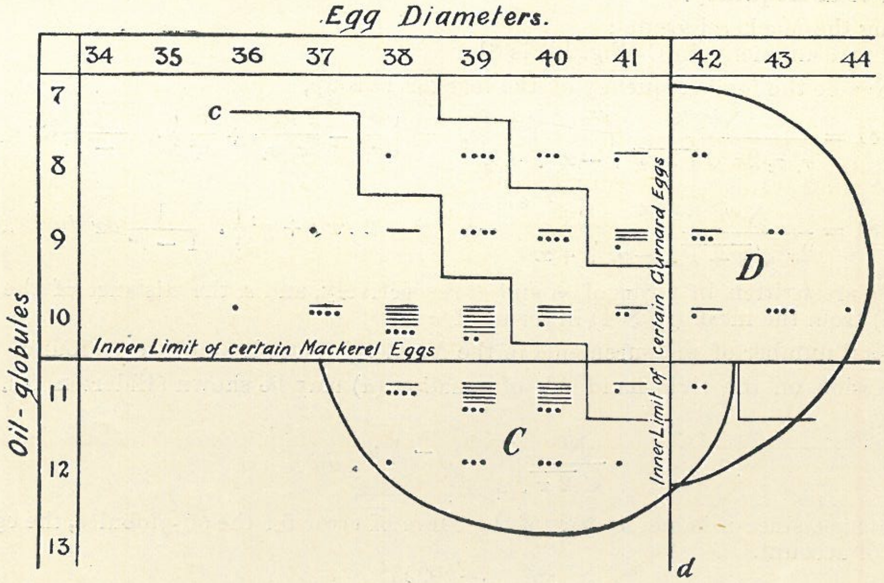


FIG. 13.

Fig. 13 is a table of measurements of 84 certainly identified eggs of Mackerel, mixed with 36 certain Grey Gurnards' eggs, all taken on voyage 109. The eggs are entered in the squares corresponding to their own diameter and that of the contained oil-globule. Each egg is measured twice, the measurements being taken as nearly as possible at right angles to each other, and a dot is placed in the table for each measurement; a line is drawn through each set of five dots. Where the pairs of measurements are found to differ both for egg-diameter and O.G.-diameter, *four* dots are entered in the table. For instance, in an egg whose measurements are $\frac{41\text{–}2}{9\text{–}10}$, dots are placed opposite $\frac{41}{9}$, $\frac{42}{9}$, $\frac{41}{10}$, and $\frac{42}{10}$, and these eggs are noted as they must be subtracted from the total of the whole group of measurements in the final calculation. We will now attempt to separate the two groups again mathematically.

The *means* of the two groups may be found (1) from any eggs of the same catch which can be certainly identified by means of the pigment or other non-measurable characters, or (2) from certainly identified eggs collected at neighbouring stations on the same voyage, or, if both of these methods are impracticable, (3) from eggs taken in another year, but at the same time of year; this last method would not be very reliable.

The standard deviations (σ_1, σ_2) of eggs and oil-globules are found either (1) in a similar way to the means, or (2) by finding the standard deviation of any pure row or column in the table, *i.e.*, any row or column all the entries in which are practically certain to belong to one species. This follows from the fact that in a normal correlation surface, the standard deviations of all the x-arrays are equal to each other and to that of the whole surface; similarly with the y-arrays (*vide* Elderton (8) pp. 113 *et seq.*). The coefficients of correlation (r) between egg-diameter and O.G.-diameter are probably sufficiently accurate if found once and for all for each species from fairly large series of measurements. "r" must be found for drawing the elliptical charts described above, but it need not be found for the separation method, as the expression obtained is independent of correlation.

In the example given, the means* as found from 115 other eggs taken on voyage 109 at the same station are for Mackerel 38·804 and 10·439 for egg-diameter and O.G.-diameter respectively, and the standard deviations, σ_1 and σ_2, are 1·16 and ·64 respectively. The coefficient of correlation (r) is found from the same group to be ·619 ± ·039. In the case of Gurnard eggs, the means are 40·765 and 8·687, as found from 29 certainly identified eggs taken at various stations on voyage 109; the standard deviations are 1·4 and ·73 and r = ·395 ± ·1. The large Probable Error of "r" is due to the small number of eggs measured.

We may now separate the given compound group into its constituents, with a fair degree of accuracy. The method is as follows:—

We may say, with fair justification, that *by reason of their measurements*, all eggs with O.G's of over 10·5 are Mackerel eggs; similarly, that all eggs of more than 41·5 in diameter are Gurnards'. In the example, the number of measurements (dots) of these certain Mackerel eggs is 81, and of gurnard 25. The straight lines in Fig. (13) are drawn through the limits mentioned. The number "2" in the square $\frac{\text{"}42\text{"}}{11}$ is included in both groups ("C" and "D" in Fig. (13)).

The whole compound group is considered as made up of two overlapping correlation surfaces.

* NOTE.—The means and standard deviations are most conveniently found by Mr. Hardy's summation method (*vide* Elderton (8) pp. 19 *et seq.*), but "r" is better obtained in the usual manner (*loc. cit.* pp. 107 and 119).

The equation to the correlation surface is :—

$$z = \frac{N}{2\pi\,\sigma_1\,\sigma_2\,\sqrt{1-r^2}}\,e^{-\frac{1}{2}\left\{\frac{x^2}{\sigma_1^2} - \frac{2\,xyr}{\sigma_1\,\sigma_2} + \frac{y^2}{\sigma_2^2}\right\}\cdot\frac{1}{1-r^2}},$$

where N is the total frequency.

Considering the Mackerel group ;
the number of measurements in C (Fig. 13) is 81.

Then, if $N^{(a)}$ be the total frequency of the mackerel group,

$$81 = \frac{N^{(a)}}{\sigma_1\,\sigma_2\,2\pi\,\sqrt{1-r^2}}\int_{-\infty}^{\infty}\int_{+\infty}^{+s} e^{-\frac{1}{2}\left\{\frac{x^2}{\sigma_1^2} - \frac{2\,rxy}{\sigma_1\,\sigma_2} + \frac{y^2}{\sigma_2^2}\right\}\cdot\frac{1}{1-r^2}}\,dx\,dy,$$

or

$$81 = \frac{N^{(a)}}{2\pi\,\sqrt{1-r^2}}\int_{-\infty}^{\infty}\int_{+\infty}^{+s} e^{-\frac{1}{2}\left\{x^2 - 2\,rxy + y^2\right\}\cdot\frac{1}{1-r^2}}\,dx\,dy \quad \ldots \quad \ldots \quad (\alpha)$$

where x and y are written in terms of σ_1 and σ_2 respectively, and s, the distance of the inner limit of c (*viz.*, 10·5) from the mean (38·804) in terms of σ_2.

$N^{(a)}$, the total number of measurements in the Mackerel group has now to be found.

The expression on the right-hand side of equation (α) may be shown (Elderton, *loc. cit.*, p. 127) to be equal to

$$\frac{N^{(a)}}{\sqrt{2\pi}}\int_{+\infty}^{+s} e^{-\frac{1}{2}y^2}\cdot dy$$

This is obvious, since it is merely part of the curve of error for the oil-globules, the egg-diameters being left out of account.

Then
$$81 = \frac{N^{(a)}}{\sqrt{2\pi}}\int_{+\infty}^{+\cdot0953} e^{-\frac{1}{2}y^2}\cdot dy$$

replacing s by its numerical value in the present case (*viz.*, ·061), divided by σ_2 (·64).

$$\therefore\ N^{(a)} = \frac{81}{\frac{1}{\sqrt{2\pi}}\int_{+\infty}^{+\cdot0953} e^{-\frac{1}{2}y^2}\cdot dy}$$

The denominator is equal to

$$\frac{1}{\sqrt{2\pi}}\int_{+\infty}^{o} e^{-\frac{1}{2}\cdot y^2}\cdot dy - \frac{1}{\sqrt{2\pi}}\int_{+\cdot0953}^{o} e^{-\frac{1}{2}y^2}\cdot dy$$

$$\text{and}\quad \frac{1}{\sqrt{2\pi}}\int_{+\infty}^{o} e^{-\frac{1}{2}y^2}\cdot dy = \cdot5$$

The second expression may be found from Davenport's Tables (Davenport (9), pp. 119 *et seq.*). It is equal to ·03784.

$$\therefore\ N^{(a)} = \frac{81}{\cdot5 - \cdot03784} = \frac{81}{\cdot46216} = 175\cdot2$$

The number of eggs in the group is thus found to be $\frac{175\cdot2}{2}$ or 88, since each egg was measured twice.

In the case of the Gurnards' eggs, $N^{(b)}$ the total number of measurements in the group is given by

$$N^{(b)} = \frac{25}{\frac{1}{\sqrt{2\pi}}\int_{+\infty}^{+\cdot525} e^{-\frac{1}{2}x^2}\cdot dx}$$

where the distance, from the mean, of the inner limit of D is written in terms of σ_1

$$N^{(b)} = \frac{25}{\cdot5 - \cdot2002} = \frac{25}{\cdot2998} = 83\cdot3$$

or the number of Gurnards' eggs present is 42.

Now the total number of eggs actually measured is seen to be 84 + 36 or 120.

This total should be divided in the proportions given by the above method.

viz., $\frac{88}{88+42} \times \frac{120}{1}$, or 81 *Mackerel eggs*.

and $\frac{42}{88+42} \times \frac{120}{1}$, or 39 *Gurnards' eggs*.

Thus the method in this case gives results very near the truth, *although the groups overlap very much, and the number of Gurnards' eggs is less than half that of Mackerel eggs*.

As a rule the standard deviations would not have to be specially calculated for each separation, but would probably already have been obtained from good pure groups taken at some neighbouring stations. They could then be applied to separate any compound groups taken on the same voyage.

Apart from the actual measuring of the eggs and oil-globules, the time required for the method is very short, and no mathematical knowledge is required *for its use* beyond that necessary to obtain the means and one of the standard deviations of each of the groups.

It will be seen that the problem here solved is really this :—"To complete two normal curves of error, when the centres, σ's, and parts of the curves between infinity and known distances from the centres are given." The problem might also be solved by tabulating the egg-diameters and O.G.-diameters separately and completing the O.G.-curve for Mackerel, and the egg-curve for Gurnards. The advantages in treating and tabulating the measurements as has been done here are (1) only half the number of entries are required ; (2) it is much more easily seen *which* eggs are practically certain to belong to one species or the other ; (3) these certain eggs often bear a larger proportion to the whole than would be the case if tabulated separately for egg-diameters and O.G.-diameters ; this is due to the correlation between the two sets of measurements. For instance there may sometimes be eggs with O.G.'s of 10 Divs., belonging to both Gurnard and Mackerel ; but, owing to correlation, nearly all the Gurnard eggs with so large an O.G. would fall some distance beyond the limit for Mackerel eggs with an O.G. of the same size, and therefore the 10-array would be seen to consist of two complete groups, one practically certain to be Gurnard, the other Mackerel.

Another quicker and more simple method is the following :—

Tabulate as before.

Tabulate in a separate correlation-table the diameters of eggs, and oil-globules in eggs, which may be certainly identified by means of pigment or other characters *not measurable.*

In the compound group divide off those eggs which *by reason of their measurements* are practically certain to belong to one species or the other.

In the separately noted eggs, if sufficient in number, find for each species what proportion the eggs of size corresponding to those divided off in the compound group bear to the whole group separately noted.

Consider the whole unknown groups for each species as made up in the same proportions, that is to say, to obtain the number in each unknown group, multiply the eggs "divided off" by $\frac{a}{b}$, where a=total number of "separately noted" eggs, and b=number of those of size corresponding to the eggs "divided off."

If an insufficient number of eggs have been "separately noted," the proportions must be obtained from catches taken elsewhere on the same voyage, as was done in the case of Gurnard in the example used in describing the longer method.

In this example, the measurements "divided off" for Mackerel numbered 81, and those for Gurnard 25.

In the group of 115 eggs used for separation of the Mackerel, the number of eggs with O.G.'s of over 10·5 was 49·5. The proportion of these in the complete group is then $\frac{49 \cdot 5}{115 \cdot 0}$. The total number of measurements in the unknown Mackerel group is then given by $\frac{81}{1} \times \frac{115}{49 \cdot 5}$ or 188.

The number of Mackerel eggs is therefore 94.

The number of Gurnard eggs is similarly found to be 35.

$$35 + 94 = 129.$$

This total must be divided, in the proportions given, to form the total of 120.

The number of Mackerel eggs is $94 \times \frac{120}{129}$ or 87.

The number of Gurnard eggs is $35 \times \frac{120}{129}$ or 33.

This result is as nearly accurate as that given by the longer method.

We are, however, justified in taking a larger number of measurements than 81 and 25, as being certainly of one species and the other respectively. The measurements divided off by the zigzag lines in Fig. 13 may be so taken.

The eggs in the standard group used, corresponding to those below the line "cd" in Fig. 13, number 102·5 ; therefore, to obtain the total number of Mackerel measurements in Fig. 13, the number below the line "cd" (viz., 148) must be multiplied by $\frac{115}{102 \cdot 5}$. This gives 166 measurements, or 83 eggs.

The Gurnard measurements are similarly found to number 77 or the eggs 38·5.

Dividing the total proportionately as before, these become 82 and 38, or each within two of the true number.

This result is quite sufficiently accurate for all practical purposes.

Though only one example of the methods has been given, it was not chosen as being in any way likely to give good results, and even had it been chosen to suit one method, that is no reason, *ipso facto*, why it should suit the other.

It may be asked why, seeing that the short method is sufficiently accurate, the long method should have been described here. In answer to this it may be said, that, where the groups are rough, and the numbers in them small, the long method might give superior results, as it is probable that the standard deviations obtained from small frequencies would show less chance variation than the number of instances in a particular part of the group. It has also another application, and that is as a method for completing the rows and columns of measurements of overlapping species, on the sides on which they overlap. In this capacity it might be useful for obtaining the measurements of a group overlapped on all sides by other species, and for which a standard could not be obtained, owing to an insufficient number of identifiable eggs being present, or other causes. The group, in this case, could be considered as composed of the remainder after the elimination of all the other groups by completion. The catch of eggs in the Petersen Trawl at Station 18 of Voyage 110 (Fig. 7), offers an instance of this, where the *Trachinus draco* eggs are overlapped in size by the groups of Mackerel, Gurnard, and Turbot, and it is impossible to obtain a standard size for the oil-globules in the first species, owing to their shrinkage in the course of development of the embryo.

List of Literature referred to in this Report (in order of reference).

(1.) *Boeke, J.*—Eier und Jugendformen von Fischen der südlichen Nordsee mit besonderer Berücksichtigung des holländischen Untersuchungsgebiets. Verhandelingen uit het Rijksinstituut voor het Onderzoek der Zee. I. Deel. 1906.

(2.) *Heincke and Ehrenbaum.*—Eier und Larven von Fischen der deutschen Bucht. II. Die Bestimmung der schwimmenden Eier und die Methodik der Eimessungen. Wissenschaftliche Meeresuntersuchungen. Abteilung Helgoland. N.F. Band III. 1900.

(3.) *Ehrenbaum, E.*—Ueber Eier und Jugendformen der Seezunge und anderer im Frühjahr laichender Fische der Nordsee. Wissenschaftliche Meeresuntersuchungen. Abteilung Helgoland. N.F. Band VIII. Heft 2. 1907.

(4.) *Tesch, J. J.*—Eier und Larven einiger im Frühjahr laichender Fische besonders der Südlichen Nordsee. Verhandelingen uit het Rijksinstituut voor het Onderzoek der Zee. Tweede Deel. 1909.

(5.) *McIntosh and Masterman.*—British Marine Food Fishes. Cambridge University Press. 1897.

(6.) *Hensen, V.*—Methodik der Untersuchungen der Plankton Expedition der Humboldt-Stiftung. Kiel. 1895.

(7.) *Dakin, W. J.*—The Filtration-Coefficients of Plankton nets. Lancs. Sea Fisheries Laboratory Report. 1908.

(8.) *Elderton, W. Palin.*—Frequency Curves and Correlation. London. 1906.

(9.) *Davenport, C. B.*—Statistical Methods. 2nd Edition. New York. 1904.

The most up-to-date and complete general treatise on the subject of Fish-eggs and Larvæ is the following, in which numerous references to other works may be found :—

Ehrenbaum, E.—Nordisches Plankton. Zehnte Lieferung. I. Eier und Larven von Fischen (2 parts). Kiel und Leipzig. 1908 & 1909.

EXPLANATION OF PLATES.

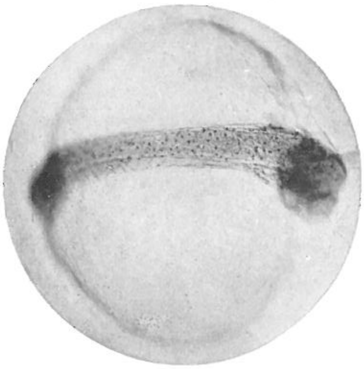
Plate I.

Fig. 1. Egg of Turbot. Stage 1.
" 2. " " " 2.
" 3 & 4 " " " 5.
Fig. 5. Egg of Greater Weever. Stage 3.
" 6. " " " " 4.
" 7 & 8 " " " " 5.

N.B.—For explanation of Stages *see* page 221.

Plate II.

Figs. 1 & 2. Egg of Mackerel (*see* pages 217 & 218).
" 3, 4, 5, 6. Eggs of Grey Gurnard (*see* page 223).
Fig. 7. Egg of Brill (*see* page 223).
" 8. Egg of Red Gurnard (*see* page 224).



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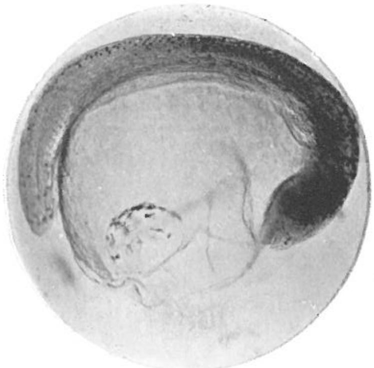

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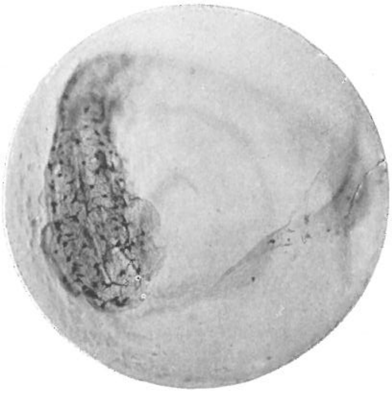

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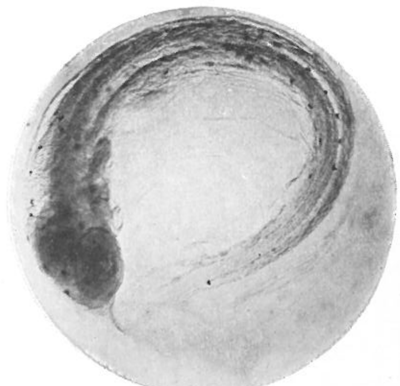

6.

7.

8.

Wollaston Fish Egg Cruise.

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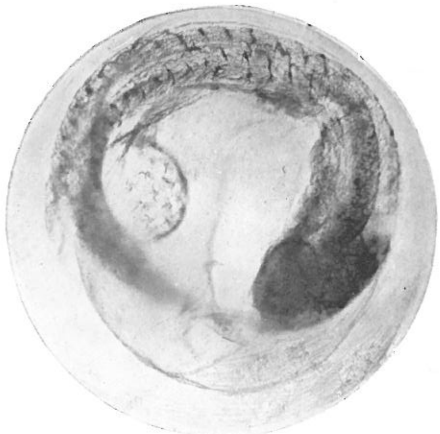

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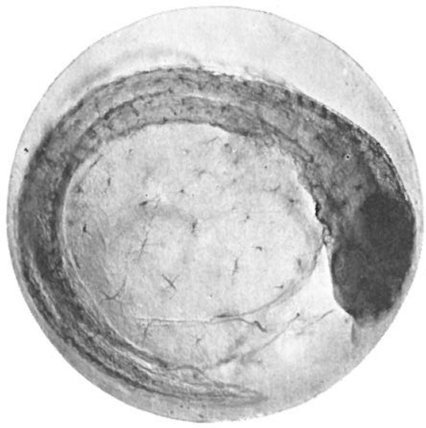

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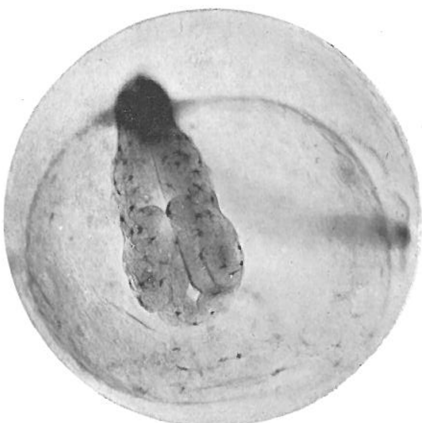

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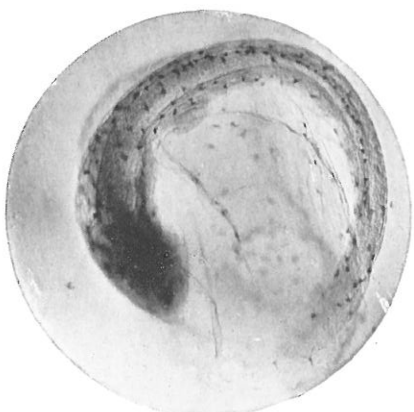

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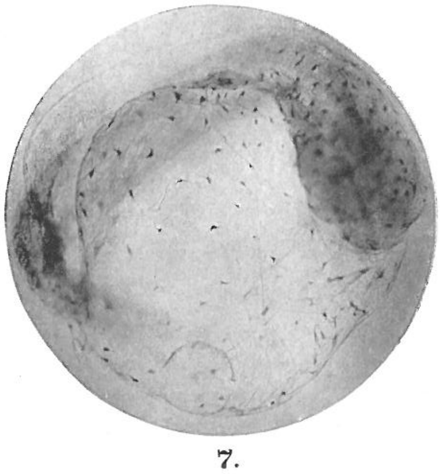

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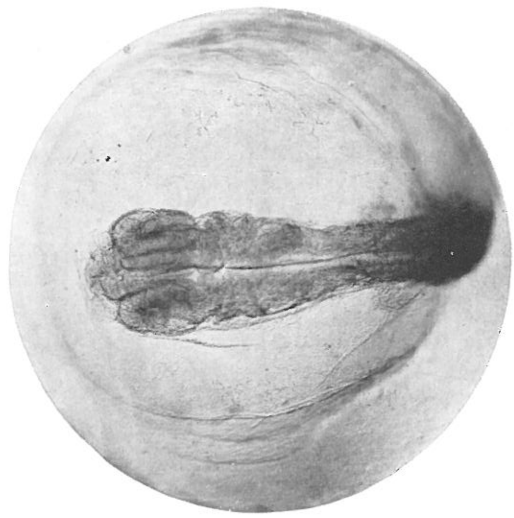

8.