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A NEW BRITISH COMMENSAL HYDROID, *PERIGONIMUS ABYSSI*, SARS.

BY

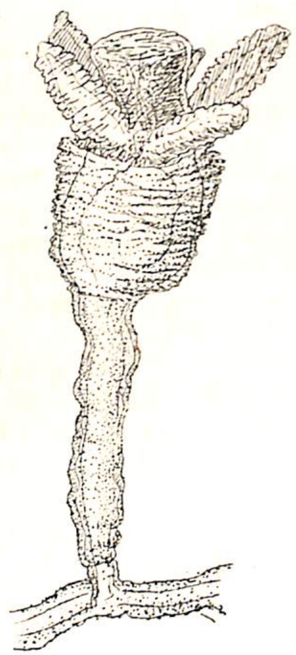
JAMES RITCHIE, M.A., D.Sc.,

Royal Scottish Museum.

In 1876, Dr. Gwyn Jeffreys described a minute Lamellibranch Mollusc found at great depths (200–1,470 fathoms) in the Bay of Biscay and North Atlantic Ocean, as *Leda pustulosa*. The specific name, signifying "full of blisters," referred to the epidermis of the shell which had a "peculiar blistered appearance," sufficient, according to Jeffreys, to help in distinguishing it from its nearest ally, *L. frigida*. On at least two occasions since 1876 *Leda*, now *Nuculana pustulosa*, has been recorded, but no further reference has been made to the blistered epidermis. Recently, however, the Irish Department of Agriculture and Technical Instruction has obtained specimens of this species, which agree with the original description in their blistered appearance. Detailed examination has shown that the "blistering" is not a normal condition of the shell, that indeed the epidermis is not actually blistered, but that the appearance is due to the presence of the stolons of a Hydroid ramifying on the surface. The mollusc was identified and forwarded to me on account of its Hydroid associate by Miss A. L. Massy, of the Fisheries Branch of the Department.

Each stolon consists of a very narrow tube of coenosarc surrounded by a much wider tube of transparent, colourless chitin, 0.03 mm. in diameter, and scattered over with fine particles of sand. In the younger stages of growth the stolons are much branched, and form an open mesh-work; but there is little chance that at this stage they could fail to be recognised, for they appear as simple tubes, circular in section, clearly lying on the surface of the epidermis, and they are generally accompanied by fairly numerous polyps. With increased age, however, the network spreads over the whole surface and becomes closer, and in the shelter of the sides of the stolon-tubes a fine débris collects, partially filling up the meshes. In this case, it is difficult at first to recognise that the tubes are upon, and not included by, the epidermis. The illusion of blistering in such a case is often heightened by the scarcity of polyps. A third and still more advanced case may be mentioned: the actual contact of the stolon with the surface, continued during the growth of the shell, has produced an effect of its own—in reflected light the tract which lay beneath a stolon appears smoother and darker, and of a bluish-grey colour, the uncovered portions of the shell being rather of a chalky white.

The polyps are exceedingly small—almost invisible to the naked eye. They consist of a proportionately long unbranched stem, narrow where it meets the stolon and widening upwards to the hydranth. The surface is protected by a soft chitinous coat continued over the hydranth to the base of the tentacles and covered with fine grains. On the stalk it is thick and slightly crumpled, but shows no sign of distinct annulation, and on the hydranth body, it is thin, loose and much and deeply wrinkled.



Perigonimus abyssi, Sars, from off S.W. of Ireland, × 200.

The hydranth body rises gradually from the widened summit of the stalk, resembles the head of an Indian club, bears a whorl of four to six short tentacles, five being most common, and is surmounted by a long proboscis, conical when closed. Its length is half of, or in some cases equal to, that of the stalk. As has been remarked, the polyps are exceedingly small, their size agreeing with Stechow's maximum of 0.5 mm. rather than with Sars' "scarcely 1 mm."

Unfortunately, no trace of gonosome was present.

Dimensions—

Stolon, diameter	0.02—0.035	mm.
Stalk, length	0.10—0.23	"
" average diameter ..	0.025—0.04	"
Hydranth, length	0.15—0.19	"
" maximum diameter	0.09	"

Locality—On valves of *Nuculana pustulosa* from S.R. 851, 9. XI. '09, M.O.T., 900 fathoms—Lat. N., 50° 48′; Long. W., 11° 41′—to the South-West of Ireland.

The localities from which *P. abyssi* has previously been recorded are scattered in the Arctic Ocean, and off the subarctic coast of Scandinavia.

Arctic Records—Storfjord, Spitsbergen, 0–10 metres (Broch 1909); Lat. N. 74.2°, Long. E. 20.30° (north of Bear Island), 165 metres (Bonnevie, 1899); and specimens perhaps belonging to this species have been found in the neighbourhood of Cape Bismark, and Storm Bay, Greenland, from 20 to 40 metres (Kramp, 1911).

Scandinavian Records—*Norway*—Bergen (Bonnevie, 1901, Stechow 1912); Hardanger Fjord, 150–400 fms. (Sars, 1873); Stavanger to Hardanger Fjord, 100–600 metres (Bonnevie, 1899); Hvitingsö, 80–100 fathoms (Sars, 1873): *Sweden*—Koster Island, 180 metres (Segerstedt, 1889).

The species, however, according to the present record from off the South-West corner of Ireland, extends from arctic and subarctic into temperate seas. It appears to be most common in deep water, occurring in Irish waters at a depth of 900 fathoms, far beyond its previously known limit of 400 fathoms in Hardanger Fjord.

Perigonimus abyssi is symbiotic with living mollusca, forming a network on the external surface of the shells. That its occurrence there is not altogether a chance one is perhaps hinted at by the narrow range of its commensalism. Apart from examples observed by Sars on shells of *Dentalium*, it has been found only (judging by published records) on minute shells of *Nuculidae*; on *Nucula nucleus* (Linn.) by Segerstedt and by Jäderholm; on *Nucula tumidula*, Malm, by Sars and by Bonnevie; and on *Nuculana pustulosa* (Jeffreys), in the present instance.

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NOTES ON THE EVIDENCE OF AGE AFFORDED BY THE GROWTH RINGS OF OYSTER SHELLS

BY

ANNE L. MASSY.

Plates I–XI.

It is rather commonly believed that the age of an oyster can be ascertained by counting the rings or groups of rings on its deep shell, each group of rings being supposed to represent a year's growth. An opportunity of testing the value of this method of computation, as applied to oysters reared under artificial conditions, occurred in the selection for the National Museum of a number of samples from the Department's oyster station at Ardfry, near Oranmore, at the head of Galway Bay, and from a former oyster station at Burren, in Muckinish Bay (an arm of the sea joining Galway Bay).[1] This station was abandoned in 1903, and the stock removed to Ardfry, where the spat is collected in a natural sea pond or saleen of about seven acres, which can be closed at will by lock gates. The collectors used are tiles coated with mortar, stacked in crates after the usual French system. The spat of one year is detached from the tiles during the autumn or winter of the year following, and subsequently kept either in *caisses ostréophiles* of the usual French pattern or in hanging baskets of wire netting, as devised by Wollebaek.[2]

The caisses and baskets are numbered, and all changes are entered in a register, so that mistake as to contents is practically impossible, and any stray oyster that may chance to establish itself by natural means in a caisse or basket can be detected as an intruder, because it lacks the fragment of mortar derived from the tile.

I understand that the experiments carried out at Ardfry since 1904 go to show that growth in caisses and baskets is in general more rapid than on the natural ground, though the latter is quite suitable for oysters. If this be so, the failure of growth which will be noticed in some of the specimens dealt with below, cannot be ascribed to general unsuitability of conditions; and, though it may to some extent be due to overcrowding and starvation of certain individuals and preservation of other

[1] *Ann. Rep. Fish. Ireland*, 1902-3, Pt. II, App. VIII [1905].
[2] *Ann. Rep. Fish. Ireland*, 1901, Pt. II, App. VI [1903].

weakly individuals from their natural enemies, it seems likely that wild oysters also manifest very marked differences in rate and evidence of growth.

Nothing can be deduced from the material tabulated below as to the proportion of oysters of a given age which exhibit so many rings or have reached a particular size, because the samples were taken without any regard to the total number of the brood to which they belonged.

The deep valve of an oyster exhibits externally a series of overlapping concentric lamellae, with more or less definite free edges. Closely examined, each lamella is seen to be made up of fine concentric elements, representing the accretions by which the growth of the lamella proceeds. The projecting edge of a lamella obviously represents some sort of interruption of growth, but does not necessarily indicate a cessation thereof, since (cf. Plate I, figs. 10 and 12) one may find more than one distinct lamella in what is obviously the accretion of a single season, i.e., from April or early May to about the beginning of October on our western coast. Often, and I suppose typically, the external surface of the shell is at once divisible into zones of lamellae or groups of lamellae, which are, in fact, annual growth rings or shoots, as may be seen in Plate IV, fig. 1, and Plate VII, fig. 2, which depict specimens in which the obvious growth-rings correspond exactly to the known age; in others (cf. Plate VII, fig. 1; IX, fig. 1; and XI, fig. 1) the rings are more complex. Such specimens have been used as a guide in determining the number of rings in the lists below, i.e., a specimen stated to have two rings is one which has two zones of shell which resemble what is really an annual ring in a typical specimen.

Petersen[1] says, "certainly the zones of growth on the shells have something to do with growth periods (years), but it is often not easy to determine them with certainty." I heartily agree with the latter statement; the difficulties which present themselves are apparent to anyone attempting the work, although not easy to describe. All I can honestly say I have learnt from a patient scrutiny of over 600 samples of various ages from eighteen months to six years, is that an oyster of eighteen months or two summers appears to possess at least 2 rings, but may have as many as 5. One of three summers has at least 2 rings, and may have 6. A four-year-old oyster may have only 3 rings or may possess 7 or 8. It is obvious, therefore, that if I have been at all correct in determining the number of rings (the photographs will allow the reader to judge of this), it is not of much use to apply the study of growth rings in ascertaining the age of a wild oyster. Wollebaek's[2]

[1] *Rept. Danish Biol. Stat.*, XV and XVIII. Copenhagen, 1908, p. 31.
[2] *Ann. Rep. Fish. Ireland*, 1901, Pt. II, App. VI [1903].

interesting series of photographs seems to show that Norwegian oysters are also somewhat vague as to the number of growth rings at a particular age. Petersen[1] found, after applying the measurement method to ascertain the age and growth of the oysters in the Lim Fjord, that it could only show "that an oyster of *ca.* 6–7 cm. is, as a rule, three summers old, and that the oyster begins to grow more slowly in length at 6–7 cm." In the list of measurements given below, it will be found that some of our specimens of three and four years of age measure only 21–22 mm. from hinge to margin.

Our Plates will be found to illustrate examples of oysters of various ages from the spat stage of one season to five-and-a-half years; in some cases normal growth is depicted, and in others the specimens appear to be remarkably stunted. Two types of shell growth are conspicuous, the first possesses a shell with a very few broad rings corresponding exactly with the known age, in the explanation of plates this kind of shell is referred to as "type *a*"; the second type, hereafter referred to as "type *b*," is represented by a shell in which the growth of each season contains more than one lamella. Frequently specimens of what is here called type *a* partake slightly of the characters of type *b*, and the converse also prevails; that both types may occur under the same conditions is shown in Plate I, where fig. 10 belongs to type *a*, and fig. 11 to type *b*; Plate IV, where fig. 1 is type *a*, and figs. 3, 4, 5, and 6 are type *b*; and Plate VII, where figs. 1 and 4 are type *a*, and fig. 2 is type *b*.

Ardfry does not seem to possess the wonderful fattening qualities of some of the Norwegian pools; Wollebaek (loc. cit. Plate IX) illustrates oysters of fourteen months measuring 67–75 mm. from hinge to ventral margin; oysters of one-and-a-half years (Plate VIII) measuring *ca.* 80 mm.; a specimen of two-and-a-half years fattened in the Nyhammer Pool for a year-and-a-half (Plate VII) measures *ca.* 105 mm.; and specimens of three-and-a-half years (Plate X) measure 90–97 mm.

Our largest samples of oysters of one-and-a-half years measure 60–65 mm.; of two-and-a-half years 65–70 mm.; and of three-and-a-half years 75 mm.

[1] *Loc. cit.*, p. 33.

MEASUREMENTS OF LOWER VALVES OF 638 OYSTERS.

BURREN SPAT, 1902. Specimens collected, March, 1906.

Hinge to ventral margin in mm. 30. 45. 57. 60. 63. 65.
Number of rings. 3. 3. 4. 5. 4. 4.

BURREN SPAT, 1902. Specimens collected 23rd January, 1907.

Hinge to ventral margin in mm. 70. 70. 70. 73.
Number of rings. 5. 4. 7. 4.

ARDFRY SPAT, pond closed for spatting season, 20th July, 1903.
Specimens collected, March, 1906.
Ref. No. Ex C 250 and N.B. 4.

Hinge to ventral margin in mm. 28. 30. 32. 40. 43. 44.
Number of rings. 3. 3. 3. 4. 3. 3.
45. 46. 47. 50. 50. 55. 55. 60. 60. 62. 62. 65.
3. 3. 3. 4. 5. 3. 3. 4. 3. 3. 3. 3.

ARDFRY SPAT, pond closed for spatting season, 20th July, 1903.
Specimen collected, January, 1907.
Ref. No. 33 D.

Hinge to ventral margin in mm. 67.
Number of rings 5.

ARDFRY SPAT, pond closed for spatting season, 25th June, 1904.
Specimens collected 23rd January, 1907.

Hinge to ventral margin in mm. 33. 43. 46. 50. 50. 50.
Number of rings 3. 3. 3. 3. 3. 5.
51. 52. 53. 55. 55. 56. 56. 56. 57. 58. 58. 60.
3. 3. 4. 3. 3. 4. 3. 4. 3. 3. 3. 3.
60. 60. 62. 62. 65. 65.
3. 3. 3. 3. 3. 5.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, 26th January, 1907.
Ref. No. C 34.

Hinge to ventral margin in mm. 23. 26. 27. 30. 30. 35.
Number of rings 2. 2. 2. 2. 2. 2.
35. 38. 40. 42. 45. 45. 46. 46. 48. 52. 53. 55.
2. 5. 2. 3. 2. 4. 3. 3. 5. 3. 4. 4.
58. 60.
3. 3.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected 26th January, 1907.
Ref. No. C 15 B.

Hinge to ventral margin in mm. 38. 50. 50. 50. 53. 56.
Number of rings 2. 3. 2. 2. 2. 3.
56. 56. 57. 57. 60. 65.
4. 2. 3. 3. 3. 4.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, 26th January, 1907.
Ref. No. C 15.

Hinge to ventral margin in mm. 37. 38. 38. 38. 38. 38.
Number of rings 2. 2 3. 3. 4. 3.
42. 50. 50. 50. 46. 47. 48. 50. 53. 53. 53. 54.
2. 3. 2. 3. 2. 2. 2. 3. 4. 4. 3. 3.
55. 55.
3. 3.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, 21st February, 1908.
Ref. No. 212 B.

Hinge to ventral margin in mm. 22. 25. 30. 32. 33. 35.
Number of rings 3. 3. 3. 3. 3. 3.
36. 38. 38. 40. 40. 42. 42. 42. 44. 45. 45. 45.
3. 4. 3. 3. 3. 3. 3. 3. 3. 4. 4. 3.
45. 45. 46. 46. 46. 49. 49. 49. 52. 54. 55. 56.
3. 3. 3. 3. 3. 3. 4. 3. 3. 4. 4. 3.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, 21st February, 1908.
Ref. No. 212 A.

Hinge to ventral margin in mm. 35. 37. 40. 40. 40. 40.
Number of rings 3. 3. 4. 3. 4. 3.
40. 40. 40. 42. 42. 45. 47. 48. 48. 50. 50. 50.
3. 3. 5. 3. 4. 3. 4. 5. 4. 5. 3. 4.
52. 52. 52. 53. 55. 56. 56. 58. 60. 60. 62. 63.
4. 4. 4. 4. 5. 5. 5. 5. 4. 4. 5. 6.
65. 65. 60.
3. 5. 4.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, 21st February, 1908.
Ref. No. 213 C.

Hinge to ventral margin in mm. 30. 35. 42. 43. 40. 43.
Number of rings 2. 2. 4. 2. 2. 3.
44. 45. 45. 45. 46. 47. 47. 52. 52. 52. 53. 53.
3. 4. 3. 5. 3. 3. 3. 3. 4. 5. 3. 3.
58.
3.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, 21st February, 1908.
Ref. No. 212 C.

Hinge to ventral margin in mm. 23. 25. 30. 33. 33. 35.
Number of rings *3. 3. 3. 3. 3. 3.*
35. 35. 37. 37. 37. 39. 40. 40. 40. 44. 45. 45.
3. 3. 3. 4. 4. 3. 4. 3. 3. 4. 3. 3.
45. 45. 45. 45. 45. 47. 47. 50. 50. 50. 52.
4. 5. 3. 4. 3. 3. 6. 4. 4. 5. 4.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, 21st February, 1908.
Ref. No. 213 A.

Hinge to ventral margin in mm. 40. 40. 42. 44. 44. 45.
Number of rings *3. 3. 3. 3. 3. 5.*
45. 45. 45. 46. 47. 47. 48. 48. 48. 48. 50. 50.
3. 3. 3. 4. 3. 4. 4. 3. 3. 3. 3. 3.
50. 50. 50. 50. 52. 52. 55. 55. 55. 55. 55. 56.
5. 3. 3. 4. 3. 4. 3. 3. 3. 3. 4. 4.
56. 57. 57. 57. 60. 60. 60. 67. 70.
4. 4. 3. 3. 4. 4. 3. 4. 3.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, 2nd March, 1908.
Ref. No. Ex N.H. Laying.

Hinge to ventral margin in mm. 35. 37. 38. 39. 43. 45.
Number of rings *3. 3. 4. 5. 3. 4.*
45. 48. 50. 50. 50. 50. 52. 53. 62. 63. 65. 77.
5. 4. 5. 4. 5. 4. 5. 5. 3. 5. 4. 6.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, 19th March, 1908.
Ref. No. C. 239, C 240, C 241, C 279.

Hinge to ventral margin in mm. 23. 24. 25. 26. 26. 27.
Number of rings *2. 3. 2. 3. 3. 2.*
28. 30. 32. 45. 50. 50. 56. 62. 62. 62. 65. 66.
3. 3. 4. 6. 4. 5. 3. 3. 4. 5. 6. 4.
67. 72. 72. 73.
5. 4. 6. 4.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, 16th January, 1909.
Ref. No. N.B. 29.

Hinge to ventral margin in mm. 44. 45. 45. 50. 53. 55.
Number of rings *4. 3. 4. 4. 4. 3.*
55. 55. 56. 60. 62. 65. 65. 70. 70.
3. 3. 3. 5. 4. 3. 4. 5. 5.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, February, 1909.
Ref. No. Laying 32.

Hinge to ventral margin in mm. 43. 45. 46. 46. 48. 48.
Number of rings *3. 3. 3. 5. 3. 3.*
50. 53. 54. 56. 67. 70.
6. 5. 3. 6. 4. 6.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, 2nd February, 1909.
Ref. No. Caisse 333 A.

Hinge to ventral margin in mm. 62. 65. 65. 70. 77. 80.
Number of rings *4. 5 5 7. 6 5*
80. 80.
5. 4.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, 2nd February, 1909.
Ref. No. Caisse 333 B.

Hinge to ventral margin in mm. 35. 44. 44. 45. 46. 46.
Number of rings *2. 3. 3. 4. 3. 4.*
48. 50. 50. 52. 55. 55. 57. 57. 60. 60. 63. 65.
3. 3. 3. 6. 3. 4. 5. 6. 4. 4. 5. 5.
72. 77.
3. 4.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, 2nd February, 1909.
Ref. No. Caisse 333 C.

Hinge to ventral margin in mm. 36. 40. 40. 43. 45. 46.
Number of rings *3. 3. 4. 2. 4. 5.*
48. 48. 48. 50. 50. 50. 52. 52. 55. 57. 60. 65.
4. 4. 6. 5. 4. 6. 5. 4. 5. 4. 5. 4.
74.
6.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, 2nd February, 1909.
Ref. No. Ex 333 C.

Hinge to ventral margin in mm. 62. 70. 73. 75. 75.
Number of rings *3. 5. 5. 5. 7.*

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, February, 1909.
Ref. No. C 171 A and C.

Hinge to ventral margin in mm. 46. 50. 50. 50. 50. 52.
Number of rings *3. 3. 4. 5. 3. 4.*
53. 54. 55. 56. 60. 60. 60. 65. 65. 70. 86.
5. 3. 4. 4. 4. 5. 5. 4. 5. 6. 7.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, February, 1909.
Ref. No. 173 A. and 176 A.

Hinge to ventral margin in mm.	39.	40.	40.	42.	45.	45.
Number of rings	5.	2.	2.	3.	3.	3.
	60.	63.	64.	75.		
	4.	4.	4.	5.		

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, February, 1909.
Ref. No. 173 C. and 176 C.

Hinge to ventral margin in mm.	45.	45.	48.	50.	73.	75.
Number of rings	3.	3.	3.	3.	8.	6.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, February, 1909.
Ref. No. C 175 A.

Hinge to ventral margin in mm.	35.	38.	38.	39.	40.	41.					
Number of rings	3.	3.	3.	3.	4.	3.					
	43.	45.	45.	45.	47.	49.	50.	51.	53.	53.	55.
	3.	3.	3.	4.	4.	4.	4.	4.	4.	4.	4.

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, February, 1909.
Ref. No. 175 B.

Hinge to ventral margin in mm.	60.	61.	63.	65.	70.	70.
Number of rings	5.	7.	4.	4.	5.	6.
	76.	78.	80.			
	4.	6.	4.			

ARDFRY SPAT, pond closed for spatting season, 8th July, 1905.
Specimens collected, February, 1909.
Ref. No. C 352, 353, 354.

Hinge to ventral margin in mm.	22.	23.	27.	33.	35.	48.						
Number of rings	3.	3.	3.	3.	3.	4.						
	50.	50.	55.	55.	55.	57.	60.	62.	63.	68,	70.	70.
	3.	4.	3.	4.	3.	3.	3.	4.	5.	3.	4.	4.
	70.	75.	75.	75.	75.	75.	79.	80.	80.	84.		
	5.	5.	4.	5.	4.	5.	5.	3.	5.	5.		

ARDFRY SPAT, pond closed for spatting season, 13th July, 1906.
Specimens collected, 18th March, 1908.
Ref. No. C 193.

Hinge to ventral margin in mm.	20.	23.	25.	27.	28.	28.				
Number of rings	2.	2.	2.	2.	3.	3.				
	30.	35.	38.	40.	40.	42.	42.	44.	45.	48.
	2.	2.	3.	3.	3.	2.	4.	3.	2.	5.

ARDFRY SPAT, pond closed for spatting season, 13th July, 1906.
Specimens collected, 18th March, 1908.
Ref. No. C 149.

Hinge to ventral margin in mm.	15.	22.	25.	26.	29.	31.					
Number of rings	2.	2.	2.	3.	2.	2.					
31.	37.	37.	40.	42.	43.	45.	45.	46.	46.	46.	47.
3.	3.	3.	3.	2.	2.	3.	4.	3.	3.	3.	2.

ARDFRY SPAT, pond closed for spatting season, 13th July, 1906.
Specimens collected, 16th January, 1909.
Ref. No. N.B. 52 and 53.

Hinge to ventral margin in mm.	26.	37.	37.	40.	42.	42.					
Number of rings	3.	4.	4.	3.	3.	3.					
42.	45,	47.	51.	57.	57.	60.	60.	60.	60.	63.	64.
4.	3.	3.	4.	3.	5.	4.	5.	4.	5.	5.	6.
65.	66.	66.	67.	67.	72.	76.					
5.	5.	5.	5.	5.	4.	6.					

ARDFRY SPAT, pond closed for spatting season, 13th July, 1906.
Specimens collected, February, 1909.
Ref. No. C 337, 174, 195.

Hinge to ventral margin in mm.	70.	70.	75.	80.
Number of rings	4.	3.	4.	4.

ARDFRY SPAT, pond closed for spatting season, 13th July, 1906.
Specimens collected, February, 1909.
Ref. No. C 350, C 351.

Hinge to ventral margin in mm.	21.	21.	23.	25.	50.	53.					
Number of rings	3.	3.	3.	3.	5.	6.					
60.	60.	62.	62.	62.	62.	63.	64.	66.	68.	68.	70.
4.	6.	6.	4.	4.	4.	7.	4.	5.	4.	5.	3.
70.											
3.											

ARDFRY SPAT, pond closed for spatting season, 13th July, 1906.
Specimens collected, March, 1909.
Ref. No. C 149, C 40, C 110, C 136.

Hinge to ventral margin in mm.	62.	65.	66.	77.
Number of rings	3.	3.	5.	4.

ARDFRY SPAT, pond closed for spatting season, 13th July, 1906.
Specimens collected, March, 1909.
Ref. No. C 332 B.

Hinge to ventral margin in mm.	25.	37.	38.	38.	39.	40.
Number of rings	2.	4.	3.	4.	5.	3.
41.	47.	57.	57.	62.		
4.	3.	3.	4.	3.		

ARDFRY SPAT, pond closed for spatting season, 13th July, 1906.
Specimens collected, March, 1909.
Ref. No. C 332 C.

Hinge to ventral margin in mm.	Number of rings
29.	*3.*
31.	*3.*
32.	*3.*
34.	*3.*
35.	*3.*
37.	*5.*
40.	*3.*
40.	*4.*
40.	*3.*
40.	*5.*
40.	*3.*
45.	*3.*
47.	*3.*
48.	*4.*
50.	*3.*
50.	*6.*
51.	*4.*
55.	*4.*
60.	*3.*
60.	*4.*
72.	*4.*

ARDFRY SPAT, 1906, from New Harbour caisses: also spat of 1906 after nine months in Norway basket; pond closed for spatting season, 13th July, 1906.
Specimens collected, 16th and 18th March, 1910.

Hinge to ventral margin in mm.	Number of rings
37.	*3.*
37.	*4.*
38.	*3.*
40.	*3.*
40.	*3.*
44.	*3.*
45.	*3.*
45.	*3.*
45.	*4.*
52.	*3.*
53.	*4.*
55.	*4.*
55.	*5.*
60.	*4.*
60.	*4.*
60.	*5.*
63.	*6.*
65.	*4.*
65.	*4.*
65.	*6.*
66.	*5.*
68.	*5.*
69.	*6.*
70.	*4.*
70.	*4.*
71.	*5.*
72.	*5.*
75.	*7.*
75.	*5.*
75.	*3.*
76.	*6.*
77.	*6.*
80.	*5.*
95.	*7.*

ARDFRY SPAT, pond closed for spatting season, 13th July, 1906.
Specimens collected, 25th April, 1912.

Hinge to ventral margin in mm.	Number of rings
50.	*4.*
70.	*6.*
85.	*9.*
90.	*10.*

ARDFRY SPAT, pond closed for spatting season, 25th July, 1910.
Specimens collected, 25th April, 1912.

Hinge to ventral margin in mm.	Number of rings
15.	*2.*
20.	*2.*
29.	*2.*
32.	*2.*
32.	*3.*
35.	*3.*
35.	*3.*
38.	*2.*
50.	*2.*
50.	*3.*
50.	*3.*
53.	*4.*
54.	*4.*
55.	*4.*
56.	*3.*
58.	*4.*
60.	*4.*
64.	*4.*
66.	*5.*

EXPLANATION OF PLATES.

PLATE I.

Figs. 1–6, Spat of 1905, specimens collected immediately gates opened, September, 1905.

Figs. 7–12, Eighteen months' oysters, spat 1905. Ref. No. C 34, specimens collected 26th January, 1907; figs. 8 and 9 illustrate stunted growth, and figs. 7, 10, 11 and 12 represent normal growth; fig. 11 is a characteristic example of type *a* and fig. 10 of type *b*.

PLATE II.

Figs. 1–4, Seventeen months' oysters, spat 1906. Ref. No. C 193, specimens collected 18th March, 1908; figs. 1 and 4, normal growth, type *a*; figs. 2 and 3, stunted growth.

Figs. 5–9, Twenty-one months' oysters, spat 1910, specimens collected 25th April, 1912; figs. 5, 8 and 9, stunted growth; figs. 6 and 7, better growth, type *a*.

PLATE III.

Figs. 1–4. Two-and-a-half years' oysters, spat 1905. Ref. No. 212 A, specimens collected 21st February, 1908; figs. 1, 2 and 4, normal growth; fig. 3, stunted growth; fig. 1, type *b*, and figs. 2 and 3, type *a*; fig. 4 shows the growth of 1907 clearly, while that of the spat year and 1906 seems merged in one.

PLATE IV.

Figs. 1–6, Two-and-a-half years' oysters, spat 1905. Ref. No. 212 B, specimens collected 21st February, 1908; figs. 1, 4, 5 and 6, normal growth; figs. 2 and 3, stunted growth; fig. 1, type *a*; figs. 3, 4 and 5, type *b*.

PLATE V.

Figs. 1–6, Two years and eight months' oysters, spat 1905. Specimens collected 19th March, 1908; figs. 1, 2, 5 and 6, average growth; figs. 3 and 4, very stunted growth; fig. 5, type *a*; figs. 1 and 2, in many respects resembling type *a*; fig. 6, type *b*.

PLATE VI.

Figs. 1–5, Two years and eight months' oysters, spat 1906. Ref. No. Ex. C 332 C, specimens collected March, 1909; figs. 2 and 5, normal growth; figs. 1, 3 and 4, stunted growth; figs. 2 and 4, type *a*; figs. 1, 3 and 5, growth of each season not clear.

PLATE VII.

Fig. 1–5, Two-and-a-half years' oysters, spat 1906. Ref. No. C 350, C 351, specimens collected February, 1909; figs. 2, 3 and 4, average growth; fig. 1, small; fig. 5, remarkably stunted; fig. 2, type *a*; figs. 1, 3 and 4, type *b*.

Plate VIII.

Figs. 1–5, Three-and-a-half years' oysters, spat 1905. Ref. No. Ex. C 333 B, specimens collected 2nd February, 1909, ; figs. 2 and 5, average growth ; figs. 3 and 4, small ; fig. 1 is very stunted and possesses such fine lamellae that the growth of the different seasons cannot be defined ; figs. 2, 3, 4 and 5, type *b*.

Plate IX.

Figs. 1–4, Three-and-a-half years' oysters, spat 1905. Ref. No. Caisse 333 C, specimens collected 2nd February, 1909 ; figs. 1 and 4, normal ; figs. 2 and 3, stunted ; fig. 4, in many respects resembling type *a* ; figs. 1, 2 and 3, type *b*.

Plate X.

Figs. 1–4, Three-and-a-half years' oysters, spat 1905. Ref. No. Ex. C 352, 353, 354, specimens collected February, 1909 ; figs. 1, 3 and 4, normal, type *b* ; fig. 2, stunted, type *a*.

Plate XI.

Figs. 1–4, Five-and-a-half years' oysters, spat 1906. Specimens collected 25th April, 1912 ; figs. 1, 3, and 4, normal ; fig. 2, stunted ; all belong to type *b*.

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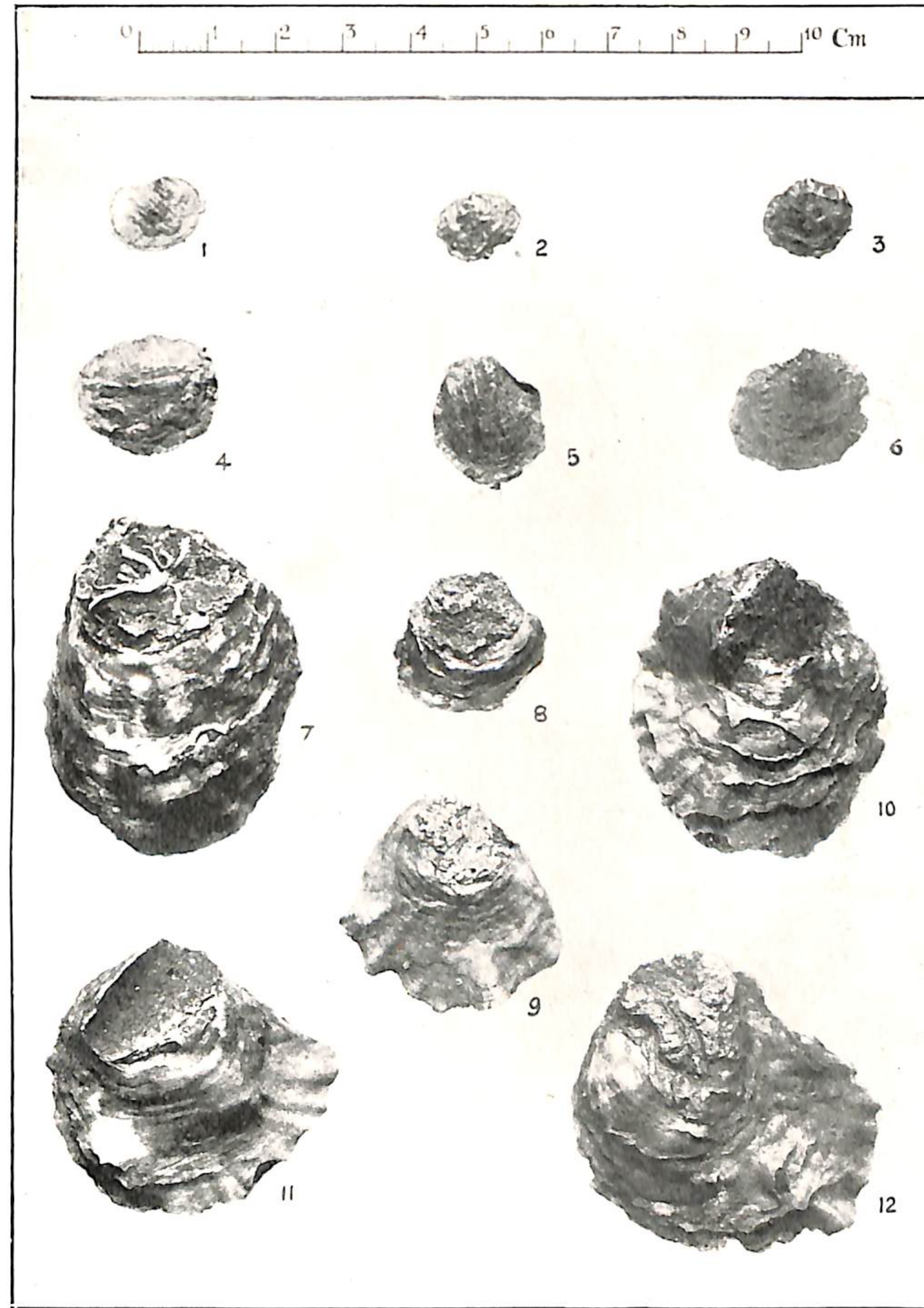

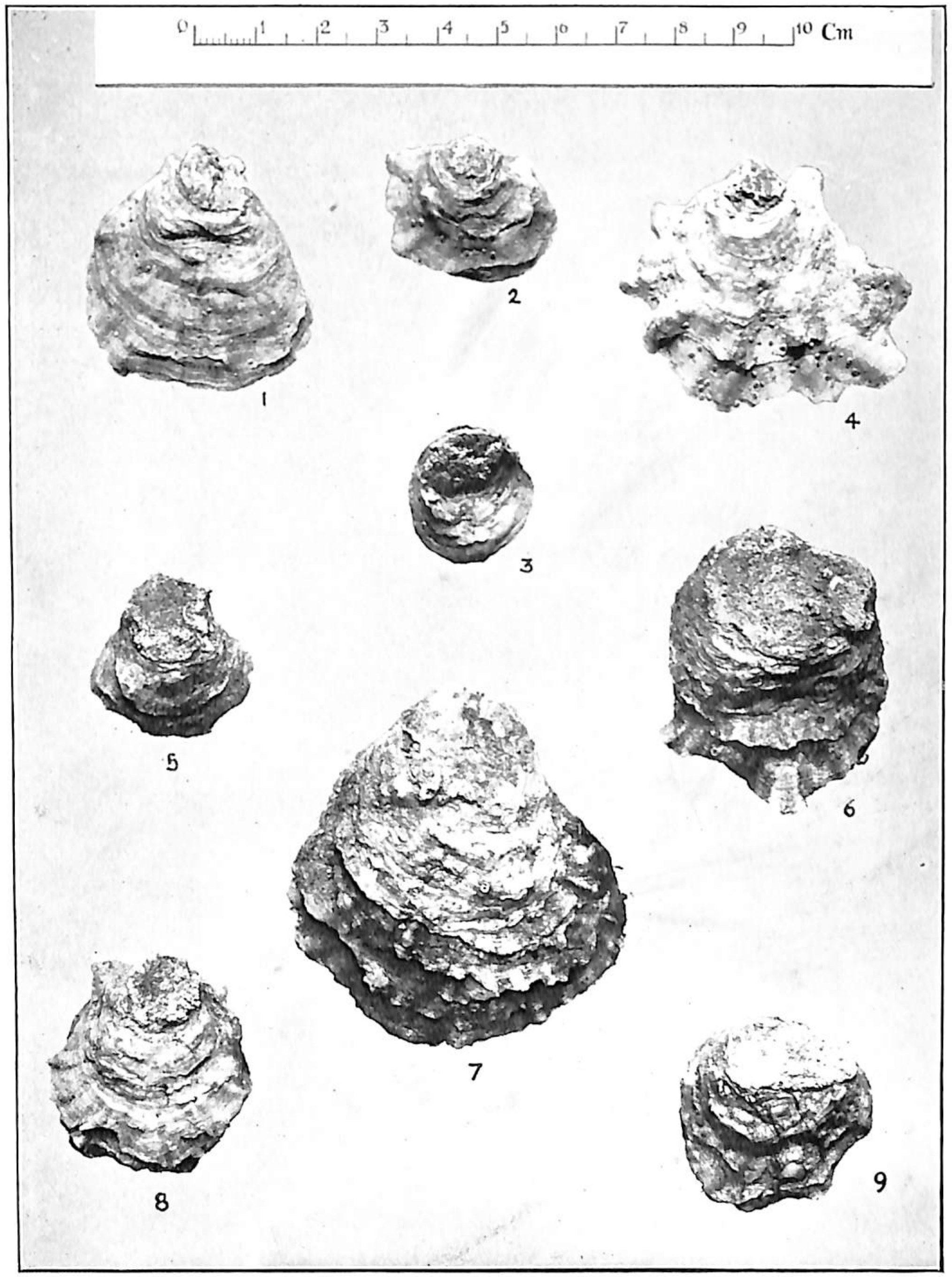
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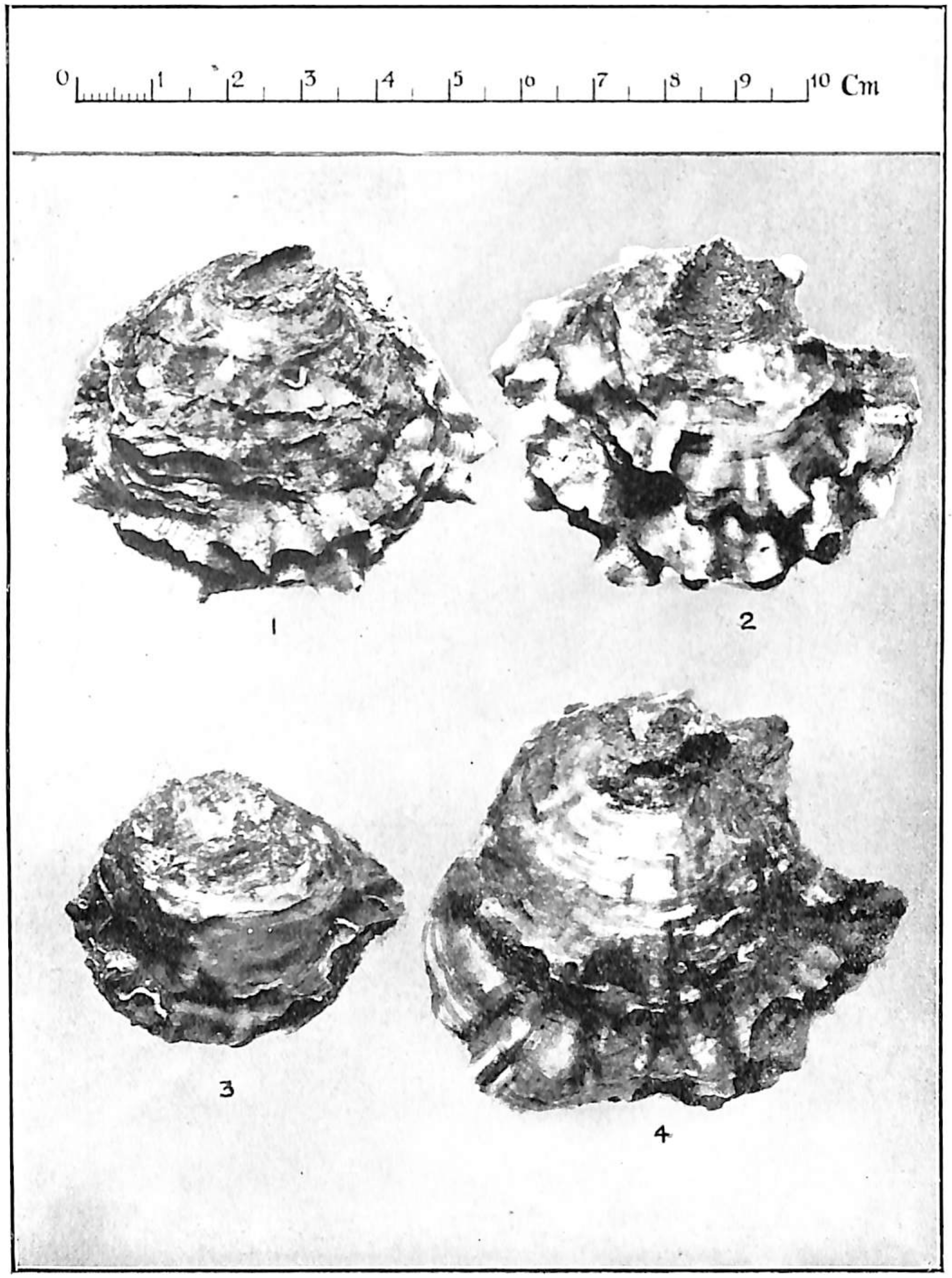
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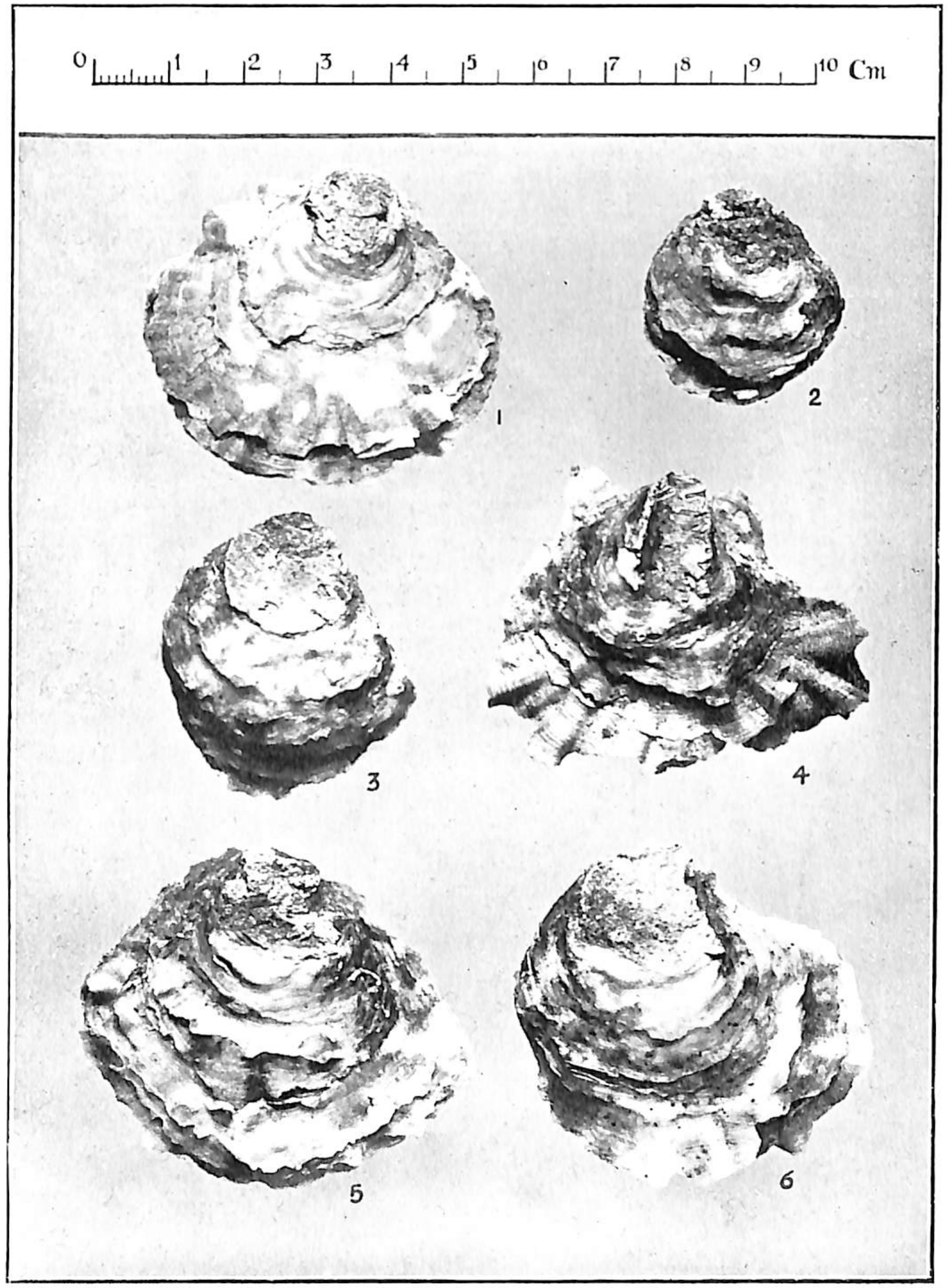
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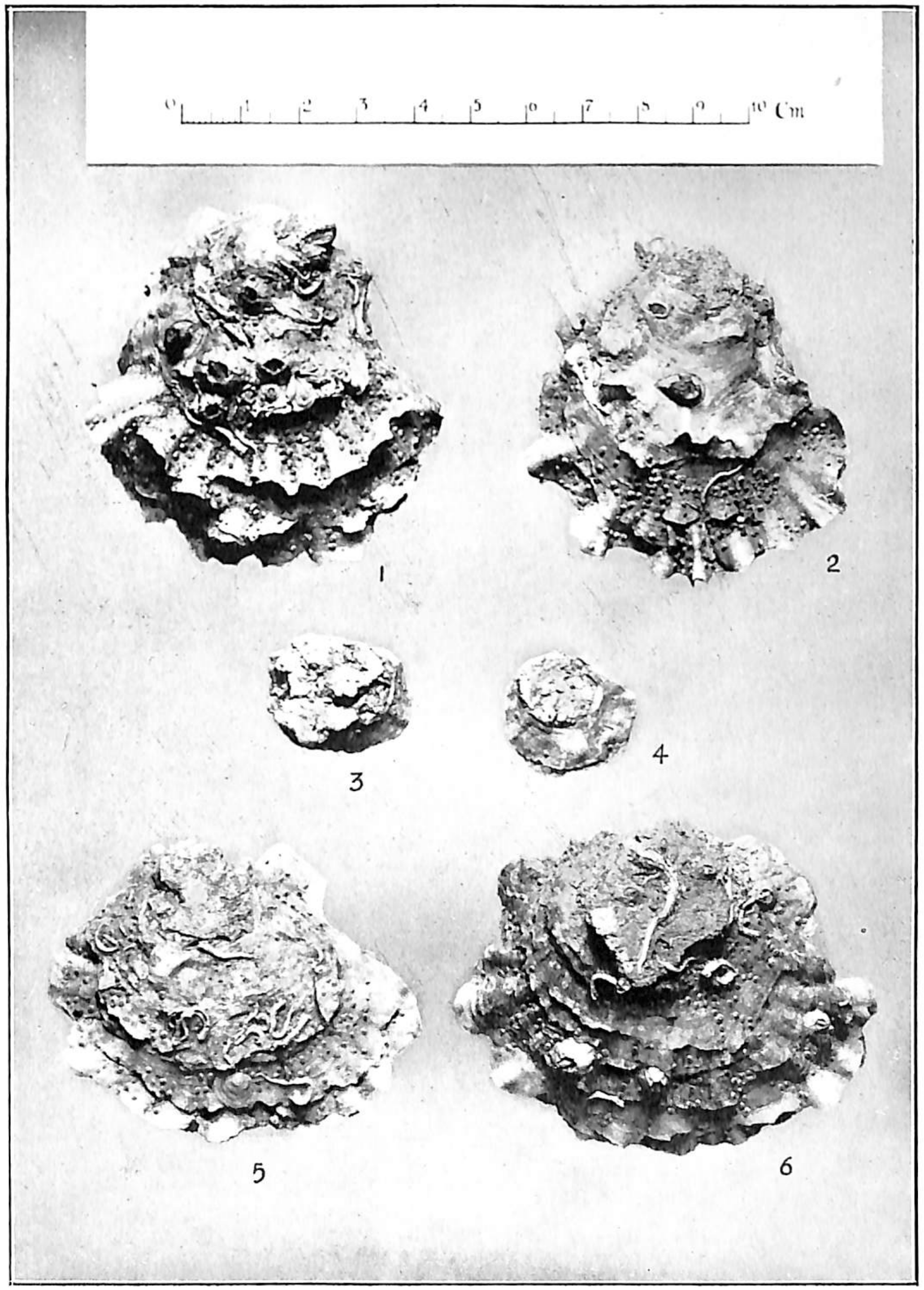
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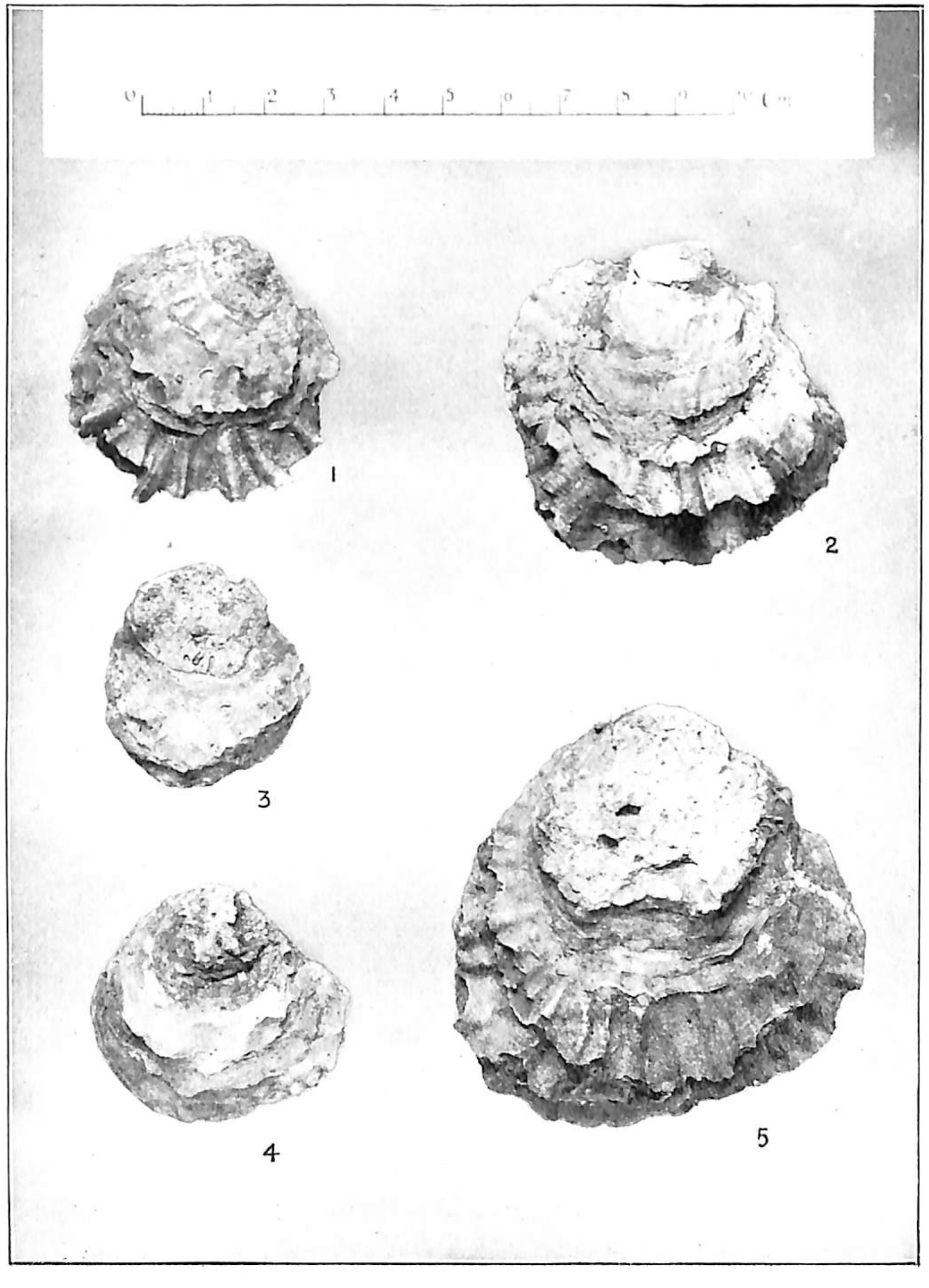
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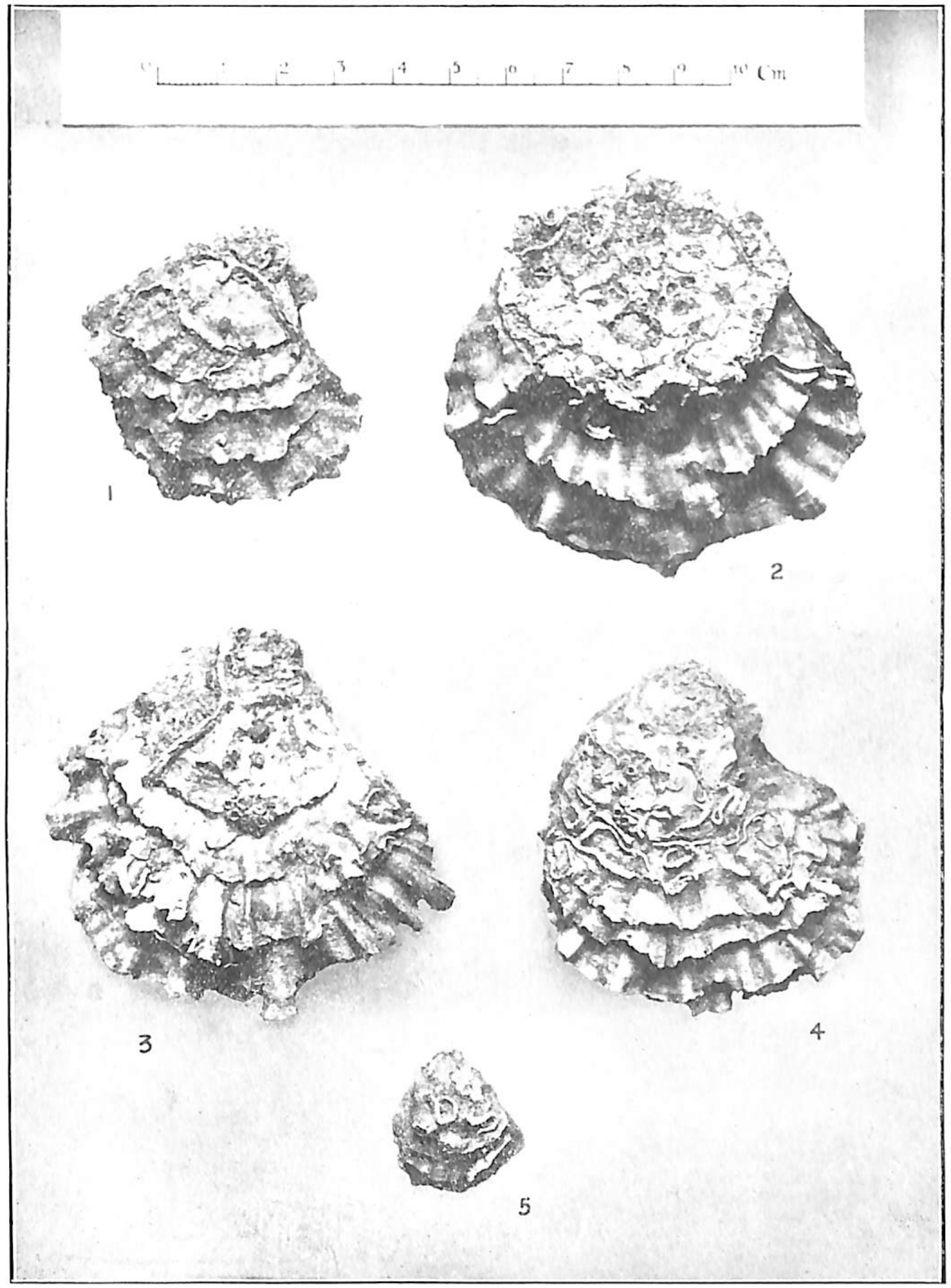
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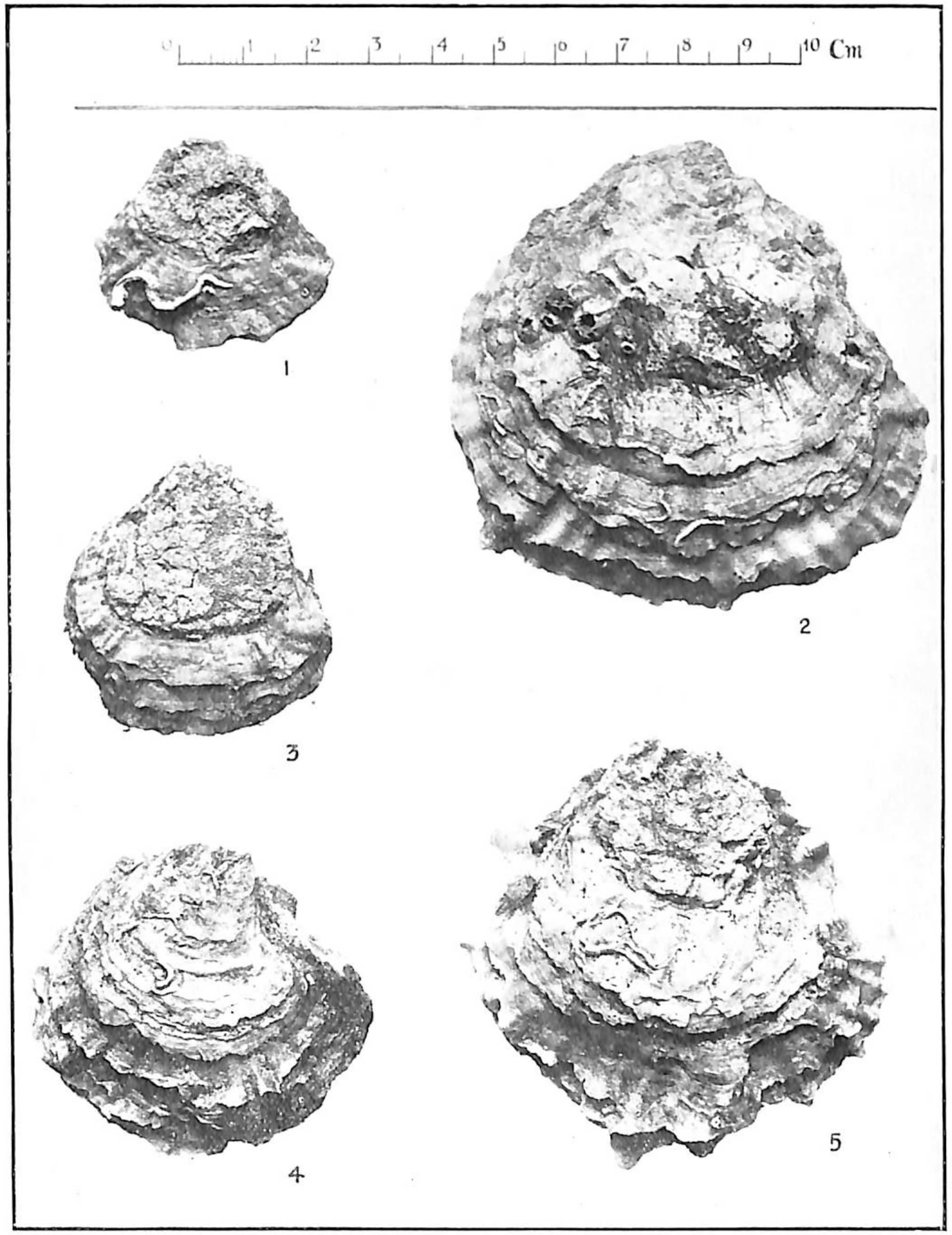
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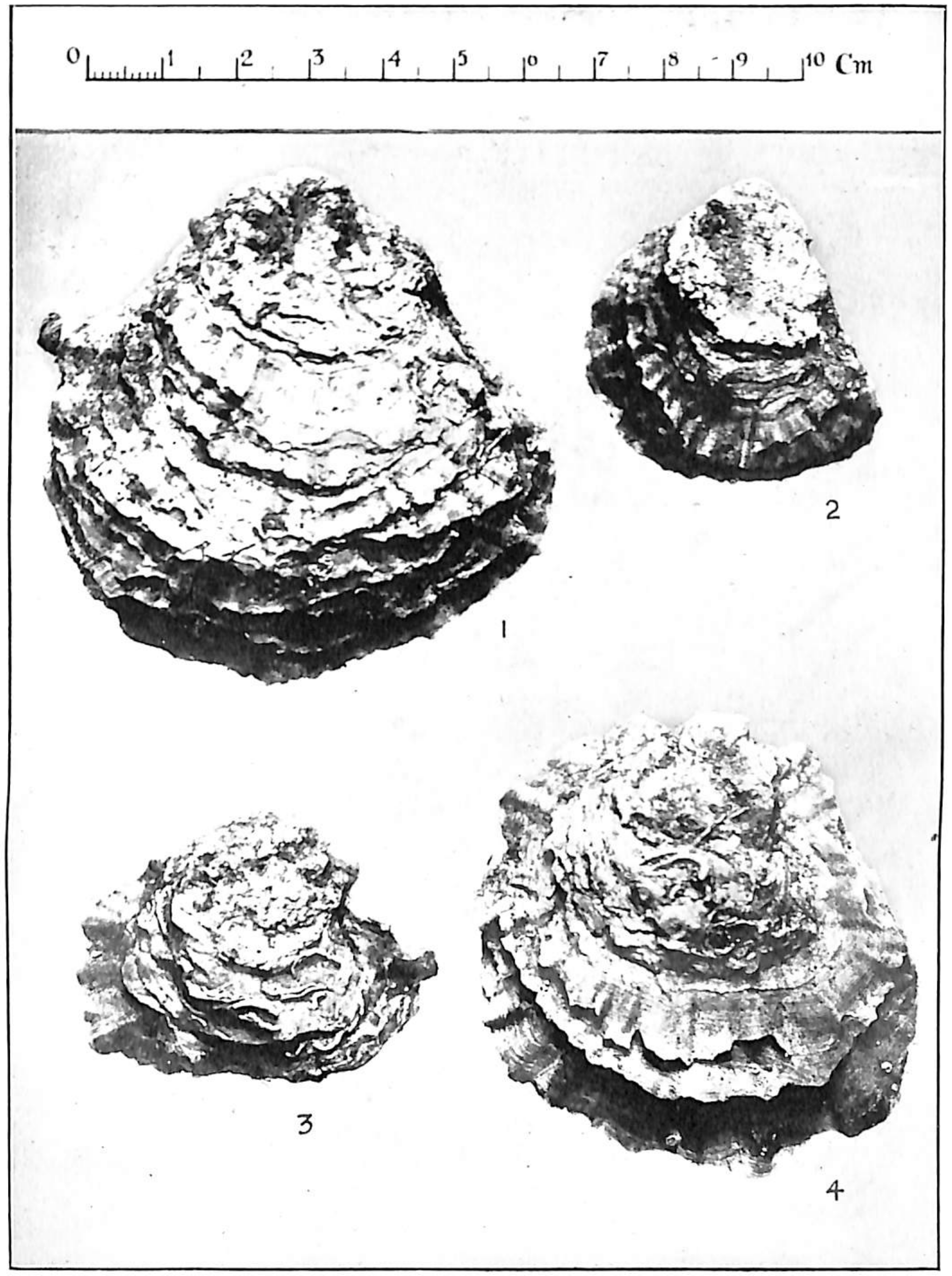
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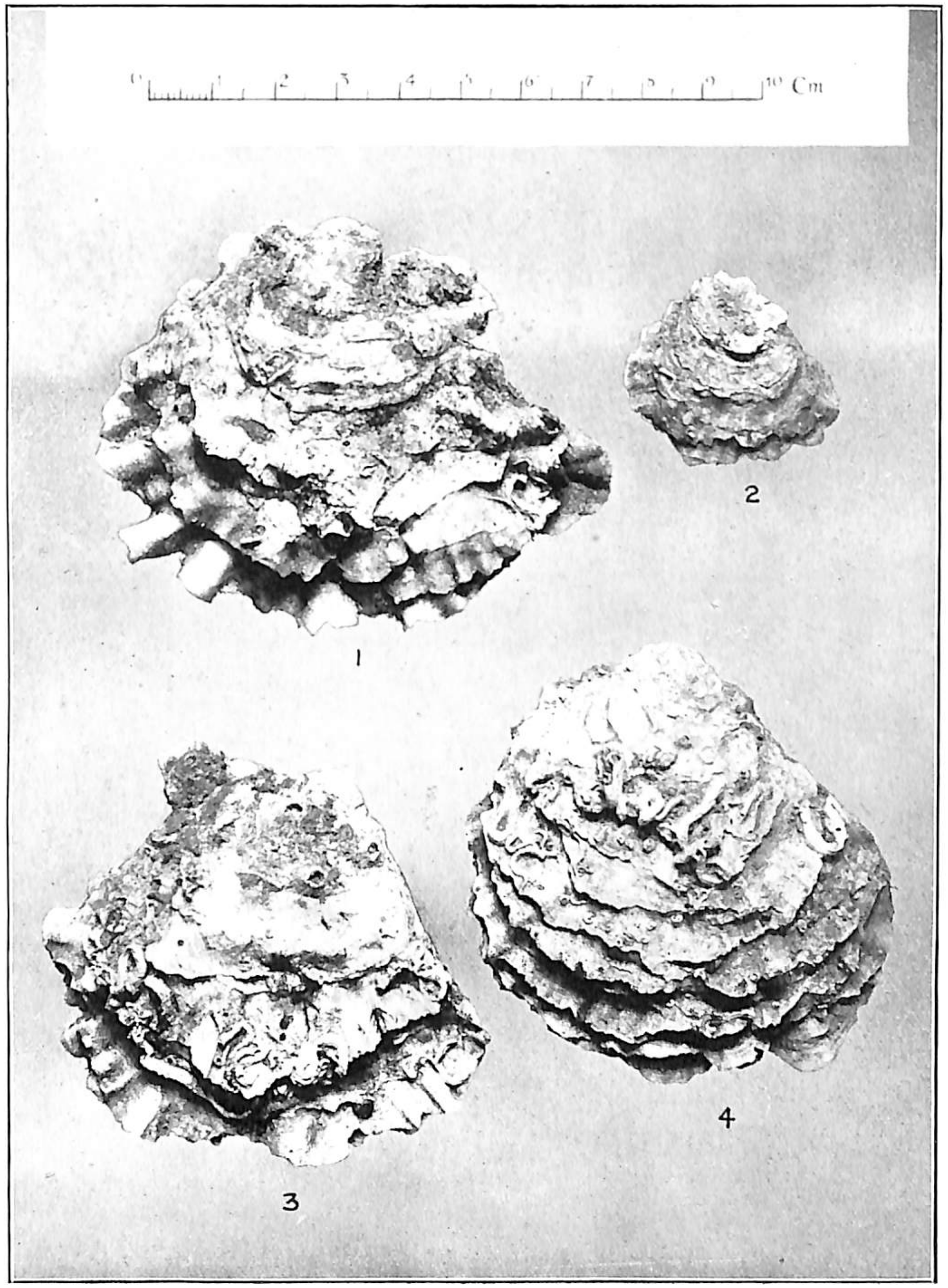
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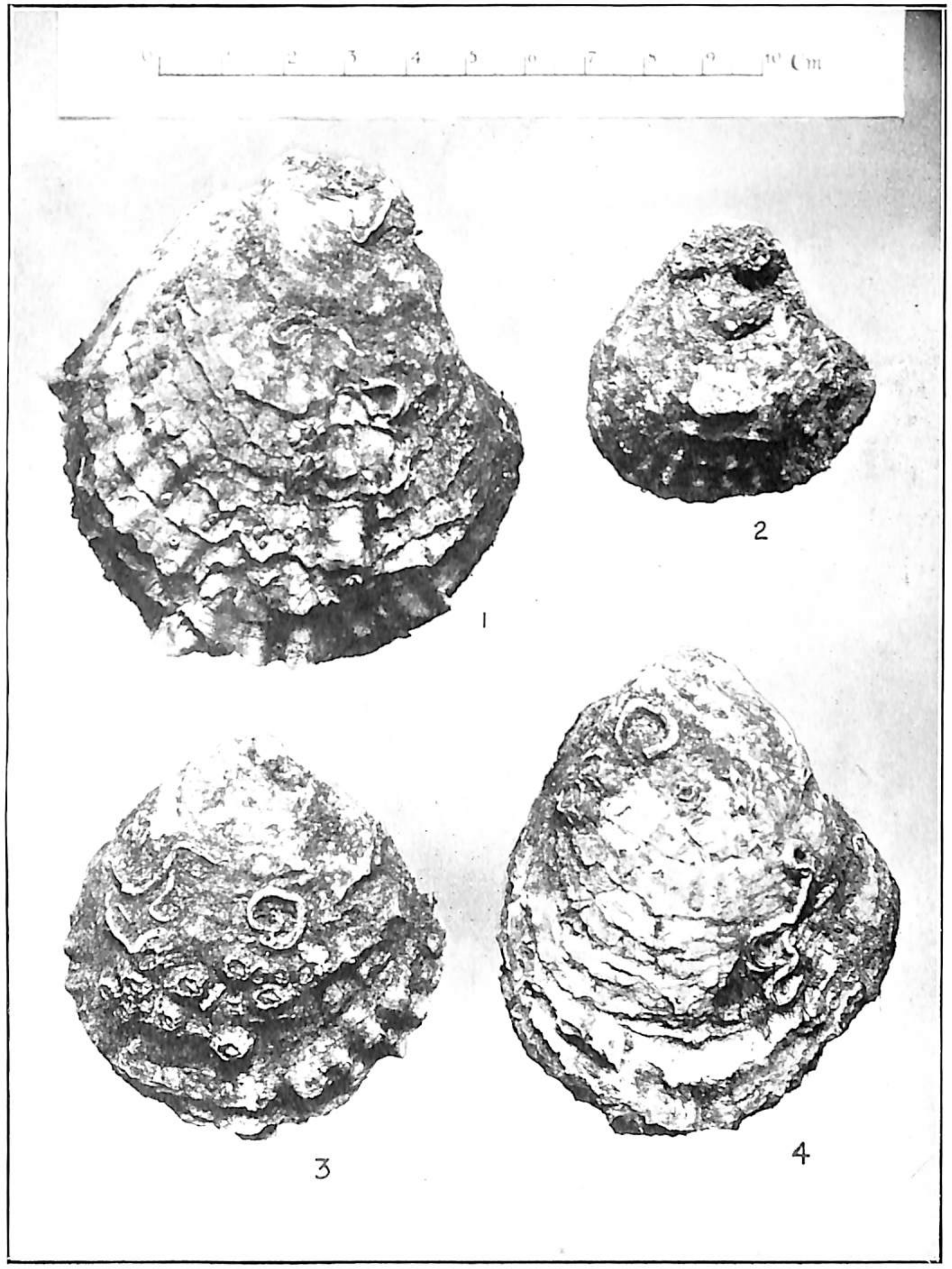
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HYDROCOELE EMBRYONALIS

BY

L. VON BETEGH, Fiume.

[Translated by ANNE L. MASSY, and published with the permission of the author and of the editors of the *Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten*, Jena.]

Plate I.

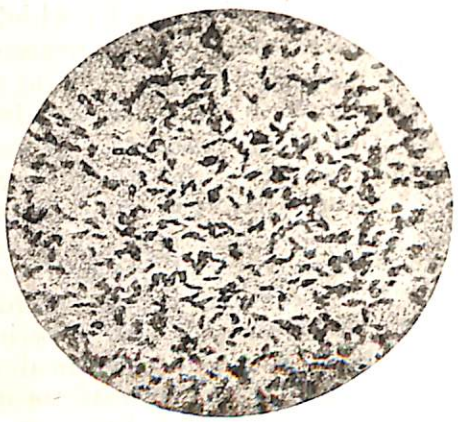
Only a few of the epidemic diseases to which alevins in fish breeding establishments are liable are at present known. The most widely spread is yolk-sac dropsy. The aetiology of this dangerous malady has not been made wholly clear, and but little special literature on the subject exists. Hofer,[1] as touching the cause of the sickness, mentions that observations of fish breeders agree that this condition is arrived at in consequence of pressure or shock to the eggs; as regards the aetiology, however, he remarks that nothing at present is certain. I have repeatedly observed this sickness in the biological station at Fiume and as the result of thorough investigations have arrived at the conviction that it is an infectious disease caused by some specific agent. The first observations date from 1907; having, however, at that time but little material available, I had to postpone exhaustive study to a later period. In that year I observed also another epidemic illness in trout alevins, which I described as *Tympanites embryonalis*.[2] I shall here mention this disease also, but reserve to myself the right of reporting fully thereon at the conclusion of the experiments.

The yolk-sac dropsy appeared again later a few times but sporadically, and destroyed many thousands of alevins. It was precisely this circumstance that first led me to think that we might be dealing with an infectious malady, since concussion or pressure would be more likely to kill the embryo than cause dropsy. Surely the circumstance that the sickness suddenly appears all at once points to this. At first the otherwise well developed alevins swim normally, after one or two days the enlarged yolk-sac attracts notice; the stricken alevins arise no longer to the surface, but, weighed down by the much enlarged

[1] Hofer, *Handbook of Fish Diseases*, p. 260.
[2] Betegh, *Tympanites embryonalis* (Halászat, 1907).

yolk-sac, move on the bottom of the hatchery box; after one or two days the sac bursts and the fish dies after a few hours.

The contents of the sac consist of a serous fluid mass which at the commencement of the sickness is quite transparent, and later, towards the end, becomes somewhat turbid. A slender *Diplobacillus* of about 2–3μ in length and 0,4—0,6μ in thickness can be isolated from the contents of the sac and moreover is in existence in the sac in pure culture. On artificial culture medium the bacillus grows after 24 hours. At first the colonies are transparent and opalescent, later grey-white and united to form a moist diffused mass. Growth is optimum at 20° C., but at 37° C. there is no growth. On gelatine the colonies after 24 hours become visible as fine, punctiform, transparent drops, which in a short time become confluent.



They develop along the course of the needle just as well as on the surface; it is characteristic that the gelatine is liquefied. On slanting gelatine, according to the nature and manner of arrangement of the particular colonies, furrows arise out of which the liquefied gelatine flows off and collects at the bottom of the tube, where the bacteria form a turbid grey-white suspension. On weak alkaline agar the colonies are also punctiform and grey-white, converging later to a moist incrustation, which causes the condensation water to become turbid. Neither in gelatine nor agar is any gas formed. The growth is similar whether at the surface or bottom of the agar. On glycerine agar the bacteria grow exactly as on ordinary agar, except somewhat more slowly. It would seem that 5% glycerine somewhat inhibits the growth of the bacteria. Morphologically, however, no distinction can be shown between such as grow on ordinary and on glycerine agar. After 24 to 36 hours the broth becomes uniformly turbid and after some days a thin scum forms on its surface.

Structure and biochemistry of the bacillus.

By dark field illumination the bacteria present are seen sharply outlined and in various stages of development. Fresh cultures show a very lively activity. The youngest bacterial forms are short and rounded at both ends. The bacterial protoplasm is homogeneous. The bacteria are short bacilli and often arranged in pairs (diplobacillus). At either pole of the bacillus the protoplasm is somewhat refractile and occasionally roundish granules are perceptible. Such little granules, which also show lively movement, are especially abundant in the condensation water of older agar cultures. Investigation by the Burri method reveals, especially in older cultures, typical *Diplobacilli*. By this method the pole granules are also quite perceptible and the granules present outside the cells are also clearly traceable. By intra vitam staining the protoplasm of the bacteria is stained uniformly and no fine structure is traceable. In bacteria stained by the Giemsa method a central part intensely coloured and a pale envelope weakly tinged, are visible. About in the centre of every organism an ovoid sharply-outlined spore-like body is visible. Whether this is a spore or nucleus must at present remain undecided. The *Diplobacilli* can be stained similarly by carbol-fuchsin: the organisms staining uniformly. In old culture the above-mentioned spore-like form is also visible and stains well with carbol-fuchsin. By the Gram method the bacillus decolorises; it is thus gramnegative and neither acid—alcohol—nor alkali—fast. On consideration of the qualities mentioned, and further the circumstances that in all the embryos examined the same micro-organism was perceptible in great quantity, it must naturally be regarded as the specific cause of the sickness. I propose to name it *Diplobacillus liquefaciens piscium*. Further experiments with this bacillus are in progress and will be reported upon later.

I shall now report briefly on the malady alluded to at the beginning of this paper, *Tympanites embryonalis*. I first observed it in 1907, since then I have only observed it epidemic this spring. Shortly after the appearance of the yolk-sac epidemic, it made its advent spontaneously. The station conduit had to be closed for some hours; when re-opened a quite turbid water began flowing in which only after many hours again became clear. Previous to this not a single case of *Tympanites* had occurred, but some thousand embryos had been affected by yolk-sac dropsy. After this occurrence in the conduit *Tympanites* suddenly set in. Only such alevins as were fully developed and were 15 days old and had completely absorbed their yolk-sac became affected by the disease.

The photographs testify clearly that the fish were distinctly more developed than those suffering from yolk-sac dropsy. It is characteristic of *Tympanites* that the whole gastric region becomes enormously distended, so that the young fish in consequence of the pressure of gas becomes bent. The disease develops very rapidly; at first the fish can still swim actively. After 6 or 8 hours the body swells up, the belly walls are tight and the interior is filled with gas. The fish breathe with difficulty; they can no longer dive, but swim with the ventral part uppermost. Finally the body wall bursts and the fish sinks dead to the bottom. The aetiology of this epidemic disease is at present the object of investigation. In all probability a micro-organism is the cause of the formation of gas. On the adjoining photograph a case of double infection is represented, viz., a young fish is seen in which *Tympanites* is beginning and two tolerably large air bubbles are present in the yolk-sac.

I am indebted to Herr Prof. von Gauss, Director of the Royal Biological Station for Marine Investigation, for kindly providing me with the material for investigation.

EXPLANATION OF PLATE I.

FIG. 1.—*Hydrocoele embryonalis*: different stages of the development of the sickness. In the centre of the picture alevins in which the disease has reached its maximum are shown. The yolk-sac is enormously enlarged and filled with serous fluid.

FIG. 2.—*Tympanites embryonalis*: Young fish of about 10—12 days, which have been attacked by *Tympanites*. The ventral wall is very tense, from the body cavity being filled with gas and the body is strongly bent dorsally. Below at the right hand side is seen a fish which has a double infection of yolk-sac dropsy and *Tympanites*; the latter is present as a secondary infection, two tolerably large air bubbles mark the commencement of the formation of gas.

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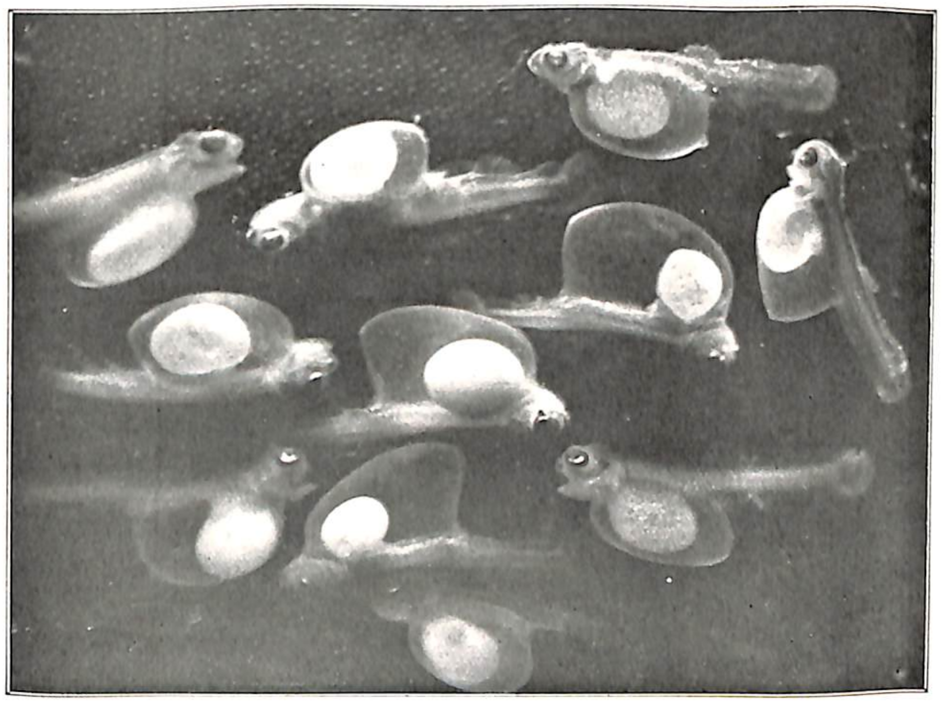
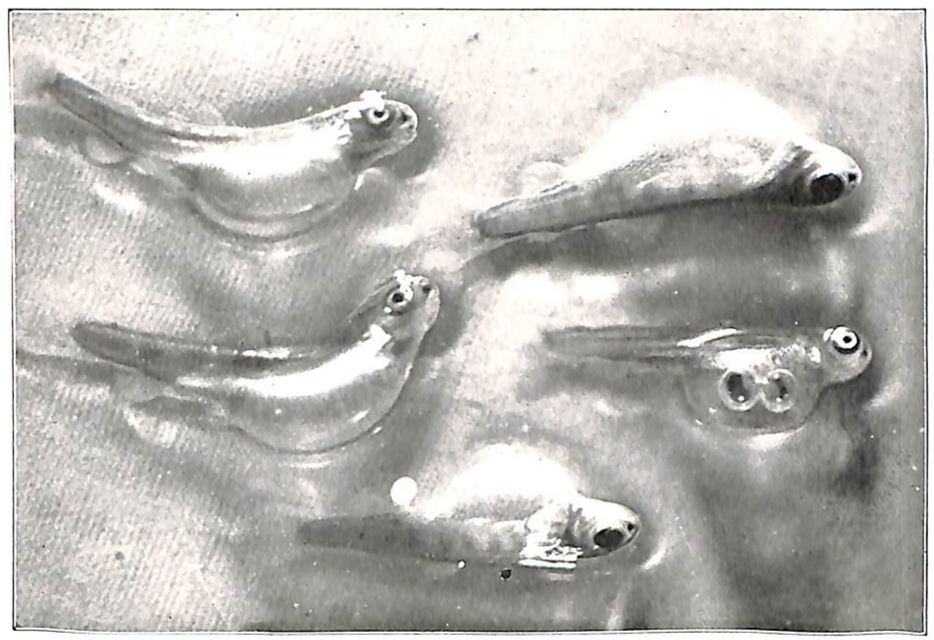


Fig. 1.



v. BETEGH, Phot. Fig. 2.

THE SALINITY AND TEMPERATURE OF THE IRISH CHANNEL AND THE WATERS SOUTH OF IRELAND.

BY

DONALD J. MATTHEWS.

PLATES I–XV.

The investigations on which this report is founded were commenced in February, 1903, and include observations up to the end of May, 1912. They consist of determinations of temperature and salinity during the months of February, May, August and November made on board the *Helga* and of observations made at all times of the year up to 1907 at three lightships and one lighthouse, and thereafter at one lightship.

APPARATUS.

On the four quarterly cruises Ekman reversing waterbottles with messengers have been used, generally in series, for observations below the surface and on occasion at the surface also. They are fitted to carry two thermometers of the reversing type but as a rule only one has been used. The thermometers were of the pattern made by Richter of Berlin, with which it is possible to read to the second place of decimals, but the temperatures cannot be considered accurate to this extent as differences as great as ·05° have been found between simultaneous readings of two instruments after applying all corrections. The fact that the thermometers have not been used in pairs also throws a certain doubt on the results, as these instruments are liable to sudden changes in the breaking-off point of the mercury thread, which may give rise to errors of considerable magnitude. Large errors are, of course, easily detected by the irregularity in the resulting temperature curve, but small ones may be overlooked if a second thermometer is not used as a control. An examination of the observations makes it almost certain that no large errors have occurred, but the small differences mentioned above are probably due to such changes.

During the earlier years of the investigations maximum-minimum thermometers were chiefly used and also reversing thermometers of Negretti and Zambra's older model. The latter were graduated to half degrees and were unprovided with auxiliary thermometers, and temperatures could only be recorded to the nearest tenth of a degree. As regards the maximum-minimum thermometers, since in the areas in which they were used the temperature generally changes continually in one direction, the readings were probably accurate except for errors caused by the index slipping in the bore, and there is no reason to suppose that this has taken place to any important extent.

Surface temperatures and water samples on the cruises have been taken as a rule by means of a bucket, and this method has of course been used at the lightships. All thermometers have been provided with a certificate showing errors, either from the National Physical Laboratory, or, in the case of Richter's thermometer, from Charlottenburg, and all, except the capsizing ones, have since 1904 been periodically compared with the standards in the Physical Laboratory of Trinity College, Dublin.

Determination of Salinity.

The water samples have been preserved in 6 oz. milk bottles with porcelain stoppers, rubber washers and spring catches. As a rule these have given very good results. A few have been broken in transit, and in some cases an abnormally high salinity has been found to be due to a leaky washer or a cracked bottle. Such causes of error are however easily detected, and very few salinities of doubtful accuracy have been used for this report; when such have been used attention has been drawn to them.

Some of the samples taken at the lightships have been found to contain so much sulphuretted hydrogen as to be useless; this is probably due to the accidental enclosure of a piece of weed or other organic matter.

For various reasons I do not consider that the observations of salinity taken previous to 1909 are so wholly reliable as to eliminate the possibility of serious error in the deduction of mean isohalines. I have therefore confined consideration in this paper to salinities determined by myself or by my assistant Mr. C. W. Frost. The samples were titrated by Mohr's method against the International Standard Water, and the results have been calculated by means of *Knudsen's Hydrographical Tables, 1901.* The pipette, of Knudsen's model, held about 16 cc., and the burette was of the bulb form, drawn out to a fine jet at the upper end. Under suitable conditions, that is, with small variations of light and temperature, one titration for each analysis has been found sufficient in the case of the upper layers, but in nearly every case samples taken at a depth of one hundred fathoms or more have been titrated in duplicate. In hot sunny weather, however, the temperature often changes so rapidly that it is necessary to make all titrations in duplicate; this was particularly the case during the summer of 1911.

For the deeper samples the salinity has often been calculated from first principles in order to avoid the slight error due to the use of Knudsen's Titration Tables, owing to the rounding off of the corrections. It is expressed in parts per thousand

of salt by weight, that is, the number of grammes of total solids contained in a thousand grammes of water, and is calculated from the chlorine content by the formula $S = 0 \cdot 03 + 1 \cdot 8050 \text{ Cl}$.

Method of Calculating the Mean Values.

Almost the whole of the observations during the quarterly cruises are vertical series, and those from the surface only are so few that they have been disregarded.

In order, as I am informed by the officer responsible, to avoid giving a specious appearance of identity to Stations which, owing to weather and other circumstances, were not in fact exactly identical in position, the Irish observing Stations have received a serial number only. For purposes of tabulation the following procedure has therefore been adopted. A chart was prepared for each of the four months, on which were plotted in their correct position all the serial numbers from the beginning for the month in question. It was seen that though the observations tended to fall into groups, yet the area of these groups varied considerably, and some observations were completely isolated. In one or two instances the stations for a cruise had been so placed that they fell midway between the groups formed by the majority; in this case a section was drawn for these observations and from this was interpolated the most probable value at the centre of each group; such values were then used as if they had been actually observed. Of course such a method is open to objection, but it is the only one possible short of neglecting the observations entirely, which would probably have given rise to even greater errors. The charts were then carefully examined and pencil lines were drawn to include all positions which fell sufficiently closely together, the size of the group being varied according to the position; in the North Channel, for instance, the group would have to be very much smaller than in the area close to the south-east coast if the probable error is to be the same in each case.

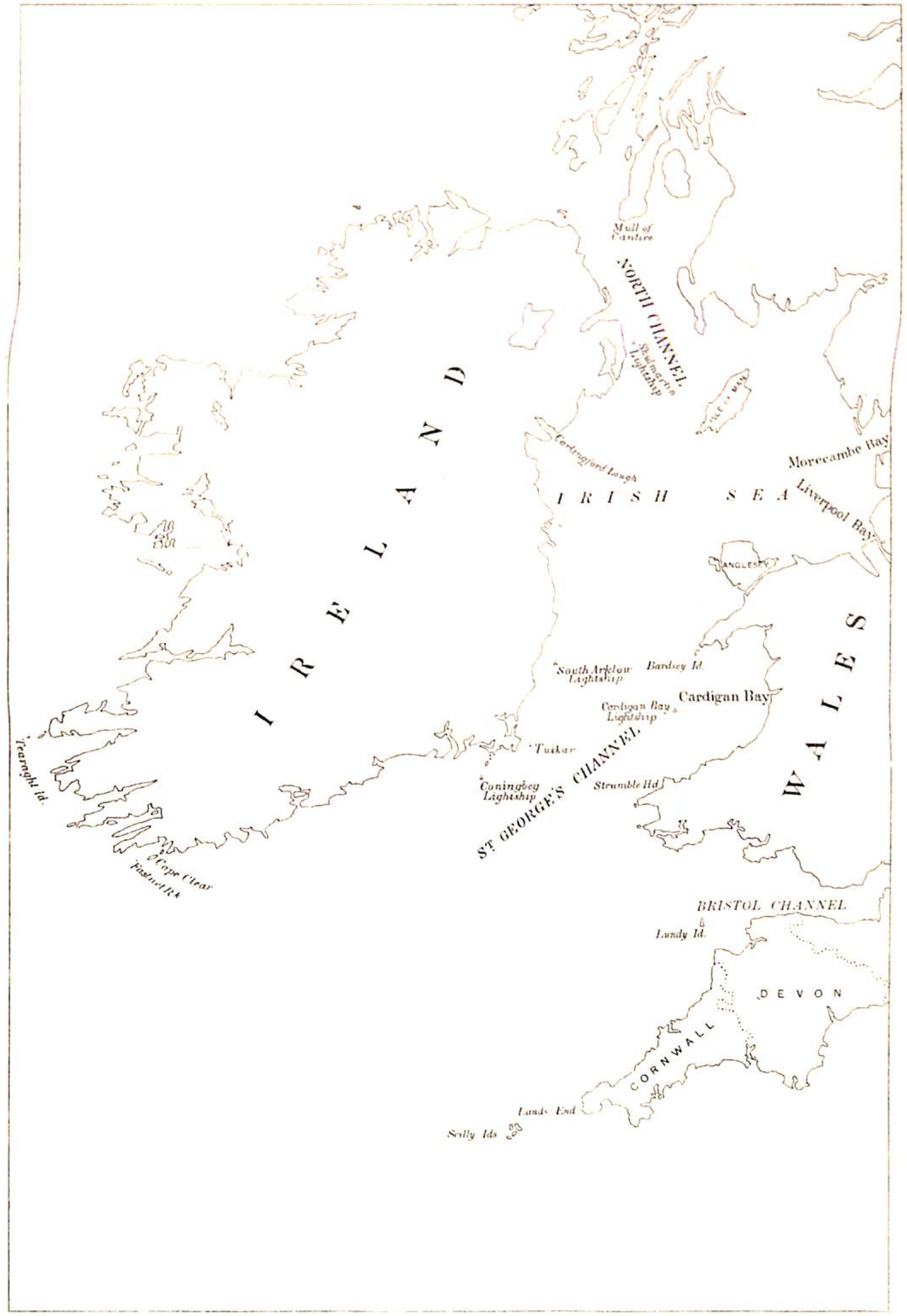
The mean date, position, depth, and temperature and salinity for various strata were then calculated for each of these groups, by interpolation from a curve when observations at a selected depth were missing. In the rather numerous cases where the *sprungschict* or surface of separation between two bodies of water of different temperature and salinity fell near the missing observation the interpolation is of course extremely uncertain, and to avoid error due to any preconceived idea as to its shape the curve has been drawn here as a straight line.

To calculate the mean conditions for the whole year a number was given to each of these groups, and these numbers were plotted again on a fifth chart. Another series of groups was thus obtained, and a final number was given to them when they contained at least two years' observations for each of the four cruises, or when they were new positions which will probably be investigated regularly in the future. Below is given a list of the more important of these mean positions.

MEAN POSITIONS OF IRISH STATIONS, WITH THE NUMBERS USED FOR REFERENCE IN THIS PAPER.

No.	Lat. N.	Long. W.	No.	Lat. N.	Long. W.
1	54° 33½′	5° 20′	35	52° 10′	6° 8′
2	54° 36′	5° 8′	36	52° 8′	5° 51′
3	54° 37′	4° 56½′	37	52° 6′	5° 36′
4	54° 16′	5° 20′	38	52° 4′	5° 20′
5	54° 21′	4° 54′	39	51° 54′	6° 48′
6	54° 31′	4° 46′	40	51° 36′	6° 38′
7	54° 0′	5° 49′	41	51° 17′	6° 28′
8	54° 0′	5° 32′	43 (E 30)	50° 57′	6° 21′
9	54° 0′	5° 14′	44	51° 20′	6° 59′
10	54° 0′	4° 58′	45	51° 25′	7° 30′
12	53° 40′	5° 48′	46	51° 36′	8° 14′
13	53° 40′	5° 31′	52	51° 14′	9° 43′
14	53° 40′	5° 14′	53	50° 56′	9° 56′
15	53° 41′	4° 56′	54	50° 19′	10° 21′
16	53° 22′	5° 46′	56	50° 35′	11° 19′
17	53° 21′	5° 30′	57	50° 52′	11° 6′
18	53° 21′	5° 12′	58	51° 10′	10° 54′
19	53° 21′	4° 55′	59	51° 27′	10° 43′
21	53° 2′	5° 45′	60	51° 38′	11° 1′
22	53° 3′	5° 30′	61	51° 31′	11° 28′
23	53° 2′	5° 12′	62	51° 23′	11° 51′
24	53° 3′	4° 56′	63	52° 2′	10° 56′
26	52° 41′	5° 53′	64	52° 0′	11° 11′
27	52° 41′	5° 37′	65	51° 58′	11° 27′
31	52° 29′	6° 0′	66	51° 56′	11° 43′
32	52° 27′	5° 45′	67	51° 54′	11° 58′
33	52° 26′	5° 27′	68	51° 50′	12° 14′
34	52° 24′	5° 10′			

As has been mentioned, the groups often cover a considerable area, even when the intention was to make the observations at one point on all cruises. Off the south-west coast where the steamer is out of sight of land for some time and the weather may make an astronomical fix impossible, it is of course unavoidable that errors should occur in making the position of a station, which cannot be discovered until the next landfall. On the other hand, in the Irish Sea, the depths are so irregular that an error of a mile in position may lead to a considerable change of the depth; thus it happens that stations which by dead reckoning were made at identical positions show a difference of depth of twenty or thirty fathoms. As will be seen from the sections, the depth has a great influence on the salinity and temperature, and this variation in the depths recorded gives rise to some uncertainty in calculating the means, and in the case of the bottom water the temperature in places is probably



Ordnance Survey, Southampton, 1914.

too high and the salinity too low. The most difficult section to draw on this account has been No. IX. Here the depth increases very rapidly seawards outside the 200-fathom line and it appears from the soundings made on the various cruises that the line of stations runs out along a submarine valley pushing up to the coast from the deeper water. Identical depths may be found here at the bottom of the valley at its shoreward end and on its slopes much further seawards; but as will be shown later, there is strong reason to suppose that the isohalines and isotherms are tilted up the sides of the valley and so the salinity and temperature would not be the same at the two positions in spite of the agreement of the depths.

The Plymouth and Liverpool Observations.

In order to make the report as complete as possible use has been made of the results obtained in connection with the International Fishery Investigations by the Marine Biological Association at Plymouth and by the Liverpool Marine Biological Committee.

The Plymouth observations consist of five stations (E on the charts) (Plates XI to XV), on the western side of the Irish Channel and south of the latitude of the Smalls Light, and of a series of surface observations at the Cardigan Bay and Seven Stones Lightships, of which the former is now removed.

Of these stations, E6 has been worked on all quarterly cruises except one, from the beginning of the investigations in February 1903 to November 1909, the last cruise before the work was transferred to the Board of Agriculture and Fisheries. Stations E26 to E30 have been worked twice in February and three times in May, August, and November; E30 has since been adopted as an Irish Station so that in some cases there are four sets of observations from this position.

In the Irish Sea the Liverpool Marine Biological Committee has a line of stations running westwards from Morecambe Bay, along the fifty-fourth parallel, to the Isle of Man, and then turning southwards a short distance to the east of the easterly Irish stations. There are here sets of observations for each of the quarterly cruises, for the years 1907 to 1910 inclusive; on some cruises only surface observations have been made, and in order to calculate the mean bottom salinity and temperature the missing values have been interpolated by calculation of the difference between the surface and bottom for the dates when observations at both are available. There is therefore some uncertainty as to the true bottom conditions, but the character of the water changes so rapidly as we cross from the shallows of Liverpool Bay to the deep water westward of the meridian of the Isle of Man that the error in the charts is negligible. It will be seen that in some cases the isohaline or isotherm running through these Liverpool Stations is shown by a broken line, indicating some doubt; this is not intended to convey that the observations here are doubtful, but that they are not such that the course of any one isohaline can be accurately traced.

The Charts and Sections.

The tabulated means show that the differences between surface and bottom over a large part of the area lying between Wales and Ireland are very small, so that no sections are necessary here.

The charts were constructed by plotting the mean values and then drawing isotherms and isohalines among them. When an isotherm or isohaline fell between two stations its position was calculated on the assumption that the value changed linearly, but this calculated position was not always used if it gave rise to sharp bends in the curve. This was particularly the case as regards the salinities; it often happened that stations with only two years' observations fell among others with three or more years results, and a strict adherence to the calculated values would have given a very complicated and improbable picture. The isohaline of 34·50 per thousand at its northern extremity, is on the whole the most doubtful for this reason.

As a rule, the chart isohalines have been drawn for 33·90, 34·00, 34·25, 34·50, 34·75, 35·00, and then for every 0·10 increase, but in special cases others have been used where they give a clearer idea of the distribution. The isotherms are drawn for every degree, often for every half degree.

Sections.

Owing to the varying depths found on different cruises the sections have not always the same bottom outline, but on the whole the difference is small.

The isotherms are drawn for every degree or half degree according to circumstances, but it has not been possible to use the same isohalines as on the charts. In all cases those have been drawn, which give the clearest idea of the position of the various water layers. On the sections the position of the mean stations are shown by short vertical lines with the number of the mean station above it. It should be remembered that the position of the mean stations (see page 4) is not exactly the same as that of the corresponding mean station for any given month, but for present purposes the difference is negligible.

The position of the stations is shown on the inset charts on the plates of sections.

The mean salinities and temperatures at the surface and bottom are given on the sections. It will be found that in a few cases there is a slight discrepancy between the charts and the sections as regards salinity. The latter show the actual calculated values depending perhaps on two years' work only; the former the more probable course of the various lines when everything is taken into consideration.

Lightship and Lighthouse Observations.

Reliable salinity observations are available from the Coningbeg Lightship from March 1909 to July 1912, and temperature observations from the beginning of 1904 to September

1912. The salinities were observed at half tide, about every seven days on the average, but there are many blanks.

Temperatures are also available from the Skulmartin and South Arklow Lightships and the lighthouse on the Fastnet Rock, for three years 1904, 1905, and 1906.

All the temperatures have been taken daily at half tide, but they vary very much in value. At the Fastnet, observations cannot be made in rough weather, and sometimes not even one is to be had during a ten-day period; and at no time were they taken more than once a day. At the other positions observations are possible in rough weather, but their value is somewhat diminished by a want of uniformity. In some cases only one observation has been made each day, but this has been the mean of several readings made within a few minutes of each other. At other times the temperature has been recorded twice a day, but in some cases only during the daylight hours, in others at all times during the twenty-four hours. All the records suffer from the fact that they have been taken at half tide, for we cannot be certain that this will give a true daily average. In the case of those from the Coningbeg Lightship the average values are founded on a larger number of years.

The chart showing the mean surface temperature for the whole year is founded on four months in each year only. In order to get some idea of how closely such a mean agrees with the true mean, the mean yearly temperatures at the Lightships and the Fastnet Rock have been calculated both from the mean values for each ten-day period throughout the year and from the first ten days of each of the cruise months. The results are shown below, and it will be seen that the differences are very small except in the case of the Fastnet Rock, where the weather has made the records very incomplete. It is not strictly permissible to argue from shore waters to the open sea, but still there is very good reason for supposing that the mean temperature charts are very close to the truth, especially in the case of that for the bottom, where the daily change is small or negligible.

Yearly Mean Temperatures.

	Skulmartin.	South Arklow.	Coningbeg.	Fastnet.
Calculated from all observations . .	9·72°	10·53°	10·76°	10·56°
Calculated from the first ten-day periods of February, May, August, and November . . .	9·80°	10·60°	10·75°	10·83°
Difference . . .	+0·08°	+0·07°	—0·01°	+0·27°

The Defects of the Method of Mean Values.

It should be remembered that the use of mean values at times tends to hide important and regularly recurring phenomena. This is particularly the case where a sharp division into two layers always occurs at a given time, but at depths varying from year to year. The mean section and curve will not show a sharp division at one depth but a more gradual transition between the two layers.

The Tides of the Irish Channel.[1]

It will be shown in the sequel that the tides exert a great influence on the distribution of salinity and temperature in the Irish Channel and a short account of their chief features may be given here with advantage.

The tidal wave is a vertical undulation of the water and is to be distinguished from the *tidal stream* to which it gives rise when checked by decreasing depths or the conformation of the land. It approaches the south-west coast of Ireland from the Atlantic in an approximately north-easterly direction, so that its crest reaches Cape Clear and Ushant at about the same time. Off the former place it divides into two portions. The western half travels northwards along the west coast of Ireland, and following the line of the shore passes southwards through the North Channel to meet the other branch in the latitude of the Isle of Man. The easterly half moves in a north-easterly and northerly direction into the Bristol Channel and through the St. George's Channel into the Irish Sea; its height is everywhere greater at its eastern than at its western extremity, so that the spring rise is on the average eleven feet higher on the English and Welsh coasts than on those of Ireland.

The tidal stream is a horizontal movement of the water resulting from the checking of the velocity of the tidal wave by shallows or the form of the coast; consequently its strength will vary considerably from place to place according to the opposition offered to the wave, and the Irish Channel shows these variations extremely well. As has been said, the two branches of the tidal wave meet between Carlingford Lough and the Isle of Man, where the two resulting streams, flowing in opposite directions, neutralize one another, while the heights of the two waves are added together; accordingly the stream is here almost imperceptible, while the spring rise is from 16 feet to 20 feet. On the other hand off Arklow there is little resistance to the wave, and the spring rise is only four feet, though the speed of the stream reaches four knots or more.

The changes in the tidal stream are referred to the time of high water at the entrance to Liverpool Bay as a standard,

[1] The Irish Channel is the whole of the sea lying between Ireland and the opposite coast of Great Britain. The "southern entrance" to the Irish Channel is in this report that part of it which lies southwards of the latitude of the Tuskar.

though as it happens the time of high water at Dover is so nearly the same that it can be used for reference for most purposes, as is done in the charts of the tidal streams in the English and Irish Channels published by the Hydrographic Office.

At high water at Liverpool Bay there is slack water over nearly the whole of the North Channel and Irish Sea, though weak shore streams are perceptible. In the St. George's Channel the ebb has already begun to flow southwards, and in the Bristol Channel it is just ending; that is, the ebb of the Irish Sea coincides with the flood of the Bristol Channel.

As the water falls at Liverpool Bay it ebbs northwards through the North Channel and southwards through the St. George's Channel. The latter part divides into two branches; the easterly one flows round the south-west coast of Wales to form the flood tide of the northern half of the Bristol Channel, and at the same time the ebb of the English Channel turns to the north-east round Land's End and flows along the north coasts of Cornwall and Devon to become the flood tide of the southern half of the Bristol Channel. Shortly, the flood tide of the Bristol Channel coincides with and is in great part derived from the ebb tides of the English Channel on one side and the St. George's Channel on the other.

The western half of the ebb of the St. George's Channel flows south-westwards along the south-east coast of Ireland to join the stream which has already been running westwards past Cape Clear for three hours.

At three hours after high water at Liverpool Bay the tide begins to set to the north-east and east on the south-east coast of Ireland, but elsewhere the ebb continues unchanged until low water at Liverpool Bay, when again there is slack water over the whole area north of the latitude of the Tuskar, neglecting as before the weak coastal streams. In the Bristol Channel, and in its southern half in particular, the last of the flood is still running.

As the water rises at Liverpool Bay the ebb sets out of the Bristol Channel, south-westwards towards Land's End, and westward and north-westwards into the St. George's Channel, where the flood is now running. The flood in the latter tends to flow to the east of north, and northwards of the latitude of Anglesey it turns almost due east to Morecambe Bay. At the same time the flood tide in the North Channel which has been running since low water at Liverpool Bay, bends eastwards to the north of the Isle of Man to meet the southern flood in Morecambe Bay, where the united effect of the two streams causes a rise as great as twenty-eight feet at spring tides.

The Irish Channel contains two areas where the stream is almost imperceptible and where the power of the tide to cause vertical mixing of the water is almost *nil*. One of these, to the westward of the Isle of Man, has already been mentioned. The other lies off the entrance to the Bristol Channel. Its position changes slightly with the state of the tide, the centre moving from about 51° N. Lat. and 6° W. Long. to a point not far from the opposite coast of Ireland. In both these areas we find a bottom consisting largely of mud which is able to deposit here owing to the small scour, and as will be shown, the relatively undisturbed state of the water is particularly favourable to the formation of horizontal layers of different salinities and temperatures.

On the other hand, in the area to the westward of Cardigan Bay the stream flows with great rapidity and the water is so thoroughly mixed that as a rule it is homogeneous from surface to bottom, as is the case in the region of strong tides in the eastern half of the English Channel.

Off the south-west coast of Ireland the tidal movement is fairly simple, the current setting backwards and forwards along the shore about six hours each way. Its strength is not great and owing to the configuration of the bottom there is no great tendency to vertical mixing. Consequently horizontal layers are well developed here at times.

Before proceeding to the detailed discussion of the varying conditions of the Irish Channel attention may be drawn to the chief causes of changes in the temperature and salinity, so far as they are of importance for the region in question. It will be seen that the fluctuations in salinity and temperature are to a certain degree dependent on one another so that it is impossible to draw a sharp line between them.

Insolation.—By far the most important source of heat for the surface both of the land and the sea is the sun. When the solar rays reach the earth's atmosphere a portion is totally reflected, and another portion is scattered and absorbed in the air; the remainder reaches the surface and is largely absorbed. There is however an important difference between the effect on dry land and on a water surface. The rays do not penetrate far into soil, and the heating effect is consequently confined to a layer of very small depth; as a result the rise of temperature is relatively great. The sea however allows the solar rays to penetrate to some distance, and a much larger volume of water will be warmed but to a far less degree. Of the heat which has been absorbed by the atmosphere a certain amount will be continually radiated to the earth at all times; but the much more important fraction of the whole heat supply, that derived directly from the penetration of the sun's rays, ceases as soon as the sun is below the horizon and is very largely reduced by cloud. There is therefore a daily and a yearly period in the amount of heat received from the sun. *Radiation of heat to space* occurs at all times, but is very much weakened by a cloudy sky. When as in the spring and summer the loss of heat by radiation is less than the gain from insolation the temperature of the surface rises; in the autumn and winter on the other hand the conditions are reversed and the temperature falls.

Admixture.—Changes of temperature also arise from admixture with warmer or colder water from another source. Thus the warm current entering the southern Irish Channel between the Scilly Isles and Land's End close to the land causes a considerable rise of temperature locally, and the water often gets colder as one proceeds seawards from the north coast of Cornwall. Similar changes on a smaller scale occur where water, highly heated in bright summer weather or strongly cooled in winter, drains off shallow sandy flats.

Finally there is the rarer case where there are strong vertical currents which either bring to the surface the cold water of great depths or carry the warm surface waters downwards. No instance of the ascending movement of any importance seems to occur in the Irish area, but on the other hand there appears to be evidence for the existence of descending currents off the south-west of Ireland, due to the banking up against the land of the warm water carried shorewards by the prevailing drift from the south and west.

Changes of salinity are due either to the relative strength of evaporation and precipitation or to admixture with fresher or salter water. In the Irish Channel the prevailing phenomenon is a steady decrease of salinity as we travel away from the open Atlantic, a change which is obviously due to the addition of fresher water, partly derived from local precipitation, but chiefly from land drainage. The change is complicated and is best described in connection with the discussion of the charts.

The Mean Conditions in the Irish Area.

In the following pages are given some of the more important results of the Irish hydrographical observations. It will be noticed that the larger part of the area lying eastwards of the meridan of the Isle of Man has not been included. The conditions here do not resemble those in the western part of the Irish Sea, and have already been described by Dr. Bassett in various reports of the Liverpool Marine Biological Committee.

In the description of the conditions observed in the various months statements often occur, such as, that the mean temperature is highest in a certain month, as August, This is not to be taken as referring to every month in the year, but only to the cruise months, February, May, August, and November, unless the contrary is distinctly expressed, as in the discussion of the lightship observations.

The Mean Temperature of the Sea in the Irish Area.

On Plates IX, X and XV will be found sections and charts showing the mean temperature for the whole year. Taking first the surface chart, it will be seen that the mean temperature increases slowly as we move southwards from about 10° in the North Channel to 11° in St. George's Channel and to 12° off the northern coast of Cornwall and the south-west coast of

Ireland. In the waters lying between Ireland and Great Britain the higher temperature is found on the eastern side, while in the open ocean it increases seawards.

The bottom water shows another temperature distribution; it is everywhere colder than on the surface, but north of St. George's Channel (sections I to V) the difference is not great. In the broader southern part of the Irish Channel quite other conditions are found. The bottom temperature is highest near the Cornish coast and decreases seawards to an isolated area of less than 9° (see section VII, station 41), surrounded on all sides by warmer water. Off the south-west of Ireland the temperature rises slowly seawards from about 9·6° to over 10°, and then falls again to less than 9° as the depth rapidly increases. There is a marked division into layers of different temperature, and in the Irish Channel proper the isotherms dip towards the English side (see section VII). To the south-west of the Fastnet the isotherms dip seaward, in spite of slowly increasing depths, so that the inshore waters are slightly colder than those of the open sea (section VIII).

Section IX is drawn in a direction slightly south of west (true) out over the edge of the continental plateau, depths as great as 600 fathoms being found at the most westerly station. The isotherms of from above 12° to that of 10·5° are crowded together near the surface and follow a nearly horizontal course, dipping towards the open sea. The isotherm of 10·5° is found at a depth of about 80 to 100 fathoms except near the shore; below this the temperature changes very slowly, 10° degrees being reached at a depth of from 250 to 300 fathoms and 9° at nearly 500 fathoms. The bottom water at about 540 fathoms has a temperature of 8·7°; near the shore it is under 10°, and between the two regions lies a band of bottom water with a temperature of a little over 10°.

The Mean Salinity in the Irish Area.

The same plates show the mean salinity for the whole year. The *surface salinity* increases from north to south, and from the shore seawards, between the North Channel and the Tuskar, a condition which would be expected, as the chief source of low salinity is to be found in drainage from the land while the supply of salt oceanic water is at the southern end. The surface isohalines bend to north and east so that the highest salinity, like the highest temperature, is found on the eastern side, from Anglesey southwards. South of the Tuskar-Strumble Head line the conditions are more complicated. The salinity is higher on the Cornish coast than on the opposite coast of Ireland, and near the centre of the southern entrance of the Irish Channel the chart shows a large area, marked by a dotted line, of water of 34·93 per thousand. This is due to a cyclonic circulation of the surface water and will be referred to again. The isohaline of 34·93 per thousand is not drawn; it would of course extend east and west from the dotted line. To the south-west of Ireland the surface salinity increases fairly rapidly seawards from 35·00 per thousand to 35·40 per thousand and then more slowly to 35·45 thousand cent.

The *bottom* salinities are higher than those at the surface in the North Channel and southwards as far as section III; from here to the Tuskar there is very little difference between surface and bottom, and over the whole area there is a tendency for the higher salinity to be found on the eastern side, excluding the shallows to the eastward of a line drawn north and south through the Isle of Man. In the southern entrance, division into layers again appears, with the higher salinities on the eastern side, but the difference between surface and bottom is nowhere much greater than 0·10 per thousand.

Off the south-west and west of Ireland the division into layers is strongly marked and the isohalines dip shorewards owing to the presence of layers of fresher water which reach the bottom near the coast but rapidly become thinner seawards. On the Tearaght line (section IX) the difference between surface and bottom nearly vanishes at a distance of about forty miles from the coast, the water having a salinity of about 35·45 per thousand, increasing to 35·50 per thousand at about 500 fathoms.

Mean Temperature and Salinity in February.

Plates I, II and XI.

At any one place there is relatively little difference between the surface and bottom temperature and salinity, on account of the thorough mixing caused by wave action and by the descending currents arising from surface cooling. The isotherms and isohalines therefore run nearly vertically except close to the shore and in the deep water off the south-west coast of Ireland (Plate XI.). The horizontal distributions of temperature and salinity at the *surface* resemble one another closely; that is, they both increase from north to south and from the shore seawards, the higher values being found slightly on the eastern side in the Irish Channel. The position of the *bottom* isohaline of 34·50 per thousand is somewhat uncertain on account of the small number of observations available at some of the stations; it is possible that its northern extremity should have been shown as an isolated patch of salt water surrounded on all sides by fresher water.

In the broad southern entrance the isohalines are worth a detailed study (that of 35·10 per thousand at the surface in particular) as they show signs of a cyclonic circulation which will be discussed more fully later.

Off the south-west coast of Ireland the conditions are very simple; it should be noted however that the isohaline of 35·60 per thousand is founded on one set of observations only.

The *surface* temperature is lower in February than at the time of the other three cruises, except in a small area in mid-channel, off Anglesey, where the coldest cruise month is May. The difference between the February and May surface temperature is often only a few tenths of a degree.

In shallow water the *bottom* temperature is lowest in February; in the deeper parts, from the North Channel to the St. George's Channel, the minimum falls in May. In the southern entrance the coldest water is also found in February except in deep central area of weak tides, and along the south and south-west coast of Ireland where the minimum is delayed till May.

The maximum surface salinity of the year falls in February in the area south of section I. and north of the line of stations 31 to 34. In the North Channel and in the southern entrance the maximum salinity occurs earlier in the winter, about the time of the November cruise. Where the surface maximum falls in February the bottom maximum generally falls in the same month or in May. A November maximum at the surface is generally accompanied by one on the bottom also.

Along the north coasts of Cornwall and Devon the conditions are more irregular, and even show in places a February minimum.

Mean Temperature and Salinity in May.

Plates III, IV and XII.

Compared with February, the *surface* temperature has risen everywhere except in the small area off Anglesey where a May minimum occurs.

The *bottom* temperature in May is less than that on the surface, and it is at its lowest value for the year over the whole of the deep water in the central line of the Irish Channel, except along the Cornish side.

In the southern entrance the surface and bottom isotherms differ considerably and the bottom chart shows a deep current of relatively warm water flowing northwards on the eastern side with colder water round it.

The *surface* salinity has fallen since February except at the two outer stations on the Fastnet line (section VIII). In some places it has already reached its minimum, as in the North Channel, off Anglesey, and in the southern part of the St. George's Channel.

The *bottom* salinity is also lower than in February on the whole, but there are a few stations to the west and south-west of the Isle of Man where it is at its maximum.

There are some striking differences between the charts for February and May; for instance, the 34·75 per thousand line has retreated on the surface, from near Bardsey Island to well south of the Tuskar-Strumble Head line, and the isohalines of 35·00 per thousand and 35·10 per thousand have been replaced by those of 34·90 and 35·00 per thousand respectively. The bottom changes are somewhat similar, but do not show so well, as the observations make the position of the 34·75 per thousand line uncertain.

The cyclonic circulation shows itself rather more strongly in the surface patch of low salinity in the centre of the southern entrance (section VII) and also, but not so well, in the form of the surface isohaline of 34·90 per thousand.

There is now a distinct division into layers of different salinity and temperature, and in the Irish Channel the higher salinities tend to occur on the eastern side; this arrangement is probably due to the earth's rotation, which causes currents to bend to the right in the northern hemisphere.

Off the south coast of Ireland (section VIII) the lower salinities near shore are found below the surface instead of at it, as if the prevailing south-westerly winds had caused a strong surface drift towards the shore; this explanation seems the most probable one, but the conditions may be due in part to a current along the shore.

Section IX shows the fresher shore water stretching seawards as far as station 65.

Mean Temperature and Salinity in August.

Plates V, VI and XIII.

August is pre-eminently the month of high temperatures and low salinities.

The *surface* temperature is higher than at the time of the other quarterly cruises, the increase since May being in many cases considerable; thus the 8° line of May has been replaced by that of 13° or more, the 9° line by the 14° line, and in the southern entrance where the water had a temperature of a little over 10° it is now 15° or 16°. Off the south-west coast of Ireland, where the conditions are nearly oceanic, the rise is not so great.

The surface chart shows two distinct types of temperature distribution. In the narrower region, northwards of the Tuskar-Strumble Head line, the warmest water is found on the coastal shallows; southwards of this line the oceanic type begins to manifest itself, and the temperature increases seawards owing to the drift of warm water from the south-west. The course of the 14° isotherm shows the transition from one type to the other very distinctly.

On the *bottom* the isotherms are crowded together and large temperature differences are encountered in a small horizontal distance as a result of changing depths. The shallower water is being warmed more quickly by the sun's rays than the deep central tract, and so we find such phenomena as the isolated cold bottom area south-westwards of the Isle of Man.

In the southern area the warm current on the Cornish coast and the cyclonic circulation show themselves in the course of the bottom isotherms, which run northwards on the eastern side and then turn westwards towards the Irish coast.

In the deepest part of the southern area, where section VI crosses it, the temperature is as low as 8·5°. This cold layer is probably of very small extent and has no connection with the deeper water of the same temperature to the southwards, as the Plymouth observations have shown.

The sections show isotherms which are generally horizontal, or, in the Irish Channel, dip eastwards. In many places, as for instance on section VII or at the shoreward end of section IX the upper ten or twenty fathoms are fairly uniform in temperature; below them comes a layer in which the temperature decreases very rapidly, and below this again a layer in which the temperature falls slowly to the bottom. At station 43 (E 30) the change is 2° between 20 metres and 30 metres (11 fathoms and 16 fathoms), and 2·9° between 30 metres and 40 metres (16 fathoms and 22 fathoms). These are mean values; in a single series of observations the fall may be much greater; at the same station in August 1909 it was 4·5°, from 30 metres to 40 metres, a drop of 0·45° per metre or 0·8° per fathom.

This discontinuity layer (*sprungschict*) is more strongly developed than appears on the sections, as it has often been necessary to omit alternate isotherms in order to prevent them becoming illegible.

The *surface* salinity is lower than during the other three cruises except in the North Channel, the southern part of St. George's Channel, and at two stations off the Cornish coast.

The lowest *bottom* salinity generally occurs in August; when it falls in November it is in regions where the August fresh surface water can mix downwards only slowly. In the northern part of the Irish Channel the surface and bottom salinity charts are fairly similar, but in the region southwards of the 34·50 per thousand isohaline the difference is well marked.

The saltest surface water enters off the west of Cornwall at a distance of only five or six miles from the shore, and flows northwards with continually falling salinity as a result of admixture with the surrounding fresher water. The 34·90 per thousand isohaline is divided into two parts one of which runs in a northeast-southwest direction on the western edge of the current, while the other encloses a surface area of over 34·90 per thousand off Strumble Head. The 34·75 per thousand line shows a peculiar loop towards the south-west, and the course of the 34·65 per thousand line, projecting south-eastwards from the Irish coast, is even more striking.

On the bottom the salt current follows a much more direct course, flowing northwards into the St. George's Channel with no backward bends.

The peculiar shape of the isohalines at the surface can be explained as follows. The salt surface current flows northwards till off Lundy Island, where it meets the outflow from the Bristol Channel and undergoes considerable dilution, the salinity falling to less than 34·90. It now divides into two parts. One flows northwards into the St. George's Channel and as it enters the region of strong tidal action its salinity is raised by admixture with the salter bottom water, and the surface isohaline of 34·90 per thousand appears again on the chart. The other branch is turned, by the narrowing of the Channel, first westwards, then southwestwards, and finally southeastwards as shown by the course of the 34·65 per thousand isohaline. Its salinity falls continually as it leaves the neighbourhood of the Bristol Channel, so the remarkably low values on station 43 in the tidal slack cannot be due to the fresh water from the latter source, but must be attributed to shore water from the south-east coast of Ireland. That the low salinity of the central area is not due to a direct current in a south-westerly direction from the Bristol Channel is shown by the English surface observations taken every ten miles between the fixed stations. Unless we assume that the fresh surface water has managed in some way to dive beneath the continuous salt surface water between the English stations, it is certain that the waters of the Bristol Channel are separated by a vertical wall of salter water from the low salinities at the centre of this cyclonic eddy.

The shore water is distinctly shown on the south-west coast of Ireland, where the 35·30 per thousand line has taken the place of the 35·50 per thousand line shown on the February surface chart.

The isohalines, like the isotherms, are largely horizontal, and in places there is a well developed discontinuity layer in in the salinity as well as in the temperature (see section VI, station 41; section VII does not show it so distinctly as some of the isohalines have been omitted for the sake of clearness).

The low surface salinities and high surface temperatures unite in preserving a sharply marked surface layer, as each gives rise to a stratum of low density which only mixes with difficulty with the heavier water beneath.

Mean Temperature and Salinity in November.

Plates VII, VIII and XIV.

As will be seen from the charts, the mean surface temperature in November is not very much lower than in August in the region north of the Tuskar-Strumble Head line; southwards of this the fall is greater. The reason is probably this: in the first place the maximum surface temperature falls later than the August cruise, which generally takes place during the first half of the month; secondly, northwards of the Tuskar the tidal mixing is much greater than in the southern entrance, and the waters in the latter region are relatively superheated but only to a very moderate depth. For instance, at station 23 the mean surface temperature in August is 13° and the mean bottom temperature in 60 fathoms is only 0·2° less. On the other hand, the depth of the highly heated surface layer south of the Tuskar-Strumble Head line is much smaller. The mean temperatures at station 40 are as follows: surface 15·2°, 20 fathoms 11·6°, bottom in 40 fathoms 10·7°; and at station 41, surface 15·7°, 10 fathoms 14·2°, 20 fathoms 9·6°, bottom in 62 fathoms 8·5°. At the northern station the layer of warm water extends to the bottom and is 60 fathoms thick; at the southern station its depth is not more than 10 or 20 fathoms. The shallow layer will lose its temperature much more quickly than the deeper one, and the cooling will appear to be much faster on the southern side of the Tuskar-Strumble Head line than on the northern.

As in August, the mean bottom temperatures in November are much more regularly distributed than those at the surface, and the isotherms are largely dependent on the depth.

From the North Channel to section IV the maximum *bottom* temperature for the four cruises is found in November, at a large number of stations, even when the depth is only 19 fathoms. From section IV to the Tuskar-Strumble Head line the maximum temperature falls in August as a result of the strong tidal mixing. Southwards and westwards where the tides are weaker the maximum occurs in November. This phase-delay takes place at varying depths. At stations 1 and 2 the maximum occurs in November even at the surface; between here and the Fastnet line of stations (section VIII) the November maximum is found at 20 fathoms and deeper; on the Fastnet and Tearaght (section IX) lines at 30 fathoms. It should be remembered that the Irish observations are made at every 10 fathoms, and the English at every 10 metres; the latter give 22 fathoms as the least depth at which the maximum is delayed to November.

The *surface* salinity chart shows a considerable rise since August, but the cyclonic circulation in the southern entrance is still strongly marked.

As in August the *bottom* isohalines follow a comparatively direct course. Northwards of section VII the division into horizontal layers is disappearing; in the southern entrance it is still fairly apparent, while on section VIII the shore water stretches seawards as an intermediate layer with salter water above and below it.

Surface Temperature and Salinity at Lightships.

Lightship observations suffer from the disadvantage of generally showing coastal conditions only; in some cases where the vessel is suitably placed, they may be very valuable, as at the Seven Stones and Cardigan Bay Lightships.

At the Skulmartin Lightship the three years' observations show a period of minimum mean temperature, 6·60°, occupying the last ten days of February and the first two ten-day periods of March. The period of maximum temperature is in September, with mean values for the three ten-day periods of 13·12°, 13·04°, and 13·12°.

At the South Arklow Lightship again there are only three years' observations available. The minimum is during the first ten days of March, 6·72°, but the second ten days are almost as cold with a mean temperature of 6·75°. The maximum, 14·86°, falls in the first ten-day period of September.

The Coningbeg Lightship records extend over nine years. The lowest temperature for a ten-day period is 7·63°, for the first ten days of March; the second ten-day period, 7·66°, is almost as cold. The maximum temperature, 14·13°, occurs in the last ten day-period of August.

At the Fastnet Rock the rather incomplete records over a period of three years point to a minimum, 8·33°, in the second ten-day period of March, and a maximum of 13·53° in the first ten-day period of August.

Salinity observations, made on samples taken about once a week, are available for three years from the Coningbeg Lightship. They give a maximum of 34·77 per thousand in May, a minimum of 34·61 per thousand in July, another higher maximum of 34·80 per thousand in November followed by a sudden fall and a slow rise to the May maximum. Six years' salinity observations at the Cardigan Bay Lightship give maxima of 34·68 per thousand and 34·63 per thousand in November and January with 34·60 per thousand in December, and a June minimum of 34·12 per thousand. Observations at the Bahama Bank Lightship in the Irish Sea, 1904-1909, also give somewhat irregular results, but the maximum in November, 33·86 per thousand is fairly distinct, as is the April minimum of 33·53 per thousand. The temperature observations show that the February cruise gives average temperatures which are above the minimum, and the August cruise averages which are below the maximum. If we assume, as is generally true, that the quarterly observations are more nearly comparable with the first ten-day period of each month than with the second, we reach the conclusion that, in the coastal waters, the February averages are above the minimum by an amount ranging from 0·7° in the North Channel to 0·3° off the south coast of Ireland, and that the August averages are below the maximum by an amount ranging from 0·4° or 0·5° down to less than 0·1°. The observations however are not sufficiently numerous to allow of any certain deductions being drawn.

The yearly march of salinity at the Coningbeg Lightship is remarkable in that it gives a maximum in May as well as in November; at the other positions a winter maximum is the rule. This may be connected with a remarkable pulse of salt water below the surface which reaches the south-west coast of Ireland about May, which will be described in the following section.

On the General Circulation of the Water in the Irish Area.

A complete account of the circulation in the Irish area would require a more detailed knowledge of the changes in the surface drift in the open ocean to the south and west of Ireland than we yet possess. At present the only information available for every month in the year is derived from the analysis of surface samples collected continuously for several years on liners sailing between the English Channel and New York. These samples were taken for the Marine Biological Association in connection with the International Fishery Investigations and analysed by the present writer. The mean salinities have been calculated for every month and plotted on charts, and at the same time curves have been drawn for certain selected areas where the observations are sufficiently numerous. One of these areas lies in 50° N. Lat. between 11° W. Long. and 20° W. Long. and has a breadth of about ten miles in a north and south direction. It is therefore in the path of the surface drift current which flows approximately northwards to the west of Ireland. The curve shows a maximum of about 35·59 per thousand in February, falling regularly to 35·54 per thousand in May, rising again slightly in June, falling in July to about 35·50 per thousand, which value remains almost unaltered to September, and reaching a sharp minimum in October with 35·43 per thousand. After this there is a sudden rise to a secondary maximum towards the end of November, a slight fall in December and January, and then again the maximum in February. Shortly, there is a well defined and sharp minimum in October, and immediately following this a rise to a high and somewhat long drawn out maximum beginning in November and culminating in February. The Plymouth observations across the entrance to the English Channel show very similar results. The maximum is in January and February, and the minimum in the late summer, though it is somewhat irregular.

The charts published in this report show that the saltest water enters the Irish area between Land's End and the Scilly Islands, and detailed observations made along this line on several cruises at intervals of from half a mile to one mile on the Marine Biological Association's steamers have shown that the axis of highest salinity lies midway between the Longships Rock and the Seven Stones Lightship, that is, at a distance of only a few miles off Land's End. This current of salt warm water is derived from a current which has already entered the English Channel from a south-westerly direction, and has in part turned northwards and north-westwards to escape into the Irish Channel. It is practically certain that this water has come from the mouth of the English Channel and not directly from the open sea because further westwards a great area of lower surface salinity stretches southwards across the fairway

and prevents any such direct current. This fresh area is really the diluted remnant of this same salt warm current, so that a portion of the water here circulates in a closed curve. Gehrke[1] has shown on theoretical grounds that more water enters the English Channel from the westward than escapes through the Straits of Dover, after allowance has been made for the addition of fresh water from the land, and that a portion must therefore turn back and escape in a north-westerly direction.

This salt warm current gives rise to the peculiar cyclonic circulation which takes place in the southern entrance of the Irish Channel and which leads to some rather unusual physical conditions, such for instance as the fact that as we travel seawards from the north-west Cornish coast the salinity begins to fall at a comparatively short distance from the shore and may reach its lowest value in midchannel. The proof of this circulation depends on the combined Irish and Plymouth observations, and as it happens the stations have been so placed that the isohalines may be drawn in two ways. The inset charts on the section plates show a small area of triangular shape immediately south of section V in which there are no stations, and it is this lack of stations which give rise to the uncertainty. One way of drawing the isohalines, which would fit the mean results perfectly, has not been followed as it would necessitate the assumption of a strong current of low salinity flowing from St. George's Channel to far south of 50° N. Lat. Such a current would be inherently improbable, and there is no reason to suppose that it exists when there is a much simpler explanation to hand. This explanation is to be found in the cyclonic or counter-clockwise circulation which has already been described in detail in the discussion of the mean conditions for August. It is more extensive than the charts show, and the Plymouth observations have proved that it reaches at times as far south as 48½° N. Lat. Its cause is to be found in great measure in the configuration of the coast, which forces the stream to turn to the left of its direction; but at the same time it would be always striving to turn to the right under the influence of the earth's rotation. While in the narrow waters it would not be able to do so to any extent, but once clear of the south coast of Ireland on the western edge of the circulation it might be expected that part at least should turn to the right. At times indeed this seems to occur; a branch is thrown off westwards which is able to travel as far as the Fastnet before it is turned to the left and southwards by the west wind drift of the ocean. The first hint of such a cyclonic circulation is to be found, as far as the writer knows, in a suggestion by

[1] J. Gehrke: The mean velocity of the Atlantic currents running north of Scotland and through the English Channel. "*Pub. de Circonstance,*" of the International Council for the Exploration of the Sea, No. 50 Copenhagen.

Nielsen[1] that there is an anticyclonic circulation round the south coast of Ireland, and later Gough,[2] in his discussion of the plankton collected by the Marine Biological Association, came to a somewhat similar conclusion.

This circulation may prove to be of considerable biological importance. The water off the south-east coast of Ireland, and in the southern edge of the cyclonic circulation off the fairway to the English Channel, has travelled a long distance since it last left the open ocean, and if, as seems probable, there is any difference, other than temperature and salinity, between oceanic and shore waters, then this water might be poorer in the minute constituents of oceanic water and richer in those of coastal water than would be expected on the ground of its distance from the open sea; and if the strength of the cyclonic movement varies from year to year, so will the character of the water at any place within its influence, such as the areas of the drift net fishing off the mouth of the English Channel and off the south coast of Ireland.

That portion of the warm salt current which has escaped the cyclonic circulation, including the larger portion of the bottom water, flows northwards through the Irish Channel, bending a little to the right under the influence of the earth's rotation, and finally escapes through the North Channel in a much diluted condition.

Since the maximum salinity in the English Channel occurs in January and February, and the Irish Channel derives its saltest water from this source, it might be expected that the Irish waters would follow the same law. As has been shown, this is largely the case, but there are some important exceptions. Off the Cornish coast there is one period of maximum salinity in the year, about February, and off the south-east coast of Ireland we again find one maximum, but in November; finally, at some of the stations off the south and southwest of Ireland there are two maxima in the year, one in August and another in May. This would point to two pulses of high salinity water, and it is not unlikely that two such pulses do exist. The winter maximum salinity is a well known phenomenon at the entrance to the English Channel, and is sufficient to account for the February maximum off the Cornish coast. For another pulse of high salinity water we must look elsewhere, and on the surface there is no distinct sign of it. At one of the newer Irish stations however, 62, which has only been worked in the last two years (1911–1912), an intermediate layer of high

[1] J. N. Nielsen: Contribution to the Hydrography of the North-eastern part of the Atlantic Ocean. *Meddelelser fra Kommissionen for Havundersøgelser: Hydrografi I*, No. 9. Copenhagen 1907.

[2] L. H. Gough: On the distribution and the migrations of *Muggiaea atlantica*; *Pub. de Circ.*, No. 29.

salinity has been found on each occasion in May.[1] The depth at which this layer occurs varies, from 50 to 120 fathoms, and in the first year it was so thin that it was shown by one observation only. The salinities were very high, as much as 35·71 per thousand, which precludes the possibility of the samples having been interchanged, for no such water has been found elsewhere in the Irish area. The other possibility, that the high salinities are due to leaky bottles, which allowed evaporation, is very improbable, as the rubber washers appeared perfectly sound, and it would be an extraordinary coincidence that such bottles should have been used in the same month and at the same station in each case. Traces of such an intermediate layer, much weakened, have been found in August also. It seems fairly certain therefore that such a pulse of high salinity has occurred in May on two occasions and may be a regular phenomenon. It would be sufficient to account for the double maximum already mentioned as taking place at some of the Irish stations, but its cause is still obscure. The Plymouth observations have shown that on the steamship route between Cape St. Vincent and Gibraltar there is a very well marked period in the surface salinity, with a maximum of 36·49 per thousand in September and a minimum of 35·15 per thousand in March. It is not impossible that this is connected in some way with the salt intermediate layer which flows out of the Mediterranean into the Atlantic, and that this layer too is subject to periodical fluctuations. The influence of this intermediate layer has been traced far to the northwards of the Straits, and it may be the source of the May maximum off the south-west of Ireland.

Dr. Bassett has published a paper in which he throws doubt on some of the conclusions arrived at by the writer in earlier papers on the English Channel. The most important point is the direction of the current through the Irish Channel. The present writer suggested that the low salinity surface water off the fairway to the English Channel was due to a southerly flow from the direction of the Irish Sea; Dr. Bassett in his paper pointed out that the direction of the main flow is from south to north, as is certainly the case, but it was not suggested by the present writer that anything more than a local eddy existed. Dr. Bassett's suggestion that the source of this fresh water is to be found in the Bristol Channel has already been dealt with in the present paper, and seems to have been due to his having overlooked the observations published in the Quarterly Bulletins of the International Council.

Dr. Bassett has also published charts showing that the highest salinities enter the southern entrance in the middle line, and that the current bends to the right and finally escapes south-

[1] Since the above was written the observations for May, 1913, have been worked up. They show that in this year the intermediate layer did not reach such high salinities, but that it covered a much larger area, and was found nearer the surface.

wards between the Scilly Islands and Land's End. He appears to have founded this chart on a few observations made by officers of liners, and to have disregarded in their favour all the observations made by trained observers and in far greater number on special research steamers. It is quite possible that he only plotted such observations as concerned the area in question and neglected the thousands of others taken all over the Atlantic. If he had plotted these also he would have seen that for various reasons they are affected by many sources of inaccuracy, and that in these latitudes they are as a rule too high.

He has in the same way expressed some doubt as to the accuracy of the present writer's chart of surface salinity for August 1905 in this region. In his own chart he has shown water of over 36·00 per thousand in the southern Irish Channel. The liner observations went to show that such water was present, but on the other hand the Plymouth observations failed to find it and having regard to the tendency for salinities from liners to be too high, it seemed better to draw the isohaline of 36·00 per thousand in a generalized form off the fairway to the English Channel in order to direct attention to the undoubted existence of abnormally high salinities here without showing them in regions where they were only doubtfully present as isolated patches, if at all. Dr. Bassett appears in this case to have overlooked the explanation which the writer gave of the way in which the chart had been drawn up.

On the Annual Temperature Change in Deep Water.

Brennecke[1] has discussed the depth at which the annual change of temperature is no longer perceptible, and concludes from a consideration of four sets of observations made in the Bay of Biscay at different times of the year by the *Planet*, *Thor* and *Princesse-Alice* that this lies at about 150 metres (82 fathoms). The older observations of Aimé were made off Algiers in the Mediterranean, a nearly enclosed sea, and are not therefore strictly comparable with those made in the open Atlantic off the south-west coast of Ireland; he found a maximum range of 1° at 200 metres (109 fathoms) and of 0·0° at 350 metres (191 fathoms).

In 1909 the *Huxley*, of the Marine Biological Association, made four sets of observations in February, May, August, and November at a station in 47° 47′ N., 7° 52′ W., on the northern edge of the deep water in the Bay of Biscay. The temperatures recorded are open to a certain amount of doubt as they were made with a single reversing thermometer (Richter). The greatest depth from which comparable observations are available is 400 metres (218 fathoms); the results were as follows,

[1] Forschungsreise S.M.S. *Planet* 1906–1907. Band III., Dr. W. Brennecke, Ozeanographie; Reichs-Marine-Amt.

beginning with February, 10·64°, 10·50°, 11·16°, and 10·77°. This shows a maximum in August, while the more certain observations made with the Nansen-Petterson insulating water-bottle point to a November maximum from 70 metres to 200 metres (38 fathoms to 109 fathoms). The lowest and highest values at the latter depth were May 10·62°, November 11·18°. The *Huxley* observations do not therefore prove that the annual change reaches a greater depth than a little over 100 fathoms.

A larger number of observations are available from the deep water off the south-west coast of Ireland. The outermost of the Irish stations, No. 68 in about 51° 50′ N., 12° 14′ W., has been worked three times in February and November, five times in August, and six times in May. It is somewhat difficult to arrive at an accurate mean value for the various depths as it has not always been possible to fix the position with sufficient accuracy, and the shape of the bottom, which here slopes quickly seaward, causes the various water strata to tilt up the sides of the submarine valley over which the station lies. In the following table are given a few of the mean values which were calculated without comparing one month with another so that they are at any rate free from bias.

F.	M.	February.	May.	August.	November.	Mean.
0	0	10·41	11·83	16·36	12·39	12·75
20	37	10·37	11·09	14·06	12·38	11·97
30	55	10·35	10·65	12·19	12·34	11·38
50	91	10·31	10·49	10·79	11·80	10·85
250	457	10·21	10·10	10·09	10·23	10·16
350	640	9·95	9·77	9·73	9·93	9·84
		8·54	8·61	8·79	8·84	8·69
Near Bottom		543F.	531F.	530F.	533F.	534F.
		993M.	971M.	969M.	975M.	977M.

The actual depths for which the bottom temperatures have been calculated are given in the two last lines.

Down to 20 fathoms the maximum temperatures occurs in August, from 30 fathoms to 250 fathoms in November, and in about 535 fathoms again in November. The mean range at 50 fathoms is 1·49°, at 100 fathoms 0·52°, at 150 fathoms 0·27°, at 250 fathoms 0·14°, at 350 fathoms 0·20°, and near the bottom 0·30°. The results are somewhat surprising, as they show that the range decreases down to about 250 fathoms and then increases again. Though instrumental errors must certainly be present, yet the changes are too regular to be due to this cause alone, and it seems probable that the explanation is to be found in two widely separated phenomenon. As the depth increases the date of the maximum temperature is progressively delayed, and at 30 fathoms it falls nearer to the November than to the August cruise. The yearly change is clearly shown at 150 fathoms, with a range of 0·27°, but below this it becomes uncertain, the range falling to 0·14° at 250 fathoms (457 metres). Below this the range increases, and this can hardly be due to any local change arising at the surface. The range of 0·30° near the bottom, with a maximum in August, is almost certainly to be attributed to horizontal currents which have received their varying temperatures near the surface at some distance, possibly hundreds of miles away.

EXPLANATION OF PLATES.

PLATE	I.—Mean surface temperature and salinity . . .	February.
,,	II.—Mean bottom temperature and salinity . . .	February.
,,	III.—Mean surface temperature and salinity . . .	May.
,,	IV.—Mean bottom temperature and salinity . . .	May.
,,	V.—Mean surface temperature and salinity . . .	August.
,,	VI.—Mean bottom temperature and salinity . . .	August.
,,	VII.—Mean surface temperature and salinity . . .	November.
,,	VIII.—Mean bottom temperature and salinity . . .	November.
,,	IX.—Mean surface temperature and salinity . . .	Whole Year.
,,	X.—Mean bottom temperature and salinity . . .	Whole Year.
,,	XI.—Sections showing mean salinity and temperature . .	February.
,,	XII.—Sections showing mean salinity and temperature . .	May.
,,	XIII.—Sections showing mean salinity and temperature . .	August.
,,	XIV.—Sections showing mean salinity and temperature . .	November.
,,	XV.—Sections showing mean salinity and temperature . .	Whole Year.

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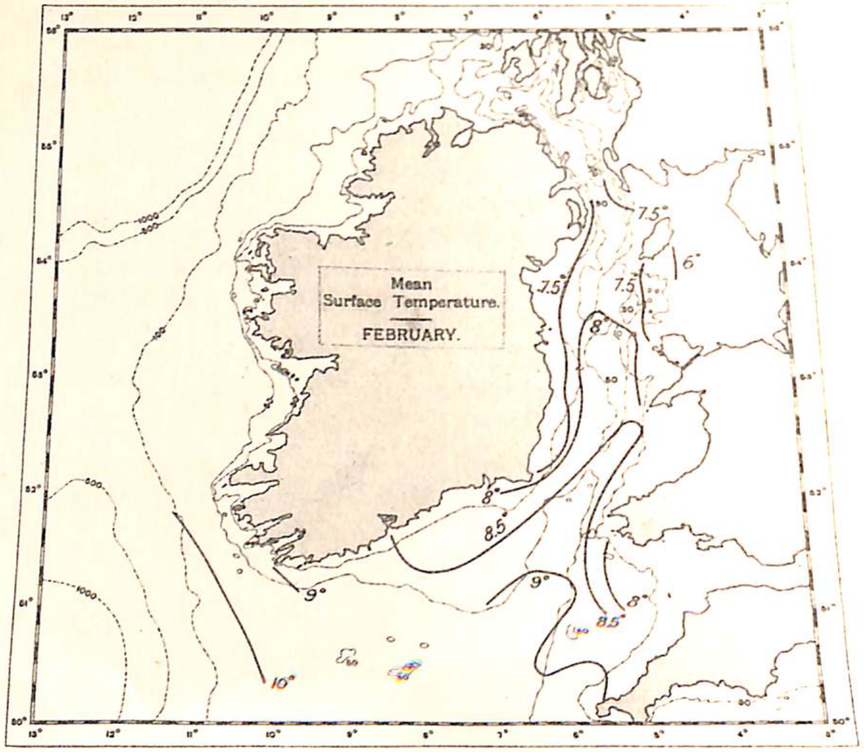

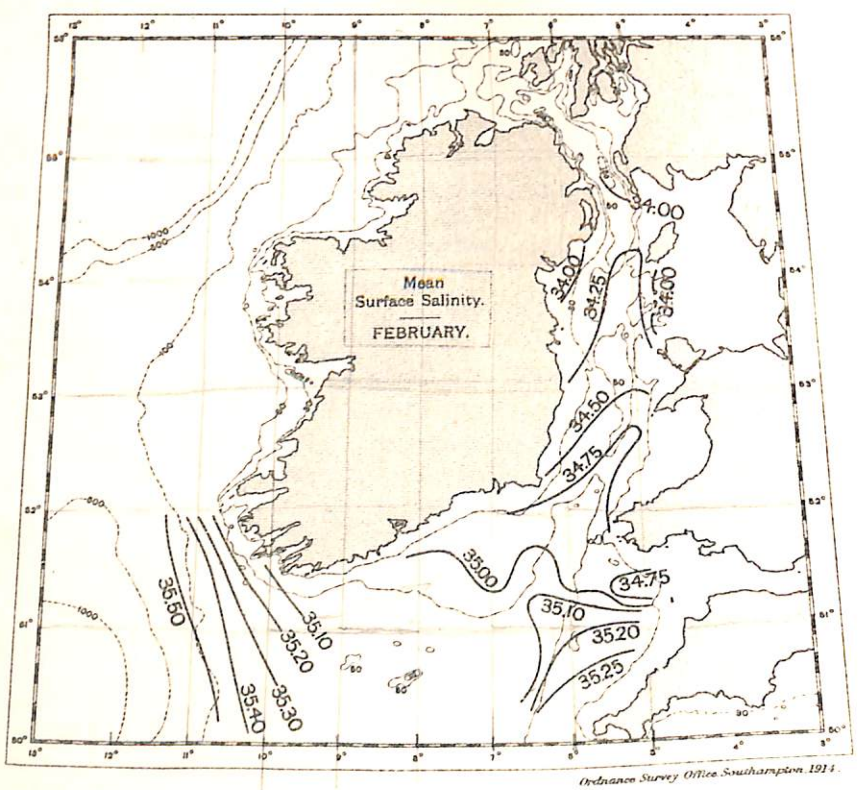

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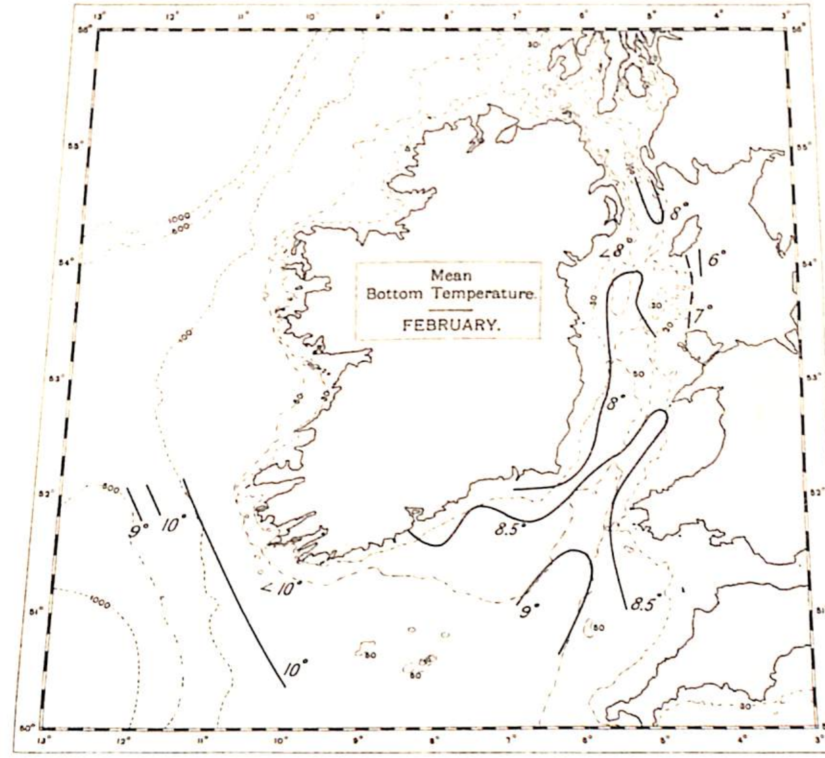

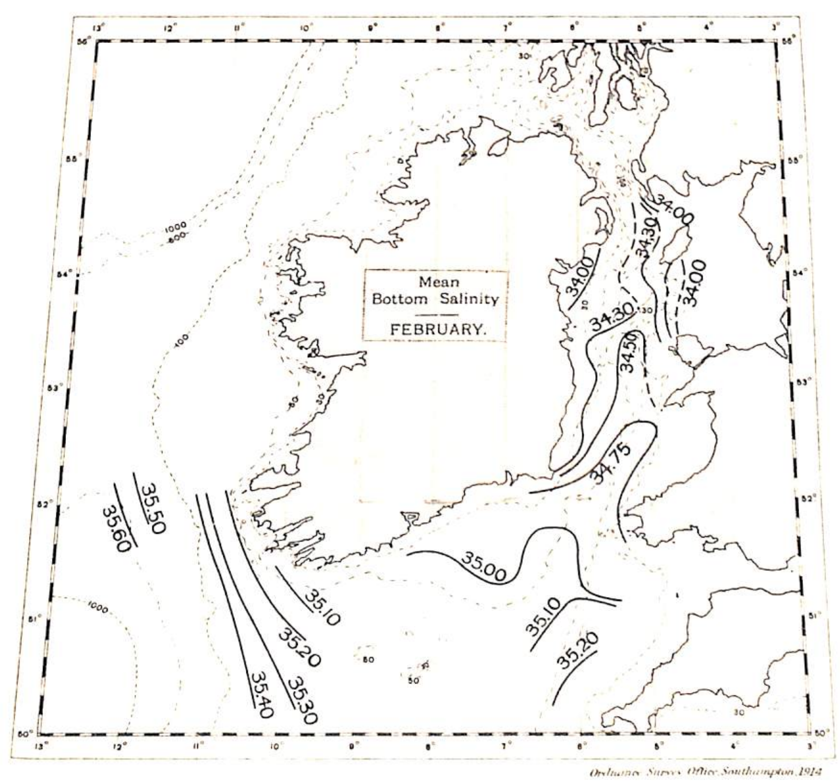

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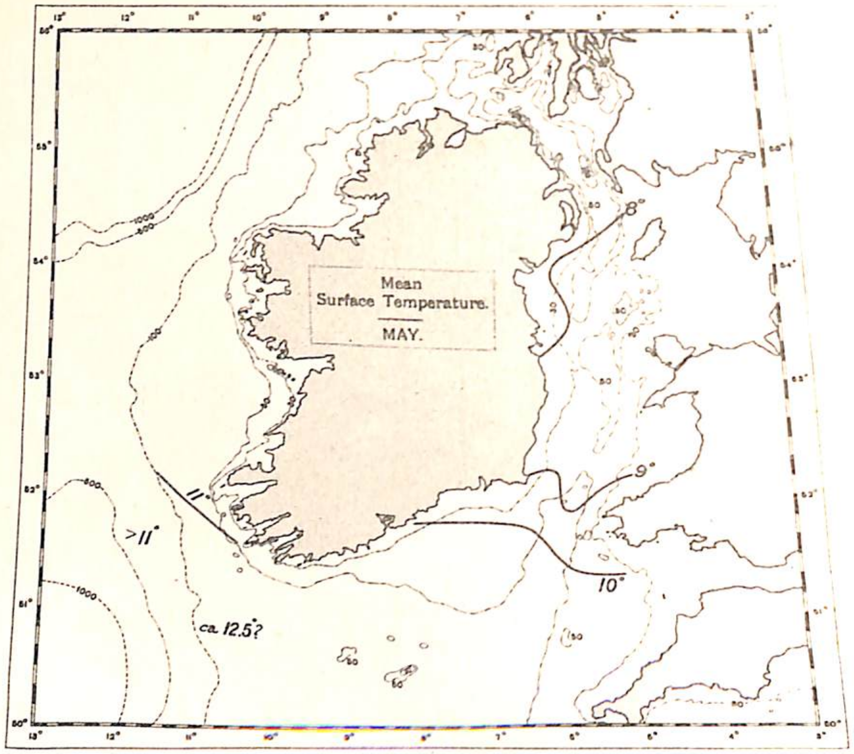

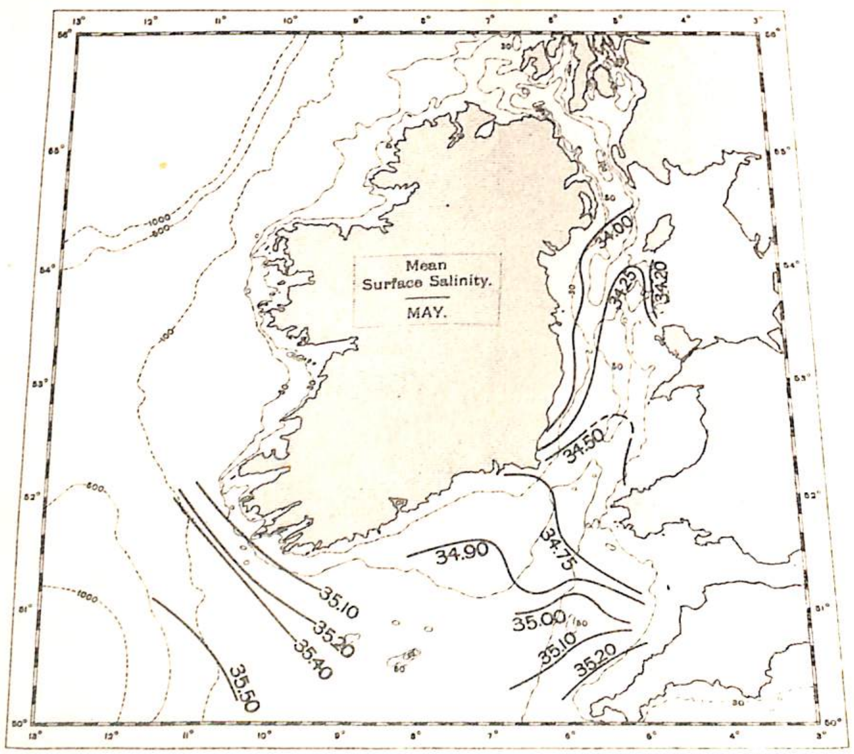

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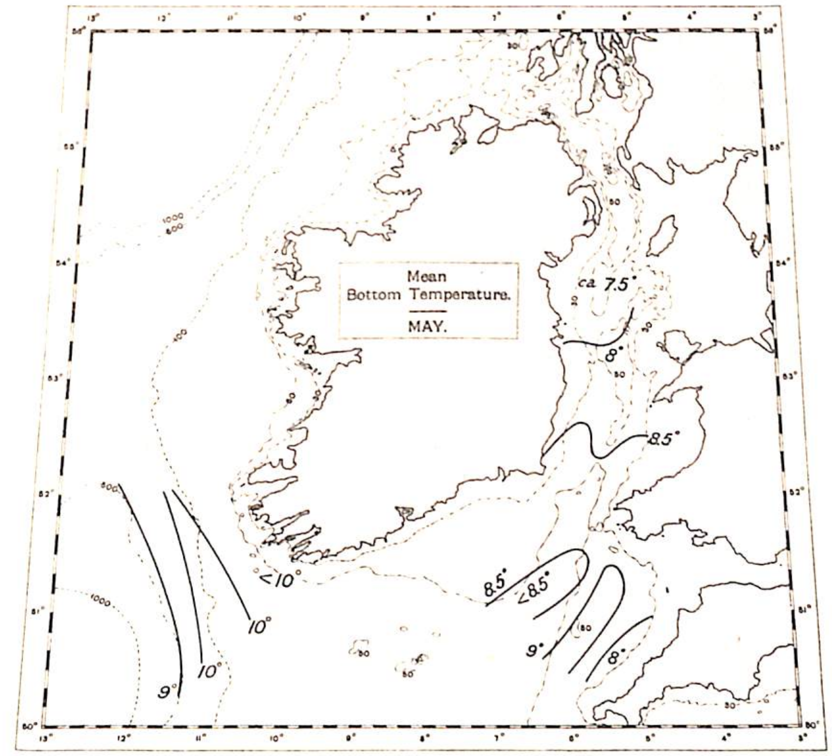

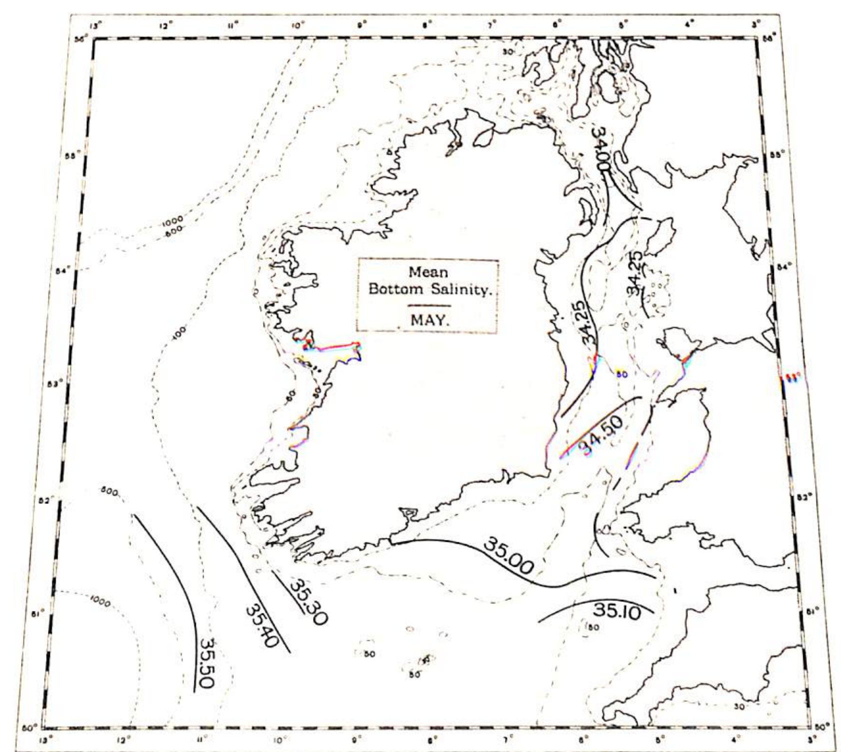

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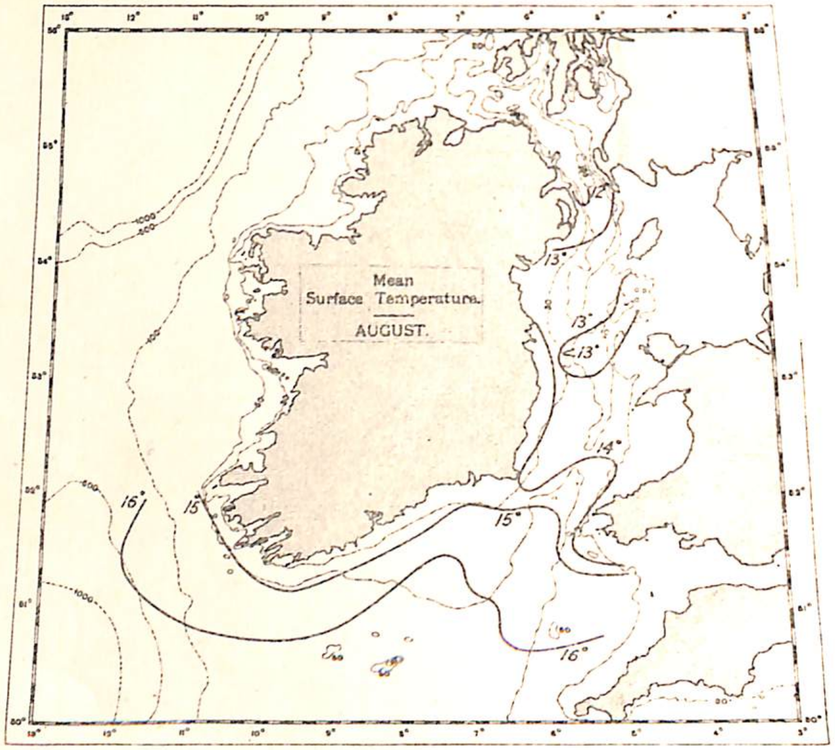

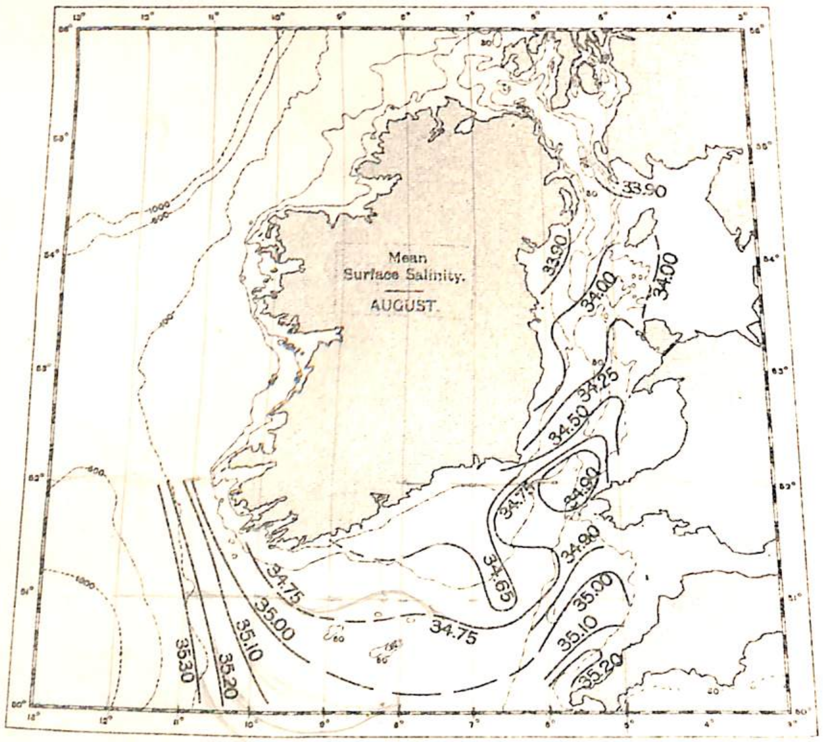

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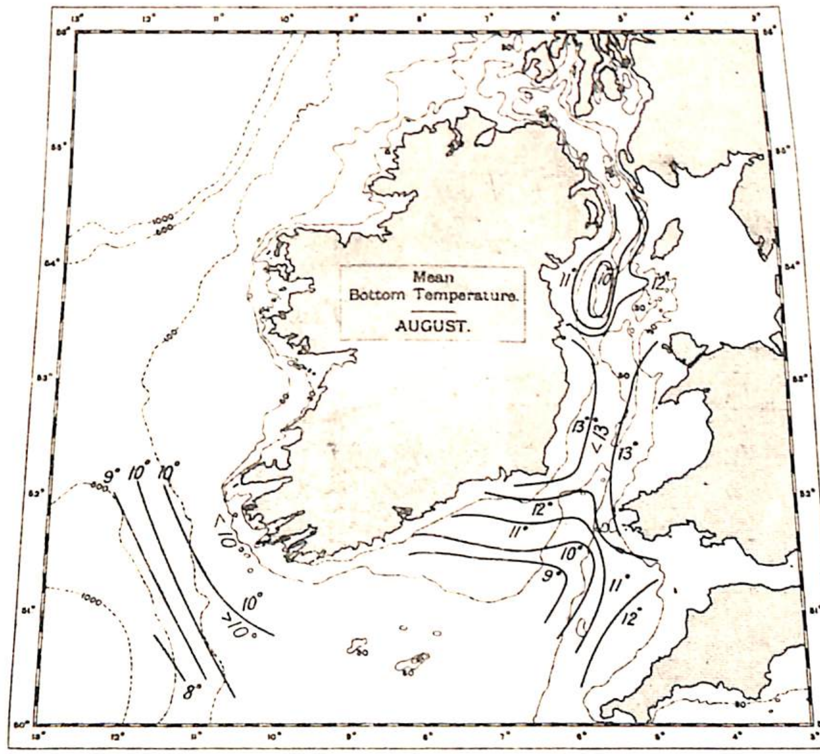

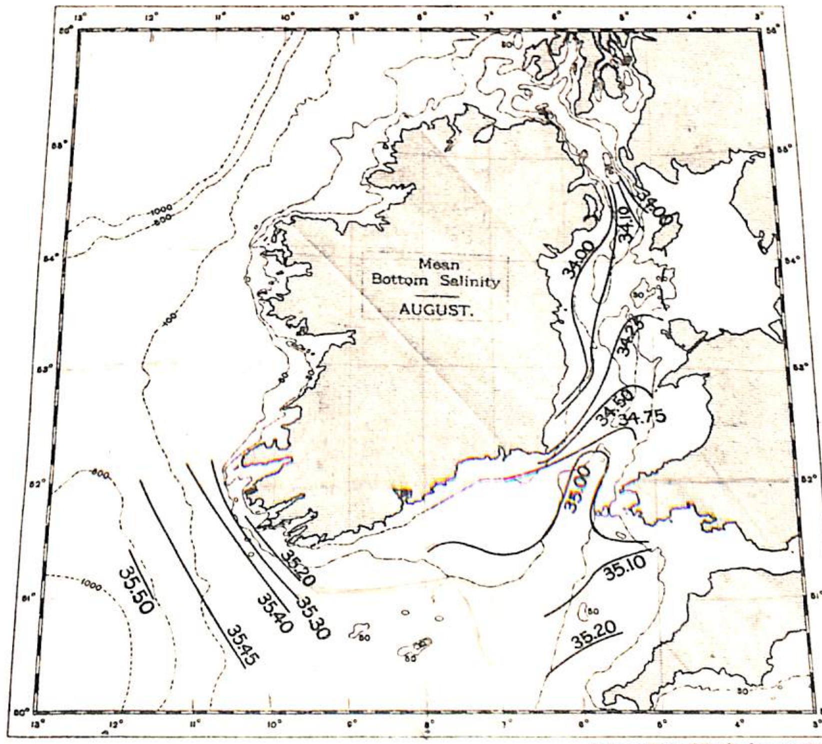

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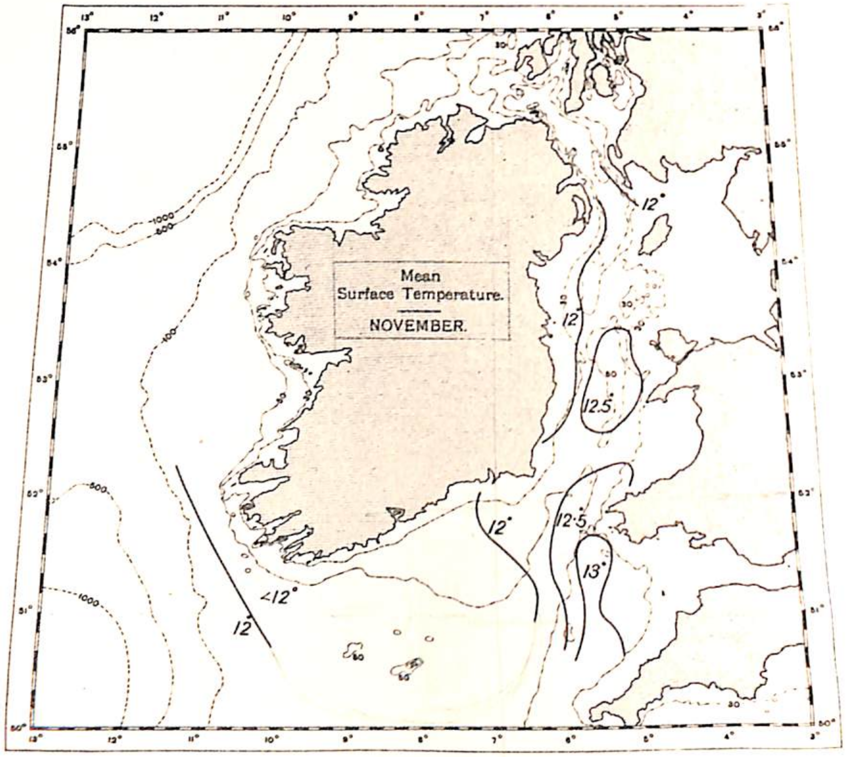

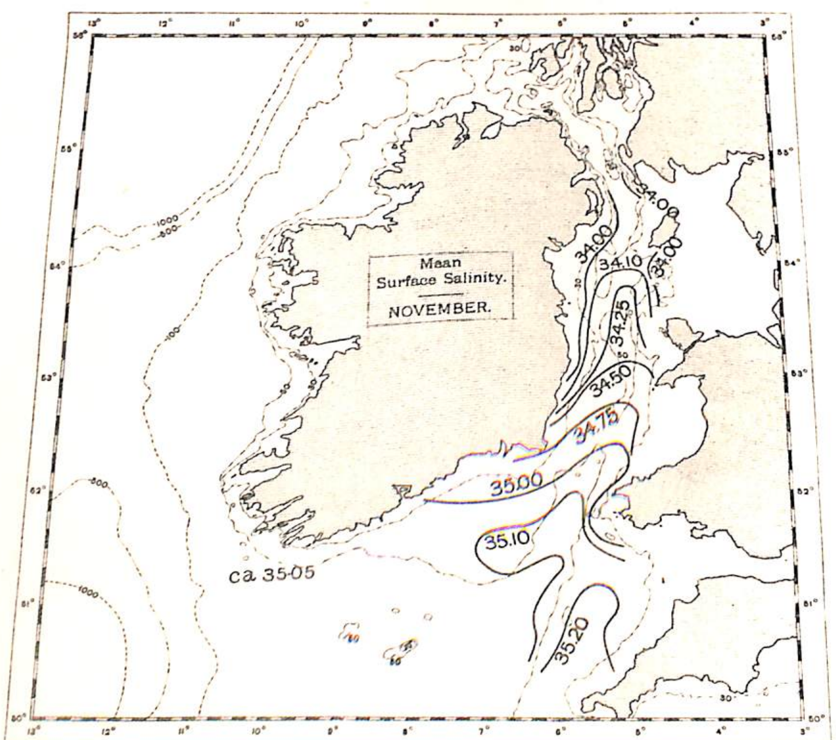

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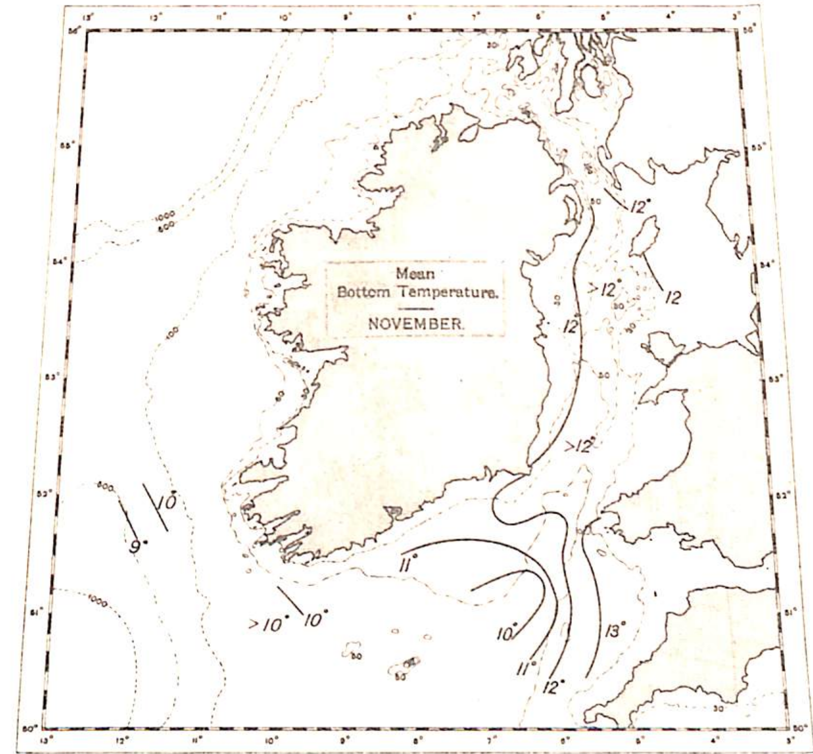

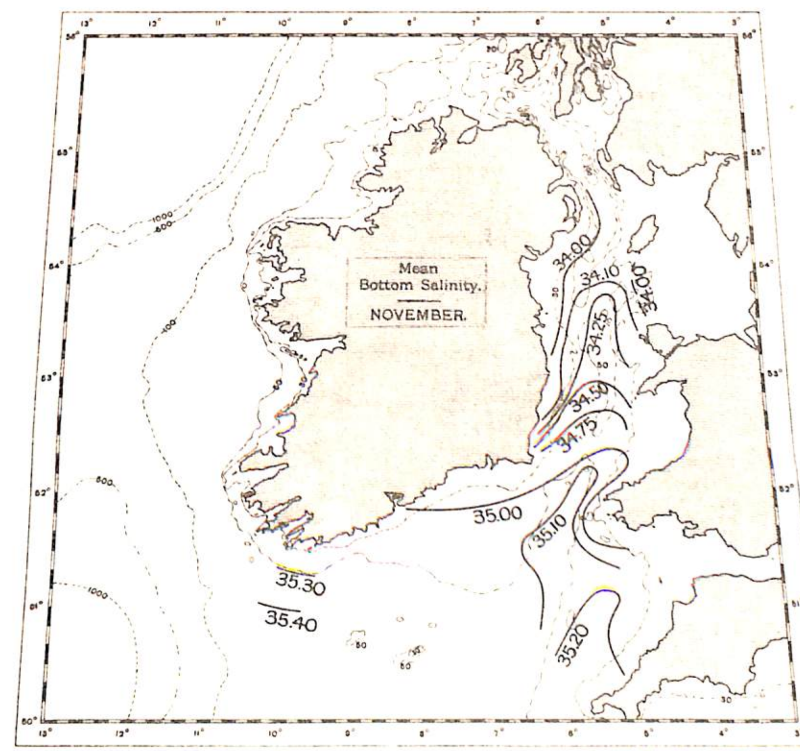

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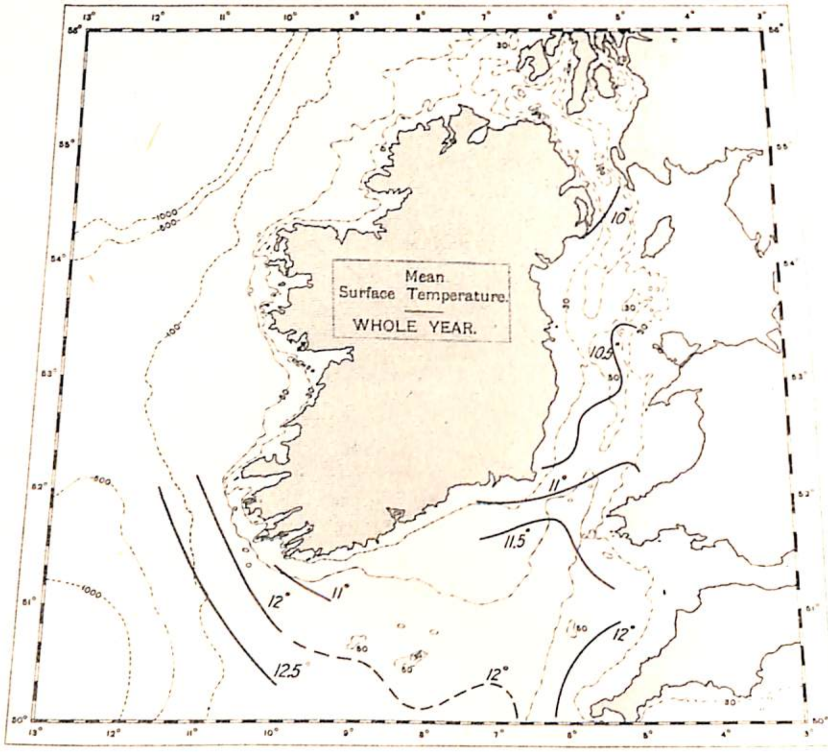
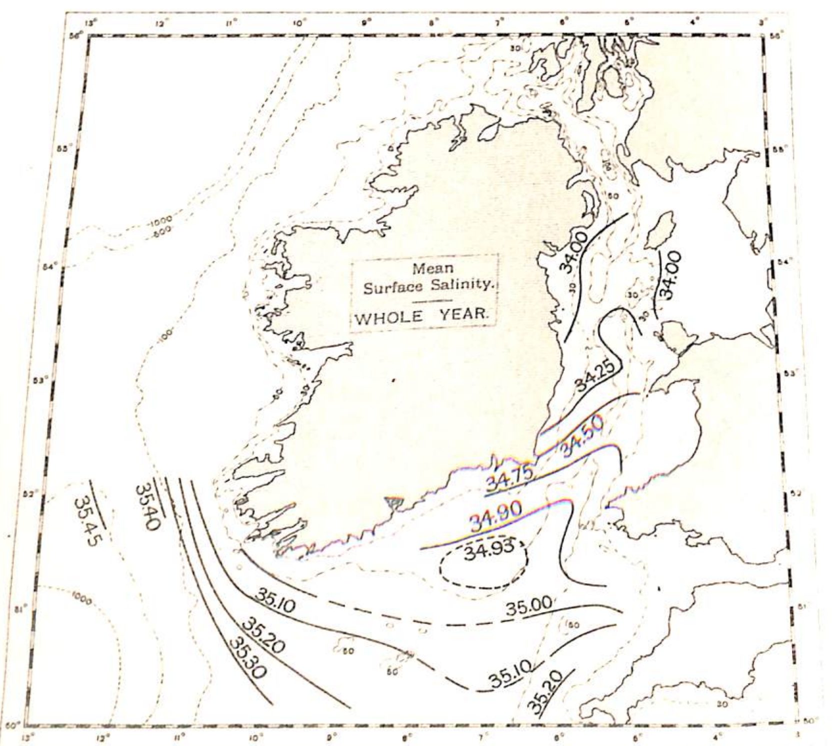
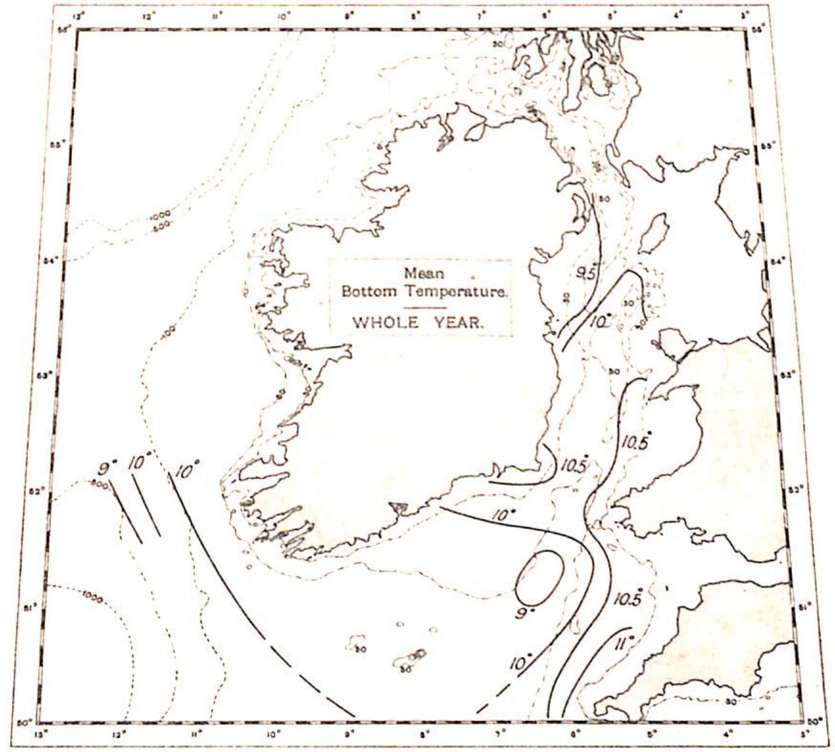
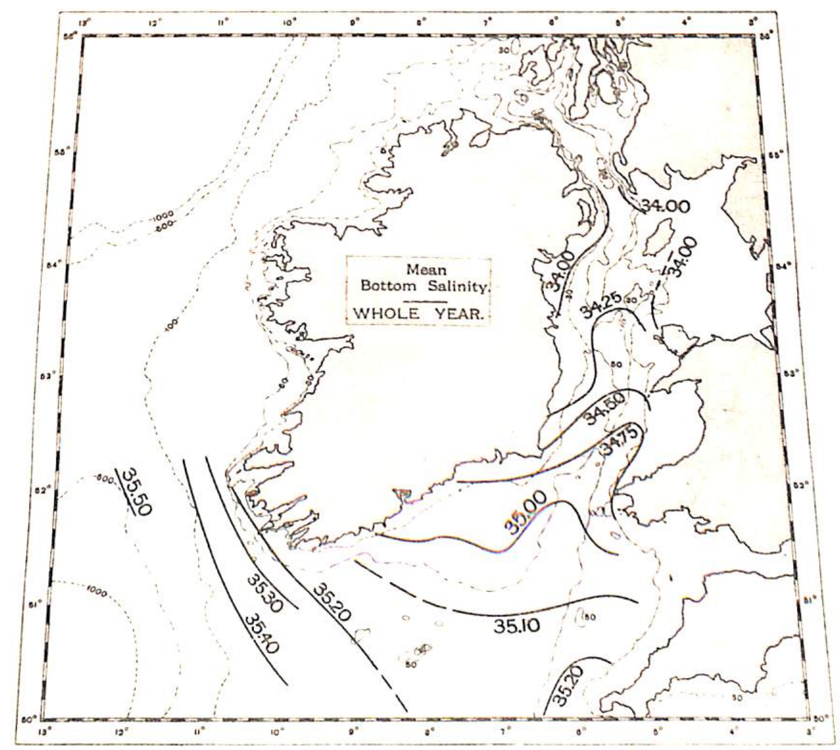


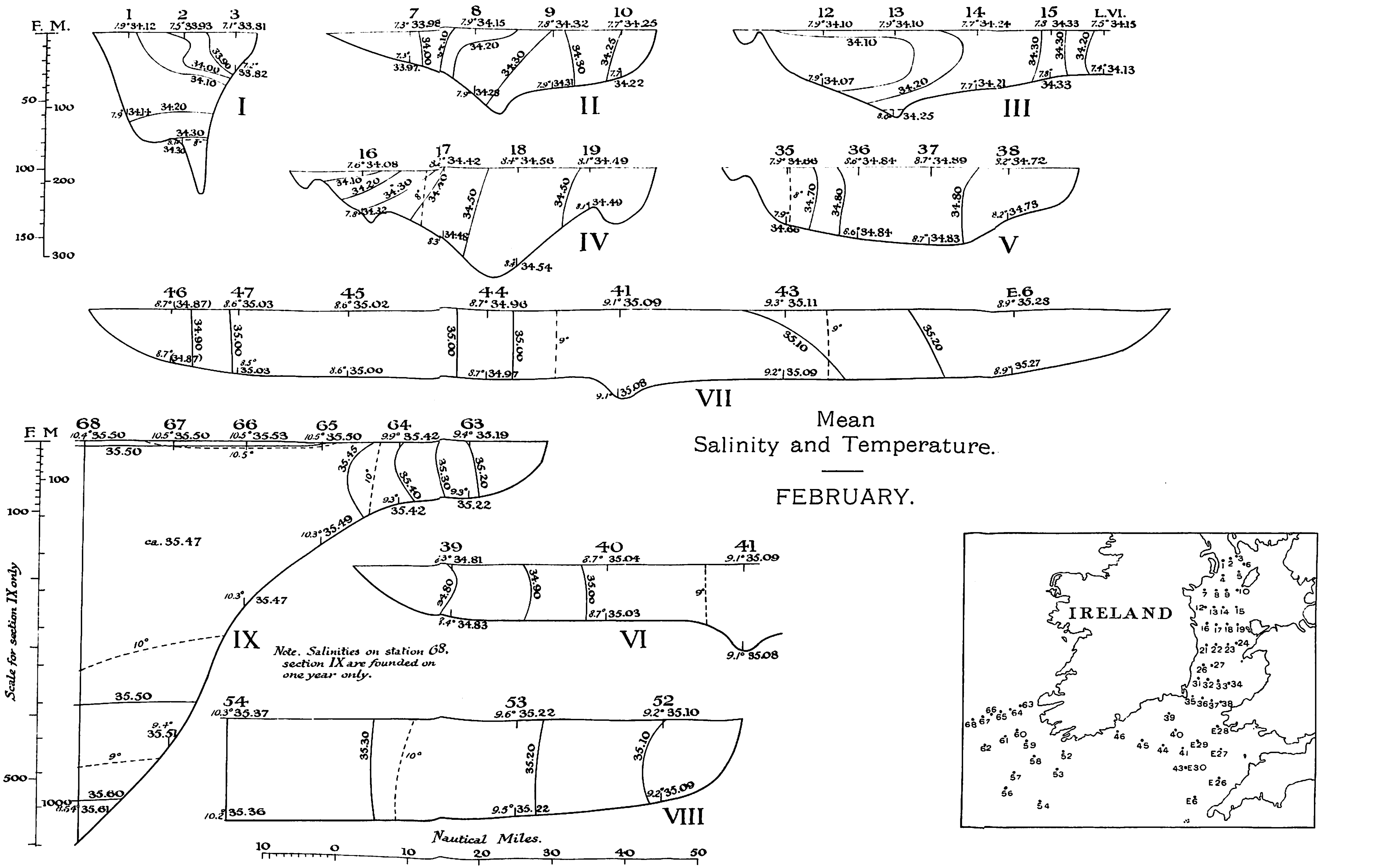


Ordnance Survey Office, Southampton, 1911.





Ordnance Survey Office, Southampton, 1911.



Mean
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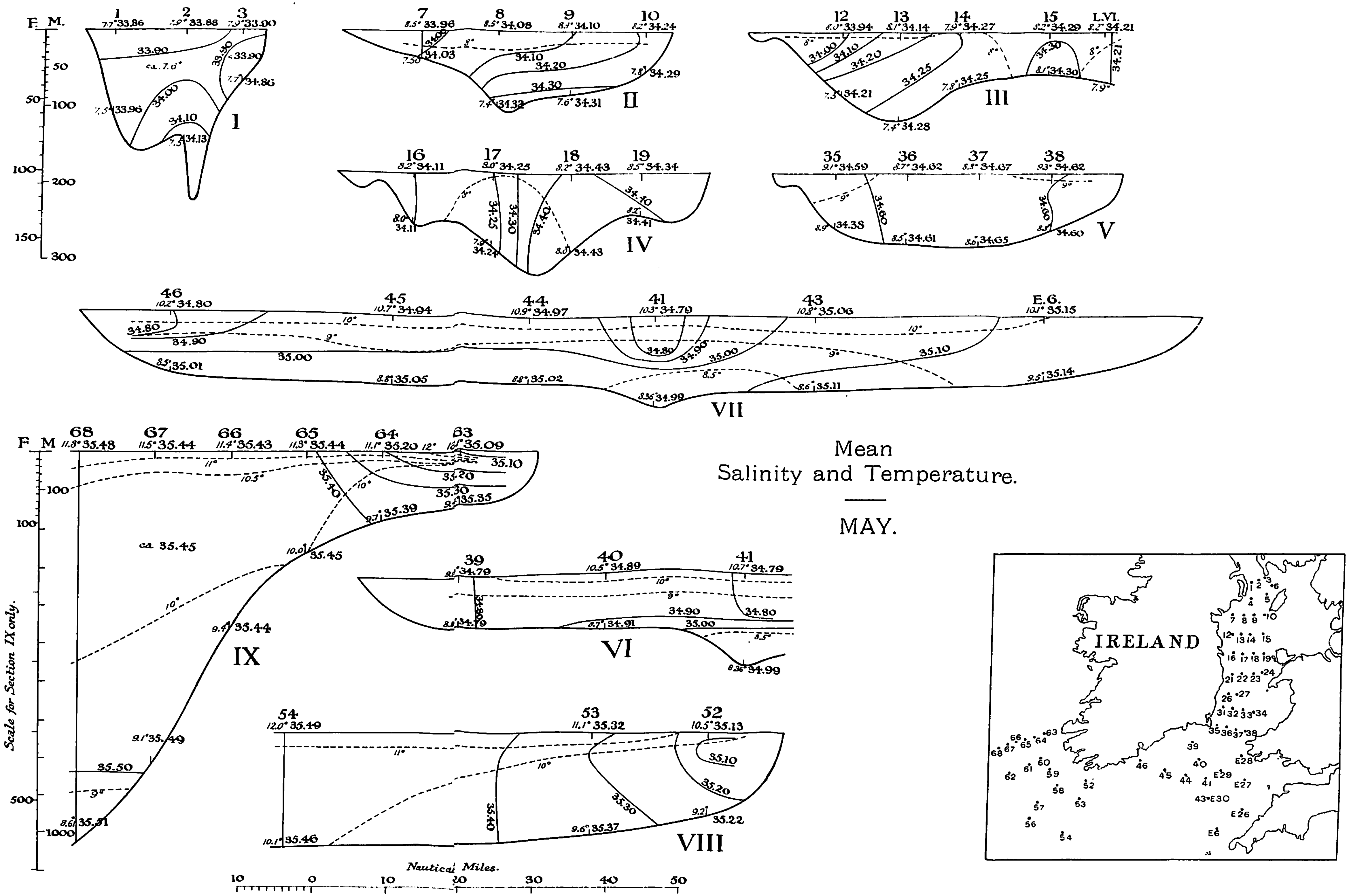
FEBRUARY.

Ordnance Survey Office, Southampton. 1914.



Mean
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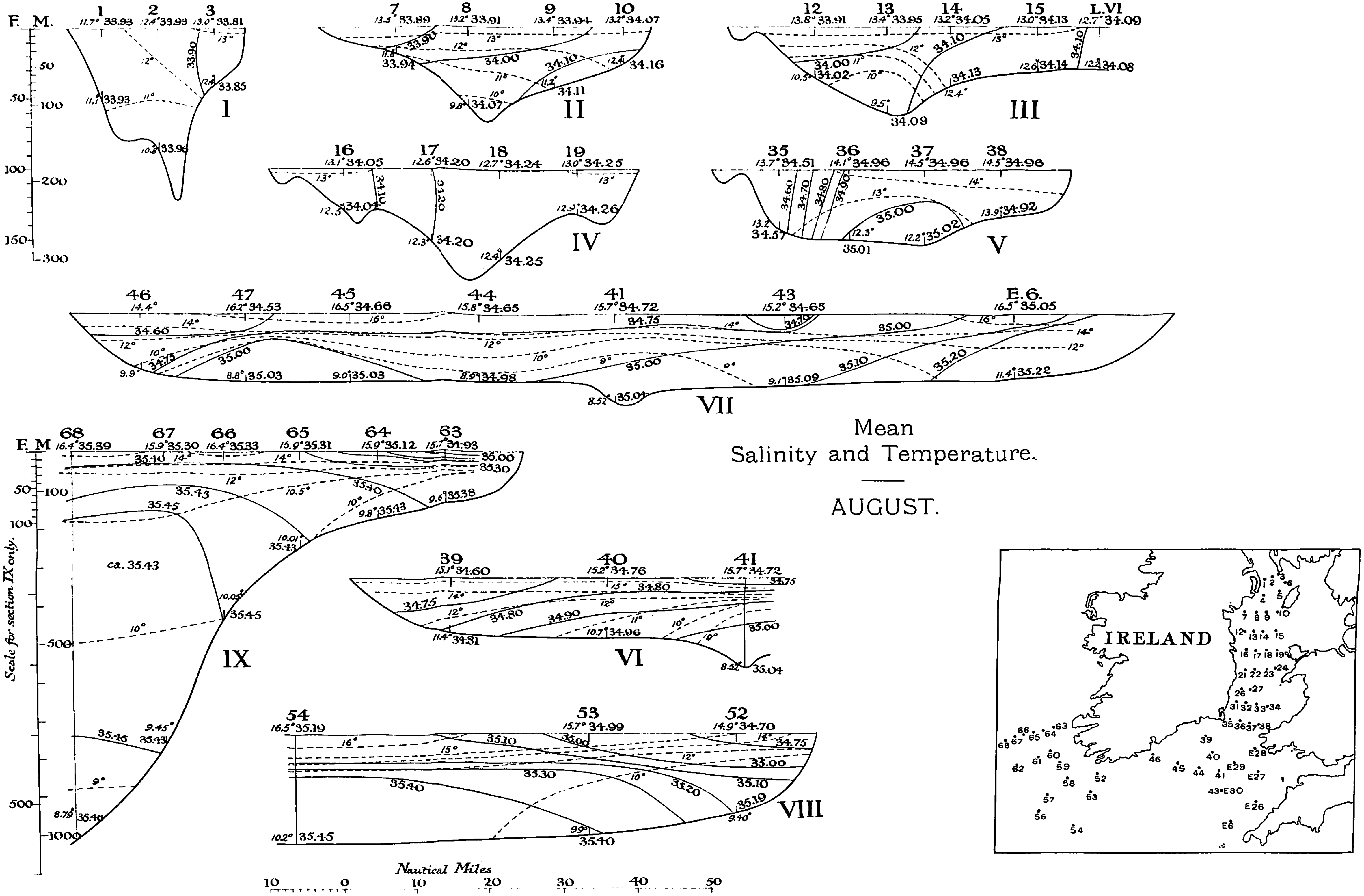
MAY.

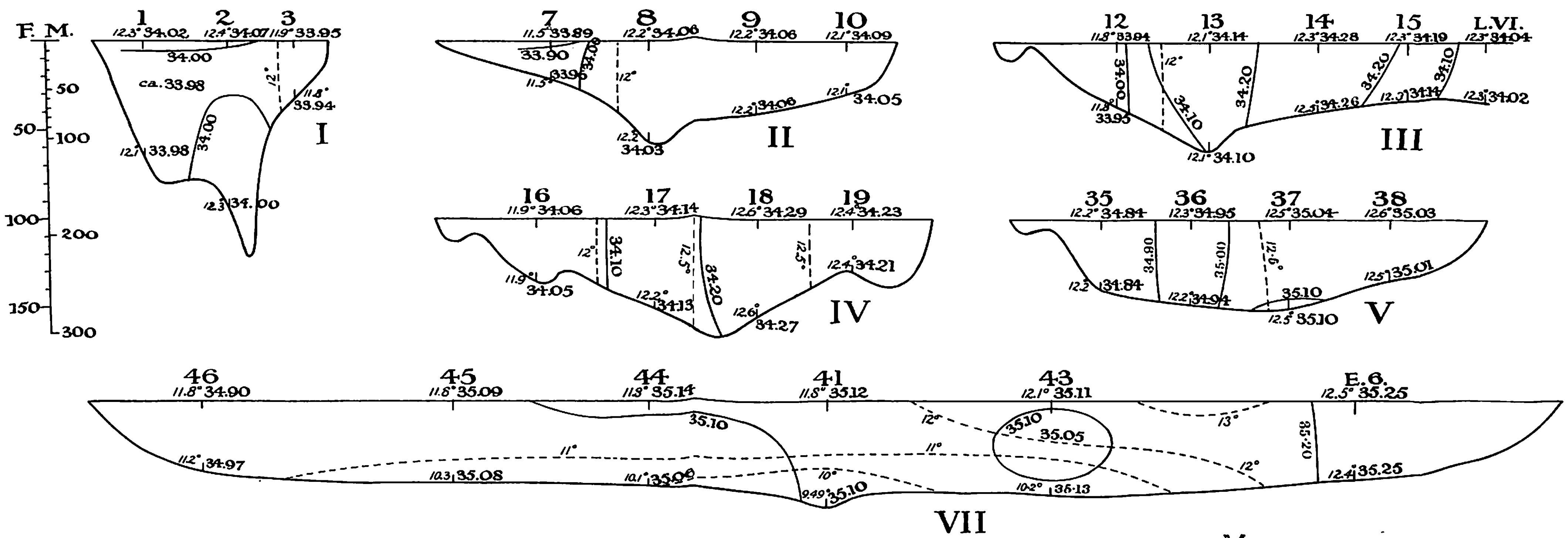
Ordnance Survey Office, Southampton, 1914.



Mean
Salinity and Temperature.

AUGUST.

Ordnance Survey Office Southampton, 1914.



Mean Salinity and Temperature.

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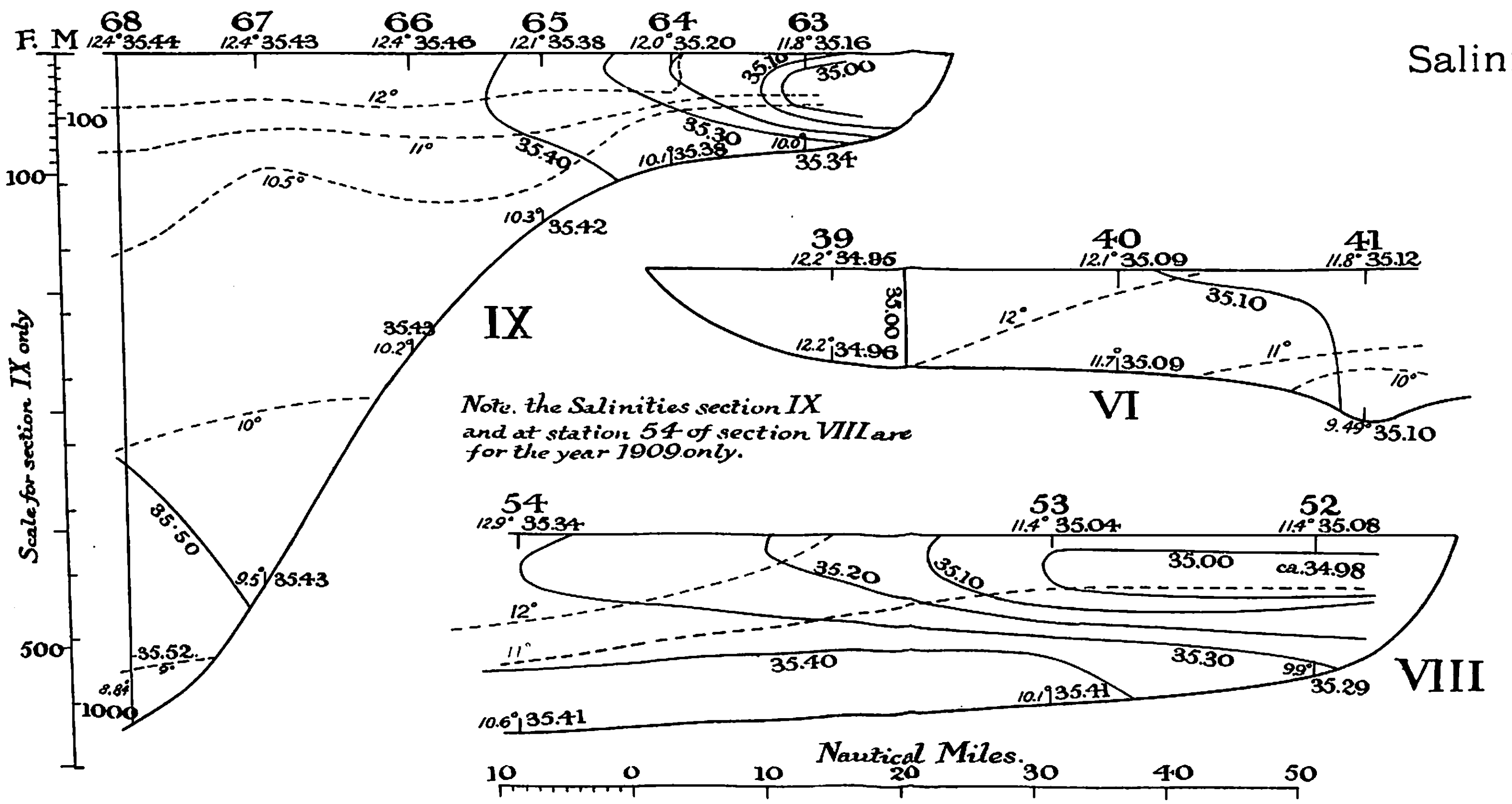

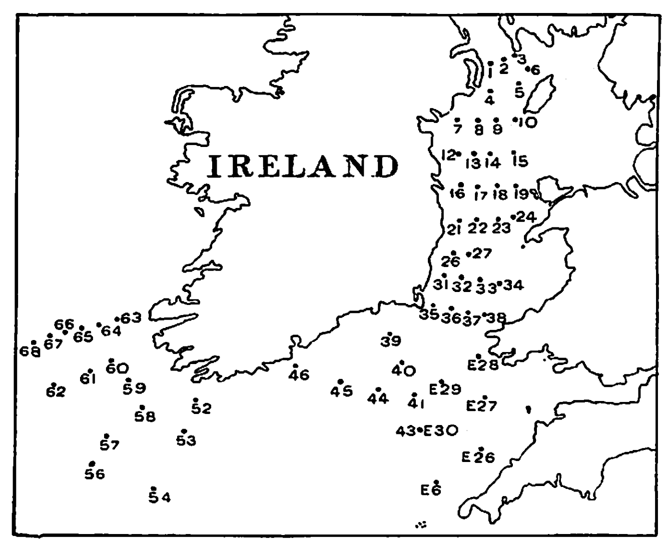

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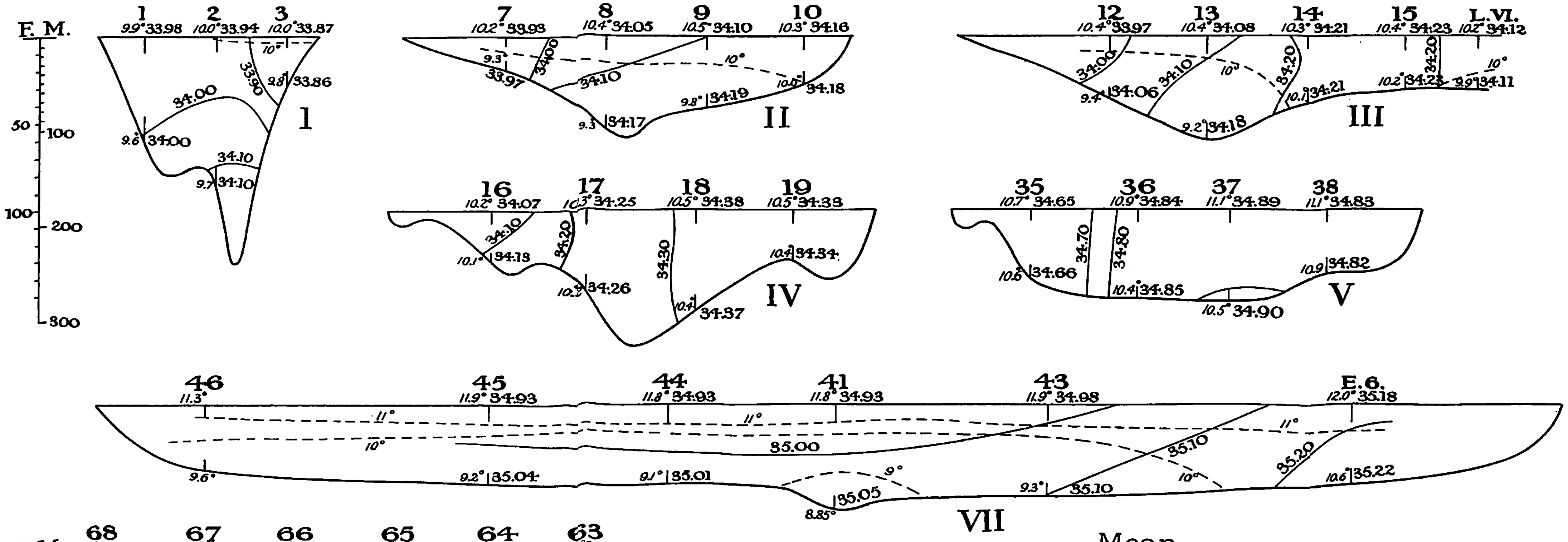
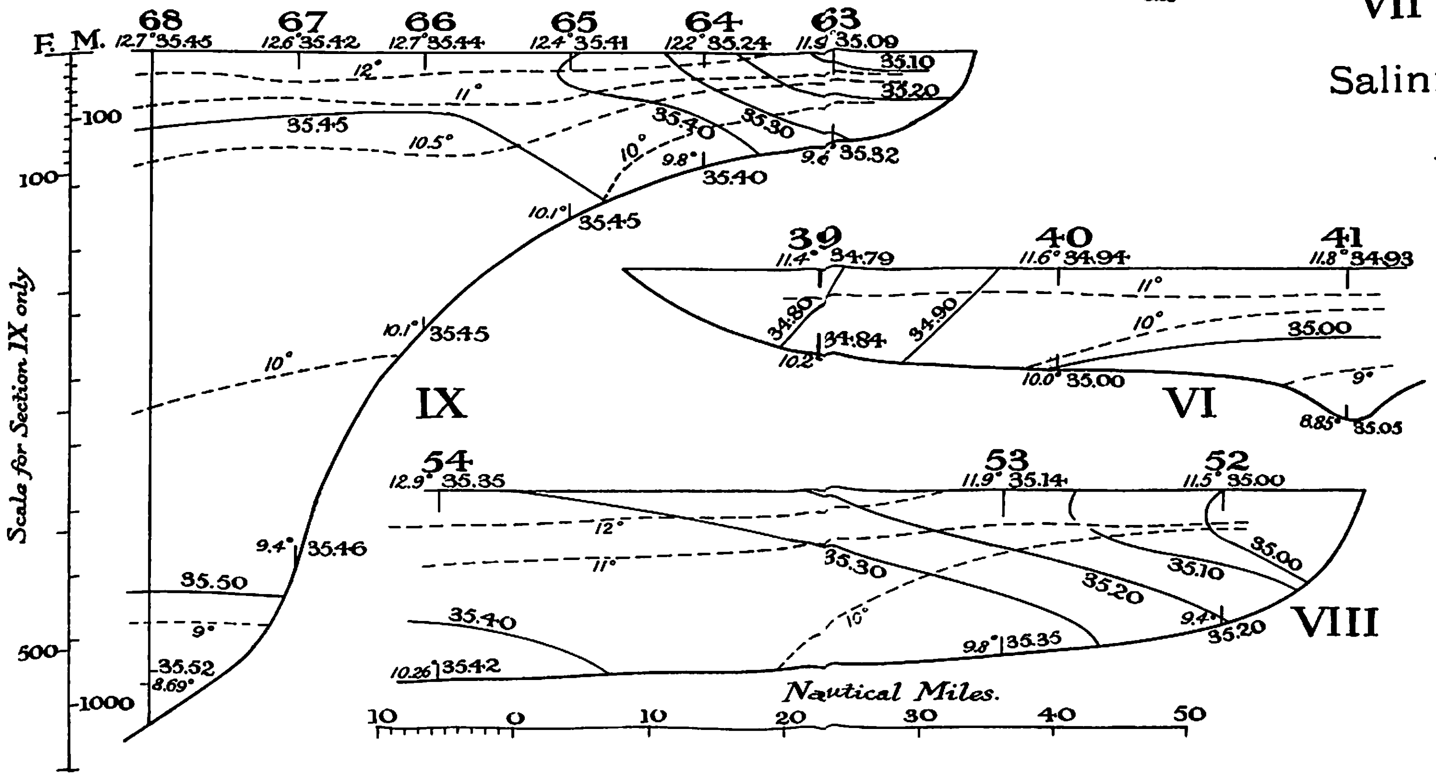
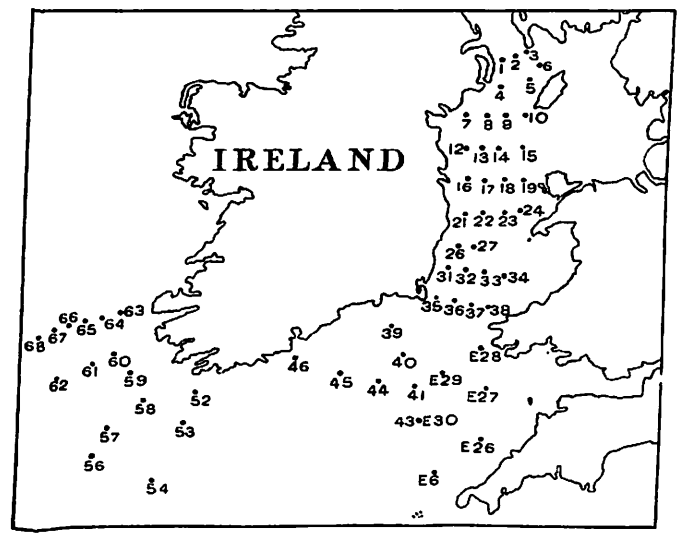


Mean Salinity and Temperature.

WHOLE YEAR.





Ordnance Survey Office, Southampton. 1914.

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