**Scientific and biological researches in the north Atlantic.**

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# SCIENTIFIC AND BIOLOGICAL RESEARCHES IN THE NORTH ATLANTIC

R. NORRIS WOLFENDEN

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# SCIENTIFIC AND BIOLOGICAL RESEARCHES IN THE NORTH ATLANTIC

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SKETCH CHART
SHOWING ROUTES OF THE YACHT
"SILVER BELLE"
1903-1907
1903 1904 1905-6 1907
NORTH SEA
NORWAY
DENMARK
SCOTLAND
IRELAND
ENGLAND
IRISH SEA
ENGLISH CHANNEL
BAY OF BISCAY
FRANCE
SPAIN
PORTUGAL
MADEIRA
AZORES OR WESTERN IS
MOROCCO
ALGERIA
MEDITERRANEAN
CORSICA
SARDINIA
Meridian of 0 Greenwich

MEMOIRS OF THE CHALLENGER SOCIETY. No. 1.

# SCIENTIFIC AND BIOLOGICAL RESEARCHES IN THE NORTH ATLANTIC

CONDUCTED BY THE AUTHOR ON HIS YACHTS
'THE WALWIN' AND 'THE SILVER BELLE'

BY R. NORRIS WOLFENDEN

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# FOREWORD

In the work which is recorded in the following pages, I owe a deep debt of gratitude to several scientific friends, notably Dr. H. N. Dickson, of Oxford and Reading, and to Mr. E. W. L. Holt (and Mr. Byrne) and his associates of the Irish Fishery Board, and to Professor Pettersson, of Stockholm, for their assistance in working up some of the results of the observations made over a number of years on my yachts. I fully recognize the fact that there is much material brought home from these cruises, which it has been impossible yet to overlook, in the midst of many occupations. I am painfully aware of the fact, that if I wait any longer for the completion of the study of these biological collections, I may have to defer the publication of such results as have been arrived at until a time too remote to contemplate. This would be unjust to my friends who have assisted me, and I must therefore give these observations to the world in a less complete form than I had originally contemplated, and hope for the opportunity to extend them at a future time. Many of them have been contributed to the meetings of the Challenger Society, which, however, does not publish *Transactions*. I can only trust that they may prove of interest to others who, like myself, have been fascinated by the study of things oceanographical. With all modesty I put this little volume out, not without the hope that it may stimulate others to assist science, as I have endeavoured to do, by observations at sea, seriously undertaken, and accurately recorded.

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## INTRODUCTORY.

In June, 1899, I made a cruise round the Shetland Islands, starting from Stromness, in Orkney, and returning to the same place, and at four stations, north, south, east, and west, I took careful temperature observations, and made collections of plankton with silk nets. This region and that of the Faeroe-Shetland Channel promising to yield results of great scientific interest, both from a hydrographical and faunistic point of view, and, moreover, having been hitherto but imperfectly examined, I determined to institute periodic cruises. At that time this area had not been taken over by the International Committee, the first cruise of the North Sea Fisheries Investigation Committee, indeed, not being undertaken until 1902 (August 25 to September 1, which was followed by a second cruise in December of that year), since which period this area has been under systematic investigation by the Scotch Fishery Board. The work which I had done in this region was preliminary to the more extended observations of this official body, and directly antecedent to it, and is therefore of interest as giving a picture of the hydrographical conditions of the Faeroe Shetland Channel for two years and a half previously to the observations of the Scotch Fishery Board.[1] As the plan of operations of the latter body did not extend beyond the Faeroe Channel in a westward direction, I made observations in 1903 from Valentia to the Faeroe Banks, along the deep-water trough of the Atlantic, not only for the purpose of making certain observations upon the plankton fauna, but also with the object, by hydrographical observations, of adding to the official work, by obtaining physical data of an area which did not come

[1] 'Report on Fishery and Hydrographical Investigations in the North Sea and Adjacent Waters,' Fishery Board for Scotland, 1902-1903.

within their scope, though adjacent to the 'official' area. During the year 1904 my yacht *Silver Belle* made an extended cruise from Valentia (Ireland) to the Azores, thence to Madeira and Gibraltar, and back to England across the Bay of Biscay to Plymouth.

The cruise of 1905, which at the time of writing was being undertaken, covered much of the same ground, certain stations of the 1904 cruise being revisited, to again examine the conditions of a large amount of Mediterranean water in the Atlantic, which formed so striking a feature of the hydrographical results of 1904. Professor Pettersson having kindly forwarded me one of his current meters, an attempt was made to use this on all occasions possible, and the faunistic work was largely devoted to trawling observations.

A private worker cannot hope to be equipped with the same costly appliances in the shape of steam vessels, etc., which a body expending Government funds may employ. Possessed only of small sailing-ships—first, in the Faeroe Channel, of a small cutter yacht of less than 40 tons, subsequently of a ketch yacht of 130 tons—all the work accomplished has been with comparatively small means. But I have taken care to have my ships equipped with apparatus of the most perfect and modern description, and the rest depends only upon accuracy of observation, and the power and patience to work under conditions often difficult, and to a landsman even appalling, but which to a seaman are but everyday incidents. I would with becoming modesty like to instance the amount of work accomplished by my yacht, as an example of what may be done by sailing-vessels of small tonnage, and to suggest that a great deal of very valuable scientific work might be accomplished by similar vessels, especially in areas which the International Council does not include within its plan of operations—work which would greatly contribute to that extended knowledge of the hydrography and conditions of life in the sea which it is now the endeavour of combined nations to acquire. I cannot but think that there are many yachtsmen who would willingly give their assistance if they were only initiated into the work, and only realized of what great importance scientific observations of this kind may be

in helping to solve many problems of oceanography. This, though a comparatively new science, practically dating only from the memorable voyage of the *Challenger* in 1876, has to-day assumed immense importance.

The scheme of work of international investigations has been well set out by Mr. D'Arcy Thompson as of three parts—viz., hydrographical researches, biological observations and experiments, and statistical inquiries. The latter, of course, is not possible for the independent worker, but the scope of the two former is well described by Mr. Thompson in the following words: 'It is laid down as necessary that we should extend our very scanty knowledge as to the phenomena of the sea itself, the distribution of its currents, the composition of its waters, and the changes that these factors undergo from season to season, and from one year to another. . . . It is not merely matter of surmise, but there is already evidence at hand to prove that the normal distribution and regular movements of many fishes are linked with these physical phenomena, and to indicate that hydrography holds the clue to the wanderings of the shoals. Together with these hydrographical problems goes the kindred study of the plankton—a multitudinous floating life that is variously associated with particular waters, and that serve as food for a variety of fish.'

The scientific yachtsman may contribute much valuable information in this and many other directions which it is not necessary to indicate here, and it is earnestly to be hoped that such may be induced before long to enter practically into this great scheme of the study of the sea.[1]

The great expeditions, such as those of the *Challenger*, *National*, *Valdivia*, and many others, which have resulted in immense additions to

[1] Professor O. Pettersson, Vice-President of the International Council for the Investigation of the Sea, has suggested to me that an association of yacht-owners, willing to devote part of their time to assistance in making observations at sea, might be formed. Such an association should not be impossible, and I should be willing to give the benefit of my experience to any who should be moved by scientific enthusiasm to join in the work.

our knowledge of oceanography and zoology, have been conducted over large areas of space. There yet remain problems of vast interest which can best be solved by smaller expeditions working over smaller areas and working continuously. Observations, for instance, which can be taken month by month over a small selected area must yield results of very great importance.

On these voyages the objects have been: (1) To take hydrographical observations—*i.e.*, records of the temperature of the water from the surface to 1,000 fathoms (sometimes to 1,500 and 1,800 fathoms), along with collection of samples of water in a suitable 'water-bottle' from these depths. These are at once bottled (in glass bottles) on board the ship, and at the termination of the cruise the water is analyzed to determine the salinity. These analyses have been carried out under the supervision of Dr. H. N. Dickson at Oxford, and his reports are given below. During 1904, also, a great many vacuum tubes were filled with water from various depths for the subsequent analysis of the proportions of oxygen and carbonic acid. These analyses, which have been made by Professor Pettersson at Stockholm, have yielded results of great interest and importance. (2) The collection of the plankton, or minute life of the sea, in fine silk nets, which gives important results, besides assisting hydrography in determining the vertical and horizontal distribution of the smaller animals and of plants, which, though in many cases actively swimming, are in all cases more or less, and in some entirely, at the mercy of oceanic currents, and which also results in the discovery of many new species.

The circulation of the oceanic waters of the North Atlantic Ocean and the causes of the same, which has been ascribed variously to physical causes—viz., the heating of surface waters of the tropical regions, and cooling of water in the Polar regions; to the influence of prevailing winds; shortly and vigorously by Pettersson to the melting of ice from the Polar regions—are matters for subsequent discussion. It is thought better for the present merely to record in the pages following the scientific observations which I have made from the

Faeroe Islands to Madeira, the Azores, and the Straits of Gibraltar, the bearing of which upon modern theories of the circulation of Atlantic waters will be better dealt with later on.

For the purpose of scientific investigations of this kind, a brief description of the appliances necessary may be given.

1. Water-bottles for the collection of samples of sea-water at different depths. It matters little what form of bottle is used, provided only that the apparatus can be guaranteed to collect the sample of water from a given area without admixture of water from any layer above or below. On board the *Challenger* the apparatus in use was the bottle devised by Buchanan, and which, notwithstanding 'improved' forms of apparatus, is still quite sufficiently accurate for the purpose. This is the form of 'bottle' which has been constantly used on board the *Silver Belle*. When the work was first undertaken in the Faeroe Channel, Mills' water-bottle was used, and this is sufficiently useful for moderate depths. Buchanan's bottle, which is a larger apparatus, carries a reversing thermometer on a frame attached to the cylinder. It is lowered and raised on a wire reeled off a drum which carries 2,000 fathoms, and the hauling on board the drum, which is fixed on a specially-made winch, is actuated by steam, as hand-hauling at such depths would not be practicable. The water-bottles of Pettersson-Nansen are much more elaborate, consisting of concentric tubes, with the thermometer inside the tubes. In a new pattern, the outside frame carries a reversing thermometer, 'which may be used instead of the deep-sea thermometer, or as a check on the results obtained thereby.[1] That the use of thermometers inside the lid of the water-bottle is not considered absolutely essential by the International Council is indicated by the remarks of Helland Hansen in the same report:[2] 'On account of faults in the manufacture three of them'—*i.e.*, Nansen-Richter thermometers—'were broken during the August cruise, so that at some stations we were obliged to use good ordinary thermometers (with milk-glass scale), which were put into the water-bottle after it had come up on deck. As the temperature of the air

[1] Robertson, 'North Sea Investigations,' p. 54. [2] *Ibid.*, p. 3.

did not differ very much from that of the water, we may neglect the errors caused by this method.'

On board the *Silver Belle* we have always employed Miller-Casella thermometers or Knudsen's bulbs, and we have been very fortunate in escaping accidents by breakages. The reversing thermometer is one supplied by Negretti and Zambra, and this and the Miller-Casella were found to vary only two or three tenths of a degree. The air and surface-water temperatures were taken by a thermometer supplied from the Plymouth Laboratory, made by Müller, Orme and Co., rising from 9° C. to 36° C., and divided in tenths (compared with thermometer 303 Richter, and verified at Charlottenburg). All our instruments have been similarly verified. The depth is recorded by a wheelmeter reading fathoms.

2. For the collection of plankton silk nets (of bolting silk 100 to 170 mesh) were employed, and as the desire was to collect the plankton at definite depths, closing-nets have been always employed when working below 100 fathoms. Closing-nets may be made to work vertically, as in Fowler's net,[1] or horizontally, as in Garstang's and the author's nets. Opinions may be divided as to the relative advantages of these two methods of fishing for plankton, but the objection that a horizontally-towing net, which has to be towed at a very gentle pace (with just sufficient way on the ship to keep her barely moving), is never at the depth imagined loses force when it is realized that a vertically-hauled net is so raised through a hundred or more fathoms at each haul between the opening and closing. Besides which it is probably of little importance in working in deep water whether the net is, say, at 1,000 or 900 fathoms, and, moreover, the accuracy of the observations is checked by appending to the net-frame one or more thermometers. A reversing Negretti thermometer is invariably attached to our nets when plankton-fishing, and as the temperatures in the Atlantic at known depths are fairly constant, the

[1] Dr. Fowler's net is described in the *Proceedings of the Zoological Society*. He was kind enough to superintend the making of one for me, which we used very much in the Faeroe Channel in 1903.

reading of the thermometer gives a pretty accurate indication of the precise depth at which the net has been. The net remains down usually for fifteen minutes after the opening messenger has been sent down, and is then closed and hauled up.

There are advantages about the use of a horizontally-towing net as compared with one vertically actuated, in that the supposed depth is more accurately located to within a few fathoms ; and again, that as marine organisms usually move in shoals, a horizontal net is more likely to capture them than a vertical net, which may pass by a moving shoal, although it may capture a large amount of material by passing through a large vertical excursus.

The chief object of these researches is to determine generally what species are mesoplanktonic and epiplanktonic throughout a portion or the whole of their existence, and to determine as far as is possible the horizontal and vertical distribution of various species, as far as regards their relation to bathymetrical and climatic conditions.

The desideratum of a good and effectively opening and closing net for deep-water work being great, the author and his skipper, Buchan Henry, set to work to devise an apparatus of the kind which should be effective in deep water ; and the instrument which is described briefly has been found to meet all requirements.

The inability to determine with absolute accuracy the depth at which any net, either of vertical or horizontal pattern is working, of course renders all real experimental work only approximate in its results ; but I think it must be conceded that all open nets—*i.e.*, nets which are not designed to open and close by messengers or other effective device at the supposed depth—can only be regarded as inefficient in any problems of vertical distribution.[1]

[1] Professor O. Pettersson attaches a small net to his current meter, so that water samples, temperature, the velocity of the current, and a sample of the plankton of the area can be taken at one and the same time. Though very useful, Professor Pettersson's statement that this is the only accurate test yet devised for taking reliable samples of plankton cannot be supported, the net being an open one with no mechanism for closing.

The worst of all nets of this kind is that the amount of plankton captured is often very small, and it is only the smaller animals which cannot escape, while larger beasts, endowed with great activity, can avoid the snare ; but as Copepoda form the great bulk of the plankton in deep water, and their distribution in relation to ocean currents is perhaps the most important, these little crustacea are captured in sufficient quantity by the horizontally-towed net.

As it may be of interest to some to describe how these operations are conducted on a small sailing-vessel, I give a short description of the disposal of apparatus and method of working on board ship.

A steam boiler is fixed under deck, and supplies motive power to a capstan amidships, of the type generally employed on the larger fishing vessels.

In series with this is a strongly-made winch, specially designed for the purpose by Messrs. Bullivant and Co., which carries two drums, one for 2,000 fathoms of wire for the closing-net and water-bottle, etc., the other a smaller reel containing fine sounding-wire. The winch is fitted with clutch and brake.

The wire used is of seven strands, galvanized, 17 gauge, ·056″ diameter, each taking 520 pounds of strain, so that the total breaking strain is about 2,800 pounds. There is a good deal of difference in wire, which requires to be of the very best manufacture. In a wire of less perfect make, which we once had from Birmingham, the strands overrode the central core, so that the wire was from the first useless, the messenger refusing to descend beyond the obstruction caused by the overriding of the wire.

In 1904 we used a wire of 16 gauge, also of seven strands, 2,000 fathoms, weighing 7 cwt., and with a diameter of ·064″, and breaking strain of nearly 4,000 pounds ; but although on one occasion in very deep water we nearly lost the heavy closing-net through the breaking of all the strands except one, caused by the riding up and down in an exceptionally heavy sea, the lighter wire is sufficiently strong for ordinary purposes. The fact is that heavy closing-nets should not be used in a heavy sea-way. The risk is great, and the results obtained

are usually very small; the violent jerking of the wire and net prevents it turning and fishing properly, and throws a terrific strain upon the whole, which is likely to lead to breaking away. On one occasion in the Faeroe Channel we thus lost 120 fathoms of fine piano wire, Garstang's net, and two thermometers, a sudden strain causing the wire to snap close to the surface.

All wire made by Messrs. Bullivant and Co. can be guaranteed to be as near perfection as possible, and to stand any strain to which such wire ought reasonably to be submitted.

From the winch the wire is led over a gun-metal wheel, to which is attached an indicator which marks in fathoms the amount of wire let out. From this wheel the wire is led over a running wheel at the upper end of a stout spar, which is fixed at the bottom by a hook on to the mainmast, and by a length of good manilla rope at the upper end over a pulley again attached to the mast, and so arranged that the spar can be readily swung out at the desired angle over the bulwarks of the port or starboard side.

In comparatively shallow water—*i.e.*, down to 500 fathoms—a sounding is made with ordinary hand-line and sounding-lead, and a sample of the bottom brought up and preserved; in deep water the hand-line is never used, the depth to which the water-bottle or heavy closing-net is lowered being read off on the fathom-indicating wheel, a preliminary sounding being generally made with the fine sounding-wire.

While it is impossible to work closing-nets with satisfaction in rough sea-way, we have never found this an obstacle to the use of the water-bottle, or temperature observations, and these observations were therefore made when at sea with regularity daily, and throughout the cruise from Valentia to the Azores, at distances of about fifty miles apart.

### Description of New Tow-Net for Deep Water.

During the 1903 and 1904 cruises we have used almost exclusively the net figured below. With it considerably over 400 hauls were then made from 50 to 2,000 fathoms, and it only failed to open or shut at the right time on very few occasions, and then only when used in

conditions of sea and weather when no tow-net could be guaranteed to act with satisfaction. On one occasion, at the end of a long cruise (in 1903), one of the side-springs broke, but this was easily replaced on board, and once, in 1904, when the net unfortunately had been bumping against the floor of the sea, the central piston became bent, and the weakening thus caused led to its breakage shortly afterwards. This, however, was quickly repaired on board. The net is designed to tow horizontally. As will be seen from the figure, it consists of four detachable pieces: (1) The main cylinder, with arrangement at the bottom for attaching weight, if necessary, and thermometers. (2) Sliding down it a central piston which runs freely through the top piece, enlarged at the bottom end that it may, when fully withdrawn, catch upon the side-springs inserted inside the upper portion of the main cylinder; these springs are then pushed through the lateral slots, and are designed to catch the arms of the net-frame and hold the lower pair in position when the net is closed ready for lowering. The upper portion of the central cylinder (detachable with the piston) has strong lateral steel springs (we have found steel preferable to any other metal for this purpose, and with proper attention it does not rust), four in number. (3) A funnel-shaped top piece put on over the top springs, and which receives the impact of the large closing messenger. (4) The four arms of the net-frame, attached to short metal tubes which slide freely over the main cylinder.

When the net is about to be used, the wire is run through the piston and main cylinder and bent on to the device at the bottom (this is cast in one piece with the main cylinder); the top piece is screwed home on the main cylinder, the funnel pushed slightly down, the arms raised, and the piston drawn up, so that the lower pair of arms catch on the smaller pair of side-springs in the main cylinder, which is insured by raising the piston. By pushing down the funnel the upper arms are caught on the four strong springs of the top piece, and they are made secure by withdrawing the funnel a little. The net is then ready, securely closed, for lowering. To open it under water, a small messenger is sent down which strikes the top of the piston, drives it down the cylinder, the lateral springs of which recede inside, and the

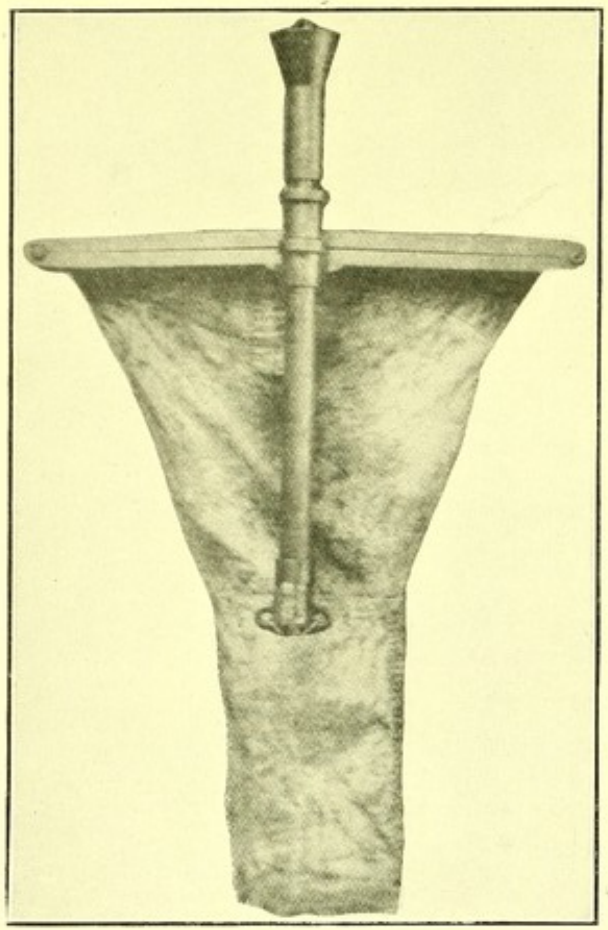


Fig. 1.

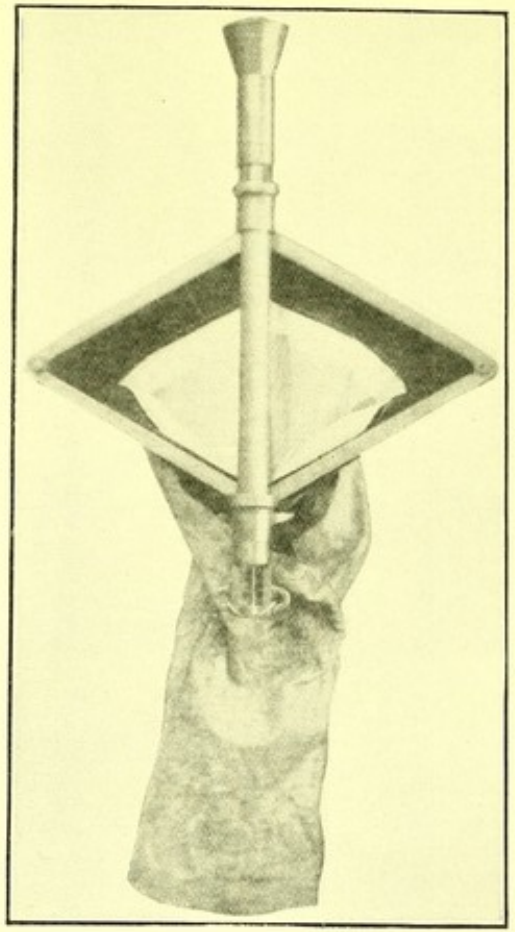


Fig. 2.

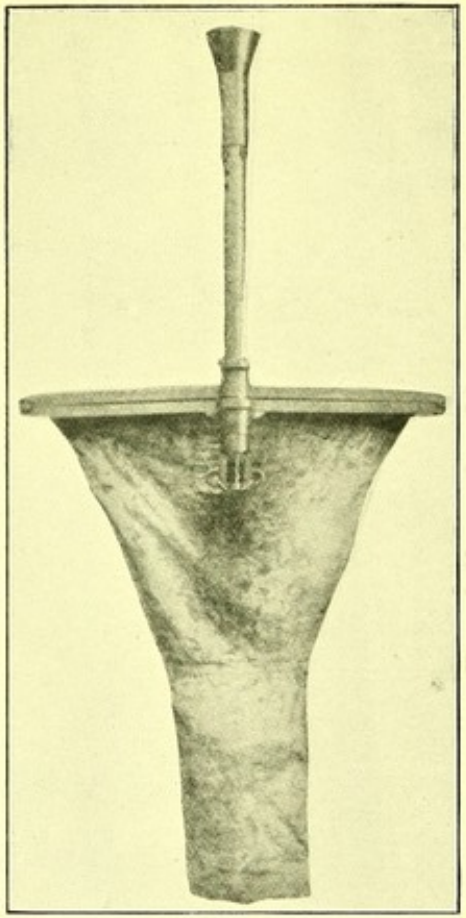


Fig. 3.

lower arms are released, falling to the bottom of the cylinder. To close it, a large messenger, the diameter of the funnel, strikes the latter, drives it down, and, compressing the upper springs, the upper arms are also released and fall to the bottom, and the net is securely closed.

The three positions of the net—(1) ready closed for lowering, (2) open as in towing, (3) closed ready for raising—are shown in the figures on p. 11.

The whole net-frame, from the top of the funnel to the bottom of the cylinder, is 3 feet 4 inches long when the net is opened, and 3 feet 2 inches when the net has been shut. The outside diameter of the main cylinder is 2 inches, and its length 2 feet 9½ inches; the length of the piston 20 inches; the top of the funnel 4⅛ inches diameter, and the lower end, which fits over the main cylinder, 2⅛ inches.

The fine silk (bolting silk) net is 3 feet 6 inches long, stitched on to a leather border of 5½ inches length, which is attached to the frame. Conical in shape, at the end it is only 6 inches diameter, and in order to prevent maceration of the captured specimens, which occurs in the ascent of the net by the friction of the sides falling together, I have for long used a cane hoop sewn into the net a little way before the end, which serves to keep the end of the net open, and has proved to be markedly advantageous to the preservation of the specimens. As silk nets are apt to get torn, and not unfrequently have burst under the pressure, we have also for long now used the protective covering of a duck-bag, inside which the silk net is freely suspended. This has effected a great saving in silk nets.

This net-frame was made for me by the eminent engineers Messrs. Bullivant and Co., of London, who expended much time and experiment in the construction of the models, and produced a net-frame of perfect workmanship. The simplicity of the apparatus, and its accuracy in opening and shutting under water, leave nothing to be desired. I have endeavoured to give a description of the net without overloading it with technical details, but a more accurate (from an engineer's point of view) description can be readily obtained from the specification drawn up by Messrs. Bullivant and Co.

## EXTRACTS FROM THE LOGS OF THE CRUISES IN THE FAEROE CHANNEL, 1899—1902.

THE *Walwin* is a little cutter of thirty-six tons, originally built at Salcombe, and was first devoted by me to scientific work in 1899. Manned by a crew of Shetlanders, than whom there are no finer seamen in the world, she cruised round Shetland from October, 1899, to June, 1900, visiting four stations, referred to afterwards as I., II., III., IV., once a month, taking temperatures, collecting water samples (part of the time), and dredging and collecting plankton. From the first Buchan Henry has been in charge of the apparatus used on board the *Walwin* and on the *Silver Belle*, in the later more extended cruises; and probably there are few who have acquired a more intimate knowledge of the conduct of such observations on board a sailing-ship than he. In July, 1900, the little *Walwin* made her first trip to Faeroe, revisiting some of the stations in August of that year. In 1901 she made other cruises to Faeroe, in May and June, and revisited some stations in the Faeroe Channel in July. In 1902 she crossed the Faeroe Channel in May, June, and July, and revisited some stations in August. It would be tedious to reproduce the ship's log of these passages; but all who know this region will admit that pitching about the Faeroe Channel in a little 36-ton boat is not the pleasantest of experiences, and it needs determination as well as scientific enthusiasm to conduct observations under these conditions. The work was especially arduous, because there was no room for steam to assist haulage in such a small vessel; consequently everything had to be done by willing hands. As an example of the kind of weather sometimes met with round Shetland in the winter-time, the following brief extract from the log may be taken:

*January* 6, 1900.—Strong gale.

*January* 9.—A storm from the north-west, and very heavy sea, the steamer from Aberdeen to Scalloway being twenty-four hours overdue.

*January* 27.—Squalls, with rain and snow.

*February* 3.—The ship kept several hours in Blue Mull Sound by snowstorm.

*February* 5.—Strong gale; both anchors down all night in Culi Voe. Thermometer 26° F.

*February* 8.—Snowstorm with frost.

*February* 11.—Strong breeze and snowstorm; two anchors down.

*February* 16.—A storm, with snow, began at 12 last night (the ship at anchor in Scalloway Bay); at 2 a.m. a hurricane, the ship dragging both anchors; at 6 a.m. she ceased to drag any farther, but at 8 a.m. there was a full hurricane, nearly every ship in the harbour dragging anchors, and three ships ashore; impossible to see twenty yards for blinding snow; force of hurricane increased till 10 a.m., the small boat towing astern having her bows completely smashed in.

*February* 17.—6 a.m. some improvement, but still a whole gale with snow. The steamer *St. Giles*, from Aberdeen, came into Scalloway with her deck badly smashed, the bridge and all boats gone.

*February* 18.—A strong gale.

*February* 21.—Strong gale from north-east, with snow showers.

*March* 1.—Snow.

*March* 2.—A gale from north-north-east.

*March* 9.—A gale from north-west.

*March* 19.—A gale from north.

*March* 25.—Whole gale north-east to north, with snow.

*April* 6.—Strong gale from south-east.

*April* 30.—Whole gale from south-west, with sleet.

*July* 5.—Left for Faeroe, but had to put back again.

*July* 10.—Double-reefed mainsail and storm-jib.

*July* 12.—Split mainsail in two places.

*July* 14.—Thick mist and almost calm; had to tow the ship to within one mile of Thorshaven. From 15th to 18th lying at Thorshaven with thick mist all the time.

*July* 20.—Left Thorshaven with light wind and calm sea.

*July* 21.—Fresh breeze which increased, at night necessitating double reef in mainsail, and small jib.

*July* 22.—Wind less and reefs shaken out; heavy rain.

*July* 23.—Early on fresh breeze, increasing, so that at 8 p.m. it was necessary to reef the mainsail.

*July* 24.—Double reefs.

On August 16 Mr. Hodgson, who had been appointed biologist to the Antarctic ship *Discovery*, left Orkney on board the *Walwin* to visit some stations in the Faeroe Channel and gain some experience before leaving for his long Antarctic cruise. After leaving Scalloway on August 21, the ship was twice put back to Hillswick, but August 24 opened absolutely calm. However, by 2 p.m. the wind was rising, and at 10 p.m. the mainsail was double-reefed and storm-jib set. For twenty-four hours the bad weather continued, and the ship was put back to Hillswick for the third time. The 27th and 28th August were fine, and station A2 was reached, after which the ship returned to Scalloway.

During the cruises of 1901, the month of June was marked by several strong gales, so that from the 18th to the 21st the mainsail was continuously double-reefed.

In 1901, the *Walwin* left Scalloway on May 13 for Faeroe; on May 14 was compelled to return to Snaraness by stress of weather. Leaving on the 20th, and for two days under double-reefed mainsail, she arrived at Thorshaven on May 22. Then from May 23 to 27 was calm weather, with fog of varying thickness, bright sunshine, and calm on the 28th. Having left Thorshaven on the 29th, on the 30th double reefs were required again, and it was necessary to run back for shelter to Trangasvaag. May 31, strong gales; June 1, terrific squalls, riding with both anchors out; June 2, strong gales, at noon the wind dying away, to a light breeze at 6.30 p.m.; on the 4th and 5th reefed sails and strong gales, anchoring the same day in Scalloway.

On June 18, again leaving Scalloway, for two days with haze and strong breeze; on the 21st was the first day of anything like summer

weather, and the first time for three days the reefs could be shaken out of the sails. By evening double reefs were required again! On the 22nd, while working in a heavy swell, the wire snapped, and the Garstang closing-net, 2 thermometers and 120 fathoms of wire, went to the bottom of the Faeroe Channel. There was nothing to do, therefore, but to return to Scalloway.

Leaving Scalloway on July 3 with a new net, the 4th and 5th were calm; the 7th, under reefed sails, Thorshaven was reached in a whole gale. From the 8th to the 11th with rain, fog and gales, anchored in Thorshaven. Leaving on the 13th in a light breeze, double reefs were not shaken out again until entering Scalloway on the 18th.

These brief extracts from the log of the *Walwin* for 1900 and 1901 show what sort of weather is to be expected in this region even in summer, and the painfully difficult conditions under which work has to be conducted. I therefore replaced the little *Walwin* by a larger ship, the *Silver Belle* (130 tons), which, having been built on North Sea fishing-ketch lines, I refitted as a yacht, putting on board a steam capstan to perform the haulage.

The *Silver Belle* left Scalloway on May 15 for Thorshaven, the weather being very much the same as the *Walwin* experienced the previous years—viz., strong gales, requiring sails reefed Lying in Thorshaven Harbour from the 24th, no communication was possible with the shore for three whole days.

May 27, after leaving Thorshaven, sails had to be reefed again, and the ship run back for Trangasvaag for shelter, and next day one trawler, four smacks, and H.M.S. *Bellona* had sought the same refuge. On the 29th the whole land was covered with snow. Leaving this anchorage on May 30, with course set for the Butt of Lewis, double reefs were required next day. On June 1, sounding on 400 fathoms, a sharp swell and the riding of the ship caused the line to break, and 400 fathoms and the 28-pound lead were lost. On June 3 the ship was brought to anchor in Stornoway, for two days previously all sails close-reefed.

The second cruise from Scalloway to Faeroe was started on June 18 after a week of continuous gales. For three days after leaving sails were double-reefed, and it required forty-eight hours of dodging round Station A2 before it was safe to venture any apparatus out. Faeroe was reached on June 22, and Scalloway again on the 30th, after three days at Thorshaven. The third cruise was commenced on July 8, double reefs again necessary, and on the 10th running back to St. Magnus Bay for shelter. Thorshaven was reached on the 17th, and Scalloway again on the 23rd.

The 'summer' weather of 1902 was but a repetition of that of 1901. The hydrographical observations made on these cruises are dealt with later on by Dr. H. N. Dickson.

## THE CRUISE OF 1903 FROM VALENTIA TO THE FAEROE BANKS AND ORKNEY.

On June 10, 1903, the *Silver Belle* left Valentia with a light breeze from north-east, overcast sky, and falling barometer, and a swell at sea growing bigger, with increasing wind. On reaching the station in Lat. 51° 56′ N., Long. 11° 21′ W., the weather was really too bad for work. A sounding gave 120 fathoms, with a bottom temperature of 10·2° C. Bad weather continued through the night, but improved at daylight next day, and settled down into a fine, warm day, and, sounding in 130 fathoms, the closing-net was put down to 125 and then 60 fathoms, getting a lot of stuff at each haul. Water samples were also taken.

Station E1.

Station E2.

Sailing and drifting about thirty-three miles west by north during the night, as daylight came the wind and sea grew worse. At 4 a.m., sounding with wire and a 56-pound lead, bottom was struck at 560 fathoms, the line 'plumb' straight, the position being Lat. 51° 46′, Long. 12° 15′. The closing-net was put down, which, with wire and 56-pound weight attached to the bottom of the frame, weighed over 2 cwt.; the line stood quite straight, and hauls were made from 550, 400, 300, 200, and 100 fathoms, and water samples at every 100 fathoms from 500. The weather completely breaking, and sea and wind growing gradually worse, work in deep water was almost out of the question. The ship was therefore put back to Valentia to wait for an improvement. There she remained until June 18, when a start was again made for deep water. Twenty miles west of the Skelligs it came on to blow hard, with a falling barometer, and this continued all the next day (Friday), but Saturday fell quite calm, and the consequence of this was that the ship never

Station E3.

got beyond the 100-fathom line until Sunday, June 21, when the position Lat. 51° 34′ N., Long. 12° 30′ W., was reached. All day the wind blew hard from the south, and the yacht dodged all day and night with sails reefed. At 4 a.m. on Monday, the weather having considerably moderated, a sounding gave 725 fathoms. The closing-net was used at 700 fathoms and each 100 fathoms above it. For the next thirty-six hours the weather was very dirty, but on June 24 the ship was hove to, the wind having dropped, in Lat. 51° 00′ N., Long. 11° 32′ W., and a sounding gave 375 fathoms. The closing-net was used down to 300 fathoms. Station E4.

After a course of 20 miles west-north-west, the ship was hove to all night, and at 5 a.m. on June 24 a sounding was taken in Lat. 51° 00′, Long. 12° 00′, giving 980 fathoms. With such a heavy sea the closing-net, put down to 900 fathoms, though with a perfectly 'plumb' line, captured nothing, and only water samples were taken from 900 fathoms to the surface. Two of the thermometers to-day were rendered useless, one having the end broken off and the other coming up with the mercury above the index. The glass falling, and everything looking as unpromising as possible for work, the ship was put back to Valentia. Station E5.

On July 5 another useless attempt was made to work a deep-water station; after dodging round for three days with strong gales and heavy sea, a sounding gave 1,030 fathoms and a bottom temperature of 4·4° the position, Lat. 50° 56′ N., Long. 12° 6′ W. With a double-reefed mainsail, storm-jib and reefed foresail and double-reefed mizzen, the ship pitched about all night with a very heavy swell from the north. Next morning, July 6, the wind dropped, and in the same position the closing-net was put down to 1,000 fathoms, bringing up quite a decent haul, then to 700, 500, 300, 200, and 100, all very successful. The triangle net, put down with 120 fathoms of rope in front of the net, a 16-pound lead, and 1,000 fathoms of wire, brought up about 2 cwt. of chalky ooze from the bottom, with nothing in it but a few shells. The closing-net brought up in the 500-fathom haul a lovely specimen of *Acanthopyra sica* (*vel Agassizi*). Station E6.

Station E7.

Running thirty-four miles during the night with a south-south-west wind, at 4 a.m., July 7, the ship was hove-to in Lat. 51° 30′ N., Long. 12° 00′ W. A sounding gave 616 fathoms, bottom stones and sand; the closing-net was used at 600, 500, 300, 200, and 100 fathoms, and water samples taken from 600, 300, etc., fathoms.

Station E8.

On July 8, the position being Lat. 52° 00′ N., Long. 12° 00′ W., depth 255 fathoms, with a bottom of fine grey sand, the closing-net and water-bottle were used.

Station E9, 10, 11.

Station E12.

On July 9, Lat. 53° 30′ N., Long. 12° 00′ W., a sounding gave 150 fathoms. Stations 10 and 11 were in shallow water respecting Lat. 53° 00′ N., Long. 11° 56′ W., depth 100 fathoms, and Lat. 53° 30′ N., Long. 12° 00′ W., depth 150 fathoms. Both were worked with closing-net and water-bottle, and on the same day in Lat. 54° 00′ N., Long. 12° 00′ W., a depth of 205 fathoms. At both stations the closing-net and water-bottle were used as usual.

Station E13.

At midnight of July 9 the position Lat. 54° 30′ N., Long. 12° 00′ W., was reached, and, double reefing the sails, although the wind was light, so as to make as little leeway as possible, a sounding gave 1,608 fathoms, with a bottom of grey ooze. A thick fog, with light breeze from west-south-west, turned to heavy rain. The net was put down to 1,600 fathoms, and brought some stuff in it, though not very much, and also at 1,000 fathoms, and at 800 and 600 fathoms good hauls. At 400 fathoms it contained a very fine specimen of *Phronomopsis sedentaria*. The hauls at 300, 200, and 100 fathoms were good. In all these hauls, the weather being favourable, the sounding-wire was perfectly 'plumb,' and the heavy wire and closing-net almost entirely so. Water samples were taken at 1,500 fathoms and upwards. Having drifted somewhat eastwards, the water-bottle struck bottom at 1,500 fathoms, and in the subsequent haul at 1,300 fathoms it again struck bottom, bringing up mud and ooze along with the water. Evidently there was here a very steep bank. During this time the ship was drifting a quarter of a mile per hour. At 1,100 fathoms there was no bottom.

A light north-west wind carried the ship to the next station at 8 p.m. on July 11, and at daylight, July 12, the position was Lat. 54° 50′ N., Long. 12° 00′ W. On this and some subsequent occasions a Massey's sounding-machine was used, and compared with the fathom-counter. The former struck bottom and registered 1,737 fathoms, the latter only 1,577 fathoms. Massey's machine was evidently not reliable in deep water. The closing-net put down to 1,000 fathoms brought up a small quantity of stuff, and at 700 and 500 fathoms about the same. From 400 fathoms the net was used at each 100 fathoms to the surface. Towards evening the ship had drifted about a dozen miles, consequently the night was spent in beating to windward to get back to the position, and at 4.30 a.m. on July 13 the ship was hove to, and water samples were taken from 1,500 fathoms upwards. The work at this station occupied two full days. Station E14.

Before the next station was reached, on July 16, four days had been spent with very dirty weather and very bad sea with a heavy cross swell, impossible to work satisfactorily. The position was Lat. 55° 17′ N., Long. 12° 28′ W., and bottom was struck at 1,561 fathoms. Massey's machine gave 1,645 fathoms, and the probable explanation of this discrepancy is that after Massey's machine touches the bottom, the ship rolling heavily, and the winch not being quick enough to stop the lead from sinking a little with every roll, the machine keeps registering, and the more the number of rolls and the greater the length of time before the machine is hauled on board, the greater the amount registered. A very simple device would cause the machine to lock directly it struck bottom, and then it would be useful and reliable. The water-bottle was put down to 1,500, 1,300, 1,100, and every 100 fathoms to the surface. The work occupied fifteen hours. During the night the ship had sailed about seven miles east-south-east to make up for the driftage of the day and get back to the position, and at 6 a.m. on July 17 she was hove to, and with a very fine morning, and very light breeze from north-east, and a long, gentle swell, the closing-net was put down to 1,000 fathoms and towed for twenty minutes, and brought up a good haul, chiefly Copepoda. The Station E15.

hauls at 800, 600, 400, 300, 200, and 100 fathoms were all good. The day was very favourable for tow-netting, the line standing almost straight.

Station E16. On July 19 the position was Lat. 55° 47′ N., Long. 10° 12′ W., and depth by sounding 1,325 fathoms. Heaving to, the closing-net was sent down to 1,000, 700, 500, 400, 300, and 100 fathoms, and water samples were taken.

Station E17. Sailing all night to north and east with light wind, the position on July 20 was Lat. 56° 11′ N., Long. 9° 50′ W., and depth by sounding 875 fathoms. The closing-net was put down to 820, 700, and 600 fathoms. At the latter haul was obtained a fine specimen of *Gnathophausia zoœa*, who with his strong spines had torn the net into shreds for about 6 inches in fighting to escape. Hauls were also taken at 500, 400, 300, 200, and 100 fathoms.

Station E18. On July 21, at 6 a.m., after a dirty night of wind and rain from the south, the ship was hove to in position Lat. 56° 37′ N., Long. 9° 48′ W., in 912 fathoms by sounding, but there was too much sea for successful tow-netting though the attempt was made at 800, 600, 500, and 400 fathoms, so a course was set for Stornoway, in the Hebrides.

Station F1. On August 4, in Lat. 58° 24′ N., Long. 8° 30′ W., the depth was 110 fathoms, and after a vertical haul with the silk net, the vessel

Station F2. proceeded to the next station, Lat. 58° 45′ N., Long. 8° 35′ W., depth 342 fathoms, and the closing-net and water-bottle were used at 300, 200, and 100 fathoms.

Station F3. On August 6, in position Lat. 59° 18′ N., Long. 8° 30′ W., the depth 841 fathoms, closing-net and water-bottle were used from 800 fathoms up, and with a fresh wind from north-west, way was made

Station F4. for the next station, reached at 2 a.m. on August 7, Lat. 59° 54′ N., Long. 8° 42′ W., depth 720 fathoms, and closing-net and water-bottle were used from 700 fathoms upwards.

Station F5. On August 8, Lat. 60° 29′ N., Long. 8° 30′ W., and depth 194 fathoms, after using closing-net and water-bottle the wind began to rise very fast, and a dirty sky and rapidly falling barometer

presaging a 'duster' from the east, way was made for the next station, which was reached at 4 a.m. on August 9. The situation was on the Faeroe Bank, Lat. 60° 41′ N., Long. 8° 50′ W., depth 75 fathoms, and while using the water-bottle one of the crew amused himself by catching two very large cod with hand-line. The weather still stormy and sea very bad, with low barometer, it was thought better to run into Thorshaven, especially as a few 'odds and ends' were required. This port was reached at 10 p.m. on August 10, leaving the Bank at 4 a.m. the same day. Station F6.

Leaving Thorshaven on August 12 with a fine and calm day, which prevented rapid progress, on the 13th, at 8 a.m. the Munk Rocks were passed, and at 4 p.m. the position Lat. 61° 1′ N., Long. 7° 42′ W., gave a depth by sounding of 475 fathoms, the depth being surprising, as much shallower water was expected here. However, it proved not to be a hole, but to continue for at least 6 miles in a northerly direction, and may have extended farther, but was not explored. The bottom temperatures showed it to be in the cold area (−0·5° at 460 fathoms, 0·0° at 420, 2·4° at 300, 6·6° at 200, 8·1° at 100, 10·7° at surface; air temperature 11·0°). Station F7.

On August 14, in Lat. 60° 30′ N., Long. 7° 47′ W., the depth 547 fathoms, and still in the cold area (bottom temperature −0·8; at 400 fathoms 1·0°; 300, 5·3°; 200, 8·1°; 100, 8·6°; surface 11·4°, air 11°), the closing-net and water-bottle were used as usual. With a falling barometer, reefed mainsail and mizzen at 10 p.m. it was blowing a gale and raining in torrents, necessitating double reefs in mainsail and mizzen and a reef in the foresail. Hove to, the ship rode it out, lying to, as the skipper expressed it, 'like a duck.' Station F8.

Next day, August 17, was fine, though the sea was heavy, and in Lat. 60° 1′ N. and Long. 6° 4′ W., depth 580 fathoms, the temperature of the bottom was only −1·0°; at 500 fathoms −0·5°; at 400, −0·5°; at 300, 4·3°; at 200, 8·8°; at 100, 9·4°; surface 11·6°, air 12·0°. Hauls were also made with the closing-net, and sail was then made for Orkney, and on August 20 the ship was brought to her anchorage in Swanbister Bay, thus terminating the cruise of 1903. Station F9.

Although the closing-net was used many times, and numerous water samples were taken on this cruise, the weather could not be said to have been favourable for work, being frequently very stormy, and with but few fine days. This, though interfering with work with the closing-net, did not hinder the collection of a continuous series of temperature observations or the collection of water samples from deep water.

## EXTRACTS FROM THE LOG OF THE 1904 CRUISE.

THE first station visited in 1904, on June 20, was situated in Lat. 50° 57′ N. and Long. 11° 41′ W., within a few miles of Station E6 of 1903. After leaving Newhaven (Sussex) on June 10, three very fine and calm days were experienced, and on the fourth day the Lizard was passed, with a fine breeze from the south-west. When nearing Cape Clear, on June 14, a very severe storm sprang up, accompanied with a very heavy sea; at 6 o'clock it was necessary to take in a single reef, and at 9 a double reef, and heave to. On June 16 the sea was so bad as to necessitate running into Bantry Bay for shelter. This weather lasted until the 17th. Moderating on the 18th, but with the wind still fresh, the ship proceeded to sea again at 9 p.m., and after running by the patent log 133 miles, an attempt was made to work the station. A sounding gave 858 fathoms, with a bottom of globigerina ooze. As soon as it was possible to do any work, the closing-net was put down to 800 fathoms, and a very fair haul was made, followed by hauls at 600, 400, 200, 100, and 50 fathoms, a fair amount of stuff being obtained at each haul, and temperature observations at the same depth. Leaving this station at 6 p.m., Station 2, Lat. 50° 25′ N., Long. 12° 38′ W., was reached at 4 a.m. on June 21, and the wind and sea having moderated, though leaving a strong swell, the closing-net was put down to 1,200 fathoms, 1,000, 700, 300, and 100 fathoms, and fair hauls obtained. Temperatures were also taken, and samples for gas analysis.

Station 1.

Station 2.

Here it was found that the new engine, put on board at considerable trouble and delay, failed. When 500 fathoms of wire were out, an experimental trial was made to raise the closing-net. Failure necessitated hauling on board by hand with such help as could be got

from the steam-winch. This took four hours to accomplish. Henceforth the old steam capstan and winch were therefore employed, and the net lowered to 1,200 fathoms. The raising on board by this means only occupied forty minutes. For the rest of the cruise being compelled to use the old tackle, limited the depth at which it could be employed to 1,600 fathoms. This was very annoying, as it was confidently hoped before starting that we should be able to make tow-net observations down to 2,000 fathoms; but it would have delayed the cruise too long to return to land for repairs and new appliances. Water and gas samples were also taken at this station.

Station 3. On June 23, 1904, in position Lat. 49° 50′ N., Long. 13° 31′ W., the tow-net was used down to 600 fathoms, the lowest depth at which it was possible to work the net satisfactorily. A fresh breeze having sprung up, with a falling barometer and a westerly wind, it was a case of beating to windward all night, and at 4 a.m., on June 24, the next station, in

Station 4. Lat. 49° 0′ N. and Long. 14° 36′ W., was reached, and the net lowered to 1,000 fathoms. While it was down the wind shifted to south-west, and the ship rolling badly in the trough of the sea, the net came up again with a kink in the wire at 35 fathoms above the frame. This had evidently occurred after the opening messenger had gone down, as the net was open, and the closing messenger was stopped by the kink in the wire. Taking out the kink, the net was again lowered to 1,000 fathoms, and this time came up with a kink in the same place, and both messengers arrested in it. The net had therefore never opened, and it was necessary to cut off the 35 fathoms below the kink. Incidentally it furnished evidence of the perfection of the opening and closing arrangements. From 4 a.m. to 10 a.m. was, therefore, so much wasted time, but a third attempt to use the net at 1,000 fathoms was rewarded by success. As there was a good deal of swell in the sea, not much came up in the net. Put down again to 800 fathoms, this time on raising it the cod end of the silk net was split, and all the contents had escaped. After repairing, it was sent down to the same depth, and this time the haul was successful. Hauls at 600, 400, and 200 fathoms were all that could now be done in deep water, the wind

having backed to south and freshening, along with rain, which came down very heavily at last.

After a dirty night of rain and a heavy sea, at 6 a.m. the next station was reached in Lat. 48° 27′ N., Long. 15° 38′ W. It was 8 a.m. before the wind and sea had moderated enough to allow of work commencing. Then the water-bottle was lowered to 1,570 fathoms, and seven water samples and fourteen samples for gas analysis were taken, and the closing-net was put down to 1,400 fathoms. It took fifty minutes to haul it up again, and it had opened and shut quite satisfactorily. Station 5.

Continuing the course through the night, Station 6, in Lat. 48° 12′ N., Long. 16° 26′ W., was reached, and the ship laid to at 8 a.m., only 30 miles from the last station, and with the sea rather rough and a long, heavy swell from the west, the closing-net was lowered to 1,500 fathoms. Hauling up occupied an hour, and though the net appeared to have worked quite properly, there was very little in it. A second attempt at the same depth was no more successful, the entire contents being a few Copepoda and a small Medusa. It was then lowered to 1,200 fathoms and towed for fifteen minutes, with no better result. At 900 fathoms there was a little more, and at 700 fathoms a similar result; at 500 fathoms the haul was much better, and at 400 fathoms it was very successful. The unsuccessful results of the hauls from 500 to 1,500 fathoms were probably due to the heavy swell, which, causing the net to ride up and down, is unfavourable for tow-netting. That the net had been at the proper depths was indicated by the temperatures of the thermometers attached to the frame, viz., 1,500 fathoms, 3·1° C.; 12,000, 3·5° C.; 900, 4·2° C.; 700, 6·4° C.; 500, 8·5° C.; 400, 9·4° C.; 200, 10·2° C.; 100, 10·5° C.; 0, 14·5° C. Station 6.

On June 28, 1904, Station 7 was reached at Lat. 47° 28′ N., Long. 17° 07′ W., after a long beat to windward, with thick fog and a very heavy westerly swell; and after waiting hove-to for some hours in hopes that wind and sea would go down, an attempt was made to use the tow-net. After having lowered to 1,500 fathoms, and commencing to heave up, the flange on the winch, which keeps the wire on the drum, Station 7.

suddenly gave way. In danger of losing the whole tackle, the device was hit upon by Buchan Henry of winding a length of stout rope on the drum of the winch and driving some long spikes through the rope into the drum. This saved the situation, which for a few minutes was serious, the loss of 1,500 fathoms of wire, the heavy closing-net, and a couple of thermometers being too dreadful to contemplate. However, the device succeeded admirably, and the net, when hauled up, was found to contain a good haul; at 1,000 fathoms the haul was similarly successful. At 700 fathoms there was not much taken in the net, and the temperature at this depth was 1° C. colder than at any of the stations of corresponding depth previously worked; at 500 and 400 fathoms the hauls were very poor—scarcely anything in the net—and the temperature was also below normal; and at 200 and 100 fathoms the hauls were of no value. This station is 360 miles from the starting-place—viz., Ireland—and all the time the wind was right ahead, except for one day. On June 29, after a long beat to windward, at noon, the position was found to be Lat. 46° 40′ N., Long. 17° 09′ W.—far enough to the south, but not to the west. The sea was much too bad for work with the closing-net, but water samples were collected from 1,200 fathoms upwards. The water-bottle can be used when it would be fruitless or folly to attempt work with the closing-nets. The thermometer showed that at this station the cold wedge of water previously referred to had been left behind, the temperature at 1,200 fathoms being 3·8° C.; at 900, 5·0° C.; at 600, 9·0° C.; at 200, 10·6° C.; at 100, 11·0° C.

Station 8.

Station 9. Just after finishing the last station a gale sprang up from west-north-west, which lasted for three days, and the ship lay close-reefed until on July 2, in Lat. 45° 6′ N., Long. 18° 14′ W., at 4 a.m. the sea had moderated sufficiently to permit the resumption of work. The closing-net was therefore put down to 1,500 fathoms, but when hauled up contained nothing; at 1,200 fathoms there was a good haul, and at 1,000 fathoms a smaller haul than the last. At 800 fathoms the haul was very good, although the temperature was very low, over 1° C. less than at the corresponding depth at any previous station. At 600 fathoms

the haul was good, the temperature being about 2° C. below normal. At 500 fathoms the temperature had risen 1·5° C. in 100 fathoms. Before noon rain commenced to fall in torrents, but at noon an observation showed the ship to be just 100 miles south-west of the last station (June 29). At 400 and 200 fathoms the hauls were unsuccessful; at the former depth the net was found to have turned inside out.

At 4 a.m. on July 3 Station 10 was reached in Lat. 44° 41′ N., Long. 19° 08′ W., after a dirty night of wind and rain, necessitating reduction of canvas. From 4 a.m. to 8 a.m. it was impossible to do any work, the ship being simply hove to, but at 8 a.m., with the weather a little better, the water-bottle was lowered to 1,500 fathoms, and samples were taken at that depth, also 1,300, 1,100, 900, 700, 500, 300, and 100 fathoms. Work with the closing-net was impossible. With the exception of one fine day at Station 2, the sea had been unfavourable since the commencement of the cruise for tow-netting. Station 10.

With a light, fair wind during the night, and the sea gradually subsiding, a passage of fifty miles was made, and Station 11, in Lat. 44° 13′ N., Long. 20° 05′ W., was reached, and work commenced by lowering the closing-net to 1,500 fathoms at 8 a.m. With the most favourable conditions the net did not capture much plankton at this depth, nor at 1,200 fathoms, but the haul at 1,000 fathoms was good, also at 800, 600, 400, 200, and 100 fathoms. The weather on this day was perfect, a light northerly breeze and gentle swell. With a very light westerly breeze throughout the night, progress was slow, and at noon on July 5 the position was only thirty-four miles from the last station. The weather still being all that could be desired, it was decided to take serial temperatures down to 2,000 fathoms, and consequently the ship was hove to (Station 12) in Lat. 44° 5′ N., Long. 20° 34′ W. The observations were as follows: Station 11. Station 12.

Temperature of air = 17·6° C.

| Temperature at— | | Temperature at— | |
|---|---|---|---|
| 0 fathom | 16·0° C. | 900 fathoms | 4·2° C. |
| 25 fathoms | 14·0° C. | 1,000 ,, | 3·9° C. |
| 50 ,, | 12·7° C. | 1,100 ,, | 3·6° C. |
| 75 ,, | 11·6° C. | 1,200 ,, | 3·6° C. |
| 100 ,, | 11·4° C. | 1,300 ,, | 3·6° C. |
| 200 ,, | 10·5° C. | 1,400 ,, | 3·5° C. |
| 300 ,, | 9·8° C. | 1,500 ,, | 3·1° C. |
| 400 ,, | 8·8° C. | 1,600 ,, | 3·0° C. |
| 500 ,, | 7·6° C. | 1,700 ,, | 3·0° C. |
| 600 ,, | 6·4° C. | 1,800 ,, | 3·0° C. |
| 700 ,, | 5·4° C. | 1,900 ,, | 2·8° C. |
| 800 ,, | 4·5° C. | 2,000 ,, | 2·7° C. |

The distance from Fayal was now 500 miles. The evening ended in almost dead calm, the little breeze there was being from south-west, and the barometer high, 30·2, and steady.

Station 13.

At noon on July 6 the position was Lat. 43° 42′ N., Long. 21° 18′ W., just forty-six miles from the last station, the sea dead calm, and everything most favourable for work with the closing-net, and it was with deep annoyance that it was discovered that the opening piston of the net was broken. Two hours' delay was occasioned while this was repaired by screwing both pieces together, and the net was lowered to 1,500 fathoms. It was with considerable surprise when the net came up that it was seen to have been trailing over the bottom, and the contents of the net were only a little fine, white sand and a small jet-black stone. The chart gives no soundings hereabouts, but at the last station, only forty-six miles away, 2,000 fathoms of wire was lowered without finding bottom, so that striking bottom here at 1,500 fathoms was quite unexpected. Plankton hauls at 1,000 and at 600 fathoms were successful. There was fog all day, with occasional drizzle, and a sight of the sun only for a few minutes at noon.

Station 14.

A fresh breeze springing up from the north-east, Station 14 was reached at 8 a.m., in Lat. 43° 11′ N., Long. 22° 27′ W., and sounding at 1,600 fathoms, no bottom was reached. Evidently the comparatively shallower water of the last station had been left behind. Other

soundings in this locality would be of interest to determine the area of this comparatively shallow water, but unfortunately the *Silver Belle* had so much work to accomplish that it was impossible to delay for the purpose of investigating this matter. The sea getting rougher as the day went on, and the swell increasing, made it quite unfavourable for tow-net work, consequently the hauls at 1,500 and 1,200 fathoms were very poor. At 900 and 700 fathoms, however, a lot of stuff was obtained, and a still greater quantity at 200 fathoms. This day the ship was just about 400 miles from Horta, over 700 from Bantry Bay, and since July 2 a station had been done every day. A strong breeze from north-north-east put the ship at Station 15 in Lat. 42° 37′ N., and Long. 23° 35′ W. At 6 a.m. on July 8 the swell was too great for the closing-net, consequently only water samples were taken from 1,500 fathoms upwards. Station 15.

The wind lasted all night, from the same quarter, and Station 16, in Lat. 41° 58′ N., Long. 24° 44′ W., was reached at 6 a.m. next day, July 9. The sea was, however, running rather high, and not very favourable for tow-netting, but the net was put down to 1,500 and 1,200 fathoms, with pretty good success at the latter, also at 700 and 500, 400, and 300 fathoms. With a light breeze during the night, a course of fifty-three miles was run by 6 a.m. on July 10, and Station 17 reached in Lat. 41° 13′ N., Long. 25° 18′ W. Being a perfect day for work with closing-nets, a light breeze and gentle swell from the north-east, the line was 'plumb' straight with the net at 1,500 fathoms, and the haul at that depth very good, also at 1,300, 1,000, 900, 700, 500, 300, and 100 fathoms. All these hauls were successful. In conditions favourable for tow-netting, there is not the slightest doubt that a considerable amount of animal plankton can be nearly always obtained in the tow-nets to at least 1,500 fathoms' depth, refuting Agassiz's contention of an azoic zone in the ocean, which, however, has been sufficiently disproved already. Station 16. Station 17.

During the night, with very light wind, the ship ran between thirty and forty miles, and at 6 a.m. Station 18, Lat. 40° 35′ N., Long. 25° 54′ W., was reached. It was not intended to make a station here, but as the Station 18.

barometer was falling, and there was every evidence of a 'blow' coming on, it was thought better to take advantage of the opportunity for work before the weather prevented it. The closing-net was therefore put down to 1,500 fathoms and a fairly good haul obtained, and a pretty good one at 1,000 fathoms, though the wind was rising all the time; and when the net was put down next to 600 fathoms, the sea was very choppy, and so increasingly bad did it become that when the net was next put down to 300 fathoms it came up torn about 8 inches across.

The night turned out very 'dirty,' with rain in torrents and a strong gale commencing from the north-west and blowing 'great guns' finally from the north. At 2 a.m. the cringle in the clew of the main-sail burst, but fortunately nothing was lost. Arriving at Station 19, July 12, in Lat. 39° 53′ N., Long. 26° 32′ W., a sounding unexpectedly gave only 488 fathoms, with a bottom of hard rock. Putting down the triangle-net, a mixed collection of sand shells, zoophytes, sponges, and echinoderms were brought up, but on the second descent of this net the frame was firmly jammed in the rocky bottom, and it, together with 100 fathoms of hemp-rope, were lost. Drifting all the time in a south-east direction, about three miles farther on gave a sounding of 600 fathoms. The bank which gave the sounding 488 fathoms is uncharted. Towards the south-east it deepens rapidly, and is possibly shallower water to the north-west.

Station 19.

Station 20.

During the night there was a light breeze from the north-north-west, and at daylight on July 13, *Terceira* hove in sight, bearing south-west by south, and about eighteen miles distant. Heaving to, a sounding gave 870 fathoms, and at 800 fathoms a good haul was made with the closing-net. A fresh breeze was now blowing with a bright sun, and *Terceira* lay about sixteen miles to windward, a white cloud of mist hanging over the highest hill. At 600 fathoms there was a good haul with the closing-net, but at 400 and 200 fathoms very little was obtained. Sounding in Lat. 38° 42′ N., Long. 28° 27′ W., gave a depth of 770 fathoms, with a bottom of fine volcanic mud, and the ship then put in and anchored in Horta Harbour, thus completing the first portion of her cruise, and

Station 21.

here she remained for one week, while various overhauls were made and stores renewed, etc.

On July 22, 1904, Horta was left behind after a week's stay, during which time the gear was thoroughly overhauled. In Lat. 38° 15′ N. and Long. 28° 32′ W., a sounding gave 472 fathoms, with a bottom of volcanic mud and sand. The closing-net was also used from 450 fathoms upwards. A very light breeze, lasting throughout the night, was against good sailing, but when at daylight on the next day forty miles had been run from the last station, a sounding was made in Lat. 37° 42′ N., Long. 27° 37′ W., and 1,000 fathoms of wire run out without reaching bottom. At this depth, and at 800, 600, 400, 200, and 100 fathoms, hauls were made with the closing-net. A brisk wind sprang up from the north-west, and on July 24 at 7 a.m. the ship was hove to in Lat. 37° 15′ N. and Long. 26° 14′ W., where a sounding gave 1,400 fathoms. The closing-net was put down to 1,400 fathoms, but with the drifting of the ship the water had become shallower, the net had been trailing on the bottom, kinks had got in the wire, and, worse than all, the piston of the net had become bent. Consequently the net had never opened, the messenger having stuck on the kinks. The best part of the day was spent in repairs to the piston, therefore the day was devoted to the collection of water samples from 1,200 fathoms upwards. A nice breeze from the north, lasting all night, put the ship in Lat. 36° 54′ N. and Long. 24° 56′ W. early on July 25, and a sounding gave 865 fathoms, with bottom of mud and sand. Hauls with the closing-net were made at 600, 500, 400, 200, and 100 fathoms. At 7.30 next morning Station 26 was reached in Lat. 36° 18′ N., Long. 23° 53′ W., and the closing-net was put down to 1,600, 1,400, 1,000, 700, 500, 300, and 100 fathoms; at night the hot, calm day was succeeded by a strong westerly breeze, necessitating shortening sail; at 8 a.m. on July 27 Lat. 35° 48′ N., Long. 22° 35′ W., was reached, and the closing-net was put down to 1,600 fathoms, and afterwards to 1,200, 900, 600, 400, 200, and 100 fathoms. All the time the wind was rising and the swell pretty sharp, so that the results of the day's work were disappointing.

Station 22.

Station 23.

Station 24.

Station 25.

Station 26.

Station 27.

A fresh wind lasted throughout the night, and early on July 28 Station 28 was reached in Lat. 25° 04′ N., Long. 21° 18′ W., and water samples were taken at every 200 fathoms from 1,400 fathoms upwards. A strong southerly current ran here, so strong that, although with a fresh to strong west-south-west breeze, the wire stood right under the ship's bottom. With a fresh breeze lasting all night, Lat. 34° 22′ N., Long. 20° 06′ W., was reached at 7 a.m., and the closing-net was put down to 1,000, 800, and successively every 100 fathoms to the surface. Coming along at a fine pace throughout the night with a good north-east breeze, at 5 a.m. the ship was at Lat. 33° 37′ N. and Long. 19° 00′ W., and the closing-net was put down to 800 and each 100 fathoms to surface. Two turtles kept round the yacht all day, and one of the crew harpooned one of them through the neck and had it fast for some time, when it broke away and disappeared. On July 31, in Lat. 32° 55′ N. and Long. 17° 48′ W., with Madeira bearing south-east twenty-nine miles away, a sounding at 1,400 fathoms gave no bottom, though the temperature was 3° C. Probably not very far from bottom, the closing-net was put down to 1,200, 1,000, 700, 500, and then each 100 fathoms to surface. Then way was made for Funchal.

Station 28.

Station 29.

Station 30.

Station 31.

Here five days was occupied cleaning up and overhauling tackle, a new chain-wheel having to be cast for the winch. After leaving and lying becalmed outside Funchal for several hours until dark, a fresh head breeze sprang up, and at 5 a.m. the station in Lat. 32° 41′ N., Long. 16° 36′ W., was reached on August 7, and in 60 fathoms an attempt was made to dredge, but, the bottom being very rocky, the hauls were not very successful, chiefly shells and coral, most of the latter in the tangles.

Station 32.

Beating to windward all night, at 8 a.m. on August 8 the ship was brought to in Lat. 32° 57′ N., Long. 15° 23′ W., for the purpose of tow-netting, but though the day was bright and clear, there was too great a swell to lower the net to great depths. However, from 600 fathoms to surface, at intervals of 100 fathoms, the hauls of the closing-net were pretty successful. At 6 a.m. the next day (August 9)

Station 33.

the next station was reached in Lat. 33° 18′ and Long. 14° 10′ W. Station 34. A fine bright day, with fresh breeze from the N., and a heavy swell, too great for successful working of the closing-net; water samples and temperatures only were taken, down to 1,600 fathoms.

Making for the next station, in Lat. 33° 45′ N., Long. 13° 03′ W., good progress was made until midnight, when a heavy squall from north-north-east compelled a shortening of sail. The station was Station 35. reached at 8 a.m., and with a very heavy swell from the north-east, the attempts to use the closing-net at 1,000 and at 800 fathoms were not very successful, though the net evidently had worked perfectly. At 500 fathoms, and successive hauls to the surface, there was more stuff, but on the whole the hauls were comparatively poor.

On August 11, at 8 a.m., the next station was reached in Station 36. Lat. 34° 16′ and Long. 11° 57′ W., with a nice little breeze all night from the north. At this station the temperatures were remarkable, being at 600 fathoms 10·8°, and from 500 to 300 fathoms identical—viz., 11·1°.

| | | | | | |
|---|---|---|---|---|---|
| 250 fathoms | ... | ... | ... | 11·7°. |
| 300 ,, | ... | ... | ... | 11·2°. |
| 350 ,, | ... | ... | ... | 11·1°. |
| 400 ,, | ... | ... | ... | 11·1°. |
| 500 ,, | . | . | ... | 11·1°. |

Being usually about 2° of difference at each of these depths, it was thought that possibly the thermometer had not been down long enough, but on being lowered a second time and kept *in situ* for ten minutes, the result was exactly the same. The occurrence of this wedge of warm water was peculiar.

On August 12, after a very light wind, this station, Lat. 34° 12′ N., Station 37. Long. 11° 05′ W., forty-four miles from the last, was reached, and tow-nettings made with the closing-net at every 100 fathoms upwards from 500, and temperature observations from 1,200 fathoms. The temperature at 500 fathoms is here seen to be nearly a degree lower than at the last station, the wedge of warm water evidently less thick.

On August 13 this station was reached, in Lat. 34° 43′ N., Long. Station 38.

9° 38′ W., at 10 a.m., and the water-bottle was put down to 1,600 fathoms, and samples taken from there to the surface at every 200 fathoms. Here a current was found to be going east, and the ship was eleven miles farther east than was expected. The temperatures from 100 to 1,200 fathoms were higher than they were at the last station, except at 400 fathoms, where it was 10·7°, as compared with 11·1° at the last station.

Station 39. August 14 was one of the most unsatisfactory days of the cruise, a strong breeze from the north-north-east all night having rendered the sea quite unsatisfactory for tow-netting, the ship rolling almost scuppers under ; and though the closing-net was lowered to 500 fathoms, and afterwards to 300, 200, and 100, the attempt to do work might as well never have been made. The position of the station was Lat. 35° 16′ N., Long. 8° 47′ W. Temperature observations were taken to a depth of 500 fathoms.

Station 40. After a rough sea all night, wind and sea, however, going down gradually, at 6 a.m. it was sufficiently improved to commence work at this station, in Lat. 35° 55′ N., Long. 7° 33′ W. A sounding gave 770 fathoms, and the closing-net was put down to 700 fathoms, and worked with success at successive depths of 100 fathoms to the surface.

Station 41. After a fine night and light fair wind, the next station was reached in Lat. 35° 55′ N., Long. 6° 35′ W., at 6 a.m. on August 16, and a sounding gave 337 fathoms, and water samples were taken as usual, and the closing-net put down to 300, 200, and 100 fathoms, with successful results.

Station 42. Before making for Gibraltar, on August 17, Lat. 35° 55′ N., Long. 5° 54′ W., a sounding was made in 172 fathoms, and water samples taken at 100, 50, and 25 fathoms, and the closing-net lowered to 170 fathoms. Unfortunately, half of the closing messenger became detached and lost, and further work was relinquished, and way made for Gibraltar.

Station 43. After five days' stay at Gibraltar, work was recommenced on August 21 at station Lat. 36° 00′ N. and Long. 5° 21′ W., where a sounding gave 500 fathoms. While hauling on board the wire

snapped about 12 fathoms from the surface, and away went not only the sounding-lead, but one of our best thermometers. Samples of water were taken at every 100 fathoms, and tubes filled for analysis. The strong current and wind, both in one direction, took the ship rapidly eastwards. The closing-net was put down, and good hauls made from 360, 300, 200, and 100 fathoms.

On August 22, with a nice light breeze from west, and strong current going south-south-east, the ship was hove to in Lat. 35° 45′ N., Long. 3° 41′ W., and a sounding made in 840 fathoms grey ooze ; and water and gas samples were taken from 800 fathoms. Then it was necessary to crowd on all sail to sail down the current, which was taking the ship fast to the south-east. The water-bottle sent down to 700 fathoms just touched bottom, but the sail enabled the ship to keep her ground better, so that it was possible to take water and gas samples from 600 fathoms at successive hundreds to the surface. Tow-nettings were also made at 600, 500, 400, 300, 200, and 100 fathoms, all with excellent results. Leaving this station on August 22, and after beating to windward against wind and current all night and next day, at 8 p.m. only ahead of Gibraltar, the anchor was dropped at 8 a.m. next morning at Tarifa for three hours, the wind having entirely dropped. A nice breeze from the west springing up, the ship lay over to leeward of Tangiers, which was reached at 3 p.m., when again it fell calm, and, dodging close to the rocks to keep out of the tide for fear of getting carried back through the straits, at 6 p.m. a breeze sprang up. Dodging about under Cape Spartel until daylight, at 6 a.m., a sounding gave 250 fathoms, Lat. 35° 53′ N., Long. 5° 52′ W.; gas and water samples were taken here. The notes recorded here give an idea of the difficulty of navigating the straits in a sailing-ship. The day the *Silver Belle* left Gibraltar three barques were passed dodging to the east of Gibraltar, waiting for wind to get to the westward, and when the yacht returned three days after they were still there !

Station 44.

Station 45.

Lying most of August 25 becalmed, sometimes gaining, sometimes losing ground, a smart breeze from the east at last carried the ship

Station 46.

along to the next station, and on August 26, at noon, the position was Lat. 36° 13′ N., Long. 7° 47′ W., a sounding giving 601 fathoms, with bottom of fine grey sand. After the closing-net had been used at 600 fathoms, the rising wind and sea hindered successful work at higher depths. Up to midnight a nice sailing breeze had assisted, when it dropped to a light air from the south-east. At 8 a.m. the position Lat. 36° 17′ N. and Long. 9° 01′ W. was reached, when good hauls were made with the closing-net from 1,000, 800, 600, 400, 300, 200, and 100 fathoms.

Station 47.

Beating to windward all day after the finish of work, with light wind from north-north-west, without making much headway, at 6 a.m. on August 29 the position Lat. 36° 37′ N., Long. 10° 05′ W., was reached, and a good haul of stuff made with the closing-net at 1,600 fathoms; also at 1,300, 1,000, 700, 500, and each 100 fathoms to surface. The day was perfect for the work, and just sufficient of a light breeze to keep sufficient tow on the net. The temperatures at this station are puzzling—a difference of 8½° between 50 fathoms and the surface, only ½° between 200 and 700, and 5½° between 700 and 1,000 fathoms. This day two butterflies were captured (fifty miles from land), and a grasshopper floating on a bit of seaweed.

Station 48.

With a dead beat to windward all night and forenoon, the next station was reached on August 30, in Lat. 37° 14′ N., Long. 10° 37′ W., and the closing-net was put down to 1,000, 800, 600, 400, 200, and 100 fathoms.

Station 49.

Close-hauled, with a fine fresh breeze from north-north-east all night and morning, at noon on August 31 the position was Lat. 37° 58′ N., Long. 11° 58′ W., and the closing-net was put down to 1,100 fathoms, then to 900, 700, 500, 300, and 100, with good results, though the sea was rather choppy. On completion of this work a course north and west was taken. A few fine showers of rain to-day were the first rain for two months. Close-hauled on the starboard tack all night and next morning, with a strong breeze from north-north-east and very choppy sea, the ship was at noon in position Lat. 38° 53′ N., Long. 13° 12′ W. The net was lowered to 500 fathoms, but there was quite sufficient

Station 50.

angle on the wire, and the net received too many jerks to work with satisfaction. However, hauls, though only small, were made at 400, 300, 200, and 100 fathoms. All night was a continual beat to windward, with a strong gale of wind from the north-north-east, and at 10 a.m. on September 3 the position was Lat. 39° 42′ N., Long. 10° 53′ W. Notwithstanding the sea the net was lowered to 1,000, 800, 600, 400, and 200 fathoms, and at the latter depth the severe jerking of the net resulted in tearing the silk net, which prevented further work. Station 51.

Over a week of gales and head-winds prevented great progress, but did not prevent the regular taking of temperatures or the lowering of the closing-net.

Towards midnight the wind lessened, but kept in the same quarter, viz., north-north-east, and at 7 a.m. on September 4 it fell to calm, the position being Lat. 40° 03′ N., Long. 12° 13′ W. Water samples were taken from 1,600, 1,400, 1,200, 1,000, 800, 600, 400, 200, and 100 fathoms, and the necessity of replacing the silk net with a new one prevented the use of the closing-net at this station. Station 52.

Lying on the starboard tack all night, the wind dropped at midnight, but stayed continually in the north-north-east. At 7 a.m. it was almost calm, and the position being Lat. 40° 03′ N., Long. 12° 13′ W., the water-bottle was put down to 1,600, 1,400, 1,200, 1,000, 800, 600, 400, 200, and 100 fathoms. Towards afternoon fine showers of rain fell, with very light wind, still in the north-north-east. Station 53.

Becalmed until 10 p.m., a light breeze then sprang up from south-west, and for the first time in nine days was the ship enabled to keep a course. At 2 p.m. the position was Lat. 41° 10′ N., Long. 11° 46′ W., and it was intended to work with the closing-net, but just as the ship was hove-to a sudden squall came on from the north-north-west, accompanied with a very sharp swell. The closing-net was therefore only put down to 500 fathoms, then to 400 and 300 fathoms, the sea getting worse all the time; the vessel rolling very heavily, it was unsafe to use the closing-net any further. Probably a heavy storm out westward caused all this sea. Station 54.

Station 55.

Beating to windward, with a light breeze, north by east, and an extraordinarily heavy swell from west-north-west, at 7 a.m. the next position, Lat. 43° 27′ N., Long. 10° 19′ W., was reached. The sea had somewhat lessened, and laying the ship's head into it, she was hove to, and the closing-net was lowered to 1,500, 1,200, 1,000, 800, 600, 400, 200, and 100 fathoms with very good results. Shortly after leaving this station the wind backed to north-north-east, and a very heavy swell continued from the north-west. On the port tack all night, about east-north-east, at noon next day the position was Lat. 42° 01′ N., Long. 10° 48′ W. About as bad a day as could well be for such work, the net was lowered to 1,000 fathoms, and while it was down the ship made two or three fearful rolls, with the result that a kink got into the wire 164 fathoms from the net, and several strands of the wire were broken. It was really not fit to attempt work with closing-nets in deep water. This portion had to be cut off, and the net was then lowered to 800, 600, 400, 200, and 100 fathoms, the results being quite successful.

Station 56.

Station 57.

Making for the next position with a nice breeze from the west-north-west, Lat. 44° 35′ N., Long. 9° 52′ W., just when the net was being lowered the wind shifted to north-north-east, blowing a strong breeze. However, the closing-net was successfully lowered to 1,500, 1,200, and 1,000 fathoms. Meanwhile the wind was continually rising and the ship rolling very heavily, and presently a dense fog came on. At 600 fathoms there was a good haul, also at 400, 200, and 100 fathoms. The afternoon closed down 'dirty,' blowing hard right ahead north-north-east, with fine drizzle. The impression derived from the hauls at this locality is that there is much more life in deep water than farther out westwards, as, on the outward trip to the Azores, with better weather and everything in favour of good working of the net, the hauls from the deeper water were much smaller.

Station 58.

With a strong breeze from north-north-east to east-north-east all night, at noon next day the position was Lat. 45° 19′ N., Long. 10° 20′ W. The sea being very disturbed, the closing-net could only with safety be lowered to 500 fathoms, subsequently to 400, 300, 200, and 100, and here the half of the closing messenger was lost.

A 'dirty' night followed this day with a good deal of wind and rain, but at 7 a.m. the position Lat. 47° 02′ N., Long. 9° 10′ W., was reached, and, heaving to, the net was put down to 1,000 fathoms, and at this depth and at 800 fathoms good hauls were obtained. While the net was down at 600 fathoms, the wind hauled round and put the ship in the trough of the sea, rolling her dreadfully for a short time, with the result that the closing messenger would not go down, owing to a kink in the wire, which had four strands completely broken, and the heavy net was held by only thin strands. Another 54 fathoms of wire had to be cut off. Further hauls were taken at 400, 200, and 100 fathoms. Station 59.

A strong wind and rising sea, ending four hours later in a strong gale, west-north-west, with high sea and very heavy squalls, prevented any further work. The bad weather continued throughout September 13, at 9.30 p.m. of which day the Lizard light was abeam. Plymouth was reached on Wednesday, September 14, when the ship was brought to anchor, and the voyage concluded so far as scientific work was concerned. Station 60.

On this cruise, lasting from June 20 (the first station) to September 12 (the day the ship was anchored in Plymouth Sound), 300 hauls were made with the closing-net, over 650 temperature observations and 150 water samples were collected, besides many hauls of plankton taken with surface-nets and midwater net, and vacuum tubes were filled with sea-water for subsequent analysis. Except when in port in the Azores, at Madeira, and Gibraltar, not a single day passed without some scientific work being accomplished.

Sixty hauls of plankton were made with the closing-net at or below a depth of 1,000 fathoms, and seventy-six hauls between 500 and 1,000 fathoms. If open vertical nets had been employed, probably greater hauls of stuff would have been obtained; but the object was not to obtain a large amount of material so much as data for determining the vertical distribution of plankton.

## THE LOG OF THE CRUISE OF 1905—1906.

It was intended to start in September, 1905, to make a cruise from the Irish Channel to Madeira. However, one delay after another occurred in fitting out the ship, and it was not until November 1 that the *Silver Belle* was able to sail out of Dublin Bay. The object of this cruise was to visit some of the deep-water stations upon which work was done in the previous year, to take water samples at these temperatures, and samples of water for gas analysis, to compare with the results of the previous year, which had shown some rather extraordinary phenomena (referred to in Dr. H. N. Dickson's report), and to determine whether these were constant and repeated in the year 1905, or merely accidental. On this occasion it was not intended to use the tow-net to collect plankton (indeed, my own special tow-net was in use by Mr. Stanley Gardiner in the Indian Ocean), but trawling gear was included in the outfit, with the intention of making trawling observations where circumstances permitted. In the equipment of trawl I was fortunate in obtaining a good deal of excellent advice from my friend Mr. Holt, of the Irish Fishery Board.

In addition, opportunity was taken, when it occurred, to use the current meter, which was kindly sent to me by Professor Pettersson from Stockholm, and I really hoped to be able to make some interesting observations with this instrument. However, the weather throughout the cruise was so very unfavourable that it was impossible to employ the current meter, except on very few occasions, and these will be referred to later on. Probably it is rare to experience such weather, even in the Bay of Biscay, as predominated at the close of the year 1905, a succession of violent storms impeding work throughout the

whole of the outward cruise to Madeira ; and the early months of 1906 were extremely stormy for the Mediterranean.

At the mouth of the English Channel a station was selected twenty miles south-west of Parson's Bank, which would join up these observations to those made by the International Fisheries investigations. Here the sounding gave 90 fathoms, and water and gas samples were taken. Here the temperature was found to be a little colder at the surface and at the bottom than at 10 fathoms, the lower temperature at the surface probably being due to the cold north-west wind which had prevailed for several days.

Nov. 8, 1905. 20 miles S.W. of Parson's Bank.

With a light breeze from north-west by west, close hauled, a course was made for the next station, 130 miles distant, which was not reached until November 14. After leaving the Parson's Bank station the fine weather disappeared, and very rough weather set in. The old Station 59 was reached on Thursday, November 9, but it was far too rough to do any work. The ship dodged round this station for two days, waiting for an opportunity to do work ; but on the Saturday the storm broke very severely, necessitating double reefs, and on Sunday morning it was necessary to take in three reefs and stow the foresail. All night it blew a whole gale, but the ship lay to like a duck, but on Monday morning the fourth reef had to be taken in, and storm-jib set, and at noon the port gangway was lost. At 4 a.m. on the Tuesday the sea was fearful, and the mainsail burst. However, the storm subsequently began to subside, and by ten o'clock it was possible to take water samples from 1,000 fathoms upwards, the sea gradually going down.

Nov. 14, 1905. Lat. 45° 37′ N., Long. 8° 20′ W.

On Wednesday, November 17, the ship was near the old Station 56, in Lat. 43° 32′ N., Long. 10° 48′ W., but as soon as arriving at this locality had to heave to with a strong gale blowing from north-east for forty hours, with a very heavy sea, before wind and sea abated enough to allow of any work. Water samples were taken from 1,200 fathoms upwards. The surface temperature was this day $1\frac{1}{2}°$ warmer than at the last station. The wind then began to rise again, and it was necessary to run with double-reefed mainsail, reefed foresail, and small jib.

Nov. 17, 1905. Lat. 43° 32′ N., Long. 10° 48′ W.

After leaving this station a fresh breeze from north-east gradually grew in strength, and at midnight reached the force of a severe gale, which increased all night, and in the morning every reef in the storm-jib had to be tied in. The sea was fearful, but the yacht lay to very well without shipping any water. It was impossible to see 100 yards for spindrift, and a big steamer passing very slowly towards the north-east could only be seen at occasional moments. The gale blew with great force all day, but at midnight the wind began to ease, and the next day it was possible to shake out all reefs. On November 20, as the wind had fallen to nearly calm, and the locality was only twenty-five miles from the station intended, it was decided to take the opportunity offered to work. Heaving to, water samples were taken from 1,400 fathoms upwards.

Nov. 20, 1905. Lat. 40° 30′ N., Long. 12° 10′ W.

On November 23 the ship was about fifty miles eastward of the old Station 61, strong westerly winds having put her off her intended course, and to general dismay it was found that the ship was making a considerable amount of water since the terrible gales of the 18th and 19th, and the two Downton pumps on board were unworkable. That the ship should have sprung a leak in this manner could only be accounted for on the supposition that she had received serious damage underneath from being laid upon the rocks in Orkney in August. I shipped a scratch crew to take the vessel from Hull to Orkney, and the certificated genius in charge of her managed to put her on the sharp rocks of Houton Cove, where she had to lie for a whole tide. No doubt, as was subsequently proved in dry dock at Gibraltar, she received serious damage then, though, owing to the absence of a slip large enough to take her in Orkney, it was not possible at the time to examine her bottom. The severe gales of the 18th and 19th in the Bay of Biscay no doubt strained her and opened a leak. However, it was decided to continue the cruise to Madeira. Consequently, on November 23, in Lat. 36° 56′ N., Long. 13° 6′ W., water samples were taken from 1,000 fathoms upwards.

Nov. 23, 1905. Lat. 36° 56′ N., Long. 13° 6′ W.

Fortunately, fine weather now set in, but with light south-west winds, which necessitated very slow progress, it was not until

November 27 that the next station was reached. This was in Lat. 33° 31′ N., Long. 16° 57′ W., where for 1,200 fathoms upwards water samples were taken. Each and every day now baling out with relays and buckets was regular—about 1,200 gallons of water in the twenty-four hours.

Nov. 27 1905. Lat. 33° 31′ N., Long. 16° 57′ W.

However, Madeira was now visible, when it was hoped that some sort of repairs could be effected. On November 28 the ship was brought to anchor in Funchal Bay. As there were no facilities in Madeira for repairs, the only thing that could be done was to put in a pulsometer pump, and with this the water was kept under during the passage from Funchal to Gibraltar. Several days were wasted here in executing the necessary repairs ; however, on December 14, work was recommenced at thirty miles' distance south-west from the old Station 38. Here water samples were taken from 1,400 fathoms. After proceeding forty-nine miles with a fair wind it dropped to calm, and the 16th and 17th were perfectly calm. However, on December 18 the position was reached of Lat. 35° 53′ N., Long. 7° 35′ W., and a sounding gave 654 fathoms with a bottom of grey ooze. The water-bottle was put down to 600 fathoms. Gannets were seen flying about, reminiscent of more northerly climates.

Nov. 28, 1905. Funchal.

Dec. 14, 1905. Lat. 34° 12′ N., Long. 10° 00′ W.

Dec. 18, 1905. Lat. 35° 53′ N., Long. 7° 35′ W.

Next day, after very light variable breezes, mostly dead ahead, the station Lat. 35° 50′ N., Long. 6° 41′ W., was reached, when a sounding gave 284 fathoms, with a very rocky bottom, the sounding-lead being deeply scored. Water samples were taken from 280 fathoms upwards. Cape Spartell was plainly visible during the day. On December 20, in Lat. 35° 55′ N., Long. 5° 53′ W., a sounding gave 164 fathoms, and water samples were taken, after which the course was Gibraltar, which was reached about 5 p.m. on December 20.

Dec. 19, 1905. Lat. 35° 50′ N., Long. 6° 41′ W.

Dec. 20, 1905. Gibraltar.

From this date until February 3, 1906, was occupied at Gibraltar, where, after long delay, the yacht was put on to the slip for examination of the bottom. The surmise as to the cause of the leak was confirmed, and after stripping a considerable length of copper, injury was discovered, which could only have been caused by putting the vessel on the rocks in Orkney. All repairs having been effected, the

ship got away on February 3, and immediately experienced extraordinary weather, mostly lying to off Cape Baba, Morocco, close-reefed, the land of Morocco all covered with snow and a wind blowing 'great guns.' A sounding on February 6 gave a depth of 500 fathoms, but the sounding was not reliable. Next morning, February 7, the wind eased, and the yacht was some miles nearer the land, when a sounding gave a depth of 300 fathoms, with a bottom of mud. The trawl was lowered with two bag-nets attached to the trawl heads and 600 fathoms of warp, and towed for an hour, when the wind strengthened, and the trawl had to be hauled up again, coming up with the beam broken, the net containing only two little fishes (a *Stomias boa* and *Scopelus, sp.*), the bag-nets containing a lot of shells, crustaceans, etc.

Feb. 7, 1906. Off Cape Baba.

Feb. 9, 1906. Off Malaga.

On February 9, the Straits having been crossed, the ship was lying off Malaga with a strong gale from north-west, and on the evening of the 9th the wind moderated enough to allow of the trawl being put down in 130 fathoms, and dragged towards the shore to 80 fathoms. A great quantity of crustacea, holothuria, shells, sand, and mud, was the result, but no fish. On the 10th the weather became better, and being well up under the land in 40 fathoms deep, the trawl was put over and towed for an hour, when several species of fish were captured (*Gobius niger*, *Callionymus maculatus*, *Capros aper*, *Citharus unguatula*, *Arnoglossus latema*), besides a number of crustacea, including a large *Aristeomorpha*.

On Sunday night, February 12, it blew 'great guns,' and being close to Malaga, the yacht was put in there for shelter.

Feb. 14, 1906. Off Malaga.

For the next two days it was very stormy, with snow throughout the day, but on the 14th it became better, and getting out of Malaga the trawl was put down in 300 fathoms, and many fish were captured, notably *Pristiurus melanostomus*, *Raia oxyrhynchus*, *Hoplostethus mediterraneus*, *Capros aper*, *Macrurus cœlorynchus*, *Lophius sp.*, *Squatina aculeata*.

Feb. 15, 1906. Lat. 35° 50′ N., Long. 4° 20′ W.

Intending to visit the old Station 44 of the 1905 cruise on February 15, in Lat. 35° 50′ N., Long. 4° 20′ W., water samples

were taken from 700 fathoms upwards. Here it was desired to use Pettersson's machine, but the water was too deep to anchor the ship. On February 16, off Marbella, the trawl was put down in 500 fathoms, and in the bag-net on the trawl-head was a *Stomias boa*, and in the trawl some *Scopelus* and *Gonostoma*, and some *Germodus parvus*.

Feb. 16, 1906. Off Marbella.

Feb. 17, 1906. Off Marbella.

On February 17, still off Marbella, but nearer to land, in 276 fathoms, the trawl was put down again, but with very unsuccessful results, both bag-nets on the trawl-heads gone, having broken away with the weight of mud contained in them.

Feb. 21, 1906. Gibraltar Bay.

Getting away from Gibraltar on February 21 with a strong blow from the west, while waiting the opportunity to get off to the Gettysburg Bank, the trawl was put down in Gibraltar Bay, and a few fishes captured, amongst which were *Hoplostethus mediterraneus*, *Gadus argenteus*, *Macrurus cætorynchus*. At night it came on to blow so very strongly that the ship was brought to anchor in Algeciras Bay, where she lay until Sunday, the 26th, a gale from the west to north-west lasting all the time. It moderated sufficiently on the Sunday to get out as far as Tarifa, when, falling quite calm, the tide took the ship right back to Gibraltar. Next day a light wind was blowing from the west, which freshened considerably as the day wore on, and a whole day was spent in getting as far as Trafalgar Bay; and from then, until March 2, the whole period was occupied endeavouring under double reefs to get to the Gettysburg. On this day a sounding on the west side of the bank gave 164 fathoms, and continuing a little farther, 230 fathoms, with a bottom of fine white sand and shells. Then east-north-east, three miles away, bottom was reached at 80 fathoms, and putting down the trawl and towing over 80 to 40 fathoms, it got fast in a rock and came up with the beam broken and without a single fish in it, but plenty of dead shells and a few crustacea. A water-breaker, with a heavy piece of iron attached, allowing a flagstaff to stand vertically in the water, on which could be fixed the anchor light, was then put out and anchored, so that as the ship dodged about all night it could be seen, and the position kept for

March 2, 1906. Gettysburg Bank.

work in the morning. Most of the next day was spent in repairing the trawl, but about 6 p.m. it was put out in 60 fathoms on the south side of the bank; but the wind dying away completely, the trawl failed to capture any fish, but a quantity of shells, coral, and sponges were brought up. Leaving the buoy in position, the yacht dodged round the light all night, which was found again next morning, Sunday, March 4, when the trawl was put over again in 100 fathoms on the east side of the bank. Suddenly passing into deep water, the trawl would not keep the bottom; consequently, amongst the mass of stuff brought up, there was only one small fish in the sprat-net. *Centriscus scolopantime* and *Serramus catrilla* were taken with a hand-line. Later on in the day the trawl was put down in 80 fathoms, when, getting fast in the bottom, it was impossible to move it, and finally broke away altogether along with 50 fathoms of wire. Though having spare beam and net on board, there were no spare trawl-heads, and nothing remained but to go back to Gibraltar to get new ones made.

March 5, 1906. Gettysburg Bank. The current meter.

March 5 was at last a suitable day to work the current meter. All previous efforts to use it were frustrated by the prevailing bad weather. It requires the calmest of weather for satisfactory results, and is in any case a very troublesome apparatus to use. On this particular day the sea was quite smooth, with a light breeze from the south—such a condition of things as but rarely occurs at this time of year, even in these latitudes.

The results of this experiment are as follows:

| Position. | Depth in Fathoms. | Direction of Current. | Number of Turns a Minute. | Velocity increase in Seconds. | Temperature. |
|---|---|---|---|---|---|
| Gettysburg Bank ... | 2 | W.N.W. | 30 | 11·3 | 15·0° |
| Lat. 36° 32′ N. ... | 30 | W.S.W. | 34 | 12·2 | 14·4° |
| Long. 11° 55′ W. ... | 50 | S.W. | 48·2 | 15·4 | 14·3° |

The surface current over the Gettysburg Bank appears to work round a circle, running longer south-west and north-east than it does in any other course.

Bottom at this spot was at 55 fathoms depth, and rocky. The Gettysburg Bank is unsuitable for trawling; everywhere under 100 fathoms rocks occur, in which a trawl is certain sooner or later to be lost. Outside 100 fathoms the water deepens very fast.

After leaving the Bank, a fine breeze from south-west soon brought the ship off Cape St. Vincent; then, veering round to east, a gale sprang up, lasting that night and all the next day, necessitating three reefs in the mainsail. Making for the old Station 42 in the mouth of the Straits, the anchor was dropped in 170 fathoms on March 10, the day being fine and sea quite smooth; but the current was altogether too strong for the current meter, the wire standing away aft, as if the ship were going before a fair breeze of wind. At 2 fathoms depth, the time allowed between opening and shutting was six minutes, and the number of turns 825 per minute, giving a result far beyond anything in Professor Pettersson's tables. At depths below 2 fathoms the apparatus could not be made to work at all, and it is evident that in a current like that passing through the Straits of Gibraltar no good result can be got out of it as at present devised. It was quite hard work getting the anchor in again, especially as it had taken a very strong hold on the bottom. March 10, 1906. Straits of Gibraltar.

Leaving Gibraltar on March 17 with a fair wind, by evening it was blowing very strong, and three reefs were necessary. On the 19th, when off Cape St. Vincent (south-east, twenty miles), the trawl was put down in 300 fathoms, when the wind dropped almost to calm; consequently the haul was very poor, containing, however, one perfect specimen of *Chauliodus Sloanii*, comparatively rare. Next day, March 20, the trawl was put out in 280 fathoms, twenty miles south by east from Cape St. Vincent. The sea was very rough, and, after towing for an hour, it had to be hauled up in consequence of the strong wind and sea. The chief captures were *Macrurus cœlorynchus* and *M. lævis*, and a couple of *Nephrops norwegicus*. March 21 and 22 were very stormy, twenty-two miles south-south-east of Lagos Bay, but on the 23rd it was possible to put the trawl out again in 400 fathoms, when, after trawling for an hour, the wind freshened so con- March 19, 1906. Off Cape St. Vincent. March 21, 1906. Off Lagos.

siderably that the trawl had to be hauled up as quickly as possible ; and with three reefs in the mainsail, double-reefed foresail, and storm-jib, the ship was put towards land to seek shelter for the night. The fish captured were *Phycis blennioides* and *Zeugopterus Boscii*, along with two flat fish of the megrim kind.

March 23, 1906. W.S.W. of Cape St. Mary.

On March 23, west-south-west of Cape St. Mary, a sounding gave 71 fathoms where the chart marks 320, evidently a new bank, the extent of which, however, must be small, as, after sailing a few miles to the eastward, the depth was 360 fathoms. The new bank was situated with Cape St. Mary bearing by compass N. 72 E., distance twenty-one miles. The trawling result in 400 fathoms included *Pagellus centrodontus*, *Scorpæna dactyloptera*, and *Macrurus cœlorynchus*, among many other things—crustacea, sponges, and anemones—one of which was growing on a lump of coal, of which several pieces came up in the trawl, probably dropped at some time from a passing steamer.

On March 26, when south-east half south from Cape St. Mary, Portugal, the trawl was shot in 350 fathoms, when several fish were captured, including *Scorpæna dactyloptera*, *Macrurus lævis*, *Gadus argenteus*, and *Lophius budegassa*, along with a miscellaneous collection of crustacea, anemones, and cup-coral. The day, though satisfactory for trawling, was very unpleasant—squally, with much rain, hail, and sleet.

On March 28, when twenty-six miles south-east by south from Cape St. Mary, the trawl was shot in 308 fathoms, and when hauled on board contained a great shark, *Echinorhinus spinosus*, 7 feet 2 inches long, the skin covered with sharp spines curved at the point, the whole weighing about 300 pounds. Too big to preserve, it was with difficulty heaved back into the sea, having first been ripped open to ascertain if there was anything in the stomach. This, however, contained only some well-digested food. In the same haul were several *Chimæra monstrosa*, *Spinas niger*, *Scorpæna dactyloptera*, *Zeugopterus Boscii*, *Macrurus lævis*, *Aphoristia sp.*, *Gadus argenteus*, *Lophius budegassa*, a fine hake, and several crustaceans, cup-coral, etc. On March 29,

trawling all day in 90 to 200 fathoms produced very poor results, beyond capture of long-spined urchins, big holothuria, and three skate and one small megrim ; and on the 30th, coming out into deeper water (Cape St. Mary bearing north-west by north eighteen miles), and trawling in 310 fathoms, again there was little but echinoderms. On such a bottom it is rare to get fish, but amongst other things, such as *Homola barbata*, *Pagurus striatus*, and coral, was one small sole (*Solea profundicola*) and a very small skate.

From March 30 to April 4 was a continuous gale from south-east when the ship was lying to, with storm trysail and storm-jib ; but on April 4, the weather moderating, a sounding was made in 417 fathoms, forty-six miles west from Cape Spartel. A good number of fishes were captured, including *Mora mediterranea*, *Scorpæna dactyloptera*, *Hoplostethus mediterraneus*, *Conger vulgaris*, *Pomatomus telescopinus*, and three species of *Macrurus*, along with a large and fine *Polycheles typhlops*, echinoderms, and sponges. April 4, 1906. Off Cape Spartel.

On April 5, thirty-one miles west-south-west of Cape Spartel, the trawl was shot in 187 fathoms, and a number of fish, including *Torpedo nobiliana*, *Scorpæna scrofa*, *Dentex macropthalmus*, *Rhombus Boscii*, *Merlucius vulgaris*, *Gadus argenteus*, *Pristiurus melanostomus*, *Scorpæna dactyloptera*, *Macrurus lævis*, and a number of large and small crustacea, were taken.

This was the last trawl of the cruise, the ship returning to Gibraltar, where, after provisioning and a few necessary renewals, she set sail to England, having completed a fairly successful cruise, considering the obstacles in the way, such as almost continuous bad weather, and as regards the trawling outfit, rather unsuitable apparatus. A much heavier trawl-beam, with the trawl-heads made of broad flat iron, would prevent the trawl sinking so heavily in the mud, would allow the trawl to move faster and capture more fish. The depth of the present trawl-heads is only about 20 inches, and when it sinks in mud it does not allow sufficient room, and probably a depth of 3 feet would not be too much. All the bottom of the net ought to be double-meshed to prevent the inevitable tearing which results over

some of this ground, which is covered with great branched coral which would tear anything to pieces.

I am sorry that more use could not be made of Professor Pettersson's current meter. Probably in the still water of a Norwegian fjord it works with satisfaction, but in the locality where the *Silver Belle* worked during this cruise it was quite impossible to do much with the instrument ; and, indeed, as the brief notes recorded show, the weather was far too stormy for the use of such a delicate instrument.

Trawling in a sailing-vessel in deep water is a difficult undertaking. Whereas with steam a ship can move in calm weather, a sailing-vessel is obliged to work in sufficient wind, and with a light trawl, directly there is any way on the trawl rises from the bottom and is liable to turn upside down. In shallow water, with a great length of wire out, it appears to keep the bottom well enough. But under the most favourable conditions for work—namely, calm weather—a sailer will, of course, scarcely move the trawl ; and, again, when it becomes fast, as it will sometimes do in rocky bottoms, the sailer is at a considerable disadvantage, and is liable to lose trawl and everything, for the ship cannot readily be backed as could be done under steam.

Then, again, from Lisbon to the coast of Morocco the bottom is really very unsuitable for trawling. Even where the sounding-lead indicates mud there are great masses of coral and rock sticking up at short intervals, and even in a steam trawler a hand has to be kept on the engine telegraph all the time the trawl is down, ready to back astern at the first indication of being caught in the bottom.

Amongst the fishes brought home from this cruise perhaps the most remarkable was the specimen of *Himantolophus Rheinhardti*, which, strangely enough, was not taken in the trawl at all. Coming ashore at Gibraltar one morning, Buchan Henry found a great commotion amongst the local fishermen over a strange fish which one of them had captured among the rocks on the east side of Gibraltar. Such a fish had never been seen there before ; and, indeed, of the only two examples ever recorded, both had been captured off the coast

of Greenland and Iceland. It was still alive when bought by Henry for ten shillings, about 16 inches long, and jet black, all except the tips of the tentacular appendage, which were pure white, and about as repulsive-looking an object as could well be imagined. That this fish should be taken in Gibraltar Bay, and at a depth of only about 20 fathoms, is extraordinary, as other congeneric angler fish are supposed to be deep-sea habitants. The specimen is such a prize that it is now in the Natural History Museum of South Kensington.

## NOTE OF THE 1907 CRUISE.

The intention was to go from Scalloway to the south end of the Faeroe banks, thence southward to the Butt of Lewis, and from there out into the deeper water along the shelf of the Atlantic slope, and continue as far southwards as time and opportunity would permit, chiefly trawling and dredging. But the weather was anything but good for this kind of work, and we got no farther south than St. Kilda. A fair number of fishes and a large number of Crustacea, and, amongst other things, a very complete collection of Pycnogonidæ were obtained; but as these collections have not yet been reported on, I defer the discussion of the results. I had the advantage of the assistance of Mr. Opie, of Cambridge, who remained on board throughout the greater part of the cruise, and who ably and energetically gave his attention to the preservation of the specimens collected.

The latter part of the cruise was continued by a passage from Shetland to Norway, which I made in response to a request from Dr. O. Pettersson, who asked me to work hydrographically across a line which he marked out, and which would connect up the observations of the Scottish, German, and Scandinavian expeditions. Dr. O. Pettersson kindly undertook to have the water samples and plankton examined in the Swedish Laboratory, and these observations are published here. The full discussion of them is not possible until the German and Scotch observations are ready for publication. As Dr. Pettersson remarks, there was an unusual flow of Atlantic water during September, 1907, into the eastern part of the North Sea, characterized by southerly plankton forms. Professor d'Arcy Thompson has very kindly made some remarks, and provided me

with information of the observations made by the *Goldseeker* at the two stations Sec. 6a and Sec. 8, and these are embodied here. The Stations 7 and 8 of the *Goldseeker* correspond closely with our Stations 2 and 3, and, while the Scottish observations were made in August, 1907, ours were made about three weeks later.

Leaving Scalloway on Tuesday, September 17, rough weather towards night necessitated shelter in Lerwick Harbour, and for two days there was a very strong blow from south-west to west. The ship did not get away until the 20th, and the first station marked by Professor Pettersson was reached on Saturday, the 21st. This was Lat. 60° 58′ N., Long. 0° 47′ E., and the depth 80 fathoms, with a continually rising wind and heavy swell from the north ; by the time the observations were finished it was really too rough to work any longer. At 2 p.m. the same day the next station (2), in Lat. 60° 5′ N., Long. 2° 0′ E., was reached, the wind still blowing strong from the north and the barometer very high. The temperature at 50 fathoms was so extraordinary that it was thought that the observation must be wrong, but two more observations at this depth proved it to be correct. The wind was very high and the swell strong, and as night was fast approaching and further work became impossible, it was decided to run past the next two stations (3 and 4), and make straight for the Norwegian shore, a distance of sixty-seven miles, so as not to lose the fine fair wind, and on the return passage to work the stations omitted. Consequently Station 5 was reached on September 22, the land being fifteen miles away east, three-quarters south, and covered with snow. The sounding gave 193 fathoms. Starting work at 5 a.m., it took five hours to take all the observations and to complete by the use of the closing-net at 190, 60, and 20 fathoms. During this time the barometer commenced to fall rapidly, and the wind backed to west-north-west, a head-wind for the return passage. Station 4, Lat. 61° 32′ N. and Long. 3° 44′ E., was reached in the afternoon, the wind strong and west by north, and the weather looking very bad. Rain began to fall, and the rough sea compelled the taking in of two reefs in the mainsail, and bonneting off the foresail and storm-jib. The barometer having

dropped an inch since morning, it gave promise of a very dirty night. At this station the extraordinary temperature at 60 fathoms suggested something wrong with the observation, but the thermometer was in perfect order. The next station (3) was about thirty miles to windward. The night of September 22 was very stormy, with a wind backing from west to south-west, and the rain falling in torrents. At 4 a.m. it veered to north, then north-east, and finally dropped very light, and at 1.30 p.m. the ship was a few miles north-east of the position intended ; but, considering the weather and the early approach of darkness, it was decided to work at this spot. The sounding marked 260 fathoms, and when work was finished at 6 p.m. it was getting dark, and the rain was descending in torrents. With a light wind a course was set for Flugga (Shetland), 124 miles distant west half south. While working this station a very large dead whale drifted past the ship. It was quite fresh, and probably had broken away from a whaler during the night. The very light wind and heavy swell made progress slow, and it was not until 11 p.m. on September 25 that Flugga light was made out through a dense fog about one mile south-east during a momentary lift.

Complete discussion of these results is not at the moment possible, but I may publish along with them the following letter from Professor d'Arcy Thompson, who has been kind enough to provide me with information as to the observations made by the *Goldseeker :*

'Dundee, *May* 4, 1908.

'My dear Wolfenden,

'The observations you have sent to me seem to be of very great interest, but it is impossible for me to go into them in detail at the moment—not only for want of time, but also because our own observations for last summer are not yet fully worked up. . . .

'Your section from Shetland to Norway is a very beautiful one, and shows, in the first place, that we miss much by not running our own line farther towards the Norwegian coast. The other section (Section II.) is taken from the *Goldseeker* observations for 1906.

'We did our two Stations 7 and 8, which correspond closely with

your 2 and 3, at the very end of August, 1907, while you did them rather more than three weeks later. We found a large superficial body of fresh water at both stations, and especially at Station 8; while this had entirely disappeared from Station 7, and very nearly so from Station 8, three weeks later.

'At these stations the alternate pulse of comparatively fresh and of oceanic water is a well-marked feature, and, on the whole, the flood of fresh water occurs in summer, and is replaced by the salter water in winter. But the dates vary very much, and one of the diagrams which I send you shows the conditions at or about the month of September in 1905, 1906, and 1907, all at Station 8. You will see that the fresh water was lacking in 1905, but abundant, according to our observations, in 1907, and still more so in 1906. Your observations in 1907 correspond very closely with ours in 1905.

'. . . . What we have in that region is a very rapid change of conditions from place to place within a short distance, and you have got into a body of water more similar to that which we found at Station 9 to the westward than what we found nearer to your position, three weeks earlier. I send you a note of our results at Station 9, and a diagram of the salinities and temperatures found by us at Stations 8 and 9 and by you in the neighbourhood of the former station. You will see that your results are, on the whole, intermediate. Accordingly, if the *Silver Belle* was a little farther to the west, or the *Goldseeker* a little farther to the east of the given positions, or if, on the other hand, the body of water, especially the surface water, had moved a very few miles eastward during the three weeks, in either case the apparent discrepancies would be very nearly explained, and the results would not be so very far from correspondence.

'It would seem, therefore, that while we, no doubt, want more frequent observations in this region, so we also want more closely contiguous stations.

'Yours very faithfully,

'D'Arcy Thompson.'

## OBSERVATIONS CONDUCTED ON SAILING-SHIPS.

As the making of scientific observations on board a sailing-ship requires some appliances and methods which differ from those on board a steam-vessel, I think it may not be out of place to briefly describe the most suitable ways and means of conducting these observations. A steam-vessel must have many advantages over a sailing-ship; but to be put against these is cost, both initial and of upkeep, and for work a long way from land and in deep water, such as the Atlantic, a steam-vessel of comparatively large size and stout build is essential, if any degree of comfort and safety is to be looked for. There is no doubt that a stoutly-built sailing-ship of anything over 100 tons (y.m.) is a much more comfortable and safe vessel to ride out a severe gale than a steam-vessel of much greater tonnage and size. The great disadvantages of a sailing-ship are the loss of time taken in completing a lengthy cruise, and the days that are wasted in beating around a 'station' and lying to very often, while waiting for a favourable opportunity to commence and complete the work involved in the use of towing-nets, etc., in deep water. For the rest, the same difficulties beset the observer in either steam or sailing vessel, such as devices to counteract the heavy strain thrown upon several hundred fathoms of wire with the weight of a heavy towing-net at the lower end, etc., when the ship is rising and falling or labouring more or less heavily in a strong swell. Where the steam-ship has the greatest advantage over the sailing-ship is in the ability to go ahead or astern at will, and to keep over or up to the towing-net or trawl lowered into deep water, and when dredge or trawl gets caught in rock at the bottom, which is not of infrequent occurrence, and occurs often when least expected, in the ability to back quickly

and release the imprisoned apparatus. A sailing-ship is, in fact, absolutely at the mercy of wind and wave, while a steam-ship has at least some control over adverse elements.

Having said so much, however, it is necessary to state that a sailing-vessel of the size of a Grimsby or Brixham trawler can really do all the work at sea comprised in the ordinary hydrographical and scientific work of fishery investigation that a much more expensive and elaborate steamship can do, and at very much less cost. It is nearly entirely a matter of good seamanship and handling the vessel in an intelligent manner. My own experience, extending over some years now, teaches me that the average cost of a three months' cruise in a ship of about 130 tons (y.m.) does not amount to more than £300, whereas in a steam-ship this figure must be doubled. Consequently, for investigations such as those which have for a long time been undertaken by the International Council and by the various Fishery Boards, I have always been at a loss to understand why use was not made of sailing-ships, which in comparatively shallow waters such as the North Sea and English Channel, and for a distance of 70 to 100 miles round our British and European coasts, could do most, if not all, of the work of fishery and hydrographic observations quite as effectively, if not always so rapidly, as steam-vessels, and at very much less cost. There seems to be a mistaken impression that steam is essential, which I do not believe to be at all correct. Indeed, if this were so, the lengthy hydrographic and other observations recorded in this book would have no value; and I hope I do not overstate the case when I say these observations prove not only what a sailing-ship can do, but that they may have considerable scientific value. I hope that they may encourage many others to follow on the same lines, and contribute, according to their ability, to the scientific study of the sea.

I have frequently, during the last few years, heard of yachtsmen who have expressed desires to do some work of this kind, but did not know how to set about it. There is really nothing mysterious about the handling of deep-sea apparatus; the only thing necessary is to

conform to the requirements of scientific accuracy, without which hydrographical observations would, of course, be absolutely useless. Dredging and trawling may be carried on by anyone, and information of the most important character obtained as regards fishes and the distribution of species of marine fauna (and flora). The tedium of many a weary hour at sea might be relieved by the excitement of putting out a tow-net or dredge, the contents of which may very often reveal some prize. Of course, to the ordinary individual, not a zoologist, the chief difficulty is that he does not know what he has got ; but a very short practical experience is all that is necessary to enable him to recognize what is common, and therefore usually of little value to the scientist, and what is a rare or uncommon, and therefore worth preserving. Scientists are always willing enough to assist in the investigation of the marine fauna, and many a museum might be thus greatly enriched with rare or uncommon specimens.

I cannot but think that to those fond of cruising away from land a new and profitable delight might be added by undertaking observations of this kind.

Still, desultory observations of this nature, however gratifying to the amateur, are of no value to the scientist unless they are carried out on a definite and continuous plan. For instance, when a yachtsman is contemplating a cruise, say to the Mediterranean, to the Azores, or across the Atlantic, or northerly to Iceland or the Faeroes, etc., observations on hydrography, or tow-nets used at regular intervals during the cruise, cannot fail to record facts of interest and of great assistance to marine scientists, especially if the observations are conducted upon a plan and under the advice of someone who can acquaint the intending observer with the essentials for successful and useful work.

Returning after this digression to the subject-matter of this chapter—namely, the apparatus and methods suitable for a sailing-ship—we may first briefly discuss the matter of what such a vessel may do and the means of accomplishing it.

A sailing-ship may quite well undertake soundings, the use of

deep-sea tow-nets, the taking of temperatures, the collection of water samples (for subsequent analysis), dredging, and trawling.

In comparatively shallow waters, such as the North Seas, extended voyages may be made and effective scientific results recorded with quite small craft. My small yacht, the *Walwin*, of only 30 tons (y.m.), has made frequent cruises from Shetland to the Faeroe Islands, some of the results of which are recorded in this volume. But as there is no room on such a vessel for steam apparatus, everything has to be hauled by hand. Where the depth is not over 100 to 200 fathoms, this is not difficult in willing hands ; but when the depth reaches 500 fathoms and over, it is too great a tax upon human endurance, even as exemplified in the Shetland sailorman. Consequently, a larger vessel is desirable, in which is placed a steam capstan.

The *Silver Belle* is a ship of 120 to 130 tons (y.m.), sufficiently large and comfortable to make extended cruises in any direction. Into this ship I fitted a steam capstan of the type commonly employed on the fishing-boats of the North of Scotland. The boiler is placed below deck, rather forward of the middle, between the forecastle and the chart-room, and steam is led from it to the capstan, which is placed on deck on the port side, at a distance behind the mainmast sufficient to permit of the big drum (on which is wound the wire) being placed forward of it and clear of the boom.

There is nothing about the drums which carry the wire which any ordinary engineer cannot devise suitably to the vessel for which they are intended. The ordinary reels used on board ship to carry short lengths of wire cable are, however, scarcely suitable for deep-water work, because the strain upon them is too great, and they sooner or later give way. The user is then lucky if he escapes without the loss of several hundred fathoms of wire and the apparatus. Something stronger than these ordinary reels is therefore required. On board the *Silver Belle* I have a special winch, made for me by Messrs. Bullivant and Co., consisting of two stout upright iron plates, bolted together by cross-pieces, and enclosing a large drum divided into two

sections—the one to carry several hundred to 2,000 fathoms of wire (according to size), the other section to carry the fine wire used for sounding. This winch also carries a clutch and brake, by which the speed of revolution may be controlled, and externally on the axis of the revolving drums is affixed a cogged wheel, which, with a similar one upon the steam capstan, carries a chain band (with movable links, so that it can be shortened or lengthened). In practice the wire is reeled off rapidly by its own weight, controlled by the foot-brake, which allows of immediate arrest of the process. In hauling in, the capstan through the chain band actuates the drums, revolving them and coiling up the wire as it comes on board. The ascent can be controlled as easily as the descent.

In order to check effectively the amount of wire paid out and to ascertain the depth to which the apparatus is lowered, the wire, after leaving the drum, is led through a pulley, the revolutions of which are registered on a counter, each revolution marking 1 fathom of wire paid out. From this counter the wire is led forward to a pulley, the method of which differs according as the work to be accomplished is trawling or tow-netting.

In tow-netting the wire used is necessarily of smaller diameter than in trawling ; consequently, at considerable depths there is much more strain upon it ; and if the ship is in a heavy swell, as is frequent in the open ocean even upon the finest days, she rides up and down considerably, and sudden jerks are thrown upon the wire, which may break the strands, or even snap it completely. On one occasion we were unlucky enough in this way to lose several hundred fathoms of wire and a closing tow-net attached, along with a couple of deep-sea thermometers.

To avoid accidents of this kind an 'accumulator' is necessary. Such an apparatus is constructed as follows : Two wooden discs are prepared—one with a hook which can be attached to the mast ; the other with a hook also, which can be attached to the spar, as seen in the diagram. Between the two discs are extended six or more lengths of stout, solid rubber bands (obtainable from any of the

wholesale rubber manufacturers). The size of the discs and length of the rubber are matters as to which it is impossible to lay down any general rule.

The wire used for tow-netting is usually a stranded wire, and one which we have used successfully was supplied to me by Bullivant and Co.—a strand of seven wires (21 gauge), $\frac{1}{8}$ inch diameter, with a breaking strain of 10 cwt. Five hundred fathoms of this wire weigh about 60 pounds. Wires of this description vary very considerably,

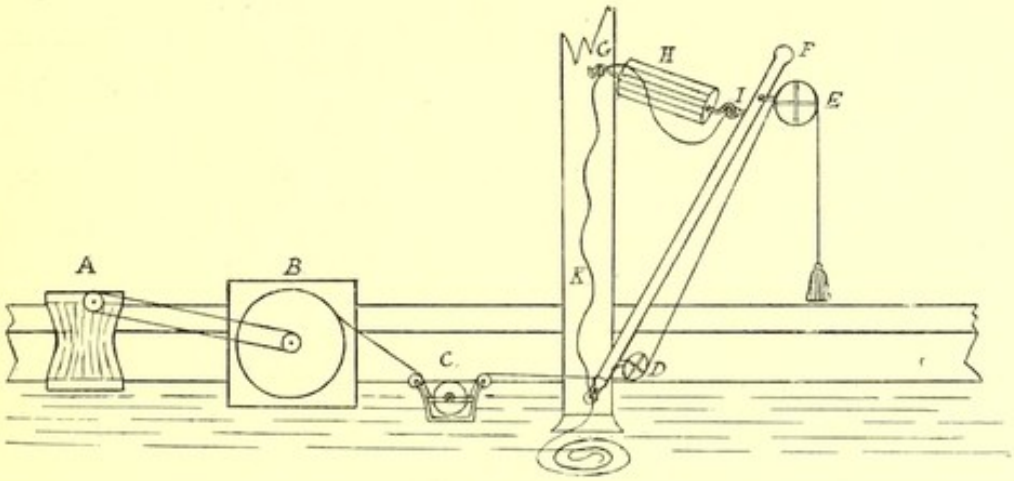



Fig. 4.

*A*, Steam capstan; *B*, large reel divided so as to carry thick wire and sounding wire; *C*, counter marking in fathoms paid out; *D*, block attached to movable spar *F*; *E*, wheel over which wire runs; *H*, accumulator attached to mainmast at *G*; *K*, coil of rope attached to spar.

and some that we have obtained elsewhere have proved quite worthless, the strands overriding, and thus preventing the descent of messengers. A 'soft' wire should never be selected, for this reason.

A sudden strain is by the accumulator greatly relieved, and though sometimes extended to a dangerous degree, we have never lost a tow-net or instrument since using it, now for some years.

The general plan is exhibited in the diagram.

From the steam capstan *A* the chain passes over the cogged wheel of the winch *B*. The wire from this drum is led to the counter *C*, thence over the pulley *D*, and from that over the pulley *E*, and carries either the sounding-lead or the tow-net. To the bottom of the mainmast is

fixed the spar *F*, and at a convenient height upon the mainmast is fixed a hook, *G*, on to which can be hooked the accumulator, *H*, which again is affixed to the spar *F* by a hook, *I*. The spar can thus move freely in all directions and give full play to the accumulator; and in order that it cannot by any accident to the latter break away, a length of manilla rope, *K*, is attached to the accumulator and coiled round the bottom of the mainmast, and at the other end to the spar at *I*.

This arrangement is suitable for work in deep water—*i.e.*, over 500 fathoms; but the spar can be dispensed with, along with the accumulator, in shallower water, the wire being led from the counter over a pulley-wheel affixed to the deck, and thence carried over a pulley attached to the end of a davit.

With such means we have found no difficulty in using the tow-net at depths of over 1,000 fathoms, and sounding to 2,000 fathoms. The depth to which a heavy tow-net may be lowered and raised again must be regulated by the capacity of the winch to haul it on board. The haulage must necessarily be slow, for if performed too quickly the condition of the animals in the bag of the net will be woeful, if they are not all mashed into pulp.

As an example of the time occupied in such operations in deep water, I may quote the following data from the log-book of the *Silver Belle*:

June 26, 1904, in Lat. 48° 12′ N., Long. 16° 26′ W.—a fine day, with long, heavy swell from the west, with a west wind.

The ship on the port tack, and the net first put down to 1,500 fathoms, and hauled up again. The result being unsatisfactory, the net was lowered a second time. This occupied altogether one hour, the net being towed for fifteen minutes; then put down successively to 1,200, 900, 700, 500, 400, and 200 fathoms. On each occasion this meant, after the net had been received on board, that its contents had to be carefully removed and washed out, and the net itself carefully cleaned with fresh water before lowering again. Some considerable time was thus expended in manipulations on deck, and the whole time occupied from start to finish was twelve hours.

On a second occasion—in Lat. 48° 27′, Long. 15° 38′ W.—the work of collecting samples of water, and filling from the water-bottle tubes of water for subsequent gas analysis, from depths 1,570, 1,400, 1,000, 700, 500, 300, and 100 fathoms respectively, occupied eight and a half hours.

On another occasion the time occupied in using the closing-net at 1,400 1,600, 1,000, 700, 500, 300, 100, 50, and 25 fathoms occupied twelve hours.

These, of course, are operations with the closing-net, which has to be lowered tightly closed, opened under water by the messenger sent down the line, and closed again under water by another messenger before hauling up ; and these successive operations occupy much more time than would be required for the mere manipulation of nets which it was not so particularly desired to open and close at specified depths.

There may be a difference of opinion as to the advantages of horizontally towing-nets, such as the author's large closing-net, or Garstang's smaller apparatus, or of vertically actuated closing-nets, such as Fowler's ; but I believe the results are practically the same with horizontally towed nets.

The drift of the ship of not more than a mile an hour is quite sufficient, and though the tow-net does not remain long at the depth to which it is primarily lowered, because by the drift of the vessel it is constantly rising, it does not rise greatly in the space of fifteen minutes and, moreover, practice proves that if there is much angle on the wire, the messengers for opening and closing cannot descend, and therefore the result is negative. In vertically acting nets the apparatus is raised through so many fathoms, and the result is the collection of the fauna between, for example, 500 and 400, or 400 and 300 fathoms, and so on. The actual quantity captured by either vertically or horizontally actuated nets is probably very little different. Unfortunately, as we cannot see what is going on at any considerable depth, we can only say that the capture has been made approximately at the depth stated.

While the use of closing-nets gives very interesting and sometimes

important results as to the character of certain fauna at certain depths, and the life-history of certain species, it is rendered much more valuable by the use at the same time of the water-bottle, whereby samples of water can be taken from the same depth and the salinity be subsequently determined, and by the simultaneous use of the thermometer attached to the tow-net. The temperature of the water at successive depths in the open ocean (*e.g.*, the Atlantic) exhibits such a fairly regular graduated scale, that the temperature taken by a thermometer attached to a tow-net at the time of opening and closing is a pretty accurate guide to the actual depth at which the net has really been. It has been our habit to attach to the tow-net when lowered two thermometers—generally a Negretti and Zambra reversing thermometer and a maximum or minimum thermometer.

Sometimes it is desirable to collect samples of sea-water from various depths for analysis of the contained gases. Such examinations are of great scientific interest taken in conjunction with the salinity observations, and were of especial interest in our 1904 cruise in elucidating the extent of water of Mediterranean origin then occupying patches in the Bay of Biscay.

For the method of preservation of these samples very little extra apparatus is requisite. When the water-bottle is raised on board, a sample of its contents is introduced into a glass bulb, which has been partially exhausted, so as to obtain a partial vacuum; the long, thin capillary neck being introduced into the nozzle of the water-bottle is then fractured by a special pair of 'scissors.' The sea-water fills the bulb, which, with its long neck, is then removed, and sealed by bending the end in the flame of a spirit-lamp. Put away in special boxes made so that the bulb and its two prolonged necks can lie in slots specially made to receive them, the flasks may safely be packed and carried on board, awaiting transmission to the laboratory for analysis.

As to the apparatus required in *trawling* in a sailing-vessel, experience must be the best teacher. This experience may be more quickly and profitably obtained by having on board, in charge of this apparatus, a professional trawler. The adventures of a trawl in inex-

perienced hands are too numerous and exciting to be pleasant, and the commonest is that, after painstaking manipulations occupying a long period of time, the trawl is found to have been upside down and the net empty.

Perhaps the simplest form of trawl and the one least likely to go wrong is the 'Agassiz' trawl. Its iron frame may bend, but is not

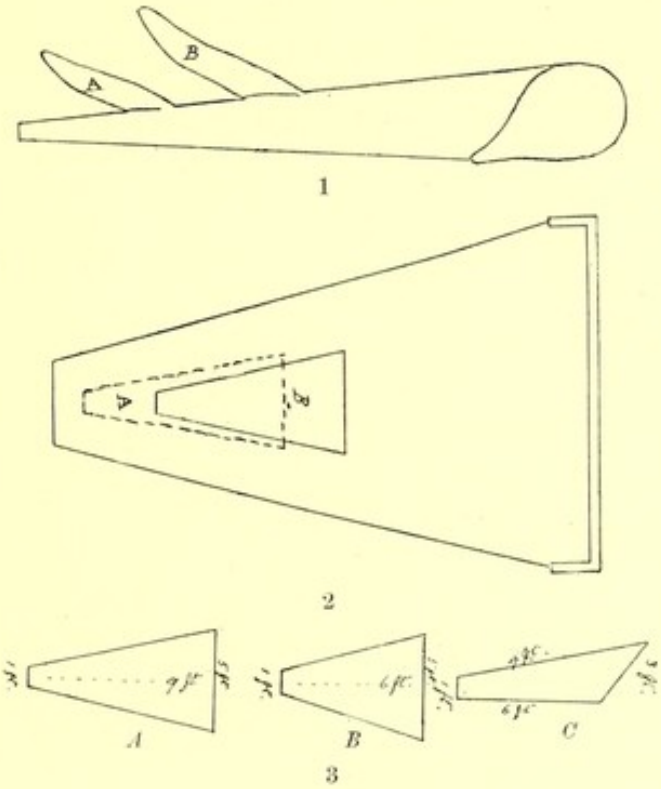



FIG. 5.

1. Trawl with muslin net, *A*, and sprat net, *B*, attached.
2. Method of placing the nets on the trawl.
3. Dimensions of the sprat net: *A*, top; *B*, bottom; *C*, sides.

easy to break, whereas wooden 'beam' trawls on unsuitable ground and deep water possess this unfortunate propensity. The 'Agassiz' trawl has the further advantage that it does not matter which side up it fishes. It is a splendid instrument for the capture of interesting Crustacea, though it takes a goodly number of fishes too.[1] Trawlers

[1] In one haul with this net we obtained seventeen fish of five different species, besides a great quantity of Crustacea, starfish, Mollusca, etc.

use the 'beam' or 'otter' trawl for this purpose. A 25-foot beam trawl is a very useful appliance. As suggested to me by Mr. Holt, of the Irish Fishery Board, we have used this trawl, with two additional nets affixed to the trawl-net.

*A* being a muslin net; *B* a net made of sprat mesh, one of convenient size having dimensions as shown in the accompanying diagram.

It is laced to the trawl, to fit the meshes of the latter when open. In order to insure that small fishes do not escape the trawl, the cod-end is lined with the same netting for the last third of its length.

The position of the net on the trawl is as shown in the diagram.

A beam trawl has the great disadvantage of frequent breakages, and many is the occasion on board the *Silver Belle*, when the beam has come up broken from dragging over rocky ground. In every expedition into deep water a spare trawl should be taken.

I believe that the otter trawl is the most useful apparatus for general use, and the Danes have a form of eel-mesh otter-trawl (Aaledrevvaad), which appears to be the latest thing devised in otter trawls, the size of the boards for which is 48 inches long, 29 inches wide, and having a weight of 110 pounds each. Glass floats are used instead of corks.

Another device of theirs is the 'Yngel' trawl, a big pelagic canvas otter-net, with boards 36 inches by 20 inches and a weight each of 40 pounds. Though we ordered these in plenty of time for the 1907 cruise, they were not delivered until the cruise was finished; therefore I am unable to state anything as to their practicability.

Besides trawls and tow-nets, dredges of the Plymouth Laboratory pattern, 3 feet 6 inches wide, should be included in the outfit.

If the object of the cruise be trawling and dredging and the collection of the larger animals (such as fish, etc.), the equipment should include a supply of 4 to 6 gallon wide-mouthed jars, with iron screw clamps and rubber rings; also air-tight preserving jars; and for smaller animals bottles and vials with good tapering corks; copper labels, such as gardeners use, which can be written upon with a pencil and

tied on to the fish by copper wire ; butter muslin to wrap fish, etc., in when to be stored in a tank or jar ; a supply of cotton-barked netting of 1-inch mesh, which is used to make bags for the top of the trawl and to line the cod-end of the same ; and a supply of mosquito netting to make bags to be attached to the trawl. These, however, are often filled with such a weight of mud as to be carried away completely.

A tin-lined tank, made like a large box, with lid which can be closed and fastened down, may be usefully affixed to some corner of the deck, and in this may be stored fish, etc.

The preservatives in use are methylated spirit and formalin, of which a plentiful supply should be carried.

Of open tow-nets nothing much need be said. There is no particular virtue in any kind of net, but a number of such nets may be clamped at intervals upon the warp, and they are, perhaps, all the better if they are supplied with tin or aluminium vessels at the bottom, with a tap. On removing the nets from the water the contents of the silk net gravitate towards the tin cup, and the inside of the net can be washed into the cup, and the collection made into bottles through the tap.

Larger nets, bent on to a framework of wood or ordinary gas-piping, may be employed to trail behind the ship at the surface or some distance below, and catch an amazing quantity of plankton ; and a very useful form of net with a triangular frame of heavy wood may be usefully employed to drag along the bottom, and many bottom species which seldom or never leave the mud are collected in this manner.

Of course open tow-nets give no accurate information as to the precise locality or depth in which species are captured, and if the latter be the object of inquiry some form of 'closing'-net must be employed.

Very nearly the same disposition of apparatus on deck as was mentioned for deep-water tow-netting is applicable to trawling. Stout wire warp is preferable to rope (the wire for closing-nets will not do), and this is reeled off a drum and taken round the steam capstan,

from which it is led forwards to a pulley, and thence to a lead affixed to the bulwark. In this case the 'counter' and the spar or davit are dispensed with.

The warp after leaving the lead may be brought up aft and secured by a stopper, as is generally done in sailing-trawlers; and it is a good thing to leave the winch free, so that if the trawl catches in a rock the stopper will break and the warp can run free, instead of being brought up short, with the loss of apparatus in consequence. It is scarcely necessary to say that the gear is always shot to windward.

The manipulation of a ship for trawling and tow-netting is not a thing which can be taught by anything but experience, and experience only can teach whether the trawl is sliding nicely over the bottom, the right speed to go, how much sail to carry, and all the details which make up good seamanship and mean all the difference between success and failure.

The collecting of water samples we find we can manage even in bad weather and a heavy sea. Trawling also can be done in weather when tow-netting is impossible; but the latter, especially if closing-nets be used, and the object is to determine the plankton fauna in different strata, really requires the calmest weather, or light breezes. In bad weather and a heavy swell the ship rides up and down so greatly as to throw very heavy strain upon the wire, and it means risking the total loss of the net, and frequently the silk net comes up torn and all its contents gone.

We prefer to tow-net under a light breeze, lowering the peak of the mainsail and swinging out the boom with a 'tackle' attached, and keeping the jib and mizzen standing. By keeping the ship well up to the wind we can regulate the speed of drift very nicely, and this must be very little in tow-netting. In trawling or dredging, a little more sail is required, and the course may be a little off the wind, so as to keep sufficient way on to move the trawl. The ship can, by careful handling, be kept fairly stationary for tow-netting, and a false anchor may even be employed. A very good substitute for this is to put out aft the big mid-water net, which may be allowed to drift with a good

length of warp. It soon fills and forms quite an efficient false anchor.

I purposely here do not go into great detail about the apparatus necessary on shipboard, or the methods of preserving different animals, as all this will be fully dealt with in the forthcoming handbook of the 'Challenger' Society. The foregoing remarks are little more than hints of the methods adopted on a sailing-ship, in which the various manipulations cannot be controlled so easily as when steam is available, and refer, of course, more particularly to our own methods, which we have had to learn for ourselves.

# HYDROGRAPHICAL OBSERVATIONS.

I.—THE FAEROE-SHETLAND CHANNEL.

II.—FROM IRELAND TO THE AZORES, MADEIRA, AND GIBRALTAR.

III.—FROM USHANT TO GIBRALTAR.

IV.—THE NORTH OF SHETLAND TO NORWAY.

# I.—THE HYDROGRAPHY OF THE FAEROE-SHETLAND CHANNEL.

By H. N. Dickson, M.A., D.Sc.

(*Reprinted from the 'Geographical Journal' for April*, 1903.)

During the summer months of 1900, 1901, and 1902, the cutter-yacht *Walwin*, belonging to Dr. R. Norris Wolfenden, was engaged in scientific research, under the owner's direction, in the channel between the Shetland and Faeroe Islands. The physical investigations consisted in (1) observations of temperature, for which Negretti and Zambra's reversing thermometers, Knudsen's modified form of the same, and the ordinary Miller-Casella instrument, were employed, sometimes separately, usually together for purposes of control; and (2) the collection of samples of water by means of Mill's slip water-bottle. Dr. Wolfenden has been good enough to entrust the working out of the observations to me, and I may be permitted at the outset to express the opinion that the way in which they have been made, in a region where work of the kind is always difficult and arduous, and under conditions in many ways unfavourable, reflects the greatest credit on Captain Buchan Henry and his crew. The labours of the *Walwin* have provided a unique series of pictures of the conditions occurring in the Channel, representing successive stages in the march of exceedingly complex phenomena with sufficient accuracy, and none of the modern expensive apparatus has been employed in the work, which was carried on from a small cutter of only 36 tons.[1]

[1] Some of the 1902 observations were made on the owner's second boat, the *Silver Belle*, a yawl of 130 tons. Dr. Wolfenden states that for all practical purposes the work is as easy to accomplish from the smaller boat. The larger the tonnage the greater the amount of wind required to sail the ship, and a good 'sailing breeze' is often too strong for satisfactory working of the instruments.

Table I. gives the characteristic numbers and the positions of the stations at which observations were made.

Table II. gives the temperatures observed. Where the observations were made with more than one instrument, the mean result is given; the differences rarely amounted to more than a few tenths of a degree Fahrenheit. The original readings were made according to the

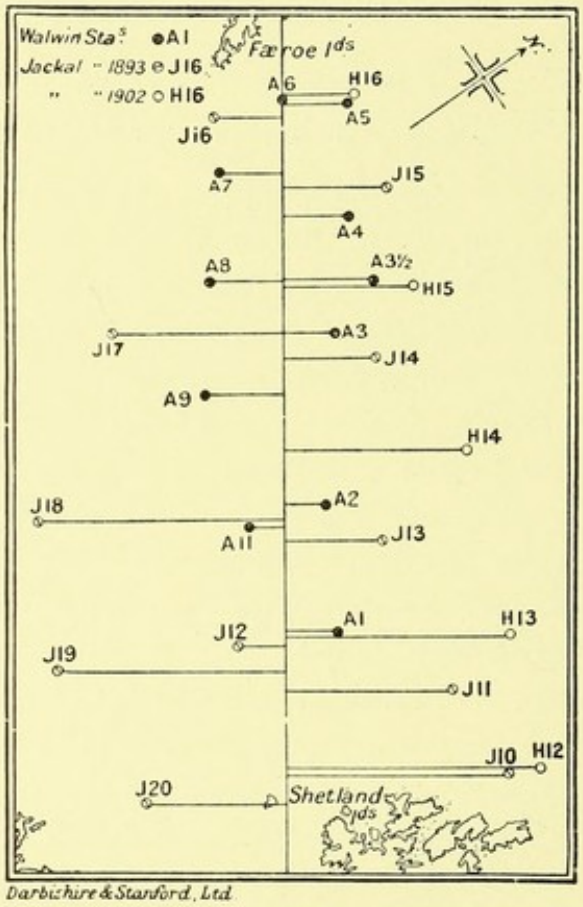



Fig. 6.—Map showing Positions of Stations and Line of Section.

Fahrenheit scale, and their consistency tested in the usual way by plotting curves. It has been thought best to convert them to the Centigrade scale, in which all the observations in the region already published are given, and which is being employed in the International investigations.

Table III. gives the salinities of the samples collected. The

chlorine titrations were carried out for me by Mr. J. J. Manley, Magdalen College Laboratory, Oxford, and my best thanks are due to him for his assistance. The salinities were originally obtained from the chlorines by the use of the table which I published in the 'Report of the Fishery Board for Scotland' (No. 12, 1893, p. 381). They have since been compared with Knudsen's authoritative tables, issued recently; the differences were insignificant.[1] I am indebted to my friend, Mr. O. J. R. Howarth, for assistance in reducing, tabulating, and plotting the results.

In arranging the material for discussion and comparison with other observations, the first point to be noted was that the most important series (and the only ones dealt with here) consist of nearly parallel double lines of soundings, one line starting from near the north end of the Shetlands, and another from near the south end, and both extending to the Faeroes. An examination of all the *Walwin's* observations, of the observations made by the *Jackal* in the cruise of 1893, and again by the *Jackal* in 1902 (see Helland-Hansen in *Nature*, vol. lxvi., p. 654), indicated that these lines were so close together that they could for all practical purposes be regarded as one and the same. Two points, in positions (approximately) Lat. 59° 56′ N., Long. 1° 24′ W., and Lat. 61° 45′ N., Long. 6° 48′ W., were accordingly selected, and joined on the chart by a straight line to which perpendiculars were drawn

[1] In his paper on hydrographical investigations in the Faeroe-Shetland Channel, etc., in the year 1902 (Report Cd. 2612, 1905), Helland-Hansen says: 'Dickson's calculations of the salinities are partially based upon Pettersson's tables. I have found that these give the salinities higher by almost 0·08 per cent. than Knudsen's tables.' I am unable to understand this, a comparison of my table with Knudsen's giving the following results:

SALINITY.

| Cl. | Knudsen. | Dickson. | Difference. |
|---|---|---|---|
| 17·5 | 31·62 | 31·65 | +0·03 |
| 18·0 | 32·52 | 32·54 | +0·02 |
| 18·5 | 33·42 | 33·44 | +0·02 |
| 19·0 | 34·33 | 34·33 | 0·00 |
| 19·5 | 35·23 | 35·23 | 0·00 |
| 20·0 | 36·13 | 36·12 | −0·01 |
| 20·5 | 37·03 | 37·01 | −0·02 |

H. N. D.

from the stations (Fig. 6). All the observations were then plotted upon vertical sections along that line. The method is no doubt open to criticism, but the errors introduced cannot exceed the errors incidental to the observations, and it makes the most of the available material.

In the result, we have from the *Walwin's* observations sections for the following dates:

July, 1900.
May and June, 1901.
June and July, 1901.
May, 1902.
June, 1902.
July, 1902 (temperature only).

To these may be added, completing the existing record:

*Jackal*, August, 1893.
,, (preliminary report only), August, 1902,

making eight more or less complete pictures in all (Figs. 7 to 15).[1]

In the Faeroe-Shetland Channel we have to deal with the opposing movements of water from the south and from the north. The northward-moving currents are of two kinds, (*a*) drift currents, produced at the surface by the winds in the locality; and (*b*) a stream current, which I have (*Phil. Trans. A.*, vol. cxcvi., p. 113) proposed to call the Norwegian branch of the European stream. This branch forms part of a stream-current relieving the water banked up against the Continental mass by the westerly winds; it varies in strength from year to year and from season to season, and its salinity also varies slightly, a high salinity probably indicating a large proportion of gulf-stream water, and a low salinity a large proportion of water from the Labrador current and the northern area of the Atlantic. Direct observations in the depth are still wanting, but the range of salinity may be estimated at from 35·4 per mille to 35·7 per mille. The southward-moving currents are also of two kinds, (*c*) water from

[1] In these sections the Shetland end of the line is on the right, the Faeroe end on the left.

the central and western parts of the Norwegian sea, most of which has probably originated in the area east and north-east of Newfoundland and been carried across as a drift, mixing with the 'Irminger' and 'Greenland' branches of the European stream. If the European stream is below its normal strength, it seems likely that this body of water will attain unusual volume, and part of it will try to make its way southward. The comparatively cold salt water observed by the *Jackal* in 1893 (Station VIII.), and again by Helland-Hansen in the *Jackal* in 1902 (*Nature*, *loc. cit.*), in the north-western part of the North Sea, is probably to be identified with it, as Helland-Hansen suggests, and it seems likely that the importance of this factor has been underestimated by the earlier investigators, especially, perhaps, in my report on the work of the *Jackal* in 1893. The second body of southward-moving water (*d*) is that derived from the melting of ice in the Arctic regions. This water is probably spread over the surface in summer and autumn, and makes its way southward to the east of Iceland and the Faeroe Islands. So far as the region under discussion is concerned, it may probably be assumed that the water from the centre of the Norwegian sea (*c*) has a salinity of 35 per mille to 35·3 per mille, and that a salinity of less than 35 per mille indicates a large admixture of water of Arctic origin (*d*).

The difficulty of interpreting the sections across the Faeroe-Shetland Channel in the light of the above is immensely increased by the fact that the line of section lies just in the region where the waters from the sources mentioned meet and mix, and that we have no simultaneous observations in the regions of origin. The difficulty is specially apparent in studying the distribution of temperature, for, unlike salinity, temperature may change without movement or mixture of the waters. The most important point is evidently to note that when the circulation is active, isothermals and isohalines are crowded together, showing strong gradients of temperature and saltness, while weak gradients are an indication of weak circulation, the waters moving slowly and being very completely mixed.

The general conditions controlling the movement and mixture of

waters are: (1) the Norwegian stream (*b*) is cut off below by the Wyville-Thomson ridge at a depth of about 300 fathoms—north of the ridge its waters are mixed with ice-cold water of slightly lower salinity drawn up by the 'undertow' to an amount depending partly on the velocity of the stream, and increasing with it (see 'Twelfth Report of the Fishery Board for Scotland,' p. 351); (2) the drift current (*a*) and the European stream are independent of one another, but where the former exists—*i.e.*, as a northward-moving current—the waters of (*a*) and (*b*) are likely to be indistinguishable by means of either temperature or salinity observations; (3) the southward-moving waters (*c*) and (*d*) may be independent, and they may or may not be fully mixed before entering the Faeroe-Shetland Channel; (4) when the northward-moving currents are strong, they will tend to be surface currents, because of the relatively high temperature of the waters. When they are weak, their waters will be cooled by contact and mixture with the cold underlying waters. The southward-moving waters will tend to be under-currents because of their low temperature, and will only rise to the surface when they are exceptionally strong relatively to the northward-moving currents, or when they contain an unusually large proportion of, on the one hand, warm Norwegian sea-water, or, on the other, fresh Arctic water.

Taking now the sections in order, the first is that for August, 1893, based on the *Jackal* observations. In the report on these observations I expressed the opinion (p. 352) that the conditions were there 'favourable to an increase of the Atlantic current,' but at the same time it was noted (p. 337) that during the observations the navigating lieutenant of the ship found 'a southerly drift amounting to approximately 10 miles in twenty-four hours.' With the information available at the time as to the sources from which the waters were derived, it was impossible to identify clearly all the factors involved, or to give a complete explanation of the movements going on. I had to content myself with an attempt to discuss the mechanism of the process of mixture of the northward and southward moving waters, on the assumption that the former (*a* and *b*) were one, and the

latter (*c* and *d*) one. The difficulties which arose led me to undertake an investigation of the movements of surface waters in the North Atlantic, and, as a result, to separate the stream current (*b*) from the surface drift (*a*); the resolution of the southward-moving waters into (*c*) and (*d*) is chiefly the result of the observations of the *Ingolf* expedition (1896) and of Professor Pettersson's discussions. In the light of these more recent conclusions, it appears from the section

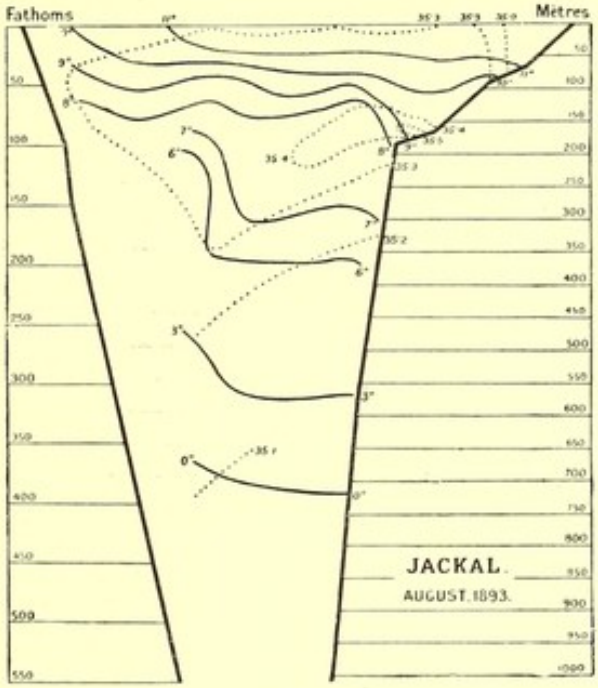



Fig. 7.—Faeroe-Shetland Channel. Temperature and Salinity, August, 1893. H.M.S. 'Jackal.'

(Fig. 7) that in August, 1893, the Norwegian stream was running strongly northward, its main centre lying on the eastern side of the channel at a depth of about 80 fathoms, while its waters extended nearly to the Faeroe Islands. The cold bottom water, which shows no marked tendency to rise towards the surface, was entirely cut off from a thin layer of relatively fresh surface water (salinity below 35·3), which covered the whole surface of the channel to a depth of a few fathoms, and near the Shetlands extended to the bottom. This layer was probably, as Helland-Hansen has suggested, water from the

Norwegian sea (*c*), rather than a mixture of it with water which had come from the south through the Faeroe-Shetland Channel, as I supposed at the time. Its southward movement would account for its appearance at Station VIII. in the north-west of the North Sea, referred to above, and for the southerly drift of the *Jackal* during the observations.

The section for July, 1900 (Fig. 8), shows a state of affairs so remarkable that if it were possible to doubt the accuracy of the

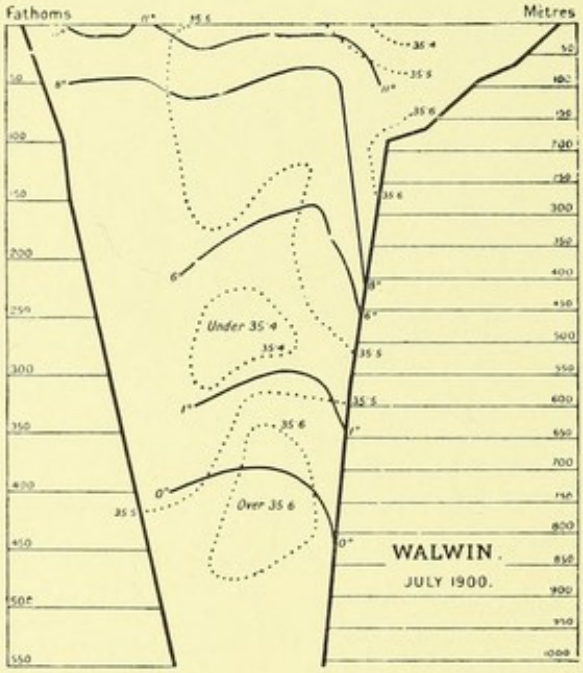



Fig. 8.—Faeroe-Shetland Channel. Temperature and Salinity, July, 1900. Yacht 'Walwin.'

observations, one would be almost inclined to take refuge in doing so, but the complete consistency of four sets of soundings makes the supposition unreasonable. Salinity is at all depths remarkably high, scarcely falling anywhere below 35·4. At a depth of 400 fathoms—*i.e.*, 100 fathoms below the Wyville-Thomson ridge, is a maximum of salinity of 35·6, in water *having a temperature of melting ice.* Above this is a mass of water of salinity about 35·4, the minimum occurring with low temperature near the middle of the channel in about 250 fathoms. Above this, again, the saltest (35·6) and warmest water

lies on the east side of the channel, although close to the Shetlands salinity falls again near the surface. This extraordinary distribution seems to indicate that at an earlier date than that of the section, probably in the previous winter, there had been a strong movement of very salt water from the Norwegian stream and surface drift (*a* and *b*), which from some external cause afterwards failed. Below 300 fathoms the water, protected by the Wyville-Thomson ridge, remained

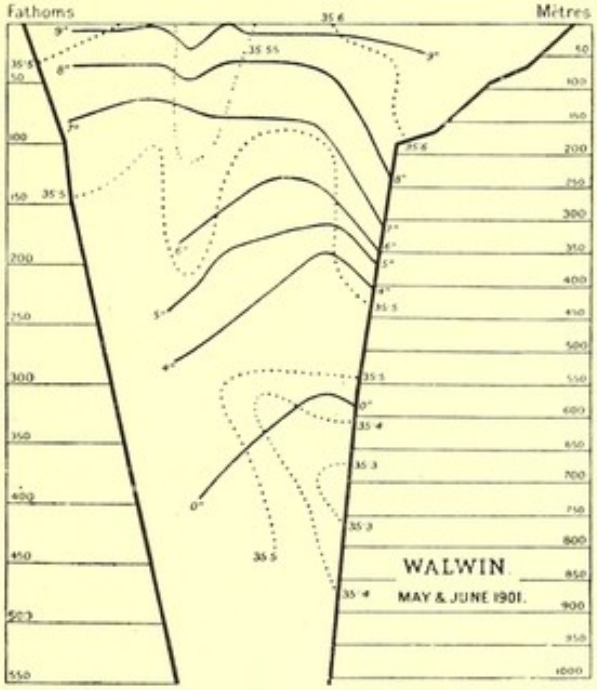



Fig. 9.—Faeroe-Shetland Channel. Temperature and Salinity, May and June, 1901. Yacht 'Walwin.'

stationary, and was gradually cooled down to 0° C. by contact and slight mixture with the water lying under it. Above 300 fathoms a southward movement probably set in, lowering both temperature and salinity, and this was followed, probably just before the date of the section, by a re-establishment of the Norwegian stream (*b*) in full force, the water being somewhat salter, but the stream in almost the same position as in 1893 (Fig. 7).

The season 1901 is represented by two sections (Figs. 9 and 10); the observations forming the first were made between May 14 and

June 4 ; those forming the second between July 4 and July 16. Thus the middle dates are May 24 and July 10, and a comparison is of particular interest, because these are the first sets of observations which have been made in this area at dates close enough to admit of direct comparison, or to give any idea of the rate at which changes occur. In both sections nearly the whole channel is filled with water of 35·5 salinity or over, and in the depth temperature is low. The

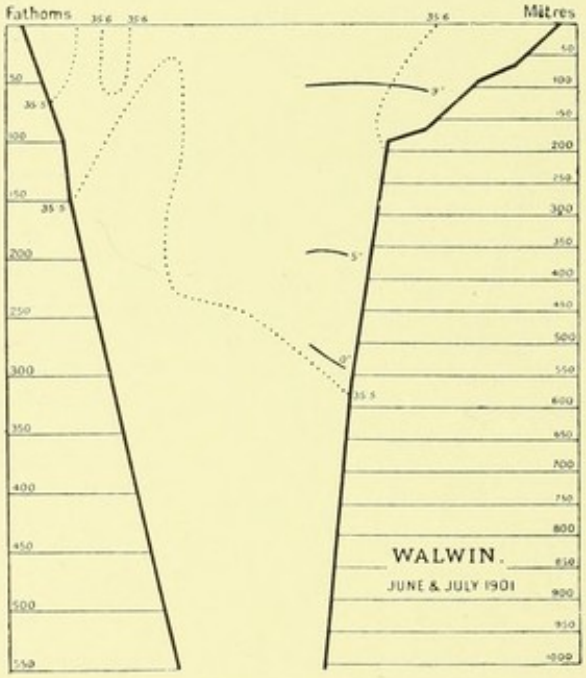



Fig. 10.—Faeroe-Shetland Channel. Temperature and Salinity, June and July, 1901. Yacht 'Walwin.'

freshest water (35·3) appears on the east side of the channel at a depth of 380 fathoms, apparently indicating an intrusion of deep water from the Norwegian sea into a mass of Atlantic water, which had been cooled down in the same way as in the previous years. It is to be observed that this centre of low salinity is also one of low temperature, the readings at 300 and 400 fathoms rising from east to west. All the western side of the channel is occupied by water of 35·5 salinity. In the strata nearer the surface we find the first indication of the features so strongly marked in 1902, in which the saltest and warmest waters

appear as two branches, one a little to the west of mid-channel, and another on the east side, close to the land. In the interval between May 24 and July 10 the distribution in the depth seems to have become more uniform. In the depth the centre of low temperature and salinity on the east side has disappeared, and apparently the whole breadth of the channel is occupied by water of about 35·4 salinity. In the upper layers the two branches of warm salt water are farther apart

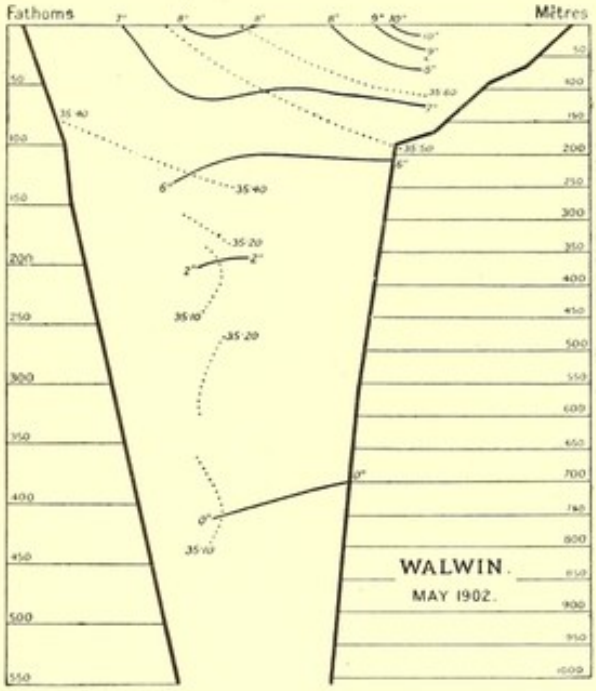



Fig. 11.—Faeroe-Shetland Channel. Temperature and Salinity, May, 1902. Yacht 'Walwin.'

at the surface, the western member is more strongly marked, while at intermediate depths (100 to 300 fathoms) salinity has increased slightly on the east side, and diminished on the west. The differences point in effect to a strengthening of both the northward and southward moving streams above 300 fathoms, the latter keeping to the west, while the former keeps to the east, but sends a narrow branch, 50 to 60 fathoms deep, along the western side. It is noteworthy that there is no indication of a southward movement of fresher water towards the Shetlands.

For the year 1902 we have four sections (Figs. 11 to 14), the middle dates being May 24, June 24, July 21, and August 29. Some are, of course, incomplete, and salinity observations are wanting for the July section, but it seems possible to follow the course of events with considerable certainty.

In the May section the first point to be noticed is the remarkably low temperature and salinity in the depth. Up to within 200 fathoms of the surface the salinity is about 35·2, slightly higher on the east

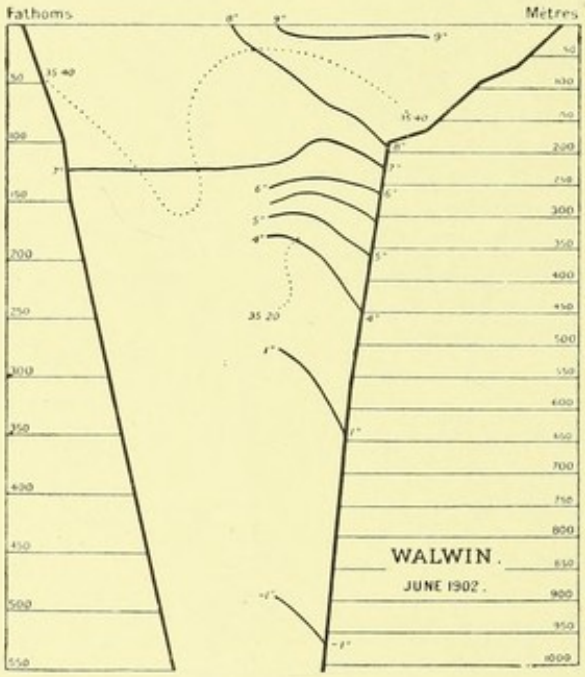



Fig. 12.—Faeroe-Shetland Channel. Temperature and Salinity, June, 1902. Yacht 'Walwin.'

side and lower on the west, while at that depth the temperature is only 2°. Nearer the surface the northward flow of water is apparent, the salinity rising above 35·6 in warm water on the east side, and scarcely falling below 35·5 on the west. In June it appears that the northward movement had ceased altogether, and that a southward set at all depths has begun, except on the west side of the channel, within about 100 fathoms of the surface, where the conditions remain practically unchanged. The surface salinity is now almost uniformly

35·4, and in the depth the isohalines of 35·2 and 35·1 appear to have moved eastwards. Temperature has fallen at the surface, become more uniform down to the 100-fathom line, and fallen at 400 and 500 fathoms. The June observations reveal for the first time, observations being wanting for May, a steep gradient of temperature on the east side between 100 and 200 fathoms. The 2° reading at Station A3 at 200 fathoms in May makes it likely that a similar distribution existed during that month.

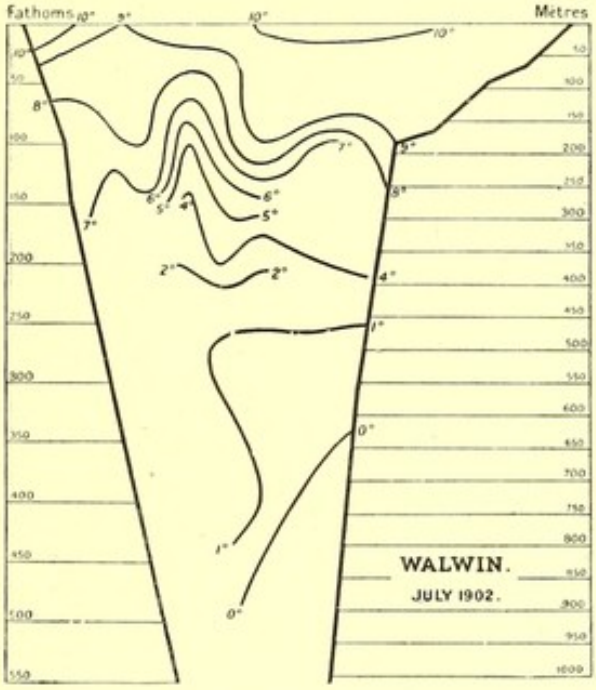



Fig. 13.—Faeroe-Shetland Channel. Temperature and Salinity, July, 1902. Yacht 'Walwin.'

In the July section the form of the isotherms shows a further advance of cold water in the depth. Temperature has fallen generally, and a wedge of cold water near Station A8 rises almost to the surface. On either side of this, warm water, possibly parts of northward-moving streams, extends down to something like 150 fathoms. In the August section, drawn from the observations of H.M.S. *Jackal* published in *Nature*, the cold wedge shows still further advance, and its summit has shifted more into the centre of the channel. The low

salinity at all depths is quite the most remarkable feature of the section, indicating an unusually large proportion of water of Arctic origin in the Norwegian sea. This water appears to be moving southwards in mid-channel, both at the surface and in the depth, a slight weakening being apparent between 50 and 100 fathoms, where the salinity rises above 35·1. On the western side the increase of salinity is so slight as to make it doubtful if any northward movement is

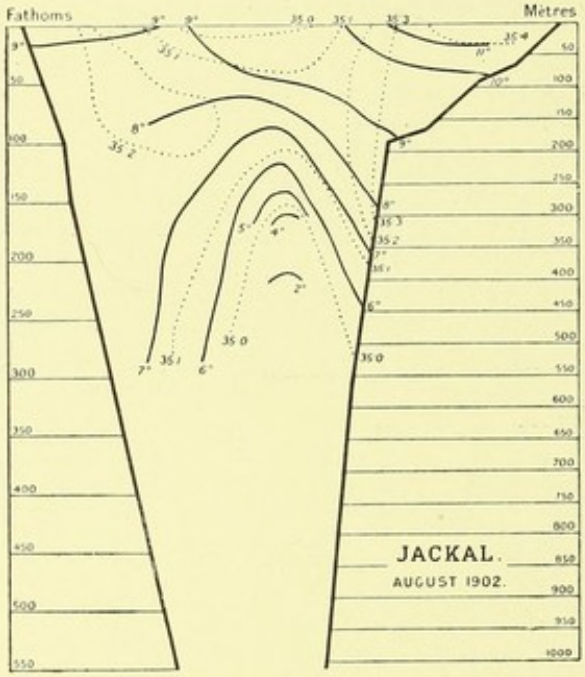



Fig. 14.—Faeroe-Shetland Channel. Temperature and Salinity, August, 1902. H.M.S. 'Jackal.'

taking place ; it seems more likely that the 35·4 water observed there in June is merely undergoing mixture with the fresher water, a view supported to some extent by its steady temperature. A northward movement is, however, apparent on the eastern side, where the temperature is relatively high, and the salinity rises above 35·4.

We may summarize these results as follows :—

1893.—Both northward and southward moving streams strong. The Norwegian stream occupied most of the channel in the intermediate depths ; below it water was moving southwards, and on the

surface a thin layer also moved southward ; this layer became thicker on both sides, and near the Shetlands extended to the bottom.

1900.—The whole channel is occupied by water from the south, northward movement having apparently been strong earlier in the season. At the date of the observations (July) little movement was in progress, but there are indications of intrusion of water from the north at a depth of about 300 fathoms, and at the surface on the east side.

1901.—There are indications of feeble southward movement in the depth, but most of the channel is occupied by water which has come from the south. A weak northerly movement is apparent near the surface, with some tendency to split into two branches, one west of mid-channel, the other near the east side.

1902.—Unusually cold fresh water filled the channel, at all depths below 150 fathoms, throughout the season. In May the surface waters were of southern origin, and were moving northward, but as the season progressed, southward movement increased both at the surface and in the depth, especially in mid-channel, the waters mixing with and driving out those of southern origin on each side. That this movement extended far to the southward is shown by the fact that an ice-floe was met with during July off the Treshinish Islands, on the west side of Mull. The summer of 1902 was one of the worst on record in the Faeroe-Shetland Channel, and hydrographical work was exceedingly difficult.

A comparison of the 1902 sections with the admirable charts of surface temperature published as insets in the British 'Pilot Chart of the North Atlantic' shows in the clearest manner the relation between the surface movements in the open ocean and the currents in the channel. In May the surface temperature was normal, or slightly below it, between the west coast of the British Isles and about Long. 15° W. Farther west, and to the north-west, there was a narrow band of water above the normal temperature, obviously supplying the water which was going northward on the east side of the channel. In June temperature was apparently below the normal over the whole of the

surface of the eastern Atlantic, and in the subsequent months the area of low temperature gradually narrowed, until in October it had entirely disappeared.

I hope to obtain data with regard to atmospheric pressure similar to those embodied in the Pilot Chart for October, for the earlier months, and to discuss their relation to the observations in the Faeroe-Shetland Channel in a later paper. The Pilot Charts in their present form will be an invaluable help in interpreting the observations to be made under the international scheme, and, as Dr. Wolfenden informs me that he intends to make simultaneous observations at depths down to 1,000 fathoms to the west of Ireland, the mechanism of the currents flowing from the central region should be completely and finally determined.

The conclusions arrived at up to the present may be stated thus:

1. Northward movement of water originating as a *drift* current is strongest in the Faeroe-Shetland Channel during winter.

2. Northward movement of water originating as a *stream* current is strongest in summer, being probably due to the extension of the 'Atlantic anticyclone.'

3. The northward movement 2 is the more uncertain, and varies most in different years.

4. In the transition stages between 1 and 2, or when 2 is abnormally weak, the water in the Faeroe-Shetland Channel may remain practically motionless for extended periods. If the channel is filled with water from the south, this water will gradually cool down and sink, being cooled by, and mixing with, the cold underlying waters.

5. To the north of the Faeroe-Shetland Channel the waters of the Norwegian sea consist of a mixture of waters of Arctic origin with those of Atlantic origin, the latter very similar to 1. The mixture is in most cases fairly complete, but during summer water of Arctic origin, set free by the melting of ice, may form a surface layer of considerable thickness.

6. The waters of the Norwegian sea make their way southward, under favourable conditions, into the Faeroe-Shetland Channel and

the North Sea. The entrance to the North Sea is probably effected every year, as there is no opposing northerly current on the western side. In the Faeroe-Shetland Channel the southward movement is normally prevented by the northerly currents 1 and 2, except at depths below 300 fathoms, where the northward currents are cut off by the Wyville-Thomson ridge, and at the surface, where there may be a southerly drift current. In exceptional cases, as in 1902, the northerly movement may be in abeyance, and water may move southward at all depths. It seems likely that the presence of this water in the North Sea has a special bearing on biological and fishery questions.

7. The movements of the surface waters of the sea and the temperature of the air near the British Isles do not stand in any direct relation of cause and effect. Northerly winds bring cold weather, and by drifting and 'banking' cold water from higher latitudes, bring cold surface water with them. Southerly winds bring warm weather, and bring warm water from low latitudes in the same way. The temperature of the surface water in the open sea influences the distribution of atmospheric pressure, as Pettersson has shown, and it will therefore affect the direction of the prevailing winds, but motion has nothing to do with this influence.

TABLE I.[1]

List of 'Walwin' Stations.

| Station. | Lat. N. | Long. W. | Station. | Lat. N. | Long. W. |
|---|---|---|---|---|---|
| | ° ′ | ° ′ | | ° ′ | ° ′ |
| A1 | 60 40 | 2 50 | A10 | 60 17 | 3 5 |
| A2 | 60 54 | 3 40 | A11 | 60 27 | 3 50 |
| A3 | 61 16 | 4 41 | B1 | 60 51 | 6 22 |
| A3½ | 61 28 | 4 50 | B2 | 60 17 | 6 22 |
| A4 | 61 32 | 5 20 | B3 | 59 46 | 6 20 |
| A5 | 61 45 | 6 02 | B4 | 60 00 | 5 20 |
| A6 | 61 34 | 6 20 | III. | Off Fitful Head. | |
| A7 | 61 14 | 6 08 | IV. | West of Yell sound. | |
| A8 | 61 00 | 5 30 | V. | Off Flugga L. H. | |
| A9 | 60 45 | 4 50 | VI. | East of Bressay. | |

[1] For numbers and positions of the *Jackal* stations in 1893 and 1902, see 'Twelfth Report of the Fishery Board for Scotland,' p. 364, and *Nature*, vol. lxvi., p. 654.

## TABLE II.

### Temperature Observations.

| Date. | Position. | Depth. Fath. | Depth. M. | Temp. °C. |
|---|---|---|---|---|
| 1899. | | | | |
| July 1 | 8 miles off Hoy Hd. | 0 | 0 | 10·6 |
| ,, | ,, ,, | 30 | 55 | 10·0 |
| ,, | N. of Westray ... | 0 | 0 | 10·6 |
| ,, | ,, ,, ... | 40 | 73 | 10·6 |
| ,, | S. W. of Sumburgh Hd. | 0 | 0 | 9·7 |
| ,, | ,, ,, | 65 | 119 | 8·9 |
| ,, 3 | N.W. of Yell sound | 0 | 0 | 11·7 |
| ,, | ,, ,, | 50 | 91 | 10·8 |
| ,, | N.E. of Lamba Ness | 0 | 0 | 11·7 |
| ,, | ,, ,, | 55 | 101 | 9·4 |
| ,, 4 | E. of Bressay ... | 0 | 0 | 12·2 |
| ,, | ,, ,, ... | 55 | 101 | 8·1 |
| ,, | E. of Fair Isle ... | 0 | 0 | 10·0 |
| ,, | ,, ,, ... | 60 | 110 | 8·6 |
| ,, | E. of Copinshay ... | 0 | 0 | 10·6 |
| ,, | ,, ,, ... | 43 | 79 | 8·9 |
| Oct. 14 | 8 miles off Hoy Hd. | 0 | 0 | 10·6 |
| ,, | ,, ,, | 40 | 73 | 11·1 |
| ,, 21 | Station IV. ... | 0 | 0 | 9·4 |
| ,, | ,, ... | 59 | 108 | 10·6 |
| ,, 23 | Station V. ... | 0 | 0 | 9·7 |
| ,, | ,, ... | 55 | 101 | 10·3 |
| ,, 27 | Station VI. ... | 0 | 0 | 9·4 |
| ,, | ,, ... | 52 | 95 | 11·1 |
| Nov. 10 | Station III. ... | 0 | 0 | 7·2 |
| ,, | ,, ... | 55 | 101 | 8·1 |
| ,, 25 | Station IV. ... | 0 | 0 | 6·9 |
| ,, | ,, ... | 60 | 110 | 9·4 |
| ,, 27 | Station V. ... | 0 | 0 | 8·3 |
| ,, | ,, ... | 52 | 95 | 9·2 |
| Dec. 3 | Station VI. ... | 0 | 0 | 7·2 |
| ,, | ,, ... | 50 | 91 | 8·9 |
| ,, 5 | Station III. ... | 0 | 0 | 6·7 |
| ,, | ,, ... | 55 | 101 | 8·9 |
| ,, 15 | Station IV. ... | 0 | 0 | 6·9 |
| ,, | ,, ... | 40 | 73 | 8·6 |
| ,, 18 | Station V. ... | 0 | 0 | 7 2 |
| ,, | ,, ... | 56 | 102 | 8·6 |
| 1900. | | | | |
| Jan. 1 | Station VI. ... | 0 | 0 | 7·2 |
| ,, | ,, ... | 52 | 95 | 7·8 |
| ,, | Station III. ... | 0 | 0 | 7·5 |
| ,, | ,, ... | 59 | 108 | 8·1 |
| ,, 30 | Station IV. ... | 0 | 0 | 7·5 |
| ,, | ,, ... | 53 | 97 | 8·1 |
| Feb. 9 | Station V. ... | 0 | 0 | 7·2 |
| ,, | ,, ... | 54 | 99 | 7·5 |
| ,, 14 | Station VI. ... | 0 | 0 | 6·1 |
| ,, | ,, ... | 46 | 84 | 6·9 |
| ,, | Station III. ... | 0 | 0 | 5·8 |
| ,, | ,, ... | 61 | 111 | 6·7 |

| Date. | Position. | Depth. Fath. | Depth. M. | Temp. °C. |
|---|---|---|---|---|
| 1900. | | | | |
| Mar. 1 | Station IV. ... | 0 | 0 | 5·0 |
| ,, | ,, ... | 58 | 106 | 5·8 |
| ,, 3 | Station V. ... | 0 | 0 | 6·1 |
| ,, | ,, ... | 53 | 97 | 6·4 |
| ,, 4 | Station VI. ... | 0 | 0 | 6·1 |
| ,, | ,, ... | 59 | 108 | 6·1 |
| ,, 6 | Station III. ... | 0 | 0 | 6·1 |
| ,, | ,, ... | 70 | 128 | 6·1 |
| ,, 23 | Station IV. ... | 0 | 0 | 6·1 |
| ,, | ,, ... | 55 | 101 | 6·1 |
| ,, 24 | Station V. ... | 0 | 0 | 5·8 |
| ,, | ,, ... | 47 | 86 | 6·4 |
| ,, 27 | Station VI. ... | 0 | 0 | 5·0 |
| ,, | ,, ... | 50 | 91 | 5·8 |
| ,, 30 | Station III. ... | 0 | 0 | 4·4 |
| ,, | ,, ... | 64 | 117 | 5·6 |
| Apr. 21 | Station IV. ... | 0 | 0 | 6·7 |
| ,, | ,, ... | 53 | 97 | 6·4 |
| ,, 22 | Station V. ... | 0 | 0 | 6·7 |
| ,, | ,, ... | 54 | 99 | 6·7 |
| ,, 24 | Station VI. ... | 0 | 0 | 6·4 |
| ,, | ,, ... | 65 | 119 | 6·4 |
| ,, 27 | Station III. ... | 0 | 0 | 5·8 |
| ,, | ,, ... | 65 | 119 | 5·8 |
| May 24 | Station V. ... | 0 | 0 | 8·4 |
| ,, | ,, ... | 54 | 99 | 7·2 |
| ,, 25 | Station IV. ... | 0 | 0 | 8·6 |
| ,, | ,, ... | 64 | 117 | 7·2 |
| ,, 26 | Station III. ... | 0 | 0 | 6·9 |
| ,, | ,, ... | 66 | 121 | 6·4 |
| June 9 | 17 miles W.N.W. of Flugga L. H. | 0 | 0 | 8·4 |
| ,, | ,, ,, | 66 | 121 | 8·4 |
| ,, | 6 miles off Yell sound ... ... | 0 | 0 | 8·1 |
| ,, | ,, ,, | 55 | 101 | 7·2 |
| ,, 12 | Station IV. ... | 0 | 0 | 10·0 |
| ,, | ,, ... | 72 | 132 | 8·6 |
| ,, 13 | 10 miles S.S.W. of IV. ... ... | 0 | 0 | 9·2 |
| ,, | ,, ,, | 60 | 110 | 7·8 |
| ,, | Station III. ... | 0 | 0 | 8·6 |
| ,, | ,, ... | 62 | 113 | 7·5 |
| July 11 | Station A1 ... | 0 | 0 | 13·3 |
| ,, | ,, ... | 50 | 91 | 11·1 |
| ,, | ,, ... | 100 | 183 | 10·6 |
| ,, | ,, ... | 150 | 274 | 9·4 |
| ,, | Station A2 ... | 0 | 0 | 11·1 |
| ,, | ,, ... | 50 | 91 | 7·2 |
| ,, | ,, ... | 100 | 183 | 7·2 |
| ,, 12 | Station A3 ... | 0 | 0 | 11·1 |
| ,, | ,, ... | 50 | 91 | 8·1 |

TABLE II.—TEMPERATURE OBSERVATIONS (*continued*).

| Date. | Position. | Depth. Fath. | Depth. M. | Temp. °C. |
|---|---|---|---|---|
| 1900. | | | | |
| July 13 | Station A4 ... | 0 | 0 | 10·3 |
| ,, | ,, ... | 50 | 91 | 7·9 |
| ,, | ,, ... | 93 | 170 | 7·2 |
| ,, | Station A5 ... | 0 | 0 | 11·1 |
| ,, | ,, ... | 50 | 91 | 7·9 |
| ,, | ,, ... | 84 | 154 | 7·9 |
| ,, 21 | Station A6 ... | 0 | 0 | 10·6 |
| ,, | ,, ... | 100 | 183 | 8·1 |
| ,, | Station A7 ... | 0 | 0 | 10·6 |
| ,, | ,, ... | 50 | 91 | 8·1 |
| ,, 22 | Station A8 ... | 0 | 0 | 11·4 |
| ,, | ,, ... | 100 | 183 | 7·8 |
| ,, | ,, ... | 350 | 640 | 0·6 |
| ,, 23 | Station A9 ... | 0 | 0 | 11·7 |
| ,, | ,, ... | 100 | 183 | 8·9 |
| Aug. 28 | 10 miles N.E. ½ N. from Station A1 | 0 | 0 | 12·2 |
| ,, | ,, ... | 50 | 91 | 9·4 |
| ,, | ,, ... | 100 | 183 | 9·2 |
| ,, | ,, ... | 200 | 366 | 8·4 |
| ,, | ,, ... | 280 | 512 | 7·8 |
| ,, | 20 miles N.N.E. of Station A1 ... | 0 | 0 | 12·2 |
| ,, | ,, ,, | 80 | 146 | 9·1 |
| ,, | ,, ,, | 150 | 274 | 8·4 |
| ,, | ,, ,, | 250 | 457 | 6·1 |
| ,, | ,, ,, | 350 | 640 | −0·6 |
| ,, 29 | Station A2 ... | 0 | 0 | 11·4 |
| ,, | ,, ... | 50 | 91 | 8·5 |
| ,, | ,, ... | 100 | 183 | 7·4 |
| ,, | ,, ... | 200 | 366 | 5·3 |
| ,, | ,, ... | 300 | 549 | 1·0 |
| ,, | ,, ... | 400 | 732 | 0·0 |
| ,, | ,, ... | 500 | 914 | −0·7 |
| Oct. 4 | Station III. ... | 0 | 0 | 9·4 |
| ,, | ,, ... | 70 | 128 | 10·0 |
| ,, 10 | Station IV. ... | 0 | 0 | 10·0 |
| ,, | ,, ... | 75 | 104 | 10·6 |
| ,, 16 | Station V. ... | 0 | 0 | 8·9 |
| ,, | ,, ... | 75 | 137 | 10·0 |
| ,, 19 | Station VI. ... | 0 | 0 | 10·0 |
| ,, | ,, ... | 57 | 104 | 10·0 |
| 1901. | | | | |
| Jan. 12 | Station IV. ... | 0 | 0 | 7·8 |
| ,, | ,, ... | 62 | 113 | 7·8 |
| ,, 19 | Station V. ... | 0 | 0 | 7·2 |
| ,, | ,, ... | 55 | 101 | 7·8 |
| Feb. 2 | Station VI. ... | 0 | 0 | 6·1 |
| ,, | ,, | 60 | 110 | 7·2 |
| ,, | Station III. ... | 0 | 0 | 5·6 |
| ,, | ,, ... | 62 | 113 | 6·7 |
| May 14 | Station A1 ... | 0 | 0 | 9·7 |
| ,, | ,, ... | 114 | 209 | 8·6 |
| ,, 15 | Station A2 ... | 0 | 0 | 9·2 |
| ,, | ,, ... | 45 | 82 | 7·4 |
| ,, | ,, ... | 100 | 183 | 6·1 |
| ,, | ,, ... | 200 | 366 | 3·0 |
| 1901. | | | | |
| May 15 | Station A2 ... | 300 | 549 | 0·1 |
| ,, | ,, ... | 400 | 732 | −0·6 |
| ,, | ,, ... | 500 | 914 | −1·0 |
| ,, 21 | Station A3 ... | 0 | 0 | 8·9 |
| ,, | ,, ... | 45 | 82 | 7·3 |
| ,, | ,, ... | 100 | 183 | 6·8 |
| ,, | ,, ... | 200 | 366 | 4·7 |
| ,, | ,, ... | 300 | 549 | 1·2 |
| ,, | ,, ... | 400 | 732 | −0·2 |
| ,, | Station A4 ... | 0 | 0 | 8·9 |
| ,, | ,, ... | 45 | 82 | 7·5 |
| ,, | ,, ... | 115 | 210 | 6·7 |
| ,, | ,, ... | 120 | 220 | 6·7 |
| ,, | Station A5 ... | 0 | 0 | 8·9 |
| ,, | ,, ... | 90 | 165 | 6·7 |
| ,, 29 | Station A6 ... | 0 | 0 | 9·2 |
| ,, | ,, ... | 45 | 82 | 7·5 |
| ,, | ,, ... | 100 | 183 | 6·8 |
| ,, | ,, ... | 145 | 265 | 6·7 |
| ,, | ,, ... | 150 | 274 | 6·7 |
| ,, | Station A7 ... | 0 | 0 | 9·2 |
| ,, | ,, ... | 45 | 82 | 7·8 |
| ,, | ,, ... | 80 | 146 | 6·7 |
| ,, | ,, ... | 135 | 247 | 6·7 |
| June 3 | Station A8 ... | 0 | 0 | 10·4 |
| ,, | ,, ... | 45 | 82 | 8·1 |
| ,, | ,, ... | 100 | 183 | 6·7 |
| ,, | ,, ... | 200 | 366 | 5·7 |
| ,, | ,, ... | 255 | 467 | 4·2 |
| ,, | Station A9 ... | 0 | 0 | 10·8 |
| ,, | ,, ... | 45 | 82 | 7·5 |
| ,, | ,, ... | 100 | 183 | 6·4 |
| ,, | ,, ... | 200 | 366 | 4·7 |
| ,, | ,, ... | 300 | 549 | 0·8 |
| ,, | ,, ... | 400 | 732 | −0·3 |
| ,, 4 | Station A11 ... | 0 | 0 | 10·6 |
| ,, | ,, ... | 50 | 91 | 8·9 |
| ,, | ,, ... | 100 | 183 | 8·4 |
| ,, | ,, ... | 200 | 366 | 8·4 |
| ,, 19 | Station A1 ... | 0 | 0 | 9·7 |
| ,, | ,, ... | 50 | 91 | 9·0 |
| ,, | ,, ... | 100 | 183 | 8·4 |
| ,, | ,, ... | 110 | 201 | 8·4 |
| ,, 20 | Station A2 ... | 0 | 0 | 10·0 |
| ,, | ,, ... | 45 | 82 | 9·1 |
| ,, | ,, ... | 100 | 183 | 8·5 |
| ,, | ,, ... | 200 | 366 | 4·4 |
| ,, | ,, ... | 300 | 549 | 0·1 |
| ,, | ,, ... | 400 | 732 | −0·3 |
| ,, | ,, ... | 500 | 914 | −0·7 |
| July 27 | Station A1 ... | 0 | 0 | 12·5 |
| ,, | ,, ... | 45 | 82 | 9·4 |
| ,, | ,, ... | 80 | 146 | 8·9 |
| ,, | ,, ... | 130 | 238 | 8·6 |
| ,, | Station A2 ... | 0 | 0 | 12·2 |
| ,, | ,, ... | 45 | 82 | 9·2 |
| ,, | ,, ... | 100 | 183 | 7·8 |

TABLE II.—TEMPERATURE OBSERVATIONS (*continued*).

| Date. | Position. | Depth. Fath. | Depth. M. | Temp. °C. |
|---|---|---|---|---|
| 1901. | | | | |
| July 27 | Station A2 ... | 500 | 914 | -0·7 |
| 1902. | | | | |
| May 17 | Station A1 ... | 0 | 0 | 10·8 |
| ,, | ,, ... | 100 | 183 | 6·1 |
| ,, 18 | Station A2 ... | 0 | 0 | 7·8 |
| ,, | ,, ... | 400 | 732 | -0·1 |
| ,, | ,, ... | 500 | 914 | -0·6 |
| ,, | ,, ... | 608 | 1112 | -1·1 |
| ,, 20 | Station A3 ... | 0 | 0 | 8·4 |
| ,, | ,, ... | 50 | 91 | 7·2 |
| ,, | ,, ... | 100 | 183 | 6·1 |
| ,, | ,, ... | 200 | 366 | 1·9 |
| ,, | ,, ... | 300 | 549 | 0·6 |
| ,, | ,, ... | 400 | 732 | 0·2 |
| ,, 21 | Station A4 ... | 0 | 0 | 7·2 |
| ,, | ,, ... | 50 | 91 | 6·7 |
| ,, | ,, ... | 108 | 198 | 6·7 |
| June 1 | Station B3 ... | 0 | 0 | 8·6 |
| ,, | ,, ... | 50 | 91 | 8·4 |
| ,, | ,, ... | 100 | 183 | 7·2 |
| ,, 19 | Station A1 ... | 0 | 0 | 9·2 |
| ,, | ,, ... | 110 | 201 | 7·8 |
| ,, 21 | Station A2 ... | 0 | 0 | 8·4 |
| ,, | ,, ... | 200 | 366 | 3·9 |
| ,, 22 | Station A3 ... | 0 | 0 | 7·8 |
| ,, | Station A4 ... | 0 | 0 | 7·9 |
| ,, | ,, ... | 50 | 91 | 7·5 |
| ,, | ,, ... | 110 | 201 | 7·2 |
| ,, | Station A5 ... | 0 | 0 | 8·1 |
| ,, | ,, ... | 55 | 101 | 7·2 |
| ,, 26 | Station A6 ... | 0 | 0 | 8·6 |
| ,, | ,, ... | 110 | 201 | 7·2 |
| ,, 27 | Between A7 and A8 | 0 | 0 | 8·9 |
| ,, | ,, ,, | 155 | 284 | 6·7 |
| ,, 28 | Between A2 and A9 | 0 | 0 | 9·4 |
| ,, | ,, ,, | 50 | 91 | 7·8 |
| ,, | ,, ,, | 100 | 183 | 7·2 |
| ,, | ,, ,, | 200 | 366 | 2·8 |
| ,, | ,, ,, | 300 | 549 | 0·6 |
| ,, | ,, ,, | 400 | 732 | -0·3 |
| ,, | ,, ,, | 500 | 914 | -1·1 |
| ,, | Station A2 ... | 0 | 0 | 9·4 |
| ,, | ,, ... | 50 | 91 | 8·4 |
| ,, | ,, ... | 100 | 183 | 6·7 |
| ,, | ,, ... | 200 | 366 | 4·4 |
| ,, | ,, ... | 300 | 549 | 1·4 |
| ,, | ,, ... | 400 | 732 | -0·6 |
| ,, | ,, ... | 500 | 914 | -0·7 |
| ,, | ,, ... | 600 | 1097 | -1·1 |
| ,, 29 | Between A1 and A10 | 0 | 0 | 9·4 |

| Date. | Position. | Depth. Fath. | Depth. M. | Temp. °C. |
|---|---|---|---|---|
| 1902. | | | | |
| June 29 | Between A1 and A10 | 120 | 220 | 8·9 |
| July 9 | 6 miles inside A1... | 0 | 0 | 10·0 |
| ,, | ,, ,, ... | 80 | 146 | 8·4 |
| ,, 15 | Station A2 ... | 0 | 0 | 10·0 |
| ,, | ,, ... | 50 | 91 | 7·8 |
| ,, | ,, ... | 100 | 183 | 6·7 |
| ,, | ,, ... | 200 | 366 | 3·9 |
| ,, | Station A3 ... | 0 | 0 | 9·4 |
| ,, | ,, ... | 50 | 91 | 7·8 |
| ,, | ,, ... | 100 | 183 | 6·7 |
| ,, | ,, ... | 200 | 366 | 3·9 |
| ,, 16 | Station A4 ... | 0 | 0 | 9·4 |
| ,, | ,, ... | 120 | 220 | 7·8 |
| ,, 17 | Station A5 ... | 0 | 0 | 8·4 |
| ,, | ,, ... | 75 | 137 | 7·8 |
| ,, 20 | Station A6 ... | 0 | 0 | 10·6 |
| ,, | ,, ... | 120 | 220 | 7·8 |
| ,, | Station A7 ... | 0 | 0 | 8·9 |
| ,, | ,, ... | 120 | 220 | 6·9 |
| ,, 21 | 8 miles E. of A8 ... | 0 | 0 | 9·7 |
| ,, | ,, ,, ... | 50 | 91 | 7·2 |
| ,, | ,, ,, ... | 100 | 183 | 5·0 |
| ,, | ,, ,, ... | 200 | 366 | 1·9 |
| ,, | ,, ,, ... | 260 | 476 | 1·1 |
| ,, | Station A9 ... | 0 | 0 | 10·0 |
| ,, | ,, ... | 50 | 91 | 9·4 |
| ,, | ,, ... | 100 | 183 | 8·9 |
| ,, | ,, ... | 200 | 366 | 2·2 |
| ,, | ,, ... | 400 | 732 | 1·1 |
| ,, | ,, ... | 500 | 914 | -0·6 |
| ,, 22 | 11 miles S. of A11 | 0 | 0 | 10·6 |
| ,, | ,, ,, | 80 | 146 | 8·9 |
| ,, | Station A10 ... | 0 | 0 | 9·4 |
| ,, | ,, ... | 80 | 146 | 8·6 |
| Aug. 1 | 17 miles off Foula | 75 | 137 | 8·4 |
| ,, | Station A1 ... | 0 | 0 | 11·4 |
| ,, | ,, ... | 110 | 201 | 8·9 |
| ,, 3 | 10 miles S. of A2... | 0 | 0 | 10·6 |
| ,, | ,, ,, ... | 100 | 183 | 6·7 |
| ,, | ,, ,, ... | 200 | 366 | 3·9 |
| ,, | ,, ,, ... | 300 | 549 | 0·3 |
| ,, | ,, ,, ... | 400 | 732 | -0·6 |
| ,, | ,, ,, ... | 500 | 914 | -1·1 |
| ,, 5 | 10 miles S. of A9... | 0 | 0 | 10·7 |
| ,, | ,, ,, ... | 200 | 366 | 8·4 |
| ,, | ,, ,, ... | 400 | 732 | 0·0 |
| ,, | ,, ,, ... | 500 | 914 | -0·6 |
| ,, | Station B4 ... | 0 | 0 | 11·7 |
| ,, | ,, ... | 150 | 274 | 9·2 |
| ,, | ,, ... | 260 | 476 | 8·4 |

## TABLE III.

### Salinity Observations.

| No. of Sample. | Date. | Position. | Depth. F'th. | Depth. M. | Cl. | Salinity per Mille. | No. of Sample. | Date. | Position. | Depth. F'th. | Depth. M. | Cl. | Salinity per Mille. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1900. | | | | | | | 1901. | | | | | |
| 1 | May 24 | V. | 0 | 0 | 19·59 | 35·40 | 53 | Jan. 19 | V. | 0 | 0 | 19·51 | 35·25 |
| 2 | ,, 25 | IV. | 0 | 0 | 19·67 | 35·54 | 54 | ,, | ,, | 112 | 205 | 19·61 | 35·43 |
| 3 | ,, 26 | III. | 0 | 0 | 19·66 | 35·52 | 55 | Feb. 2 | III. | 0 | 0 | 19·63 | 35·47 |
| 4 | June 3 | III. | 0 | 0 | 19·63 | 35·47 | 56 | ,, | ,, | 130 | 238 | 19·59 | 35·40 |
| 5 | ,, 12 | IV. | 0 | 0 | 19·66 | 35·52 | 57 | ,, | VI. | 0 | 0 | 19·60 | 35·41 |
| 6 | ,, 13 | III. | 0 | 0 | 19·77 | 35·72 | 58 | ,, | ,, | 153 | 280 | 19·65 | 35·50 |
| 7 | July 11 | A1 | 0 | 0 | 19·58 | 35·38 | 59 | May 14 | A1 | 0 | 0 | 19·71 | 35·61 |
| 8 | ,, | ,, | 100 | 183 | 19·74 | 35·66 | 60 | ,, | ,, | 57 | 104 | 19·72 | 35·63 |
| 9 | ,, | ,, | 150 | 274 | 19·67 | 35·54 | 61 | ,, | ,, | 114 | 209 | 19·67 | 35·54 |
| 10 | ,, | A2 | 400 | 732 | 19·70 | 35·59 | 62 | ,, | ,, | 0 | 0 | 19·74 | 35·66 |
| 11 | ,, | ,, | 500 | 914 | 19·67 | 35·54 | 63 | ,, 15 | A2 | 0 | 0 | 19·70 | 35·59 |
| 12 | ,, 12 | A2 | 0 | 0 | 19·65 | 35·50 | 64 | ,, | ,, | 100 | 183 | 19·65 | 35·50 |
| 13 | ,, | ,, | 100 | 183 | 19·65 | 35·50 | 65 | ,, | ,, | 200 | 366 | 19·65 | 35·50 |
| 14 | ,, | ,, | 200 | 366 | 19·68 | 35·56 | 66 | ,, | ,, | 300 | 549 | 19·65 | 35·50 |
| 15 | ,, | ,, | 300 | 549 | 19 61 | 35·43 | 67 | ,, | ,, | 400 | 732 | 19·53 | 35·28 |
| 16 | ,, | A3 | 0 | 0 | 19·65 | 35·50 | 68 | ,, | ,, | 500 | 914 | 19·61 | 35·43 |
| 17 | ,, | ,, | 100 | 183 | 19·65 | 35·50 | 69 | ,, | 60° 43′ N. 3° 22′ W. | 0 | 0 | 19·69 | 35·58 |
| 18 | ,, | ,, | 200 | 366 | 19·63 | 35·47 | | | | | | | |
| 19 | ,, | ,, | 300 | 549 | 19·58 | 35·38 | 70 | ,, | 60° 35′ N. 2° 25′ W. | 0 | 0 | 19·76 | 35·70 |
| 20 | ,, 13 | A4 | 0 | 0 | 19·61 | 35·43 | | | | | | | |
| 21 | ,, | ,, | 50 | 91 | 19·63 | 35·47 | 71 | ,, 21 | A3 | 0 | 0 | 19·69 | 35·58 |
| 22 | ,, | ,, | 90 | 165 | 19·61 | 35·43 | 72 | ,, | ,, | 100 | 183 | 19·67 | 35·54 |
| 23 | ,, | A5 | 0 | 0 | 19·61 | 35·43 | 73 | ,, | ,, | 200 | 366 | 19·65 | 35·50 |
| 24 | ,, | ,, | 50 | 91 | 19·61 | 35·43 | 74 | ,, | ,, | 300 | 549 | 19·65 | 35·50 |
| 25 | ,, | ,, | 80 | 146 | 19·60 | 35·41 | 75 | ,, | ,, | 400 | 732 | 19·65 | 35·50 |
| 26 | ,, 20 | A7 | 0 | 0 | 19·67 | 35·54 | 76 | ,, | A4 | 0 | 0 | 19·66 | 35·52 |
| 27 | ,, 21 | A6 | 0 | 0 | 19·61 | 35·43 | 77 | ,, | ,, | 80 | 146 | 19·65 | 35·50 |
| 28 | ,, | A7 | 100 | 183 | 19·65 | 35·50 | 78 | ,, | ,, | 115 | 210 | 19·63 | 35·47 |
| 29 | ,, | ,, | 150 | 274 | 19·61 | 35·43 | 79 | ,, | A5 | 0 | 0 | 19·65 | 35·50 |
| 30 | ,, 22 | A8 | 0 | 0 | 19·65 | 35·50 | 80 | ,, | ,, | 80 | 146 | 19·65 | 35·50 |
| 31 | ,, | ,, | 100 | 183 | 19·65 | 35·50 | 81 | ,, 29 | A6 | 0 | 0 | 19·63 | 35·47 |
| 32 | ,, | ,, | 150 | 274 | 19·65 | 35·50 | 82 | ,, | ,, | 100 | 183 | 19·65 | 35·50 |
| 33 | ,, | ,, | 250 | 457 | 19·60 | 35·41 | 83 | ,, | ,, | 150 | 274 | 19·65 | 35·50 |
| 34 | ,, | ,, | 350 | 640 | 19·61 | 35·43 | 84 | ,, | A7 | 0 | 0 | 19·65 | 35·50 |
| 35 | ,, | ,, | 450 | 823 | 19·67 | 35·54 | 85 | ,, | ,, | 80 | 146 | 19·65 | 35·50 |
| 36 | ,, 23 | A9 | 0 | 0 | 19·67 | 35·54 | 86 | ,, | ,, | 130 | 238 | 19·65 | 35·50 |
| 37 | ,, | ,, | 100 | 183 | 19·65 | 35·50 | 87 | ,, | 61° 37′ N. 6° 18′ W. | 0 | 0 | 19·70 | 35·59 |
| 38 | ,, | ,, | 250 | 457 | 19·58 | 35·38 | | | | | | | |
| 39 | ,, | ,, | 350 | 640 | 19·72 | 35·63 | 88 | ,, 30 | 61° 30′ N. 6° 37′ W. | 0 | 0 | 19·81 | 35·79 |
| 40 | ,, | ,, | 440 | 805 | 19·75 | 35·68 | | | | | | | |
| 41 | Oct. 4 | III. | 35 | 64 | 19·65 | 35·50 | 89 | June 3 | A8 | 0 | 0 | 19·69 | 35·58 |
| 42 | ,, | ,, | 70 | 128 | 19·59 | 35·40 | 90 | ,, | ,, | 100 | 183 | 19·69 | 35·58 |
| 43 | ,, | ,, | 0 | 0 | 19·67 | 35·54 | 91 | ,, | ,, | 200 | 366 | 19·66 | 35·52 |
| 44 | ,, 10 | IV. | 30 | 55 | 19·67 | 35·54 | 92 | ,, | ,, | 255 | 467 | 19·65 | 35·50 |
| 45 | ,, | ,, | 57 | 104 | 19·73 | 35·64 | 93 | ,, | A9 | 0 | 0 | 19·67 | 35·54 |
| 46 | ,, 16 | V. | 70 | 128 | 19·76 | 35·70 | 94 | ,, | ,, | 100 | 183 | 19·63 | 35·47 |
| 47 | ,, | ,, | 35 | 64 | 19·61 | 35·43 | 95 | ,, | ,, | 200 | 366 | 19·65 | 35·50 |
| 48 | ,, 19 | VI. | 30 | 55 | 19·60 | 35·41 | 96 | ,, | ,, | 300 | 549 | 19·61 | 35·43 |
| 49 | ,, | ,, | 57 | 104 | 19·39 | 35·03 | 97 | ,, | ,, | 400 | 732 | 19·65 | 35·50 |
| 50 | ,, 20 | IV. | 0 | 0 | 19·65 | 35·50 | 98 | ,, | 60° 56′ N. 5° 18′ W. | 0 | 0 | 19·65 | 35·50 |
| | 1901. | | | | | | | | | | | | |
| 51 | Jan. 12 | IV. | 0 | 0 | 19·59 | 35·40 | 99 | ,, 4 | A11 | 0 | 0 | 19·72 | 35·63 |
| 52 | ,, | ,, | 115 | 210 | 19·71 | 35·61 | 100 | ,, | ,, | 100 | 183 | 19·78 | 35·73 |

TABLE III.—SALINITY OBSERVATIONS (*continued*).

| No. of Sample. | Date. | Position. | Depth. F'th. | Depth. M. | Cl. | Salinity per Mille. | No. of Sample. | Date. | Position. | Depth. F'th. | Depth. M. | Cl. | Salinity per Mille. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1901. | | | | | | | 1902. | | | | | |
| 101 | June 4 | A11 | 200 | 366 | 19·68 | 35·56 | 133 | May 17 | A1 | 0 | 0 | 19·74 | 35·66 |
| 102 | ,, | 60° 37′ N. 3° 30′ W. | 0 | 0 | 19·71 | 35·61 | 134 | ,, | ,, | 50 | 91 | 19·72 | 35·62 |
| | | | | | | | 135 | ,, | ,, | 100 | 183 | 19·65 | 35·50 |
| 103 | ,, 19 | A1 | 0 | 0 | 19·68 | 35·56 | 136 | ,, 20 | A3 | 0 | 0 | 19·69 | 35·57 |
| 104 | ,, | ,, | 50 | 91 | 19·71 | 35·61 | 137 | ,, | ,, | 100 | 183 | 19·61 | 35·43 |
| 105 | ,, | ,, | 100 | 183 | 19·71 | 35·61 | 138 | ,, | ,, | 200 | 366 | 19·43 | 35·10 |
| 106 | July 4 | ,, | 0 | 0 | 19·70 | 35·59 | 139 | ,, | ,, | 300 | 549 | 19·50 | 35·23 |
| 107 | ,, | ,, | 80 | 146 | 19·71 | 35·61 | 140 | ,, | ,, | 400 | 732 | 19·48 | 35·19 |
| 108 | ,, | ,, | 115 | 210 | 19·69 | 35·58 | 141 | ,, 21 | A4 | 0 | 0 | 19·63 | 35·46 |
| 109 | ,, 5 | A2 | 0 | 0 | 19·67 | 35·54 | 142 | ,, | ,, | 100 | 183 | 19·60 | 35·41 |
| 110 | ,, | ,, | 100 | 183 | 19·67 | 35·54 | 143 | ,, 30 | A6 | 0 | 0 | 19·63 | 35·46 |
| 111 | ,, | ,, | 200 | 366 | 19·66 | 35·52 | 144 | ,, | ,, | 100 | 183 | 19·59 | 35·39 |
| 112 | ,, | ,, | 300 | 549 | 19·65 | 35·50 | 145 | ,, 31 | B1 | 0 | 0 | 19·65 | 35·50 |
| 113 | ,, | ,, | 400 | 732 | 19·63 | 35·47 | 146 | June 1 | B2 | 0 | 0 | 19·72 | 35·62 |
| 114 | ,, | ,, | 500 | 914 | 19·65 | 35·50 | 147 | ,, | B3 | 0 | 0 | 19·79 | 35·75 |
| 115 | ,, 6 | A3½ | 0 | 0 | 19·65 | 35·50 | 148 | ,, 19 | A1 | 0 | 0 | 19·62 | 35·44 |
| 116 | ,, | ,, | 100 | 183 | 19·63 | 35·47 | 149 | ,, | ,, | 100 | 183 | 19·59 | 35·39 |
| 117 | ,, | ,, | 220 | 403 | 19·66 | 35·52 | 150 | ,, 21 | A2 | 0 | 0 | 19·60 | 35·41 |
| 118 | ,, | A4 | 0 | 0 | 19·67 | 35·54 | 151 | ,, 22 | A3 | 0 | 0 | 19·60 | 35·41 |
| 119 | ,, | ,, | 80 | 146 | 19·65 | 35·50 | 152 | ,, | ,, | 100 | 183 | 19·57 | 35·35 |
| 120 | 6 | ,, | 110 | 201 | 19·65 | 35·50 | 153 | ,, | ,, | 200 | 366 | 19·59 | 35·39 |
| 121 | ,, 7 | A5 | 0 | 0 | 19·65 | 35·50 | 154 | ,, | A4 | 0 | 0 | 19·61 | 35·43 |
| 122 | ,, 14 | A6 | 0 | 0 | 19·70 | 35·59 | 155 | ,, | ,, | 100 | 183 | 19·60 | 35·41 |
| 123 | ,, | ,, | 45 | 82 | 19·65 | 35·50 | 156 | ,, | A5 | 0 | 0 | 19·63 | 35·46 |
| 124 | ,, | ,, | 100 | 183 | 19·68 | 35·56 | 157 | ,, 26 | A6 | 0 | 0 | 19·60 | 35·41 |
| 125 | ,, | A7 | 0 | 0 | 19·72 | 35·63 | 158 | ,, | ,, | 100 | 183 | 19·59 | 35·39 |
| 126 | ,, | ,, | 50 | 91 | 19·71 | 35·61 | 159 | ,, 27 | Between A7 and A8 | 0 | 0 | 19·60 | 35·41 |
| 127 | ,, | ,, | 120 | 220 | 19·63 | 35·47 | | | | | | | |
| 128 | ,, 15 | A8 | 0 | 0 | 19·66 | 35·52 | 160 | ,, | ,, | 155 | 284 | 19·59 | 35·39 |
| 129 | ,, | ,, | 100 | 183 | 19·65 | 35·50 | 161 | ,, 28 | Between A2 and A9 | 200 | 366 | 19·48 | 35·19 |
| 130 | ,, | ,, | 200 | 366 | 19·70 | 35·59 | | | | | | | |
| 131 | ,, | ,, | 266 | 487 | 19·61 | 35·43 | 162 | ,, | ,, | 400 | 732 | 19·42 | 35·08 |
| 132 | ,, 16 | A9 | 400 | 732 | 19·63 | 35·47 | | | | | | | |

# II.—HYDROGRAPHICAL OBSERVATIONS MADE IN THE NORTH ATLANTIC DURING 1903 AND 1904 ON BOARD DR. WOLFENDEN'S YACHT 'SILVER BELLE'

By H. N. Dickson, M.A., D.Sc.

In the summer of 1903 the *Silver Belle* made two cruises. One, to the west of Ireland, during June and July, gave a valuable section along the meridian of Long. 12° W. from Lat. 51° N. to Lat. 54° 45′, besides other stations. A second, in August, gave two lines across the entrance to the Faeroe-Shetland Channel, one south of the Wyville-Thomson ridge, and one a little to the north of it, as well as a longitudinal section from the south of the ridge northwards so as to connect with the observations of the International Council, which were made almost at the same time. The total number of soundings made was twenty-two, and at each station temperature observations were made and samples collected.

During 1904 the *Silver Belle* made a still more extended voyage. Starting from the south-west of Ireland on June 20, a line of twenty soundings at depths down to 2,000 fathoms was run to the Azores. Temperature observations were made at all the stations, and samples were collected at six.

The next line was from the Azores to Madeira, and thence to Gibraltar, through the Straits and eastward in the Mediterranean as far as Long. 3° 41′ W. This line includes soundings at twenty-two stations; samples were collected at eight.

The third and last line runs westwards from Gibraltar to about Long. 10° W., then northwards to the mouth of the English Channel, connecting with the line of the International Council. On this line

there are fifteen stations, at all of which temperatures were observed; samples were collected at two.

The samples brought home numbered 139 in 1903, and, by an odd coincidence, 139 in 1904. The chlorines of all these samples have been determined by Mr. J. J. Manley in the laboratory at Magdalen College, Oxford, the methods employed being the same as in previous years. With regard to these determinations, it should be noted that a comparison of the values at the International Station Sc. 19A and *Silver Belle* station F9 shows perfect agreement. While analyzing the samples brought home by the *Discovery* expedition, Mr. Manley received a sample of the standard sea-water issued by the International Council. Chlorine determined differed from chlorine given by 1 part in 3,500. The *Discovery* samples were treated in precisely the same way as those of the *Silver Belle*, and there can, therefore, be no doubt that the values are strictly comparable with those of the International investigations. At my request Professor Pettersson also had the chlorines of some of the gas samples sent to him (see below) determined. A comparison of these values with those of Mr. Manley show somewhat serious differences:

SALINITY PER MILLE.

| No. of Sample. | Pettersson. | Manley. | Difference. |
|---|---|---|---|
| 7 | 35·51 | 35·70 | −0·19 |
| 17 | 35·61 | 35·82 | −0·21 |
| 18 | 35·23 | 35·41 | −0·18 |
| 89 | 36·13 | 36·62 | −0·49 |
| 103 | 36·44 | 36·58 | −0·14 |
| 117 | 38·35 | 38·62 | −0·27 |
| 124 | 36·20 | 35·90 | −0·30 |

The complete agreement which exists between the values as plotted and those of the International sections, and in the determinations with standard water, makes it very difficult to account for these discrepancies.

Table I. gives the positions of the stations for 1903 and their characteristic numbers.

Table II. gives the observations for 1903, with the chlorine values (Cl), salinities (P), and specific gravities *in situ* ($\sigma_t$), of the samples.

Table III. gives the data for the 1904 cruise. The positions of the sounding stations are given on the charts (Plates I. and II.).

A number of samples for gas analysis were collected during the 1904 cruise. The tubes were sent to Professor Pettersson, in Stockholm, and the analyses carried out by Miss A. Palmquist in the Hogskolas Laboratorium. The results are given in Table IV. Column 1 gives the number of the station, as in Table III. ; columns 2 and 3 the depths from which the samples were obtained; column 4 the amount of nitrogen ($N_2$), measured in c.c. at 0° C., 760 mm. pressure, absorbed in 1 litre of the sample; column 5 the amount of oxygen ($O_2$), measured at the same temperature and pressure, absorbed in 1 litre of the sample; column 6 gives the amount of oxygen expressed in per cent. of the whole gas absorbed—*i.e.*, $\frac{100\ O_2}{N_2 + O_2}$; column 7 the amount of carbonic acid ($CO_2$) measured in 1 litre under the same conditions. This carbonic acid is partly absorbed, partly in chemical combination.

With reference to these analyses, Miss Palmquist writes:

'Several tubes were so thinly drawn out that it looked as if they were melted together, though they really were open. If a tube is open, the nitrogen and oxygen can, of course, not be analyzed, and usually I do not either determine the carbonic acid, as the result often becomes too high. But as the opening of these tubes was so very capillary, I thought it better to analyze them; the results are marked " ?"

'The point of the tube from Station 41, 150 fathoms, was quite broken, and the result is obviously too high.

'Both of the samples from Station 8, 1,200 fathoms, were not melted together. The air bubble in one of these tubes being rather small, and the thin tube being quite filled up with water, I thought it just possible that the nitrogen and oxygen might be correctly determined. Although the result was too high, and some air must have come into the tube, something might be got out of the analysis. The deep water at the Stations 2 and 8 seems to be about the same, and the

nitrogen in this sample might be supposed to be about 14·40 c.c. per litre. The nitrogen that has come into the tube from the atmosphere then amounts to 19·79 — 14·40 = 5·39 c.c. per litre, and the oxygen may be calculated at 1·43 c.c. per litre (air = 79 per cent. $N_2$, 21 per cent. $O_2$). The water sample should have 14·40 c.c. $N_2$, 5·94 c.c. $O_2$, 29·17 per cent. $O_2$.'

Column 8 of the table gives the temperature *in situ* of the sample (Table III.), and column 9 the temperature of saturation calculated from the amount of nitrogen by a graphical extension of Hamberg's table. These values of T, which do not profess to be more than approximations, are of great interest, but their number is too small to justify full discussion.

Two points arise out of these analyses. The large amount of carbonic acid in the deeper Mediterranean waters is very remarkable, for, as Professor Pettersson has pointed out to me, in the Scandinavian fjords the amount of $CO_2$ per litre never exceeds 50 to 51 c.c. even if the oxygen has been reduced by the action of animal life to 4 or 5 per cent. of the normal. Yet it is suggested that these Mediterranean waters are of Atlantic origin. The second point is the occurrence of a minimum of oxygen in the Atlantic at a depth of 500 to 600 fathoms. This confirms the results of the temperature and salinity observations, and suggests that in this particular case at least the method of gas analysis is the most sensitive. It seems well to defer further discussion until the observations of Dr. Wolfenden's 1905 cruises are available.

As has been stated, the soundings may be conveniently grouped in a series of sections. The stations in each section are as follows:

1903.

| | | | |
|---|---|---|---|
| Section | I. ... | ... | Stations F3, F9, Sc. 19A, Sc. 15A. |
| ,, | II. ... | ... | ,, F4, F9, Sc. 19A, Sc. 15A. |
| ,, | III. ... | ... | ,, F5, F4, F3, F2, F1. |
| ,, | IV. ... | ... | ,, F7, F8, F9. |
| ,, | V. ... | ... | ,, E15, E16. |
| ,, | VI. ... | ... | ,, E15, E14, E13, E12, E11, E10, E9, E8, E7, E5. |

1904.

| | | | |
|---|---|---|---|
| Section | I. ... | ... | Stations 1 to 20. |
| ,, | II. ... | ... | ,, 22 to 31, 33 to 44. |
| ,, | III. ... | ... | ,, 48 to 51, 53 to 59. |
| ,, | IV. ... | ... | ,, 15 and 53, salinity only. |
| ,, | V. ... | ... | ,, 53 and 38 ,, |

Of the 1903 sections, Section I. forms a line running north-eastward nearly along the centre of the Faeroe-Shetland Channel. It is extended northwards by the use of two of the International stations, the data being extracted from the *Bulletin*. The dates of the observations are :

| | | | | | | |
|---|---|---|---|---|---|---|
| Station | F3 | ... | ... | ... | August | 6 |
| ,, | F9 | ... | ... | ... | ,, | 17 |
| ,, | Sc. 19A | ... | ... | ... | ,, | 20 |
| ,, | Sc. 15A | ... | ... | ... | ,, | 18 |

So that they may be regarded as fully comparable.

Section II. is the same as Section I., except that it begins at Station F4, more to the westward.

Section III. extends practically from the Faeroe Bank to off the Flannan Isles, right across the southern entrance of the channel.

Section IV. is roughly parallel to Section III., but farther north, beyond the Wyville-Thomson ridge. It begins on the Faeroe Bank, but ends at Station F9, in mid-channel.

Sections V. and VI. are off the west coast of Ireland. The two Stations, E15 and E16, are nearly east and west of one another ; hence Section V. gives some idea of the changes of distribution from the sea towards the land. Section VI. runs due north and south across the shallow bank to the West of Ireland. The middle of the section almost touches the 100-fathom line, and there is deep water at both ends.

The Sections I., II., and III. for 1904 follow the three lines already described. Section I. extends from the South-West of Ireland to the Azores, Section II. from the Azores through the Straits of Gibraltar into the Mediterranean, and Section III. from a point (Station 38) south of Cape St. Vincent to opposite the mouth of the English Channel, in line with the International Station E4. Sections IV. and

V. connect up points on the other lines with Station 53, the chief station on Section III. at which samples were taken.

Perhaps the most striking result of the minute study of special parts of the sea which has been made during recent years is the recognition of the wide range of variation in the movements of waters from season to season and from year to year. It has been shown that not only in enclosed areas like the North Sea, where varying land influences are important, but in the open ocean itself, the currents are constantly changing in direction and speed of movement, and the same parts of the ocean are occupied at different times by water derived from widely different sources.

An immediate consequence of this discovery is that the problems of oceanography are vastly more difficult of complete solution than was supposed. It is now practically impossible to draw general conclusions as to the circulation in a given area from one set of observations, however complete; the records must extend over a number of years, and include different seasons of the year precisely as in meteorology.

Under these circumstances it seems useless to attempt a general discussion of Dr. Wolfenden's observations. They form a very valuable contribution, probably the most valuable ever made by a private individual, at least in this country, to the steadily increasing amount of material; but the discussion of the 1903 observations really involves the whole question which it is one of the main objects of the International Council to elucidate, and the 1904 observations refer to an area about which we have not as yet anything like as much information as we have about the Faeroe-Shetland Channel. It is permissible, however, to state shortly the main features of the distributions shown by the sections, and to compare them where possible with those of other years.

1903.—The sections enumerated above, and the sections 'Faeroe-Shetland,' I. and II., for the same period, published by the International Council, suggest that the events of 1902 are being repeated,

but at a much later date, and with less intensity. A wedge of water of salinity over 35·5 lies with its axis passing almost directly through Stations F4 and F9, and the same axis of maximum salinity passes through Stations Sc. 19A and Sc. 15A, although the actual values are lower. A quantity of water of salinity over 35·5 also appears at the bottom at Station F2, Section III.; and at Station E16, Section V., there is a maximum of salinity (over 35·5) at a depth of about 120 fathoms. If we compare the May and August observations at the International Stations Sc. 19A and Sc. 15A, we find that while salinity is higher at the former station in August than in May, at the latter station it is lower.

Again, in Section VI., water of salinity less than 35·5 appears at the surface (Stations E12 and E13) to the north of the shallow area which extends westwards to the Porcupine Bank.

The general situation would seem to be that after the month of May there was a decided movement of salt water—salinity about 35·6 per mille—towards the west coasts of Ireland and Scotland, and that this water banked itself up and flowed partly downwards (note the isohalines of 35·3 and 35·2 in Section VI.) and partly northwards into the Faeroe-Shetland Channel. At the date of the observations the northward movement had almost ceased, and water from the Norwegian sea was making its way southward along the eastern side of the Faeroe-Shetland Channel. It can be traced from north to south as follows:

International Faeroe-Shetland, Section II., Stations Sc. 14A and Sc. 13A.
" " Section I., Station Sc. 19B.
*Silver Belle*, Section III., Stations F1 and F2.
" " V., Station E16.
" " VI., Stations E12 and E13.

Some importance may be attached to the increased steepness of the gradients of temperature and of salinity off the Continental shelf at a depth of about 700 to 800 fathoms. If we compare the salinities at Station E5, 1903, with Stations 2 and 5, 1904, it is noticeable that

a similar feature occurs, although less well marked. A salinity of 35·3 per mille occurs in both cases at a depth of about 850 fathoms, and this would seem to indicate the limit in depth of the surface system of movements. The point is well worth further observation. At depths greater than about 900 fathoms salinity seems to change very little with depth—at least, down to 2,000 fathoms; the lowest salinity in the 1904 Section I. was 35·21 in 1,600 fathoms. But north of the Porcupine Bank (Section VI., 1903) the salinity falls suddenly to 35·2 at about 800 fathoms, and then slowly to 35·08 in 1,500 fathoms.

The observations of the *Silver Belle* in 1903 afford definite information about the extension southward of water coming from the Norwegian sea over the Wyville-Thomson ridge. The occurrence of these southward movements may now be regarded as proved, and it seems that they take place pretty frequently, if not every year. The question of the cause of these changes is one that can best be discussed after the observations of the International Council have been kept up for some time longer, but the work of the *Silver Belle* in depths beyond 700 fathoms seems to support the hypothesis that we are here dealing with stream currents set up by the banking of drift water against a mass of land, in the same way as the Equatorial currents give rise to the Gulf Stream.

1904.—The outstanding features of Section I.—Ireland to the Azores—are easily described. Temperature and salinity increase at the surface from north to south; vertically they diminish together till the isothermal of 4° and the isohaline of 35·3 are reached at depths varying from 850 to 1,000 fathoms. At these values the lines are practically horizontal, and beyond 1,000 fathoms the fall of temperature and salinity is extremely slow. Whether the view that these iso-surfaces represent the lower boundary of the surface circulation be accepted or not, it is, I think, evident that they indicate a critical level of some kind, and that they are practically horizontal along the line under consideration.

The distribution of temperature shows few irregularities, the chief being a 'hump' of relatively cold water at Stations 6 and 7 between

300 and 800 fathoms. Salinities show a remarkably large volume of water between 35·6 and 35·8 per mille down to 500 fathoms from the Irish coast to Station 8. It would seem that the increased surface salinity as the Azores are approached is due to increased evaporation, and the general impression conveyed by the temperature and salinity sections together is that the line is nearly perpendicular to the direction in which the water is moving, if it is moving at all.

The main question raised by the remaining sections is that of the effect of the extremely saline water flowing out of the Mediterranean through the Straits of Gibraltar. The effective width of the strait may be taken as about 7½ miles, and depth about 200 fathoms.

Below the level of the 'sill' the temperature on the Mediterranean side (Stations 43 and 44) is uniformly 12·5°, and the salinity 38·6. The plane of separation of the inflowing and outflowing waters lies at a depth of between 50 and 100 fathoms at Station 44, and in the strait itself (Stations 42 and 45) between 100 and 150 fathoms, apparently nearer the first figure. Thus we have an outflowing stream some 70 fathoms thick and 7 miles across, consisting of water which at this season is of practically the same temperature as the water outside in the Atlantic, and 2 to 3 per mille salter than it.

It is clear that the outflowing water at first streams over the ridge and falls down, mixing rapidly with the fresher waters, until it begins to reach the layers of equal density in the lower temperatures below. This apparently happens at a depth of about 600 fathoms, and from this level the horizontal movements are more extensive than the vertical. At the time these observations were made it would seem that the influence of Mediterranean water was inappreciable west of about Long. 22° W. and below 1,300 fathoms. Northwards the effect is still apparent at Station 53, where there is a remarkable stratum of water, salter and *heavier* than the water above and below it, between 1,000 and 1,200 fathoms. This is the only 'inversion' of specific gravity which occurs in these observations, and it does not seem easy to account for it. It is certainly a temporary phenomenon. Its occurrence so far north, and so close to the land, is rather unexpected,

and suggests that periodic and irregular variations of wide extent probably occur in this coastal belt.

TABLE I.

POSITIONS OF STATIONS, 1903.

| | N. | W. | | N. | W. |
|---|---|---|---|---|---|
| Station E1 ... | 51° 56′ | 11° 24′ | Station E15 ... | 55° 47′ | 12° 28′ |
| „ E2 ... | 51° 46′ | 12° 16′ | „ E16 ... | 55° 43′ | 10° 12′ |
| „ E5 ... | 51° 00′ | 12° 00′ | „ F1 ... | 58° 24′ | 8° 30′ |
| „ E7 ... | 51° 30′ | 12° 00′ | „ F2 ... | 58° 45′ | 8° 35′ |
| „ E8 ... | 52° 00′ | 12° 00′ | „ F3 ... | 59° 18′ | 8° 30′ |
| „ E9 ... | 52° 30′ | 12° 00′ | „ F4 ... | 59° 50′ | 8° 42′ |
| „ E10 ... | 53° 00′ | 11° 57′ | „ F5 ... | 60° 29′ | 9° 30′ |
| „ E11 ... | 53° 30′ | 12° 00′ | „ F6 ... | 60° 41′ | 8° 50′ |
| „ E12 ... | 54° 00′ | 12° 00′ | „ F7 ... | 61° 01′ | 7° 42′ |
| „ E13 ... | 54° 30′ | 12° 00′ | „ F8 ... | 60° 30′ | 7° 47′ |
| „ E14 ... | 54° 45′ | 12° 00′ | „ F9 ... | 60° 01′ | 6° 04′ |

## III.—HYDROGRAPHICAL OBSERVATIONS MADE IN 1905.

The observations made to the west of Gibraltar during 1904 having established the fact that a regular survey of the region in connection with the international observations was of the first importance, Dr. Wolfenden sent the *Silver Belle* over part of the area at the end of 1905. Soundings were made at eleven stations, beginning near Station E4 of the international series, off Ushant, on November 8, and ending in the Strait of Gibraltar on December 20. The line closely follows Section III. of 1904 as far south as Station 51, and then runs south-westward to Madeira, repeating the line of Section II., 1904, to the Strait. From the remarks in Captain Henry's log, it appears that the work was carried out under great difficulties, and its successful achievement is a remarkable example of endurance and skill.

The total number of temperatures and samples obtained was seventy-six. The chlorines have been determined by Mr. Manley, and all the observations treated in precisely the same way as in the previous years. The results will be found in Table V.

Sections I. and II., 1905, show the distribution of temperature and salinity disclosed. Section I. is, in its northern part, comparable with Section III. of 1904, as has already been stated, and we have now the advantage of a section showing salinity as well as temperature. Section II. is, of course, comparable with the Section II. of 1904.

The general type of distribution is the same in both years, and there seems little reason to suppose that the type is not constant, with a wide range of variations. There is, therefore, little to be gained by further detailed discussion of the two years' observations, as they do not supply sufficient material to enable us to ascertain the full extent of the variations, and how far they are periodic or irregular.

A few points may, however, be noticed.

In 1905, notwithstanding a much lower surface temperature (probably chiefly due to difference of season), a larger body of relatively warm water occurred at intermediate depths off the Bay of Biscay than

in 1904 (compare Stations 2 and 3, 1905, with Stations 56 and 58, 1904). Again, the salinity of Section I. indicates that the Mediterranean water, represented by the layer of maximum salinity at a depth of about 600 fathoms, had moved mostly northwards, forming a stratum of over 36 per mille about 500 fathoms thick at Station 5, and over 400 fathoms thick at Station 3, but thinning to about 100 fathoms at Station 4, off the coast of Spain. The thinning at Station 4 may be due to downward movement from the surface of water drifted against the land.

The supposition that the movement of Mediterranean water was more northerly during or just before the second series of observations than in the first, is confirmed by a comparison of the sections eastward from Madeira to Gibraltar. Taking the isohaline of 36 per mille again, we find its western extension at Station 34 in 1904 and Station 6 in 1905, a difference of about 140 miles ; the layer of water over 36 is thinner, and the layer under 36 being correspondingly thicker.

We may, therefore, conclude that at different dates the extension of water from the Mediterranean varies very considerably northwards and westwards, and possibly also southwards, though as to this we are as yet without information. Whether the variations are periodic or irregular, or (as seems likely) both, we do not know. The causes of these variations must necessarily be extremely complex, as they are probably due partly to far-reaching changes in the movements of the Atlantic waters, and partly also, though in a less degree, to fluctuations in the volume and salinity of the water pouring out of the Mediterranean. It seems certain that the northward movement of the Mediterranean water may extend at least as far as the entrance to the English Channel, and it is obviously of the first importance to determine how often, and under what conditions, this takes place. The conditions which give rise to the formation of Rennell's Current may induce something of the nature of upwelling of waters west and south-west of Ushant, and such upwelling might bring Mediterranean water to the surface and into the Channel.

## TABLE II.

### Observations, 1903.

| No. of Sample. | Date. | Position. | Depth. | | Temp. ° C. | Cl. | P. | $\sigma_t$. |
|---|---|---|---|---|---|---|---|---|
| | | | Fath. | Metres. | | | | |
| 1 | June 11 | Station E1 ... | 0 | 0 | 15·0 | 19·73 | 35·64 | 26·48 |
| 2 | ,, | ,, | 60 | 110 | 10·5 | 19·70 | 35·59 | 27·34 |
| 3 | ,, | ,, | 130 | 238 | 10·2 | 19·71 | 35·61 | 27·41 |
| 4 | ,, 12 | Station E2 ... | 0 | 0 | 12·8 | 19·73 | 35·64 | 26·95 |
| 5 | ,, | ,, ... | 100 | 183 | 10·5 | 19·67 | 35·53 | 27·30 |
| 6 | ,, | ,, ... | 200 | 366 | 10·4 | 19·68 | 35·55 | 27·33 |
| 7 | ,, | ,, .. | 300 | 549 | 10·2 | 19·69 | 35·57 | 27·38 |
| 8 | ,, | ,, ... | 400 | 732 | 10·0 | 19·71 | 35·61 | 27·45 |
| 9 | ,, | ,, ... | 500 | 914 | 8·4 | 19·73 | 35·64 | 27·74 |
| 10 | ,, 25 | Station E5 ... | 0 | 0 | 14·5 | 19·73 | 35·64 | 26·60 |
| 11 | ,, | ,, ... | 100 | 183 | 10·8 | 19·73 | 35·64 | 27·33 |
| 12 | ,, | ,, ... | 200 | 366 | 10·6 | 19·71 | 35·61 | 27·34 |
| 13 | ,, | ,, ... | 300 | 549 | 10·3 | 19·72 | 35·62 | 27·41 |
| 14 | ,, | ,, ... | 400 | 732 | 10·0 | 19·72 | 35·62 | 27·46 |
| 15 | ,, | ,, ... | 500 | 914 | 9·4 | 19·74 | 35·66 | 27·59 |
| 16 | ,, | ,, ... | 600 | 1,097 | 8·6 | 19·78 | 35·73 | 27·78 |
| 17 | ,, | ,, ... | 700 | 1,280 | 7·6 | 19·70 | 35·59 | 27·82 |
| 18 | ,, | ,, ... | 800 | 1,463 | 5·8 | 19·56 | 35·34 | 27·87 |
| 19 | ,, | ,, ... | 900 | 1,646 | 4·8 | 19·49 | 35·21 | 27·89 |
| 20 | July 7 | Station E7 ... | 0 | 0 | 14·3 | 19·67 | 35·53 | 26·57 |
| 21 | ,, | ,, | 300 | 549 | 10·0 | 19·68 | 35·55 | 27·40 |
| 22 | ,, | ,, | 600 | 1,097 | 8·0 | 19·68 | 35·55 | 27·73 |
| 23 | ,, 8 | Station E8 ... | 0 | 0 | 14·5 | 19·74 | 35·66 | 26·61 |
| 24 | ,, | ,, | 150 | 274 | 10·5 | 19·69 | 35·57 | 27·33 |
| 25 | ,, | ,, | 250 | 457 | 10·3 | 19·69 | 35·57 | 27·37 |
| 26 | ,, | Station E9 ... | 0 | 0 | 14·9 | 19·73 | 35·64 | 26·51 |
| 27 | ,, | ,, ... | 60 | 110 | 10·6 | 19·72 | 35·62 | 27·35 |
| 28 | ,, | ,, ... | 120 | 220 | 10·4 | 19·70 | 35·59 | 27·36 |
| 29 | ,, | Station E10 ... | 0 | 0 | 14·6 | 19·73 | 35·64 | 26·57 |
| 30 | ,, | ,, ... | 50 | 91 | 10·6 | 19·73 | 35·64 | 27·36 |
| 31 | ,, | ,, ... | 95 | 174 | 10·0 | 19·69 | 35·57 | 27·42 |
| 32 | ,, | Station E11 ... | 0 | 0 | 14·0 | 19·70 | 35·59 | 26·66 |
| 33 | ,, | ,, ... | 70 | 128 | 10·2 | 19·70 | 35·59 | 27·39 |
| 34 | ,, | ,, ... | 145 | 265 | 10·0 | 19·71 | 35·61 | 27·45 |
| 35 | ,, 9 | Station E12 ... | 0 | 0 | 13·5 | 19·63 | 35·46 | 26·67 |
| 36 | ,, | ,, ... | 100 | 183 | 9·6 | 19·68 | 35·55 | 27·47 |
| 37 | ,, | ,, ... | 200 | 366 | 9·4 | 19·66 | 35·52 | 27·47 |
| 38 | ,, 11 | Station E13 ... | 0 | 0 | 13·3 | 19·64 | 35·48 | 26·72 |
| 39 | ,, | ,, ... | 100 | 183 | 9·8 | 19·68 | 35·55 | 27·43 |
| 40 | ,, | ,, ... | 200 | 366 | 9·5 | 19·62 | 35·44 | 27·40 |
| 41 | ,, | ,, ... | 300 | 549 | 9·3 | 19·61 | 35·43 | 27·42 |
| 42 | ,, | ,, ... | 400 | 732 | 9·0 | 19·61 | 35·43 | 27·47 |
| 43 | ,, | ,, ... | 500 | 914 | 8·2 | 19·63 | 35·46 | 27·63 |
| 44 | ,, | ,, ... | 600 | 1,097 | 7·5 | 19·62 | 35·44 | 27·71 |
| 45 | ,, | ,, ... | 700 | 1,280 | 6·0 | 19·63 | 35·46 | 27·94 |
| 46 | ,, | ,, ... | 800 | 1,443 | 5·3 | — | — | — |

TABLE II.—OBSERVATIONS, 1903 (*continued*).

| No. of Sample. | Date. | Position. | Depth. Fath. | Depth. Metres. | Temp. ° C. | Cl. | P. | $\sigma_r$. |
|---|---|---|---|---|---|---|---|---|
| 47 | July 11 | Station E13 ... | 900 | 1,646 | 4·3 | 19·52 | 35·26 | 27·99 |
| 48 | „ | „ ... | 1,000 | 1,829 | 3·7 | 19·43 | 35·10 | 27·94 |
| 49 | „ | „ ... | 1,100 | 2,012 | 3·6 | — | — | — |
| 50 | „ | „ ... | 1,300 | 2,377 | 3·1 | 19·43 | 35·10 | 27·98 |
| 51 | „ | „ ... | 1,500 | 2,743 | 3·1 | 19·42 | 35·08 | 27·96 |
| 52 | „ 13 | Station E14 ... | 0 | 0 | 13·0 | 19·67 | 35·53 | 26·83 |
| 53 | „ | „ ... | 100 | 183 | — | 19·64 | 35·48 | — |
| 54 | „ | „ ... | 200 | 366 | 9·4 | 19·63 | 35·46 | 27·43 |
| 55 | „ | „ ... | 300 | 549 | 9·2 | 19·64 | 35·48 | 27·48 |
| 56 | „ | „ ... | 400 | 732 | 8·7 | 19·64 | 35·48 | 28·57 |
| 57 | „ | „ ... | 500 | 914 | 8·2 | 19·63 | 35·46 | 27·63 |
| 58 | „ | „ ... | 600 | 1,097 | 7·0 | 19·64 | 35·48 | 27·81 |
| 59 | „ | „ ... | 700 | 1,280 | 5·6 | 19·58 | 35·37 | 27·92 |
| 60 | „ | „ ... | 800 | 1,463 | 5·0 | 19·48 | 35·19 | 27·85 |
| 61 | „ | „ ... | 900 | 1,646 | 4·1 | 19·46 | 35·16 | 27·92 |
| 62 | „ | „ ... | 1,000 | 1,829 | 3·8 | — | — | — |
| 63 | „ | „ ... | 1,100 | 2,012 | 3·6 | 19·45 | 35·14 | 27·96 |
| 64 | „ | „ ... | 1,300 | 2,377 | 3·2 | — | — | — |
| 65 | „ | „ ... | 1,500 | 2,743 | 3·0 | 19·46 | 35·16 | 28·03 |
| | „ | „ ... | 1,577 | 2,884 | 2·8 | — | — | — |
| 66 | „ 16 | Station E15 (chalky ooze) | 0 | 0 | 13·7 | 19·66 | 35·52 | 26·66 |
| 67 | „ | „ „ ... | 100 | 183 | 9·5 | 19·66 | 35·52 | 27·46 |
| 68 | „ | „ „ ... | 200 | 366 | 9·3 | 19·63 | 35·46 | 27·46 |
| 69 | „ | „ „ ... | 300 | 549 | 8·6 | 19·63 | 35·46 | 27·56 |
| 70 | „ | „ „ ... | 400 | 732 | 8·1 | 19·62 | 35·44 | 27·63 |
| 71 | „ | „ „ ... | 500 | 914 | 7·8 | 19·58 | 35·37 | 27·63 |
| 72 | „ | „ „ ... | 600 | 1,097 | 7·0 | 19·56 | 35·34 | 27·71 |
| 73 | „ | „ „ ... | 700 | 1,280 | 6·0 | 19·50 | 35·26 | 27·78 |
| 74 | „ | „ „ .. | 800 | 1,463 | 5·0 | 19·44 | 35·12 | 27·79 |
| 75 | „ | „ „ ... | 900 | 1,646 | 4·2 | 19·44 | 35·12 | 27·88 |
| 76 | „ | „ „ ... | 1,000 | 1,829 | 3·8 | 19·43 | 35·10 | 27·91 |
| 77 | „ | „ „ ... | 1,100 | 2,012 | 3·6 | 19·42 | 35·08 | 27·91 |
| 78 | „ | „ „ ... | 1,300 | 2,377 | 3·2 | 19·42 | 35·08 | 27·95 |
| 79 | „ | „ „ ... | 1,500 | 2,743 | 3·0 | 19·42 | 35·08 | 27·97 |
| | „ | „ „ ... | 1,561 | 2,854 | 2·8 | — | — | — |
| 80 | „ 19 | Station E16 (chalky ooze bottom) ... | 0 | 0 | 13·5 | 19·60 | 35·41 | 26·63 |
| 81 | „ | „ „ ... | 100 | 183 | 9·5 | 19·66 | 35·52 | 27·46 |
| 82 | „ | „ „ ... | 200 | 366 | 9·3 | 19·64 | 35·48 | 27·46 |
| 83 | „ | „ „ ... | 300 | 549 | 8·6 | 19·62 | 35·44 | 27·54 |
| 84 | „ | „ „ ... | 400 | 732 | 8·1 | 19·61 | 35·43 | 27·61 |
| 85 | „ | „ „ ... | 500 | 914 | 7·2 | 19·57 | 35·35 | 27·68 |
| 86 | „ | „ „ ... | 600 | 1,097 | 6·3 | 19·56 | 35·34 | 27·80 |
| 87 | „ | „ „ ... | 700 | 1,280 | 5·6 | 19·46 | 35·16 | 27·75 |
| 88 | „ | „ „ ... | 800 | 1,463 | 5·0 | 19·44 | 35·12 | 27·79 |
| 89 | „ | „ „ ... | 900 | 1,646 | 4·2 | 19·43 | 35·10 | 27·87 |
| 90 | „ | „ „ ... | 1,000 | 1,829 | 3·6 | 19·41 | 35·07 | 27·90 |

TABLE II.—OBSERVATIONS, 1903 (*continued*).

| No. of Sample. | Date. | Position. | Depth. | | Temp. ° C. | Cl. | P. | $\sigma_t$. |
|---|---|---|---|---|---|---|---|---|
| | | | Fath. | Metres. | | | | |
| 91 | July 19 | Station E16 ... | 1,100 | 2,012 | 3·4 | 19·41 | 35·07 | 27·92 |
| 92 | ,, | ,, ,, ... | 1,300 | 2,377 | 3·0 | 19·40 | 35·05 | 27·94 |
| 93 | Aug. 4 | Station F I. ... | 0 | 0 | 13·3 | 19·59 | 35·39 | 26·65 |
| 94 | ,, | ,, ... | 100 | 183 | 9·2 | 19·60 | 35·41 | 27·43 |
| 95 | ,, 5 | Station F II.... | 0 | 0 | 13·3 | 19·60 | 35·41 | 26·67 |
| 96 | ,, | ,, ... | 100 | 183 | 9·4 | 19·66 | 35·52 | 27·47 |
| 97 | ,, | ,, ... | 200 | 366 | 9·2 | 19·66 | 35·52 | 27·51 |
| 98 | ,, | ,, ... | 300 | 549 | 8·6 | 19·66 | 35·52 | 27·61 |
| 99 | ,, 6 | Station F III. | 0 | 0 | 12·9 | 19·63 | 35·46 | 26·79 |
| 100 | ,, | ,, .. | 100 | 183 | 9·2 | 19·63 | 35·46 | 27·47 |
| 101 | ,, | ,, ... | 200 | 366 | 8·6 | 19·63 | 35·46 | 27·57 |
| 102 | ,, | ,, ... | 300 | 549 | 8·4 | 19·63 | 35·46 | 27·60 |
| 103 | ,, | ,, ... | 400 | 732 | 8·2 | 19·63 | 35·46 | 27·63 |
| 104 | ,, | ,, ... | 500 | 914 | 8·0 | 19·63 | 35·46 | 27·66 |
| 105 | ,, | ,, ... | 600 | 1,097 | 7·0 | 19·63 | 35·46 | 27·80 |
| 106 | ,, | ,, ... | 700 | 1,280 | 5·8 | 19·59 | 35·39 | 27·91 |
| 107 | ,, | ,, ... | 800 | 1,463 | 4·4 | 19·58 | 35·37 | 28·07 |
| 108 | ,, 7 | Station F IV. | 0 | 0 | 12·7 | 19·66 | 35·52 | 26·87 |
| 109 | ,, | ,, ... | 100 | 183 | 9·0 | 19·66 | 35·52 | 27·54 |
| 110 | ,, | ,, ... | 200 | 366 | 8·6 | 19·63 | 35·46 | 27·57 |
| 111 | ,, | ,, ... | 300 | 549 | 8·4 | 19·63 | 35·46 | 27·60 |
| 112 | ,, | ,, ... | 400 | 732 | 8·2 | 19·63 | 35·46 | 27·63 |
| 113 | ,, | ,, ... | 500 | 914 | 7·9 | 19·63 | 35·46 | 27·67 |
| 114 | ,, | ,, ... | 600 | 1,097 | 6·8 | 19·63 | 35·46 | 27·83 |
| 115 | ,, | ,, ... | 700 | 1,280 | 5·6 | 19·63 | 35·46 | 27·99 |
| 116 | ,, 8 | Station F V. ... | 0 | 0 | 11·0 | 19·65 | 35·50 | 27·18 |
| 117 | ,, | ,, ... | 100 | 183 | 8·3 | 19·64 | 35·48 | 27·62 |
| 118 | ,, | ,, ... | 185 | 339 | 8·0 | 19·60 | 35·41 | 27·62 |
| 119 | ,, 9 | Station F VI. | 0 | 0 | 10·0 | 19·63 | 35·46 | 27·33 |
| 120 | ,, | ,, ... | 35 | 64 | 9·6 | 19·63 | 35·46 | 27·40 |
| 121 | ,, | ,, ... | 65 | 119 | 9·0 | 19·63 | 35·46 | 27·50 |
| 122 | ,, 13 | Station F VII. | 0 | 0 | 10·7 | 19·60 | 35·41 | 27·16 |
| 123 | ,, | ,, ... | 100 | 183 | 8·1 | 19·60 | 35·41 | 27·61 |
| 124 | ,, | ,, ... | 200 | 360 | 6·6 | 19·60 | 35·41 | 27·82 |
| 125 | ,, | ,, ... | 300 | 549 | 2·4 | 19·48 | 35·19 | 28·12 |
| 126 | ,, | ,, ... | 450 | 823 | 0 | 19·45 | 35·14 | 28·24 |
| 127 | ,, 14 | Station F VIII. | 0 | 0 | 11·4 | 19·63 | 35·46 | 27·07 |
| 128 | ,, | ,, ... | 100 | 183 | 8·6 | 19·63 | 35·46 | 27·56 |
| 129 | ,, | ,, ... | 200 | 366 | 8·1 | 19·56 | 35·34 | 27·55 |
| 130 | ,, | ,, ... | 300 | 549 | 5·3 | 19·53 | 35·28 | 27·88 |
| 131 | ,, | ,, ... | 400 | 732 | 1·0 | 19·41 | 35·07 | 28·12 |
| 132 | ,, | ,, ... | 500 | 914 | 0·8 | 19·39 | 35·03 | 28·19 |
| 133 | ,, 17 | Station F IX. | 0 | 0 | 11·6 | 19·72 | 35·62 | 27·17 |
| 134 | ,, | ,, ... | 100 | 183 | 9·4 | 19·66 | 35·52 | 27·47 |
| 135 | ,, | ,, ... | 200 | 366 | 8·8 | 19·66 | 35·52 | 27·57 |
| 136 | ,, | ,, ... | 300 | 549 | 4·3 | 19·63 | 35·46 | 28·15 |
| 137 | ,, | ,, ... | 400 | 732 | 0·5 | 19·41 | 35·07 | 28·20 |
| 138 | ,, | ,, ... | 500 | 914 | 0·5 | 19·41 | 35·07 | 28·20 |
| 139 | ,, | ,, ... | 590 | 1,079 | 1·0 | 19·40 | 35·05 | 28·21 |

TABLE III.—OBSERVATIONS, 1904.

| No. of Sounding. | Date. | Hour. | Latitude. | Longitude. | Wind. | Weather. | Sea. | Air Temp. | Nature of Bottom. | Depth in Fathoms. | Depth in Metres. | Temp. | No. of Sample. | Cl. | P. | $\sigma_r$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | ° C. | | | | ° C. | | | | |
| 1 | June 20 | 12 noon. | 50° 57′ N. | 11° 41′ W. | N.W. by W. | Clear. | Choppy. | 14·0 | Glob. ooze. | 0 | 0 | 12·8 | | | | |
| | | | | | | | | | | 25 | 46 | 12·6 | | | | |
| | | | | | | | | | | 50 | 91 | 12·0 | | | | |
| | | | | | | | | | | 100 | 183 | 11·0 | | | | |
| | | | | | | | | | | 200 | 366 | 10·2 | | | | |
| | | | | | | | | | | 400 | 732 | 9·6 | | | | |
| | | | | | | | | | | 600 | 1,097 | 8·4 | | | | |
| | | | | | | | | | | 800 | 1,463 | 6·2 | | | | |
| | | | | | | | | | | 858 | 1,569 | 6·0 | | | | |
| 2 | June 21 | 4 p.m. | 50° 25′ N. | 12° 38′ W. | Light, variable. | Fine. | Long, gentle swell. | 15·0 | — | 0 | 0 | 13·0 | 1 | 19·76 | 35·70 | 26·95 |
| | | | | | | | | | | 25 | 46 | 12·2 | | | | |
| | | | | | | | | | | 50 | 91 | 11·0 | | | | |
| | | | | | | | | | | 100 | 183 | 10·5 | | | | |
| | | | | | | | | | | 200 | 366 | 10·4 | 2 | 19·76 | 35·70 | 27·45 |
| | | | | | | | | | | 300 | 549 | 9·8 | | | | |
| | | | | | | | | | | 450 | 823 | 9·5 | | | | |
| | | | | | | | | | | 600 | 1,097 | 8·8 | 3 | 19·82 | 35·81 | 27·81 |
| | | | | | | | | | | 700 | 1,280 | 7·4 | | | | |
| | | | | | | | | | | 900 | 1,646 | 4·8 | 4 | 19·53 | 35·28 | 27·94 |
| | | | | | | | | | | 1,000 | 1,829 | 4·0 | | | | |
| | | | | | | | | | | 1,200 | 2,195 | 3·5 | 5 | 19·51 | 35·25 | 28·05 |
| 3 | June 23 | 6 a.m. | 49° 50′ N. | 13° 31′ W. | S., fresh. | Clear, cloudy sky. | Rough. | 13·3 | — | 0 | 0 | 13·3 | | | | |
| | | | | | | | | | | 25 | 46 | 12·5 | | | | |
| | | | | | | | | | | 50 | 91 | 10·8 | | | | |
| | | | | | | | | | | 100 | 183 | 10·5 | | | | |
| | | | | | | | | | | 200 | 366 | 10·4 | | | | |
| | | | | | | | | | | 300 | 549 | 10·1 | | | | |
| | | | | | | | | | | 400 | 732 | 9·6 | | | | |
| | | | | | | | | | | 500 | 914 | 9·1 | | | | |
| | | | | | | | | | | 600 | 1,097 | 8·2 | | | | |
| 4 | June 24 | 4 a.m. | 49° 0′ N. | 14° 36′ W. | W. to S.W., fresh. | Overcast sky and heavy rain. | Rather rough. | 13·0 | — | 0 | 0 | 13·5 | | | | |
| | | | | | | | | | | 25 | 46 | 12·8 | | | | |
| | | | | | | | | | | 50 | 91 | 10·8 | | | | |
| | | | | | | | | | | 100 | 183 | 10·5 | | | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 200 | 366 | 10·4 | | | | |
| | | | | | | | | | | 400 | 732 | 10·0 | | | | |
| | | | | | | | | | | 600 | 1,097 | 8·6 | | | | |
| | | | | | | | | | | 800 | 1,463 | 6·0 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 4·0 | | | | |
| 5 | June 25 | Noon. | 48° 28′ N. | 15° 38′ W. | E.S.E., light breeze. | Cloudy sky. | Long, irregular swell from W. | 15·0 | — | 100 | 183 | 11·0 | 6 | 19·80 | 35·77 | 27·40 |
| | | | | | | | | | | 300 | 549 | 10·4 | 7 | 19·76 | 35·70 | 27·45 |
| | | | | | | | | | | 500 | 914 | 9·2 | 8 | 19·80 | 35·77 | 27·72 |
| | | | | | | | | | | 700 | 1,280 | 6·7 | 9 | 19·69 | 35·57 | 27·94 |
| | | | | | | | | | | 1,000 | 1,829 | 4·0 | 10 | 19·53 | 35·28 | 28·03 |
| | | | | | | | | | | 1,100 | 2,012 | 3·6 | | | | |
| | | | | | | | | | | 1,400 | 2,560 | 3·3 | 11 | 19·49 | 35·21 | 28·05 |
| | | | | | | | | | | 1,570 | 2,871 | 3·0 | 12 | 19·53 | 35·28 | 28·13 |
| 6 | June 26 | 8 a.m. | 48° 12′ N. | 16° 26′ W. | W. | Fine. | Rather rough; long swell from W. | 16·5 | — | 0 | 0 | 14·5 | | | | |
| | | | | | | | | | | 25 | 46 | 13·0 | | | | |
| | | | | | | | | | | 50 | 91 | 11·5 | | | | |
| | | | | | | | | | | 100 | 183 | 10·5 | | | | |
| | | | | | | | | | | 200 | 366 | 10·2 | | | | |
| | | | | | | | | | | 400 | 732 | 9·4 | | | | |
| | | | | | | | | | | 500 | 914 | 8·5 | | | | |
| | | | | | | | | | | 700 | 1,280 | 6·4 | | | | |
| | | | | | | | | | | 900 | 1,646 | 4·2 | | | | |
| | | | | | | | | | | 1,200 | 2,194 | 3·5 | | | | |
| | | | | | | | | | | 1,500 | 2,743 | 3·1 | | | | |
| 7 | June 28 | 6 a.m. | 47° 28′ N. | 17′ 07° W. | Fresh S.W. | Sky clear; fine. | Rough. | 15·5 | — | 0 | 0 | 14·5 | | | | |
| | | | | | | | | | | 25 | 46 | 12·8 | | | | |
| | | | | | | | | | | 50 | 91 | 10·8 | | | | |
| | | | | | | | | | | 100 | 183 | 10·3 | | | | |
| | | | | | | | | | | 200 | 366 | 10·1 | | | | |
| | | | | | | | | | | 400 | 732 | 8·7 | | | | |
| | | | | | | | | | | 500 | 914 | 7·8 | | | | |
| | | | | | | | | | | 700 | 1,280 | 5·3 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 4·0 | | | | |
| | | | | | | | | | | 1,500 | 2,743 | 3·1 | | | | |
| 8 | June 29 | After-noon. | 46° 40′ N. | 17° 09′ W. | W., fresh breeze. | Heavy detached clouds. | Very heavy swell. | 16·0 | — | 0 | 0 | 14·8 | 13 | 19·80 | 35·77 | 26·63 |
| | | | | | | | | | | 25 | 46 | 13·5 | | | | |
| | | | | | | | | | | 50 | 91 | 11·5 | | | | |
| | | | | | | | | | | 100 | 183 | 11·0 | 14 | 19·80 | 35·77 | 27·40 |
| | | | | | | | | | | 200 | 366 | 10·6 | 15 | 19·80 | 35·77 | 27·47 |
| | | | | | | | | | | 400 | 732 | 10·2 | 16 | 19·78 | 35·73 | 27·51 |
| | | | | | | | | | | 600 | 1,097 | 9·0 | 17 | 19·83 | 35·82 | 27·79 |
| | | | | | | | | | | 900 | 1,646 | 5·0 | 18 | 19·60 | 35·41 | 28·02 |
| | | | | | | | | | | 1,200 | 2,194 | 3·6 | 19 | 19·51 | 35·25 | 28·04 |

TABLE III.—OBSERVATIONS, 1904 (*continued*)

| No. of Sounding. | Date. | Hour. | Latitude. | Longitude. | Wind. | Weather. | Sea. | Air Temp. | Nature of Bottom. | Depth in Fathoms. | Depth in Metres. | Temp. | No. of Sample. | Cl. | P. | $\sigma_t$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | ° C. | | | | ° C. | | | | |
| 9 | July 2 | 4 a.m. | 45° 06′ N. | 18° 14′ W. | Light S. to E. | Heavy rain. | Moderate. | 16·5 | — | 0 | 0 | 15·0 | | | | |
| | | | | | | | | | | 25 | 46 | 14·0 | | | | |
| | | | | | | | | | | 50 | 91 | 11·5 | | | | |
| | | | | | | | | | | 100 | 183 | 11·1 | | | | |
| | | | | | | | | | | 200 | 366 | 10·5 | | | | |
| | | | | | | | | | | 400 | 732 | 10·0 | | | | |
| | | | | | | | | | | 500 | 914 | 9·2 | | | | |
| | | | | | | | | | | 600 | 1,097 | 6·7 | | | | |
| | | | | | | | | | | 800 | 1,463 | 4·8 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 4·0 | | | | |
| | | | | | | | | | | 1,200 | 2,194 | 3·7 | | | | |
| | | | | | | | | | | 1,500 | 2,743 | 3·2 | | | | |
| 10 | July 3 | All day, from 8 a.m. | 44° 41′ N. | 19° 08′ W. | E.S.E., fresh breeze. | Sky overcast. | Long swell | 17·0 | — | 0 | 0 | 16·2 | 20 | 19·90 | 35·95 | 26·44 |
| | | | | | | | | | | 50 | 91 | 12·5 | 21 | 19·86 | 35·88 | 27·19 |
| | | | | | | | | | | 100 | 183 | 11·5 | 22 | 19·83 | 35·82 | 27·34 |
| | | | | | | | | | | 300 | 549 | 10·1 | 23 | 19·78 | 35·73 | 27·53 |
| | | | | | | | | | | 500 | 914 | 9·2 | 24 | 19·80 | 35·77 | 27·72 |
| | | | | | | | | | | 700 | 1,280 | 6·4 | 25 | 19·66 | 35·52 | 27·93 |
| | | | | | | | | | | 900 | 1,646 | 4·3 | 26 | 19·63 | 35·46 | 28·15 |
| | | | | | | | | | | 1,100 | 2,012 | 3·9 | 27 | 19·51 | 35·25 | 28·00 |
| | | | | | | | | | | 1,300 | 2,377 | 3·6 | 28 | 19·49 | 35·21 | 28·02 |
| | | | | | | | | | | 1,500 | 2,743 | 3·2 | 29 | 19·49 | 35·21 | 28·06 |
| 11 | July 4 | 8 a.m. | 44° 13′ N. | 20·05° W. | Light breeze, N. | Cloudy sky. | Gentle swell. | 18·0 | — | 0 | 0 | 15·8 | | | | |
| | | | | | | | | | | 25 | 46 | 13·5 | | | | |
| | | | | | | | | | | 50 | 91 | 13·0 | | | | |
| | | | | | | | | | | 100 | 183 | 12·4 | | | | |
| | | | | | | | | | | 200 | 366 | 11·1 | | | | |
| | | | | | | | | | | 400 | 731 | 10·0 | | | | |
| | | | | | | | | | | 600 | 1,097 | 8·6 | | | | |
| | | | | | | | | | | 800 | 1,463 | 5·0 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 4·0 | | | | |
| | | | | | | | | | | 1,200 | 2,194 | 3·5 | | | | |
| | | | | | | | | | | 1,500 | 2,743 | 3·2 | | | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | July 5 | Noon to 8 p.m. | 44° 05′ N. | 20° 34′ W. | S.W., very light. | Clear and fine; fog for four hours previously. | Smooth. | 17·6 | — | 0 | 0 | 16·0 | | | | |
| | | | | | | | | | | 25 | 46 | 14·0 | | | | |
| | | | | | | | | | | 50 | 91 | 12·7 | | | | |
| | | | | | | | | | | 75 | 137 | 11·6 | | | | |
| | | | | | | | | | | 100 | 183 | 11·4 | | | | |
| | | | | | | | | | | 200 | 366 | 10·5 | | | | |
| | | | | | | | | | | 300 | 549 | 9·8 | | | | |
| | | | | | | | | | | 400 | 731 | 8·8 | | | | |
| | | | | | | | | | | 500 | 914 | 7·6 | | | | |
| | | | | | | | | | | 600 | 1,097 | 6·4 | | | | |
| | | | | | | | | | | 700 | 1,280 | 5·4 | | | | |
| | | | | | | | | | | 800 | 1,463 | 4·5 | | | | |
| | | | | | | | | | | 900 | 1,645 | 4·2 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 3·9 | | | | |
| | | | | | | | | | | 1,100 | 2,012 | 3·6 | | | | |
| | | | | | | | | | | 1,200 | 2,195 | 3·6 | | | | |
| | | | | | | | | | | 1,300 | 2,377 | 3·6 | | | | |
| | | | | | | | | | | 1,400 | 2,560 | 3·5 | | | | |
| | | | | | | | | | | 1,500 | 2,743 | 3·1 | | | | |
| | | | | | | | | | | 1,600 | 2,926 | 3·0 | | | | |
| | | | | | | | | | | 1,700 | 3,109 | 3·0 | | | | |
| | | | | | | | | | | 1,800 | 3,292 | 3·0 | | | | |
| | | | | | | | | | | 1,900 | 3,475 | 2·8 | | | | |
| | | | | | | | | | | 2,000 | 3,658 | 2·7 | | | | |
| 13 | July 6 | Noon. | 43° 42′ N. | 21° 18′ W. | Light to moderate N.N.E. to N.E. | Fog all day, with occasional fine rain. | Smooth. | 17·0 | Fine Sand. | 0 | 0 | 16·2 | | | | |
| | | | | | | | | | | 25 | 46 | 14·5 | | | | |
| | | | | | | | | | | 50 | 91 | 13·0 | | | | |
| | | | | | | | | | | 100 | 183 | 11·5 | | | | |
| | | | | | | | | | | 400 | 732 | 9·2 | | | | |
| | | | | | | | | | | 600 | 1,097 | 6·8 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 3·9 | | | | |
| | | | | | | | | | | 1,200 | 2,195 | 3·6 | | | | |
| | | | | | | | | | | 1,500 | 2,743 | 2·9 | | | | |
| 14 | July 7 | 8 a.m. to 8.30 p.m. | 43° 11′ N. | 22° 27′ W. | Fresh breeze from N.E. | Clear. | Heavy swell from N.W. | 18·0 | — | 0 | 0 | 16·8 | | | | |
| | | | | | | | | | | 25 | 46 | 13·8 | | | | |
| | | | | | | | | | | 50 | 91 | 13·0 | | | | |
| | | | | | | | | | | 100 | 183 | 12·4 | | | | |
| | | | | | | | | | | 200 | 366 | 11·4 | | | | |
| | | | | | | | | | | 400 | 731 | 9·8 | | | | |
| | | | | | | | | | | 700 | 1,280 | 6·8 | | | | |
| | | | | | | | | | | 900 | 1,646 | 4·6 | | | | |
| | | | | | | | | | | 1,200 | 2,195 | 3·6 | | | | |
| | | | | | | | | | | 1,500 | 2,743 | 3·3 | | | | |
| | | | | | | | | | | 1,600 | 2,926 | 3·1 | | | | |

TABLE III.—OBSERVATIONS, 1904 (*continued*).

| No. of Sounding. | Date. | Hour. | Latitude. | Longitude. | Wind. | Weather. | Sea. | Air Temp. | Nature of Bottom. | Depth in Fathoms. | Depth in Metres. | Temp. | No. of Sample. | Cl. | P. | $\sigma_r$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | °C. | | | | °C. | | | | |
| 15 | July 8 | 6 a.m. to dark. | 42° 37′ N. | 23° 35′ W. | N.E. by N.; fresh breeze. | Cloudy; occasional sunshine. | Heavy swell. | 18·0 | — | 0 | 0 | 17·8 | 30 | 19·97 | 36·08 | 26·17 |
| | | | | | | | | | | 25 | 46 | 14·5 | | | | |
| | | | | | | | | | | 50 | 91 | 13·0 | 31 | 19·97 | 36·08 | 27·24 |
| | | | | | | | | | | 100 | 183 | 12·8 | 32 | 19·97 | 36·08 | 27·28 |
| | | | | | | | | | | 200 | 366 | 12·0 | 33 | 19·83 | 35·82 | 27·24 |
| | | | | | | | | | | 400 | 731 | 9·7 | 34 | 19·75 | 35·68 | 27·55 |
| | | | | | | | | | | 600 | 1,097 | 8·3 | 35 | 19·83 | 35·82 | 27·90 |
| | | | | | | | | | | 800 | 1,463 | 5·5 | 36 | 19·69 | 35·57 | 28·09 |
| | | | | | | | | | | 1,000 | 1,829 | 4·4 | 37 | 19·53 | 35·28 | 27·99 |
| | | | | | | | | | | 1,200 | 2,195 | 3·6 | 38 | 19·53 | 35·28 | 28·07 |
| | | | | | | | | | | 1,500 | 2,743 | 3·5 | 39 | 19·53 | 35·28 | 28·08 |
| 16 | July 9 | 6 a.m. | 41° 58′ N. | 24° 44′ W. | N.E. | Clear. | Moderate. | 18·6 | — | 0 | 0 | 18·0 | | | | |
| | | | | | | | | | | 25 | 46 | 15·0 | | | | |
| | | | | | | | | | | 50 | 91 | 13·2 | | | | |
| | | | | | | | | | | 100 | 183 | 13·0 | | | | |
| | | | | | | | | | | 300 | 549 | 11·0 | | | | |
| | | | | | | | | | | 400 | 731 | 10·1 | | | | |
| | | | | | | | | | | 500 | 914 | 9·1 | | | | |
| | | | | | | | | | | 700 | 1,280 | 6·5 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 4·1 | | | | |
| | | | | | | | | | | 1,200 | 2,195 | 3·6 | | | | |
| | | | | | | | | | | 1,500 | 2,743 | 3·5 | | | | |
| 17 | July 10 | 6 a.m. | 41° 13′ N. | 25° 18′ W. | Light breeze from N.E. | Fine and clear. | Gentle swell from N.E. | 19·0 | — | 0 | 0 | 18·0 | | | | |
| | | | | | | | | | | 25 | 46 | 15·0 | | | | |
| | | | | | | | | | | 50 | 91 | 13·2 | | | | |
| | | | | | | | | | | 100 | 183 | 12·8 | | | | |
| | | | | | | | | | | 300 | 549 | 11·1 | | | | |
| | | | | | | | | | | 500 | 914 | 9·1 | | | | |
| | | | | | | | | | | 700 | 1,280 | 6·5 | | | | |
| | | | | | | | | | | 900 | 1,646 | 4·5 | | | | |
| | | | | | | | | | | 1,100 | 2,012 | 3·7 | | | | |
| | | | | | | | | | | 1,300 | 2,377 | 3·5 | | | | |
| | | | | | | | | | | 1,500 | 2,743 | 3·3 | | | | |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | July 11 | 6 a.m. | 40° 35′ N. | 25° 54′ W. | Rising S.W. | Clear. | Strong. | 19·0 | — | 0 | 0 | 18·0 | | | | | |
| | | | | | | | | | | 25 | 46 | 15·0 | | | | | |
| | | | | | | | | | | 50 | 91 | 14·0 | | | | | |
| | | | | | | | | | | 100 | 183 | 13·0 | | | | | |
| | | | | | | | | | | 300 | 549 | 11·1 | | | | | |
| | | | | | | | | | | 600 | 1,097 | 8·1 | | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 4·1 | | | | | |
| | | | | | | | | | | 1,500 | 2,743 | 3·4 | | | | | |
| | | | | | | | | | | 1,800 | 3,292 | 3·0 | | | | | |
| 19 | July 12 | 8 a.m. | 39° 53′ N. | 26° 32′ W. | N., light breeze. | Fair. | Heavy swell. | 20·0 | Hard rock; at 600 fathoms fine sand and shells. | 0 | 0 | 19·0 | 40 | 20·13 | 36·36 | 26·09 | |
| | | | | | | | | | | 25 | 46 | 16·0 | | | | | |
| | | | | | | | | | | 50 | 91 | 14·8 | | | | | |
| | | | | | | | | | | 100 | 183 | 13·8 | 41 | 19·97 | 36·08 | 27·08 | |
| | | | | | | | | | | 200 | 366 | 12·4 | 42 | 19·90 | 35·95 | 27·26 | |
| | | | | | | | | | | 400 | 732 | 9·9 | 43 | 19·76 | 35·70 | 27·53 | |
| | | | | | | | | | | 600 | 1,097 | 7·6 | 44 | 19·75 | 35·68 | 27·89 | |
| 20 | July 13 | 8 a.m. | 39° 21′ N. | 27° 05′ W. | Rising S.W. | Clear. | Stormy swell. | 20·0 | Glob. ooze. | 0 | 0 | 19·0 | | | | | |
| | | | | | | | | | | 25 | 46 | 15·0 | | | | | |
| | | | | | | | | | | 50 | 91 | 14·0 | | | | | |
| | | | | | | | | | | 100 | 183 | 13·4 | | | | | |
| | | | | | | | | | | 200 | 366 | 12·5 | | | | | |
| | | | | | | | | | | 400 | 732 | 10·5 | | | | | |
| | | | | | | | | | | 600 | 1,097 | 7·6 | | | | | |
| | | | | | | | | | | 800 | 1,463 | 5·6 | | | | | |
| | | | | | | | | | | 870 | 1,591 | 5·2 | | | | | |
| 22 | July 22 | 6 a.m. | 38° 15′ N. | 28° 32′ W. | Light S.E. | Clear. | Calm. | 22·7 | Volcanic mud and sand. | 0 | 0 | 20·3 | | | | | |
| | | | | | | | | | | 25 | 46 | 16·5 | | | | | |
| | | | | | | | | | | 50 | 91 | 14·0 | | | | | |
| | | | | | | | | | | 100 | 183 | 13·1 | | | | | |
| | | | | | | | | | | 200 | 366 | 12·1 | | | | | |
| | | | | | | | | | | 300 | 549 | 11·0 | | | | | |
| | | | | | | | | | | 450 | 823 | 8·8 | | | | | |
| | | | | | | | | | | 472 | 864 | 8·4 | | | | | |
| 23 | July 23 | Noon. | 37° 42′ N. | 27° 37′ W. | Light N.W. | Fine. | Gentle swell. | 23·0 | — | 0 | 0 | 21·0 | | | | | |
| | | | | | | | | | | 25 | 46 | 17·3 | | | | | |
| | | | | | | | | | | 50 | 91 | 14·5 | | | | | |
| | | | | | | | | | | 100 | 183 | 13·9 | | | | | |
| | | | | | | | | | | 200 | 366 | 12·1 | | | | | |
| | | | | | | | | | | 400 | 732 | 9·8 | | | | | |
| | | | | | | | | | | 600 | 1,097 | 7·4 | | | | | |
| | | | | | | | | | | 800 | 1,463 | 5·7 | | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 4·5 | | | | | |

TABLE III.—OBSERVATIONS, 1904 (*continued*).

| No. of Sounding. | Date. | Hour. | Latitude. | Longitude. | Wind. | Weather. | Sea. | Air Temp. | Nature of Bottom. | Depth in Fathoms. | Depth in Metres. | Temp. | No. of Sample. | Cl. | P. | $\sigma_\rho$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | °C. | | | | °C. | | | | |
| 24 | July 24 | 7 a.m. | 37° 15′ N. | 26° 14′ W. | N., fresh breeze. | Cloudy. | Choppy. | 22·0 | Glob. ooze and sand. | 0 | 0 | 21·4 | 45 | 20·12 | 36·35 | 25·42 |
| | | | | | | | | | | 25 | 46 | 16·8 | | | | |
| | | | | | | | | | | 50 | 91 | 15·0 | 46 | 20·03 | 36·18 | 26·90 |
| | | | | | | | | | | 100 | 183 | 14·5 | 47 | 20·03 | 36·18 | 27·02 |
| | | | | | | | | | | 200 | 366 | 12·5 | 48 | 19·88 | 35·91 | 27·22 |
| | | | | | | | | | | 300 | 549 | 11·3 | 49 | 19·83 | 35·82 | 27·38 |
| | | | | | | | | | | 500 | 914 | 9·0 | 50 | 19·80 | 35·77 | 27·75 |
| | | | | | | | | | | 700 | 1,280 | 6·6 | 51 | 19·71 | 35·61 | 27·98 |
| | | | | | | | | | | 900 | 1,646 | 4·7 | 52 | 19·53 | 35·28 | 27·95 |
| | | | | | | | | | | 1,200 | 2,195 | 3·7 | 53 | 19·53 | 35·28 | 28·06 |
| | | | | | | | | | | 1,400 | 2,560 | 3·0 | | | | |
| 25 | July 25 | 7 a.m. | 36° 54′ N. | 24° 56′ W. | N.N.E. | Bright sunshine. | Calm. | 24·4 | Volcanic mud and sand. | 0 | 0 | 21·2 | | | | |
| | | | | | | | | | | 25 | 46 | 18·0 | | | | |
| | | | | | | | | | | 50 | 91 | 15·1 | | | | |
| | | | | | | | | | | 100 | 183 | 14·0 | | | | |
| | | | | | | | | | | 200 | 366 | 12·5 | | | | |
| | | | | | | | | | | 400 | 732 | 10·5 | | | | |
| | | | | | | | | | | 500 | 914 | 9·1 | | | | |
| | | | | | | | | | | 600 | 1,097 | 8·5 | | | | |
| | | | | | | | | | | 865 | 1,582 | 4·5 | | | | |
| 26 | July 26 | 7.30 a.m. | 36° 18′ N. | 23° 53′ W. | W.N.W. | Fine, but cloudy. | Calm. | 23·0 | — | 0 | 0 | 23·0 | | | | |
| | | | | | | | | | | 10 | 18 | 21·0 | | | | |
| | | | | | | | | | | 25 | 46 | 17·5 | | | | |
| | | | | | | | | | | 50 | 91 | 15·2 | | | | |
| | | | | | | | | | | 100 | 183 | 14·1 | | | | |
| | | | | | | | | | | 300 | 549 | 11·2 | | | | |
| | | | | | | | | | | 500 | 914 | 9·0 | | | | |
| | | | | | | | | | | 700 | 1,280 | 8·3 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 4·8 | | | | |
| | | | | | | | | | | 1,400 | 2,560 | 3·5 | | | | |
| | | | | | | | | | | 1,600 | 2,926 | 3·1 | | | | |
| 27 | July 27 | 8 a.m. | 35° 48′ N. | 22° 35′ W. | W., increasing all day. | Clear. | Strong, increasing. | 24·0 | — | 0 | 0 | 23·0 | | | | |
| | | | | | | | | | | 10 | 18 | 22·0 | | | | |
| | | | | | | | | | | 25 | 46 | 18·0 | | | | |
| | | | | | | | | | | 50 | 91 | 16·2 | | | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 100 | 183 | 14·5 | | | | |
| | | | | | | | | | | 200 | 366 | 12·6 | | | | |
| | | | | | | | | | | 400 | 732 | 10·2 | | | | |
| | | | | | | | | | | 600 | 1,097 | 8·0 | | | | |
| | | | | | | | | | | 900 | 1,646 | 5·7 | | | | |
| | | | | | | | | | | 1,200 | 2,195 | 3·9 | | | | |
| | | | | | | | | | | 1,600 | 2,926 | 3·4 | | | | |
| 28 | July 28 | 8 a.m. | 35° 04′ N. | 21° 18′ W. | W., fresh breeze. | Cloudy and sunshine. | Rather rough. | 25·0 | — | 0 | 0 | 23·5 | 54 | 20·34 | 36·74 | 25·13 |
| | | | | | | | | | | 10 | 18 | 21·5 | | | | |
| | | | | | | | | | | 25 | 46 | 18·5 | | | | |
| | | | | | | | | | | 50 | 91 | 17·2 | 55 | 20·20 | 36·49 | 26·63 |
| | | | | | | | | | | 100 | 183 | 14·6 | 56 | 20·00 | 36·13 | 26·95 |
| | | | | | | | | | | 200 | 366 | 12·7 | 57 | 19·90 | 35·95 | 27·20 |
| | | | | | | | | | | 400 | 732 | 10·2 | 58 | 19·76 | 35·70 | 27·48 |
| | | | | | | | | | | 600 | 1,097 | 8·7 | 59 | 19·82 | 35·81 | 27·83 |
| | | | | | | | | | | 800 | 1,463 | 6·6 | 60 | 19·73 | 35·64 | 28·00 |
| | | | | | | | | | | 1,000 | 1,829 | 4·4 | 61 | 19·53 | 35·28 | 28·00 |
| | | | | | | | | | | 1,200 | 2,195 | 3·8 | 62 | 19·55 | 35·32 | 28·08 |
| | | | | | | | | | | 1,400 | 2,560 | 3·4 | 63 | 19·53 | 35·28 | 28·09 |
| 29 | July 29 | 7 a.m. | 34° 22′ N. | 20° 06′ W. | W., light. | Bright sunshine. | — | 25·0 | — | 0 | 0 | 24·1 | | | | |
| | | | | | | | | | | 10 | 18 | 22·0 | | | | |
| | | | | | | | | | | 25 | 46 | 18·5 | | | | |
| | | | | | | | | | | 50 | 91 | 15·5 | | | | |
| | | | | | | | | | | 100 | 183 | 14·4 | | | | |
| | | | | | | | | | | 200 | 366 | 12·4 | | | | |
| | | | | | | | | | | 300 | 549 | 11·1 | | | | |
| | | | | | | | | | | 400 | 732 | 10·2 | | | | |
| | | | | | | | | | | 500 | 914 | 9·9 | | | | |
| | | | | | | | | | | 600 | 1,097 | 8·8 | | | | |
| | | | | | | | | | | 800 | 1,463 | 7·1 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 5·3 | | | | |
| 30 | July 30 | 6 a.m. | 33° 37′ N. | 19° 00′ W. | N.E. | Bright sunshine. | Heavy swell from N.W. | 25·0 | — | 0 | 0 | 23·7 | | | | |
| | | | | | | | | | | 10 | 18 | 22·0 | | | | |
| | | | | | | | | | | 25 | 46 | 19·0 | | | | |
| | | | | | | | | | | 50 | 91 | 16·6 | | | | |
| | | | | | | | | | | 100 | 183 | 15·1 | | | | |
| | | | | | | | | | | 200 | 366 | 14·3 | | | | |
| | | | | | | | | | | 300 | 549 | 12·1 | | | | |
| | | | | | | | | | | 400 | 732 | 10·8 | | | | |
| | | | | | | | | | | 500 | 914 | 10·1 | | | | |
| | | | | | | | | | | 600 | 1,097 | 9·2 | | | | |
| | | | | | | | | | | 800 | 1,463 | 7·4 | | | | |
| | | | | | | | | | | 1,400 | 2,560 | 4·0 | | | | |
| | | | | | | | | | | 1,600 | 2,926 | 4·0 | | | | |

TABLE III.—OBSERVATIONS, 1904 (*continued*).

| No. of Sounding. | Date. | Hour. | Latitude. | Longitude. | Wind. | Weather. | Sea. | Air Temp. | Nature of Bottom. | Depth in Fathoms. | Depth in Metres. | Temp | No. of Sample. | Cl. | P. | $\sigma_r$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | °C. | | | | °C. | | | | |
| 31 | July 31 | 8 a.m. | 32° 55′ N. | 17° 48′ W. | N.E., fresh breeze. | Bright sunshine. | Stormy N.W. swell. | 25·0 | — | 0 | 0 | 23·3 | | | | |
| | | | | | | | | | | 10 | 18 | 22·5 | | | | |
| | | | | | | | | | | 25 | 46 | 19·0 | | | | |
| | | | | | | | | | | 50 | 91 | 16·6 | | | | |
| | | | | | | | | | | 100 | 183 | 15·2 | | | | |
| | | | | | | | | | | 200 | 366 | 13·0 | | | | |
| | | | | | | | | | | 300 | 549 | 11·5 | | | | |
| | | | | | | | | | | 400 | 732 | 10·6 | | | | |
| | | | | | | | | | | 500 | 914 | 9·9 | | | | |
| | | | | | | | | | | 700 | 1,280 | 9·0 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 5·2 | | | | |
| | | | | | | | | | | 1,200 | 2,195 | 4·2 | | | | |
| | | | | | | | | | | 1,400 | 2,560 | 3·0 | | | | |
| 33 | Aug. 8 | 8 a.m. | 32° 57′ N. | 15° 23′ W. | — | Bright and clear. | Rather strong swell. | 25·0 | — | 0 | 0 | 22·7 | | | | |
| | | | | | | | | | | 25 | 46 | 19·5 | | | | |
| | | | | | | | | | | 50 | 91 | 16 8 | | | | |
| | | | | | | | | | | 100 | 183 | 15·5 | | | | |
| | | | | | | | | | | 200 | 366 | 12·9 | | | | |
| | | | | | | | | | | 300 | 549 | 11·2 | | | | |
| | | | | | | | | | | 400 | 732 | 10·1 | | | | |
| | | | | | | | | | | 500 | 914 | 9·3 | | | | |
| | | | | | | | | | | 600 | 1,097 | 9·0 | | | | |
| | | | | | | | | | | 800 | 1,463 | 7·7 | | | | |
| 34 | Aug. 9 | 6 a.m. | 33° 18′ N. | 14° 10′ W. | N., light breeze. | Fair; sunshine. | Long heavy northerly swell. | 24·0 | — | 0 | 0 | 22 3 | 64 | 20·23 | 36·55 | 25·34 |
| | | | | | | | | | | 25 | 46 | 20·0 | 65 | 20·23 | 36·55 | 25·97 |
| | | | | | | | | | | 50 | 91 | 16·2 | 66 | 20·21 | 36·51 | 26·88 |
| | | | | | | | | | | 100 | 183 | 14·9 | 67 | 20·10 | 36·31 | 27·03 |
| | | | | | | | | | | 200 | 366 | 13·0 | 68 | 19·92 | 35·99 | 27·17 |
| | | | | | | | | | | 400 | 732 | 10·8 | 69 | 19·90 | 35·95 | 27·57 |
| | | | | | | | | | | 600 | 1,097 | 9·6 | 70 | 19·96 | 36·06 | 27·87 |
| | | | | | | | | | | 800 | 1,463 | 7·5 | 71 | 19·83 | 35·82 | 28·02 |
| | | | | | | | | | | 1,000 | 1,829 | 5·4 | 72 | 19·63 | 35·46 | 28·01 |
| | | | | | | | | | | 1,200 | 2,195 | 4·2 | 73 | 19·56 | 35·34 | 28·06 |
| | | | | | | | | | | 1,400 | 2,560 | 3·5 | 74 | 19·53 | 35·28 | 28·08 |
| | | | | | | | | | | 1,600 | 2,926 | 3·1 | 75 | 19·53 | 35·28 | 28·12 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 35 | Aug. 10 | — | 33° 45′ N. | 13° 03′ W. | N.E. breeze; stormy swell. | — | — | 24·0 | — | 0 | 0 | 22·3 |
| | | | | | | | | | | 25 | 46 | 20·3 |
| | | | | | | | | | | 50 | 91 | 16·4 |
| | | | | | | | | | | 100 | 183 | 14·9 |
| | | | | | | | | | | 200 | 366 | 12·9 |
| | | | | | | | | | | 300 | 549 | 11·5 |
| | | | | | | | | | | 400 | 732 | 11·1 |
| | | | | | | | | | | 500 | 914 | 10·7 |
| | | | | | | | | | | 600 | 1,097 | 10·0 |
| | | | | | | | | | | 800 | 1,463 | 8·8 |
| | | | | | | | | | | 1,000 | 1,829 | 5·7 |
| 36 | Aug. 11 | — | 34° 16′ N. | 11° 57′ W. | None. | Bright sunshine. | Calm. | 29·4 | — | 0 | 0 | 24·0 |
| | | | | | | | | | | 5 | 9 | 22·8 |
| | | | | | | | | | | 10 | 18 | 22·0 |
| | | | | | | | | | | 20 | 37 | 20·0 |
| | | | | | | | | | | 25 | 46 | 18·0 |
| | | | | | | | | | | 50 | 91 | 16·0 |
| | | | | | | | | | | 100 | 183 | 14·5 |
| | | | | | | | | | | 150 | 274 | 13·5 |
| | | | | | | | | | | 200 | 366 | 12·6 |
| | | | | | | | | | | 250 | 457 | 11·7 |
| | | | | | | | | | | 300 | 549 | 11·2 |
| | | | | | | | | | | 350 | 640 | 11·1 |
| | | | | | | | | | | 400 | 732 | 11·1 |
| | | | | | | | | | | 450 | 823 | 11·1 |
| | | | | | | | | | | 500 | 914 | 11·1 |
| | | | | | | | | | | 600 | 1,097 | 10·8 |
| | | | | | | | | | | 700 | 1,280 | 10·4 |
| | | | | | | | | | | 800 | 1,463 | 8·0 |
| | | | | | | | | | | 900 | 1,646 | 6·4 |
| 37 | Aug. 12 | — | 34° 12′ N. | 11° 05′ W. | Light breeze from N. | — | — | 24·5 | — | 0 | 0 | 23·1 |
| | | | | | | | | | | 10 | 18 | 21·8 |
| | | | | | | | | | | 25 | 46 | 18·0 |
| | | | | | | | | | | 50 | 91 | 14·9 |
| | | | | | | | | | | 100 | 183 | 13·5 |
| | | | | | | | | | | 200 | 366 | 11·9 |
| | | | | | | | | | | 300 | 549 | 11·1 |
| | | | | | | | | | | 400 | 732 | 11·1 |
| | | | | | | | | | | 500 | 914 | 10·4 |
| | | | | | | | | | | 600 | 1,097 | 10·4 |
| | | | | | | | | | | 700 | 1,280 | 9·6 |
| | | | | | | | | | | 800 | 1,463 | 8·0 |
| | | | | | | | | | | 900 | 1,646 | 6·6 |
| | | | | | | | | | | 1,000 | 1,829 | 5·3 |
| | | | | | | | | | | 1,200 | 2,195 | 4·2 |

TABLE III.—OBSERVATIONS, 1904 (*continued*).

| No. of Sounding. | Date. | Hour. | Latitude. | Longitude. | Wind. | Weather. | Sea. | Air Temp. | Nature of Bottom. | Depth in Fathoms. | Depth in Metres. | Temp. | No. of Sample. | Cl. | P. | $\sigma_t$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | ° C. | | | | ° C. | | | | |
| 38 | Aug. 13 | 10 a.m. to 6 p.m. | 34° 43′ N. | 9° 38′ W. | Breeze from N. | Fine bright sun. | Fairly smooth. | 24·0 | — | 0 | 0 | 22·4 | 76 | 20·30 | 36·67 | 25·39 |
| | | | | | | | | | | 10 | 18 | 21·0 | | | | |
| | | | | | | | | | | 25 | 46 | 18·8 | 77 | 20·17 | 36·44 | 26·29 |
| | | | | | | | | | | 50 | 91 | 15·1 | 78 | 20·13 | 36·36 | 27·03 |
| | | | | | | | | | | 100 | 183 | 14·2 | 79 | 20·00 | 36·13 | 27·05 |
| | | | | | | | | | | 200 | 366 | 12·2 | 80 | 19·86 | 35·88 | 27·24 |
| | | | | | | | | | | 400 | 732 | 10·7 | 81 | 19·93 | 36·00 | 27·63 |
| | | | | | | | | | | 600 | 1,097 | 10·7 | 82 | 20·10 | 36·31 | 27·87 |
| | | | | | | | | | | 800 | 1,463 | 8·1 | 83 | 19·90 | 35·95 | 28·02 |
| | | | | | | | | | | 1,000 | 1,829 | 5·4 | 84 | 19·66 | 35·52 | 28·05 |
| | | | | | | | | | | 1,200 | 2,195 | 4·4 | 85 | | | |
| | | | | | | | | | | 1,400 | 2,560 | 3·5 | 86 | 19·53 | 35·28 | 28·08 |
| | | | | | | | | | | 1,600 | 2,926 | 3·0 | 87 | 19·53 | 35·28 | 28·13 |
| 39 | Aug. 14 | — | 35° 16′ N. | 8° 47′ W. | Strong breeze from N.N.E. | — | Stormy swell. | 23·0 | — | 0 | 0 | 23·0 | | | | |
| | | | | | | | | | | 10 | 18 | 22·0 | | | | |
| | | | | | | | | | | 25 | 46 | 16·2 | | | | |
| | | | | | | | | | | 50 | 91 | 16·6 | | | | |
| | | | | | | | | | | 100 | 183 | 13·7 | | | | |
| | | | | | | | | | | 200 | 366 | 11·9 | | | | |
| | | | | | | | | | | 300 | 549 | 11·1 | | | | |
| | | | | | | | | | | 400 | 732 | 10·6 | | | | |
| | | | | | | | | | | 500 | 914 | 10·6 | | | | |
| 40 | Aug. 15 | — | 35° 55′ N. | 7° 33′ W. | Wind dropping. | Impending. | Falling. | 25·5 | Grey mud and ooze. | 0 | 0 | 23·5 | | | | |
| | | | | | | | | | | 10 | 18 | 22·0 | | | | |
| | | | | | | | | | | 25 | 46 | 16·1 | | | | |
| | | | | | | | | | | 50 | 91 | 14·6 | | | | |
| | | | | | | | | | | 100 | 183 | 13·9 | | | | |
| | | | | | | | | | | 200 | 366 | 12·1 | | | | |
| | | | | | | | | | | 300 | 549 | 11·0 | | | | |
| | | | | | | | | | | 400 | 732 | 10·5 | | | | |
| | | | | | | | | | | 500 | 914 | 10·4 | | | | |
| | | | | | | | | | | 700 | 1,280 | 9·5 | | | | |
| | | | | | | | | | | 770 | 1,408 | 8·5 | | | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | Aug. 16 | 6 a.m. | 35° 55′ N. | 6° 35′ W. | S.W., light. | Fair, bright sunshine. | Fairly calm. | 26·0 | At 337 fathoms fine shells and sand. | 0 | 0 | 24·0 | 88 | 20·34 | 36·74 | 24·98 |
| | | | | | | | | | | 10 | 18 | 21·4 | 89 | 20·27 | 36·62 | 25·63 |
| | | | | | | | | | | 50 | 91 | 15·2 | 90 | 20·16 | 36·42 | 27·04 |
| | | | | | | | | | | 100 | 183 | 14·4 | 91 | 20·06 | 36·24 | 27·06 |
| | | | | | | | | | | 150 | 274 | 13·5 | 92 | 19·97 | 36·08 | 27·14 |
| | | | | | | | | | | 200 | 366 | 12·6 | 93 | 19·90 | 35·95 | 27·22 |
| | | | | | | | | | | 250 | 457 | 12·6 | 94 | 20·06 | 36·24 | 27·45 |
| | | | | | | | | | | 300 | 549 | 12·6 | 95 | 20·23 | 36·55 | 27·69 |
| | | | | | | | | | | 336 | 615 | 12·5 | 96 | 20·64 | 37·29 | 28·29 |
| 42 | Aug. 17 | 8 to 10 a.m. | 35° 55′ N. | 5° 54′ W. | Light. | Fog all night; fine day. | Calm. | 26·0 | Quantity pebbles and coral. | 0 | 0 | 23·5 | 97 | 20·27 | 36·62 | 25·03 |
| | | | | | | | | | | 10 | 18 | 20·0 | | | | |
| | | | | | | | | | | 25 | 46 | 16·4 | 98 | 20·21 | 36·51 | 26·82 |
| | | | | | | | | | | 50 | 91 | 15·0 | 99 | 20·13 | 36·36 | 27·05 |
| | | | | | | | | | | 100 | 183 | 14·0 | 100 | 20·34 | 36·74 | 27·56 |
| | | | | | | | | | | 172 | 315 | 13·0 | 101 | 21·22 | 38·33 | 29·00 |
| 43 | Aug. 21 | Noon to dark. | 36° 00′ N. | 5° 21′ W. | W., light. | Very fine and calm. | Smooth. | 26·0 | Shells and stones. | 0 | 0 | 21·0 | 102 | 20·17 | 36·44 | 25·62 |
| | | | | | | | | | | 10 | 18 | 15·5 | | | | |
| | | | | | | | | | | 25 | 46 | 15·3 | 103 | 20·25 | 36·58 | 27·13 |
| | | | | | | | | | | 50 | 91 | 13·8 | 104 | 20·67 | 37·34 | 28·06 |
| | | | | | | | | | | 100 | 183 | 13·0 | 105 | 21·18 | 38·26 | 28·94 |
| | | | | | | | | | | 200 | 366 | 12·5 | 106 | 21·31 | 38·49 | 29·23 |
| | | | | | | | | | | 300 | 549 | 12·5 | 107 | 21·38 | 38·62 | 29·33 |
| | | | | | | | | | | 400 | 732 | 12·5 | 108 | 21·43 | 38·71 | 29·40 |
| | | | | | | | | | | 500 | 914 | 12·5 | 109 | 21·40 | 38·66 | 29·36 |
| 44 | Aug. 22 | 6 a.m. to 4.30 p.m | 35° 45′ N. | 3° 41′ W. | Light from S.W. to N.W. | Very fine and warm. | Quite smooth. | 27·0 | Grey ooze. | 0 | 0 | 25·5 | 110 | 20·40 | 36·85 | 24·01 |
| | | | | | | | | | | 10 | 18 | 21·5 | 111 | 20·25 | 36·58 | 25·58 |
| | | | | | | | | | | 50 | 91 | 15·0 | 112 | 20·25 | 36·58 | 27·21 |
| | | | | | | | | | | 100 | 183 | 13·2 | 113 | 20·96 | 37·86 | 28·61 |
| | | | | | | | | | | 200 | 366 | 12·8 | 114 | 21·38 | 38·62 | 29·26 |
| | | | | | | | | | | 300 | 549 | 12·5 | 115 | 21·38 | 38·62 | 29·32 |
| | | | | | | | | | | 400 | 732 | 12·5 | 116 | 21·38 | 38·62 | 29·32 |
| | | | | | | | | | | 500 | 914 | 12·5 | 117 | 21·38 | 38·62 | 29·32 |
| | | | | | | | | | | 600 | 1,097 | 12·5 | 118 | 21·38 | 38·62 | 29·32 |
| | | | | | | | | | | 700 | 1,280 | 12·5 | 119 | 21·14 | | |
| | | | | | | | | | | 800 | 1,463 | 12·5 | 120 | 21·38 | 38·62 | 29·32 |
| 45 | Aug. 25 | 6 a.m. | 35° 53′ N. | 5° 52′ W. | W. breeze. | Clear. | Calm. | 22·7 | — | 0 | 0 | 23·0 | 121 | 20·28 | 36·64 | 25·19 |
| | | | | | | | | | | 10 | 18 | 16·2 | 122 | 20·20 | 36·49 | 26·87 |
| | | | | | | | | | | 50 | 91 | 14·2 | 123 | 20·13 | 36·36 | 27·23 |
| | | | | | | | | | | 100 | 183 | 13·2 | 124 | 20·04 | 36·20 | 27·30 |
| | | | | | | | | | | 150 | 274 | 13·0 | 125 | 21·31 | 38·49 | 29·12 |
| | | | | | | | | | | 200 | 366 | 12·5 | 126 | 21·30 | 38·48 | 29·20 |
| | | | | | | | | | | 250 | 457 | 12·5 | 127 | 21·35 | 38·57 | 29·27 |

TABLE III.—OBSERVATIONS, 1904 (*continued*).

| No. of Sounding. | Date. | Hour. | Latitude. | Longitude. | Wind. | Weather. | Sea. | Air Temp. | Nature of Bottom. | Depth in Fathoms. | Depth in Metres. | Temp. | No. of Sample. | Cl. | P. | $\sigma_t$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | °C. | | | | °C. | | | | |
| 46 | Aug. 26 | Noon to 4.30. | 36° 13′ N. | 7° 47′ W. | E. | Fine. | Wind and sea rising. | 26·0 | — | 0 | 0 | 23·4 | | | | |
| | | | | | | | | | | 100 | 183 | 13·2 | | | | |
| | | | | | | | | | | 200 | 366 | 11·6 | | | | |
| | | | | | | | | | | 300 | 549 | 10·2 | | | | |
| | | | | | | | | | | 400 | 732 | 10·2 | | | | |
| | | | | | | | | | | 500 | 914 | 10·2 | | | | |
| | | | | | | | | | | 600 | 1,097 | 10·2 | | | | |
| 47 | Aug. 27 | — | 36° 17′ N. | 9° 01′ W. | Light from S.E. | Fine. | Strong swell from S.E. | 25·0 | — | 0 | 0 | 21·0 | | | | |
| | | | | | | | | | | 25 | 46 | 15·7 | | | | |
| | | | | | | | | | | 50 | 91 | 14·9 | | | | |
| | | | | | | | | | | 100 | 183 | 13·7 | | | | |
| | | | | | | | | | | 200 | 366 | 12·1 | | | | |
| | | | | | | | | | | 300 | 549 | 11·3 | | | | |
| | | | | | | | | | | 400 | 732 | 11·3 | | | | |
| | | | | | | | | | | 600 | 1,097 | 10·6 | | | | |
| | | | | | | | | | | 800 | 1,463 | 8·6 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 5·2 | | | | |
| 48 | Aug. 29 | 6 a.m. to 4 p.m. | 36° 37′ N. | 10° 05′ W. | Light W.N.W. | — | — | 26·0 | — | 0 | 0 | 22·4 | | | | |
| | | | | | | | | | | 50 | 91 | 14·0 | | | | |
| | | | | | | | | | | 100 | 183 | 13·2 | | | | |
| | | | | | | | | | | 200 | 366 | 11·3 | | | | |
| | | | | | | | | | | 300 | 549 | 11·3 | | | | |
| | | | | | | | | | | 400 | 732 | 11·3 | | | | |
| | | | | | | | | | | 500 | 914 | 11·0 | | | | |
| | | | | | | | | | | 700 | 1,280 | 11·0 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 5·5 | | | | |
| | | | | | | | | | | 1,300 | 2,377 | 3·8 | | | | |
| | | | | | | | | | | 1,600 | 2,926 | 3·1 | | | | |
| 49 | Aug. 30 | Noon to 6 p.m. | 37° 14′ N. | 10° 37′ W. | Light W.N.W. | Fair and clear. | Heavy swell from N.W. | 22·5 | — | 0 | 0 | 22·0 | | | | |
| | | | | | | | | | | 50 | 91 | 14·2 | | | | |
| | | | | | | | | | | 100 | 183 | 13·1 | | | | |
| | | | | | | | | | | 200 | 366 | 11·7 | | | | |
| | | | | | | | | | | 400 | 732 | 11·2 | | | | |
| | | | | | | | | | | 600 | 1,097 | 10·7 | | | | |
| | | | | | | | | | | 800 | 1,463 | 7·9 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 5·2 | | | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 | Aug. 31 | Noon. | 37° 58′ N. | 11° 58′ W. | N.N.E. fresh breeze. | Cloudy; light showers. | Choppy. | 21·8 | — | 0 | 0 | 22·0 | | | | |
| | | | | | | | | | | 100 | 183 | 13·2 | | | | |
| | | | | | | | | | | 300 | 549 | 10·8 | | | | |
| | | | | | | | | | | 500 | 914 | 10·7 | | | | |
| | | | | | | | | | | 700 | 1,280 | 10·2 | | | | |
| | | | | | | | | | | 900 | 1,646 | 7·2 | | | | |
| | | | | | | | | | | 1,100 | 2,012 | 5·1 | | | | |
| 51 | Sept. 1 | Noon. | 38° 53′ N. | 13° 12′ W. | N.N.E., strong. | — | Very choppy. | 20·7 | — | 0 | 0 | 21·6 | | | | |
| | | | | | | | | | | 50 | 91 | 14·2 | | | | |
| | | | | | | | | | | 100 | 183 | 13·1 | | | | |
| | | | | | | | | | | 200 | 366 | 11·7 | | | | |
| | | | | | | | | | | 300 | 549 | 11·4 | | | | |
| | | | | | | | | | | 400 | 732 | 11·3 | | | | |
| | | | | | | | | | | 500 | 914 | 10·3 | | | | |
| 52 | Sept. 3 | 10 a.m. | 39° 42′ N. | 10° 58′ W. | Strong breeze from N.N.E. | Misty. | Rough. | 20·4 | — | 0 | 0 | 20·4 | | | | |
| | | | | | | | | | | 100 | 183 | 12·8 | | | | |
| | | | | | | | | | | 200 | 366 | 11·6 | | | | |
| | | | | | | | | | | 400 | 732 | 11·4 | | | | |
| | | | | | | | | | | 600 | 1,097 | 11·1 | | | | |
| | | | | | | | | | | 800 | 1,463 | 10·2 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 5·6 | | | | |
| 53 | Sept. 4 | 7 a.m. | 40° 03′ N. | 12° 13′ W. | N.N.E. | — | Calm. | 22·0 | — | 0 | 0 | 20·5 | 128 | 20·01 | 36·15 | 25·52 |
| | | | | | | | | | | 25 | 46 | 16·5 | 129 | 19·97 | 36·08 | 26·47 |
| | | | | | | | | | | 50 | 91 | 13·6 | 130 | 19·97 | 36·08 | 27·12 |
| | | | | | | | | | | 100 | 183 | 12·5 | 131 | 19·86 | 35·88 | 27·19 |
| | | | | | | | | | | 200 | 366 | 11·1 | 132 | 19·86 | 35·88 | 27·45 |
| | | | | | | | | | | 400 | 732 | 10·9 | 133 | 19·93 | 36·00 | 27·60 |
| | | | | | | | | | | 600 | 1,097 | 10·3 | 134 | 20·10 | 36·31 | 27·95 |
| | | | | | | | | | | 800 | 1,463 | 7·6 | 135 | 19·86 | 35·88 | 28·04 |
| | | | | | | | | | | 1,000 | 1,829 | 5·6 | 136 | 20·01 | 36·15 | 28·53 |
| | | | | | | | | | | 1,200 | 2,195 | 4·6 | 137 | 20·11 | 36·33 | 28·80 |
| | | | | | | | | | | 1,400 | 2,560 | 3·6 | 138 | 19·53 | 35·28 | 28·05 |
| | | | | | | | | | | 1,600 | 2,926 | 3·1 | 139 | 19·52 | 35·26 | 28·11 |
| 54 | Sept. 5 | 2 p.m. | 41° 10′ N. | 11° 46′ W. | Light S.W. | Calm all night; sudden squall. | Stormy swell. | 19·0 | — | 0 | 0 | 19·8 | | | | |
| | | | | | | | | | | 200 | 366 | 11·2 | | | | |
| | | | | | | | | | | 300 | 549 | 10·9 | | | | |
| | | | | | | | | | | 400 | 732 | 10·8 | | | | |
| | | | | | | | | | | 500 | 914 | 10·0 | | | | |
| 55 | Sept. 6 | Noon. | 42° 01′ N. | 10° 48′ W. | N.N.E. | Squally. | Heavy swell. | 20·0 | — | 0 | 0 | 19·0 | | | | |
| | | | | | | | | | | 50 | 91 | 12·4 | | | | |
| | | | | | | | | | | 100 | 183 | 11·6 | | | | |
| | | | | | | | | | | 200 | 366 | 11·1 | | | | |
| | | | | | | | | | | 400 | 732 | 10·6 | | | | |
| | | | | | | | | | | 600 | 1,097 | 10·4 | | | | |
| | | | | | | | | | | 800 | 1,463 | 9·0 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 4·9 | | | | |

TABLE III.—OBSERVATIONS, 1904 (*continued*).

| No. of Sounding. | Date. | Hour. | Latitude. | Longitude. | Wind. | Weather. | Sea. | Air Temp. | Nature of Bottom. | Depth in Fathoms. | Depth in Metres. | Temp. | No. of Sample. | Cl. | P. | $\sigma_t$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | °C. | | | | °C. | | | | |
| 56 | Sept. 8 | 7 a.m. | 43° 27′ N. | 10° 19′ W. | N.N.E. | — | Very heavy swell from W.N.W., dying down. | 22·0 | — | 0 | 0 | 19·0 | | | | |
| | | | | | | | | | | 50 | 91 | 12·6 | | | | |
| | | | | | | | | | | 100 | 183 | 11·5 | | | | |
| | | | | | | | | | | 200 | 366 | 11·1 | | | | |
| | | | | | | | | | | 400 | 732 | 10·3 | | | | |
| | | | | | | | | | | 600 | 1,097 | 9·6 | | | | |
| | | | | | | | | | | 800 | 1,463 | 7·0 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 4·9 | | | | |
| | | | | | | | | | | 1,200 | 2,195 | 3·9 | | | | |
| | | | | | | | | | | 1,500 | 2,743 | 3·3 | | | | |
| 57 | Sept. 9 | — | 44° 35′ N. | 9° 52′ W. | N.N.E. strong breeze. | At first fine; then fine rain. | Heavy swell. | 18·3 | — | 0 | 0 | 19·0 | | | | |
| | | | | | | | | | | 25 | 46 | 15·0 | | | | |
| | | | | | | | | | | 50 | 91 | 11·8 | | | | |
| | | | | | | | | | | 100 | 183 | 11·2 | | | | |
| | | | | | | | | | | 200 | 366 | 11·0 | | | | |
| | | | | | | | | | | 400 | 732 | 10·4 | | | | |
| | | | | | | | | | | 600 | 1,097 | 9·8 | | | | |
| | | | | | | | | | | 800 | 1,463 | 6·6 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 4·5 | | | | |
| | | | | | | | | | | 1,200 | 2,195 | 3·7 | | | | |
| | | | | | | | | | | 1,500 | 2,743 | 3·3 | | | | |
| 58 | Sept. 10 | Noon. | 45° 49′ N. | 10° 20′ W. | N.N.E. to E.N.E., strong. | — | Choppy. | 18·3 | — | 0 | 0 | 18·3 | | | | |
| | | | | | | | | | | 50 | 91 | 12·3 | | | | |
| | | | | | | | | | | 100 | 183 | 11·2 | | | | |
| | | | | | | | | | | 200 | 366 | 10·8 | | | | |
| | | | | | | | | | | 300 | 549 | 10·8 | | | | |
| | | | | | | | | | | 400 | 732 | 10·5 | | | | |
| | | | | | | | | | | 500 | 914 | 10·4 | | | | |
| 59 | Sept. 11 | 7 a.m. | 47° 02′ N. | 9° 10′ W. | E.S.E., fresh. | — | Strong swell. | 18·3 | — | 0 | 0 | 17·3 | | | | |
| | | | | | | | | | | 25 | 46 | 15·8 | | | | |
| | | | | | | | | | | 50 | 91 | 11·6 | | | | |
| | | | | | | | | | | 100 | 183 | 10·9 | | | | |
| | | | | | | | | | | 200 | 366 | 10·6 | | | | |
| | | | | | | | | | | 400 | 732 | 10·0 | | | | |
| | | | | | | | | | | 600 | 1,097 | 9·2 | | | | |
| | | | | | | | | | | 800 | 1,463 | 7·3 | | | | |
| | | | | | | | | | | 1,000 | 1,829 | 4·8 | | | | |

## TABLE IV.

### Analyses of Gas Samples, 1904.

| No. of Station. | Depth in Fathoms. | Depth in Metres. | $N_2$ c.c. | $O_2$ c.c. | $O_2$ per Cent. $=\frac{100O_2}{N_2+O_2}$ | $CO_2$ c.c. | Temp. $t$ | Temp. $T$ |
|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| | | | | | | | ° C. | ° C. |
| 2 | 1,200 | 2,195 | 14·25 | 5·39 | 27·47 | 50·48 | 3·5 | 1·7 |
| 5 | 100 | 183 | 12·53 | 5·72 | 31·34 | 47·93 (?) | 11·0 | 7·8 |
| | 500 | 914 | 12·91 | 4·35 | 25·19 | 49·53 | 9·2 | 6·4 |
| | 700 | 1,280 | 13·37 | 4·95 | 27·01 | 49·57 | 6·7 | 4·9 |
| | 1,000 | 1,829 | 14·09 | 5·95 | 29·69 | 49·21 | 4·0 | 2·3 |
| | 1,400 | 2,560 | 14·48 | 5·84 | 28·76 | 50·38 | 3·3 | 1·1 |
| | 1,570 | 2,871 | 14·43 | 5·76 | 28·52 | 50·36 | 3·0 | 1·3 |
| 8 | 100 | 183 | 12·41 | 5·56 | 30·94 | 48·11 | 11·0 | 8·4 |
| | 200 | 366 | 12·24 | 5·54 | 31·17 | 48·58 | 10·6 | 9·1 |
| | 400 | 732 | 12·40 | 4·45 | 26·40 | 48·98 | 10·2 | 8·4 |
| | 600 | 1,097 | 12·94 | 4·29 | 24·92 | — | 9·0 | 6·2 |
| | 900 | 1,646 | — | — | — | 49·64 | 5·0 | — |
| | 1,200 | 1,829 | [19·79] | [7·37] | [27·14] | 50·77 (?) | 3·6 | — |
| 41 | 10 | 18 | 10·38 | 4·94 | 32·23 | — | 21·4 | 18·7 |
| | 100 | 183 | 11·46 | 4·94 | 30·12 | 47·95 | 14·4 | 12·5 |
| | 150 | 274 | 11·76 | 4·78 | 28·91 | 51·95 (?) | 13·5 | 11·0 |
| | 200 | 366 | 12·07 | 4·52 | 27·26 | 48·99 | 12·6 | 9·7 |
| | 250 | 457 | 11·87 | 4·46 | 27·30 | 49·96 | 12·6 | 10·5 |
| | 300 | 549 | 11·84 | 4·31 | 26·70 | 50·97 | 12·6 | 10·6 |
| | 336 | 615 | 11·84 | 4·01 | 25·29 | 52·09 | 12·5 | 10·4 |
| 43 | 25 | 46 | — | — | — | 49·10 | 15·3 | — |
| | 50 | 91 | 12·06 | 4·57 | 27·50 | 49·94 | 13·8 | 9·5 |
| | 100 | 183 | 12·13 | 4·86 | 28·59 | 52·44 | 13·0 | 8·9 |
| | 200 | 366 | 11·77 | 4·00 | 25·35 | 51·23 (?) | 12·5 | 10·4 |
| | 300 | 549 | 11·89 | 4·10 | 25·64 | 53·60 (?) | 12·5 | 9·9 |
| | 400 | 732 | 11·74 | 3·45 | 22·71 | 53·63 (?) | 12·5 | 10·4 |
| | 500 | 914 | — | — | — | 54·05 (?) | 12·5 | — |
| 44 | 10 | 18 | 10·64 | 4·92 | 31·62 | 47·93 | 21·5 | 17·0 |
| | 50 | 91 | — | — | — | 48·54 | 15·0 | — |
| | 100 | 183 | 11·75 | 4·64 | 28·28 | — | 13·2 | 10·5 |
| | 200 | 366 | 11·82 | 4·18 | 26·10 | 53·65 (?) | 12·8 | 10·2 |
| | 300 | 549 | 11·86 | 3·99 | 25·16 | 53·73 | 12·5 | 10·1 |
| | 400 | 732 | 11·85 | 3·54 | 22·98 | 53·10 | 12·5 | 10·1 |
| | 600 | 1,097 | 11·82 | 4·72 | 28·52 | 53·38 | 12·5 | 10·2 |
| | 700 | 1,280 | 12·17 | 3·85 | 24·04 | — | 12·5 | 8·6 |
| | 800 | 1,463 | — | — | — | 53·29 | 12·5 | — |
| 45 | 10 | 18 | 11·35 | 5·71 | 33·49 | 47·33 | 16·2 | 12·9 |
| | 50 | 91 | 11·93 | 4·94 | 29·28 | 48·96 (?) | 14·2 | 10·6 |
| | 100 | 183 | — | — | — | 52·16 (?) | 13·2 | — |
| | 150 | 274 | 11·78 | 4·21 | 26·34 | 52·94 | 13·0 | 10·3 |
| | 200 | 366 | 11·80 | 4·06 | 25·59 | 52·90 | 12·5 | 10·4 |
| | 250 | 457 | 11·69 | 5·17 | 30·67 | 53·32 | 12·5 | 10·5 |

TABLE V.—OBSERVATIONS, 1905.

| No. of Sounding. | Date. | Hour. | Latitude. | Longitude. | Wind. | Weather. | Sea. | Air Temp. | Nature of Bottom. | Depth in Fathoms. | Depth in Metres. | Temp. | No. of Sample. | Cl. | P. | $\sigma_t$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | ° C. | | | | ° C. | | | | |
| 1 | Nov. 8 | 6 a.m. to 9 a.m. | 48° 7′ N. | 6° 37′ W. | N.W., fresh. | Fair. | Moderate, smooth. | 12·0 | Gravel and shells. | 0 | 0 | 12·3 | 1 | 19·72 | 35·62 | 27·04 |
| | | | | | | | | | | 10 | 18 | 12·7 | 2 | 19·76 | 35·70 | 27·01 |
| | | | | | | | | | | 90 | 165 | 12·0 | 3 | 19·72 | 35·62 | 27·10 |
| 2 | Nov. 14 | All day. | 45° 37′ N. | 8° 20′ W. | N.E., light breeze. | Small detached clouds. | Heavy westerly swell. | 12·0 | Intermediate. | 0 | 0 | 13·2 | 4 | 19·88 | 35·91 | 27·07 |
| | | | | | | | | | | 200 | 366 | 11·5 | 5 | 19·79 | 35·75 | 27·29 |
| | | | | | | | | | | 400 | 732 | 10·6 | 6 | 19·85 | 35·86 | 27·54 |
| | | | | | | | | | | 600 | 1,097 | 10·5 | 7 | 20·02 | 36·17 | 27·80 |
| | | | | | | | | | | 800 | 1,463 | 8·5 | 8 | 19·90 | 35·95 | 27·96 |
| | | | | | | | | | | 1,000 | 1,829 | 5·0 | 9 | 19·76 | 35·70 | 28·26 |
| | | | | | | | | | | 1,200 | 2,195 | 4·0 | 10 | 19·47 | 35·17 | 27·95 |
| 3 | Nov. 17 | All day. | 43° 32′ N. | 10° 48′ W. | N.N.E., fresh breeze. | Showery. Wet. Hail. | Cross swell. | 11·0 | Intermediate. | 0 | 0 | 13·5 | 11 | 19·86 | 35·88 | 26·99 |
| | | | | | | | | | | 100 | 183 | 12·0 | 12 | 19·82 | 35·81 | 27·24 |
| | | | | | | | | | | 200 | 366 | 11·4 | 13 | 19·79 | 35·75 | 27·30 |
| | | | | | | | | | | 400 | 732 | 11·4 | 14 | 20·03 | 36·18 | 27·64 |
| | | | | | | | | | | 600 | 1,097 | 11·0 | 15 | 20·10 | 36·31 | 27·81 |
| | | | | | | | | | | 800 | 1,463 | 8·0 | 16 | 19·90 | 35·95 | 28·04 |
| | | | | | | | | | | 1,000 | 1,829 | 4·8 | 17 | 19·55 | 35·32 | 27·97 |
| | | | | | | | | | | 1,200 | 2,195 | 4·0 | 18 | 19·48 | 35·19 | 27·96 |
| 4 | Nov. 20 | All day. | 40° 30′ N. | 12° 10′ W. | N.E., light breeze. | Fair. | Long N.E. swell. | 12·6 | Intermediate. | 0 | 0 | 14·8 | 19 | 19·93 | 36·00 | 26·81 |
| | | | | | | | | | | 100 | 183 | 12·1 | 20 | 19·82 | 35·81 | 27·22 |
| | | | | | | | | | | 200 | 366 | 11·2 | 21 | 19·75 | 35·68 | 27·28 |
| | | | | | | | | | | 400 | 732 | 10·8 | 22 | 19·83 | 35·82 | 27·47 |
| | | | | | | | | | | 600 | 1,097 | 10·2 | 23 | 19·93 | 36·00 | 27·72 |
| | | | | | | | | | | 800 | 1,463 | 7·5 | 24 | 19·72 | 35·62 | 27·87 |
| | | | | | | | | | | 1,000 | 1,829 | 4·5 | 25 | 19·83 | 35·82 | 28·41 |
| | | | | | | | | | | 1,200 | 2,195 | 3·9 | 26 | 19·48 | 35·19 | 27·97 |
| | | | | | | | | | | 1,400 | 2,561 | 3·3 | 27 | 19·45 | 35·14 | 28·00 |
| 5 | Nov. 23 | All day. | 36° 56′ N. | 13° 6′ W. | W., light breeze. | Hazy. | Fairly smooth. | 17·0 | Intermediate. | 0 | 0 | 16·8 | 28 | 20·16 | 36·42 | 26·68 |
| | | | | | | | | | | 100 | 183 | 13·3 | 29 | 19·90 | 35·95 | 27·08 |
| | | | | | | | | | | 200 | 366 | 12·8 | 30 | 19·84 | 35·84 | 27·10 |
| | | | | | | | | | | 400 | 732 | 12·1 | 31 | 20·12 | 36·35 | 27·63 |
| | | | | | | | | | | 600 | 1,097 | 11·6 | 32 | 20·20 | 36·49 | 27·85 |
| | | | | | | | | | | 800 | 1,463 | 9·7 | 33 | 20·02 | 36·17 | 27·94 |
| | | | | | | | | | | 1,000 | 1,829 | 5·8 | 34 | 19·69 | 35·57 | 28·06 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | Nov. 27 | 7 a.m. to 2 p.m. | 33° 31′ N. | 16° 57′ W. | N.E., moderate breeze. | Showery and hazy. | Long north-westerly swell; choppy. | 19·0 | Intermediate. | 0 | 0 | 19·0 | 35 | 20·40 | 36·85 | 26·46 |
| | | | | | | | | | | 100 | 183 | 15·0 | 36 | 20·03 | 36·18 | 26·91 |
| | | | | | | | | | | 200 | 366 | 12·8 | 37 | 19·93 | 36·00 | 27·23 |
| | | | | | | | | | | 400 | 732 | 10·7 | 38 | 19·83 | 35·82 | 27·49 |
| | | | | | | | | | | 600 | 1,097 | 9·5 | 39 | 19·93 | 36·00 | 27·85 |
| | | | | | | | | | | 800 | 1,463 | 7·4 | 40 | 19·76 | 35·70 | 27·94 |
| | | | | | | | | | | 1,000 | 1,829 | 5·0 | 41 | 19·55 | 35·32 | 27·95 |
| | | | | | | | | | | 1,200 | 2,195 | 3·8 | 42 | 19·52 | 35·26 | 28·04 |
| 7 | Dec. 9 | 9 a.m. to 5.3 p.m. | 33° 14′ N. | 13° 30′ W. | E., fresh breeze. | Cloudy but fine. | Long northerly swell. | 19·5 | Intermediate. | 0 | 0 | 18·5 | 43 | 20·31 | 36·69 | 26·47 |
| | | | | | | | | | | 100 | 183 | 15·0 | 44 | 20·16 | 36·42 | 27·09 |
| | | | | | | | | | | 200 | 366 | 12·3 | 45 | 19·87 | 35·90 | 27·25 |
| | | | | | | | | | | 400 | 732 | 10·6 | 46 | 19·84 | 35·84 | 27·52 |
| | | | | | | | | | | 600 | 1,097 | 10·2 | 47 | 20·07 | 36·26 | 27·92 |
| | | | | | | | | | | 800 | 1,463 | 8·0 | 48 | 19·90 | 35·95 | 28·01 |
| | | | | | | | | | | 1,000 | 1,829 | 5·6 | 49 | 19·65 | 35·50 | 28·02 |
| | | | | | | | | | | 1,200 | 2,195 | 4·3 | 50 | 19·63 | 35·46 | 28·15 |
| | | | | | | | | | | 1,400 | 2,561 | 3·6 | 51 | 19·55 | 35·32 | 28·10 |
| 8 | Dec. 14 | 9 a.m. | 34° 12′ N. | 10° 00′ W. | E.N.E., light breeze. | Fair and fine. | Long gentle northerly swell. | 17·3 | Intermediate. | 0 | 0 | 18·0 | 52 | 20·34 | 36·74 | 26·63 |
| | | | | | | | | | | 100 | 183 | 14·5 | 53 | 20·03 | 36·18 | 27·02 |
| | | | | | | | | | | 200 | 366 | 12·6 | 54 | 19·89 | 35·93 | 27·27 |
| | | | | | | | | | | 400 | 732 | 10·4 | 55 | 19·83 | 35·82 | 27·55 |
| | | | | | | | | | | 600 | 1,097 | 9·[illegible] | 56 | 19·97 | 36·08 | 27·83 |
| | | | | | | | | | | 800 | 1,463 | 8·2 | 57 | 19·83 | 35·82 | 27·92 |
| | | | | | | | | | | 1,000 | 1,829 | 5·5 | 58 | 19·63 | 35·46 | 28·01 |
| | | | | | | | | | | 1,200 | 2,195 | 4·3 | 59 | 19·57 | 35·35 | 28·06 |
| | | | | | | | | | | 1,400 | 2,561 | 3·5 | 60 | 19·51 | 35·25 | 28·05 |
| 9 | Dec. 18 | Noon to 3.30 p.m. | 35° 53′ N. | 7° 35′ W. | S.W., light air. | Fine; clear bright sunshine. | Quite smooth. | 18·5 | Grey ooze. | 0 | 0 | 17·4 | 61 | 20·23 | 36·55 | 26·62 |
| | | | | | | | | | | 20 | 37 | 16·3 | 62 | 20·20 | 36·49 | 26·85 |
| | | | | | | | | | | 100 | 183 | 14·2 | 63 | 20·03 | 36·18 | 27·09 |
| | | | | | | | | | | 200 | 366 | 12·4 | 64 | 19·93 | 36·00 | 27·29 |
| | | | | | | | | | | 400 | 732 | 10·8 | 65 | 19·89 | 35·93 | 27·56 |
| | | | | | | | | | | 600 | 1,097 | 10·4 | 66 | 20·13 | 36·36 | 27·97 |
| 10 | Dec. 19 | After-noon. | 35° 50′ N. | 6° 41′ W. | E.S.E., light breeze. | Cloudy but fine. | Smooth. | 16·3 | Rocky. | 0 | 0 | 17·0 | 67 | 20·38 | 36·82 | 26·93 |
| | | | | | | | | | | 50 | 91 | 16·0 | 68 | 20·27 | 36·62 | 27·01 |
| | | | | | | | | | | 100 | 183 | 14·4 | 69 | 20·04 | 36·20 | 27·06 |
| | | | | | | | | | | 200 | 366 | 13·5 | 70 | 20·27 | 36·62 | 27·56 |
| | | | | | | | | | | 280 | 512 | 13·5 | 71 | 20·80 | 37·57 | 28·30 |
| 11 | Dec. 20 | 2 a.m. to 4 a.m. | 35° 55′ N. | 5° 53′ W. | E.S.E., fresh breeze. | Fair, moonlight. | Smooth. | 14·5 | Coral shell. | 0 | 0 | 16·5 | 72 | 20·24 | 36·56 | 26·86 |
| | | | | | | | | | | 20 | 37 | 15·5 | 73 | 20·27 | 36·62 | 27·13 |
| | | | | | | | | | | 60 | 110 | 15·2 | 74 | 20·16 | 36·42 | 27·04 |
| | | | | | | | | | | 110 | 201 | 14·0 | 75 | 20·84 | 37·65 | 28·25 |
| | | | | | | | | | | 160 | 293 | 13·2 | 76 | 21·24 | 38·37 | 28·98 |

## IV.—HYDROGRAPHICAL OBSERVATIONS, SHETLAND TO NORWAY, 1907.

STATION Sc. 6*a*.—September 1, 1907 (*Goldseeker*).

Lat. 60° 4′ N., Long. 0° 33′ E. Depth of the station, 120 metres.

| Metres. | $t°$ | $S$ ‰ | $\sigma_t$ | Remarks. |
|---|---|---|---|---|
| 115 | 7·03 | 35·35 | 27·72 | Time, 1.15 to 2 p.m. Strong wind, N.W.; force, 5. Air temperature: dry bulb, 7·0° C.; wet bulb, 6·9° C. Hail at 11.30 a.m. Corrected barometer, 767·1. |
| 100 | 7·07 | ,, | 27·71 | |
| 80 | 7·37 | 35·30 | 27·62 | |
| 60 | 7·58 | ,, | 27·59 | |
| 40 | 8·32 | ,, | 27·48 | |
| 30 | 10·98 | 35·01 | 26·81 | |
| 20 | ,, | 34·97 | 26·78 | |
| 10 | ,, | 34·96 | 26·76 | |
| 0 | 10·85 | 35·03 | 26·85 | |

$t$ = Temperature in C.
$S$ ‰ = Salinity in ‰.
$\sigma_t$ = Density *in situ* referred to pure water of + 4° C.

STATION Sc. 7.—August 28, 1907 (*Goldseeker*).

Lat. 61° 06′ N., Long. 2° 01′ E. Depth of the station, 131 metres.

| Metres. | $t°$ | $S$ ‰ | $\sigma_t$ | Remarks. |
|---|---|---|---|---|
| 125 | 7·19 | 35·30 | 27·65 | Time, 5.25 to 6.55 p.m. Wind S.S.W.; force, 2. Air temperature: dry bulb, 11·2° C.; wet bulb, 9·7° C. Barometer (corrected), 768·9. |
| 100 | 7·73 | 35·28 | 27·55 | |
| 80 | 8·00 | ,, | 27·51 | |
| 60 | 8·40 | ,, | 27·45 | |
| 40 | 9·22 | 35·26 | 27·31 | |
| 30 | 10·91 | 34·88 | 26·72 | |
| 20 | 11·34 | 34·58 | 26·41 | |
| 10 | 11·50 | 34·49 | 26·30 | |
| 0 | 11·65 | 34·38 | 26·17 | |

STATION Sc. 8.—August 28, 1907 (*Goldseeker*).

Lat. 61° 30′ N., Long. 3° 03′ E. Depth of the station, 375 metres.

| Metres. | $t°$ | $S$ ‰ | $\sigma_t$ | Remarks. |
|---|---|---|---|---|
| 370 | 5·92 | 35·12 | 27·67 | Slight swell. Sunshine. Time, 7.50 a.m. to 12 noon. Wind S.W.; force, 1. Air temperature: dry bulb, 120° C.; wet bulb, 11·4° C. Barometer (corrected), 768·8. |
| 300 | 5·86 | ,, | 27·68 | |
| 250 | 5·84 | 35·03 | 27·61 | |
| 200 | 5·98 | ,, | 27·60 | |
| 150 | ,, | ,, | ,, | |
| 100 | 7·82 | 35·23* | 27·50 | |
| 80 | 7·18 | 35·03 | 27·43 | |
| 60 | 6·58 | 34·85 | 27·37 | |
| 40 | 7·17 | 34·65 | 27·14 | |
| 30 | 8·02 | 34·43 | 26·85 | |
| 20 | 9·60 | 33·95 | 26·22 | |
| 10 | 11·12 | 33·44 | 25·56 | |
| 0 | 11·25 | 33·40 | 25·50 | |
| 125 | 6·02 | 35·05* | 27·60 | |

* These salinities were redetermined.

STATION 1.—September 21, 1907 (*Silver Belle*).

Lat. 60° 59′ N., Long. 0·47′ E.

| Fathoms. | $t°$ | $S$ ‰ | $\sigma_t$ | Remarks. |
|---|---|---|---|---|
| 5 | 10·0 | 35·28 | 27·19 | Thermometer used: J. Hicks, No. 909,128. Wind N., strong breeze; heavy swell; weather showery and very squally. Time, 7 a.m. to 8.30 a.m. |
| 15 | 10·0 | 35·28 | 27·19 | |
| 25 | 10·0 | 35·28 | 27·19 | |
| 30 | 9·9 | 35·32 | 27·24 | |
| 40 | 9·8 | 35·30 | 27·24 | |
| 50 | 9·2 | 35·21 | 27·28 | |
| 75 | 8·2 | 35·28 | 27·48 | |

STATION 6.—September 21, 1907 (*Silver Belle*).

Lat. 61° 5′ N., Long. 2° 0′ E.

| Fathoms. | $t°$ | $S$ ‰ | $\sigma_t$ | Remarks. |
|---|---|---|---|---|
| 0 | 8·8 | 35·21 | 27·34 | Strong breeze N., heavy swell from N.N.W.; weather squally and showery. Time, afternoon, 2 p.m. Air temperature, 6·0° C. At 50 fathoms the observation was repeated three times, always with the same result. |
| 5 | 9·6 | 35·21 | 27·21 | |
| 10 | 9·6 | 35·21 | 27·21 | |
| 20 | 9·6 | 35·21 | 27·21 | |
| 30 | 9·6 | 35·21 | 27·21 | |
| 40 | 9·6 | 35·21 | 27·21 | |
| 50 | 8·3 | 35·21 | 27·41 | |
| 70 | 9·0 | 35·19 | 27·29 | |

STATION 3.—September 23, 1907 (*Silver Belle*).

Lat. 61° 31′ N., Long. 3° 4′ E. Depth of the station, 210 fathoms.

| Fathoms. | $t°$ | $S$ ‰ | $\sigma_t$ | Remarks. |
|---|---|---|---|---|
| 0 | 9·3 | 34·87 | 26·99 | Wind variable. Weather, drizzle. Sea very choppy. Nature of bottom, fine sand. Number of thermometer, 106,206. Time, afternoon. Air temperature, 8·0° C. |
| 5 | 9·2 | 35·01 | 27·12 | |
| 10 | 9·0 | 35·01 | 27·15 | |
| 20 | 9·1 | 35·30 | 27·35 | |
| 30 | 9·6 | 35·41 | 27·36 | |
| 40 | 9·1 | 35·30 | 27·35 | |
| 60 | 9·1 | 35·37 | 27·41 | |
| 80 | 8·6 | 35·30 | 27·45 | |
| 100 | 8·2 | 35·28 | 27·48 | |
| 120 | 8·2 | — | — | |
| 140 | 8·2 | 35·28 | 27·48 | |
| 160 | 7·2 | 35·10 | 27·49 | |
| 180 | 6·8 | 35·03 | 27·49 | |
| 200 | 5·7 | 35·03 | 27·64 | |

STATION 4.—September 22, 1907 (*Silver Belle*).

Lat. 61° 32′ N., Long. 3° 44′ E.

| Fathoms. | $t°$ | $S$ ‰ | $\sigma_t$ | Remarks. |
|---|---|---|---|---|
| 0 | 11·0 | 32·38 | 24·75 | Weather showery and cold, blowing strong and backing N.W. to W.; variable, rain later. Time, afternoon. Air temperature, 7·0° C. |
| 5 | 10·9 | 32·38 | 24·77 | |
| 10 | 10·9 | 32·38 | 24·77 | |
| 20 | 10·8 | 33·69 | 25·81 | |
| 30 | 10·3 | 34·60 | 26·61 | |
| 40 | 9·2 | 35·03 | 27·13 | |
| 60 | 7·2 | 34·88 | 27·32 | |
| 80 | 7·8 | 35·16 | 27·44 | |
| 100 | 7·6 | 35·19 | 27·50 | |
| 120 | 7·0 | 35·14 | 27·55 | |
| 140 | 7·0 | 35·14 | 27·55 | |

STATION 5.—September 22, 1907 (*Silver Belle*).

Lat. 61° 15′ N., Long. 4° 9′ E.

| Fathoms. | $t°$ | $S$ ‰ | $\sigma_t$ | Remarks. |
|---|---|---|---|---|
| 0 | 10·9 | 32·25 | 24·68 | Wind N.N.W.; light, long swell. Time, morning, 5 a.m. Air temperature, 6·5° C. |
| 5 | 11·2 | 32·25 | 24·63 | |
| 10 | 11·2 | 32·25 | 24·63 | |
| 20 | 11·7 | 32·47 | 24·70 | |
| 30 | 10·0 | 33·86 | 26·08 | |
| 40 | 10·0 | 34·87 | 26·87 | |
| 60 | 9·0 | 35·12 | 27·23 | |
| 80 | 8·2 | 35·12 | 27·36 | |
| 100 | 7·9 | 35·23 | 27·48 | |
| 120 | 6·7 | 35·01 | 27·49 | |
| 140 | 6·6 | 35·01 | 27·51 | |
| 160 | 6·9 | 35·10 | 27·53 | |
| 180 | 6·2 | 35·05 | 27·56 | |

# PLANKTON, 'SILVER BELLE,' SEPTEMBER, 1907, SHETLAND TO NORWAY.

## Closing-Net.

| Arten. | Station II. | | Station III. | | | | | Station IV. | | | Station V. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 70 Faden. | 50 Faden. | 200 Faden. | 150 Faden. | 100 Faden. | 50 Faden. | 20 Faden. | 100 Faden. | 50 Faden. | 20 Faden. | 100 Faden. | 100 Faden. | 60 Faden. | 20 Faden. |
| *Radiolaria.* | | | | | | | | | | | | | | |
| 1. Hexacontium entacanthium (Jörgensen) ... ... .. ... | — | — | — | — | — | — | × | — | — | — | — | — | — | — |
| 2. Protocystis xiphodon (Haeckel) ... | — | — | × | × | — | × | — | — | — | — | — | — | — | — |
| 3. Rhizoplegma boreale (Jörgensen) ... | — | — | — | × | — | — | — | — | — | — | — | — | — | — |
| *Bryozoa.* | | | | | | | | | | | | | | |
| 4. Cyphonautes ... ... ... ... | — | — | — | — | — | — | — | — | — | + | — | + | r | r |
| *Cœlenterata.* | | | | | | | | | | | | | | |
| 5. Aglantha digitalis (O. F. Müller)) ... | — | r | — | — | — | r | — | — | — | — | — | — | — | — |
| 6. Arachnactis albida (M. Sars) ... | — | — | — | — | r | r | — | — | r | r | — | — | — | — |
| 7. Diphyes truncata (M. Sars) .. ... | — | — | — | — | r | r | — | r | r | — | — | r | — | — |
| 8. Pleurobrachia pileus (Flem) ... ... | — | — | — | — | — | — | — | — | — | r | — | — | — | — |
| *Vermes* (sens. gener.). | | | | | | | | | | | | | | |
| 9. Annelida larva ... ... ... | — | — | — | — | r | r | — | — | r | — | — | r | — | — |
| 10. Sagitta bipunctata (Quoy and Gaim) | r | — | — | — | r | r | — | r | r | r | — | — | r | r |
| 11. Tomopteris helgolandica (Greef) ... | — | — | — | — | r | — | — | — | — | — | — | — | — | — |
| *Copepoda.* | | | | | | | | | | | | | | |
| 12. Acartia clausi (Giesbr) ... ... | — | — | — | — | — | — | r | — | — | r | — | r | — | + |
| 13. ,, longiremis (Lillieb) ... ... | — | — | — | — | r | — | r | — | — | — | — | — | — | + |
| 14. Aetideus armatus (Boeck) ... ... | — | — | — | r | — | — | — | — | — | — | — | — | — | — |
| 15. Calanus finmarchicus (Gunn) ... | + | r | + | — | r | + | + | r | + | + | + | + | r | r |
| 16. ,, hyperboreus (Kröyer) ... | — | — | r | — | — | — | — | — | — | — | r | — | — | — |
| 17. Centropages typicus (Kröyer) ... | — | — | — | — | — | — | — | — | r | r | — | r | — | r |
| 18. Euchaeta norvegica (Boeck) ... ... | — | — | — | r | — | r | — | r | — | — | r | r | — | — |
| 19. Gaidius brevispinus (G. O. Sars) ... | — | — | r | — | — | — | — | — | — | — | — | — | — | — |
| 20. ,, tenuispinus (G. O. Sars) ... | — | — | — | — | r | — | — | — | — | — | — | — | — | — |
| 21. Metridia longa (Lubbock) ... ... | — | — | r | — | — | — | — | — | — | — | r | — | — | — |
| 22. ,, lucens (Boeck) ... ... | + | r | r | r | r | + | — | + | + | — | r | + | r | r |
| 23. Microcalanus pusillus (G. O. Sars) ... | r | — | — | — | — | + | — | + | — | — | — | r | — | — |
| 24. Microsetella norvegica (Boeck) ... | — | — | — | × | — | — | × | — | — | — | — | — | — | — |
| 25. Oithona plumifera (Baird) ... ... | r | r | r | r | — | — | — | r | — | — | — | + | r | — |
| 26. ,, similis (Claus) ... ... | + | r | r | r | c | c | c | + | c | c | r | + | + | c |
| 27. Oncæa mediterranea (Claus) ... | r | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 28. Pseudocalanus elongatus (Boeck) ... | r | — | — | r | + | + | r | r | c | c | + | c | + | — |
| 29. Rhincalanus nasutus (Giesbr) ... | — | — | — | — | — | r | r | — | — | — | — | r | — | — |
| 30. Scolecithrix minor (Brady) ... ... | — | — | — | — | — | r | — | — | — | — | — | — | — | — |
| 31. Temora longicornis (O. F. Müller) ... | — | — | — | — | r | — | r | r | + | + | — | — | — | c |
| *Crustacea* (citer.). | | | | | | | | | | | | | | |
| 32. Conchoecia sp.... ... ... ... | — | — | — | r | — | r | — | — | — | — | r | r | — | — |
| 33. Evadne Normani (Lillieborg) ... | — | — | — | — | — | — | — | — | r | r | — | — | — | — |
| 34. Nyctiphanes norvegica (Sars) ... | — | — | — | — | — | — | r | r | — | — | — | — | — | — |
| 35. Pagŭrus (Zoëa) ... ... ... | — | — | — | — | — | — | r | — | — | — | — | — | — | — |
| 36. Parathemisto oblivia (Kröyer) ... | — | — | — | — | — | — | — | — | — | — | r | — | — | — |
| 37. Thysanoessa longicaudata (Kröyer) ... | — | — | r | — | — | — | r | — | — | — | — | — | r | — |
| 38. ,, neglecta (Kröyer) ... | — | — | — | — | — | — | — | — | — | — | — | r | — | — |
| *Mollusca.* | | | | | | | | | | | | | | |
| 39. Gasteropoda larva ... ... ... | — | — | — | r | + | r | + | — | + | r | — | r | — | + |
| 40. Lamellibranchiata larva ... ... | — | — | — | — | + | r | r | r | r | r | — | r | — | r |
| 41. Limacina retroversa (Flem.) ... ... | — | — | — | — | — | — | r | r | — | — | — | — | — | — |
| *Prochordata.* | | | | | | | | | | | | | | |
| 42. Doliolum tritonis ... ... ... | r | — | — | — | — | r | — | — | — | — | — | — | — | — |
| 43. Oikopleura sp.... ... ... .. | — | — | — | — | — | r | r | — | + | r | — | r | — | — |

Planktonet viser en avgjort sydlig karakter, kun i de dypeste pröver fra Station III. & Station V., tyder forekomsten av *Calanus hyperboreus* & *Metridia longa* paa en tilblanding av koldt vand (arktisk tilblanding ?). Former som *Rhincalanus nasutus* & *Arachnactis albida* tyder paa vand av en höure temperatur, likesom forekomsten av *Oncaea mediterranea Doliolum tritonis* paa Station III. & Station II., viser i retning mot, at der her er en tilblanding av neget utpraget, varmere atlantisk plankton.

Liggende kryds ( × ) betegner at arten forekom, uten at man kan dömme om dens hyppighet paa grund av netdukens for grovmaskete konstruktion.

## ANMÄIKNINGAR.

### Snitt. No. 1.

1. Djupen på stationerna I., II., IV. ō V. uttagna ur Nordsjökortet.

2. Skalan enl. Bulletinen, men *fördubblad* (i enlighet med hoad jag. fick göra på Centralbigran i K.).

3. Afstånden mellan stationerna:

| | |
|---|---|
| I. and II. ... ... ... ... | 36′ |
| II. „ III. ... ... ... ... | 41′ |
| III. „ IV. ... ... ... ... | 19′ |
| IV. „ V. ... ... ... ... | 21′ |
| V. till land ... ... ... ... | 19′ |

4. Förefaller egendomligt all observationerna på stationerna II. ō IV. äro verkställda *samma* dag, bägge på eftermiddagen. Afståndet mellan dessa båda stationer aï i det näimaste 60′.

### Snitt. No. 2.

1. Djupen Sc. 6., Sc. 7 ō Sc. 8 enligt Nordsjökortet.

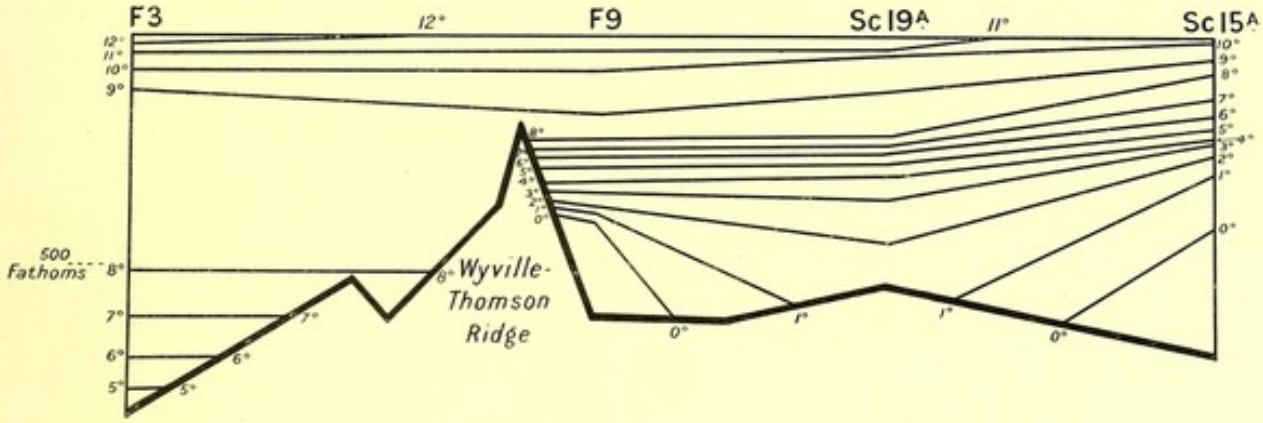
2. Samma skala som No. 1.

3. Afstånden mellan stationerna:

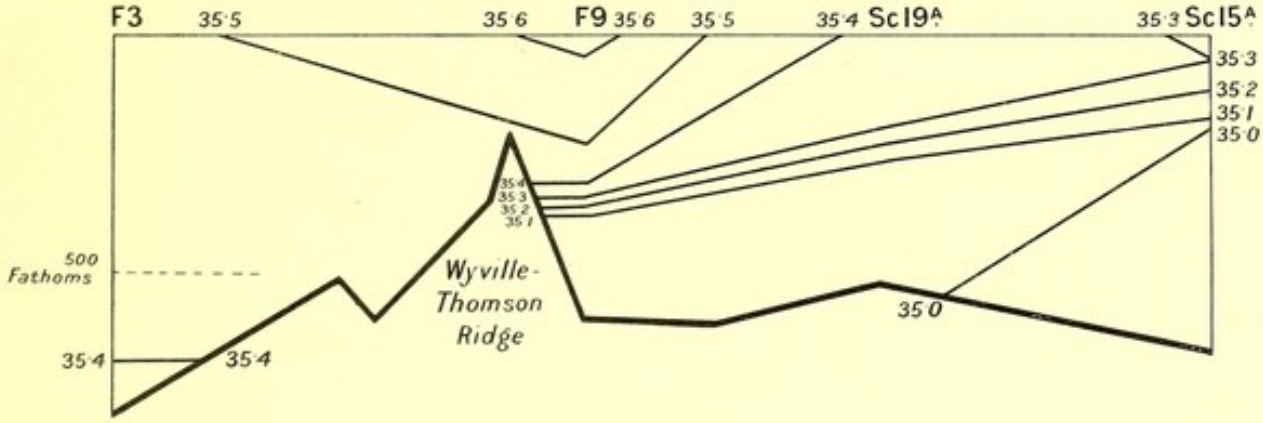
| | |
|---|---|
| Sc. 6 and Sc. 7 .. ... ... ... | 54′ |
| Sc. 7 „ Sc. 8 ... ... ... ... | 38′ |

4. Enligt uppgiften skulle S. Foo i ytan på Sc. 8 vara 31·35. Della äi väl felskrifning för 34·35.

## TEMPERATURE, 1903. SECTION I.




## SALINITY, 1903. SECTION I.



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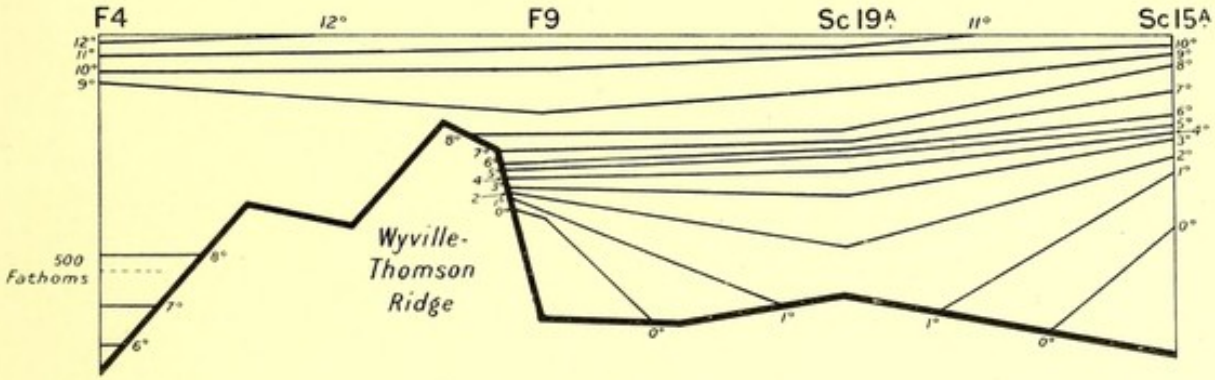
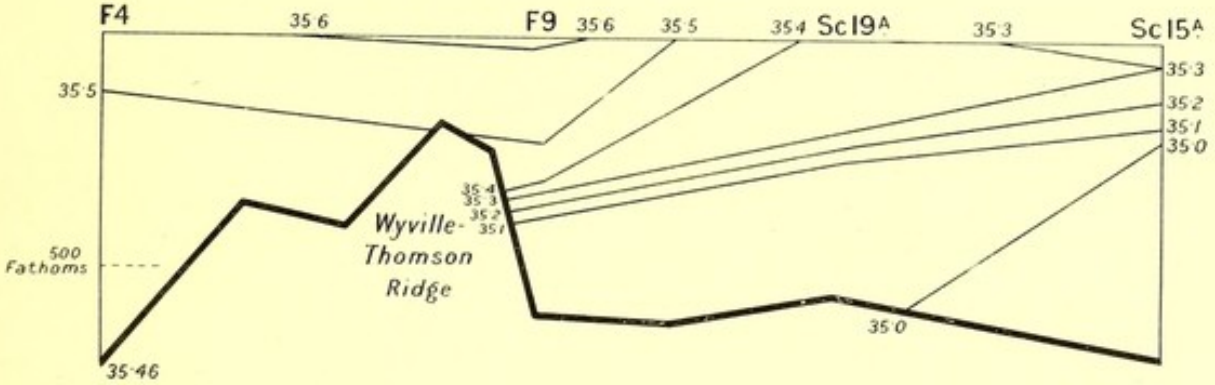
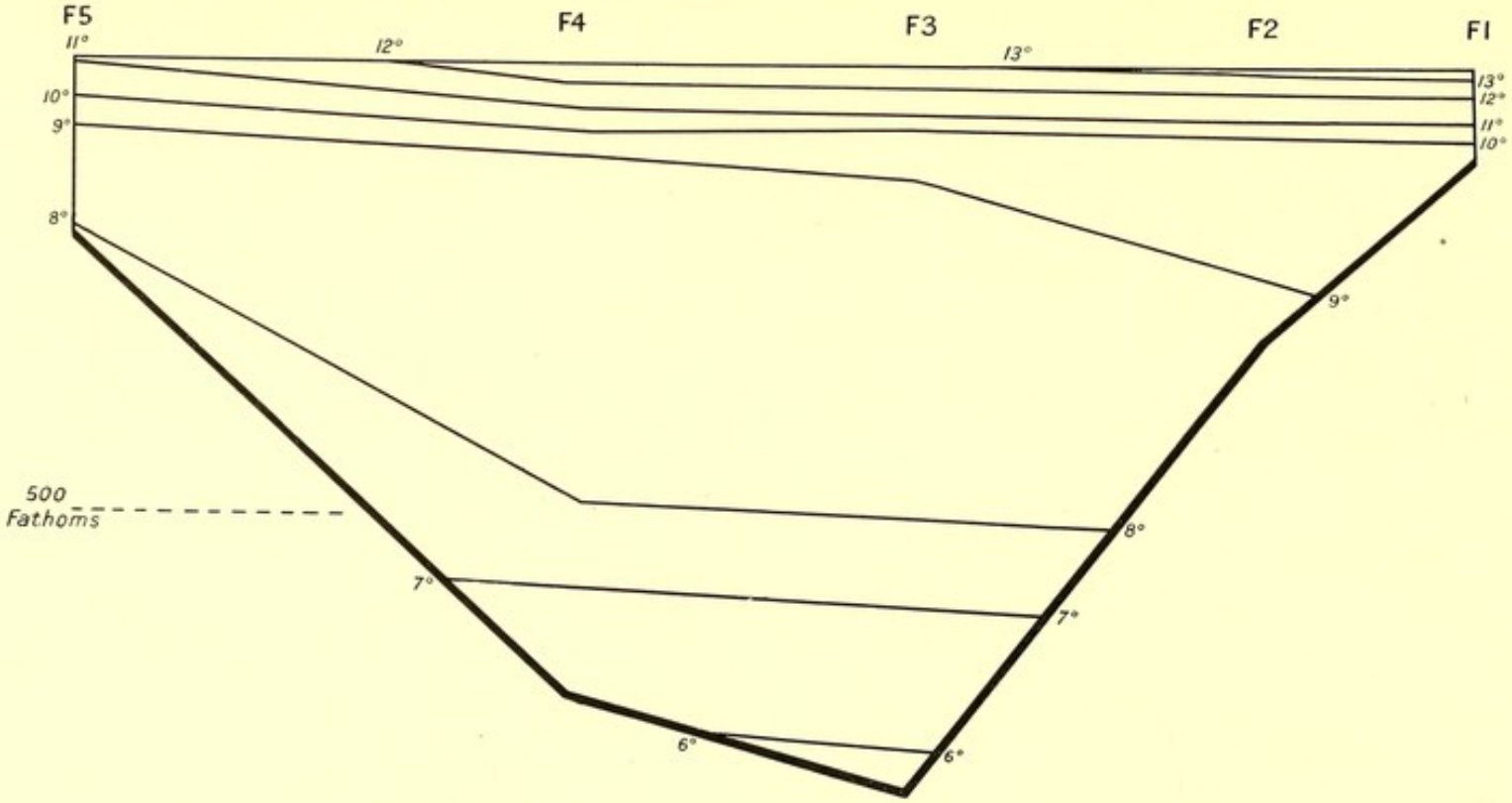


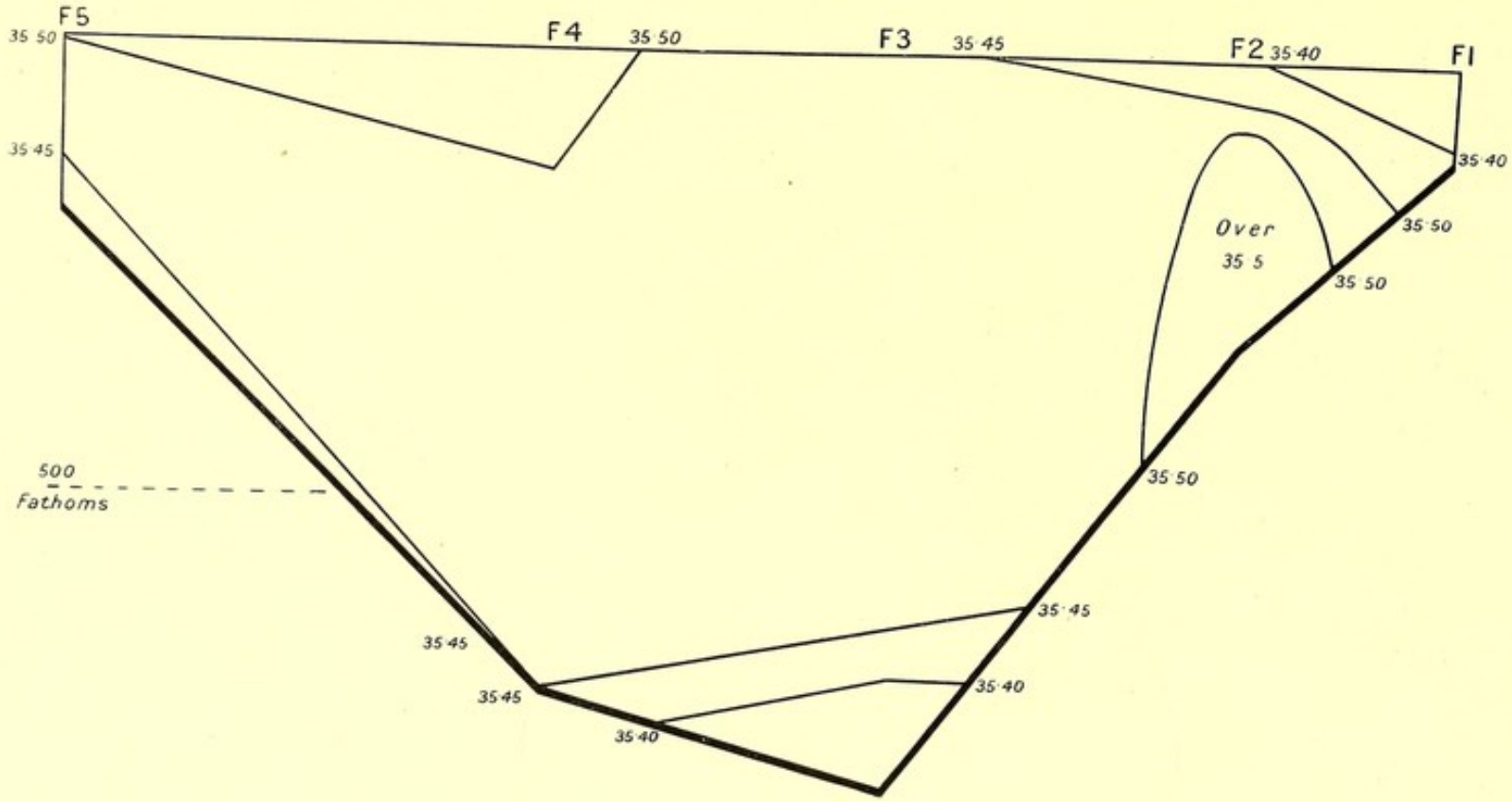

## SALINITY, 1903. SECTION II.



TEMPERATURE, 1903. SECTION III.



SALINITY, 1903. SECTION III.



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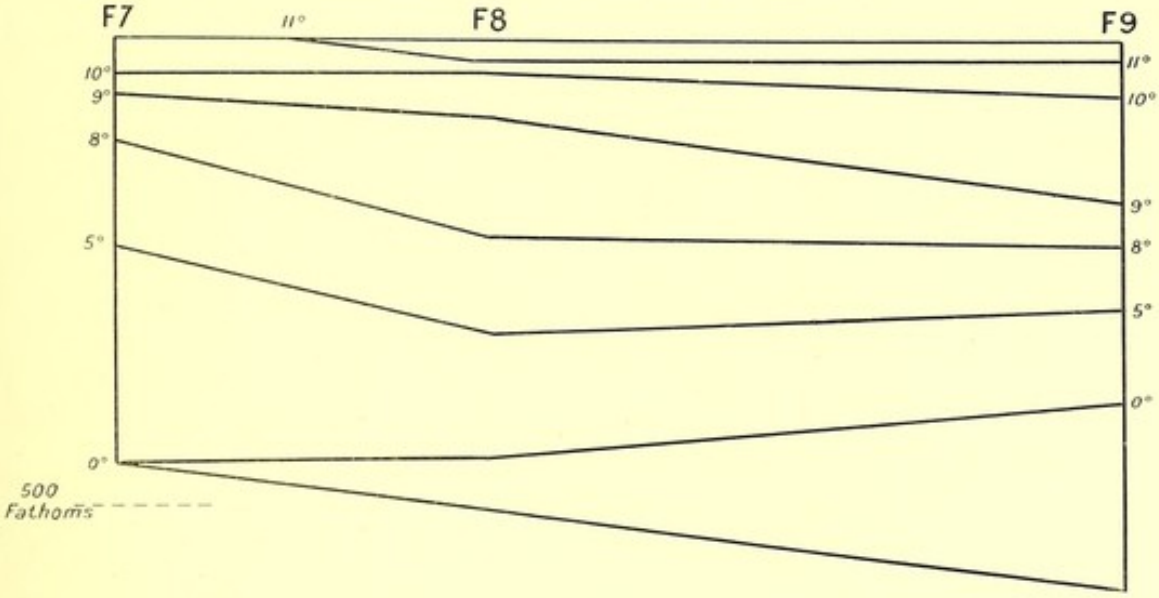


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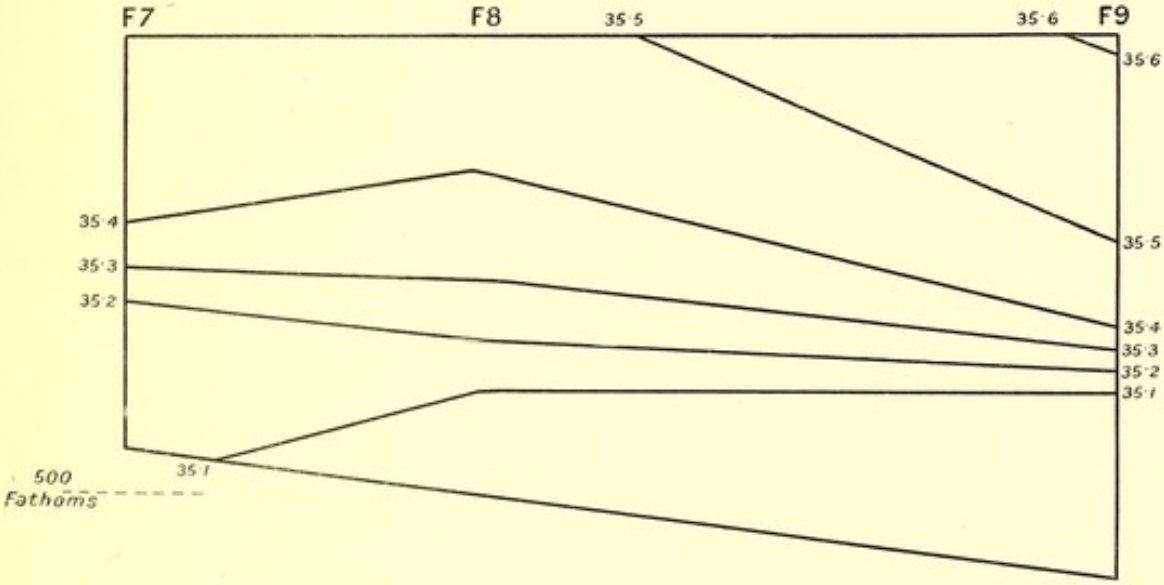

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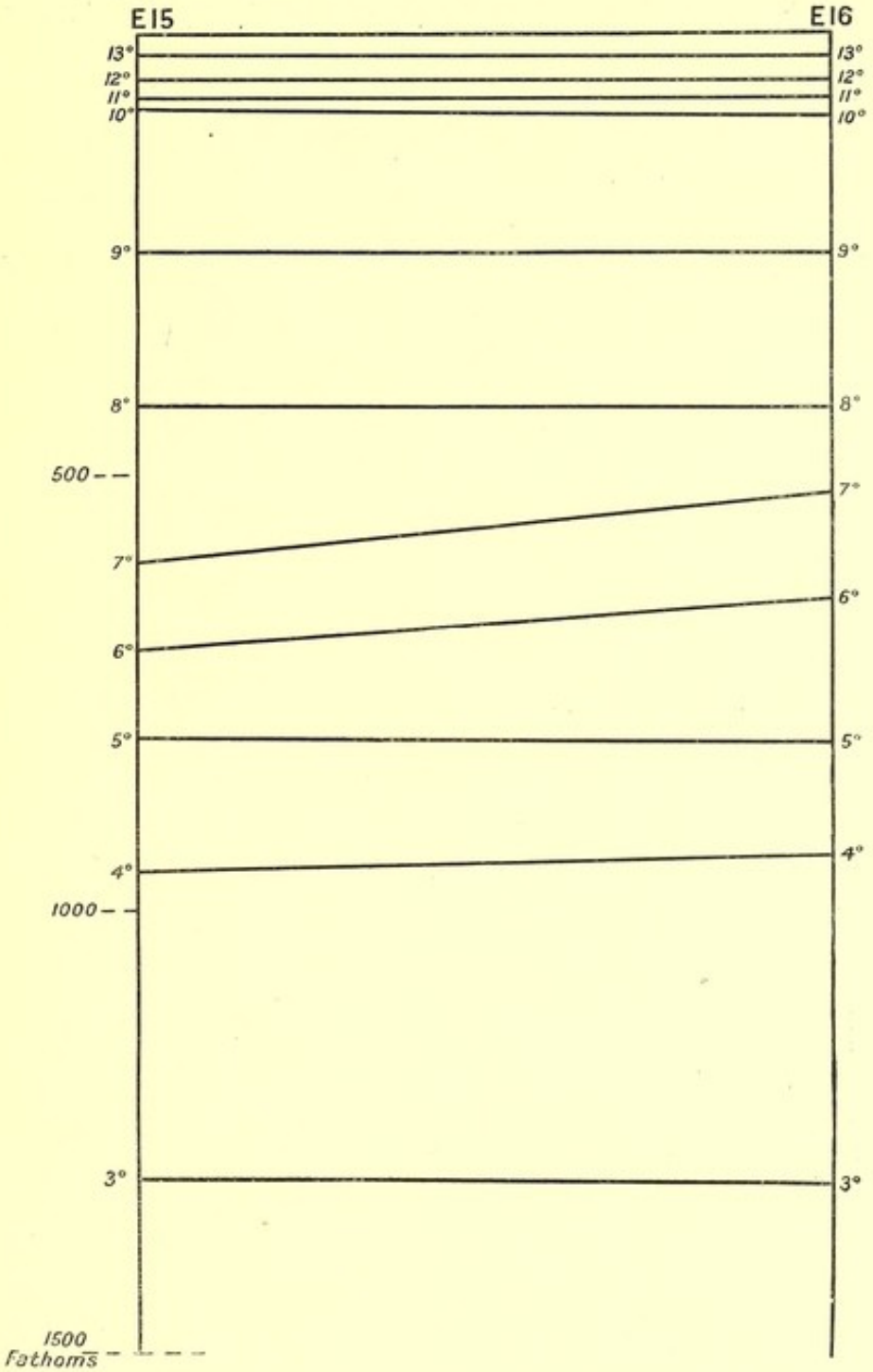

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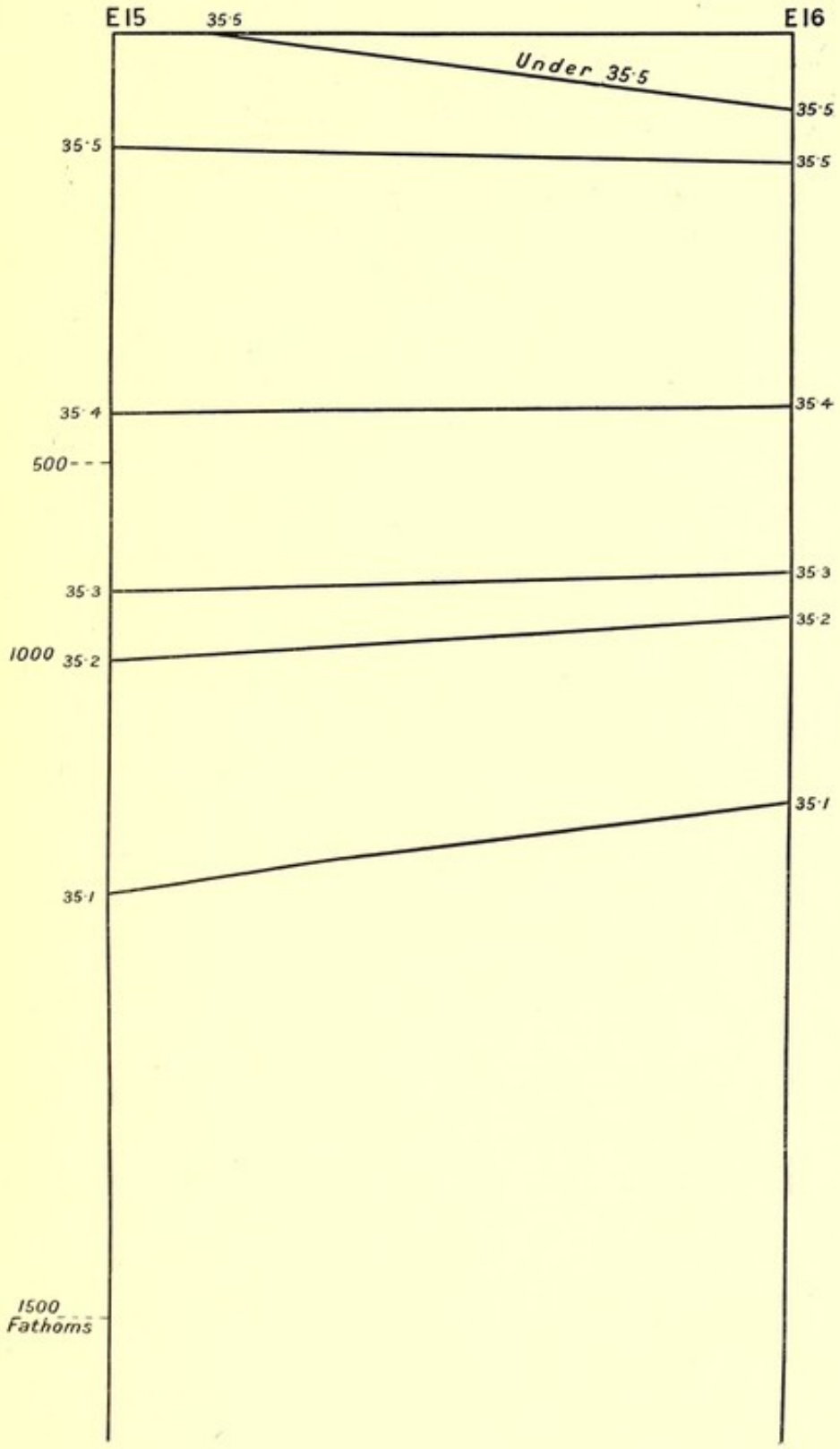
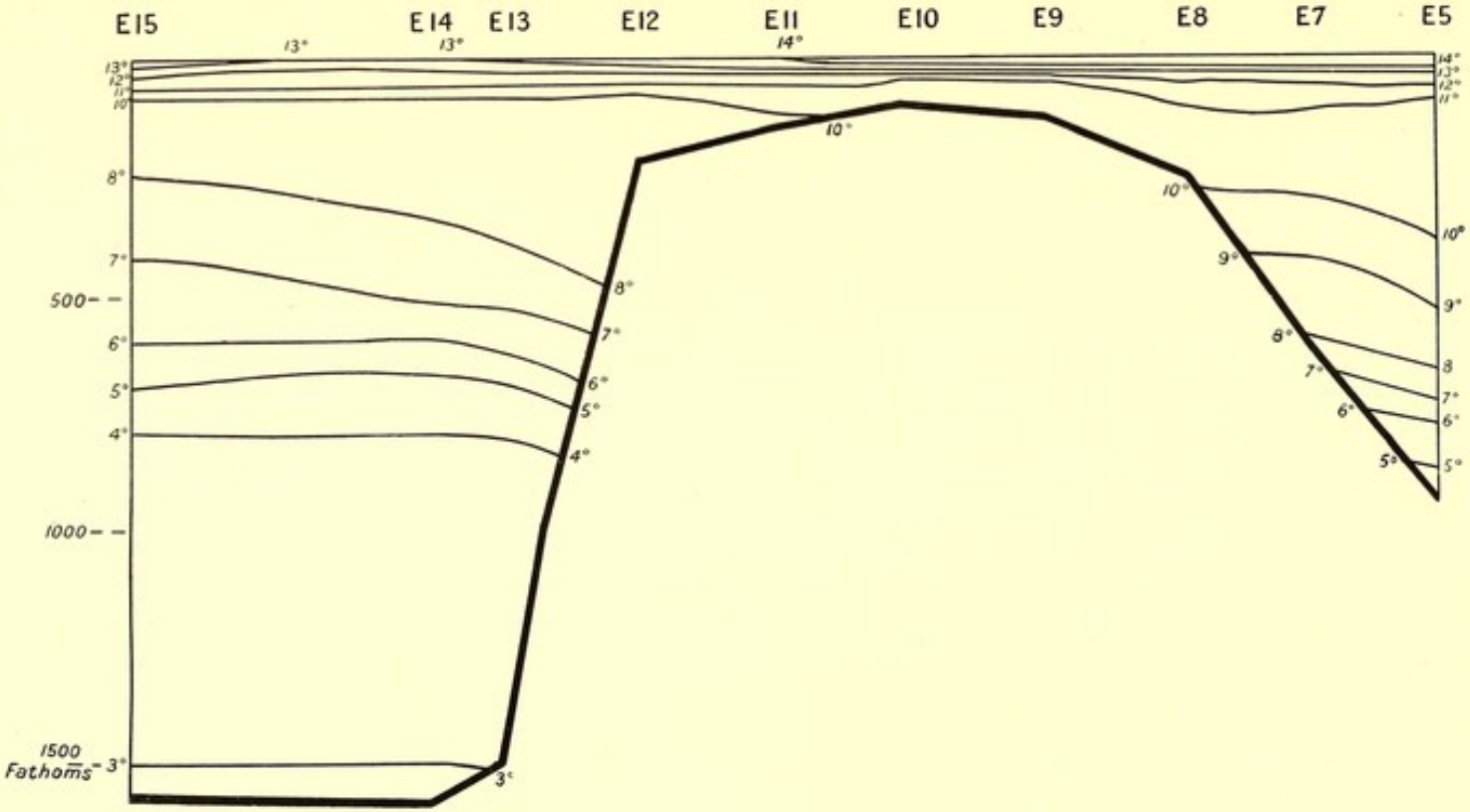


TEMPERATURE, 1903. SECTION VI



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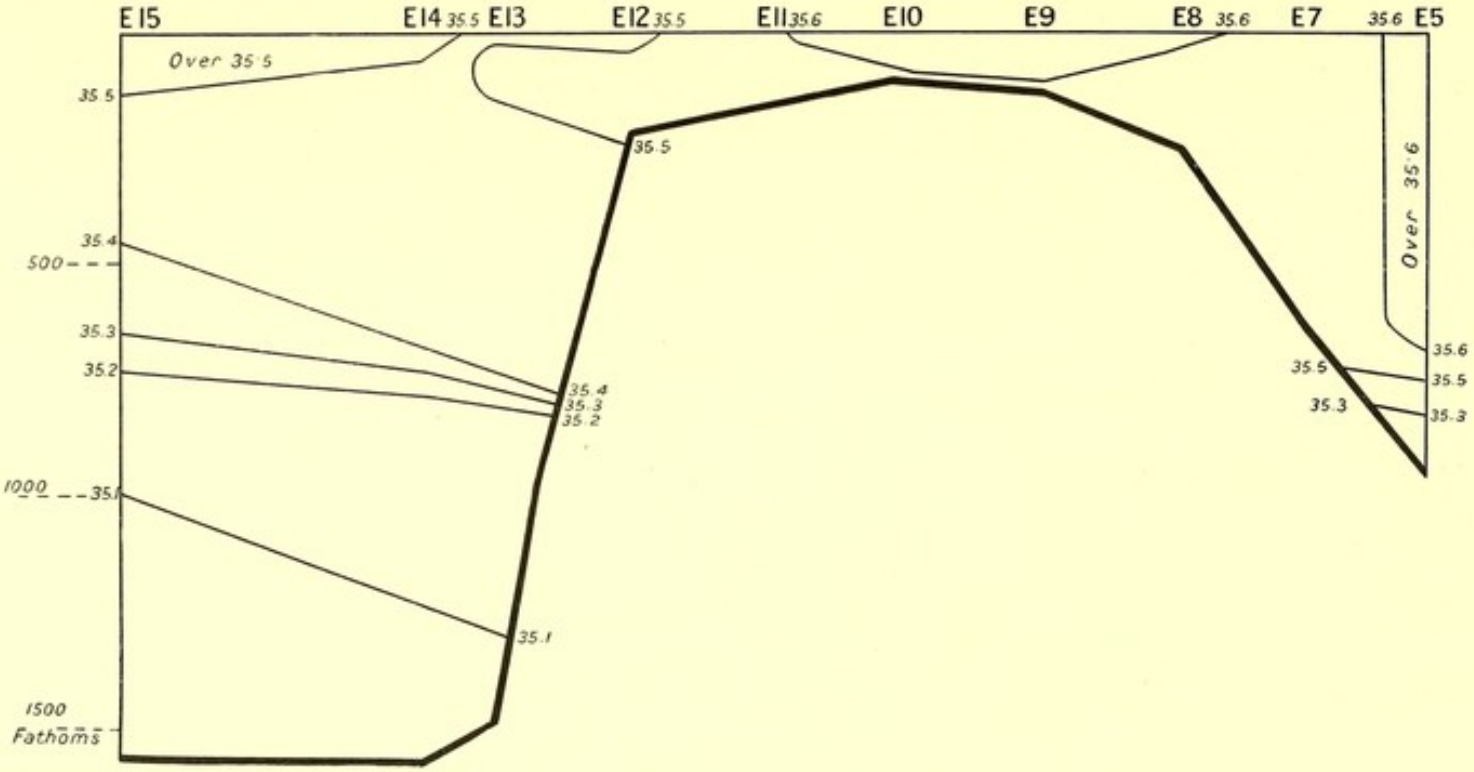

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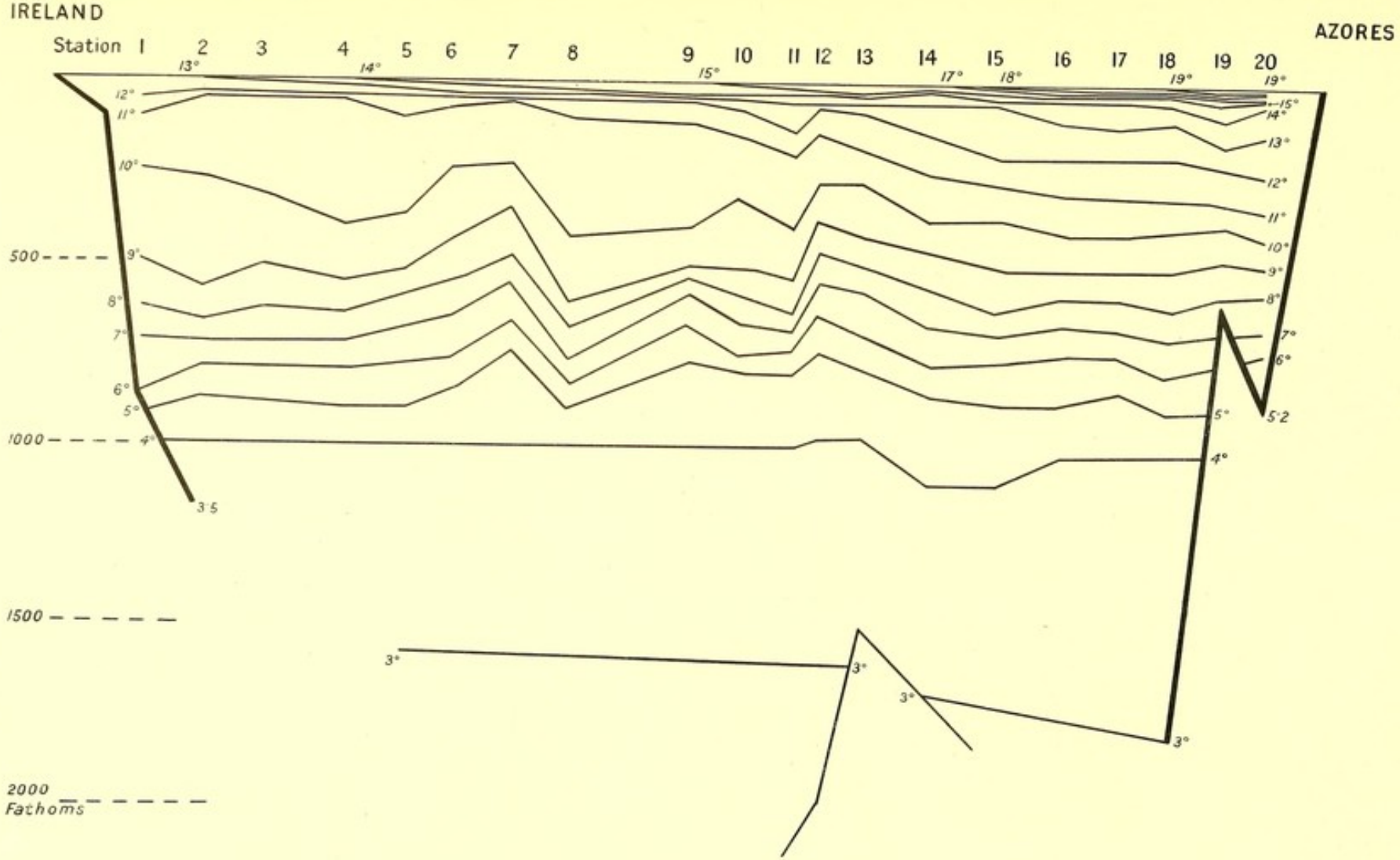
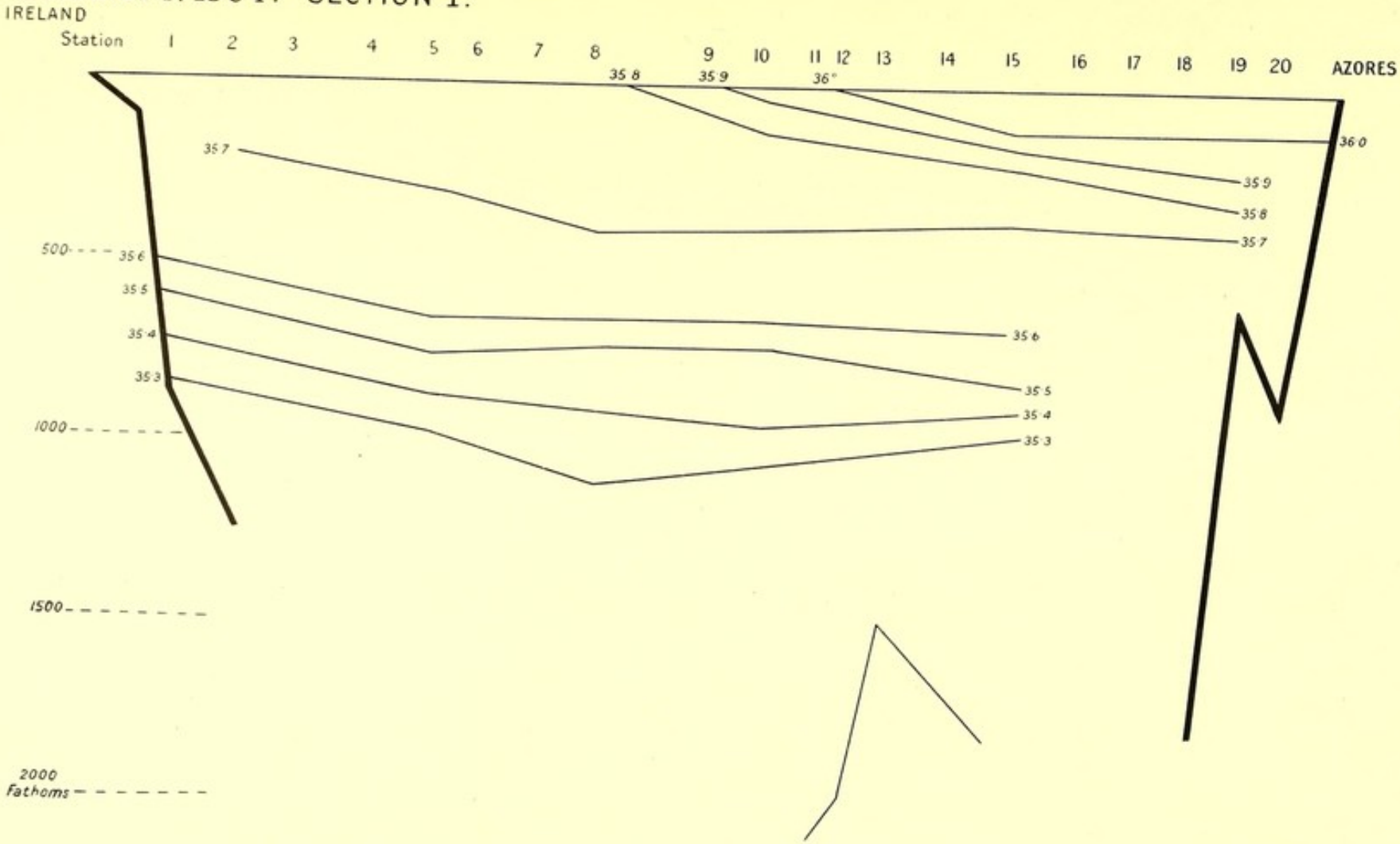


# SALINITY. 1904. SECTION I.



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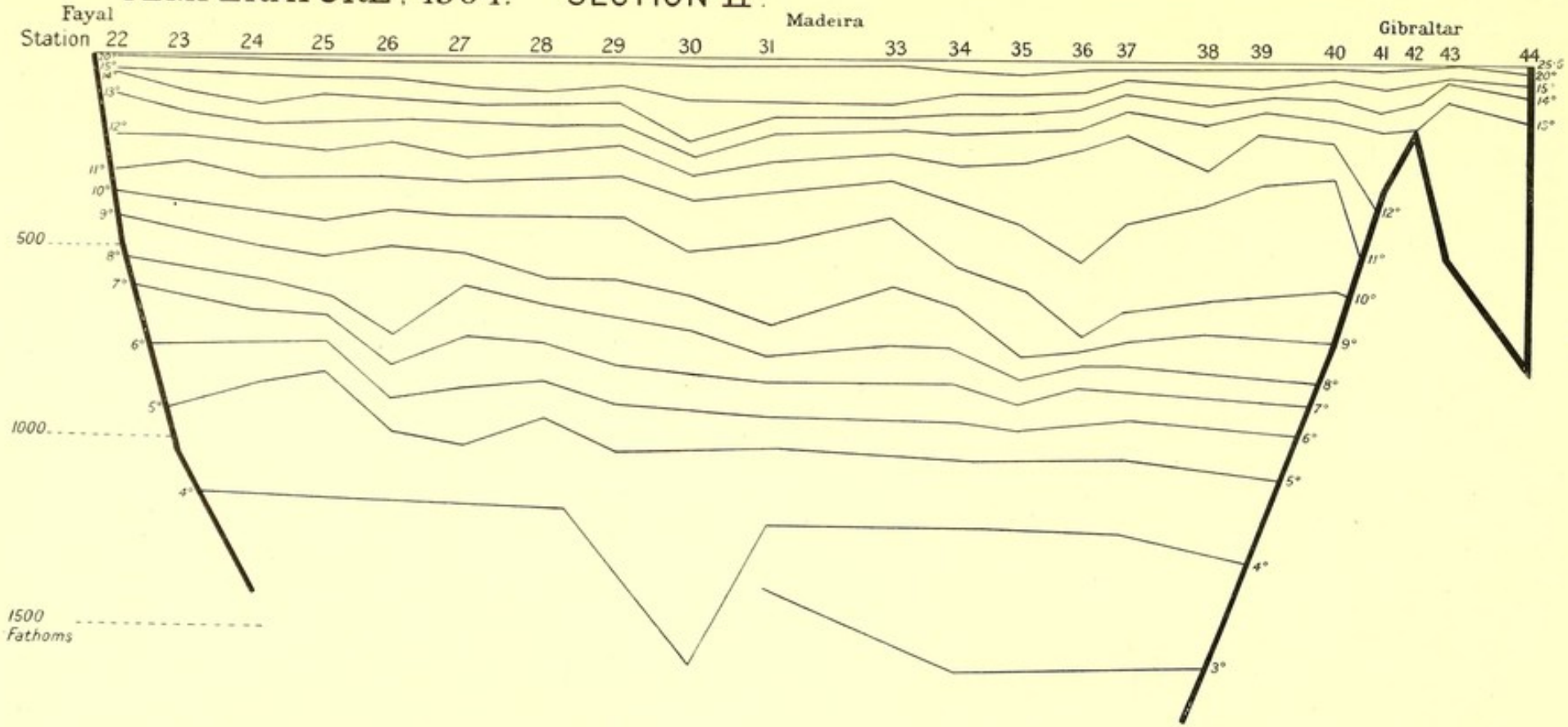
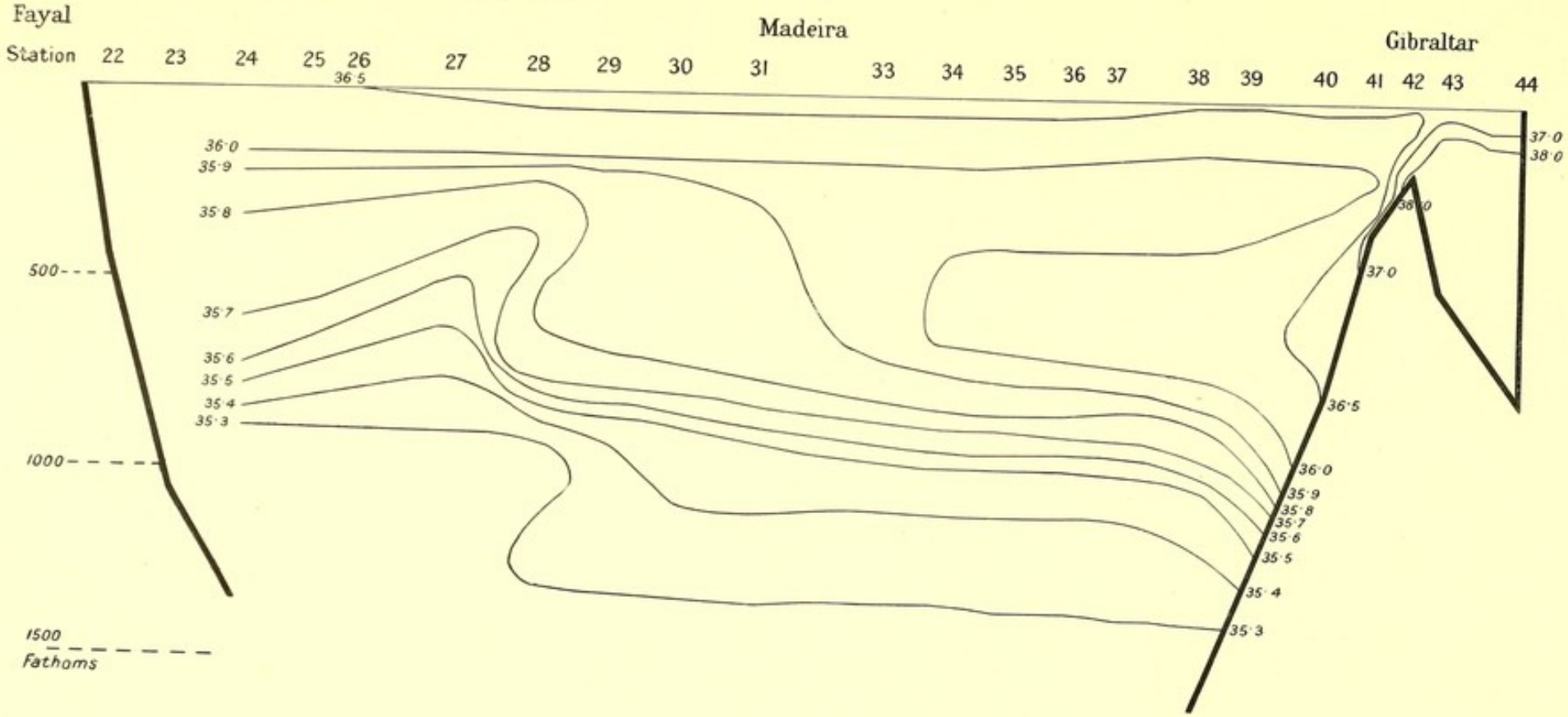
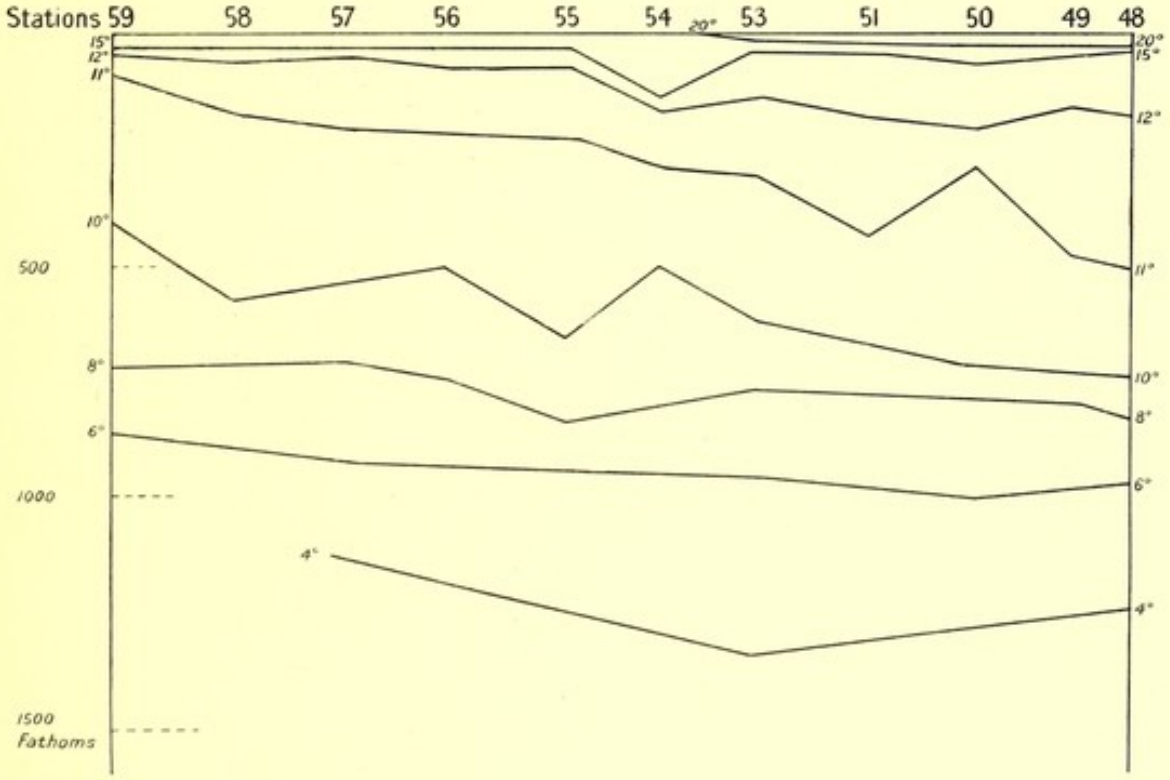
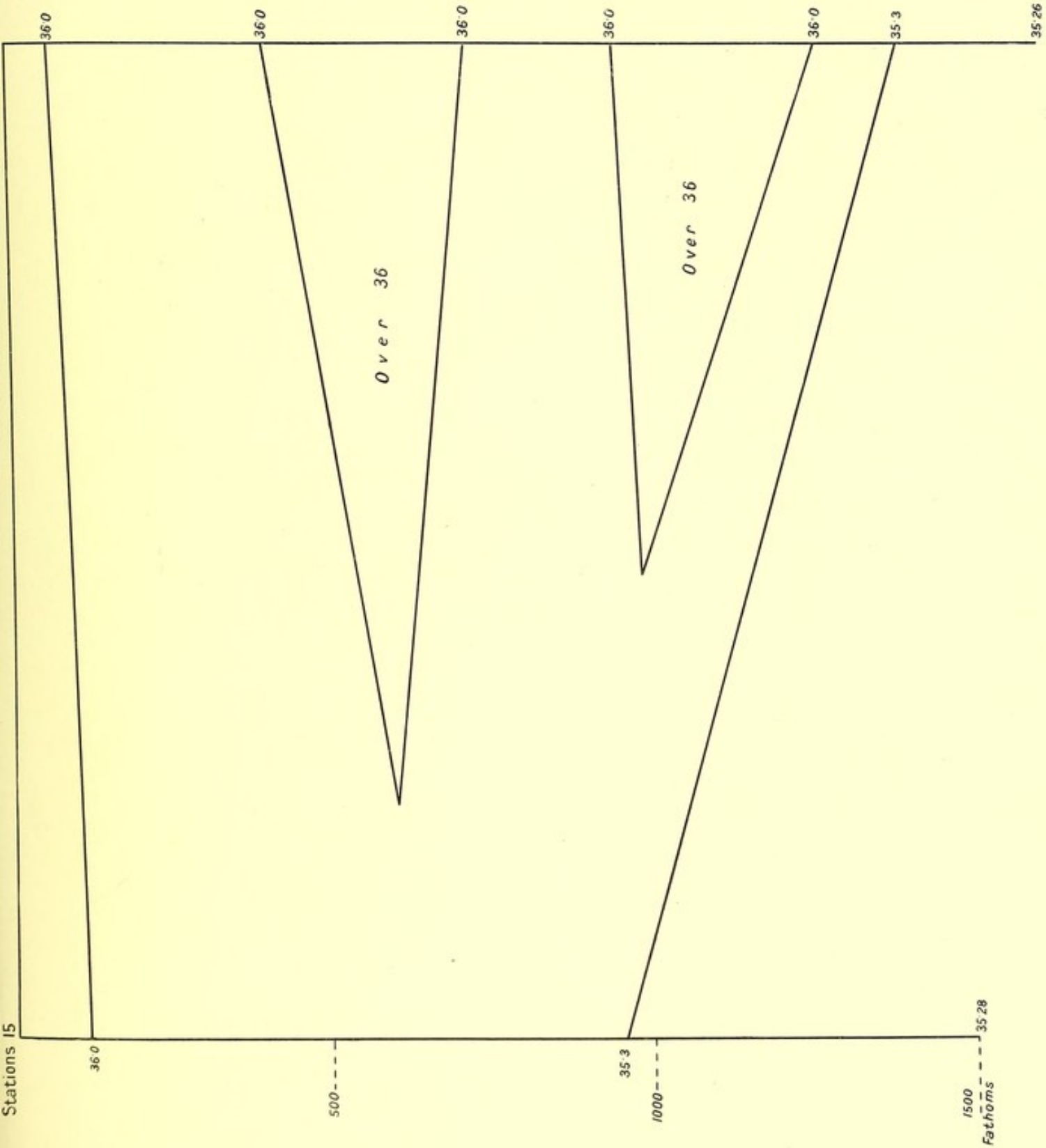


## SALINITY, 1904. SECTION II.

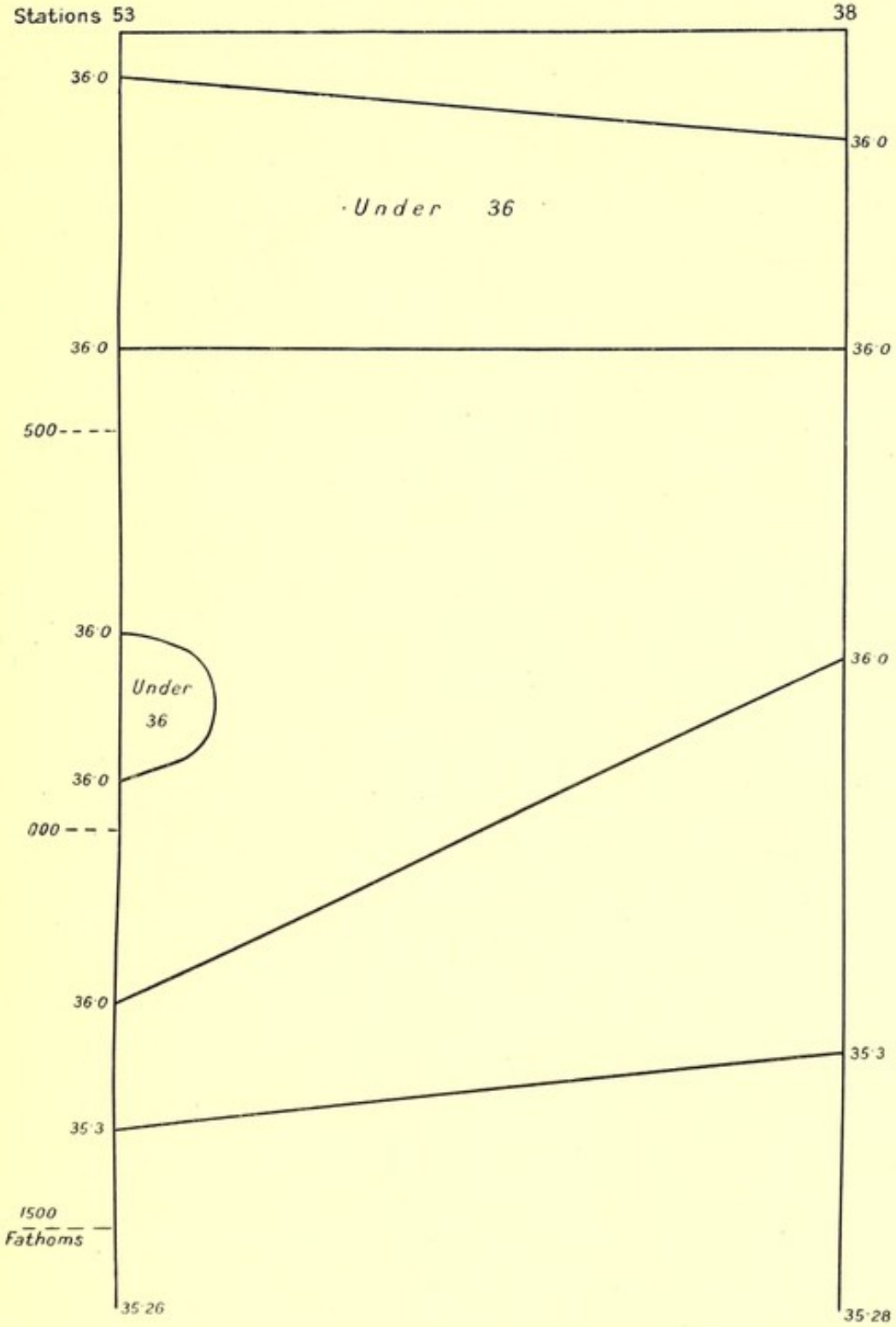


TEMPERATURE, 1904. SECTION III.




Stations 15
36·0
36·0
500
35·3
1000
1500
Fathoms
35·28
36·0
36·0
36·0
Over 36
Over 36
36·0
35·3
35·26

SALINITY, 1904. SECTION V.



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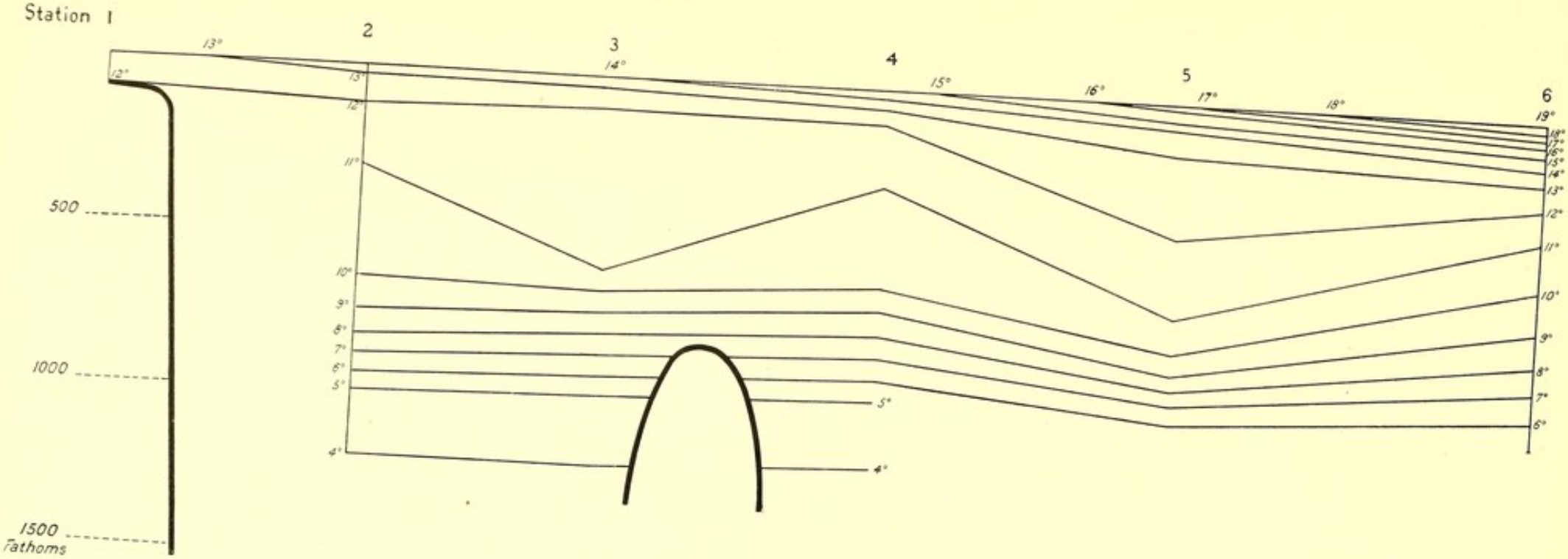
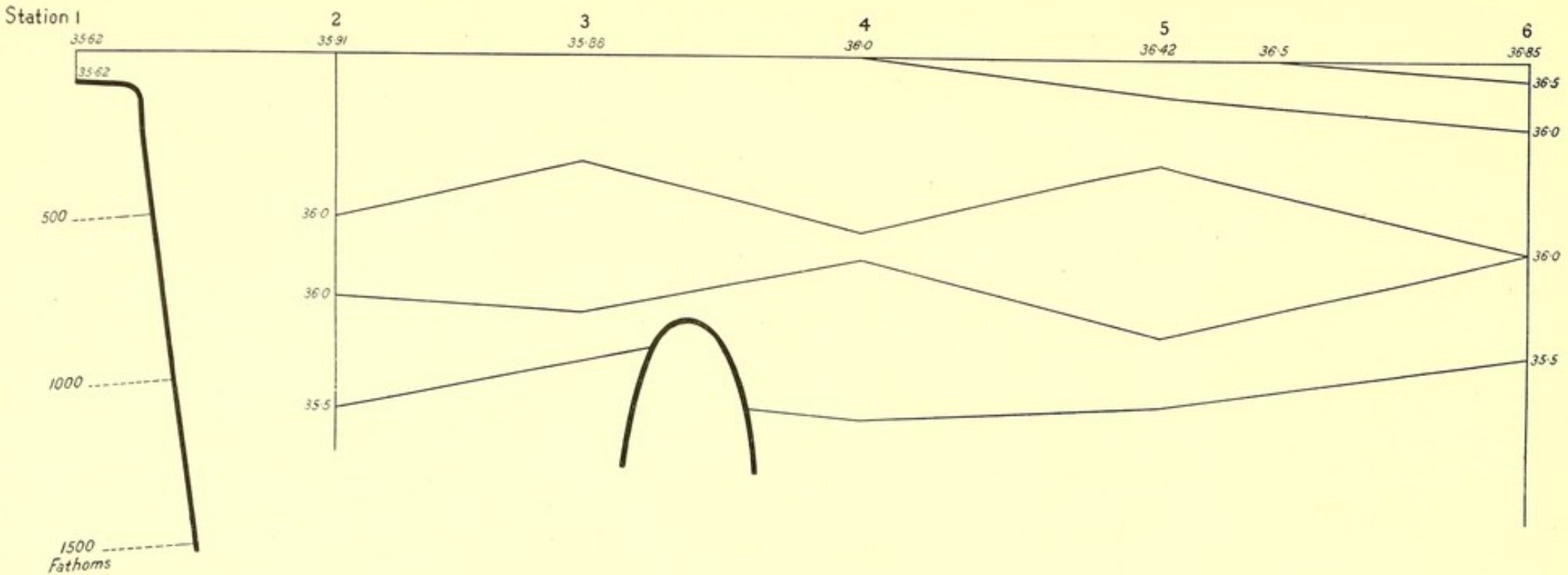


# SALINITY, 1905. SECTION I.



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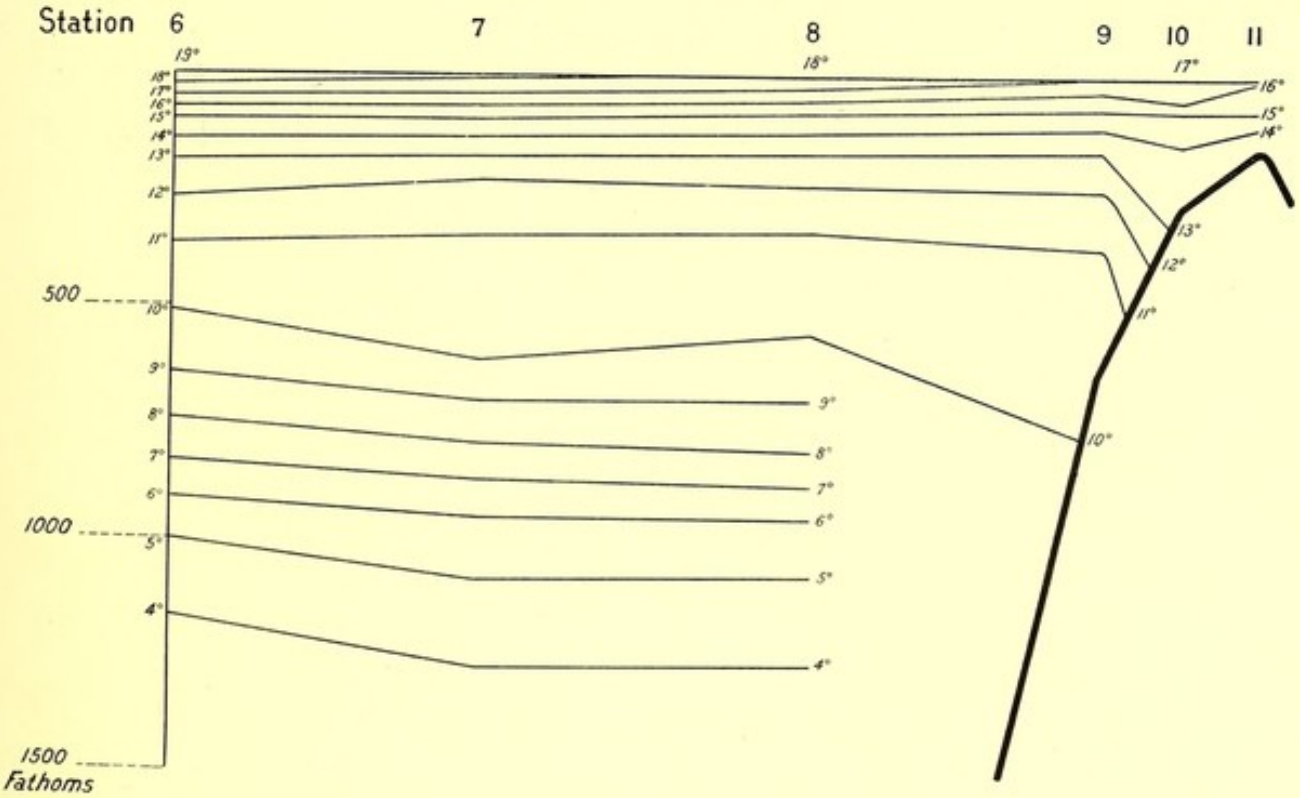
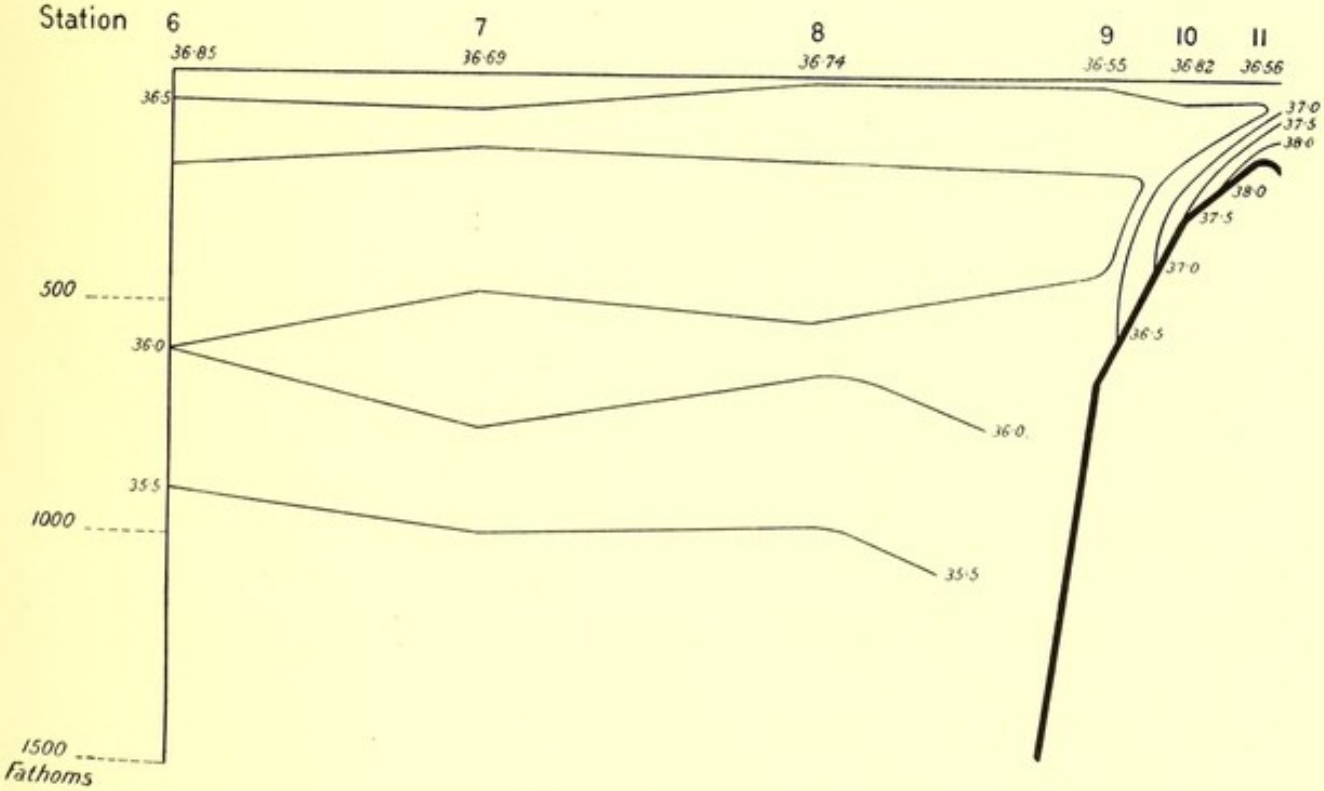
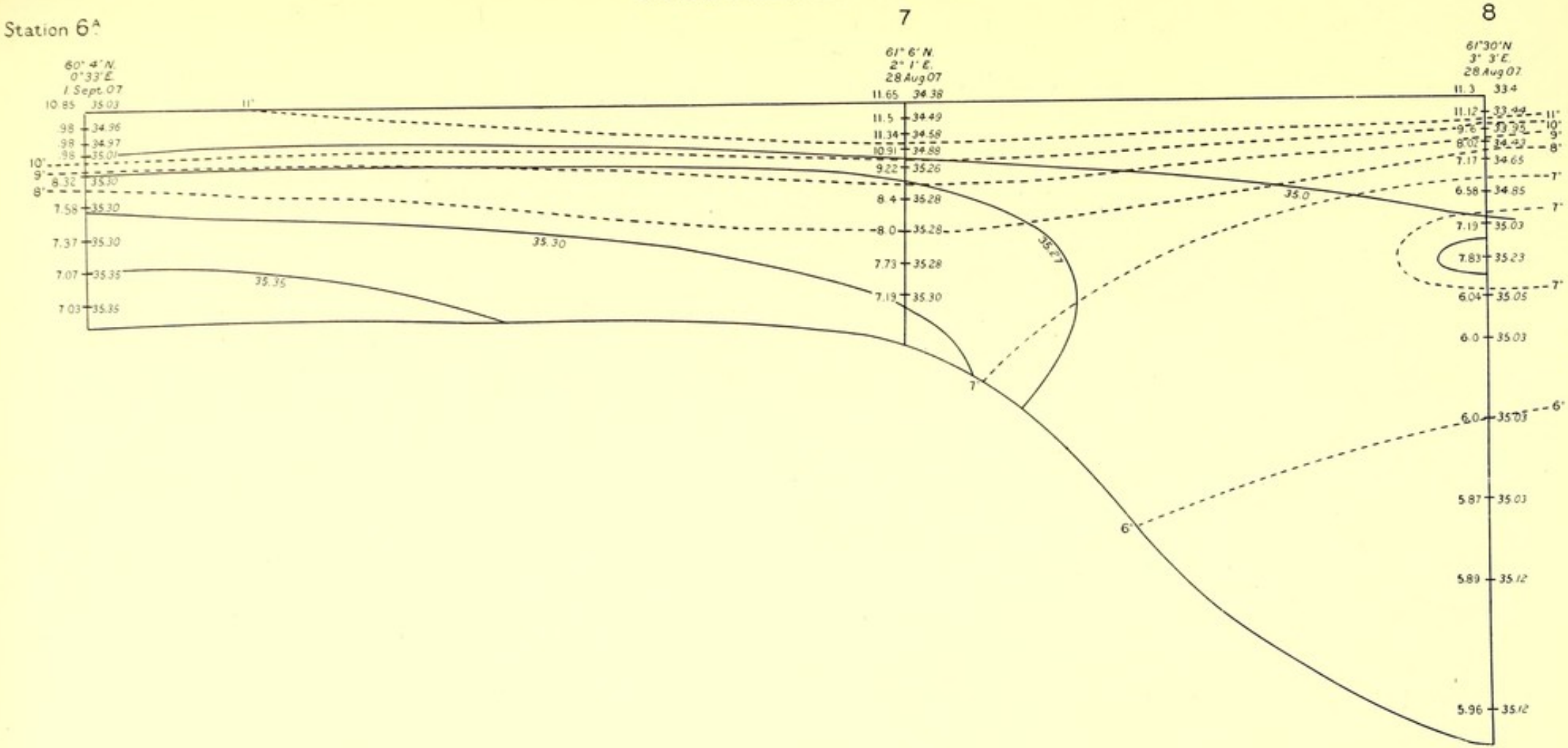



## SALINITY, 1905. SECTION II.

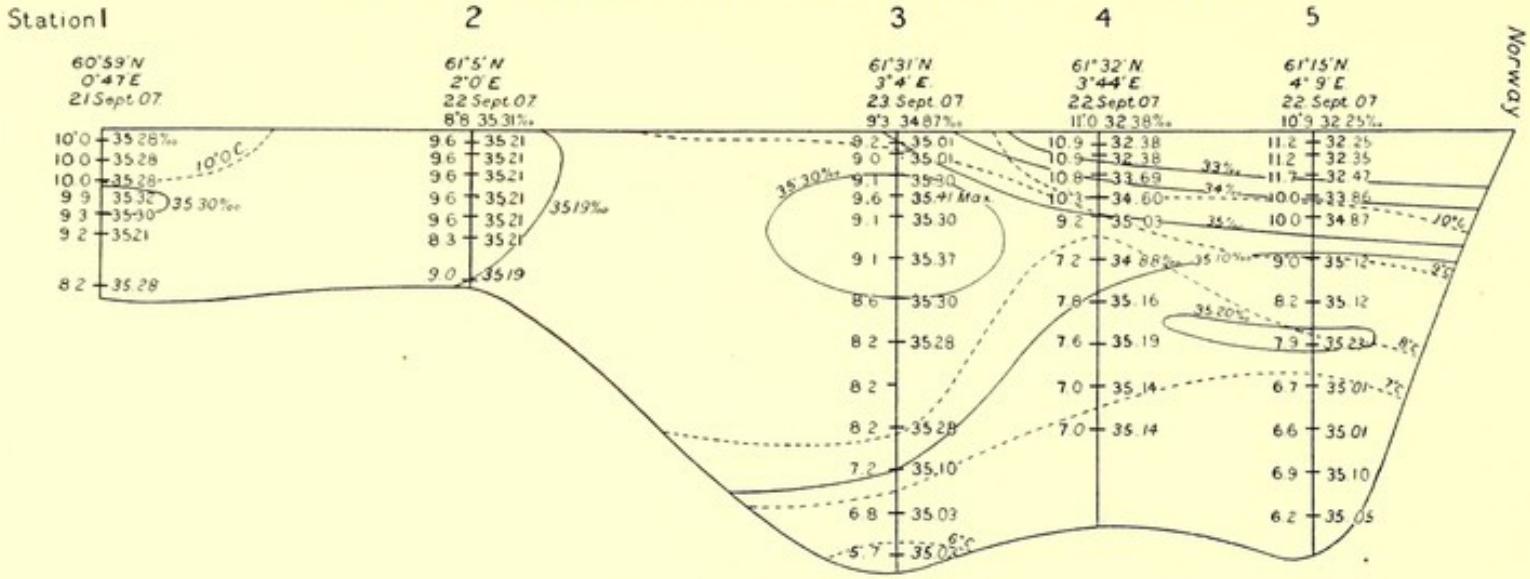


# "GOLDSEEKER" 1907.



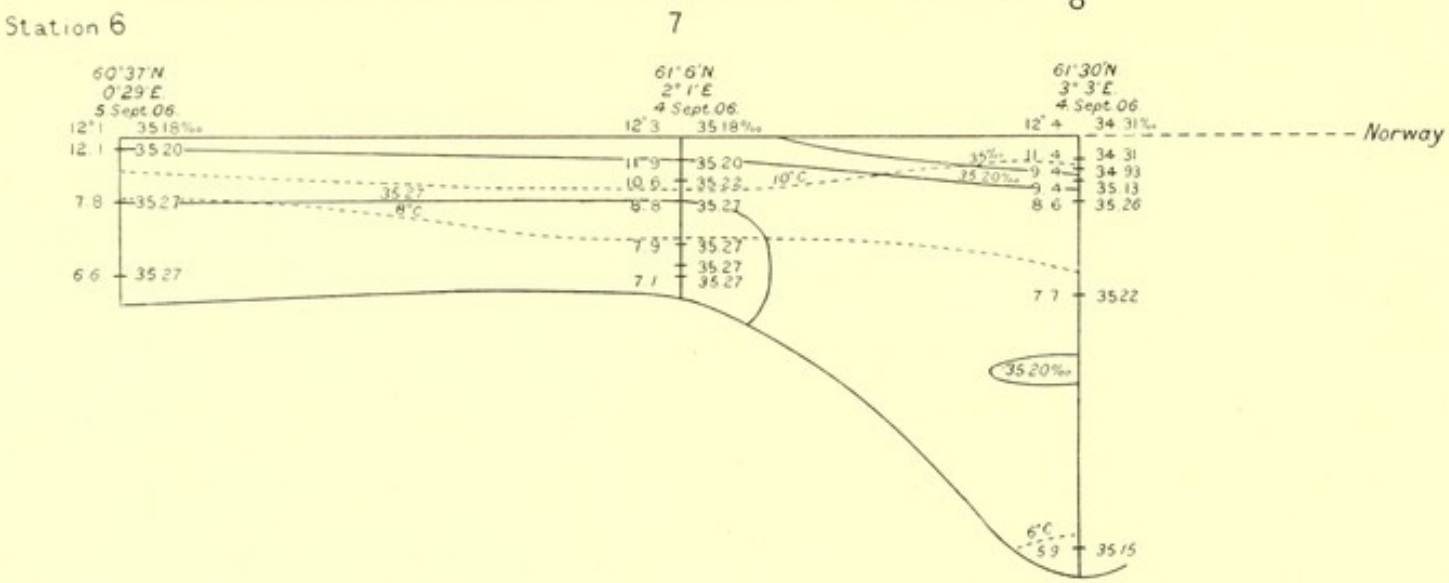
# SECTION Nº I

## "SILVER BELLE" FROM SHETLAND TO NORWAY



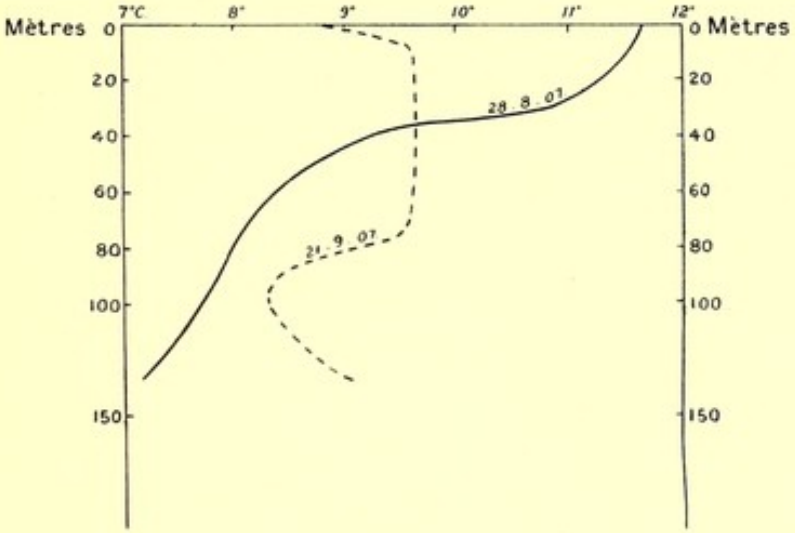
# SECTION No.2

## "GOLDSEEKER" FROM SHETLAND TO NORWAY



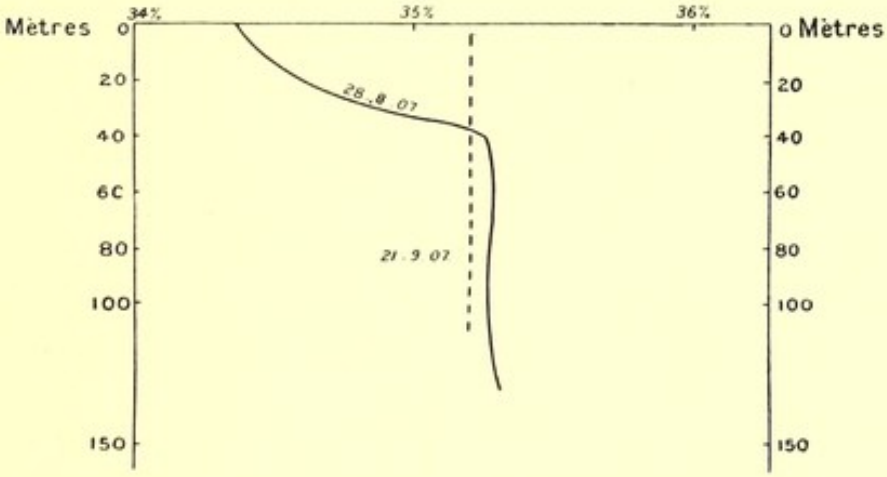
## TEMPERATURE OBSERVATIONS

*Station 2 "Silver Belle" 21.9.07 61° 5'N. 2° 0'E.*
*Station 7. "Goldseeker" 28.8.07 61° 6'N. 2° 1'E.*



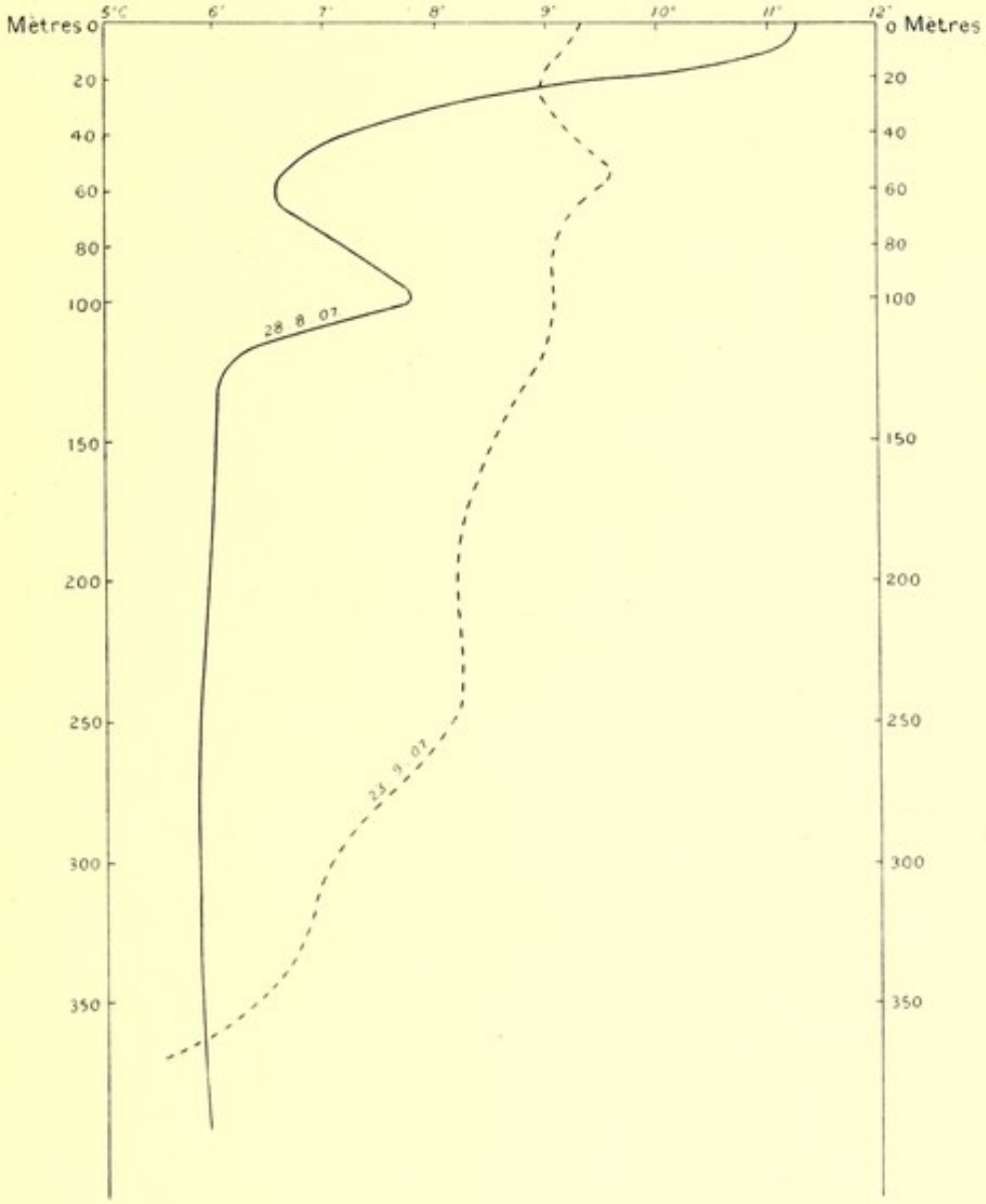

## SALINITIES AT STATION 7

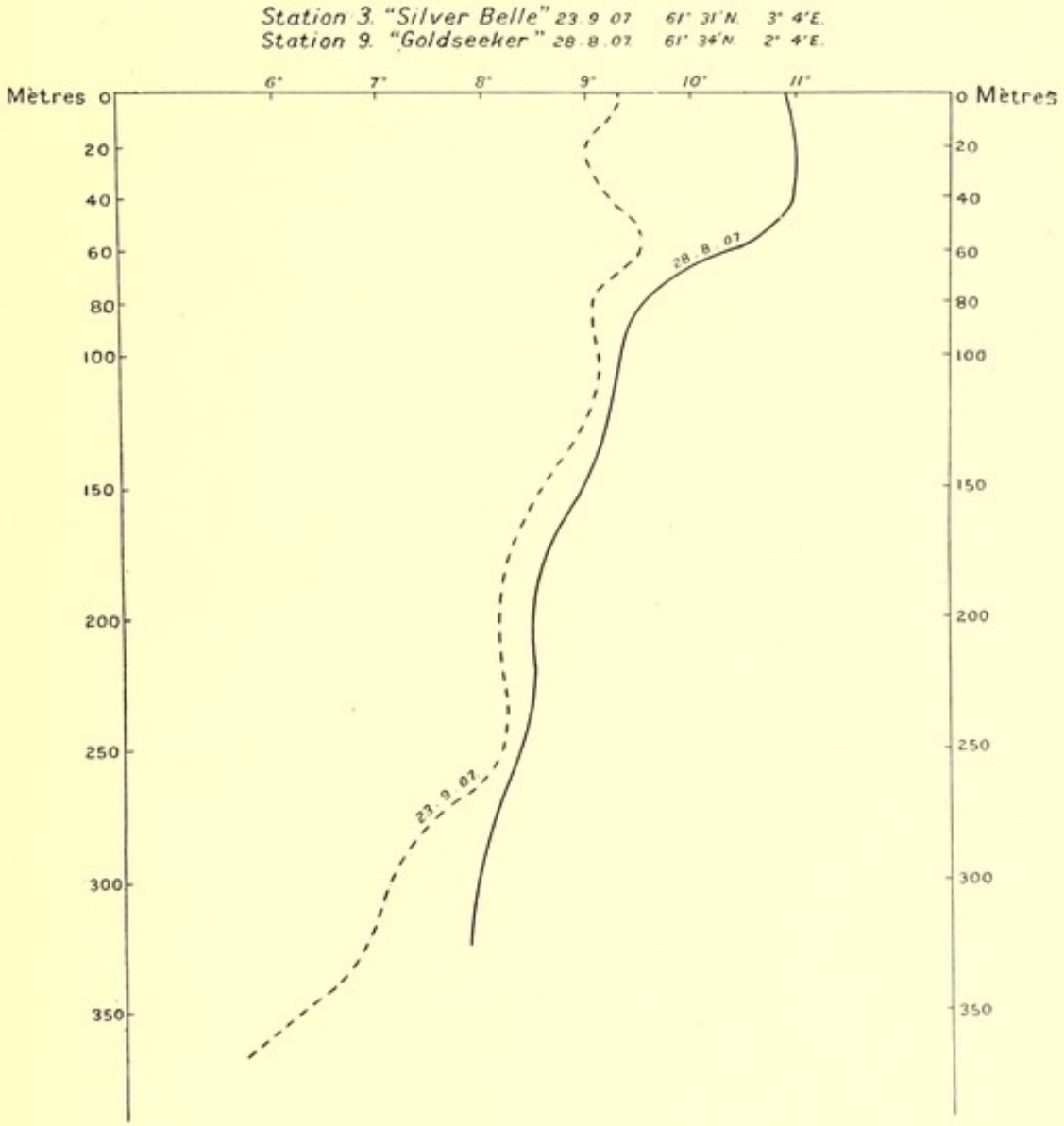
*Station 2. "Silver Belle" 21.9.07 61° 5'N. 2° 0'E.*
*Station 7. "Goldseeker" 28.8.07 61° 6'N. 2° 1'E.*

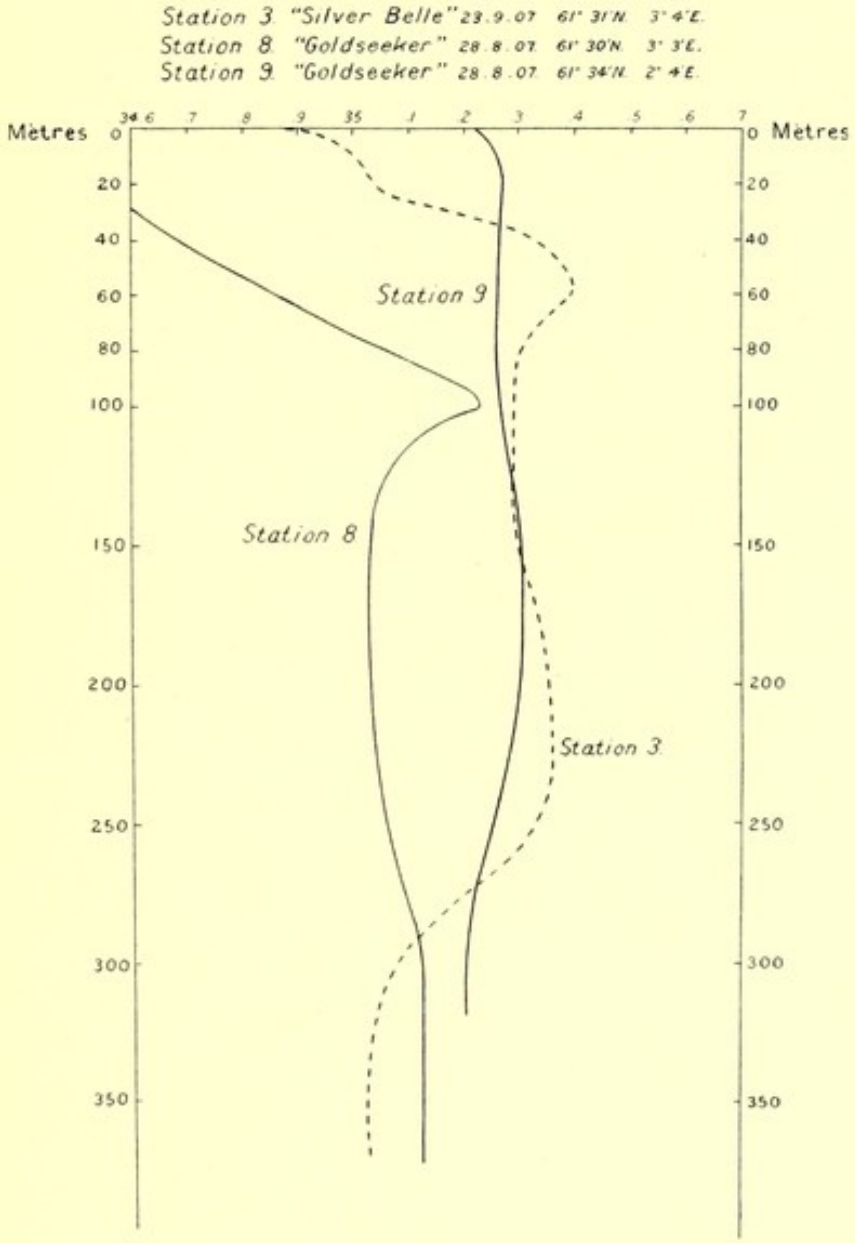


## TEMPERATURE OBSERVATIONS

*Station 3. "Silver Belle" 23. 9. 07. 61° 31'N. 3° 4'E.*
*Station 8. "Goldseeker" 28. 8. 07. 61° 30'N. 3° 3'E.*

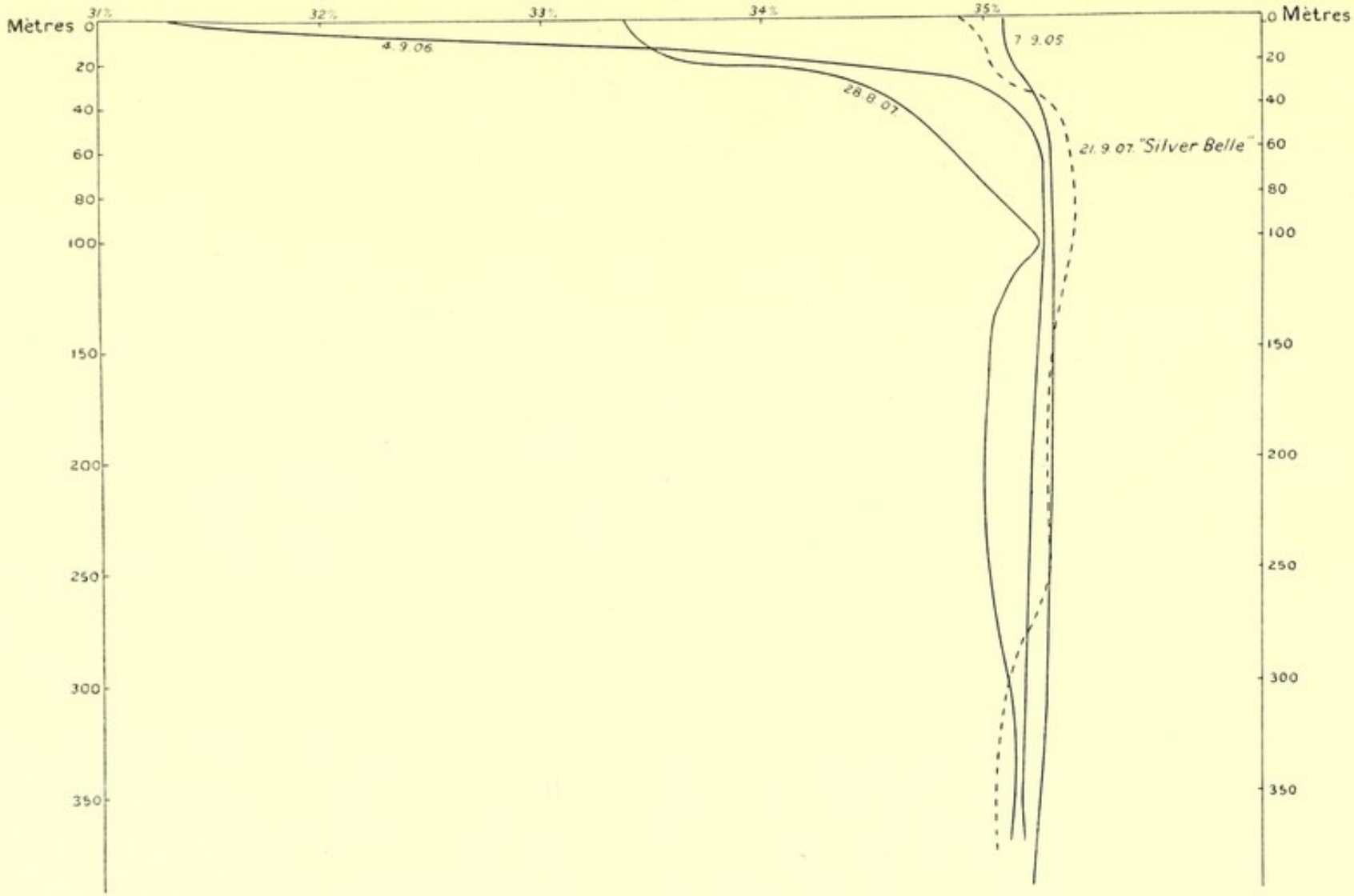



Station 3. "Silver Belle" 23. 9. 07 61° 31'N. 3° 4'E.
Station 9. "Goldseeker" 28. 8. 07 61° 34'N. 2° 4'E.
Mètres
0
20
40
60
80
100
150
200
250
300
350
6°
7°
8°
9°
10°
11°
28. 8. 07
23. 9. 07


Station 3. "Silver Belle" 23.9.07 61° 31'N. 3° 4'E.
Station 8. "Goldseeker" 28.8.07 61° 30'N. 3° 3'E.
Station 9. "Goldseeker" 28.8.07 61° 34'N. 2° 4'E.
Mètres
Mètres
Station 9
Station 8
Station 3

# SALINITIES AT STATION 8

"Goldseeker" 7. 9. 05 4. 9. 06 28. 8. 07 "Silver Belle" 21. 9. 07.



# BIOLOGICAL OBSERVATIONS

# BIOLOGICAL OBSERVATIONS.

## I.—FISHES.

By E. W. L. Holt and L. W. Byrne.

## II.—AMPHIPODA AND ISOPODA.

By W. M. Tattersall.

## III.—PYROSOMA.

By G. P. Farran.

# I.—FISHES.

By E. W. L. Holt and L. W. Byrne.

## 1. Himantolophus Rheinhardti, Lütken.

*Plates I. and II.*

The genus *Himantolophus*, Rheinhardt, may be characterized as follows:

*Ceratiidæ* of stout and somewhat compressed form, with relatively enormous heads and minute eyes. Spinous dorsal represented by a single stout, club-like tentacle, folding backwards into a groove, and bearing at its tip two short digitiform processes and numerous simple or branching thong-like appendages. Soft dorsal and anal fins, short, only separated by a short interval from the caudal. Epidermis thick and rugose, with scattered bony plates, each with a roughly circular base and short central spine; similar but smaller plates thickly scattered over the dorsal tentacle.

This genus was originally founded by Rheinhardt (1837) for the reception of a fish nearly 2 feet in length, found in 1833, cast up upon the coast of Greenland after a heavy storm. This specimen had been partially eaten by gulls and crows, and was half decomposed before it came into the hands of Rheinhardt, who described it as *Himantolophus grœnlandicus*. Only the club-like tentacle of this specimen appears to have been preserved.

A second specimen, 40 centimetres long, was picked up dead, floating at the surface of the sea off the south coast of Greenland at the end of 1876, and exhaustively described by Lütken (1878) as the type of a new species, *H. Rheinhardti*. This species appeared to differ

from that described by Rheinhardt (1837) in having a comparatively deeper body, fewer thong-like appendages to the tentacle, and five rays in the soft dorsal, and seventeen in the pectoral fin, as against nine and twelve mentioned by Rheinhardt.

Gill (1878), on the strength of these differences, proposed to refer Lütken's species to a separate genus, *Corynolophus*, but his proposal has never found any favour outside the United States.

A third specimen, 20·7 centimetres long, was captured off the coast of the Westman Isles, near Iceland, in 1886, and examined by Lütken (1887), who identified it as a young example of *H. Rheinhardti*.

A fourth specimen, 41 centimetres long, was captured alive in a trawl in 80 to 90 fathoms of water, fourteen miles from Nazareth on the west coast of Portugal (a short distance north of the Burlings) in 1892, and was examined and described by Girard (1893). This fish had lost its tentacle (cut off by the captors) before it came into Girard's hands, but was otherwise in good condition, and appears to have very closely resembled Lütken's larger example and that next described. Girard suggested that *H. grœnlandicus* and *H. Rheinhardti* might well be synonyms for the same species, a question to which we will revert later.

The fifth known example of this remarkable genus was captured by the *Silver Belle* in March, 1906, while trawling in 20 to 25 fathoms of water close to the east of Gibraltar. This specimen is smaller than Lütken's first specimen or Girard's, but agrees with them in all essential particulars. It is unfortunately somewhat distorted from being preserved in too small a receptacle.

The history of the genus may be completed by adding that Lütken tentatively referred to it some very young specimens taken at the surface of the South Atlantic; but the generic identity of these specimens is open to so much doubt that we leave them out of consideration in discussing the probable habits and habitat of these fishes.

A brief description of the specimen taken by the *Silver Belle* follows:

Form stout and somewhat compressed; greatest depth of body

some way in front of pectorals, and (including the loose skin of the belly, the original contour of which cannot now be ascertained) about three-quarters of total length, exclusive of mandible and caudal fin; depth of caudal peduncle about one-fifth of greatest depth of body.

Head very large and stout; its length (measured from end of premaxilla to branchial opening) about five-eighths of total length (measured as above), and equal to its depth at parietal spines. Eye minute, about twenty-four times in head, and five times in preorbital length. Greatest width of head between extremities of jaws, somewhat more than half its length, and about one and a half times the distance between the parietal spines. Distance between eyes about one and a half times preorbital length.

Tentacle club-shaped; length of its stem equal to length of its longest filament, and about twice distance between parietal spines; digitiform processes less than one-fifth of length of stem. Thong-like filaments, nine in number.

Soft dorsal fin with five rays, originating about four-fifths of the distance from end of premaxilla to origin of caudal. Anal with four rays originating six-sevenths of the distance from end of premaxilla to origin of caudal. Pectoral with fourteen rays.

Teeth hinged and of varying size, in two to four regular rows.

Colour uniform black; membranes of unpaired fins dead white. Tentacle black, paler at its tip and on basal parts of digitiform processes. Upper parts of digitiform processes and thong-like filaments black, with white tips.

Extreme length, 365 millimetres.

The principal measurements of this specimen are as follows:

| | Millimetres. |
|---|---|
| Extreme length (including mandible and caudal fin) ... | 365 |
| Length (excluding mandible, but including caudal fin) | 347 |
| ,, (excluding mandible and caudal fin) ... ... | 285 |
| Front of snout to branchial opening ... ... ... | 169 |
| ,, ,, origin of dorsal fin ... ... ... | 225 |
| ,, ,, ,, anal fin ... ... ... | 238 |

| | Millimetres. |
|---|---|
| Greatest depth of body (including loose skin of belly)[1] | 219 |
| Depth of head at parietal spine (exclusive of loose skin of belly)[1] ... ... ... ... ... ... | 170 |
| Depth of caudal peduncle ... ... ... ... | 45 |
| Length of snout to front of eye ... ... ... ... | 37 |
| Longitudinal diameter of eye ... ... ... ... | 7 |
| Width of head at mouth (outside jaws)... ... ... | 92 |
| ,, ,, between parietal spines ... ... ... | 63 |
| ,, ,, between nostrils... ... ... ... | 51 |
| Length of stem of tentacle ... ... ... ... | 124 |
| ,, digitiform processes ... ... ... ... | 22 |
| ,, thong-like appendages ... ... ... | 124 |

The present occurrence serves to materially extend the recorded horizontal range of *H. Rheinhardti*, but, unfortunately, adds nothing to our knowledge of its normal habitat.

The species is only known from isolated specimens taken in coastal waters or cast up upon the shore at widely scattered localities in the North-East Atlantic. It is inconceivable that our records could be so scanty were a fish of so striking and singular an appearance a normal denizen of shallow water in the East Atlantic.

The well-defined Pediculate family of *Ceratiidæ*, to which *Himantolophus* belongs, and of which it appears to comprise by far the largest species at present known, had until lately, by the general consensus of ichthyologists, been regarded, at any rate when adult, as confined to very deep water, and its members have been termed by Günther and other authors following him 'Bathybial sea-devils.'

As already stated, Lütken obtained very small specimens of some Ceratiids from the surface of the South Atlantic, and more recently Dr. Brauer (1902) has stated that the *Valdivia* expedition 'has shown with certainty in the case of all *Ceratiidæ* taken that they do not live on the bottom of the sea, as was hitherto almost generally assumed,

[1] These measurements will be found not to correspond with the dimensions shown in the figure, in which the loose skin is represented in the moderately distended condition apparently normal in life.

but are pelagic.' The exact records of captures of Ceratiids by the *Valdivia* are given by Dr. Brauer (1906), and although these records do not include *Himantolophus*, we regard his statement as probably referable to that genus also on account of the anatomical peculiarities below noted, which *Himantolophus* shares with most Ceratiids, and as being perfectly consistent with all that is certainly known of the members of this obscure genus. Accordingly, with the greatest respect for many earlier authors, we are unable to regard *Himantolophus* as a bathybial form, and prefer to consider it as a pelagic fish normally living, perhaps not actually at the surface, but at any rate in the upper strata of the ocean.

Our reasons for advancing this view are briefly as follows:

1. The apparently healthy condition of Dr. Wolfenden's specimen when taken in shallow water.

2. The somewhat compressed form, normally-formed pectorals, and absence of ventrals, which contrast strongly with the depressed form and geniculated pectorals of the allied but bottom-living *Lophiidæ*. The loose skin of the abdomen strongly suggests a correlation with a belly capable of being distended with air and acting as a float, as in some pelagic *Antennariidæ*.

3. The known records, which are perfectly consistent with the view that we have to deal with a pelagic Atlantic fish occasionally carried shorewards by the easterly and northerly Atlantic drift. Such an eastward or northward wandering of a pelagic species of the Western Atlantic may be paralleled by the record from the Norwegian coast of a specimen of *Antennarius histrio*, and by the arrival, on at least two occasions, of shoals of *Lirus perciformis* following drifting timber or wreckage on the Irish coast.

The impossibility of preserving Rheinhardt's original specimen makes the task of discussing the question of its specific identity with the subsequently described specimens difficult. Girard (1893) seems to have regarded all recorded specimens as referable to the same species, and there is much to be said in favour of this view.

The differences stated to exist between *H. grœnlandicus* and *H. Rheinhardti* are briefly as follows :

1. The considerably deeper body in the latter species. To this we can attach but little importance, as the degree of distension of the loose skin of the belly is a very material factor, and Rheinhardt's specimen was half decomposed.

2. The dorsal fin rays, stated by Rheinhardt to have been nine, and five in all other examples. Girard points out that the four posterior bifid rays might well have been reckoned as two each by Rheinhardt in a damaged specimen.

3. The pectoral rays, stated by Rheinhardt to have been twelve in his example, and by Lütken and Girard to be seventeen in theirs ; in Dr. Wolfenden's specimen the number is thirteen. Even apart from this recorded range and the bad state of Rheinhardt's specimen, we are not inclined to attach much importance to this difference.

4. The number of tentacular appendages—eleven in Rheinhardt's specimen, and eight and seven respectively in Lütken's. Girard's example had lost its tentacle ; Dr. Wolfenden's has nine such appendages. It seems to us that the exact number of these appendages cannot under the circumstances be regarded as a specific character.

It must be remembered that the reference of all known specimens to a single species, however probably correct, rests upon inference alone ; and it seems better to us to retain Lütken's name for the specimens with five rays in the soft dorsal, and with a body whose depth is contained one and a half times or less in its length (without caudal fin or mandible), while confining Rheinhardt's *H. grœnlandicus* to specimens (should any be found) with nine rays in the soft dorsal, and with a body whose depth is contained more than twice in its length.

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Lütken (1887), *K. D. Vid. Selsk. Skr.*, 6th Ser., iv. 325.
Rheinhardt (1837), *K. D. Vid. Selsk. Afhand.*, 74.

## 2. Squatina Aculeata, Cuvier.

*Plate III.*

*S. aculeata*[1] (E. Dumeril, MSS., 1804), Cuvier, 'Le Règne Animal,' 2nd edit., ii. 394 (1829).

*S. fimbriata*,[1] Müller and Henle, 'Plagiostomen,' 101 and 192 (1839).

*Rhina aculeata*,[1] Aug. Dumeril 'Ichth. Générale,' i. 465 (1865).

Our friend Mr. C. T. Regan has suggested to us that a figure and description of the specimen taken by the *Silver Belle* might prove useful, as the species appears to be little known and constantly confused with the common *S. angelus* or with Bonaparte's *S. oculata*, and we are unaware of any extant figure beyond the sketch of the front part of the head given by Müller and Henle (*loc. cit.*, *sub. nom. S. fimbriata*).

In this specimen, which is 36·5 centimetres long (excluding lobes of caudal fin), the greatest breadth across pectorals is contained just over two and a half times, the greatest breadth across ventrals rather more than three and a half times, and the length to the anus a little over twice in the total length. Depth of body at origin of ventrals four-fifths of its breadth, and at origin of its dorsal five-sixths of its breadth.

The length of the head to the first gill opening is contained three times in the length to anus, and about one and a half times in its own greatest breadth. The snout is very blunt, and the distance from its anterior point to the level of the spiracles is equal to the distance between the spiracles or to the interorbital width. The longitudinal diameter of the eyes is a little greater than their distance from the level of the anterior point of the snout, and more than one-third of the interorbital width.

The anterior narial flaps are each divided into two fringed processes, with a third small and inconspicuous distal process, and the posterior

[1] These descriptions appear to refer to the present species only. We can find no other description in which this species is not confused with either *S. angelus* or the *S. oculata* of Bonaparte.

narial flaps are divided into a larger proximal and smaller distal fringed process. From the nostrils a skinny flap extends along the sides of the head, and is broadened opposite the corners of the mouth into two rounded processes.

The pectoral and ventral fins have slightly convex anterior margins very slightly concave outer margins, and are pointed posteriorly. The claspers are very small. The dorsal fins are subequal in size, and the lower lobe of the caudal fin is the longer.

The spines on the head are small but sharp; they form orbital series of five, the first and last spines of each series being respectively in front and behind the orbit: two spines occur on each side of the snout internal to the nostrils. There is a vertebral series of comparatively large and sharp backwardly directed spines—twenty-six between the pectoral girdle and the first dorsal fin, three and two small lateral spines between the dorsal fins, and three small spines behind the second dorsal fin. The dermal covering as a whole is rough, but without any very conspicuous asperities.

Colour impossible to ascertain, but apparently greenish-grey in life, with small faint darker spots on the fins and sides of the head and tail dorsally, and dead white ventrally.

Length, 36·5 centimetres[1] (including lower lobe of caudal, 38 centimetres). Probably attains a far larger size.

Locality, Mediterranean, off Malaga, 300 fathoms. Previously recorded from the Mediterranean.

It is probable that the characters of *S. aculeata* undergo some change with growth; but the specimen described above is easily distinguished from *S. angelus* of comparable size by the difference in the dermal armature. The general dorsal surface is much rougher in *S. angelus* by reason of the larger size of the asperities, which are pointed and closely set, while the spines of the head and back are not very much larger than the surrounding asperities at any period of life. In a *S. angelus* of 240 millimetres, presumably new-born, the spines of

[1] The specimen is somewhat distorted by careless preservation, and may in life have been a few millimetres longer or shorter.

the middle line in front of the first dorsal are more conspicuous than in older specimens. They are about thirty-six in number, and relatively a good deal smaller than in *S. aculeata* of 365 millimetres. In *S. angelus* of 375 millimetres these spines are relatively smaller than in the younger stage, hardly conspicuous, and very much smaller than in our *S. aculeata*, which is of practically the same length. Head spines can be detected in *S. angelus* of 240 and 365 millimetres, but grade insensibly into the surrounding asperities. The nasal flaps are probably variable in both species, and form no safe guide for distinction. Normally they seem to be tucked away out of sight. *S. angelus*, at 365 millimetres, is somewhat more massive in appearance than *S. aculeata*, and differs a little in some of its proportions. The width across the pectorals is contained less than twice, across the ventrals about three and a half times in the total length ; the length of the head is less by about one-third than its greatest width, and occupies about one-third of the distance between snout and anus. The eye is smaller than in *S. aculeata*,[1] its length being equal to distances separating it from the spiracle and from the anterior margin of the head directly in front of it, and is only about one-fourth of the interorbital width. The latter is equal to the distance from the snout to a line joining the spiracles, but is a little less than the distance between the spiracles. The hind margins of the pectorals are broadly rounded in *S. angelus*, not more or less pointed, as in *S. aculeata*.

We are not acqnainted with larger specimens of *S. aculeata*.

[1] We are not in a position to affirm or deny the specific distinction of Bonaparte's *S. oculata* from *S. angelus*. The former species is said by him to have the eye larger than in his *S. angelus*, from which it does not otherwise appear to differ in any important respect of which the author took note. It appears to have lacked both the vertebral spinulation and pointed pectorals of *S. aculeata*.

## 3. List of Fishes taken by Dr. R. N. Wolfenden in Deep Water in the Neighbourhood of the Straits of Gibraltar.

We have already discussed the most interesting outcome, ichthyologically, of Dr. R. N. Wolfenden's early spring cruise in the *Silver Bell* in the neighbourhood of the Straits of Gibraltar. The few other fishes captured in shallow water are of no particular interest, but it seems worth while to put on record those taken in deeper water, as such a list may be of interest to future workers in the same region.

We have added a few notes on some of the more interesting species, and for the purposes of this paper have treated the hauls made in the Atlantic and Mediterranean separately.

### A. MEDITERRANEAN.

Four deep-water hauls were made on the Mediterranean side of the Straits of Gibraltar, as follows :

| | | | |
|---|---|---|---|
| 1. | February 7, 1906. | Off Cape Baba, Morocco - | - 300 fathoms |
| 2. | ,, 9, ,, | Off Malaga - - | - 300 ,, |
| 3. | ,, 10, ,, | Off Malaga - - | 280-300 ,, |
| 4. | ,, 16, ,, | Off Marbella - - | - 500 ,, |

The following species were captured :

Scyllidæ.

*Pristiurus melanostomus*, Raf. - Station 2.

Squatinidæ.

*Squatina aculeata*, Cuvier - - Station 2.

Raiidæ.

*Raia oxyrhynchus*, L. Bonaparte - Station 2.

Stomiatidæ.

*Stomias boa*, Risso - - - - Stations 1 and 4.

*Gonostoma microdon* (?), Gthr. - - Station 4.

The specimen is too damaged for certain identification.

Scopelidæ.

*Scopelus glacialis*, Rheinhardt - - Station 4.

The capture of examples of this species, 29 to 39 millimetres long (without caudal fin), considerably extends its known horizontal range, which did not previously include the Mediterranean. Although full records of the temperatures of the strata in which this species has occurred are not available, its range with regard to latitude appears to be worthy of remark, and is nearly, if not quite, as wide as that of the pelagic Schizopod *Meganyctiphanes norvegica*. The specimens are damaged, but there seems no doubt of their specific identity. Fragments of a smaller *Scopelus* from Station 4 and a badly damaged specimen from Station 1 are not improbably referable to the same species.

MACRUSIDÆ.

*Macrurus cœlorhynchus*, Risso - - Stations 2 and 3.

GADIDÆ.

*Molva elongata*, Risso - - - Station 3.
*Phycis blennioides*, Brünn - - Station 3.

CAPROIDÆ.

*Capros aper*, L. - - - - Stations 3 and 4.

Also taken in shallow water off Malaga, where its vertical range appears to extend at least from 40 to 300 fathoms. Probably, as in the English Channel and in the Mediterranean off Marseilles, it also ranges into soundings of considerably less than 40 fathoms.

TRIGLIDÆ.

*Peristedion cataphractum*, L. - - Station 3.

The two specimens taken appear to be male and female, the former having the longest filament of the spinous dorsal extending nearly to the end of the base of the second dorsal, while in the latter it only reaches the origin of the fifth ray of that fin. The greater convergence of the rostral spatulæ in the male appears to be an individual rather than a sexual character.

LOPHIIDÆ.

*Lophius budegassa*, Spinola - - Station 2.

## B. ATLANTIC.

Ten hauls were made in deep water, eight of them off the south coast of Portugal, and two of them to the west of Cape Spartel :

| | | | |
|---|---|---|---|
| 1. | March 19, 1906. | Off Cape St. Vincent - - - | 300 fathoms |
| 2. | ,, 20, ,, | Twenty miles south by east of Cape St. Vincent - - - - | 266-280 ,, |
| 3. | ,, 22, ,, | Twenty-two miles south-south-east of Lagos Bay - - - - | 379 ,, |
| 4. | ,, 23, ,, | West-south-west of Cape St. Mary - | 321-360 ,, |
| 5. | ,, 26, ,, | Eighteen miles south-east half south of Cape St. Mary - - - | 350 ,, |
| 6. | ,, 28, ,, | Twenty-six miles south-east (or south-east by south) of Cape St. Mary - - | 308 ,, |
| 7. | ,, 29, ,, | South-east of Cape St. Mary - - | 200 ,, |
| 8. | ,, 30, ,, | South-south-east of Cape St. Mary - | 310 ,, |
| 9. | April 4, ,, | Forty-six miles west of Cape Spartel - | 417 ,, |
| 10. | ,, 5, ,, | Thirty-one miles west-south-west of Cape Spartel - - - - | 187-200 ,, |

The following species were captured :

### Squalidæ.

*Spinax niger*, L. - - - - Station 6.

### Raiidæ.

*Raia clavata*, L. - - - - Station 7.

*Raia*, sp. - - - - - Station 8.

This is a very small ray, measuring 35 millimetres across the disk, and 74 millimetres in total length. The umbilical sac, however, has completely disappeared. The disk is broadly rounded at its lateral edges and in front. The tip of the rostrum appears as a minute papilla in a slight resilient depression of the anterior contour. There is a slight incurvature of the margins opposite the eyes, separating anterior and lateral prominences of the general outline. The shape of the disk, therefore, approaches that of Bonaparte's figure of *R. radula*,[1] but the latter has the anterior margin more truncate and the lateral margins less rounded.

[1] 'Icon. Fauna Ital.,' iii., Pesc.

The eyes are relatively large, about as long as the width of the interorbital space, and about two and a half in the preoral length. There is a spine in front of, and a group of three spines behind, each eye. On the shoulder region are two spines in the middle line and one on either side. A median row of spines extends from behind the shoulder to the first dorsal fin. The whole of the dorsal surface of disk and tail is set with small asperities. The ventral surface is smooth.

The dorsal surface is brown, speckled with larger and smaller black spots. On the tail such larger spots form several more or less definite transverse bands. There is a pale spot on each side, just external to the branchial region and opposite to the anterior spine of the shoulder region.

The teeth are relatively large, few in number, and obtuse.

The specimen appears from its small size, and from the absence of any trace of the umbilical sac, to belong to a very small species. Its characters, however, are too juvenile to be of much good for specific determination without comparison with a series of older stages.

NARCOBATIDÆ.

*Torpedo nobiliana*, Bonaparte - - Station 10.

CHIMÆRIDÆ.

*Chimæra monstrosa*, L. - - - Station 6.

STOMIATIDÆ.

*Chauliodus Sloani*, Bl. and Sch. - Station 1.

An almost perfect specimen, 116 millimetres in length, unfortunately distorted by careless bottling. There is a thin, colourless epidermis, similar to that of *Stomias*, more or less stripped off as a continuous membrane; the underlying scales have an opalescent lustre, while the body pigment is dark brown or black. The dorsal filament extends nearly to the adipose fin.

ANGUILLIDÆ.

*Conger vulgaris*, Cuvier - - - Station 9.

This record, 417 fathoms, is the deepest of which we are aware for an adult of this species.

MACRURIDÆ.

*Macrurus cœlorhynchus*, Risso - Stations 2, 4 and 9.
*M. lævis*, Lowe - - - Stations 5 and 6.
*M. æqualis*, Gthr. - - - Stations 2 and 9.

GADIDÆ.

*Merluccius vulgaris*, Cuvier - Station 10.
*Phycis blennioides*, Brünn - Station 3.
*Mora mediterranea*, Risso - Station 9.
*Gadus argenteus*, Guich - - Stations 5, 6, and 10.

BERYCIDÆ.

*Trachichthys mediterraneus*, C. and V. - Station 9.

ACROPOMATIDÆ.

*Epigonus* (*Pomatomus*) *telescopus*, Risso - Station 9.

SPARIDÆ.

*Dentex macrophthalmus*, Bloch - - Station 10.
*Pagellus centrodontus*, Delaroche - - Station 4.

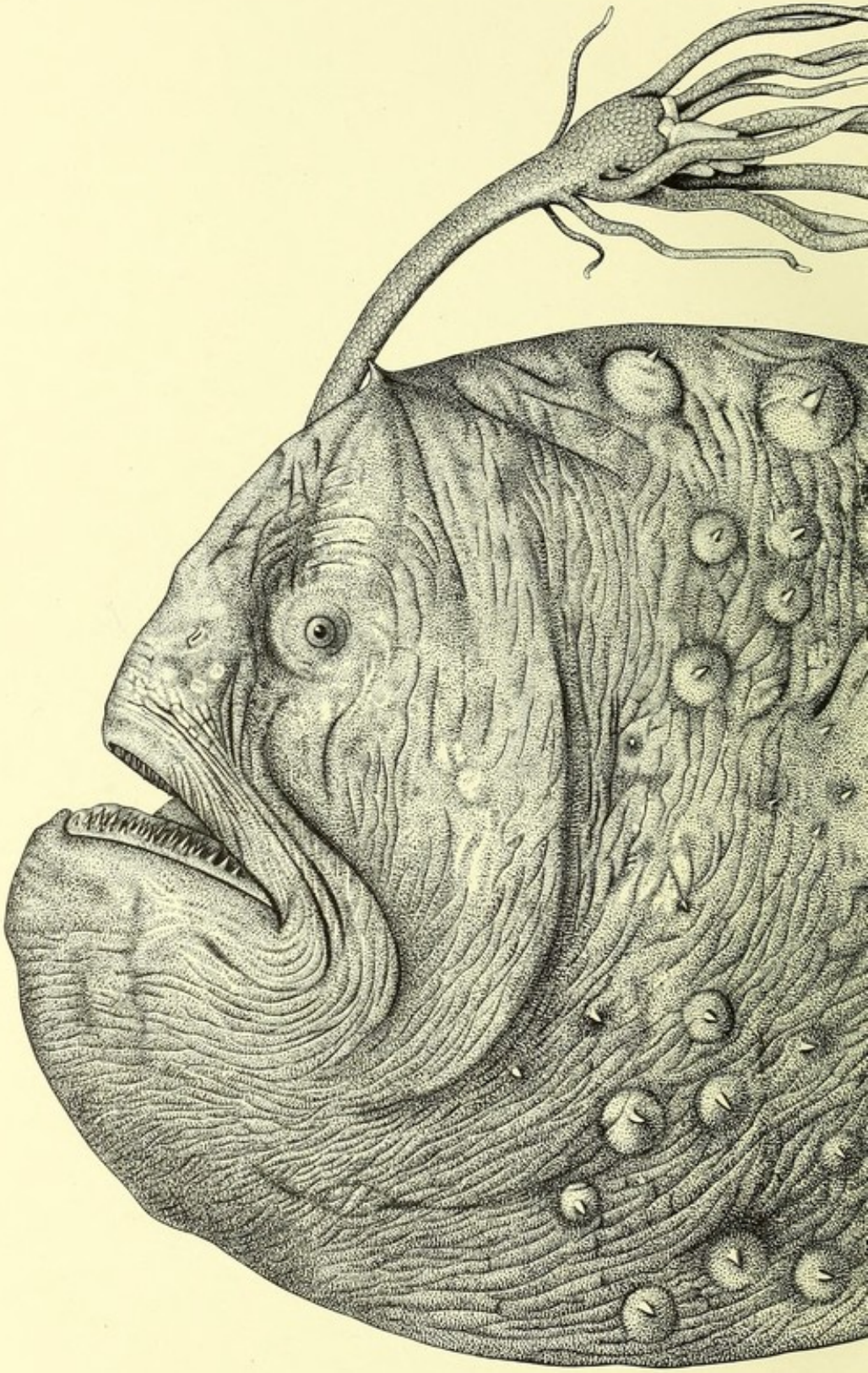
This observation extends the known vertical range of the common sea-bream to at least 320 fathoms.

PLEURONECTIDÆ.

*Zeugopterus Bosci*, Risso - Stations 3, 6, and 10.

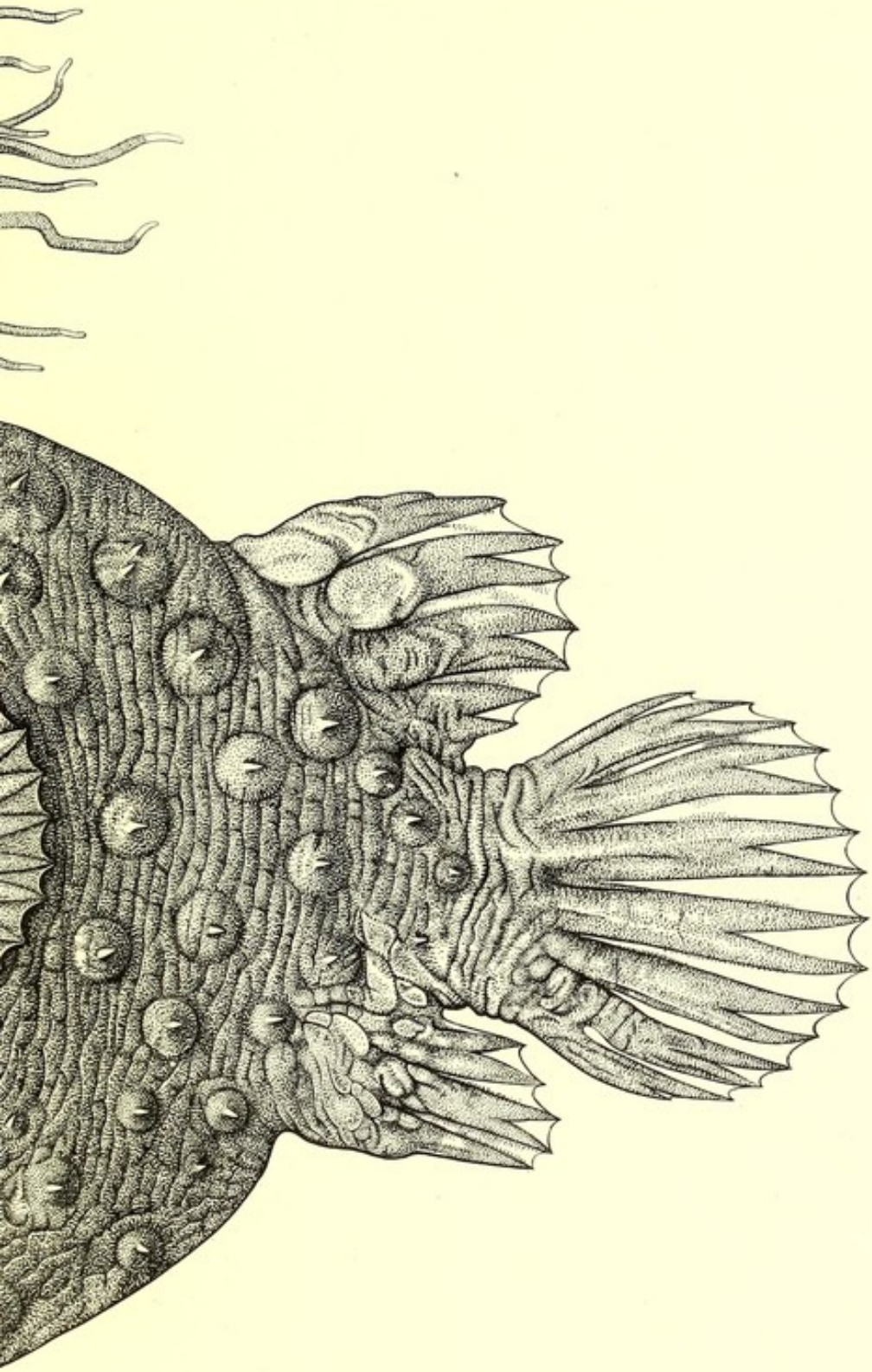
The *Zeugopteri* taken by the *Silver Belle* do not all possess the black spots on the dorsal and anal fins usually found in this species, but have the shape of *Z. Bosci* rather than of *Z. megastoma*. Specimens from the Bay of Biscay, regarded by one of us as *Z. megastoma*, had the shape of shallow-water representatives of that species. In the Irish deep-water collections the unspotted examples are shaped similarly to shallow-water *Z. megastoma*, and the spotted examples show some distinction in shape from South European *Z. Bosci*. If the two species are really distinct, their definition requires more care than has been hitherto bestowed upon it.

*Solea profundicola*, Vaill - - Station 8.



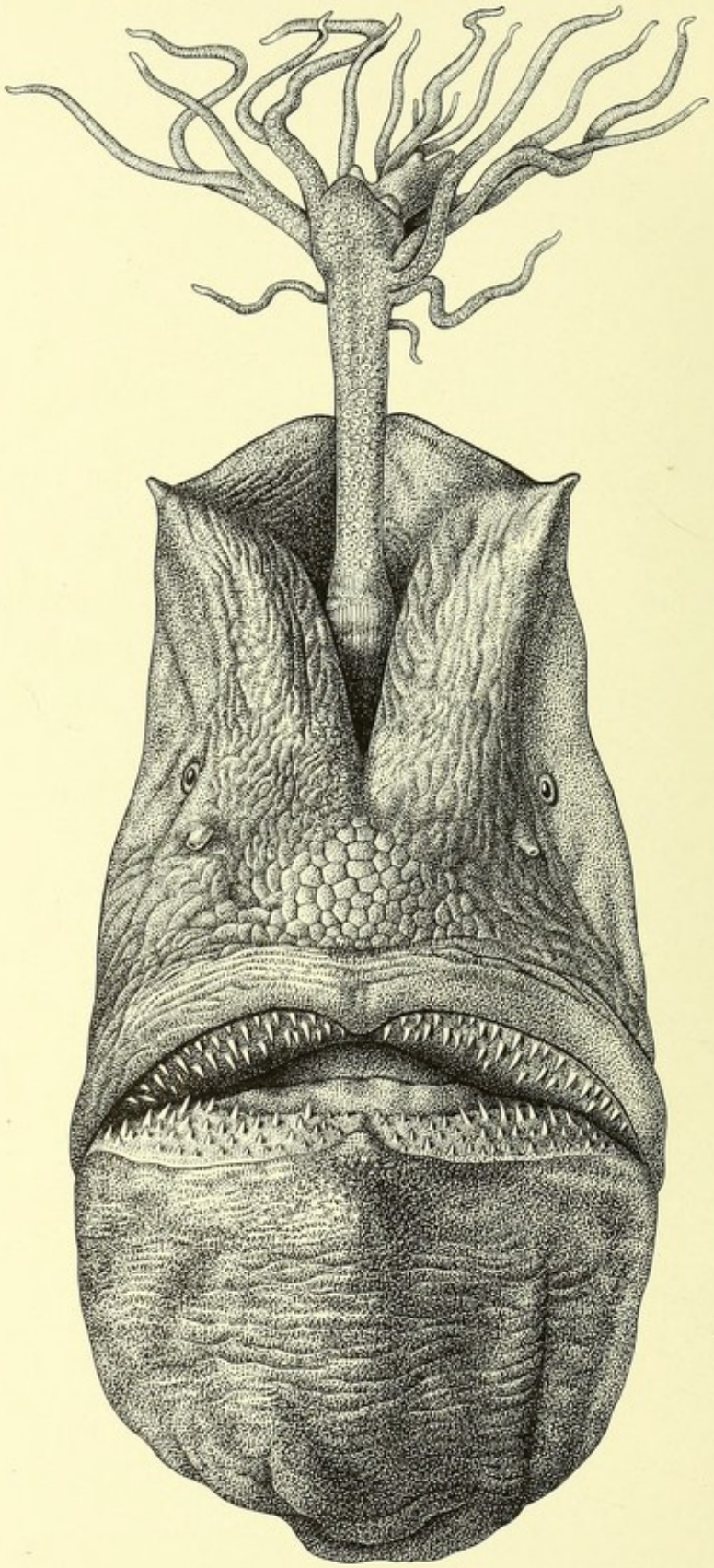
*G. M. Woodward del.*

Himantolop



ardti. × $\frac{5}{7}$

Lith. Anst. v. E. A. Funke Leipzig



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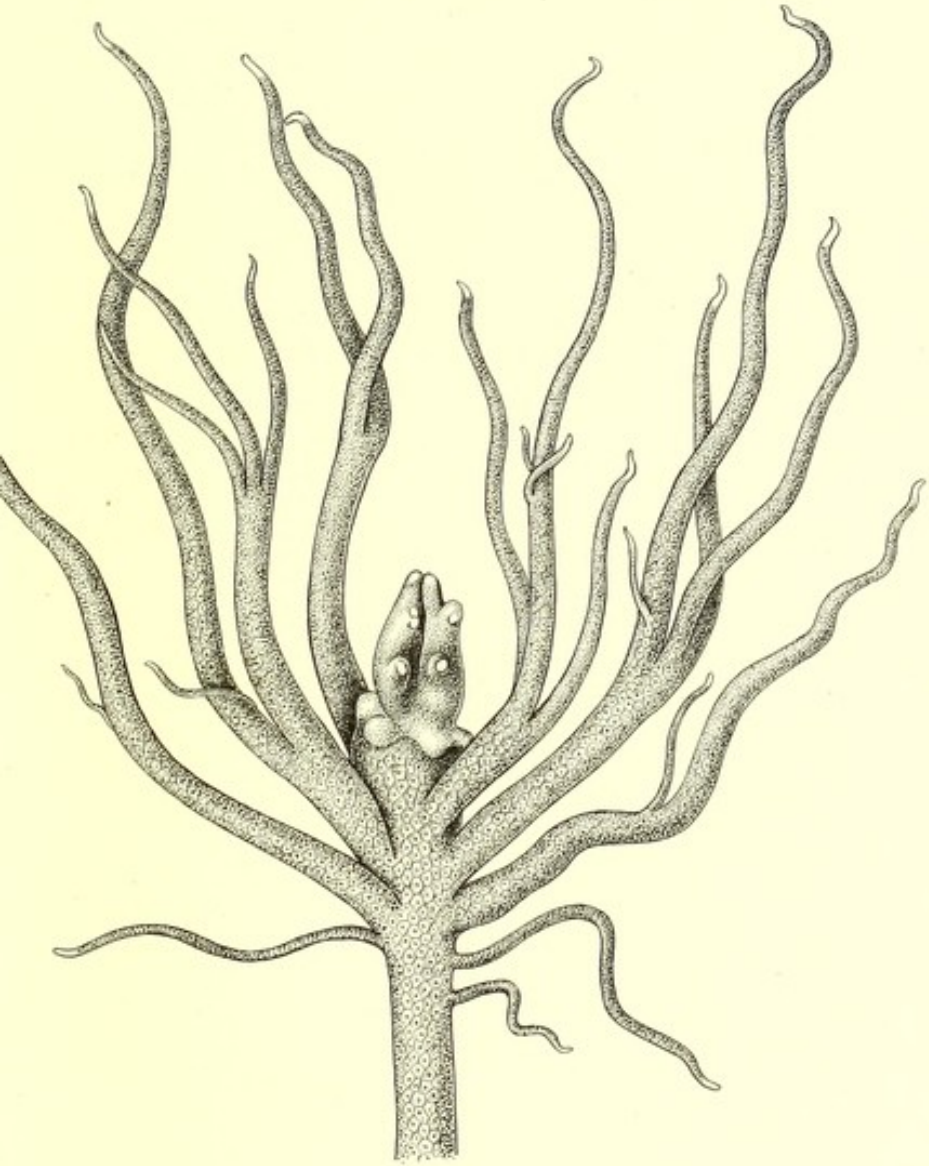

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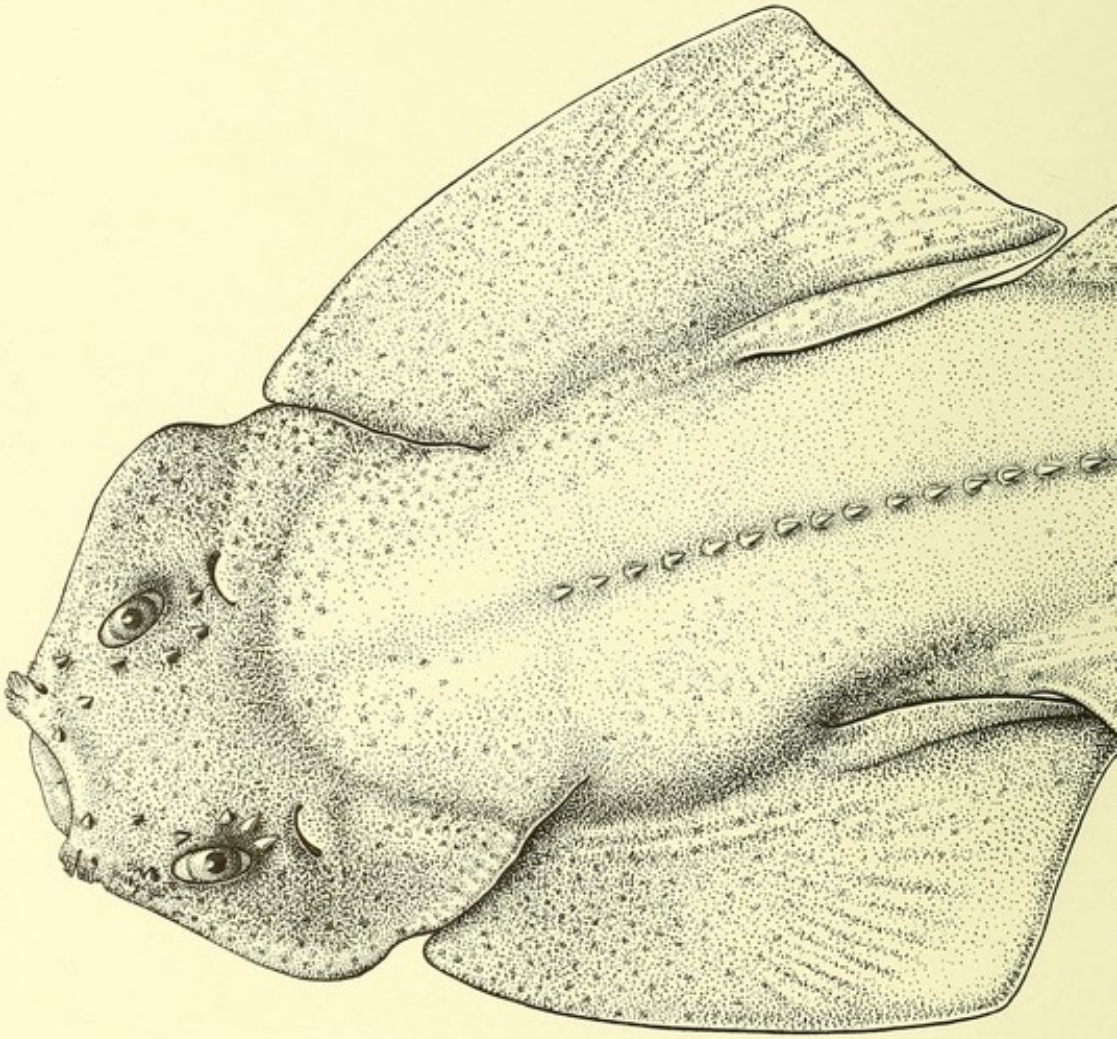

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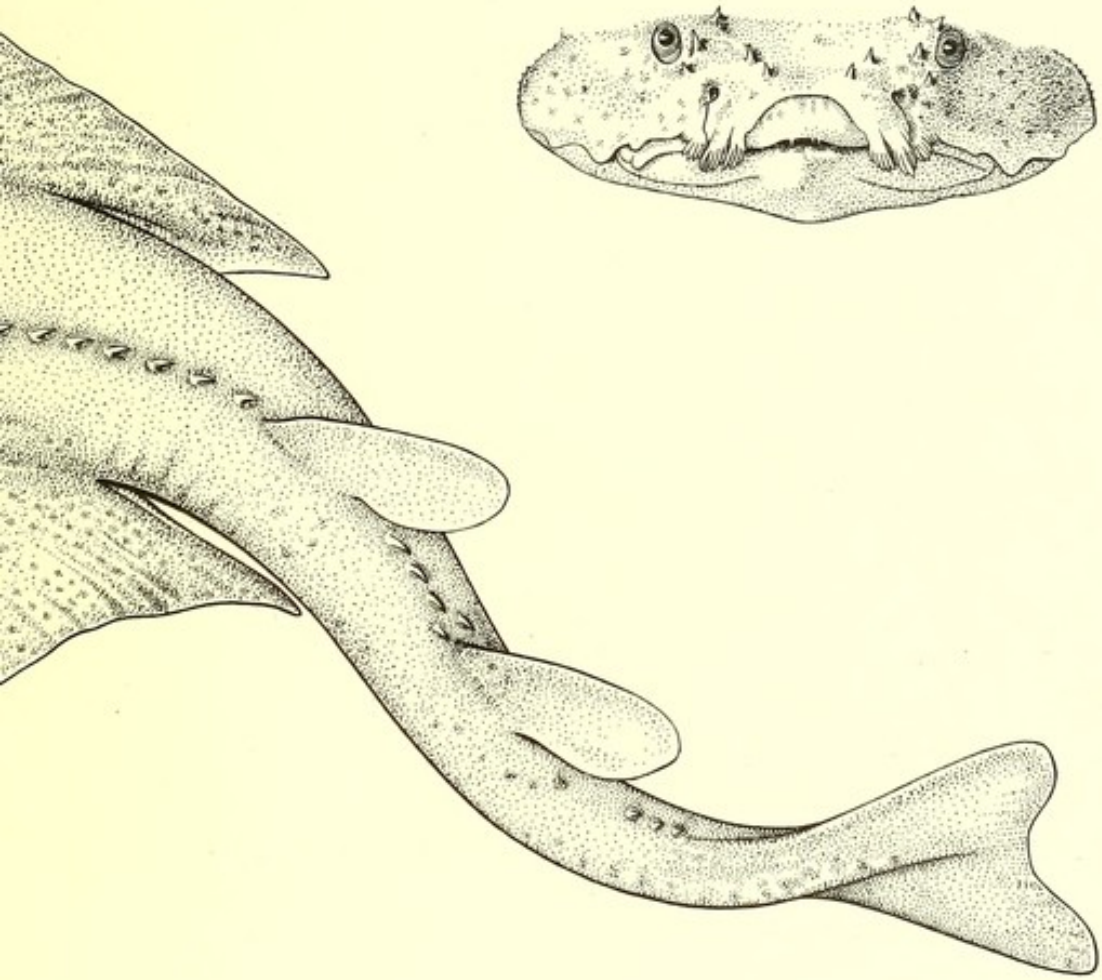
Squatin



1 . × $\frac{2}{3}$

Lith. Anst. v. E. A. Funke, Leipzig.

SCORPÆNIDÆ.

*Scorpæna dactyloptera*, Delaroche - Stations 4, 5, 6, and 9.
*S. scrofa*, L. - - - - - Station 10.

The larger of the two specimens, 260 millimetres in length, belongs to Lowe's *var. obesa.*

LOPHIIDÆ.

*Lophius budegassa*, Spinola - Stations 5 and 6.

The species is, therefore, not actually confined to the Mediterranean.

## EXPLANATION OF THE PLATES.

PLATE I.

*Himantolophus Rheinhardti.*

Lateral view - - - - - - - - × $\frac{5}{7}$.

PLATE II.

*Himantolophus Rheinhardti.*

Anterior view - - - - - - - × $\frac{5}{7}$.
Tentacle - - - - slightly magnified.

PLATE III.

*Squatina Aculeata* - - - - - - - × $\frac{5}{6}$.

## II. AMPHIPODA AND ISOPODA, WITH DESCRIPTIONS OF TWO NEW SPECIES.

By W. M. Tattersall, M.Sc.

During the examination of a small collection of Amphipoda and Isopoda made by Dr. Wolfenden in the course of various cruises in the eastern part of the Atlantic, between the Faeroe Islands and the Azores, the two new species here described were met with. They are both deep-water forms of great interest, the Amphipod of true bottom-haunting habits, the Isopod more probably belonging to the bathypelagic fauna of the ocean.

In addition to these new forms, several interesting species, which, however, do not call for more than brief notice here, were found in the collection. Among the Amphipoda may be mentioned a remarkably fine specimen of *Mimonectes Loveni*,[1] Bovallius; two examples of *Lycæopsis Lindbergi*,[2] Bovallius, a species not taken again since its description by Bovallius in 1889[3]; *Katius obesus*,[4] Chevreux, recently described[5] from the collections of the Prince of Monaco, and since rediscovered in deep water off the west coast of Ireland[6]; and a magnificent specimen of *Œdiceros saginatus*,[7] Kröyer, measuring 26 millimetres, a length 6 millimetres in excess of that given for the species by G. O. Sars in his work on the 'Amphipoda of Norway.' Among the more noteworthy of the Isopoda may be noticed *Arcturella*

[1] Lat. 43° 57′ N., Long. 10° 19′ W., September 8, 1904, open net, 4 fathoms.
[2] Lat. 45° 6′ N., Long. 18° 14′ W., July 29, 1904, open net, 5 fathoms.
[3] *Bih. K. Svensk. Vet. Akad. Hand.*, Bd. 11, No. 16, Stockholm, 1887.
[4] Lat. 44° 5′ N., Long. 20° 34′ W., 1904, surface.
[5] *Bull. Mus. Océan. Monaco*, No. 35, 1905.
[6] Tattersall, 'Fisheries, Ireland, Sci. Invest.,' 1905, iv. (1906).
[7] Lat. 59° 18′ N., Long. 8° 30′ W., 1903, 460 fathoms, closing-net.

*dilatata*,[1] G. O. Sars ; *Cirolana Hanseni*,[2] Bonnier (both recent additions to the British and Irish fauna) ; *Metamunna typica*,[3] Tattersall, a recently described[4] form from the west coast of Ireland ; and *Eurycope latiuostris*,[5] G. O. Sars, from two new British localities.

I am greatly indebted to Dr. Wolfenden for entrusting this collection to my charge, and have much pleasure in associating his name with one of the new species here described.

## Amphipoda.

*Family*, Lysianassidæ. *Genus*, Anonyx, Kröyer.

Anonyx Wolfendeni, *sp. nov.* (Plate IV., Figs. 1-17.)

*Locality.*—Lat. 39° 53′ N., Long. 26° 32′ W., 1904. Dredge, 600-700 fathoms.

*Body* moderately slender and slightly compressed laterally ; combined length of the metasome and urosome slightly greater than that of the cephalon and mesosome.

*Cephalon* shorter than the first segment of the mesosome ; rostrum almost obsolete ; lateral lobes not prominent, the margin of the head between the bases of the superior and inferior antennæ being, in fact, practically straight.

*First segment of the mesosome* longer than any of the remainder ; third, fourth, and fifth segments, subequal in length, slightly shorter than the second, and a little longer than the subequal sixth and seventh segments ; coxal plates more or less closely resembling those of the other species of the genus.

[1] Twenty-five miles north-north-west of Butt of Lewis, August 16, 1902, 80 fathoms.

[2] Lat. 39° 53′ N., Long. 26° 32′ W., 1904, 600-700 fathoms, dredge.

[3] Twenty-five and forty-five miles north-north-west of Butt of Lewis, August 16, 1902, 80 and 110 fathoms.

[4] 'Fisheries, Ireland, Sci. Invest.,' 1904, ii. (1905).

[5] Twenty-seven miles north-north-west of Rona, August 15, 1902, 120 fathoms ; twenty-five miles north-north-west of Butt of Lewis, August 16, 1902, 80 fathoms.

*Third segment of the metasome* (Plate IV., Fig. 1), with the posterior lateral angle obtusely rounded.

*Eyes* apparently quite absent.

*Superior antenna* (Plate VI., Fig. 3) about equal in length to the head and the first two segments of the mesosome combined ; peduncle rather stout, equal in length to the head, first joint longer than the remaining two taken together ; flagellum nearly three times as long as the peduncle, composed of thirteen joints—the first joint equal in length to two-sevenths of the whole flagellum, and bearing two rows of sensory setæ ; accessory flagellum about half the length of the main flagellum, composed of six joints, the first of which is slightly longer than one-third of the whole accessory flagellum. There is a single rather prominent and strong seta at the lower distal corner of the first joint of the main flagellum.

*Inferior antenna* (Plate IV., Fig. 4) extending to about the level of the tip of the superior, and, therefore, as a whole, somewhat longer than the latter ; rather slender ; peduncle armed with a few scattered setæ, and having the fifth joint longer than the fourth ; flagellum equal in length to the peduncle, composed of seventeen joints.

*Epistome* (Plate IV., Fig. 2) remarkably prominent, projecting almost entirely in front of the head (Plate IV., Fig. 2), as a large compressed, linguiform, rounded lobe, overhanging the anterior lip in front.

*Mandibles* (Plate IV., Figs. 5 and 6) robust ; cutting edge with a single small spine at the internal extremity, and a small tooth at the other end, otherwise smooth ; molar process well developed ; between the latter and the cutting edge there is a row of setæ, among which are to be found three or four strong simple spines ; palp elongate and slender, arising at about the same level as the molar tubercle ; third joint only half the length of the second, and bearing about fourteen long simple setæ, while the second joint has about eleven setæ on the distal part of its inner margin ; the left mandible bears, in addition, near to the cutting edge, a short, stout, blunt, and slightly recurved cylindrical spine.

*First maxillæ* (Plate IV., Fig. 7) with the inner plate much shorter than the outer, and armed at its apex with two plumose setæ, the outer of which is remarkably stout and very densely hirsute; outer plate armed at the apex with eleven strong spines, seven of which are longer and stouter than the rest, and bear numerous small spinules, the remaining four expanding somewhat towards the tip, which bears few rather coarse teeth; palp, two-jointed, extending slightly beyond the apex of the outer plate, the second joint expanding somewhat towards the extremity, which is armed with eight short, stout, distinctly articulated spines, in addition to a small tooth at the inner distal corner, its inner margin, at some distance from the apex, bearing two slender teeth.

*Second maxillæ* (Plate IV., Fig. 8) with both plates rather broad, the inner rather shorter than the outer, their apices armed with a row of strong plumose setæ and numerous fine hairs.

*Maxillipedes* (Plate IV., Fig. 9) with the inner lobe very well developed, quadrangular in shape, its inner margin armed with six long setæ, a single small spine and a few short setæ present on its inner corner; outer lobe large and expanded, reaching to the distal end of the second joint of the palp, its inner border finely crenulated throughout; palp well developed and rather stout, four-jointed, with numerous setæ on its inner edge.

*First gnathopods* (Plate IV., Fig. 10) moderately robust and distinctly subchelate; basal joint about as long as the remainder of the limb, and armed with numerous setæ on its anterior border; carpus longer than the propodus, and somewhat expanded, armed with numerous long setæ on its inner edge; propodus quadrangular in shape, narrowing very slightly towards the nail, the palmar edge slightly and finely serrated and bearing two long prominent spines on the corner, as well as a few long setæ; nail longer than the palmar edge, with a small secondary spine on its inner margin.

*Second gnathopods* (Plate IV., Fig. 11) longer than the first, very slender; carpus longer than the propodus; the latter, with the nail, forms a minute chelate extremity to the limb; both propodus and carpus with the usual fringe of fine hairs on both margins, and numerous

long setæ on the inner edge only, and also at the extremity of the propodus.

*Third and fourth pairs of legs* (Plate IV., Fig. 12) of similar structure, rather slender; basal joint about equal in length to the two succeeding joints combined; merus longer than either the carpus or propodus; latter longer than the carpus; nail rather more than one quarter of the length of the propodus; the whole limbs armed with numerous long and short setæ on their posterior margins, but no spines.

*Seventh pair of legs* (Plate IV., Fig. 13) long and slender; basal joint greatly expanded, longer than wide, with a row of short slender spines on its anterior border; carpus about one and a half times as long as the merus; propodus equal in length to, but narrower than, the carpus; nail rather more than one-quarter of the length of the propodus; the last three joints with a row of slender, short spines, and numerous setæ on their anterior border.

*First pair of uropods* (Plate IV., Fig. 14) with the peduncle longer than the subequal rami, and bearing a raised ridge, armed with short spines.

*Second pair of uropods* (Plate IV., Fig. 15) having the rami subequal in length to each other and to the peduncle; the inner ramus with a marked constriction near the tip.

*Third pair of uropods* (Plate IV., Fig. 16) with the peduncle shorter than either ramus; inner ramus very slightly shorter than the outer, both edges minutely pectinate, the inner edge with six spines and the outer edge with four; outer ramus with a small terminal joint, the inner edge minutely pectinate, and bearing a row of very short spines, the outer edge with a single spine at the extremity of the basal joint, and one about halfway along its length.

*Telson* (Plate IV., Fig. 17) about one and a half times as long as broad, deeply cleft for one-half of its length; the apices of the lobes of the cleft bear a small spine and two short setæ; there is a single spine on the dorsal surface of each lobe about the centre of the whole length of the telson.

*Length* of the single specimen, a female with incubatory lamellæ, and therefore presumably sexually mature, 9·5 millimetres from the anterior border of the head to the tip of the telson.

The generic position of this species is at present a matter of some doubt. I am unable to speak with certainty as to the structure of the branchial vesicles, and failing precision on this point, the species is provisionally referred to the genus *Anonyx*, to which it, at any rate, seems most closely allied. It differs from all the other species of the genus in its less compact and more slender form, in the absence of eyes, in the want of distinctly forwardly projecting lateral lobes to the head, in the very prominent and projecting epistomal plate, and in the rounded epimera of the third segment of the metasome. The form of the head closely resembles that seen in the genus *Cyclocaris*, but the structure of the first gnathopods is quite sufficient to exclude it from that genus. The latter character would also seem to separate it from the genus *Tmetonyx*[1] (= *Hoplonyx*, G. O. Sars), to which, however, its mouth parts more closely approximate than they do to those of *Anonyx*, though the differences from either genus are at most slight. It would be hazardous to define a new genus for its reception in the absence of definite information on the structure of the branchial vesicles. In the meantime it appears to be distinct, specifically, from all known species of either of the three genera, *Anonyx*, *Tmetonyx*, or *Cyclocaris*. The species is named in honour of its discoverer.

## Isopoda.

### *Family*, Ægidæ.

### *Genus*, Xenuræga, *nov.*

The mouth parts in the single specimen of this new genus available were not dissected, and, in the absence of information on this point, the new genus may be defined as follows :

*Body* depressed, with the cephalon very small, and the metasome distinctly narrower than the mesosome

[1] See Stebbing, 'Das Tierreich,' 21 Lief., Amphipoda, i., Gammaridea, 1906, p. 73.

*Eyes* absent.

*Superior antennæ* with a three-jointed peduncle.

*Inferior antennæ* with a fine-jointed peduncle, flagellum greatly elongated and many-jointed.

*First three pairs of legs* with the propodus smooth, cylindrical, not expanded ; dactylus extremely strong, hooked, sharply curved in the centre, and terminating in a darkened, very sharp point.

*Last four pairs of legs* moderately slender, successively increasing in length, ischium provided with a posterior lobe ; dactylus hook-shaped.

*Pleopods* consisting throughout of a pair of broad lamellæ, provided with setæ all round.

*Telson* very small, leaving the pleopods quite uncovered, linguiform in shape, unarmed.

*Uropods* uniramous, consisting of short basal joint articulated ventrally to the telson, and a terminal very long, stout spinous seta, provided with numerous fine plumose setæ.

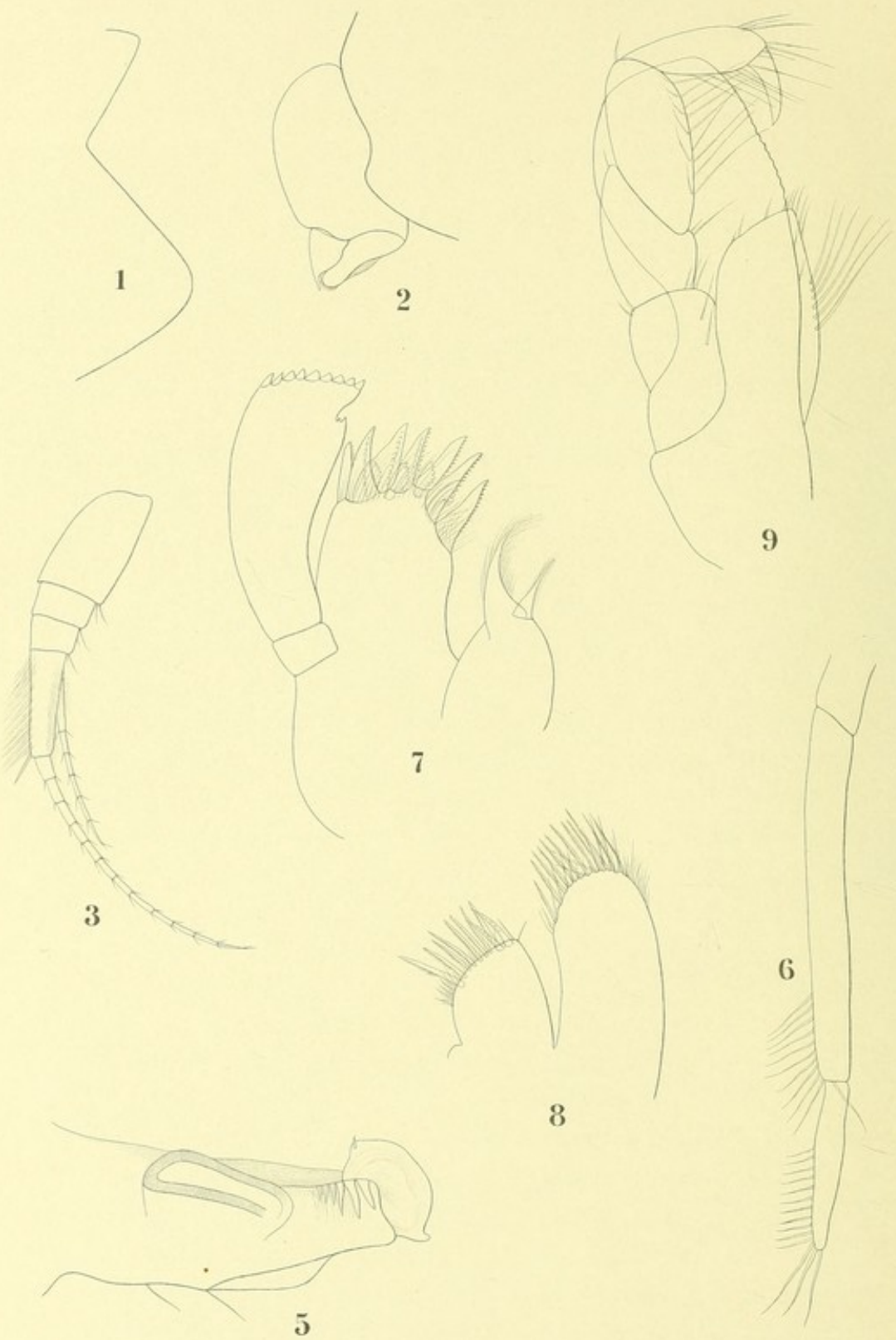
This remarkable new genus anteriorly resembles the genus *Syscenus*, Harger ; but the form of the telson, the uncovered pleopods, and the unique and rather anomalous form of the uropods at once separates it from all other known members, not only of the family *Ægidæ*, but of the whole tribe *Flabellifera*.

### Xenuræga Ptilocera, *gen. et sp. nov.*

*Locality.*—Lat. 36° 18′ N., Long. 23° 53′ W., June, 1904. Closing-net, 400 fathoms.

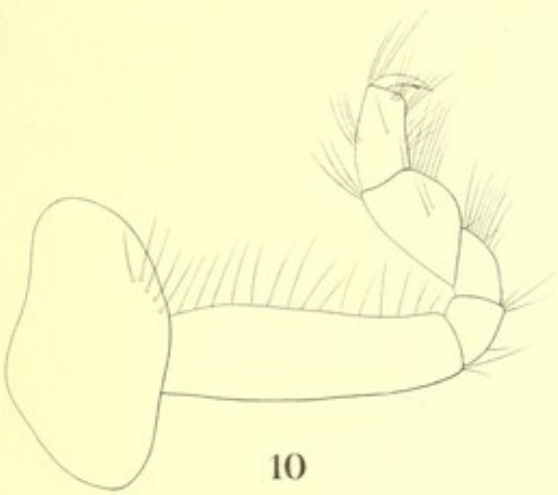
*Body* (Plate V., Fig. 1) rather slender and slightly depressed, about four times as long as the greatest width of the mesosome ; cephalon very small and triangular in shape, much narrower than the first segment of the mesosome ; metasome rather more than one-third of the total length of the body, much narrower than the mesosome, the segments successively narrowing towards the posterior end.

*Mesosome* (Plate V., Fig. 1) with the first segment larger than any of the succeeding ones, the remaining ones more or less subequal




W.M. Tattersall del.

Anony



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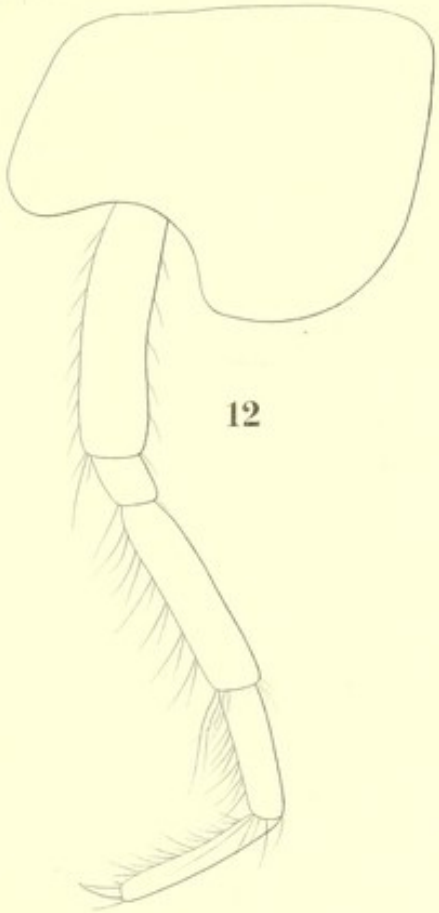

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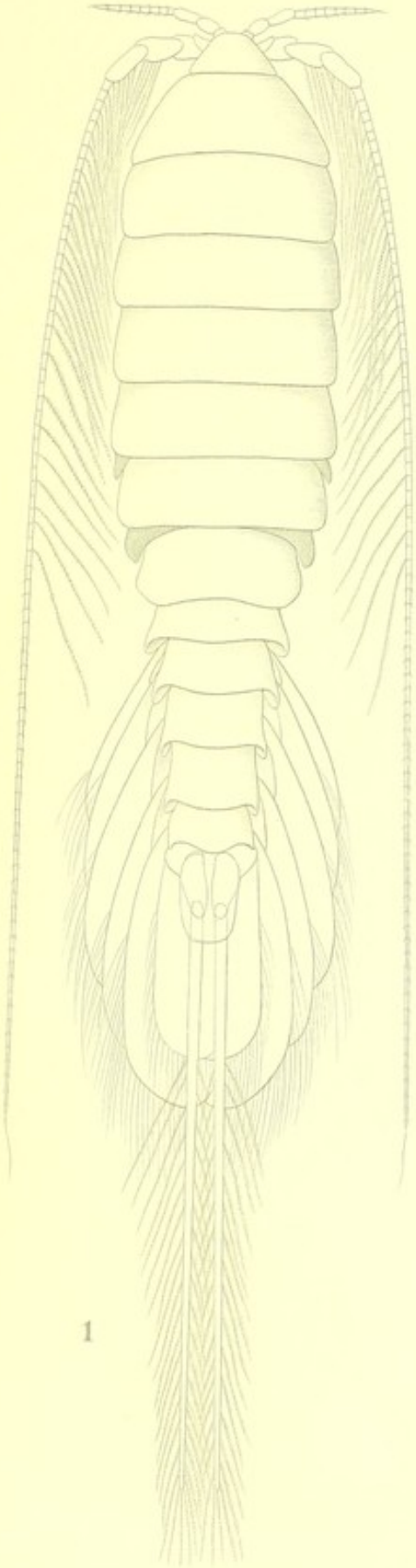

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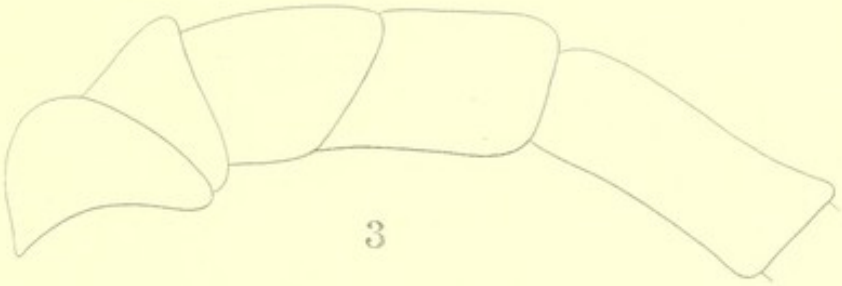

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Xenuraega ptilocera, gen. et. sp. nov.

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in length, but the posterior two narrower than any of the preceding; coxal plates well developed on all segments, those of the first segment apparently fused to the segment anteriorly, but free posteriorly.

*Metasome* (Plate V., Fig. 1) with the epimeral plates well developed, slightly produced posteriorly, with their hinder margins broadly emarginate.

*Eyes* absent.

*Superior antennæ* (Plate V., Figs. 1 and 2) not longer than the cephalon plus the first segment of the mesosome; peduncle three-jointed, the last joint the longest; flagellum slightly longer than the peduncle, and composed of eight joints.

*Inferior antennæ* (Plate V., Figs. 1 and 2) about 22 millimetres in length, longer than the body and very slender; peduncle five-jointed, the last joint the longest; flagellum composed of more than seventy joints; last two joints of the peduncle and the proximal half of the flagellum ornamented profusely with numerous very long, delicate plumose setæ.

*Mouth parts* not examined, but judging from other characters of the species, probably closely resembling those of the genus *Syscenus*.

*First three pairs of legs* (Plate V., Fig. 4) comparatively short and very strong and stout, unarmed; carpus quite small; propodus cylindrical, not expanded; dactylus remarkably strong, hooked, sharply curved at the centre, tip very sharp and darkened in colour.

*Fourth pair of legs* (Plate V., Fig. 5) moderately slender; ischium with its outer distal corner produced into a lobe extending almost to the centre of the merus and armed with four stout spines, a similar spine on its inner distal corner; merus longer and stouter than the carpus, with two and one spines on its outer and inner distal corners respectively; carpus with two small spines on its inner edge and two larger spines on its inner distal corner; propodus long and narrow, equal in length to the carpus and merus combined, armed with four small spines on its inner edge; dactylus moderately stout and slightly curved; a few long, fine plumose setæ on the inner edges of the

ischium, merus, and carpus, similar to those on the inferior antennæ.

*Fifth to seventh pairs of legs* similar in structure to the fourth, but successively longer, so that the seventh pair of legs extend considerably beyond the telson and up to about the level of the posterior margin of the pleopods ; fifth pair of legs with the propodus slightly less than the merus and carpus combined, and the latter longer than the merus ; sixth pair of legs with the carpus one and a half times as long as the merus, and only one-seventh less than the propodus ; seventh pair of legs with the carpus but very little less than the propodus, and still one and a half times as long as the merus.

*Pleopods* wholly uncovered by the telson, with the lamellæ of all five pairs narrowly oval in shape, and all setose on both margins, including the inner lamellæ of the first pair.

*Telson* (Plate V., Fig. 1) quite small, little more than twice as long as the last segment of the metasome, and about as broad at its base as long, linguiform in shape, truncate at the apex, its margins suddenly narrowing at about one-third of the length of the whole telson, unarmed.

*Uropods* (Plate V., Fig. 1) uniramous, consisting of a single basal joint articulated ventrally to the telson, and about two-thirds as long as the latter, and a terminal very stout and very long stiff spinous seta, 11 millimetres in length, and ornamented along the posterior three-quarters of its length with numerous long fine plumose setæ.

*Length* of the single specimen, 18 millimetres from the head to the tip of the telson, 29 millimetres from the head to the tip of the uropods ; inferior antennæ, 22 millimetres long.

I am unable to determine the sex of the type specimen. No incubatory lamellæ could be detected, nor, on the other hand, could any trace of appendage be found on the inner lamellæ of the second pleopod.

The structure of the telson and uropods, and the exceedingly long inferior antennæ, with its beautiful decoration of delicate plumose setæ,

at once distinguish this species from all other Isopoda. The specimen was caught in a closing-net lowered to 400 fathoms, at a depth of over 1,000 fathoms, and the species is therefore presumably bathypelagic in habitat.

## EXPLANATION OF THE PLATES.

### Plate IV.

*Anonyx Wolfendeni*, sp. nov.

Fig. 1.—Posterior lateral angle of the third segment of the metasome.
„ 2.—Epistomal plate, with outline of the head to show amount of projection.
„ 3.—Superior antenna.
„ 4.—Inferior antenna.
„ 5.—Oblique inside view of right mandible.
„ 6.—Mandibular palp.
„ 7.—First maxilla.
„ 8.—Second maxilla.
„ 9.—Maxillipede.
„ 10.—First gnathopod.
„ 11.—Second gnathopod.
„ 12.—Fourth leg.
„ 13.—Seventh leg.
„ 14.—First uropod.
„ 15.—Second uropod.
„ 16.—Third uropod.
„ 17.—Telson.

### Plate V.

*Xenuræga ptilocera*, gen. et sp. nov.

Fig. 1.—Dorsal view of whole animal.
„ 2.—Peduncle of superior antenna.
„ 3.—Peduncle of inferior antenna.
„ 4.—First leg.
„ 5.—Fourth leg.

## III.—PYROSOMA SPINOSUM, HERDMAN.

By George P. Farran, B.A.

Through the kindness of Dr. Wolfenden, I have had an opportunity of examining two specimens of *Pyrosoma*, which had been taken by his yacht, the *Silver Belle*, in February, 1906, off Cape St. Mary, Portugal, at a depth of 200 fathoms.

Both of these apparently belong to *Pyrosoma spinosum*, which was described by Herdman in 1888, from fragments of specimens taken by the *Challenger* in the South Atlantic.

These specimens, like those taken by the *Challenger*, were captured in the trawl, though possibly during the ascent of the net, and lead one to suspect that the species lives at or near the bottom in deep water, a fact which would account for the comparatively few records —viz., two from the *Challenger* (Herdman, 1888), one from the *Talisman* (Perrier, 1886), and one—a very young colony—from the *Helga* (Farran, 1906). The two colonies were approximately equal in size ; they were preserved in formalin, and were in excellent condition. The one figured, from which the measurements were taken, measured 85 centimetres in length by 19 centimetres in circumference, but was capable of a considerable amount of extension without rupture. The walls were 6 millimetres in thickness throughout the greater part of their length, but thickened considerably at the closed ventral end, and thinning away round the common cloacal aperture. The whole colony was tapered gradually to the closed end, which was rounded off bluntly. The open end had an irregular aperture of almost the full width of the colony. Its edges did not show any trace of lips or diaphragm,

but were thinned away and slightly contracted, the zooids being continued to the extreme margin. The substance of the test is gelatinous and rather firm to the touch, but easily torn. It is almost colourless, but the whole colony has a reddish tinge, due mainly to the colour in the stomach and intestine of the zooids.

The outer surface of the colony is covered with short, sharp spines, each spine being situated ventrally to the oral aperture of an ascidiozooid, and sloping towards it. The spines are keeled ventrally and laterally, and are about 1 millimetre in height. The inner surface of the colony, as mentioned by Herdman, is smooth and glistening.

The ascidiozooids are scattered closely through the test in no apparent order, the old and young being irregularly mixed together. They are very readily detached from the test, a considerable number falling out, through the internal aperture, every time the specimen was handled.

The general appearance of the individual ascidiozooid is best explained in the accompanying figure, drawn from a full-sized individual. The prebranchial space is very small, but varies with the amount of contraction. The cloacal space is small in full-grown individuals, but in young zooids is considerably elongate, forming almost one-third of the total length.

The oral aperture is usually very much contracted, and sometimes apparently completely closed. It is fringed by a circle of tentacles, about sixteen in number, irregular both in shape and size, and a single long ventral tentacle rising from a cushion-like base. The ventral tentacle is usually held vertically, projecting slightly from the mouth opening, and is excluded when the mouth is completely closed. The other tentacles are folded inwards.

The atrial opening is not circular, as is usual in *Pyrosoma*, but pear-shaped, rounded above, and with the sides of the opening approximating for some distance below before they unite. This peculiar arrangement seems to be due to the absence of muscle-fibres on the ventral side of the opening, which allows the atriopore to split ventrally. The pear-shaped opening was, however, found in zooids

of only 2 millimetres in length, which had not penetrated the inner wall of the test.

The musculature of the oral opening consists of a well-developed sphincter, outside which run several more or less completely circular muscle fibres. The atrial opening is not closed by a sphincter, but by a horseshoe-shaped band of muscle, thinning away at each end.

The atrial muscle is placed much farther forward than is usual, lying across the centre of the branchial sac. It consists on either side of a hollow fusiform band, split externally for the greater part of its length. It is much longer and more slender proportionately in the young than in the old ascidiozooids. It lies in the thickness of the body-wall. There are also two transverse muscle bands situated in front of the branchial sac. The most anterior is situated between the endostyle and the mouth opening, and consists of a broad transverse ventral band of muscle, whose ends break up into fine branches in the lateral body-wall. The other band is similar and similarly branched, and lies slightly anterior to the dorsal ganglion.

The luminous organs are present as a patch of large circular refractive cells, lying on either side of the body across the ciliated band. There is a similar but smaller patch of cells on either side of the atrial opening, which probably has a similar function.

The dorsal ganglion has been figured by Herdman. It gives rise, with others, to two pair of easily-observed nerves, the posterior of which run to the upper ends of the two atrial muscles, and the anterior pair to the anal muscle, giving rise to branches on the way which could not be traced.

The number of stigmata in a large ascidiozooid average about forty, and the number of transverse bars about thirty. The relative position of the stigmata and bars with reference to the oral aperture and the œsophagus is rather unusual, as a line joining the two last cuts across both stigmata and bars diagonally, while in the other species of *Pyrosoma* such a line would be approximately parallel to the bars and at right angles to the stigmata. This apparent distortion is due to the wide distance which intervenes between the first of the dorsal

languets, which marks the point of attachment to the dorsal stolon in young zooids, and the dorsal nucleus. In other species of *Pyrosoma* the languets and the dorsal nucleus are closely approximated. The number of languets is about twelve, of the usual form. The endostyle is bent at an angle of about 140 degrees at its anterior third. The stomach and gut are of a greenish-brown colour, the œsophagus being bright red. They lie in the horizontal plane, the gut being folded back laterally along the left side of the stomach.

The ovary was only observed in a few zooids. It contained a single ovum; a testis was not found in any instance. The presence of filaments running through the test, and putting into communication the atrial muscles of separate zooids, has been noted by several observers (Huxley, 1860; Seeliger, etc.). Similar fibres could be seen in *P. spinosum*, and numerous acicular and fusiform cells, similar to those composing the filaments, were evident, scattered irregularly through the test and, much more densely, in the body-walls of the zooids themselves.

It will be seen from the above remarks that *P. spinosum* differs very markedly from all other members of the genus. The principal differences may be summed up as follows:

Test processes situated ventral to the oral openings of the zooids.

Atriopore with the sphincter incomplete.

Anterior position of the atrial muscle.

Wide separation of dorsal ganglion and dorsal languets.

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Herdman (1888), 'Report on the Tunicata,' Pt. iii.; *Challenger* Reports, *Zool.*, vol. xxvii.

Huxley (1860), 'On the Anatomy and Development of Pyrosoma,' *Trans. Linn. Soc.*, vol. xxiii., 1860.

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## EXPLANATION OF PLATES

### Plate I.

*Pyrosoma spinosum.* $\times \frac{2}{3}$. From a photograph.

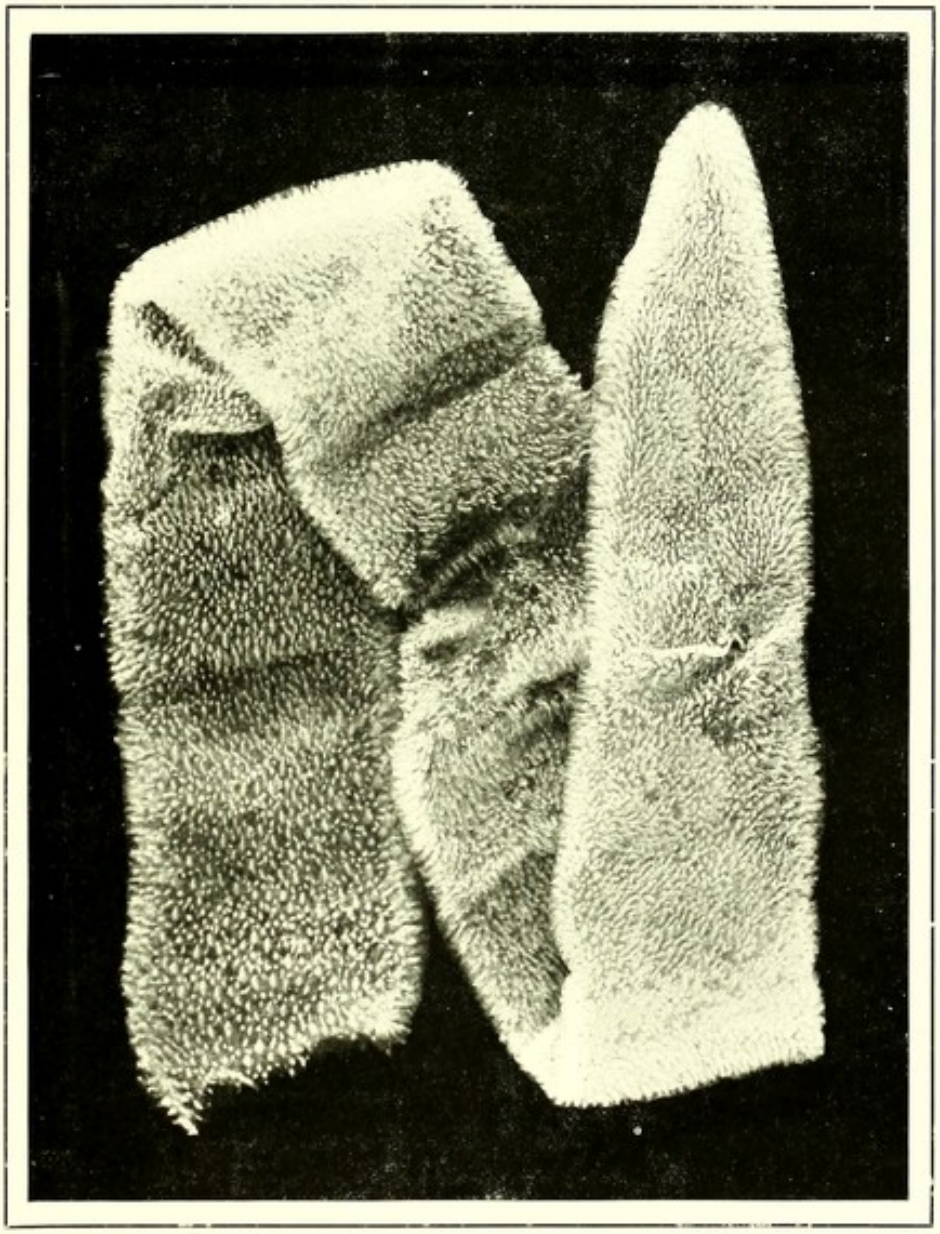
### Plate II.

Fig. 1. – *Pyrosoma spinosum:* lateral view of zooid.
Fig. 2.– *Pyrosoma spinosum:* oral aperture of zooid, from within.

*a.m.*, atrial muscle.
*an.*, anus.
*a.s.*, anal sphincter.
*d.g.*, dorsal ganglion.
*en.*, endostyle.
*lan.*, languets.
*lu.*, luminous organ.
*m.*, oral aperture.
*o.s.*, oral sphincter.
*ov.*, ovary.
*st.*, stolon.
*s.*, stomach.
*t.m.*, transverse muscle.
*v.t.*, ventral tentacle.

## ERRATA.

On page 224, *for* Plate I *read* Plate VI
*for* Plate II *read* Plate VII



Pyrosoma spinosum.

Lith. Anstalt v. E. A. Funke, Leipzig.

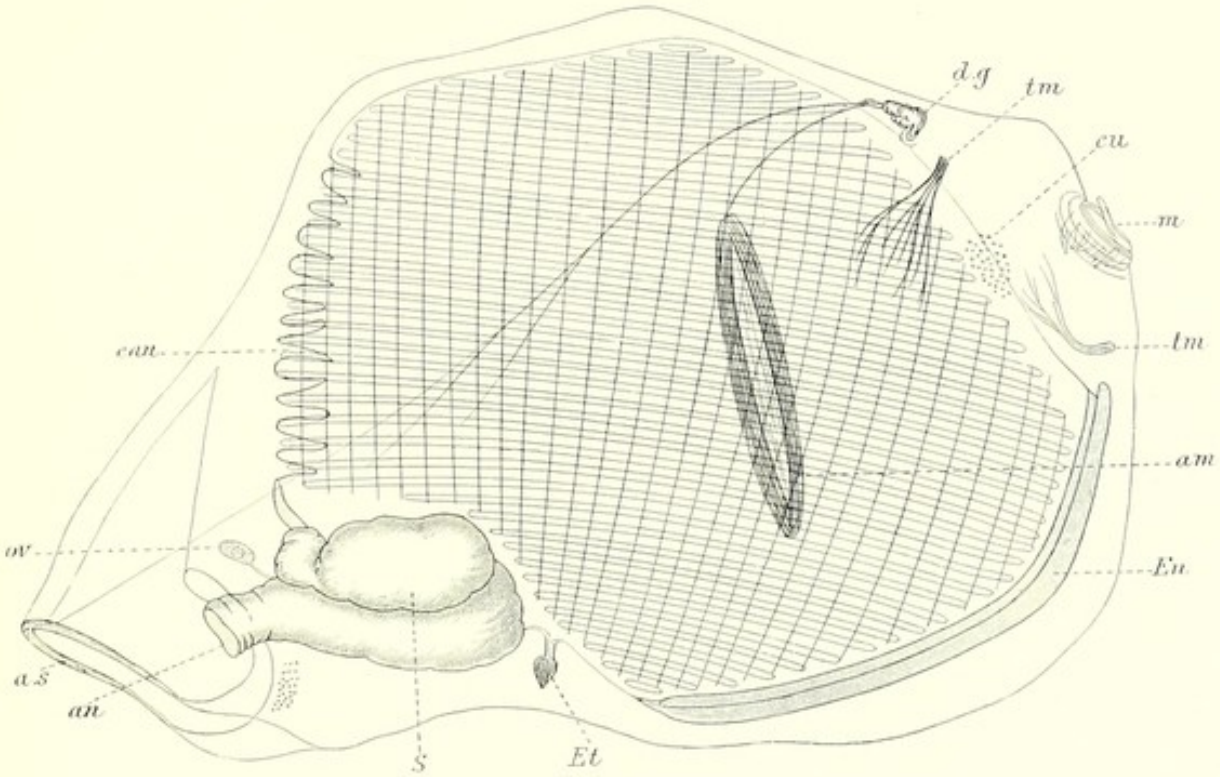



Fig. 1.

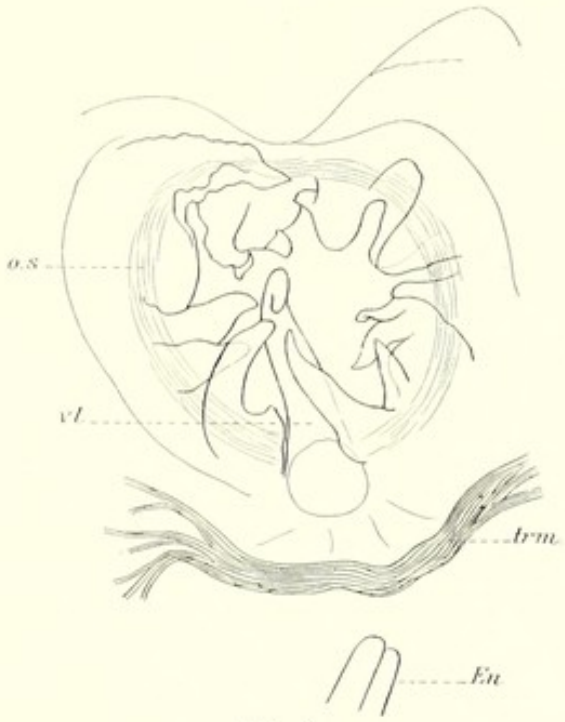



Fig. 2.

Pyrosoma spinosum.

Lith. Anst. v. E. A. Funke, Leipzig.

# CRUISE OF THE 'SILVER BELLE' IN JULY AND AUGUST, 1907.

## Fishes.

By E. W. L. Holt and L. W. Byrne.

The cruise is divisible into two sections. In the last half of July the ship ran from Scalloway about north-west to the 100-fathom line, and thence proceeded on a zigzag course in a general south-westerly direction, fishing and taking physical observations at sixteen stations, at soundings ranging from 107 to 550 fathoms, until she came north of the Butt of Lewis.

The next section of the cruise occupied the first seventeen days of August, and comprised six stations (17 to 22), at soundings of 144 to 385 fathoms, between 58° and 59° N. and 8° and 9° W., thus continuing the first section to the south-west, at an interval of about a degree of longitude, and on the farther side of the Wyville-Thomson ridge. A single station (23) was taken in shallow water (72 fathoms), west of the Butt of Lewis, in the last week of August. Dr. Wolfenden's original design was to link up the numerous faunistic observations which have been made in and about the Faeroe Channel with those of the Irish coast, where the Atlantic slope has been pretty thoroughly explored, down to 500 fathoms, from about 55° N. southwards. Incidentally it was intended to make a thorough exploration of the grounds on which the *Michael Sars* in 1902 made a few hauls with most interesting results. The weather appears to have been about as bad as possible, and to have interfered greatly with the efficiency of such operations as were possible, with the result that fish were taken at only seven of the twenty-three stations.

We are indebted to Mr. Opie, who acted as naturalist during the first section of the cruise, for very careful notes on the specimens which came under his observation. During the rest of the cruise the material was dealt with by Captain Buchan Henry.

So far as the fishes are concerned, the main interest lies in the additional evidence afforded of the difference between the fauna of the comparatively cold-water area lying to the north and east of the Wyville-Thomson ridge and that of the warmer water which extends southwards and westwards from that ridge.

The absence of any hauls from the immediate neighbourhood of the actual ridge makes it impossible to say whether the species of fish ordinarily found on either side of it are ever to be found in company in its immediate neighbourhood, or whether the comparatively sudden change of temperature forms a barrier which is not passed by fishes which elsewhere have a range including both extremes. Among the species taken by the *Silver Belle*, *Sebastes marinus* alone among bottom-living forms was captured on both sides of the ridge, in positive temperatures of 9·6° C. and 1·8° C. It is perhaps worthy of remark that, while in the neighbourhood now under consideration *Cottunculus Thomsoni* is found only in the warmer regions, in temperatures of about 7° to 8° C., and *C. microps* only in the colder region, in temperatures of about 0° to −2° C., yet both species have been taken between Iceland and Greenland in temperatures of about 3·5° C. (Lütken, 1898) and between 3·9° C. and 7·7° C. in the Western Atlantic by the *Albatross*.

The main interest, so far as the fishes are concerned, lies in the fact that some hauls were made in the cold-water area lying to the north and east of the Wyville-Thomson ridge, and others in the warm-water area to the south and west of that ridge. The extraordinary difference of the fish fauna of these two adjacent areas shows most clearly the great influence of temperature—or, perhaps, more accurately speaking, of a sudden change of temperature—upon the distribution of even such active animals as fishes.

Of the fifteen species of fish taken by the *Silver Belle* in the warm

area, all but one (*Sebastes marinus*) occur at similar depths off the west and south-west of Ireland; while of the six species (excluding the pelagic *Scopelus glacialis*) taken in the cold area, not one is known to occur off the Irish coast. The only species common to both areas is *Sebastes marinus*.

Further, of all the fishes recorded from the cold area, not a single bottom-living species, with the solitary exception above mentioned, has been found south or west of the Wyville-Thomson ridge; while the numerous species which have been taken immediately to the south or west of the ridge (again excepting *Sebastes marinus*) are all known from the deep water of the Irish Atlantic slope or from the Lusitanian region.

Among the genera and species typical of the two regions, we may mention: in the cold area, *Lycodes*, *Lycodonus*, *Liparis Rheinhardti*, and *Motella Rheinhardti*; and in the warm area, *Centrophorus*, *Macrurus*, *Alepocephalus Criardi*, *Haloporphyrus eques*, *Synaphobranchus pinnatus*, and *Epigonus telescopium*.

Cases are even to be found of closely allied species each confined to one area. Thus *Cottunculus Thomsoni* is found in the warm area at a bottom temperature of about 7° to 8° C., and ranges south from its northern boundary to the north-west coast of Africa; while *C. microps* occurs in the cold area at a bottom temperature of about 0° to -2° C., and ranges northwards to the neighbourhood of Spitzbergen. Yet both these species have been taken at temperatures of 3·5° C. between Iceland and Greenland (Lütken, 1898), and at temperatures between 3·9° C. and 7·7° C. by the *Albatross* in the Western Atlantic. It is, therefore, quite probable that the difference in the faunas of the two regions is in part rather due to the sudden change in temperature than to the absolute difference. Some, however, of the species of the cold area—*e.g.*, *Lycodes endipleurostictus* and *Lycodonus flagellicauda*—are only known to occur at very low temperatures; while other species found in the warm area—for example, *Alepocephalus Criardi* and *Epigonus telescopium*—are distinctly warm-water fishes.

### Scyllidæ.

*Pristiurus melanostomus* (Raf.).

Station 21. 58° 19′ N., 8° 51′ W. 191 fathoms. Sand. Bottom temperature, 9·6° C. One, 565 millimetres.

### Raidæ.

*Raia circularis* (Couch—*sensu stricto*).

Station 19. 58° 28′ N., 8° 29′ W. 180 fathoms. Sand. One, 165 millimetres. (A second skate, of about the same size, not preserved, was probably of the same species.)

Station 21. 58° 19′ N., 8° 51′ W. 191 fathoms. Sand. Bottom temperature, 9·6° C. One, young.

*Raia nævus*[1] (Müller and Henle).

*R. miraletus* (Couch, *nec* L.).

Station 23. 58° 49′ N., 6° 35′ W. 72 fathoms. Shells and sand. One, 73 millimetres across disc, with well-marked ocelli.

The depth at which this specimen was taken is worthy of note, as *R. nævus* is, in our experience, usually a littoral species not commonly ranging beyond about the 40-fathom line.

### Scopelidæ.

*Scopelus glacialis* (Rheinhardt).

Station 8. 60° 18′ N., 4° 43′ W. 330 fathoms. Gravel and shells. Two, 67 and 55 millimetres (without caudal fins), were brought up by the dredge ; there was nothing to show at what depth they entered the net.

### Macruridæ.

*Macrurus lævis* (Lowe).

Station 19. 58° 28′ N., 8° 29′ W. 180 fathoms. Sand. Two, 325 millimetres and 235 millimetres.

[1] This is the only name which seems to us to have been *first* applied to the familiar cuckoo ray.

Station 21. 58° 19′ N., 8° 51′ W. 191 fathoms. Sand. Bottom temperature, 9·6° C. One, 515 millimetres.

[Station 22. 58° 5′ N., 8° 46′ W. 144 fathoms. Sand. Bottom temperature, 9·5° C. Four *Macrurus* (not preserved) were probably of this species.]

This widely-ranging species is apparently absent from the cold-water area of the North Atlantic, as it was not met with either by the Norwegian North Atlantic Expedition (Collett, 1880), *Ingolf* (Lütken, 1898), or *Michael Sars* (Collett, 1905), although abundant off the southern part of the west coast of Ireland. With the exception of two specimens found dead on the coasts of Norway and Denmark, the above are the most northerly records known to us.

GADIDÆ.

*Gadus argenteus* (Guichenot).

Station 21. 58° 19′ N., 8° 51′ W. 191 fathoms. Sand. Bottom temperature, 9·6° C. One, 125 millimetres long.

*Brosmius brosme* (Müller).

Station 19. 58° 28′ N., 8° 29′ W. 180 fathoms. Sand. One, 480 millimetres.

Station 21. 58° 19′ N., 8° 51′ W. 191 fathoms. Sand. Bottom temperature, 9·6° C. One, 610 millimetres, *ca.* (*teste* Buchan Henry).

*Phycis blennioides* (Brünnich).

Station 19. 58° 28′ N., 8° 29′ W. 180 fathoms. Sand. One, 315 millimetres, *ca.* (damaged).

Station 21. 58° 19′ N., 8° 51′ W. 191 fathoms. Sand. Bottom temperature, 9·6° C. One, 430 millimetres, *ca.*

Station 22. 58° 5′ N., 8° 46′ W. 144 fathoms. Sand. Bottom temperature, 9·5° C. One (*teste* Buchan Henry).

*Motella Rheinhardti* (Kröyer).[1]

Station 9. 60° 4′ N., 5° 47′ W. 495 fathoms. Bottom temperature, −0·8° C. One, 145 millimetres long.

[1] We are indebted to Mr. C. T. Ryan for kindly identifying this species.

Station 10. 60° 3′ N., 6° 24′ W. 496 fathoms. Gravel, sand, mud, shells, and stones. Bottom temperature, −0·1° C. Two, 115 and 135 millimetres long.

Mr. Opie notes the colours shortly after capture as pinkish-brown or light brown, slightly darker dorsally, belly between anus and ventral fins very dark ; pectoral, anal, and caudal fins pink, dorsal fin darker.

PLEURONECTIDÆ.

*Hippoglossoides platessoides* (Fabricius).

Station 19. 58° 28′ N., 8° 29′ W. 180 fathoms. Sand. One, 175 millimetres (perhaps others, which were not preserved).

*Pleuronectes microcephalus* (Donovan).

Station 23. 58° 49′ N., 6° 35′ W. 72 fathoms. Shells and sand. Two, 115 and 103 millimetres.

*Pleuronectes cynoglossus* (L.).

Station 21. 58° 19′ N., 8° 51′ W. 191 fathoms. Sand. Bottom temperature, 9·6° C. Two, 235 and 230 millimetres.

*Zeugopterus megastoma* (Donovan).

Station 19. 58° 28′ N., 8° 29′ W. 180 fathoms. Sand. One, 315 millimetres (perhaps others, which were not preserved).

Station 21. 58° 19′ N., 8° 51′ W. 191 fathoms. Sand. Bottom temperature, 9·6° C. One, 225 millimetres, and (*teste* Buchan Henry) seven others up to 300 millimetres, *ca.*

Station 22. 58° 15′ N., 8° 46′ W. 144 fathoms. Sand. Bottom temperature, 9·5° C. Five (*teste* Buchan Henry).

Station 23. 58° 49′ N., 6° 35′ W. 72 fathoms. Shells and sand. One, 150 millimetres.

The specimen from Station 23 was speckled with black more or less all over the ocular side of the body and fins, and had a few larger blotches on the body.

GOBIIDÆ.

*Gobius Jeffreysii* (Günther).

Station 23. 58° 49′ N., 6° 35′ W. 72 fathoms. Shells and sand. One, 50 millimetres.

SCORPÆNIDÆ.

*Scorpæna dactyloptera* (Delaroche).

Station 15. 50° 15′ N., 8° 1′ W. 320 fathoms. Grey sand. Bottom temperature, 8·7° C. One, 285 millimetres.

*Sebastes marinus* (L.).

Station 8. 60° 18′ N., 4° 43′ W. 330 fathoms. Gravel and shells. Bottom temperature, 1·8° C. Two, 280 and 245 millimetres.

Station 21. 58° 19′ N., 8° 51′ W. 191 fathoms. Sand. Bottom temperature, 9·6° C. One, 240 millimetres.

COTTIDÆ.

*Cottunculus microps* (Collett).

Station 10. 60° 3′ N., 6° 24′ W. 496 fathoms. Gravel, sand, mud, shells and stones. Bottom temperature, −0·1° C. Ten specimens, 148 to 245 millimetres long.

One of the smallest specimens, 148 millimetres long, was a female containing ripe ova, which were 4 millimetres in diameter. Collett (1905) observed ova 4·5 millimetres in diameter in a female 195 millimetres long. The ova are evidently demersal, like those of *Cottus*, and, in all probability, are similarly deposited in masses. Mr. Opie made the following note of the colours of these specimens when freshly caught: 'The tail was light-coloured; anterior to this was a brown band, and in front of this another light band, including the dorsal and anal fins; then another brown band, followed by another light band, and then a brown band extending to the operculum. In front of this another light band extended nearly to the eye. The face was spotted more distinctly in some specimens than in others; the tip of the nose was light in most cases, but not in all; there was a dark patch under the eye. The belly was a bluish-white; the under side of the pectoral fin was very dark. The eye was bright bluish-green, with a bright margin.'

The specimens show considerable variation in the occipital spines or tubercles, which may be practically simple or bicornate or tricornate.

*C. microps* occurs on muddy, sandy, gravelly, and stony ground, at depths of from about 100 to 680 fathoms. It appears to be a distinctly cold-water species, the highest temperature record being 7·7° C. (*Albatross*), and the lowest −0·21° C. (Collett, 1905). On the eastern side of the Atlantic it ranges as far north as the open sea south and west of Spitzbergen, up to 80° N. (Collett, 1880), and as far south as the cold area of the Faeroe Channel, where it has been taken by the *Knight Errant* in 307 to 608 fathoms (Günther, 1887), and by the *Silver Belle*. It was not found by the *Michael Sars* in hauls south-west of Faeroe and north-west of the Hebrides, where the bottom temperature was about 8° C. (Collett, 1905), and has never occurred in the area west of Ireland fished by the *Helga*.

On the American side of the Atlantic the recorded range of *C. microps* extends as far north as Davis Strait (Lütken, 1895) and as far south as 31° N. (Goode and Bean, 1895), the recorded temperatures varying from 7·7° C. to 3·2° C.; the former temperature is considerably higher than any at which the species is known to occur in the Eastern Atlantic, where, however, it has been taken at 5·8° C. between Iceland and Greenland.

*Liparis Rheinhardti* (Kröyer).

Station 10. 60° 3′ N., 6° 24′ W. 496 fathoms. Gravel, sand, mud, shells, and stones. Bottom temperature, −0·1° C. Three—62, 55, and 52 millimetres long.

When newly captured these fish were (*teste* Mr. Opie) pink in colour, with shiny bluish-white abdomens.

CALLIONYMIDÆ.

*Callionymus*, sp.

Station 23. 58° 49′ N., 6° 35′ W. 72 fathoms. Shells and sand. One very small specimen, 21 millimetres long.

*Lycodes endipleurostictus* (Jensen).

Station 10. 60° 3′ N., 6° 24′ W. 496 fathoms. Gravel, sand, mud, shells, and stones. Bottom temperature, −0·1° C. One, 115 millimetres long.

Mr. Opie noted the colour soon after capture as light brown, with white vertical bands; the fins darker in colour than the body; abdomen brilliant blue.

*Lycodonus flagellicauda* (Jensen).

Station 10. 60° 3′ N., 6° 24′ W. 496 fathoms. Gravel, sand, mud, shells, and stones. Bottom temperature, −0·1° C. One, 234 millimetres long.

Mr. Opie noted the colour soon after capture as follows: 'Behind the abdomen the body was a very pale French grey; the abdomen was a shiny brilliant blue.'

A widely distributed species, ranging from near Spitzbergen and north of Iceland to the Faeroe Channel, at depths of from 460 to 1,000 fathoms—always in cold water, the recorded temperatures all lying between −0·03° C. and −1·5° C. (see Jensen, 1904, and Collett, 1905).

## STATIONS OF THE 'SILVER BELLE,' 1907.

Station 1.—July 12: 60° 44′ N., 2° 50′ W. 153 fathoms. Trawl. Nearly one hour.

Station 2.—July 12: 60° 47′ N., 2° 55′ W. 280 to 300 fathoms. Bottom temperature, 8° C. Trawl, two hours, on its back.

Station 2 (*continued*).—Same locality. 300 fathoms. Trawl, one hour.

Station 3.—July 13: 60° 46′ N., 3° 36′ W. Temperature, −0·4° C. 451 fathoms. Trawl, not on bottom.

Station 3 (*continued*).—507 fathoms. Shingle. Bottom temperature, 0·4° C. Trawl.

Station 4,—July 14: '507 fathoms. Bottom temperature, 0·4° C.' This entry is probably wrong. The depth at station 4 appears from chart of cruise to have been 550 fathoms. Trawl did not reach bottom, so any bottom animals labelled station 4 must belong to station 3.

Station 5.—July 14: 60° 15′ N., 4° 25′ W. 265 fathoms. Shingle. Bottom temperature, 7° C. Trawl.

Station 5 (*continued*).—July 15: 60° 26′ N., 4° 8′ W. 352 fathoms. Rough ground. Bottom temperature, 1·8° C. Agassiz trawl.

Station 6.—July 16: 59° 55′ N., 4° 38° W. 97 fathoms. Rocks and stones. Surface temperature, 11·4° C. Bottom temperature, 9·5° C. Dredge.

Station 7.—July 17: 60° 7′ N., 4° 52′ W. 216 fathoms. Gravel and large stones. Bottom temperature, 7° C. Dredge.

Station 8.—July 17: 60° 18′ N., 4° 43′ W. 330 fathoms. Gravel and shells. Surface temperature, 10° C.; bottom temperature, 1·8° C. Dredge and trawl.

Station 9.—July 18: 60° 4′ N., 5° 47′ W. 495 fathoms. Surface temperature, 11° C.; bottom temperature, 0·8° C. Trawl.

Station 10.—July 19: 60° 3′ N., 6° 24′ W. 496 fathoms. Gravel, sand, mud, shells, and stones. Bottom temperature, 0·1° C. Agassiz trawl.

Station 11.—July 20: 60° 4′ N., 6° 23′ W. 160 fathoms. Beam trawl.

Station 12.—July 27: 60° 37′ N., 8° 10′ W. 220 fathoms. Rocks and shingle. Surface temperature, 10·6° C.; bottom temperature, 8° C. Otter trawl.

Station 13.—July 27: 60° 32′ N., 8° 8′ W. 357 fathoms. Rocks and shingle. Surface temperature, 10·6° C. Otter trawl, when hauled, found to be broken.

Station 14.—July 28: 60° 13′ N., 8° 40′ W. 760 fathoms. Mud. Plankton net. Plankton was taken at the following depths:

| | Temperature. |
|---|---|
| Surface ... ... ... ... | 11·3° C. |
| 100 fathoms ... ... ... | 8·8° C. |
| 200 „ ... ... ... | 8·3° C. |
| 300 „ ... ... ... | 7·9° C. |
| 400 „ ... .. ... | 7·6° C. |
| 500 „ ... ... ... | 6·8° C. |
| 600 „ ... ... ... | 6·2° C. |
| 700 „ ... ... ... | 4·0° C. |

Station 15.—July 29: 60° 15′ N., 8° 1′ W. 320 fathoms. Grey sand. Surface temperature, 12·3° C.; bottom temperature, 8·7° C. Otter trawl.

Station 15 (*continued*).—Same locality. Agassiz trawl.

Station 16.—July 31: 59° 17′ N., 7° 52′ W. 383 fathoms. Shingle. Surface temperature, 11·4° C.; bottom temperature, 8·8° C. Otter trawl.

Station 17.—August 1: 58° 58′ N., 8° 14′ W. 385 fathoms. Shingle. Surface temperature, 11·6° C. Agassiz trawl.

Station 18.—August 1: 58° 54′ N., 8° 30′ W. Gravel. Surface temperature, 12° C. Otter trawl.

Station 18 (*continued*).—Same locality. Dredge.

Station 19.—August 2: 58° 28′ N., 8° 29′ W. 180 fathoms. Sand. Otter trawl.

Station 20.—August 3: 58° 32′ N., 8° 28′ W. 216 fathoms. Sand. Bottom temperature, 9·4° C. Otter trawl.

Station 20 (*continued*).—Same locality. Agassiz trawl.

Station 21.—August 4: 58° 19′ N., 8° 51′ W. 191 fathoms. Sandy. Bottom temperature, 9·6° C. Otter trawl.

Station 22.—August 17: 58° 15′ N., 8° 46′ W. 144 fathoms. Sand. Bottom temperature, 9·5° C. Otter trawl.

Station 23.—August 8: 58° 49′ N., 6° 35′ W. 72 fathoms. Shells and sand Agassiz trawl.

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