Physical Investigations.

Preliminary Paper.

By

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With Plate XI.

It may be taken for granted that, apart from its purely scientific value, a knowledge of the physical conditions affecting the waters of the sea has been shown to throw considerable light on many important economical questions. In its bearing on fish and fisheries, the inquiry may be said to have reached a point where it is conclusively shown that there is a problem to solve.

In a report of the Herring Committee of the Scottish Meteorological Society we find the following stated as preliminary results:—"If, during the herring season, there be a district where, from any cause, the temperature of the sea is lower than in surrounding districts, the catch of herrings is heavier in that district; and conversely if there be a district where, from any cause, the temperature of the sea is higher than in surrounding districts, in that district the catch of herrings is less. Among the causes which bring about a local increase or decrease of sea temperature, the chief are clouded or clear skies in respective districts, according as these occur during the day or during the night. . . .

"The above refers to local fluctuations of temperature during the fishing season, when the temperature of the sea is high. It appears from the observations of past years that the herring seasons have closed about the time when the temperature of the sea in its annual fall has fallen generally to 54·5° F. It is of importance to ascertain how far this relation exists from year to year and in different districts.

"Another important point is the relation of surface temperature to bottom temperature, and the relations of the deepest parts of the sea to the positions of the fishing-grounds. It is found, for instance, that when the surface temperature is high—higher than lower down—the fish, if any can be caught, strike the nets far

down in such a way as to lead to the supposition that a good deal of failure may often arise from the nets not going deep enough. The fish prefer, apparently, so far as the inquiry has gone, the lower to the higher temperature."*

Again, in summarising the results of physical investigations carried out for the Fishery Board for Scotland, Dr. John Gibson says, "I am not sure that the observations already made do not even now point to a connection between the presence of Atlantic water in the Moray Firth as a condition of successful inshore herring fishing. In the summer of 1883, when surface Atlantic water filled the Moray Firth, the inshore herring fishings in this firth are reported to have been unusually productive; while, on the other hand, in the summer of 1886, when water from the bottom of the North Sea filled the firth, during the month of August at any rate, it is reported that more than one half of the entire season's catch in the inshore waters was made during one single week, and that all the rest of the season these inshore waters were comparatively unproductive."†

That this opinion is general is shown by the extensive physical investigations carried on by the German Government, both by means of coast stations and exploring expeditions, such as those of the "Pommerania"‡ and the "Drache,"§ by the Norwegian Government, and by the U.S. Commission of Fish and Fisheries, the last named being about to publish an extensive series of observations of temperature and density on the Atlantic seaboard.

So far, however, the problem has only been stated; it has been shown that a more or less indirect relation exists between the physical and meteorological conditions affecting any particular region of the sea, and the quantity and quality of the fish to be caught in that region. Further, it has been shown that two methods of investigation give the most promising results:—(1) Continuous observations of temperature at fixed stations extending over a considerable period of time; and (2) Expeditions making a rapid survey of a certain area at intervals; the distribution of temperature being observed, and samples of water collected for subsequent examination.

These facts ascertained and defined, it remains at present to increase as far as possible, in either or both of the above-mentioned directions, the material for discussion.

In organising, at the request of the Director, a section for physical

* Journ. Scott. Met. Soc., 1876, vol. v, p. 30.

† Report of the Fishery Board for Scotland, 1888, p. 471.

‡ Jahresbericht der Commission zu Wissenschaftlichen Untersuchung der deutschen Meere in Kiel, 1872–3, Berlin, 1875.

§ Ergebnisse der Untersuchungsfahrten der Drache, Berlin, 1886.

work under the auspices of the Association, I have been chiefly guided by these considerations, and the work has divided itself into two separate investigations:—(1) The collection and discussion of existing observations, especially those of surface temperature; and (2) An inquiry into the physical conditions obtaining in the English Channel generally, and specially in the local fishing-grounds, by observations of temperature, examination of water samples, &c.

Through the kindness of the Meteorological Council, access has been obtained to all the records of surface temperature stored in the Meteorological Office. Part of the material has already been handed over to me, and a beginning has been made with its reduction and discussion. This work is necessarily laborious, and some time must elapse before any results can be presented for publication.

The difficulties in the way of commencing practical work were considerable. The steam launch belonging to the Association is useless for sounding outside the harbour except under unusually favourable conditions. I accordingly made an application to the Government Grant Committee of the Royal Society for the sum of £100, to pay hires of steam tugs for trips across the Channel at intervals. This application was granted. The unusually bad weather of the past summer, and the comparatively small amount of time at my disposal for research, have unfortunately prevented more than one trip being made, the results of which are given below.

The methods of marine physical investigation are now sufficiently well known to make it unnecessary to describe in detail the instruments and apparatus used. Temperature observations are made with Negretti and Zambra's reversing thermometer, in the Scottish frame,* and samples collected by Mill's self-locking water-bottle.† Where surface observations only are made, a sample of water is obtained in a wooden bucket, the temperature being taken by means of an ordinary thermometer, and the sample transferred to a glass bottle. All thermometers used have been verified by repeated comparison with a Kew standard belonging to the Association, and in most cases the instruments have Kew certificates in addition. Every care has been taken throughout to keep the errors of temperature observations within 0·1° F.

As the samples collected are at once brought to the Laboratory and their examination proceeded with, it has not been thought necessary to take special precautions in sealing the bottles. Winchester quarts of the ordinary type are used, note being made that the stoppers are well ground in each case.

Determinations of density have been made in the first place with

* Proc. Roy. Soc. Edin., xii, p. 928.

† Mill, ibid., 1886, vol. xiii, pp. 539—546.

an hydrometer of the "Challenger"* type, kindly presented to the Association by J. Y. Buchanan, Esq., F.R.S. This instrument weighs *in vacuo* 150·6897 grammes, and is furnished with seven brass weights varying from 0·3102 gr. to 4·0100 gr., giving for each sample of water at any temperature at least two distinct determinations. The constants of the instrument have been carefully determined twice at temperatures varying from 5° C. to 30° C., and the maximum probable error has been found to be 0·00005, a result agreeing with that arrived at by Mill.†

The want of a sufficiently delicate and reliable balance made the further examination of samples at first almost impossible. Through the kindness of Messrs. Balkwill, chemists, Plymouth, we now have access to an instrument giving results reliable to 0·1 mgrm.; and recently Prof. A. M. Worthington, of the Naval Engineering College, Devonport, has lent to the Laboratory a balance capable of weighing 100 gr. to within 1·0 mgrm. While we are unable to carry out analyses with the high precision reached, for example, in Dr. Gibson's work for the Scottish Fishery Board, we may now hope to make determinations sufficiently accurate to be of considerable value. The first object aimed at is to obtain determinations of density by means of the modified form of Sprengel's pyknometer.‡ In the hydrometer determinations given, the densities are reduced to 15·56° C. compared with distilled water at its maximum density point by Dittmar's tables.§ These tables, however, can only be safely used where the sample approaches the standard density of 1·02600 at 15·56° C. In all other cases determinations made with Sprengel tubes filled in melting ice are much to be preferred.

In the more strictly chemical work I have had the advantage of the co-operation of Mr. F. Hughes, the Chemist of the Association. The alkalinities of all the samples already collected have been determined by the usual methods with a fair degree of accuracy, and considerable progress has been made with estimation of the amounts of chlorine. I have thought it best to defer publication of the chlorine results until more progress has been made with the densities.

Table I gives the results of observations made in a trip on ss. "Deerhound" in the Channel in June last. On June 15th a line was taken from Bolt Head to a point west of Hanois Light, and thence to St. Peter's Port, Guernsey; on June 16th from Guernsey to St. Catherine's in the Isle of Wight; and on June 17th

* Challenger Reports, Narrative, vol. ii, pt. 2.

† Proc. Roy. Soc. Edin., xiii, p. 35.

‡ Report of the Fishery Board for Scotland, 1887, p. 336.

§ Challenger Reports, Physics and Chemistry, vol. i, p. 70.

from Anvil Point back to Bolt Head (see Plate XI). Column 1 gives the laboratory number of each sample of water; columns 2 and 3, the date and hour; columns 4 and 5, the position and depth of the sounding; column 6, state of the tide; 7 and 8, direction and force of the wind; 9, weather at the time of observation; 10, temperature of the air as ascertained by a sling thermometer; 11, depth of observation; 12, the temperature (corrected) at that depth; 13 and 14, the densities, referred to 4° C., at 15·56° C., and *in situ*. Column 15 shows the density at 0° C. referred to distilled water at 0° C., as determined by the Sprengel tubes; and column 16 the alkalinity.

The values given in column 13 are the means of at least three double determinations, and may be taken as accurate to $\pm$ 3 in the fifth place of decimals. The reductions, as before stated, have all been effected by means of Dittmar's tables; and as the deviations from standard water are in most cases very small, it is improbable that additional error has been introduced.

The numbers in column 15 are the means of at least two determinations in each case, and may be taken as correct within $\pm$ 2 in the fifth place.

The alkalinities have in great part been estimated twice, and are subject to an actual error not exceeding unity, the relative error being probably considerably less.

Table II gives extra observations of surface temperature, taken at intervals of about half an hour. The positions are given with reference to the sounding stations I, II, III, &c., as in Table I.

The route followed in the trips under consideration was chosen simply with the view of finding the most promising fields of investigation. I hope under more favourable conditions to repeat the observations in various parts of the Channel at intervals of two or three months. If this could be done regularly for several seasons we cannot doubt that a good deal of light would be thrown on variations of climate on different parts of our coasts, as well as on the distribution of fish at different periods.

Any general discussion of the observations made in June last is of course useless until material for comparison has been obtained, but a few noticeable features may be pointed out. It appears in the first place that the water in the area surveyed is extremely uniform. The densities at 15·56° C. show but little variation, the highest values, 1·02618 and 1·02612 at surface, and 1·02625 and 1·02612 at bottom, occurring at stations IIa and VIII; and the lowest, 1·02588 at surface and 1·02582 at bottom, at station X, off St. Catherine's. The mean density is practically that of normal sea water, both at surface and bottom, except off St. Catherine's.

The alkalinities also show great uniformity, varying only between

51 and 53, and the surface and bottom samples for each station showing no marked differences. The highest values are found for samples taken down Channel and on the southern side, a decrease being observed in Start Bay and along the coast to the eastwards.

At a depth of 10 fathoms a distribution of temperature is found which remains practically unaltered at all stations until the bottom is reached; even in the case of station VII the temperature at 73 fathoms is only 0·2° F. lower than that at 10 fathoms. At these depths the highest temperatures are found off the English coast east of the Bill of Portland, and again in the neighbourhood of the Channel Islands, colder water occurring in mid-Channel at stations II, IIa, and III, and VII and VIII, and between Start Point and the Bill of Portland, where the minimum of 50·6° F. is reached, the isothermals curving into Start Bay and turning south again.

On the surface the distribution of temperature is peculiar; and although the observations here are very much more numerous, less weight can be attached to their results on account of the action of wind. It is to be noted that on the first day of the cruise the wind was south-westerly, light, freshening, and veering a little towards evening, till at 2 a.m. next morning it was blowing hard from about west. After daybreak the force greatly diminished, and the wind gradually veered to north-west and died away altogether. On the third day the wind was westerly and extremely light, dying away to a calm at times.

Wherever undisturbed by land influences, the line between stations I and IV may be said to show a uniform temperature at the surface of 53·7° F. Further up Channel, *i. e.* between stations VI, VII, VIII, and IX, a lower temperature is found, varying irregularly at the time of observation between 52° F. and 53° F.; and this colder surface water seems to extend at any rate round the island of Guernsey. In the area covered by stations IX, X, XI, and XII a temperature between 53° F. and 54° F. is found, rising as we approach Poole Bay to about 55° F.

In the region between Start Point and the Bill of Portland a totally different distribution occurs. We find here the highest temperatures of the whole cruise, rising suddenly 2° as the Bill of Portland is passed, and slowly increasing thereafter till the maximum of 57° F. is reached off Beer Head. A sudden drop to below 52° is observed over the Skerries off Dartmouth Harbour. Soundings XIII and XIV show that the layer of warmer water is quite superficial, the temperature falling to 51·9° F. at 6 fathoms in XIII, and to 50·9° F. at 8 fathoms in XIV. It may be noted that extra samples, No. 42 and No. 45, show no change in the density at 15·56°. With regard to column 14, densities *in situ*, we have of course simply the results of the distribution of temperature, with the small variations of

column 13. On the bottom the highest values are obtained in mid-Channel and in Start Bay, decreasing slightly on the southern coast, and more markedly to the east of the Bill of Portland. On the surface, again, the highest values are found at stations IIa and VIII, and on the southern side; and the lowest off the English coast, those to the east of the Bill of Portland being due to differences in the water, those to the west to differences of temperature.

The results suggested by these observations may be summarised as follows :

(1) The waters of the Channel are subject to a peculiar circulation, the nature of which cannot be determined without more extended investigation.

(2) The distribution of temperature in Start Bay demands special investigation. In this area we find the highest surface temperatures and the lowest bottom temperatures, the warm surface layer being about 6 fathoms in thickness, while at the same time there is no change in the composition of the water. In Start Bay we have a notedly good trawling-ground, and this confirms the result obtained off the east coast of Scotland by Dr. Gibson as already quoted, and again by myself,* viz. that where we have true oceanic waters, unmixed with estuarine or river waters, subject to special temperature conditions due to the presence of land or other causes, we find favourable conditions for successful fishing. This result seems to be to some extent borne out by observations on the Dogger Bank fishing-grounds.

What these temperature conditions actually are must be shown by investigation. The preliminary trip in the Channel indicates that more numerous and detailed temperature observations must be made over a large area, and that the samples collected need not be so numerous, but must in all cases be subjected to a rigorous examination of the greatest attainable accuracy.

In conclusion, I may say that the material discussed in my paper already quoted seems to me exceptionally valuable in the inquiry in hand. Observations of surface temperature taken regularly *on the fishing-grounds* by fishermen afford data of extreme interest even when great accuracy is not attempted. I have tried to initiate such observations amongst the local fishermen on these coasts, so far, unfortunately, without much success. The Association will be glad to supply instruments and books to any fisherman or seaman on any part of the coast who will take such observations.

During the winter months I hope also to investigate the conditions of local estuarine waters in relation to fisheries.

* Journ. Scott. Met. Soc.,' 1889, vol. viii, No. 6, p. 332.

TABLE I.

No. of sample.	Date.	Hour.	Position.	Depth. Fath.	Tide.	Wind.		Weather	Temp. of air.	Depth of observation	Temp. of sea. T.	S. 4. 15·56.	S. 4. T.	S. o. o.	Alkalinity.
						Direction.	Force.								
13	12/6/91	Noon	Eddystone, S.W. 7 miles	28	½ ebb	S.W.	0	*b*	...	0	53·8	1·02607	1·02679	...	53·4
										1½	52·0				
										5	51·1				
										10	51·0				
										15	50·7				
										20	50·7				
14	...	...	...	...	...	...	...	...	...	27	50·6	1·02620	1·02725	...	53·1
15	12/6/91	1.30 p.m.	Between Penlee Point and Mewstone	10	½ ebb	...	...	...	...	0	54·0	1·02551	1·02621	...	52·0
										5	51·5				
16	...	...	...	...	...	...	...	...	...	9	50·9	1·02599	1·02700	1.02829	52·2
17	15/6/91	9 a.m.	I. Bolt Head, N.E. × E. 1½ miles	20	½ fl.	W.S.W.	0—1	*f*°	55	0	52·6	1·02601	1·02686	1·02820	52·8
										5	51·8				
										8	51·5				
										10	51·8				
										13	51·6				
										15	51·4				
										17	51·6				
18	...	...	...	...	...	...	...	...	...	19	51·4	1·02599	1·02695	...	52·2
19	15/6/91	12.30 p.m.	II. S.E. × S. ¼ S., 20 miles from I	40	H. W.	W.S.W.	1	o	56	0	53·9	1·02606	1·02676	...	53·0
										5	53·4				
										7	52·9				
										10	51·1				
										15	50·9				
										20	51·0				
20	...	...	...	...	...	...	...	...	...	39	50·9	1·02616	1·02717	...	52·8
21	15/6/91	2.30 p.m.	IIa. S.E. × S. ¼ S., 16 miles from II	42	½ ebb	...	...	...	56	0	53·8	1·02618	1·02690	1·02856	51·6
										22	51·4				

22	...	...	...	...	...	...	...	...	...	41	51·2	1·02625	1·02723	...	52·4
	15/6/91	3 p.m.	III. S.E. × S. ¼ S., 18 miles from II	40	...	...	...	...	55	0	53·8				
										5	53·1				
										10	51·5				
										12	51·4				
										15	51·3				
										20	51·3				
										39	51·2				
23	15/6/91	6 p.m.	IV. S.S.E. ½ S., 23½ miles from III. Hanois E.N.E. 3 miles	32	L.W.	W.S.W.	0—1	∞	55	0	52·6	1·02603	1·02688	...	52·2
										5	52·2				
										10	52·0				
										15	51·9				
										22	51·9				
24	...	...	...	...	...	...	...	...	...	31	51·9	1·02611	1·02702	...	52·5
25	15/6/91	7.25 p.m.	V. St. Martin's Point N.E. 2 miles	30	½ fl.	W.S.W.	0—1	f^{∞}	...	0	52·2	1·02608	1·02697	...	52·4
										10	52·0				
										15	51·9				
										20	51·9				
26	...	...	...	...	...	...	...	...	...	29	51·8	1·02601	1·02693	...	52·0
27	16/6/91	8.30 a.m.	VI. Caskets N.W. ½ N. 9 miles	28	1 hr. fl.	N.N.W.	1	∞	...	0	53·2	1·02604	1·02682	...	52·1
										5	53·0				
										10	52·8				
										15	52·7				
										20	52·4				
										23	52·4				
28	...	...	...	...	...	...	...	...	...	27	52·2	1·02606	1·02695	...	52·2
29	16/6/91	12.30 p.m.	VII. Caskets S.W. × S. 9 miles	73	H. W.	N.W.	1	Cloud-less	...	0	53·6	1·02607	1·02681	...	52·2
										5	51·9				
										10	51·6				
										20	51·4				
										30	51·3				
										40	51·3				
										53	52·0				
										60	51·9				
30	...	...	...	...	...	...	...	...	...	72	51·4	1·02609	1·02705	...	52·6

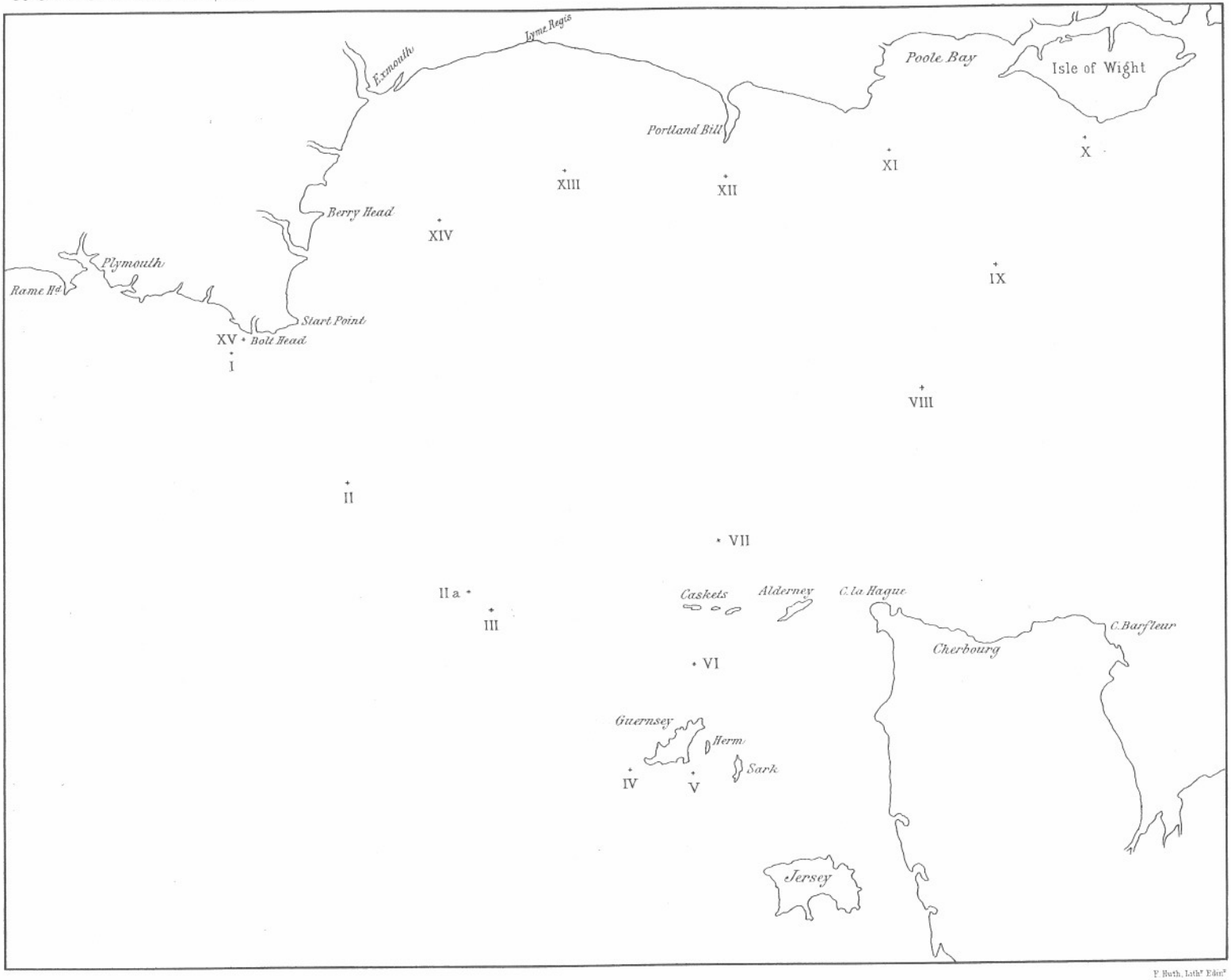
TABLE I (*continued*).

No. of sample.	Date.	Hour.	Position.	Depth. Fath.	Tide.	Wind.		Weather	Temp. of air.	Depth of observation	Temp. of sea. T.	S. 4. 15·56.	S. 4. T.	S. o. o.	Alkalinity.
						Direction.	Force.								
31	16/6/91	4.15 p.m.	VIII. E. × N., 29 miles from VII	40	1 hr. ebb	N.W.	1	∞	...	0	52·0	1·02612	1·02703	...	52·2
										5	51·8				
										10	51·6				
										20	51·4				
										30	51·4				
32	...	...	...	...	...	...	...	...	...	39	51·3	1·02612	1·02710	...	51·5
33	16/6/91	6.15 p.m.	IX. N.E. × E., 15 miles from VIII	29	2 hr. ebb	N.W.	1	*b*	...	0	53·0	1·02604	1·02684	...	50·8
										5	52·9				
										10	52·8				
										19	52·8				
34	...	...	...	...	...	...	...	...	...	28	52·7	1·02599	1·02682	...	50·8
35	16/6/91	8.15 p.m.	X. St. Catherine's N.E. ¼ E. 2 miles	30	½ ebb	W.N.W.	1	*b*	...	0	54·6	1·02588	1·02650	...	51·1
										5	54·5				
										10	54·3				
										20	54·4				
36	...	...	...	...	...	...	...	...	...	29	54·3	1·02582	1·02648	...	51·1
37	17/6/91	6.45 a.m.	XI. Anvil Point N. × W. 10 miles	22	¾ ebb	Var.	0	*b*	...	0	53·7	1·02604	1·02676	...	51·1
										5	53·3				
										12	53·4				
38	...	...	...	...	...	...	...	...	...	21	53·3	1·02602	1·02680	...	51·9
39	17/6/91	10 a.m.	XII. Portland Low Light N.N.E.	29	¼ fl.	Westerly	0	*b*	56	0	54·3	1·02606	1·02672	...	52·0
										2	53·2				
										5	53·5				
										10	53·1				
										19	53·1				
40	...	...	...	...	...	...	...	...	...	28	53·0	1·02602	1·02682	...	51·2

41	17/6/91	Noon	XIII. Beer Head N. × E. 18 miles	28	¾ fl.	W.S.W.	0—1	o	57	0	55·9	1·02611	1·02659	...	51·9
										2½	55·0				
										5	52·9				
										6	51·9				
42	...	...	...	...	...	...	...	...	...	8	51·5	1·02608	1·02704	...	51·1
										10	51·4				
										20	51·0				
43	...	...	...	...	...	...	...	...	...	27	51·0	1·02611	1·02710	...	51·0
44	17/6/91	2.15 p.m.	XIV. W.S.W. 14 miles from XIII	26	H. W.	W.S.W.	0—1	o	...	0	56·6	1·02608	1·02648	...	52·1
										3	56·3				
										5	55·2				
										6	51·9				
45	...	...	...	...	...	...	...	...	...	7	...	1·02608	1·02709	...	52·0
										8	50·9				
										10	50·9				
										15	50·6				
										20	50·6				
46	...	...	...	...	...	...	...	...	...	25	50·6	1·02608	1·02713	...	51·7
47	17/6/91	6.10 p.m.	XV. Bolt Head N.N.E. 1½ miles	20	¾ ebb	Calm	0	o	...	0	53·5	1·02598	1·02674	...	52·3
										1	52·5				
										2	52·5				
										5	52·2				
										10	52·0				
48	...	...	...	...	...	...	...	...	...	19	51·9	1·02602	1·02693	...	52·7

TABLE II.—*Surface Temperatures.*

Date.	Hour.	Position.	Temperature.
15/6/91	9 a.m.	I. Bolt Head N.E. × E. .....1½ miles	52·6°
	10	*a.* S.E. × S. ¼ S. from I..... 4 „	54·2
	10.30	*b.* „ „ ..... 9 „	54·1
	11	*c.* „ „ .....13 „	53·5
	11.30	*d.* „ „ .....18 „	53·0
	12.30 p.m.	II. „ „ .....20 „	53·9
	1.20	*a.* S.E. × S. ¼ S. from II ..... 5 „	53·6
	1.50	*b.* „ „ ..... 9 „	53·6
	2.20	*c.* „ „ .....14 „	53·7
	2.30	II. *a.* „ „ .....16 „	53·8
	3	III. „ „ .....18 „	53·8
	4	*a.* S.S.E. ½ S. from III..... 4 „	53·4
	4.30	*b.* „ „ ..... 9 „	53·7
	5	*c.* „ „ .....14 „	53·7
	5.30	*d.* „ „ .....18 „	53·1
	6	IV. „ „ .....23½ „	52·6
	7	Pleinmont Point N.W. × N. ..... 4 „	52·2
	7.25	V. St. Martin's Point N.E..... 2 „	52·2
16/6/91	8.30 a.m.	VI. Caskets N.W. ½ N..... 9 „	53·2
	9.30	*a.* „ „ ..... 6 „	53·0
	10	*b.* „ „ ..... 3 „	52·1
	10.30	Off the Caskets	52·2
	11	Caskets S.W. × S. ..... 4 „	52·0
	12.30 p.m.	VII. „ „ ..... 9 „	53·6
	1.50	*a.* E. × N. from VII ..... 4 „	53·1
	2.20	*b.* „ „ ..... 9 „	52.6
	2.50	*c.* „ „ .....14 „	52·6
	3.20	*d.* „ „ .....19 „	52·3
	3.50	*e.* „ „ .....24 „	52·3
	4.15	VIII. „ „ .....29 „	52·0
	5.50	*a.* N.E. × E. from VIII..... 9 „	52·2
	6.15	IX. „ „ .....15 „	53·0
	7.15	*a.* „ from IX..... 4 „	53·9
	7.45	*b.* „ „ ..... 9 „	54·5
	8.15	X. St. Catherine's Light N.E. ¼ E... 2 „	54·6
	9	S.W. off Brixton..... 4 „	54·8
17/6/91	6.15 a.m.	Anvil Point N. × W. ..... 6 „	55·6
	6.45	XI. „ „ .....10 „	53·7
	7.30	*a.* W. ½ N. from XI ..... 4 „	53·9
	8	*b.* „ „ ..... 9 „	53·7
	8.30	*c.* „ „ .....14 „	53·8
	9	*d.* „ „ .....18 „	54·1
	9.20	*e.* „ „ .....20 „	53·9
	10	XII. Portland Light N.N.E. ..... 9 „	54·3
	10.30	*a.* N.W. × W. from XII..... 5 „	54·0
	11	*b.* „ „ ..... 9 „	55·8
	11.30	*c.* „ „ .....13 „	55·5
	12 noon	XIII. Beer Head N. × E. .....18 „	55·9
	1 p.m.	*a.* W. ½ N. from XIII ..... 4 „	56·3
	1.30	*b.* „ „ ..... 9 „	56·2
	2.15	XIV. Berry Head W.N.W. ½ N.....11 „	56·6
	3.15	*a.* W.N.W. ½ W. from XIV... 5 „	57·4
	3.50	*b.* Off Berry Head.....	57·1
	4.20	*c.* Off Dartmouth	54·1
	4.50	*d.* Off Beeson.....	52·6
	5	*e.* Start Point W. ¾ S. ..... ¼ mile	54·0
	5.10	*f.* „ N.E. × E. ..... ¼ „	52·4
	6.10	XV. Bolt Head N.N.E. .....1½ miles	53·5



P. Ruth, Lith^r Edin^r