Mackerel and Sunshine.

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With Figs. 1–5 in the Text and Tables I.–VII. at the end.

In his paper on "Plankton Studies in Relation to the Western Mackerel Fishery," in the last number of this Journal (Vol. VIII., p. 269), G. E. Bullen shows that for the years 1903–1907 there appears to be a correlation between the number of mackerel taken during May and the amount of Copepod plankton, upon which the mackerel feed, taken in the neighbourhood of the mackerel fishing grounds during the same month.

It was clearly worth while, therefore, to consider what conditions favour the production of an abundant supply of Copepods in the fishing area, since it appears to be this supply of food which attracts the mackerel into that area, or at any rate into its surface waters.

The hydrographical investigations carried out at the mouth of the English Channel have rendered it probable that the movement of the water there is comparatively slow. It may therefore be assumed that on the mackerel grounds to the westward of the Cornish coast the water which is present at any particular time has not recently moved into the district from any very remote region, and, treating the matter broadly, has been subjected for some time to the general climatic conditions of the neighbourhood.

The question then suggests itself, can the differences which occur from year to year in the abundance of the Copepods be referred in any way to such climatic conditions? If such a connection exists it will probably be not direct, but indirect, through the action of the climatic conditions on the food of the Copepods. The food of Copepods seems to be largely the vegetable organisms of the plankton, chiefly diatoms and Peridinidæ,*

* This has long been recognised in a general way, but useful direct evidence of it has recently been brought forward by W. J. Dakin. *Notes on the Alimentary Canal and Food of the Copepoda. Internat. Revue der gesam. Hydrobiologie u. Hydrographie*, I., 1908.

though even if a considerable proportion of it were found to consist of minute animal organisms, these in their turn would feed upon the phytoplankton. It is therefore to the conditions which favour the production of phytoplankton, the fundamental food supply, that we must turn.

The three most obvious matters to be considered in connection with the production of this vegetable plankton are: (1) the composition of the sea-water itself, (2) the temperature, and (3) the amount of light which is available for the production of plant life.

With regard to the composition of the sea-water itself, the only information available refers to its salinity, and up to the present it has not been possible to show any simple relation between changes in salinity and changes in the vegetable or animal production in the area under consideration. The same is true of temperature, though this will be considered in more detail below.

It is the object of the present paper to call attention to what appears to be evidence of the influence of the third factor, the intensity of light. Experiments on the cultivation of marine plankton diatoms in the laboratory, upon which I had been engaged, had drawn my attention to the great importance to be attached to the intensity of the light to which the diatoms were exposed. It therefore occurred to me that a special abundance of Copepods during the month of May in any year might be due to a special amount of sunshine during the earlier months of the year, which would increase the amount of phytoplankton, the Copepod food. An attempt was therefore made to correlate the average quantity of mackerel per boat taken in May with the number of hours of bright sunshine recorded during the first quarter of the year.

The official statistics of mackerel landed are not very satisfactory for such a purpose, since they give only the total quantities of fish and give no information as to the number of vessels from which the fish are obtained. In making use of them, therefore, one must bear in mind that the number of vessels to which the figures relate varies from year to year, although the amount of this variation over a small number of consecutive years will not generally be very large.

In order to get figures of a more definite character, I applied to Messrs. Peacock & Co., of Lowestoft, who have had vessels engaged in the western mackerel fishery for many years. Messrs. Peacock were good enough to furnish me with a series of figures giving the number of hundreds of mackerel landed each month from February to June, at Newlyn and Milford,* by three of their steam drifters, for each of the

* These vessels landed fish only at Newlyn and Milford, so that, by combining the figures for the two ports, we get the total number of fish taken by each boat from the western fishing grounds.

years 1902–1908, as well as similar figures for three sailing drifters. These figures are given in Tables I. and II.

Messrs. Peacock's figures show that by far the largest quantities of mackerel are landed in the month of May, and that, as in the case of the official statistics (cf. Bullen, *loc. cit.*, p. 277), the figures representing the May landings dominate the curve representing the total landings from the spring fishing. Moreover, it is practically certain that the vessels fished throughout May, whereas for the other months, except, perhaps, April, one has not generally any definite knowledge as to when they began or ended their fishing.

In the diagram below (Fig. 1) the average number of mackerel per

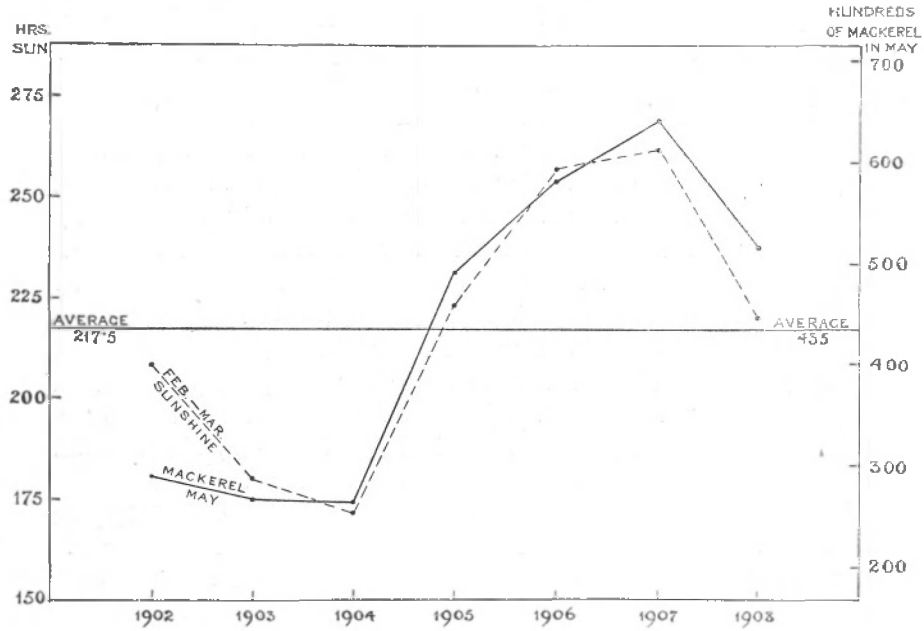

FIG. 1.—The dotted line indicates the average number of hours of bright sunshine recorded for the months of February and March, in each of the years 1902–1908, at the meteorological stations at Plymouth, Falmouth, and Scilly.

The continuous line indicates the average number of "hundreds" (120 fish) of mackerel per boat landed at Newlyn and Milford in the month of May of the same years 1902–1908, by three steam drifters belonging to Messrs. Peacock & Co., of Lowestoft.

boat in "hundreds" (each "hundred" really means 120 fish) landed in May by Messrs. Peacock's three steam drifters is represented by the continuous line, whilst the number of hours bright sunshine during February and March is represented by the dotted line. The sunshine figures were obtained by taking the average of the number of hours

recorded at the three meteorological stations, Plymouth, Falmouth, and Scilly. Although the extreme closeness of the agreement between the two curves may be due to chance, it seems scarcely possible to doubt that they indicate a fundamental correlation between the abundance of mackerel in May and the amount of bright sunshine during the earlier months of the year. The sunshine curve, it should be added, has practically the same shape, whether it is taken for the three stations chosen, or for the whole south-western district of England, which includes inland stations, or for the south-west of England and south Ireland combined. The figures on which the sunshine curve is based will be found in Table III.

In Fig. 2 the continuous line gives the total number of cwts. of mackerel landed on the south and west coasts of England and Wales in May* for each of the years from 1886–1908, as given by the official statistics of the Board of Trade and Board of Agriculture and Fisheries (see Table IV.), whilst the dotted line gives the average number of hours bright sunshine recorded for the south-west of England and south Ireland for the first quarter of the year (Jan.–March), as given in the reports of the Meteorological Office (see Table V.). As already pointed out, the official figures of mackerel landed take no account of the number of boats fishing, and those taken during the first four or five years are known to be very imperfect and should therefore be neglected. It is practically certain that the fishing power has increased during the years for which the records are given, more especially since the introduction of steam drifting about 1902. Comparing the two curves in Fig. 2 generally, and bearing in mind the above limitations, there is, I think, sufficient similarity in the way in which they rise and fall together to justify us in regarding them as in no way contradicting the very definite agreement shown between Messrs. Peacock's figures and the sunshine curve as seen in Fig. 1.

Considering in more detail the years 1902–1908, it will be seen that the most striking difference between the curve given by the official figures and that representing the averages for Messrs. Peacock's boats is the great drop which the official figures show in 1906. A similar though less marked drop in 1906 is also shown by the curve given in Fig. 3, which represents the average number of "hundreds" of mackerel landed by Messrs. Peacock's three sailing drifters. A reference to the figure given by Bullen (*loc. cit.*, p. 279, Fig. 1) also shows a minimum in 1906 for the Copepods taken at the International Stations E.5. and E.6. The high figure for 1906 given by the three steam drifters, although it agrees with the high February and March sunshine for that

* Most of the fish are landed at Newlyn and Milford Haven.

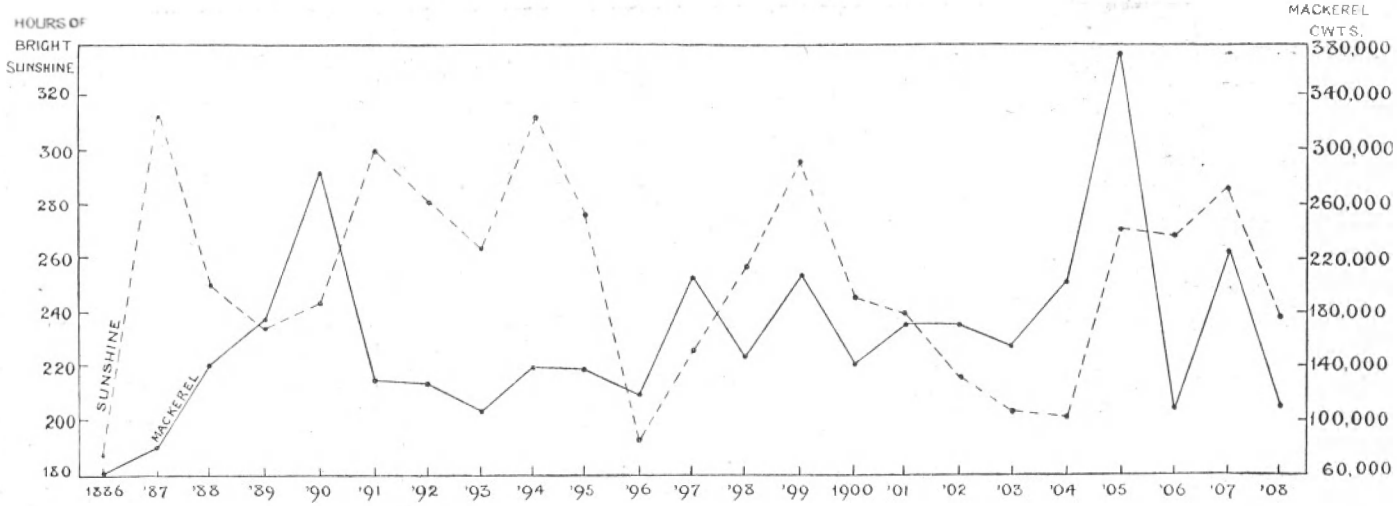

FIG. 2.—The dotted line indicates the average number of hours of bright sunshine recorded for the first quarter of the year (January to March) for each of the years 1886–1908, for the Meteorological Office Districts England S.W. and S. Wales, and Ireland South.

The continuous line indicates the number of hundredweights of mackerel recorded as landed on the South and West Coasts of England and Wales, in the month of May, for each of the years 1886–1908 (Official Statistics).

year, does not therefore agree with the official figures for mackerel, with the catches of the three sailing drifters, nor with the figure taken to represent the Copepods. Any explanation of this discrepancy can only be of a speculative kind, but it is probable that the steam drifters fished much further west of the Scillies than the sailing drifters would go, or than the International Stations are situated. If this is the explanation of the difference shown, it would seem to suggest that in May, 1906, there was some local factor at work on the grounds nearer the shore which did not operate on those which were more distant.

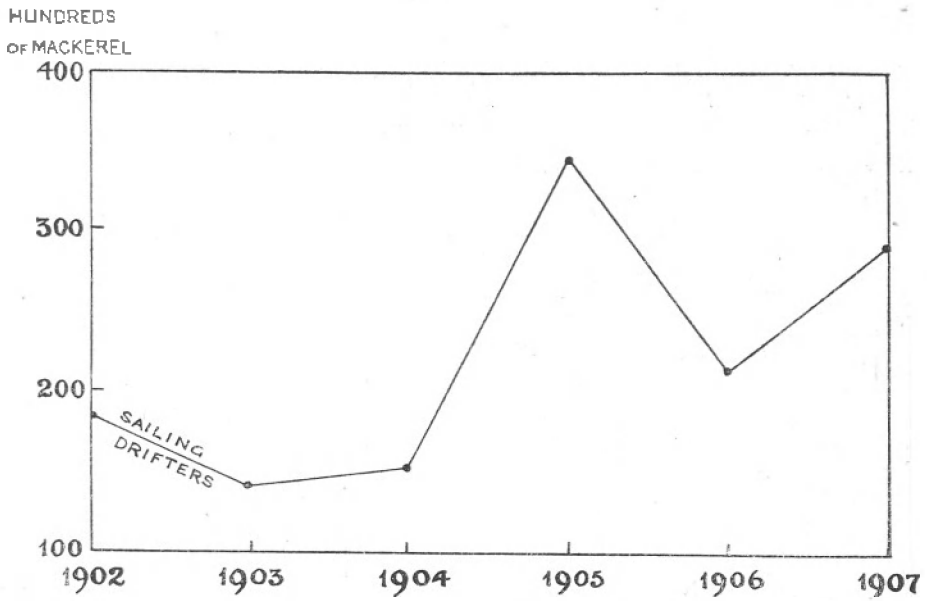

FIG. 3.—Curve indicating the average number of "hundreds" (120 fish) of mackerel per boat, landed at Newlyn and Milford, in the month of May of the years 1902–1907, by three sailing drifters belonging to Messrs. Peacock & Co., of Lowestoft.

Before leaving the question of sunshine it should be stated that curves representing the bright sunshine in the months of April and May have not shown any kind of correlation with the quantities of mackerel taken.

In order to ascertain whether the temperature of the water during the fishing months in the different years bore any relation to the takes of mackerel, and to meet the suggestion that the effect of the bright sunshine might have been simply to increase that temperature, a series of curves have been drawn showing the average temperature of the surface water in February, March, April, and May for each of the years 1902–1908 in the area between 48° and 50° North Latitude and 4° and 10° West Longitude. The temperatures given in Table VI., and

represented in Fig. 4, are the means of the six temperature averages given for this area on the Monthly Pilot Charts of the North Atlantic, issued by the Meteorological Office in London. For comparison with these, Table VII., and Fig. 5 give the mean temperatures at the surface and at 10 meters (5 fathoms) depth found at Stations E.5. and E.6. on the International Cruises carried out in May in each of the years 1903–8. It will be seen that the two curves follow the same general course. The outstanding feature of these temperature curves is the occurrence of two very marked maxima in 1903 and 1905. On

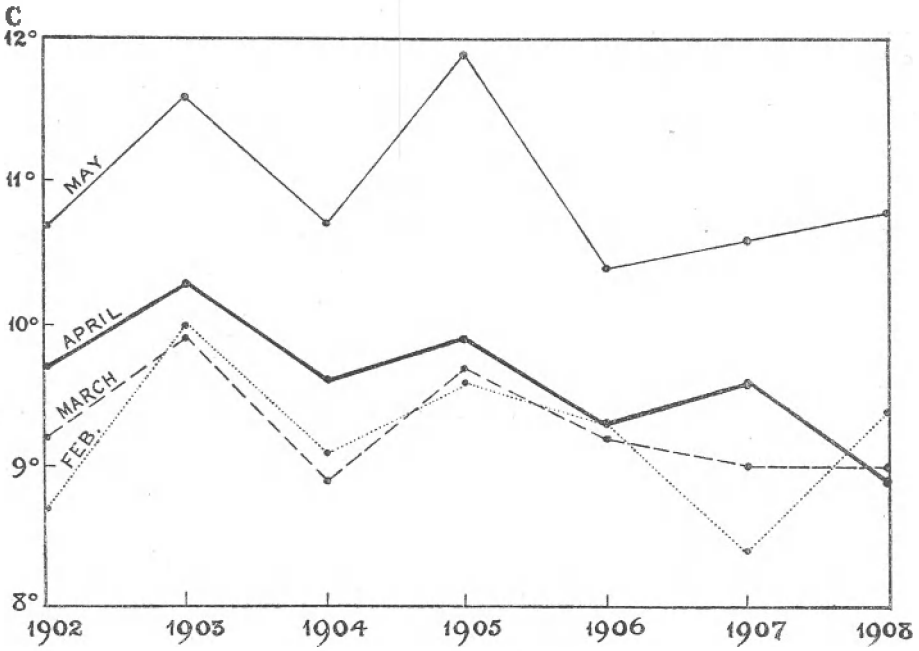

FIG. 4.—Curves showing the mean surface temperature of the sea in degrees Centigrade in the area between Lat. 48° and 52° N., and Long. 4° and 10° W., as given on the Monthly Pilot Charts of the Meteorological Office for the months of February, March, April, and May, in the years 1902–1908.

comparing the curves with the curves representing the catches of mackerel, either with that given by Messrs. Peacock's figures, or by the official figures, no relation between the two can be traced. Whilst the 1905 temperature maximum agrees with the maximum total catch of mackerel as shown by the official statistics and the high average catch shown by Messrs. Peacock's figures, the temperature maximum of 1903 is accompanied by low catches of mackerel. The other parts of the curves also give no indication of any close connection between the surface sea temperatures and the mackerel catches.

I have to thank Mr. G. E. Bullen for assistance in plotting the early curves which rendered the relation between sunshine and mackerel probable, though I am myself entirely responsible for the accuracy of the curves and figures as given in this paper. Mr. D. J. Matthews has also helped me in various ways.

My thanks are especially due to Messrs. Peacock & Co., of Lowestoft, for the very great trouble they have taken in supplying the figures showing the numbers of mackerel caught by their vessels and for allowing them to be used. Without their ready co-operation this paper could not have been written.

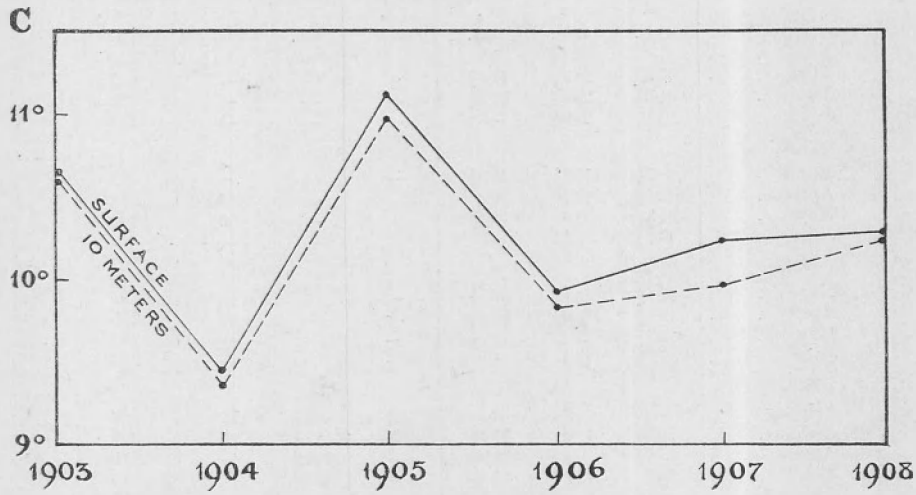

FIG. 5.—Curves showing the means of the temperatures, in degrees Centigrade, recorded at Stations E.5 and E.6 at the surface (continuous line) and at 10 meters (dotted line), on the International Investigation Cruises in the month of May, for the years 1903-1908.

TABLE I.

Table showing the number of "hundreds" of Mackerel landed by three STEAM DRIFTERS at Newlyn and Milford Haven for the years 1902–8, from figures supplied by Messrs. Peacock & Co., of Lowestoft.

	LANDED AT NEWLYN.			LANDED AT MILFORD.			Average Number of 'hundreds' per boat landed at Newlyn and Milford.
	Steam drifter A.	Steam drifter B.	Steam drifter C.	Steam drifter A.	Steam drifter B.	Steam drifter C.	
1902.	Hds.	Hds.	Hds.	Hds.	Hds.	Hds.	Hds.
March . .	—	222½	18	—	—	—	120
April . .	103¾	263¾	134½	—	—	—	201
May . .	490½	263	113½	—	—	—	289
June . .	287	289½	—	—	—	—	288
1903.							
March . .	247½	127¼	409¼	—	—	—	261
April . .	120¼	140¾	202	—	—	24½	162
May . .	328½	218	196½	—	—	60¾	268
June . .	117½	57½	47	—	—	—	74
1904.							
March . .	300¼	347½	237¼	—	—	—	295
April . .	111¾	216¾	313½	—	—	34	225
May . .	293¾	293	197½	—	—	—	261
June . .	277½	143	—	—	—	—	210
1905.							
February .	—	19½	—	96	49¼	12½	59
March . .	120½	182	374¼	98½	87¼	25	296
April . .	235¾	—	291¼	—	429¾	—	319
May . .	585	87	470¼	—	378¾	—	490
June . .	47½	—	—	—	—	—	47
1906.							
February .	—	—	—	4	—	—	—
March . .	27½	16	12½	4	111¾	12¼	61
April . .	110½	62	129¼	—	83½	—	125
May . .	269	767	708½	—	—	—	581
June . .	29	—	21	—	—	—	25
1907.							
March . .	160¼	9¼	48¼	—	32¼	—	83
April . .	105¼	320¼	105¼	—	4¼	—	178
May . .	457	869	584¾	—	—	—	637
June . .	—	—	—	—	—	—	—
1908.							
March . .	109½	66¼*	37†	—	—	—	71
April . .	363¾	266	326¾	—	—	—	319
May . .	418	616¾	237¾¶	—	—	—	517††
June . .	—	—	—	—	—	—	—

* Steam drifter B is not the same vessel in 1908 as in previous years.

† Commenced March 17th.

¶ Finished May 19th.

†† Average for vessels A and B.

TABLE II.

Table showing the number of "hundreds" of Mackerel landed by three SAILING DRIFTERS at Newlyn and Milford Haven for the years 1902–7, from figures supplied by Messrs. Peacock & Co., of Lowestoft.

	LANDED AT NEWLYN.			LANDED AT MILFORD.			Average Number of 'hundreds' per boat landed at Newlyn and Milford.
	Sailing drifter A.	Sailing drifter B.	Sailing drifter C.	Sailing drifter A.	Sailing drifter B.	Sailing drifter C.	
1902.	Hds.	Hds.	Hds.	Hds.	Hds.	Hds.	Hds.
March	1½	9	—	—	—	—	5
April	57¼	241	129½	—	—	—	144
May	—	150½	215½	—	—	—	183
June	—	—	113	—	—	—	113
1903.							
March	1½	53½	—	—	—	—	27
April	83¼	160	77½	—	—	—	107
May	93¼	—	123¼	—	202	—	139
June	88	57½	166¾	—	—	—	104
1904.							
March	—	31	10¾	—	594	—	318
April	19	—	47½	—	86	—	51
May	187	107	143½	—	35	—	157
June	113	81½	103¾	—	—	—	99
1905.							
March	—	—	162½	—	240	—	201
April	42¾	—	237¼	—	265¾	—	182
May	259¾	250	457¾	—	70	—	346
June	52½	—	—	—	—	—	52½
1906.							
March	19½	—	6½	—	12½	—	13
April	226¾	—	157¼	—	151	—	178
May	90	—	111½	—	443	—	215
June	—	10½	—	—	—	—	10½
1907.							
March	56¼	—	—	—	15½	—	36
April	240½	64	148¾	—	80½	—	178
May	—	58	260	—	266½	—	292
June	—	—	—	—	—	—	—

TABLE III.

Table showing the average number of hours of BRIGHT SUNSHINE recorded at the three Meteorological Stations, Plymouth, Falmouth, and Scilly, in January, February, and March of the years 1902–8.

1902.	January.	February.	March.	Average for February and March together.
Plymouth . .	45·6	92·5	108·4	
Falmouth . .	49·3	87·0	123·3	
Scilly . .	56·5	92·7	121·5	
Average .	50·4	90·7	117·7	208·4
1903.				
Plymouth . .	38·6	59·3	110·8	
Falmouth . .	55·3	63·3	126·7	
Scilly . .	71·5	50·2	129·6	
Average .	51·5	57·6	122·4	180·0
1904.				
Plymouth . .	42·0	52·1	121·5	
Falmouth . .	48·0	57·7	104·7	
Scilly . .	49·6	55·5	123·3	
Average .	46·5	55·1	116·5	171·6
1905.				
Plymouth . .	69·4	81·0	136·6	
Falmouth . .	65·1	88·0	137·7	
Scilly . .	61·7	81·9	146·3	
Average .	65·4	83·6	140·2	223·8
1906.				
Plymouth . .	66·9	96·2	142·9	
Falmouth . .	64·6	110·7	164·8	
Scilly . .	77·9	101·7	154·3	
Average .	69·8	102·9	154·0	256·9
1907.				
Plymouth . .	75	91	186	
Falmouth . .	74	76	178	
Scilly . .	66	69	186	
Average .	72	79	183	262
1908.				
Plymouth . .	72	67	147	
Falmouth . .	49	74	153	
Scilly . .	56	61	158	
Average .	59	67	153	220

TABLE IV.

Table showing the number of hundredweights of MACKEREL landed at Ports on the South and West Coasts of England and Wales in the month of MAY for the years 1886–1908, compiled from official statistics of the Board of Trade and Board of Agriculture and Fisheries.

Year.	*May. No of cwts. Mackerel.*	*Year.*	*May. No. of cwts. Mackerel.*
1886 ...	63,338	1898 ...	146,769
1887 ...	71,117	1899 ...	207,962
1888 ...	139,739	1900 ...	138,723
1889 ...	173,828	1901 ...	169,020
1890 ...	280,444	1902 ...	169,857
1891 ...	127,148	1903 ...	152,753
1892 ...	127,183	1904 ...	199,884
1893 ...	105,754	1905 ...	378,157
1894 ...	139,384	1906 ...	108,273
1895 ...	135,238	1907 ...	222,151
1896 ...	119,323	1908 ...	108,144
1897 ...	193,769		

TABLE V.

Table showing the Number of Hours of BRIGHT SUNSHINE recorded over *England S.W. and S. Wales* and *Ireland S.* for the first Quarter of the years 1886–1908. From the records of the Meteorological Office.

Year.	England S.W. and S. Wales. Hours.	Ireland S. Hours.	Mean. Hours.
1886	174	203	188
1887	314	309	312
1888	240	260	250
1889	227	243	235
1890	239	247	243
1891	300	300	300
1892	305	257	281
1893	285	244	264
1894	330	293	312
1895	292	260	276
1896	195	190	192
1897	215	237	226
1898	260	255	257
1899	304	286	295
1900	234	256	245
1901	240	238	239
1902	217	215	216
1903	205	201	203
1904	207	193	200
1905	272	268	270
1906	286	250	268
1907	315	256	286
1908	246	229	238

TABLE VI.

Table showing the average surface temperature in degrees Centigrade of the Area between 48° and 52° North Latitude and 4° and 10° West Longitude from February to May, as given on the Monthly Pilot Charts of the Meteorological Office. Each temperature given is the average of six means printed on the charts.

	1902.	1903.	1904.	1905.	1906.	1907.	1908.
February ...	8·7	10·0	9·1	9·6	9·3	8·4	9·4
March ...	9·2	9·9	8·9	9·7	9·2	9·0	9·0
April ...	9·7	10·3	9·6	9·9	9·3	9·6	8·9
May ...	10·7	11·6	10·7	11·9	10·4	10·6	10·8

TABLE VII.

MAY HYDROGRAPHIC CRUISES.

TEMPERATURES (C°) AT STATIONS E.5 AND E.6.

	Surface.			10 *meters.*		
	E.5.	**E.6.**	**Mean.**	**E.5.**	**E.6.**	**Mean.**
1903 . .	11·08	10·20	10·64	11·02	10·19	10·60
1904 . .	9·63	9·30	9·46	9·60	9·15	9·37
1905 . .	11·39	10·83	11·11	11·25	10·71	10·98
1906 . .	10·16	9·68	9·92	10·03	9·62	9·82
1907 . .	10·69	9·79*	10·24	10·63	9·33*	9·98
1908 . .	10·69	9·91	10·30	10·69	9·85	10·27

Station E.5 is situated in Lat. 49° 6′ N., Long. 6° 32′ W.; i.e. about 50 miles to the southward of the Scilly Isles.

Station E.6 is situated in Lat. 50° 24′ N., Long. 6° 5′ W.; i.e. about 30 miles to the northward of the Scilly Isles.

The Temperature records are taken from the *Bulletin des résultats acquis pendant les croisières periodiques.* 1902 onwards.

* Sta. E. 1907. V. 14. 50° 35′ N. Lat., 6° 14′ W. Long., 89 m., worked for E.6. (about 11 miles further north). Probable surface temp. at E.6. would be 0·4° lower.