REPORT ON THE

PHYSICAL CONDITIONS

IN THE

ENGLISH CHANNEL AND ADJACENT WATERS, 1906,

WITH A NOTE ON THE MEAN CONDITIONS FOR 1903–1909.

BY

DONALD J. MATTHEWS.

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ENGLISH CHANNEL AND ADJACENT WATERS, 1906, WITH A NOTE ON THE MEAN CONDITIONS FOR 1903-1909.

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INTRODUCTORY.

The hydrographic investigations in the English Channel were carried out during the year 1906 according to the programme of the previous year,* on board the Marine Biological Association's steamers *Oithona* and *Huxley*.

In addition to the observations made on the four quarterly cruises, surface samples were collected and temperatures recorded every fortnight on board four cross-channel steamers, and every week on five lightships.

As in previous years, the Nansen-Pettersson small model insulating water bottle was used, except on the three extra stations worked in August in the deep water of the Bay of Biscay, where the reversing water bottle and thermometer were employed.

The analyses of the water were made by Mohr's method against standard water supplied by the Central Laboratory at Christiania, and I take this opportunity of expressing my thanks to Mr. D. O. Mitchell for the care and accuracy with which he carried them out.

The observations on which this report is founded have already been published,† and are therefore not reprinted here.

It may be accepted as an axiom that for the purposes of fishery investigation it is not so much the mean hydrographic conditions as the deviations from this mean which are of primary importance, and this holds with special force in areas of which the fish fauna is fairly well known. The mean conditions have of course a bearing on such problems, and one would not expect to find a warm water fish in regions where the mean temperature is near freezing point; but it is only in comparatively unknown seas which have not been fished commercially that a knowledge of the mean conditions alone could be of much use, by suggesting, for instance, the possibility of fishing grounds hitherto untouched. In the British area, or at any rate in the English area, such conditions are not found. The kinds of fish present in sufficient quantity to make fishing a commercial possibility are a matter of common knowledge, and fishery investigation must be directed to determining the factors which influence the catch from year to year, to increasing this catch, and finally to furnishing, if possible, some forecast which will minimise the losses resulting from bad years, and enable those engaged in the industry to take advantage of a good year.

If the hydrographic conditions vary *irregularly* about a fixed mean and have done so for a long period of time, the fish population will have arrived at a state of equilibrium with this mean in the various regions, and in so far as it is affected by hydrographic conditions it will also vary irregularly about its own mean condition.

If on the other hand the hydrographic conditions undergo on the average a regular periodic change and have done so for a long period, we may suppose that the fish have reached a state of equilibrium with such periodic changes, and if abnormal deviations occur in the salinity or temperature or in the strength of the currents of the sea, they will

* Internat. Invest. Mar. Biol. Assoc. Report II., Part II. [Cd. 4641] 1904-1905. Matthews, Physical Conditions in the English Channel, &c., 1904 and 1905.

† Cons. Perm. Internat. pour l'Explor. de la Mer: Bulletin Trimestriel, année 1905-1906, Nos. 3 and 4, année 1906-1907, Nos. 1 and 2.

be affected abnormally only by such deviations, just as the land flora follows the course of the seasons every year, and is affected by abnormal spells of high or low temperature, of drought or of heavy rain.

We know that there is a regular seasonal variation in the temperature of the sea, and in the movements and conditions (*e.g.* spawning) of some fish ; and if we wish to look for any connection between the two we must not consider the deviations from the mean temperature of the year, but rather the deviations from the mean temperature for each period of the year.

With regard to salinity the problem is more complex. If there is a regular seasonal change here also, and the fish are affected by the changes in the salinity, or, more probably by other factors such as food supply which may change with the salinity or be influenced by it, then we must fix our attention on the deviations from the weekly or monthly mean salinity ; and if superimposed on the seasonal change there are also changes of longer period which affect but do not obliterate the seasonal change we must endeavour to trace these also. The difficulty increases rapidly with the length of the period because changes which require years for their completion demand a great increase of the length of time over which regular observations must be carried out.

The question then arises, is the salinity subject to any periodic change ? Such changes with a period of one year have been clearly demonstrated in other regions, and the author of the present paper considers that he will be able to prove beyond dispute that a similar change takes place in the whole of the water of the English Channel on the surface, and at all depths in the part lying to the eastward of Start Point, and that it is also probable that there is superimposed on this yearly change another change which is completed every two years, though of course the evidence for this has less than half the weight of that for the yearly change. There also seem to be signs of a much slower change with a period of perhaps twelve years, but this would require investigations carried on for at least fifty years more for its elucidation. So far the only evidence for it is in a fairly regular fall in the salinity of the western part of the English Channel from the beginning of the international investigations in 1903 up to the date of the present paper (November, 1909). More complete analysis of the curves may show that this long period variation is really composed of others of very different lengths.

If we consider the bottom waters of the western area as a whole, the evidence in favour of a yearly period is unconvincing, and there is so little difference between the means for the various months that it does not matter greatly whether we take as a basis of comparison the average for corresponding cruises or for the whole year. On the other hand the variations from time to time are often considerable, and it is extremely probable that further investigations would show that the salinity here also changes according to definite laws. The problem is one of considerable importance, because the bulk of the oceanic water in the English Channel is probably derived from this source ; the high salinity surface water which is sometimes found near Parsons Bank is confined to a very thin layer and appears to be too small in quantity to have any great influence on the general conditions.

Assuming then that there are regular periodic changes in temperature and in the salinity, it is clear that we ought to compare the conditions at any one epoch with the mean for the same epoch. In the case of changes which are completed in one year we compare the salinity or temperature with the means for the same date ; when the longer periods are considered, we take the mean for the corresponding phase.

The question then arises, what are the mean values for the various epochs. Knudsen has published a series of charts and sections of the mean conditions, and in the case of the temperature he gives the average values for the times of the four quarterly cruises. These averages are all that is required for the purpose, and only suffer from the disadvantage of having been founded on a comparatively short period. For salinity, however, he only gives a mean of the whole year, and this is clearly insufficient for the present purpose.

The author has in preparation a series of charts and sections showing the mean salinities, as far as possible, for every month in the year, and also for the "odd" and "even" years. The calculations are not yet complete, as it is intended to include all observations up to the end of 1909, but the following description of the chief points brought out will be of assistance in the discussion of the conditions during 1906.

THE MEAN CONDITIONS.

According to the programme arranged in 1903 the western boundary of the English hydrographic investigations was a line drawn north and south in about $6\frac{1}{2}^{\circ}$ W. longitude from the western side of the Scilly Islands to Parsons Bank, and though the cruises have

been extended of late years, it is only within the narrower limits that we have as yet sufficient observations to make it possible to draw reliable charts of the average distribution of temperature and salinity.

From the point of view of physical oceanography this area is divided naturally into two parts by a line drawn from Start Point to Guernsey. To the westward there is a broad and unbroken stretch of relatively deep water, at least half of which shows soundings of fifty fathoms and upwards, and if we except the coastal shallows the depths are not less than thirty-six fathoms. The eastern part is more irregular ; the soundings are less, and fall to twenty-five fathoms near the Straits of Dover, and this progressive decrease in the depth, combined with the influence of the constriction between the Isle of Wight and the Cotentin Peninsula, gives rise to much swifter tidal movements than are found to the westward.

The observations made in the English Channel fall into two series. We have in the first place the investigations of the four quarterly cruises of February, May, August and November, which are made at all depths and under the most favourable conditions for accuracy over the whole of the English Channel ; and secondly, observations made regularly every fortnight since June, 1904, on board four cross-channel steamers in what may be called for convenience the " Central Area," between lines drawn from Start Point to Guernsey and thence to St. Brieuc, and from Newhaven to the mouth of the Seine. These latter observations are necessarily confined to the surface, and it might be supposed that for various reasons they would not be so reliable as those made on the special research steamers. The quarterly cruises have shown however that, at least at the times at which the latter are made, the tidal mixing of this central area is so complete that the water is nearly always of the same salinity at all depths, so that we are justified in considering that surface observations are all that is required here ; and the general regularity of the curves drawn from the analyses of the samples collected on the cross-channel steamers speaks well for their accuracy. Remarkable variations of course occur at times, but similar irregularities, on a somewhat smaller scale, have been found occasionally on the cruises, and it has been thought best under the circumstances to use all the material available, while drawing attention to any doubtful points.

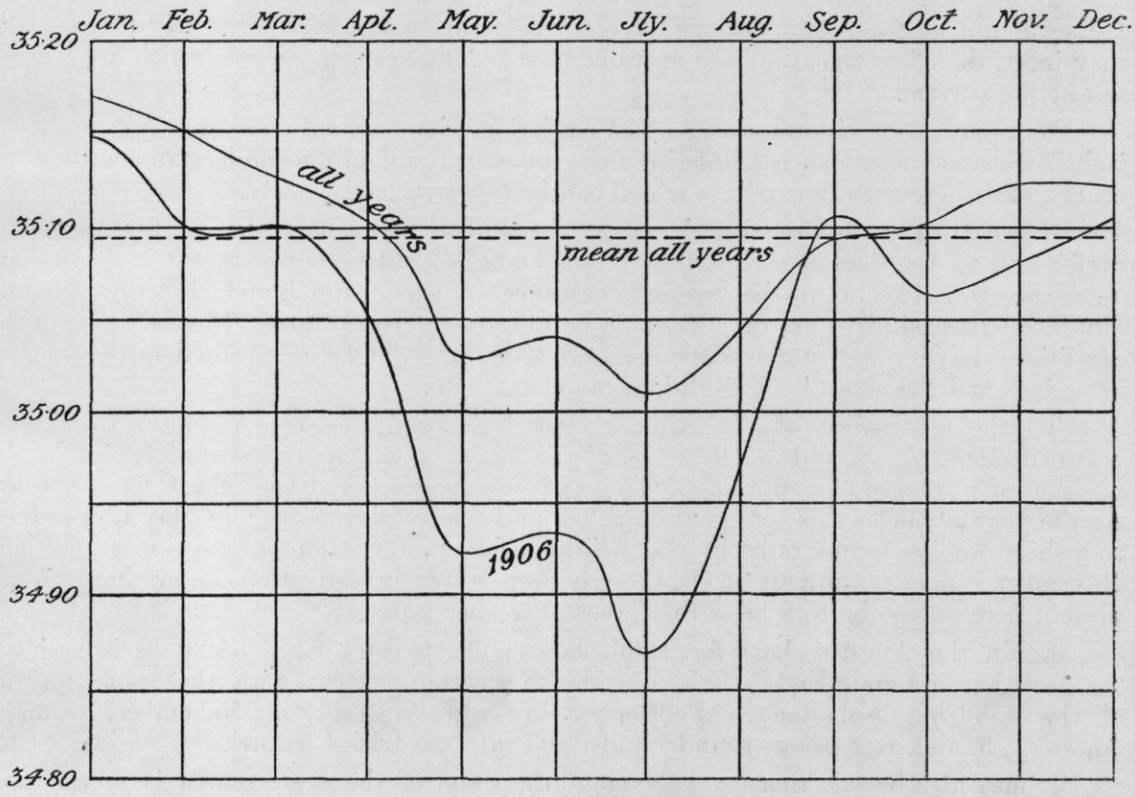

FIG. 1.—Curves of monthly salinities in the Central area. The curve marked " all years " is the mean of all observations made on the four cross-channel steamers from October, 1903, to September, 1909. The horizontal broken line marked " mean " is the mean of all observations irrespective of date.

Finally there are the observations made at the East Goodwin, Varne and Seven Stones Lightships. These are somewhat less useful than the others and show very irregular changes. The explanation is not far to seek ; the salter stream which is found in the central line of the channel not only advances and retreats in an approximately east and west direction, but also oscillates from side to side of the central line, and so it

happens that a slight retreat from the shore may give the appearance of falling salinities when as a matter of fact the salter water is actually pushing further eastwards.

It will be seen from what has been said above that our knowledge is most complete in the central area, and it is summarised in the curve marked "all years" in Fig. 1. This curve shows the average monthly value of the salinities of all the samples collected on board the four cross-channel steamers from June, 1904, to September, 1909, with the exception of a few taken so close to the mouth of the Seine as to be unduly influenced by river water. There is a well marked change during the course of the year; the salinities are at a maximum in January, and fall regularly, if we neglect a slight check in June, to a minimum in July, and then increase again to the end of the year, and as has been pointed out, we may assume that this change extends to all depths. The difference between the highest and lowest values is about $0{\cdot}16°/_{oo}$.

In the western area we have only the observations made at the times of the four quarterly cruises and at the Seven Stones Lightship. It is therefore somewhat difficult to express the changes by means of curves, and the charts of average salinity are not yet complete.

There are three lines on which surface salinities have been observed at ten mile intervals on every cruise, *i.e.*, from Plymouth to Ushant, from Ushant to Parsons Bank, and from Parsons Bank to Station 5.* If we treat these as representing or rather varying proportionately to the surface salinity of the western area, as has been done in the case of the fortnightly observations in the central area, we find that the highest values occur on the average in February and the lowest in August, and that the range is about $0{\cdot}07°/_{oo}$, or less than half that of the central area. There appears to be no doubt that here also there is a yearly period in the salinity of the surface, but it is not possible to say that the minimum falls in August; it may occur in July as in the central area, and the same doubt arises as to the date of the maximum.

It has already been mentioned that on the basis of the six stations in the western area the *mean* bottom salinity hardly varies throughout the year though, at any one time, there may be and often are large deviations from this mean. We can hardly attribute this to the small number of observations, since the surface salinities, calculated from the values found at these six stations, do show a slight though distinct yearly period. We may infer, therefore, that the bottom water here is influenced by factors which are scarcely felt at the surface.

We may also discuss the surface variations in the western area by means of isohalines, and though such a description is somewhat difficult to understand without the charts, still there are a few points which can be followed fairly easily.

If we turn to any of the charts at the end of this report, the one for August for preference, we see that, as a rule, the various bodies of water are drawn out in an east and west direction, except at the western entrance to the channel, and that the isohalines (lines of equal salinity) are on the whole parallel to the coast lines. Charts of the mean conditions have roughly the same general appearance, and the parallelism between the isohalines and the shore is, if anything, more complete.

To the south-west of the August chart there will be seen a tongue of water of between $35{\cdot}30°/_{oo}$ *S.* and $35{\cdot}40°/_{oo}$ *S.*; this may be taken as a rough guide to the position of a tongue of water of $35{\cdot}4°/_{oo}$ *S.*† in the *mean* surface chart for February. As the year advances this tongue diminishes and finally disappears; in May it is reduced to a short wedge found only in the neighbourhood of Station 4, and in August and November it does not appear at all, though deep water investigations show that it is still present here on the bottom beneath a layer of fresher water.

Again the August chart for 1906 shows a sharp bend in the $35{\cdot}20°/_{oo}$ isohaline in the direction of Lands End. This coincides to a certain extent with the *mean* position of the $35{\cdot}30°/_{oo}$ isohaline in February, May and August; in November, water of $35.30°/_{oo}$ *S.* and over passes round Lands End into the Irish Channel.

It may also be said that on the average the water of the western area is of the same composition from surface to bottom in February and May; in August and November it is divided into layers of different salinity, and it is only the upper and fresher layer which shows a well marked seasonal change.

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* The positions of these points can be found in the larger charts at the end of this report.

† $35{\cdot}4$ $°/_{oo}$, giving only one decimal place, is to be understood as including all values from $35{\cdot}40$ $°/_{oo}$ to $35{\cdot}49$ $°/_{oo}$; and so with other figures.

THE CONDITIONS DURING THE YEAR 1906.

The curves of Fig. 1 give a general idea of the course of the changes in the central area considered as a whole. The salinity was below the general mean during the larger part of the year, and the average defect for the whole of the period was about 0·054 $^{\circ}/_{\circ\circ}$; it was also below the monthly mean at all times except in September. The yearly period was well marked, with a maximum in January and an abnormally low minimum in July.

The surface salinity of the western area does not lend itself readily to such treatment, but we can get a general idea of the conditions by comparing the surface observations on the line from Plymouth to Ushant, Parsons Bank and Station 5. The average value on this track irrespective of year or month, is 35·331$^{\circ}/_{\circ\circ}$, and the figures in the accompanying table show that in 1906 there was a defect in August only and that the maximum occurred in May.

Average for all cruises and years ...	35·331	35·331	35·331	35·331
	February	May	August	November
1906	35·363	35·371	35·309	35·339
	+0·032	+0·040	−0·022	+0·008

Comparing the figures for the four cruises with the corresponding means for the same months,

	February	May	August	November
Mean salinity in	35·370	35·331	35·299	35·326
1906	35·363	35·371	35·309	35·339
	−0·007	+0·040	+0·010	+0·013

we find that the salinities were nearly normal except in May, when they were somewhat above the monthly mean, so that the maximum occurred in that month instead of in February. If we compare the mean salinity for the whole of 1906 with the mean of all the years we find that there was an excess of 0·014$^{\circ}/_{\circ\circ}$.

The mean *bottom* salinity of the western area, calculated from the observations on stations only, is 35·327$^{\circ}/_{\circ\circ}$, the corresponding value for 1906 was 35·344$^{\circ}/_{\circ\circ}$, showing an excess of 0·017$^{\circ}/_{\circ\circ}$, about equal to that found at the surface.

Comparing the separate cruises with the general mean, one sees that there was a defect in February only, and that the excess was greatest in May.

Average of all years and months ...	35·327	35·327	35·327	35·327
	February	May	August	November
1906	35·308	35·370	35·347	35·352
	−0·019	+0·043	+0·020	+0·025

The values for 1906 were alternately high and low, and there seems to be no regular change.

If one uses the mean bottom salinities for each of the four months as a basis of comparison

	February	May	August	November
Mean for all years	35·345	35·329	35·318	35·315
1906	35·308	35·370	35·347	35·352
	−0·037	+0·041	+0·029	+0·037

we again find a defect in February, but there is still no regular change or distribution of excess and defect such as was found in the central area, and for the present all we can say is that the observations at present available are insufficient for such a method of treatment.

In *January* the observations were confined to the surface of the central area, where the salinity was at its maximum for the year, and a fairly extensive body of water of $35{\cdot}4^{\circ}/_{\circ\circ}$ *S.* is shown on the chart off Start Point. The average salinity of the whole area was above the annual mean, but less than that for the month.

The *February* cruise showed that the general distribution of salinity agreed fairly well with monthly mean, the chief points of difference shown on the surface chart being the break in the $35{\cdot}3^{\circ}/_{\circ\circ}$ water southward of Start Point and its northerly extension past Lands End, combined with an unusually strong southerly flow of lower salinity to the westward of the meridian of the Scilly Isles.

If we compute the average surface salinity we see that in the central area it had fallen since January, and now agreed almost exactly with the annual mean, but was about $0{\cdot}05^{\circ}/_{\circ\circ}$ lower than the mean for the corresponding monthly period. In the western area the surface salinity was both actually and relatively higher, even if we neglect the north western part of it, and showed an excess of $0{\cdot}032^{\circ}/_{\circ\circ}$ over the annual mean and a defect of only $0{\cdot}007^{\circ}/_{\circ\circ}$ when compared with the average for the month.

As is normally the case in February, the isohalines were generally vertical, if we neglect the thin surface layers at Stations 5 and 2. If we calculate the bottom salinity in the western area from the bottom samples at the six stations we find that it fell short of the annual and monthly means by $0{\cdot}019^{\circ}/_{\circ\circ}$ and $0{\cdot}037^{\circ}/_{\circ\circ}$ respectively. Such calculations are never satisfactory when founded on a small number of observations, and in the present instance are probably misleading ; for we find that the average surface salinity at these stations was $35{\cdot}325^{\circ}/_{\circ\circ}$, exactly equal to the yearly mean and $0{\cdot}047^{\circ}/_{\circ\circ}$ less than the mean for the month. The mean of all the surface observations at ten mile intervals on the runs between Plymouth and Station 5 showed an excess over the annual mean of $0{\cdot}032^{\circ}/_{\circ\circ}$, and on account of their much larger number they are more reliable. If we increase the bottom salinity by this amount we get an excess over the annual mean of $0{\cdot}013^{\circ}/_{\circ\circ}$, and a defect of only $0{\cdot}005^{\circ}/_{\circ\circ}$ from the monthly value. We are probably justified in doing so because the $35{\cdot}4^{\circ}/_{\circ\circ}$ surface water was present in about normal quantity, but was so distributed as to avoid the stations almost entirely. On the whole, we may say that the water was below the average salinity for the month everywhere, but only very slightly so in the western area, while it was equal to the annual mean in the central area and above it to the westward.

For *March* and *April* there are only the observations of the cross-channel steamers. In March a break appeared in the $35{\cdot}3^{\circ}/_{\circ\circ}$ water to the north-west of the Cotentin Peninsula, and became more pronounced in the following month ; the curve shows no fall from March to April, and the change must have been due at first to mixing only, but later to dilution also. In both months the salinity was lower than the average for the corresponding epochs, but a defect from the annual mean occurred in April only.

At the time of the *May* cruise the salinity of the central area was very low, though it had not yet reached its minimum. Water of $35{\cdot}3^{\circ}/_{\circ\circ}$ *S.* was no longer found eastward of Start Point, and the isohalines of $35{\cdot}20^{\circ}/_{\circ\circ}$ and $35{\cdot}10^{\circ}/_{\circ\circ}$ were broken to the southward of the Isle of Wight, while the salinity of the area, as a whole, was much less than the average either for the year or for the month.

In the western area the conditions were entirely different, and the chart shows abnormally high salinity. The $35{\cdot}30^{\circ}/_{\circ\circ}$ isohaline passed far to the northward of its mean position round Lands End, and the area enclosed by that for $35{\cdot}40^{\circ}/_{\circ\circ}$ was greater than normally is the case in May ; and finally to the extreme south-west was found an area of water with a salinity as high as $35{\cdot}5^{\circ}/_{\circ\circ}$ which does not appear on any of the charts of mean conditions.

On the lines from Plymouth to Station 5 the surface salinity, calculated from the observations made at intervals of ten miles, was higher than the mean for either the year or the month by $0{\cdot}40^{\circ}/_{\circ\circ}$, and the average bottom salinity showed an excess of almost exactly the same amount over the corresponding monthly and yearly values.

The sections show that the isohalines were still approximately vertical except between Plymouth and Ushant ; near the latter position the difference between surface and bottom was as much as $0{\cdot}13^{\circ}/_{\circ\circ}$, a decidedly unusual condition to find in an area of such strong tidal mixing.

The difference between the general characters of the distribution in the two areas which showed itself in February was accentuated in May. In the central area the defect from the monthly mean had increased, while the almost negligible deficiency of the western area had been replaced by a decided excess.

In *June* the salinity of the central area was very slightly higher than in May ; the chart shows a rather unusual condition, even for the time of the minimum, with no water as high as $35{\cdot}00^{\circ}/_{\circ\circ}$ between Newhaven and the mouth of the Seine.

July was the month of lowest salinities for the year, in the central area at any rate, where there was a defect of about 0·14°/$_{oo}$ below the average July value and as much as 0·22°/$_{oo}$ below the yearly mean.

In *August* the salinity of the central area showed a considerable rise though it was still much less than the monthly or yearly averages. The salinity of the western area was lower now than at the times of the other cruises, but the date of the actual minimum is uncertain. The observations made at the Seven Stones Lightship put it in this month, but owing to their position the evidence is inconclusive.

The chart shows a considerable change since May. The isohaline for 35·30°/$_{oo}$ had been driven westwards and southwards by an increased southerly current from the Irish Channel, and water of 35·4°/$_{oo}$ was found at two positions only, on the surface, where it probably formed a thin layer not extending to any depth. In spite of this the salinity on the lines between Plymouth and Station 5 was still slightly above the average for the month, but it is unfortunately impossible to include in the calculation the area where the change was most marked as the course followed here has been altered from time to time. Compared with the annual mean there was a defect of 0·022°/$_{oo}$. The water of 35·5°/$_{oo}$ shown on the chart lies outside the usual area of investigation and will be discussed later.

The sections show that the water in the western area was divided into layers of varying composition as is normally the case during the latter half of the year and particularly at the time of the August cruise. The average salinity on the bottom at the six stations was higher than the monthly and yearly means by 0·029°/$_{oo}$ and 0·020°/$_{oo}$ respectively.

The transverse section from Station 4 to Station 6 presents several points of interest. Water of 35·4°/$_{oo}$ was still present at Station 4, but was now confined to the lower layers. The surface salinities at Stations 5 and 6 were unusually low owing to the influence of the Irish Channel, and at Station 5 the highest values were found between the depths of 20 and 40 metres, an arrangement which appears to be normal.

In *September* the salinity of the central area underwent a sudden increase and was slightly above the monthly and yearly averages. The cause of this change is doubtful and the abnormally high value (35·88°/$_{oo}$) found at one position on the Southampton—St. Malo line might be considered as pointing to some inaccuracy ; but on the other hand the average salinity on the line from Newhaven to Caen also showed a sudden rise.

There is another consideration which tends to confirm the general accuracy of the curve. As has been mentioned already and will be explained more fully later, there appear to be two distinct types of annual change in the central area, which occur in alternate years. The curves of Fig. 3 show that the general course of the changes during 1906 followed the type of the "even" years to which it belongs with remarkable fidelity, but with decidedly lower values, until August, when the two curves almost coincide. In September the curve for 1906 was above the monthly mean, but in October it returned to the "even" year curve and followed it for the rest of the year, but now on the side of excess. One might imagine in fact that the changes had followed the "even" year type throughout, but that a sudden increase in the salinity had spread quickly over the whole of the surface of the Channel and had brought the curve permanently from the side of defect to that of excess.

In *October** the salinity of the central area was lower than in September, but in other respects it showed the general autumn rise, and water of 35·3°/$_{oo}$ *S.* is marked on the chart between Start Point and the Channel Islands. The average was still below the monthly and yearly means.

At the time of the *November* cruise the salinity had nearly reached the mean value in the central area, but it was still somewhat low for the time of the year.

In the western area the surface salinities were abnormally high for this month. The chart shows a considerable area of 35·4°/$_{oo}$ water, which on the average is not found now on the surface, and 35·3°/$_{oo}$ water again passed round Lands End. Between Plymouth and Station 5 there was an excess of 0·008°/$_{oo}$ over the yearly average and of 0·013°/$_{oo}$ over that for the month. Unfortunately this high salinity water was not found on any of the stations and there is some doubt as to how it should be represented in the sections. The author has taken the view that it was continuous to the bottom in most places, spreading out somewhat on the surface near its edges, a view which is confirmed to a certain extent by the average bottom salinity at the stations, which was 0·037°/$_{oo}$ above the monthly values, and 0·025°/$_{oo}$ above that for the year.

The sections show that the western water was still divided into layers of varying salinity at Stations 4 and 5, but not at 6 and 7 as in August.

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* The charts for October and December have been accidently misplaced on Plate 4.

Finally in *December* the salinity of the central area rose to above the yearly mean value, though it still fell short of the average for the month. The chart shows the presence of the isohaline of 35·40°/$_{oo}$ for the first time since December 1905, if we neglect the abnormal conditions of September.

TEMPERATURE.

The author's calculation of the mean temperatures in the depths has been completed up to May, 1909, but the surface charts are not yet ready, and for purposes of comparison it will therefore be necessary to use Knudsen's surface values, founded in the shorter period from February, 1903, to May, 1906.

The surface temperatures in the central area observed by the cross-channel steamers do not appear to be so reliable as the salinities, and the following discussion will therefore be confined to the months of the four quarterly cruises.

February.—In February the temperatures were the same or nearly so at all depths on any station, and were normally distributed in that the coldest water was found under the shores and in the eastern part of the Channel. They were decidedly lower than the mean for the month and ranged from 10° C. down to less than 6° C. ; according to Knudsen's charts the mean only falls below 7° in the coastal waters of northeastern France. The chief defect from the mean was in the area of water of 10° C., which was found only in the neighbourhood of Station 4 instead of reaching the meridian of Ushant.

The following table gives the mean bottom temperatures for the month on the western stations, calculated on seven years' observations, and those observed in 1906.

Bottom Temperatures for February.

——	Station 4.	Station 5.	Station 7.	Station 6.
	C.°	C.°	C.°	C.°
Mean of seven years	10·20	9·64	9·15	8·89
1906	10·07	9·19	8·70	8·45
	−0·13	−0·45	−0·45	−0·44

May.—In May the surface temperatures were again below the normal. Water of a temperature as high as 11° C. was only found as a thin surface layer round Station 7 south of Lands End ; Knudsen draws the 11° C. isotherm in the neighbourhood of Ushant. The 10° C. isotherm ran northwards from Ushant towards the English coast and then turned northwestward with the 35·3°/$_{oo}$ water into the Irish Channel. That for 9° C. followed an irregular north and south course from Start Point, and coincided roughly with Knudsen's 10° C. line. To the eastward the temperature was between 8° C. and 9° C., about 1° below the mean.

Bottom Temperatures for May.

——	Station 4.	Station 5.	Station 7.	Station 6.
	C.°	C.°	C.°	C.°
Mean of seven years	10·30	9·81	9·78	9·55
1906	10·28	9·53	9·57	9·32
	−0·02	−0·28	−0·21	−0·23

The western bottom temperatures were still below the mean, but less so than in February, and the isotherms were nearly vertical, though the surface layer showed some signs of seasonal warming.

August.—In this month the temperature distribution undergoes a complete change in comparison with the two previous cruises of February and May. The surface water is strongly heated by the sun, and this heating reaches progressively greater depths as the water becomes shallower and the tidal mixing stronger. The general course of the isotherms tends to become horizontal.

The warmest water, 18° C. and over, was found stretching northeastward on the surface from Station 4. It was surrounded by a broad band of water of between 17° and 18° C., and outside this by narrow bands of water with temperatures down to less than 16° C. In the central and eastern areas the temperatures lay in the reverse order; under the English coast they were above 16° C. and fell to less than 15° C. in the central line of the Channel. The surface chart shows two minor points of interest; one is the sharpness of the dividing line between the hot and cold currents westward of Ushant, where the temperature changes by 4° in the course of a few miles; the other the peculiar kink in the 17° C. line in the neighbourhood of Station 2, where it follows the isohaline of $35{\cdot}30°/_{\infty}S$.

A comparison with Knudsen's charts shows that the surface temperature was above the mean in the western part of the Channel and below it in the eastern part.

The sections show that on the western stations the seasonal heating had little influence below 30 metres, at which depth or near it, there was a sudden change. Following the longitudinal section from Station 5 eastwards to Stations 2 and 19 we see the isotherms dipping to the bottom as the effect of the sun's rays penetrates more deeply into the shallower and more quickly moving waters. Eastwards of Station 19 the mixing was so complete that only the surface could be heated to a temperature appreciably above that of the bottom.

In the transverse western section, from Station 4 to Station 6, the conditions were similar and the isotherms were nearly horizontal, with the exception of that for 10° C., which followed the course of the low salinity current entering on the bottom from the Irish Channel.

BOTTOM TEMPERATURES FOR AUGUST.

——	Station 4.	Station 5.	Station 7.	Station 6.
	C.°	C.°	C.°	C.°
Mean of six years	10·72	10·16	11·83	11·59
1906	10·56	9·85	10·91	10·53
	−0·16	−0·31	−0·92	−1·06

The western temperatures were therefore slightly below the mean on the bottom in the southern half of the Channel and about 1° below it in the neighbourhood of the southwest coast of England.

November.—The surface temperatures in November were distributed in a somewhat peculiar way, which showed the broad features of Knudsen's mean chart. Between Start Point and the Cotentin peninsula lay an area of water with a temperature above 13° C., which was surrounded on all sides by slightly cooler water. The lowest temperature recorded was above 11° C. so that the total range was very small.

The temperatures were now fairly uniform from surface to bottom except at Stations 4 and 5, where the deviation of the isotherms from the vertical still showed some trace of the summer conditions. On Station 5 the 11° C. isotherm followed the course of the 10° C. isotherm for August.

BOTTOM TEMPERATURES FOR NOVEMBER.

——	Station 4.	Station 5.	Station 7.	Station 6.
	C.°	C.°	C.°	C.°
Mean of six years	11·84	10·78	12·45	12·47
1906	11·32	10·38	12·34	12·52
	− 0·52	− 0·40	− 0·11	+ 0·05

The bottom temperatures were still below the mean on the western stations except Station 6, but no defects approaching those of August were recorded.

DEEP WATER INVESTIGATIONS.

After the completion of the August cruise the *Huxley* made a five days trawling and dredging cruise along the edge of the deep water in the neighbourhood of La

Chappelle Bank. She was not at that time fitted with gear suitable for hydrographic work in such great depths, and it was not possible to work more than three stations or to make many observations on them. The observations are not sufficient to enable one to draw a section.

The only point of particular interest brought out was the salinity and temperature on Station C, in 820 metres (448 fathoms). The salinity rose steadily from the surface downwards and reached 35·62°/$_{oo}$ on the bottom, in the stratum which is generally supposed to have its source in the Mediterranean. The temperature, 16·10° C., was so high as to be open to grave doubt though it was perhaps not quite impossible considering the origin of the water. Similar abnormally high readings have been made since, in May and November 1909, at the same position and depth. On the two first occasions a single Richter reversing thermometer was used ; in November 1909, this was supplemented by a Negretti and Zambra reversing thermometer which showed a perfectly regular rise from bottom to surface, and it is therefore almost certain that the high readings were due to an error. The Richter instrument was only used for great depths, and accordingly very few opportunities had offered for testing its accuracy. When comparative readings had been made with it and with the Nansen-Pettersson insulating waterbottle it had always given excellent results, and it is possible that its failure in the deep water may have been due in some way to pressure.

THE TWO YEAR PERIOD.

Reference has been made in this paper and also in the report on the investigations of 1904 and 1905 to a two year period in the English Channel. This will be fully discussed in a later report on the general results of the hydrographic work during the years 1903 to 1909, which is now in preparation, but a few words on the question may not be out of place here.

The curves below, (Fig. 2) give the mean monthly salinities of the central area in the "odd" years 1903 (October to December only), 1905, 1907, and January to September 1909, in the "even" years 1904, 1906 and 1908, and also the mean of all years from 1903 onwards to September 1909.*

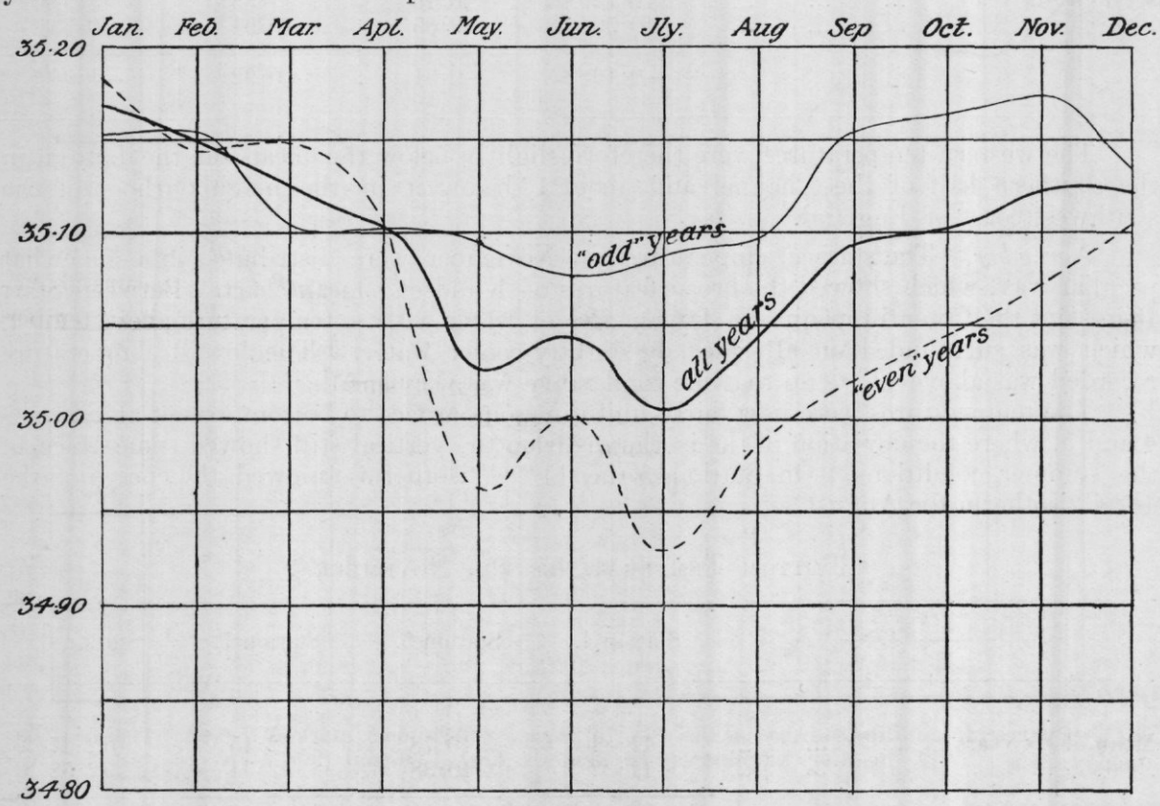

FIG. 2.—Curves of monthly salinities in the Central Area. Heavy curve : the mean of the observations made in all years from October 1903 to September 1909. Light curve : mean of the observations made in 1903, 1905, 1907 and 1909—"odd" years. Broken curve : mean of the observations made in 1904, 1906 and 1908—"even" years.

* The terms "odd" and "even" have been used for convenience, but it will probably be better to use the expressions "low range" and "high range." It is extremely probable that unperiodic changes, or changes of very long period, may give rise at times to accelerations or retardations which would result in the "even" years taking on the characteristics which in this paper have been described as belonging to an "odd" year. It is possible that such a change took place in the abnormal period 1902–1903.

The observations of 1903 have little effect on the result as there were only a small number of them. It is probable that they would have shown wide deviations from the curves, as 1903 was abnormal over the whole of the northern European area.

Neglecting the observations of 1903, we find that since then there have been alternately years of high and low range of salinity. In the "even" years there is a well marked maximum in January, a rapid fall from March to May, a slight rise in June and then a slower fall to a definite minimum in July, followed by a nearly uniform rise to the end of the year. The salinities are below the "all years" monthly mean except at the January maximum and in March.

The "odd" years show a lower and less definite maximum in January and February and also in November. The minimum is in June, but there is so little change that it might almost be said to last from May to August. The salinity is above the monthly mean except in January and March.

The mean range in all years is $0{\cdot}16^{\circ}/_{\circ\circ}$, in the "odd" years $0{\cdot}08^{\circ}/_{\circ\circ}$, and in the "even" years $0{\cdot}25^{\circ}/_{\circ\circ}$, three times that of an "odd" year.

In the western area it is not possible to show the difference by means of curves, as we have here only four sets of observations in each year. On the whole it seems probable that in the "odd" years the current of high salinity water from the Bay of Biscay sets in somewhat earlier than in the "even" years, and extends further up Channel. This appears particularly in the course of the $35{\cdot}40^{\circ}/_{\circ\circ}$ isohaline. In the "odd" years, in February, it encloses an island of high salinity, covering Stations 2 and 19, but cut off from the west by fresher water. In the "even" years it takes the form of a broad-based wedge which does not reach even Station 2. The subject will be treated more fully in the report on the general results of the investigations.

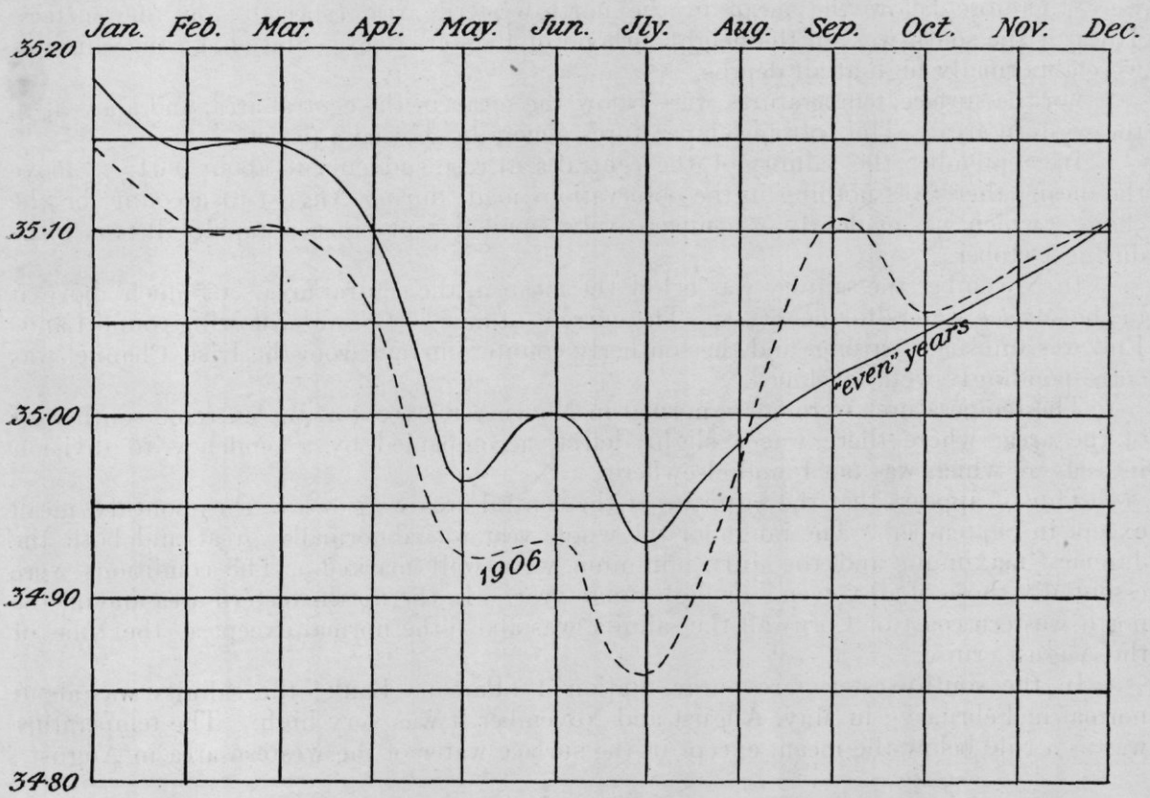

FIG. 3.—Curves of monthly salinity in the Central Area. The curve marked "even" years is the mean of the observations made in 1904, 1906 and 1908.

In Fig. 3* we have the central area curve for 1906 and for the mean of the "even" years. The agreement is remarkably good as to the general shape of the curve except in the month of September (see page). Before September the salinities of 1906 were below the "even" year mean, and slightly above it afterwards.

In the western area the conditions at the beginning of the year also approximated more nearly to the "even" type than to that of an "odd" year.

* There is a slight error in the broken curve in July and October. Compare Fig. 1.

SUMMARY.

During the first half of the year 1906 the water was of approximately the same salinity and temperature from surface to bottom.

At the beginning of the year the salinities in the Central Area were somewhat below the average ; in the western area they were nearly normal except in the north-western region, north and south of the Scilly Isles and Lands End. The current of water flowing from the English Channel round Lands End was of higher salinity than usual, and was accompanied by, and probably connected with an abnormal southerly set of low salinity from the Irish Channel.

The temperatures were below the average in February both at the surface and on the bottom.

The salinity of the central area continued to fall during March and April and was about as much below the monthly means as in January and February.

The May salinities were abnormally low in the central area, and also in the eastern half of the western region.

In the Scilly area the current passing northwards round Lands End was much salter than the average, while on Station 4 the salinities were very high, reaching $35{\cdot}50°/_{oo}$. The temperatures were still below the normal, but only very slightly so in the bottom water to the extreme south-west.

The minimum salinity of the central area was reached in July and was $0{\cdot}15°/_{oo}$ below the average for the month.

In August it rose rapidly but was still below the mean. In the western area the salinity was the lowest recorded during the year ; the minimum probably occurred during the preceding month.

The southerly flow from the Irish Channel was unusually strong, and the salinities were therefore below the mean in the north-western area, especially on the surface. Towards the south-west in the neighbourhood of Parsons Bank (Station 4) the salinities were abnormally high at all depths.

On the surface, temperatures were below the mean in the central area, and above it in the western area. The bottom temperatures generally showed a defect.

In September the salinity of the central area rose suddenly to about $0{\cdot}01°/_{oo}$ above the mean ; there was nothing in the observations made during August to account for the change, which was evidently of comparatively small extent since a rapid fall took place during October.

In November the salinity was below the mean in the central area, but much above it in the surface waters further west. The current of $35{\cdot}3°/_{oo}$ *S.* water flowing round Lands End was unusually strong, and the southerly counter current from the Irish Channel was correspondingly well developed.

The temperatures were fairly normal in November, except at the extreme south-west of the area, where there was a slight defect, accompanied by a tendency to division into layers which was not found elsewhere.

Thus it appears that the salinities of the central area were below the monthly mean except in September. The range for the whole year was abnormally great and both the January maximum and the July minimum were well marked. The conditions were essentially those of an " even " or high range year. In the north-western area and off the north-western coast of Cornwall the salinity was above the normal except at the time of the August cruise.

In the south-western area near Station 4 (Parsons Bank) the salinity was about normal in February ; in May, August and November it was very high. The temperature was as a rule below the mean, except in the surface water of the western area in August.

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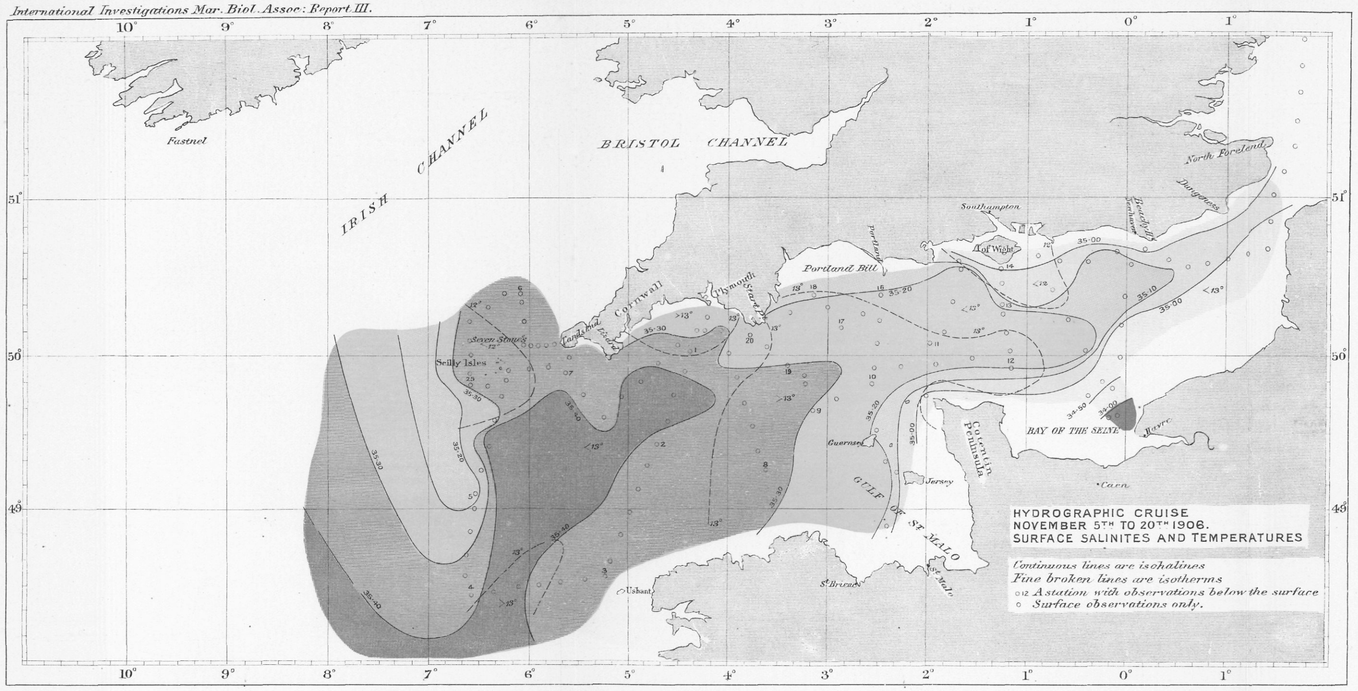
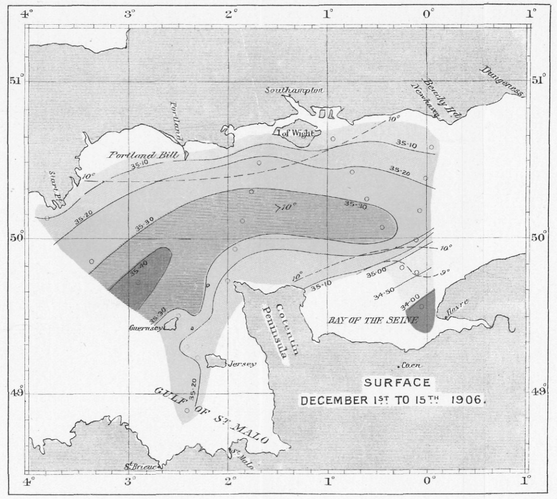
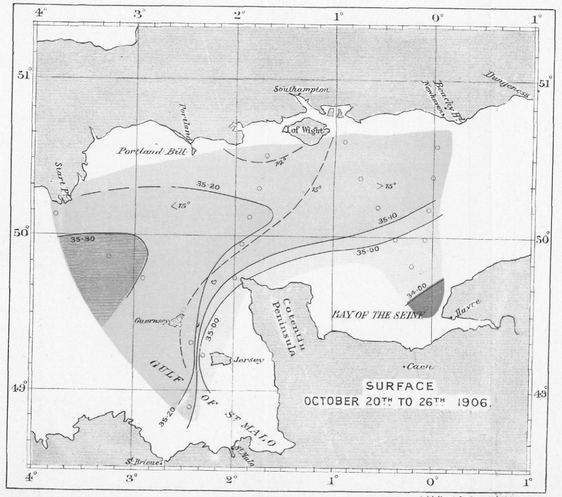
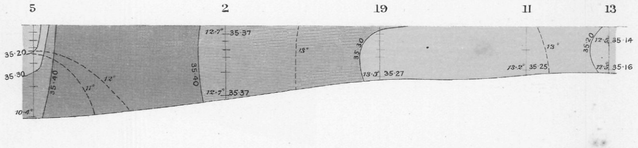


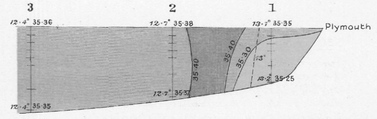


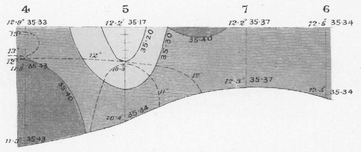


SCALE OF SALINITY COLOURING

BELOW 33·00
34·00
35·00
35·10
35·20
35·30
35·40
35·50 AND OVER







Fathoms Metres
50
50
100
150
100
200

SECTIONS NOVEMBER 1906.

Stations are shown by vertical lines with the number of the station above.
Observations below the surface are shown by short horizontal lines.
Isohalines are shown by continuous lines. Isotherms by broken lines.
The horizontal scale is the same as that of the charts.

Matthews. Physical Conditions in English Channel.

3314.

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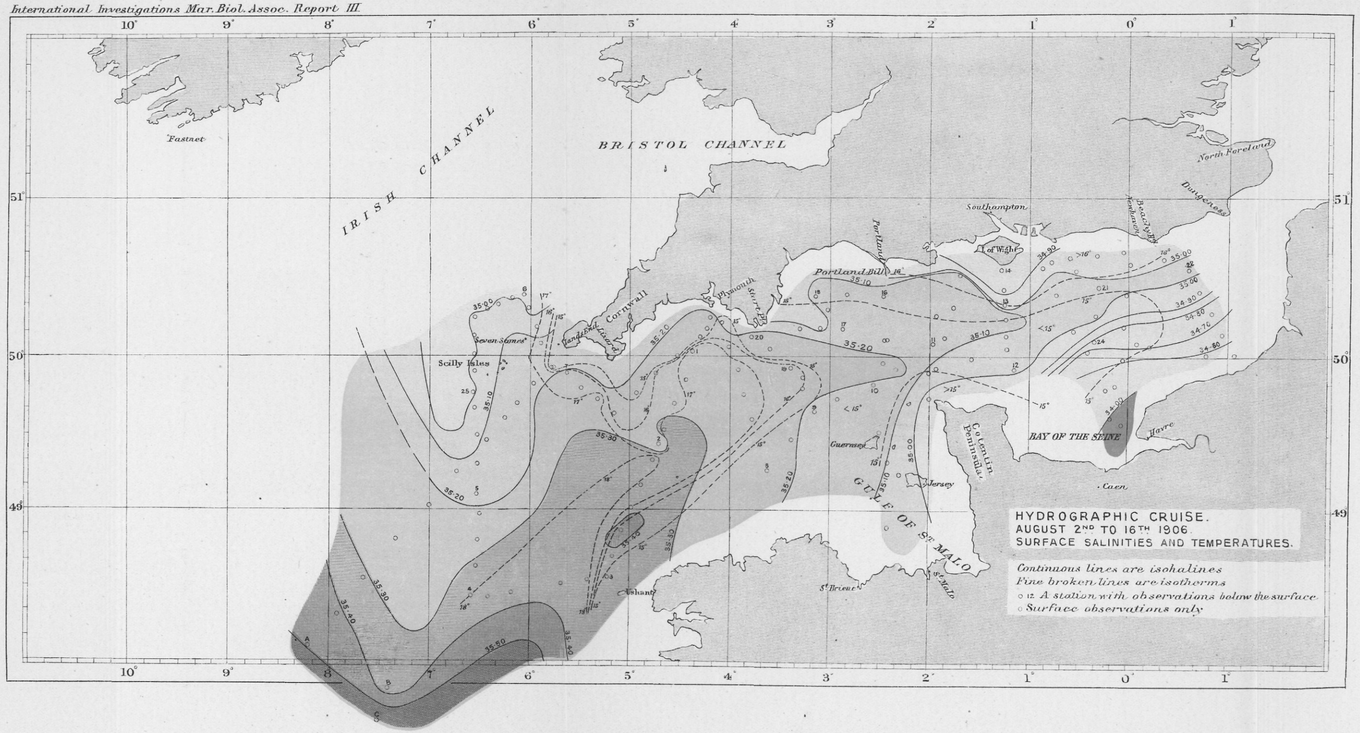
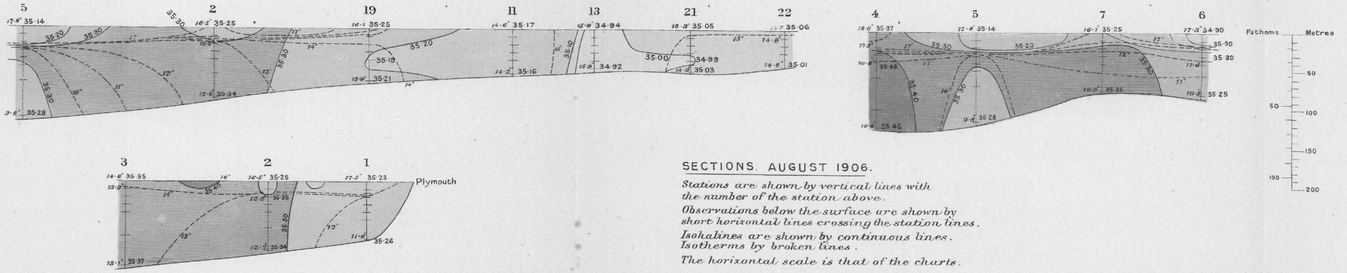
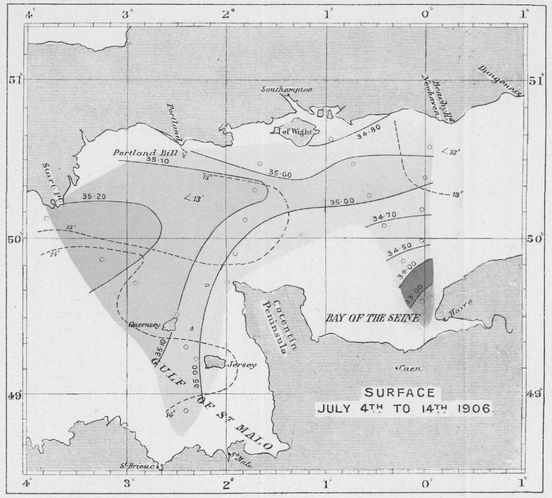
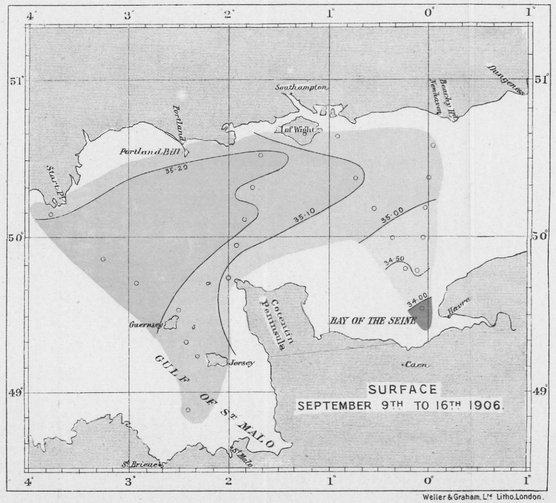


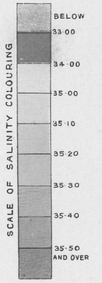


SECTIONS. AUGUST 1906.

Stations are shown by vertical lines with the number of the station above.
Observations below the surface are shown by short horizontal lines crossing the station lines.
Isohalines are shown by continuous lines. Isotherms by broken lines.
The horizontal scale is that of the charts.







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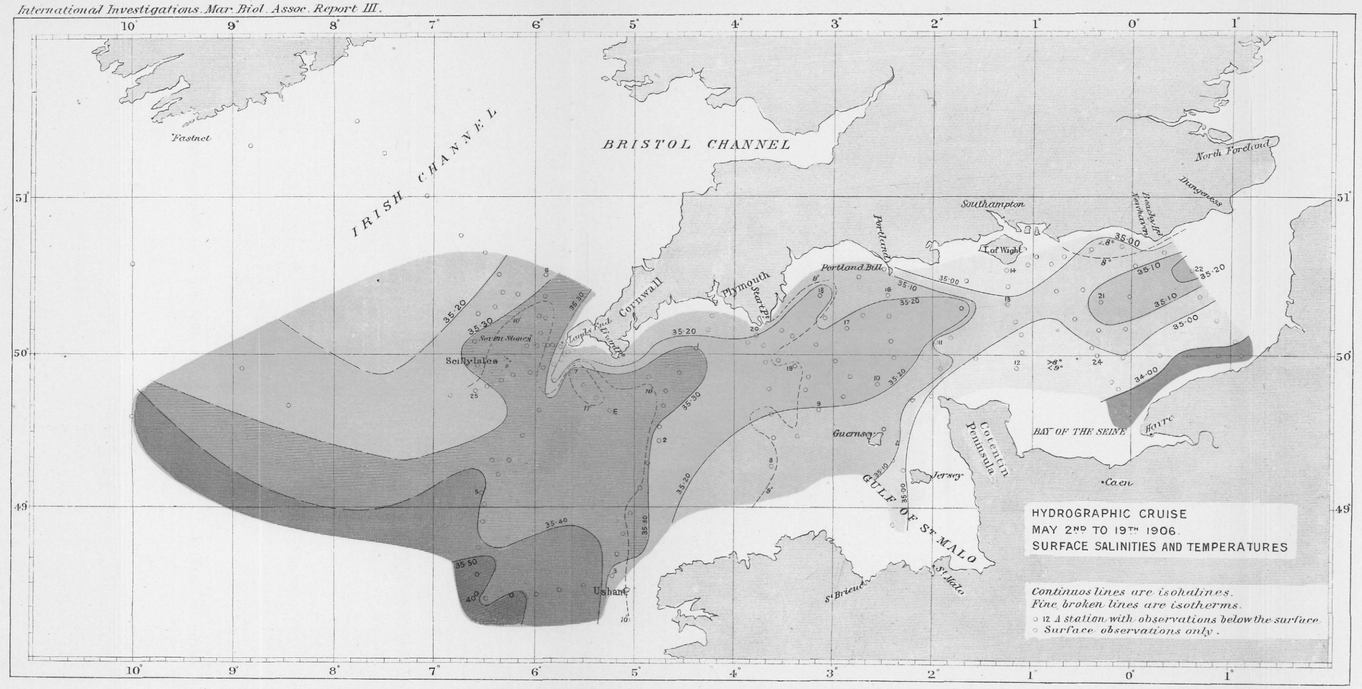

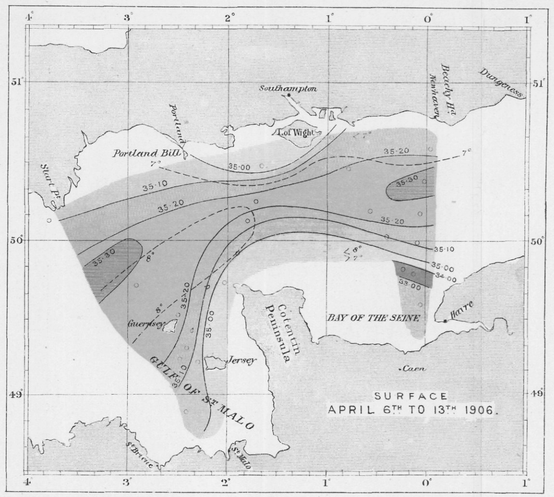

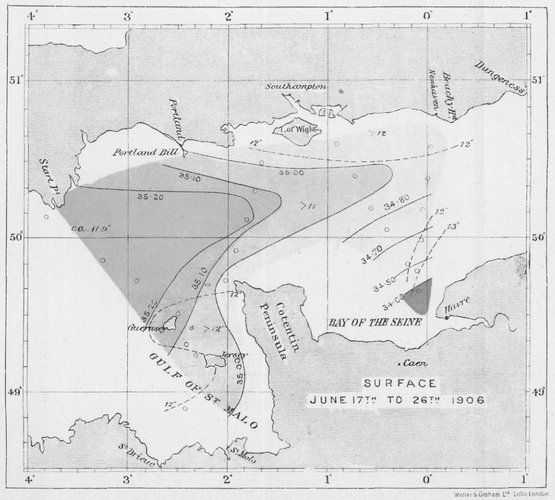

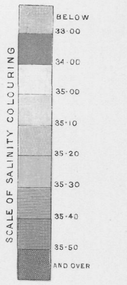

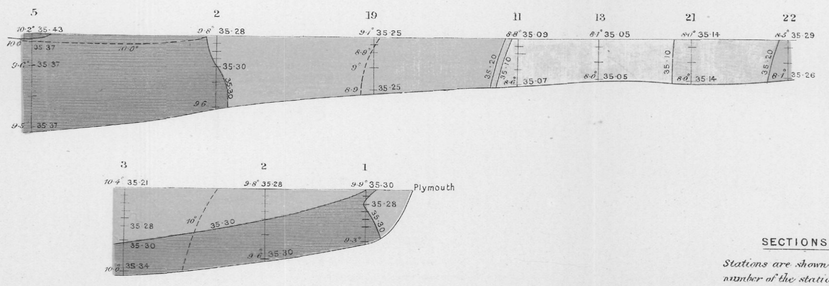

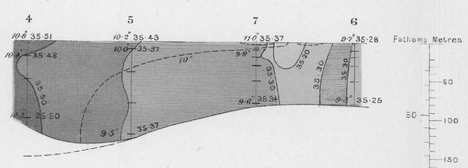

Matthews Physical Conditions in English Channel.

3534.

SECTIONS. MAY 1906.

Stations are shown by vertical lines with the number of the station above.
Observations below the surface are shown by short horizontal lines crossing the station lines.
Isohalines are shown by continuous lines.
Isotherms are shown by broken lines.

The horizontal scale is that of the charts.

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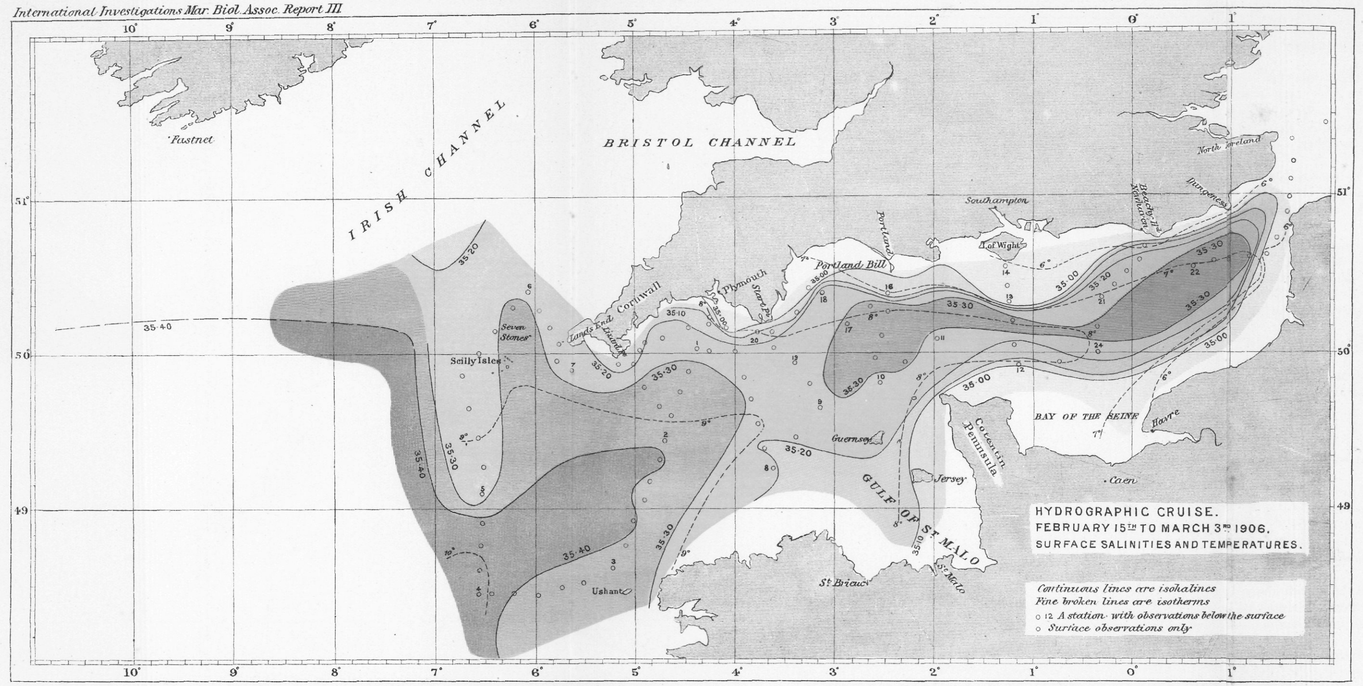

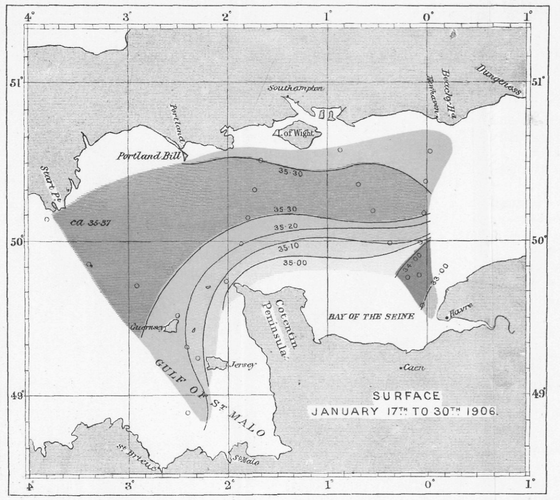

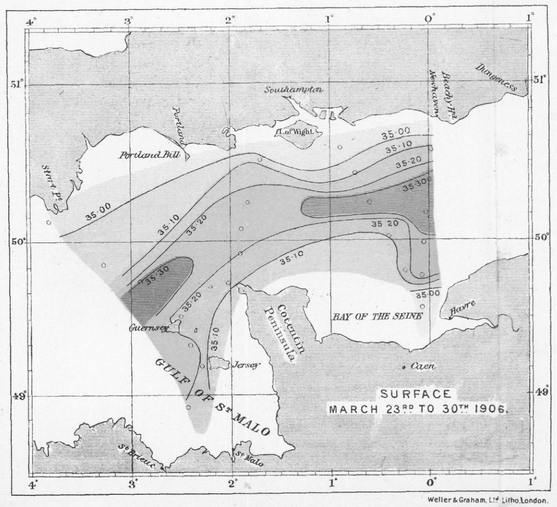

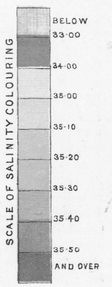

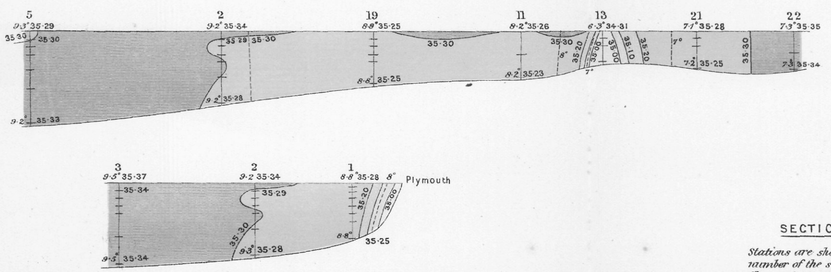

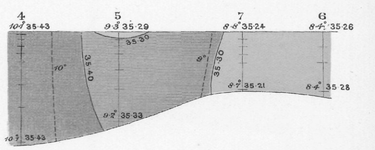

Matthews Physical Conditions in English Channel.

3334

SECTIONS. FEBRUARY, 1906.

Stations are shown by vertical lines, with the number of the station above.
Observations below the surface are shown by short horizontal lines
Isohalines are shown by continuous lines
Isotherms by broken lines

The horizontal scale is the same as that of the charts.

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