REPORT

ON THE

DEEP CURRENTS OF THE NORTH SEA

AS ASCERTAINED BY

EXPERIMENTS WITH DRIFT BOTTLES.

By

Captain C. H. BROWN.

CONTENTS.

(WITH THREE CHARTS).

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INTRODUCTION.

The action of the restless waters of the sea in transporting the eggs and young of fishes and other floating organisms to localities other than those in which they originated, has undoubtedly an important bearing on many of the fishery problems which are gradually being elucidated. If by direct experiment we can ascertain, at various selected positions, the general movements of the water, its temperature and its salinity, the origin of the ever changing waters of the North Sea may be confidently traced.

While the trend of the surface waters of the North Sea has been ably investigated by Dr. T. Wemyss Fulton, and the relation of the movement of the surface waters to fisheries discussed by him (Fifteenth Annual Report of Scottish Fishery Board, 1896, Part iii., p. 334), no attempt has been made, at least on a comprehensive scale, to ascertain directly, by means of floats, the horizontal motion of the bottom waters.

Heretofore, the obstacle to this method of finding the direction of the bottom currents has apparently lain in the difficulty of procuring an independent float, which should remain poised a foot or two above the sea bottom, and yet be carried along with the bottom drift. It might be suggested that a weighted float could be suspended at any desired depth by means of a cord from an auxiliary surface float, having a reserve of buoyancy. The objections to this method are twofold: (1) The resultant direction taken by the lower float would be affected by the motion of other layers of water acting on the upper float and on the suspending cord, and (2) the lower float would become grounded on reaching shallow water.

A beautiful current-meter has been designed by Dr. Ekman, which, on being lowered to any desired depth and the mechanism released by means of a messenger, registers the direction and rate of flow of the current at that particular depth. The instrument is perfect, but in order to use it, the ship must be at anchor and the sea smooth; the former condition confines its practical use to comparatively shallow water, while a placid condition of the surface is seldom experienced in the North Sea.

The present experiments were conducted by a special drift bottle, the device of Mr. G. P. Bidder. This is a bottle so weighted as just to float in sea-water; a long copper wire is then attached to it by which it is caused to sink, but as soon as the wire trails upon the bottom the bottle tends to float again. Accordingly it remains floating a few inches above the sea bottom, is carried along by the bottom current, and in the course of time may be scooped up by a trawl net or found stranded on a beach.

The results of our first experiments, although covering a comparatively small area of the North Sea, have so far proved remarkably successful, and further experiments are now being made on a much larger scale.

APPARATUS AND METHODS.

The special apparatus employed during the period now under review, was simple consisting essentially of a drift bottle, similar in shape and size to an ordinary soda-water

bottle, made of strong glass to resist pressure, and containing an addressed card, the reverse side being as follows :—

No.....

INTERNATIONAL FISHERY INVESTIGATIONS.

Please state **where** and **when** this card was found, and then put it in the nearest Post Office. You will be informed in reply where and when it was set adrift. Our object is to find out the Direction of the Deep Currents of the North Sea.

Locality *where found?*

Depth

Date *when found?*

Name of Sender

Address No.

The weight of the bottle was carefully adjusted by means of small shot placed securely inside of the neck, fitted with a screw stopper, made thoroughly water-tight by being dipped in pitch, and then a piece of straightened copper wire about twenty-four inches in length was attached to the neck of the bottle. Finally, the total weight of the finished bottle was carefully tested in order to insure that its specific gravity was slightly greater than that of the sea water, just sufficiently in excess to admit of its sinking slowly, neck downwards, when the slightest pressure of the tip of the copper wire referred to would prevent it from resting on the sea bottom.

The experiments were begun in June, 1906, and since then 1,012 of these submarine messengers have been put away at intervals, in the northern part of the North Sea, from the "Goldseeker," during her periodic cruises.

Twenty per cent. of these have been recovered at various times and positions, most of them at sea by means of the trawl net. Twenty bottles were found at various points on the coast of Shetland and east coast of Scotland, while thirteen were found on the coasts of Denmark, Norway and Sweden.

Guided by the positions of their recovery, we may conveniently divide the bottles, for the purposes of discussion, into three distinct groups. The most important group is composed of the bottles trawled up from the sea bottom and which we have designated "Trawled Bottles." They supply the information on which the calculations are based, and from which the bottom currents (Plate I.) have been determined.

The bottles found on our home coasts, which have traversed a track of comparatively small mileage, have been called "Stranded Bottles," as distinguished from the third group, which is composed of the bottles found on the Scandinavian coasts and which have been named "Long Distance Drifts."

We are much indebted to the captains of trawlers and to the several gentlemen who kindly forwarded the cards from the stranded bottles, for their courteous assistance and for the valued information they have supplied.

TRAWLED BOTTLES.

The set and drift from the position where each bottle was put overboard to the position where it was recovered, have been calculated from the simple formulae

$$\text{I. Tan Co} = \frac{L}{l} \text{Cos Lat.}$$

$$\text{II. Distance} = l \text{ Sec Co.}$$

Where L represents the difference of longitude,
l the difference of latitude, and
Co the direction of drift.

The direction and apparent distance drifted by each bottle were first plotted on a chart, but the lines thus obtained appeared confused ; after, however, reducing each drift to a common period of time, and again projecting on the chart, the results appeared more systematic.

Even then a few of the drifts seemed abnormal—some in direction, some in distance—but on re-examination, these were found to have been less than thirty days adrift. Considering the fact that the positions given must of necessity be approximate, and that an error in the averaged distance arising from any inaccuracy in the positions

given varies in inverse ratio to the time occupied, it was decided to eliminate from the calculations all bottles having a drift of less than thirty days duration.

The North Sea was then divided into areas equal to a half degree of latitude and one degree of longitude, each area being a square of approximately thirty miles, and all the drifts through each area were tabulated. The resultant direction and distance of drift for each area were then calculated and projected ; but in order to obtain a line of convenient magnitude, the resultants shown on Plate I. represent the average distance drifted by the bottles in one hundred days.

It has been assumed in the first instance, when calculating the direction and drift of each bottle, that it has drifted on the rhumb line joining the points of its submersion and recovery, but our information goes to show that this could seldom be the case. For example, bottle No. 107 was put overboard in the Moray Firth, off Kinnaird Head, and was picked up to the south of Buchanness, and must have followed a curved course to do so. The resultants of the areas are therefore tangential to curves, and it follows that by plotting the tangents conveniently close together, a very close approximation to the natural curve is obtained. Since the several resultants are found to arrange themselves in a very systematic way, the curved resultants group them together and complete the diagram.

The results are clear and important. They reveal the existence of an outstanding and clearly defined eddy, having a left handed circulation, the vortex of which is situated about midway between the Witch Ground and Bressay Shoal. It covers an area extending in latitude from the southern edge of the Long Forties to the parallel of Sumburgh Head, and from the second meridian of west longitude, eastward to the Norwegian coast.

Coming into the North Sea through the Shetland–Norway Channel, the bottom current flows southward on the east side of the Shetland Isles, and sets towards Kinnaird Head. The water of the main eddy gradually inclines more and more easterly, and, about the meridian of Greenwich, bends to the northward of east, and flows polarwise through the Norwegian Rift.

A deflection of the western periphery of the eddy takes place off the north-east shoulder of Scotland, for we find a south-westerly set towards the Cromarty Firth, while part of the waters trend southerly along the Aberdeenshire coast.

About the parallel of fifty-seven degrees latitude a divergence takes place, part of the stream setting eastward, and, as will subsequently be shown, continues across to the Skagerrak, while part branches sharply to the southward and south-west, forming a very decided set towards the Firth of Forth and the coasts lying south of it.

In this locality there is a suggestion that another eddy, similar to that just described, exists in the southern portion of the North Sea.

Stranded Bottles.

In obtaining the resultant for each area, no account has been taken of bottles found on the beach, as it must remain problematical how long they may have lain there before being found. They are, however, tabulated in Table IV., and their assumed track projected on Plate II. ; for although they may be of little value in indicating the rate of drift, yet they are most valuable in giving us the direction of the current. The several places where these stranded bottles—some 20 in number—were picked up, is given with great precision, and as the position where each bottle was put overboard is clearly defined, the consequent direction of drift can be relied upon. This affords us an independent factor by which we may verify—for a few of the inshore areas at least—the value of our bottom curves ; and if these independent drifts reconcile themselves in a natural and reasonable way to the curved resultants of Plate I., they supply important corroborative evidence that the deductions derived from the Trawled Bottles are practically correct.

It may, therefore, be profitable for us to refer for a moment to the individual drifts of the group, and briefly to trace the probable track along which each may have been carried, so as to see in how far this supposed direction coincides with the bottom curves.

Group I.

Bottle No. 108 was put overboard two miles east from Out Skerries, Shetland, and was found on the beach close to Sumburgh Head, having been carried a distance of some 39 miles in a direction which coincides with that of the bottom curves.

In contra-distinction to this, however—

Bottle No. 200 was put overboard 9 miles east-half-south from Noss Head, Bressay Island, and was found on Fetlar Island, having apparently drifted 30 miles almost due

north, a direction which is almost opposite to that of No. 108. This is the only drift which is difficult to reconcile with the bottom curves. At a first glance one might evade the difficulty by conjecturing it to have floated on the surface, but the direction is still contrary to the known general southerly trend of the surface current.

The history of this bottle was veiled in obscurity for a period of 621 days. May it not have been carried south towards Sumburgh Head, then northward along the west coast of Shetland, round Muckle Flugga, and finally southward again to its resting place on Fetlar Island. To traverse this route it would have to attain an average speed of only something between two and three tenths of a mile per day.

We are inclined to believe that this may have been the route followed by this elusive messenger, and are encouraged to do so by the information derived from—

Bottle No. 97, the only one returned from the west coast of Shetland. This bottle was put away four miles south of Sumburgh Head, and was evidently carried round Fitfull Head towards Scalloway Bay, for it was found on Burra Isle, having drifted at an apparent average speed of ·21 miles per day in some 95 days.

This drift is particularly interesting, as it indicates the existence of a deep current setting northward along the west coast of Shetland, and offers a reasonable explanation of the manner by which bottle No. 200 managed to get north of the place where it was put away.

Group II.

Bottle No. 138 was put away 34 miles north of Kinnaird Head, whence, guided by the bottom curves, we would expect it to be carried towards Buchanness and south along the Aberdeenshire coast. This is, doubtless, what happened, for it was found on the beach close to the River Ythan, about midway between Aberdeen and Buchanness.

Bottle No. 107 was put away 11 miles north-east ½-east from Kinnaird Head, right in the assumed line of progression of the previous bottle. We would, therefore, expect it to pursue the same course, and apparently it has done so, for it was also found close to the River Ythan, about 1 mile north from No. 138.

It is of interest to note that bottle No. 138 was put overboard on the 27th May, 1907, and found 254 days later, having drifted 57 miles at an apparent daily speed of ·22 miles. Bottle No. 107 was put overboard on the 4th July, 1907, and found 123 days later, having drifted 30 miles at practically the same average speed, namely ·24 miles per day.

Bottle No. 64 was put overboard 33 miles north by east from Kinnaird Head, about 7 miles from the position where No. 138 was dispatched. We would expect this bottle to be guided by much the same influences as the preceding two, and to be set close past Buchanness and southward along the coast. We find this was the case. It, however, escaped, being drawn inshore on the Aberdeenshire coast, and continued its journey south until it was eventually stranded on the beach of St. Andrew's Bay, having drifted 117 miles in some 193 days.

Bottle No. 19 was put away two miles east from Kinnaird Head, and was found on the beach in Rattray Bay, having thus been carried southeasterly round Rattray Head.

Bottles Nos. 83 and 135 were put away on the same day, within three miles of each other, the former one mile, and the latter four miles off Kinnaird Head. Both were found about one mile to the west of Kinnaird Head, both having been carried, along with all the bottles of this group, in a direction which agrees with the bottom curves.

Group III.

Bottle No. 57 was put away in the Dornoch Firth, two miles from Tarbetness, and was found 72 days later on the beach, six miles further up the Firth.

Bottle No. 153 was put away about the middle of the Moray Firth in Lat. 57° 57′ N., Long. 2° 53′ W., when, from the bottom curves, we would expect it to be carried westward. This was the case, for it was found at Brora, having drifted 31 miles due west.

The drift of the two bottles of this group indicates a continuance of the bottom current, right into the corner of the Moray Firth.

Group IV.

Bottle No. 20 was put overboard one mile to the west of May Island, and was found on the beach 2½ miles west of North Berwick, having been carried ten miles in a south-west direction.

Bottle No. 51 was put overboard 31 miles east from Fifeness, a position from which we would expect it to be carried to the southwest. Evidently this was so, for it was found 184 days later at Alnmouth Bay, a few miles north of Coquet Island, having drifted 58 miles during the interval. This drift indicates that the bottom current may haul more to the southward and set along the Coast of England. It also suggests, in conjunction with the scanty bottom curves we have been able to obtain in this latitude, that in the southern part of the North Sea an eddy may exist having a similar circulation to the eddy which has been established in the northern part.

Bottle No. 179 was put away on the Aberdeen Bank in Lat. 57° 15′ N., Long. 0° 47′ W. This is the locality where the bottom current appears to separate, the main body of the water recurving to the east and north, while part sets to the south, hauling south-westerly into the Firth of Forth. Of these two forces, the bottle apparently came under the influence of the latter, as it was found on the beach close to Dunbar, having followed, along with the two preceding bottles, a direction in close agreement with the bottom drift.

Group V.

Bottle No. 47 was put away 35 miles east by north from Fifeness. It was found at Crail, close to Fifeness.

Bottle No. 177 was put away ten miles east half south from Fifeness. It was found on Tentsmoor Sands, a mile to the south of the entrance to the Firth of Tay. It has evidently been carried through St. Andrew's Bay, which suggests that a divergence of the bottom current takes place off Fifeness, part of the water continuing to flow to the southwest, while part flows along the north shore of Fife.

Bottle No. 165 was put away 37 miles east north east from Fifeness, and from the bottom curves we would expect it to be carried to the westward. This bottle was also found on Tentsmoor Sands, so, like the preceding one, it also had been carried through St. Andrew's Bay.

Bottle No. 123 was put away 10 miles east half south from Fifeness, the same position as No. 177, and on the same day as bottle No. 165, namely 25th July, 1907. It would in all probability be subjected to the same influences, and should likewise have been carried into St. Andrew's Bay. It was found at Johnshaven, eight miles north of Montrose. In addition to the set into St. Andrew's Bay, this drift suggests that a deep current sets northward from the Bay.

Bottle No. 48 was put away 13 miles east south-east from Fifeness, and within six miles of the position of the preceding bottle. It also escaped the set into the Firth of Forth, and was apparently carried through St. Andrew's Bay. The fact of its being found on the beach at Auchmithie, 5 miles north of Arbroath, again suggests the existence of a north-going, in-shore, deep current.

Bottle No. 154 was put away in Lat. 56° 35′ N., Long. 1° 07′ W., a position 49 miles due east from Arbroath. From our curves we would expect it to be carried by the south-west drift towards Fifeness. This bottle also escaped the set into the Firth of Forth, and was apparently carried through St. Andrew's Bay. It was found on the beach at Arbroath, which gives further evidence that a deep current sets northerly across the mouth of the Firth of Tay.

The two bottles of this group found on Tentsmoor Sands clearly show that the bottom current sets westward along the northern shore of the Fifeshire promontory, and sweeps in a northerly direction through St. Andrew's Bay. The three bottles found at different places on the coast of Forfarshire and Kincardineshire indicate the existence of a deep current setting northerly across the entrance to the Firth of Tay, its horizontal flow extending at least as far north as Johnshaven, and being sandwiched between the Scottish coast and the south-going bottom current which exists more to seaward. The observations are, however, too meagre to show whether this in-shore drift is of a permanent character, or subject to seasonal changes.

The apparent directions of drift of the several "Stranded Bottles" having freely reconciled themselves to the curves obtained from the "Trawled Bottles," give us confidence to believe in the correctness of the deductions made therefrom. They do more. They add to our information by bringing fragmentary but striking evidence of the continuance of the bottom curves through the prohibited trawling grounds on the Scottish coast.

The two drifts of Group III. show that the bottom current of the Moray Firth continues to the shores of Sutherlandshire. The stranded bottles of Group IV. show a continuation of the deep current setting southerly along the Berwickshire and Northumbrian coasts.

The three bottles of Group I. found on the coast of Shetland—it is a pity that the returns from here are not more numerous—offer a vague suggestion that a deep current having a right handed circulation, may possibly circumgyrate the Shetland Islands.

The bottles of Group V. disclose a separation of the bottom waters off Fifeness, and also reveal the existence of the north going, in-shore, drift, already referred to.

Long Distance Drifts.

It has not been considered practicable to include the information supplied by the bottles found on the coasts of Denmark, Norway and Sweden in the system of areas into which the North Sea has been arranged. The considerable mileage traversed by these bottles occupying a long period of time, added to the lack of information from any intermediate point during their passage, rendered it difficult to conjecture the possible route they may have taken ; in fact, it was at first hastily assumed that somehow or other the bottles had become underweighted and consequently floated on the surface.

Most of the bottles were found on the beach, but when two were recovered from deep water, conclusively proving that these two were yet submerged and still on their passage, it became necessary to reconsider the case of the long distance drifts.

Without being dogmatic as to whether these particular bottles have been surface or bottom drifts, it will be profitable to discuss for a moment, the possible track of the individual drifts, and so to see in how far these long distance voyagers may have followed the trend of the bottom waters as revealed by the "Trawled Bottles," and set forth in Plate III.

In the absence of positive proof to the contrary, it is to be assumed for the mileage calculations, that the bottles have followed the rhumb line between their points of origin and termination, hence the distances given are less than the bottles have actually traversed. It is also to be understood that the average distances given are further vitiated by dubiety as to how long the stranded bottles may have been lying on the beach before being found.

Group I.

Referring to Plate III., we find that Bottle No. 44 was put overboard on the 14th August, 1906, in the Moray Firth. If it escaped the set into the south-west corner of the Firth, it would probably be carried round Rattray Head, and southward towards the Aberdeen Bank. It would then either continue in a southerly direction, or be carried to the eastward by the southern periphery of the eddy which has been referred to. The latter was apparently the case, the bottle being found on the coast of Denmark, about midway between Hanstholm and the Hirtshals, having drifted a distance of 399 miles in 198 days, an average rate of 2 miles per day.

Bottles Nos. 50 and 201 were both put away on the 8th October, 1906, in proximity to No. 44, and would most likely be subjected to the same influences, and both would probably traverse a similar route. Towards the end of their journey, however, they appear to have been carried more northerly than No. 44, for they both cleared the Skaw, and drifted through the Skagerrak. No. 50 was found near Tonsberg, Norway, having covered some 420 miles during its sojourn of 164 days, an average rate of 2·56 miles per day, while No. 201 was found on the coast of Bohuslan, Sweden, having covered 404 miles in 833 days, an average of ·48 miles per day.

Bottle No. 184 was put away on the 4th July, 1907, a few miles to the north of the preceding bottles. According to our bottom curves it would first be carried to the southward, then easterly and more easterly across the Long Forties towards the Skagerrak. It was found on the coast of Norway, four miles east from Ryvingen Lighthouse, having traversed 296 miles in 446 days, an average of ·67 miles per day.

Group II.

Bottle No. 85 was put overboard on the southern edge of the Long Forties on the 21st October, 1906, and No. 186 about sixty miles due east of it on the 19th December, 1906, both bottles at the outset of their journey being on the assumed line of progression of the four bottles of Group I. We would expect them to be also carried eastward. They were eventually found on the coast of Denmark within twenty miles of each other. No. 85 was picked up on Blokhus Strand, having drifted 324 miles in 284 days, an

average speed of 1·14 miles per day. No. 186 was found one mile to the east of the Hirtshals Lighthouse, having drifted 285 miles in 656 days, an average of ·43 miles per day.

Bottle No. 207 was put overboard on the 19th December, 1906, in Lat. 56° 53′ N., Long. 1° 20′ E. We would expect it to be carried either to the southward, or to the eastward towards the Skagerrak. The latter was the case, the bottle being found at the Skaw, having drifted 305 miles in 790 days, an average speed of ·39 miles per day.

Group III.

Bottle No. 162 was put away on the 20th November, 1906, about forty miles north-east from Rattray Head, and No. 192 on the 15th August, 1906, in close proximity to it. We would expect them to be at first carried slightly to the eastward of south, trending more easterly as they advanced, and after passing between the Witch Ground and the Long Forties, they would either be carried towards the Skagerrak or northward through the Norwegian Rift. The latter was what happened, No. 162 being trawled up from a depth of 70 fathoms, off the Utvaer Light, having been carried 248 miles in 511 days, an average speed of ·48 miles per day. No. 192 was picked up on the beach at Melingsvaag, Norway, a position 30 miles south of that where No. 162 was found. This bottle had drifted 210 miles in 818 days, an average speed of ·26 miles per day.

Bottle No. 195 was put overboard on the 28th July, 1906, close to the assumed line of progression of the two preceding bottles. It would in all probability follow the same track. It was found on the coast of Norway, near Vigsnaes, in four fathoms of water, having been carried some 218 miles in 849 days, an average speed of ·26 miles per day.

Bottle No. 143 was put away on the southern edge of the Aberdeen Ground on the 21st October, 1906. This is the locality where the bottom currents seem to separate. The initial direction taken by the bottle would be the resultant of various influences, but the fact of its having been found at Froien Island, Alansund, Norway, indicates that at first the set to the eastward predominated, and afterwards the bottle was carried northward through the Norwegian Rift to its ultimate resting place. This bottle drifted 346 miles in 478 days, an average speed of ·73 miles per day.

Bottle No. 205 was put overboard on the middle of the Long Forties on the 16th August, 1906. Our curves indicate that it would be carried to the north-east, towards the Norwegian Rift, thence along the coast of Norway. It was found near Kristiansund, having drifted 451 miles in 890 days, an average of ·51 miles per day.

Group IV.

The two bottles of this group are of outstanding interest owing to the fact that No. 175 was found on the verge of, and No. 60 within, the Arctic Circle.

Bottle No. 60 was put overboard off Sumburgh Head, Shetland, on 12th June, 1906, and according to our bottom curves, would be carried well to the south, possibly passing eastwards over the Long Forties, and then trending more and more northerly as it advanced towards the Norwegian Rift. It has then apparently followed a direction about parallel to the Norwegian Coast, for it was found 24 miles north-west from Hammerfest.

Unfortunately the information supplied does not make it quite clear whether this bottle was brought up from the bottom, or found on the surface. Its average rate per day is at least 2·78 miles.

Bottle No. 175 was put overboard close to the positions of the bottles of Group III., on July 23rd, 1907, and during the first part of its journey it would likely be subjected to, and has apparently obeyed, the same influences. In drifting northward through the Norwegian Rift, it has escaped being drawn coastwise until reaching Indre Kvaro, Helqiland, Norway. Again the information supplied does not define whether this bottle was brought up from deep water, found on the surface, or on the beach. But the position of its recovery, protected as it is from the open sea by many intervening rocks and islands, makes it difficult to believe that a messenger, moving involuntary along the bottom, could have escaped and passed so many obstacles.*

The average rate of this bottle was at least 2·0 miles per day.

This discussion goes to show that the several directions taken by the long distance drift bottles, reasonably accommodate themselves to the curves obtained from the bottles trawled up from the bottom.

Our information, so far, covers a comparatively small area of the North Sea, and terminates abruptly about the third meridian of east longitude, leaving a blank between this

* We now learn that this bottle was found on the beach, without its wire, and had certainly therefore floated with the surface current.

and the coasts lying to the eastward. These submarine messengers have, however, bridged this unknown region. Their silent evidence testifies to the continuity of the curves.

The curves obtained from the "Trawled Bottles" have indicated that in the vicinity of the meridian of Greenwich and the parallel of 57 degrees latitude, the bottom current sets to the east. From this point, the long distance bottles indicate that a divergence takes place, part of the waters continuing directly east, towards and through the Skagerrak, and part setting more and more to the north as it advances, forming the eastern side of the cyclonic eddy and flowing northward through the Norwegian Rift.

Velocity.

In estimating the average rate of speed of the bottom drifts, it has to be borne in mind that the rate here given is the actual rate, diminished indeterminately by the effects of unknown errors in the three factors, distance, time, and retardation due to friction.

It has been premised that the distances employed in the calculations are the measurements of rhumb lines, but we know that most of the bottles have traversed a greater distance than this, so in general the average rate of movement as here given is less than the actual rate.

Again, the bottles found on the beach must have been lying for some time, more or less, before being discovered, and this unknown lengthening of the apparent period of flotation will also tend to give—by an uncertain amount—an average rate of movement less than the actual rate.

Further, there must be a slight amount of retardation due to friction of the tip of the wire in touching the ground, as the bottle moves over the bottom, and this not being allowed for will also tend to give an average rate less than the actual rate of motion.

All the bottles will be affected in like measure by possible retardation due to friction, and for comparative purposes this factor may be neglected.

The averages of the "Long Distance Drifts" will be affected by the unknown errors just referred to, in their time and distance factors. The period of transition of the bottles trawled up at sea is correctly known, so that their apparent average speed is only diminished by an error in the remaining factor, namely the difference between the actual distance traversed and the estimated distance. This will affect the average in a relatively small degree, however. The distance traversed by the "Trawled Bottles" has been comparatively short, and even if they followed a curved course between the positions where they were put away and recovered, the length of the arc thus described would be but little in excess of the length of the chord on which our calculations are based.

We may therefore assume that the speed of the bottom current is but little in excess of that set forth in each area of Plate I.

In order to discuss the bearing which the Long Distance Drifts may have on the estimated velocities, it might be as well to refer to the four groups into which they have been arranged. Neglecting then, for the time being, the effects of unknown errors in time and distance which have undoubtedly crept into the averages, and referring to—

Group I., the bottles of which were all put overboard in the Moray Firth and found on the shores of the Skagerrak, we find that the average speed per day varies from ·48 to 2·56 miles. Curiously enough the extremes are of bottles Nos. 50 and 201, both of which were put away close to each other on the same day, and both of which drifted through the Skagerrak. The average drift of this group is 1·43 miles per day.

Group II. are a closely related combination, having been all put away near the parallel of 57 degrees latitude, all carried nearly due east and all deposited on the beach to the westward of the Skaw. The average rate for this group is ·65 miles per day.

Group III. were put away to the north-eastward of Rattray Head, with the exception of No. 143 which was put away on the Aberdeen Bank. The members of this group were found at widely different positions on the west coast of Norway. Two of the bottles Nos. 162 and 195, were brought up from 70 fathoms and 4 fathoms respectively, being still "en route," so that these two are particularly interesting for the purposes of comparison, owing to the removal from their estimated average speed of the effects of possible error in their time factor. The speed of the individual bottles of this group is surprisingly uniform, varying only from one quarter to three quarters of a mile per day. The average rate for the group is ·45 miles per day, as compared with ·37 miles, the average speed of the two interesting messengers recovered in deep water.

Group IV.—The two bottles of this group were found in a high latitude, and show an average speed much in excess of the others. The actual distance traversed by No. 60 is in all probability much greater than that which is tabulated, as may be conjectured

from its trace on Plate III. It has apparently travelled some 1,150 miles, which would increase its average daily rate from 2·78 miles to 3·63 miles. The average daily velocity of No. 175 is also increased from 2 to 2·38 miles, when its probable additional mileage is taken into account.

The average speed, 2·39 miles per day, of these two arctic voyagers is in agreement with the rate of motion of the surface waters as given by Dr. Fulton, who says : " The speed of the movement is usually about two or three geographical miles a day, but may be much accelerated or retarded by the action of the wind." (Fifteenth Annual Report of Scottish Fishery Board, 1896. Part iii., p. 367.) It seems highly probable, therefore, that these two bottles have drifted on the surface.

As might be expected from a liquid body moving in frictional contact over practically level ground, the horizontal rate of motion of the bottom layer of water is comparatively slow and relatively uniform.

The " Trawled Bottles " show that the southward flow from the Shetland Islands has an apparent speed of about ·14 miles per day, the progressive motion increasing slightly as the current bends to the eastward. This acceleration is accentuated by the Long Distance Drifts, Group II., which indicate an apparent average velocity of ·65 miles per day as the waters approach the Skaw, while Group I. shows the daily speed accelerated to 1·43 miles in passing through the Skagerrak.

The cyclonic speed of the water is diminished as the vortex of the eddy is approached, near which the apparent speed is only about ·02 miles per day. In the vicinity of the parallel of 57 degrees latitude, where the waters separate and the consequent route of the bottles will for a short time be undecided, the velocity obtained thereby is seen to be considerably diminished, until the current sets south-westerly towards the Firth of Forth, when the average rate increases to ·14 miles per day.

Summary.

The results of the present experiments show that a deep current, composed of Atlantic water, enters the North Sea through the Norwegian Channel. It flows south along the east coast of Shetland, continues in this direction towards Kinnaird Head, and sets south-westerly into the Moray Firth. The main body of this advancing bottom-water gradually trends more and more to the eastward, circulates round an area of almost motionless water, and passes northward along the west coast of Norway, into the Atlantic again.

While part of the waters on the southern edge of this cyclonic current bend sharply to the south and south-westward, and set towards the Firth of Forth, part continues to flow eastward towards the Skagerrak.

The general trend along the east coast of Scotland is to the south, but a deep inshore current—possibly only periodic—flows northward from St. Andrew's Bay and penetrates as far north as Johnshaven.

The progressive motion of the bottom current is slow, varying from less than one-tenth to fully three-tenths of a mile per day. The speed increases as the water flows through the Norwegian Rift, and a considerable acceleration—possibly to about one mile per day—is noticeable towards the shores of the Skagerrak.

The number of observations obtained from the first experiments are not nearly numerous enough, nor have they extended over a sufficiently long period of time, to offer an indication as to the seasonal or periodic changes, which may possibly occur in the direction or rate of drift of the bottom currents. This should prove an interesting study when the expected returns of the new experiments come to hand, the observations of which will no doubt supply the necessary information to fill the gaps which occur in the present statistics.

Table I.—Drift-bottles Recovered by Trawlers.

Reference Number.	Position.				Depth in Fathoms.	Date.		Number of Days Adrift.	Distance (in miles) between position in 30 days.	Mean Drift (in miles) in 30 days.	Direction True.	Difference of Latitude.		Departure.	
	Cast Out.		Recovered.			Cast Out.	Recovered.					N.	S.	E.	W.
	° ′	° ′	° ′	° ′							°				
2	58 9 N.	1 50 W.	57 52 N.	1 34 W.	48	11.6.06	11.8.06	61	19·0	9·3	S. 26 E.	—	8·36	4·08	—
4	58 12 N.	0 17 W.	58 10 N.	0 20 W.	75	28.7.06	5.9.06	39	2·75	2·1	S. 40 W.	—	1·61	—	1·35
5	57 49 N.	0 54 W.	57 43 N.	0 47 W.	58	28.7.06	12.9.06	46	7·00	4·60	S. 32 E.	—	3·90	2·44	—
6	58 11 N.	0 32 W.	58 04 N.	0 56 W.	64	28.7.06	15.9.06	49	14·5	8·9	S. 62 W.	—	4·18	—	7·86
7	56 19 N.	2 11 W.	56 15 N.	2 17 W.	23	9.8.06	17.9.06	39	5·25	4·0	S. 40 W.	—	3·10	—	2·60
10	56 20 N.	2 07 W.	56 16 N.	2 22 W.	28	10.8.06	21.9.06	42	9·50	6·8	S. 64 W.	—	2·98	—	6·11
11	58 24 N.	0 24 W.	58 02 N.	0 34 W.	65	15.8.06	24.9.06	40	23·0	17·3	S. 14 W.	—	16·79	—	4·19
13	59 22 N.	0 37 W.	59 28 N.	1 02 W.	66	7.9.06	7.10.06	30	14·0	14·0	N. 64 W.	6·10	—	—	12·60
14	59 44 N.	1 07 W.	59 43 N.	1 22 W.	51	7.9.06	11.10.06	34	7·5	6·6	S. 83 W.	—	0·80	—	6·55
15	60 00 N.	2 02 E.	60 30 N.	2 46 E.	64	27.7.06	13.10.06	78	37·0	14·2	N. 36 E.	11·49	—	8·35	—
16	57 10 N.	1 48 W.	56 58 N.	2 00 W.	—	16.8.06	21.10.06	66	13·5	6·1	S. 29 W.	—	5·34	—	2·96
17	57 11 N.	1 41 W.	56 57 N.	1 55 W.	40	16.8.06	30.10.06	75	16·0	6·4	S. 28 W.	—	5·65	—	3·00
18	59 56 N.	2 00 E.	59 43 N.	1 35 E.	61	27.7.06	30.10.06	95	18·0	5·7	S. 43 W.	—	4·24	—	3·81
21	57 22 N.	0 42 E.	58 00 N.	1 07 E.	62	16.8.06	16.11.06	92	40·0	13·0	N. 20 E.	12·20	—	4·40	—
22	60 37 N.	2 14 E.	61 06 N.	2 35 E.	109	26.7.06	14.11.06	111	31·0	8·4	N. 20 E.	7·89	—	2·87	—
23	57 40 N.	1 08 W.	57 23 N.	0 33 W.	43	21.6.06	23.11.06	155	25·5	5·0	S. 48 E.	—	3·30	3·70	—
25	57 19 N.	0 21 W.	58 10 N.	0 40 W.	65	14.8.06	30.11.06	108	52·0	14·4	N. 11 W.	14·14	—	—	2·75
26	59 11 N.	0 21 E.	59 07 N.	0 12 E.	75	20.6.06	4.12.06	167	6·0	1·1	S. 48 W.	—	0·74	—	0·82
27	57 42 N.	0 55 W.	57 12 N.	1 40 W.	40	8.9.06	8.12.06	91	39·0	12·9	S. 38 W.	—	10·17	—	7·94
28	59 34 N.	1 18 W.	59 20 N.	1 18 W.	73	12.6.06	2.12.06	173	14·5	2·5	South.	—	2·50	—	—
29	56 14 N.	2 26 W.	56 21 N.	2 23 W.	—	9.8.06	10.12.06	123	7·00	1·7	N. 14 E.	1·65	—	0·41	—
30	56 46 N.	1 13 E.	56 12 N.	1 10 E.	47	13.8.06	11.12.06	120	34·0	8·5	S. 3 W.	—	8·49	—	0·44
31	59 40 N.	1 14 W.	59 33 N.	1 27 W.	65	20.11.06	18.12.06	28	9·5	10·2	S. 42 W.	—	7·58	—	6·83
32	56 39 N.	1 14 W.	56 18 N.	1 34 W.	30	20.10.06	18.12.06	59	24·0	12·2	S 27 W.	—	10·87	—	5·54
34	57 52 N.	0 52 W.	57 07 N.	1 17 W.	40	28.7.06	5.1.07	161	48·0	8·9	S. 17 W.	—	8·51	—	2·60
35	59 32 N.	0 30 E.	59 38 N.	1 39 E.	70	20.6.06	12.1.07	205	35·0	5·1	N. 80 E.	0·89	—	5·02	—
36	57 53 N.	0 52 W.	58 13 N.	0 18 E.	70	21.6.06	16.1.07	209	42·0	6·0	N. 62 E.	2·80	—	5·30	—
37	58 22 N.	0 52 E.	58 32 N.	1 01 E.	77	19.12.06	16.1.07	28	11·0	11·8	N. 24 E.	10·78	—	4·80	—
40	56 35 N.	0 8 W.	56 33 N.	0 15 W.	—	20.12.06	27.1.07	38	4·5	3·6	S. 27 W.	—	3·21	—	1·63
41	58 8 N.	1 59 W.	57 58 N.	1 42 W.	45	18.12.06	3.2.07	47	13·5	8·6	S. 42 E.	—	6·39	5·75	—
42	59 29 N.	1 20 W.	58 34 N.	1 37 W.	62	21.8.06	18.2.07	181	56·0	9·3	S. 9 W.	—	9·19	—	1·45
43	60 26 N.	0 22 W.	59 50 N.	0 40 W.	72	21.11.06	24.2.07	95	37·0	11·7	S. 14 W.	—	11·35	—	2·83
46	56 26 N.	1 00 W.	56 15 N.	2 14 W.	27	13.10.06	16.3.07	154	43·0	8·4	S. 75 W.	—	2·17	—	8·11
49	56 24 N.	1 21 W.	56 13 N.	2 05 W.	25	20.12.06	8.4.07	109	27·0	7·4	S. 66 W.	—	3·01	—	6·76
52	59 19 N.	0 28 E.	59 07 N.	1 35 W.	75	25.11.06	13.4.07	139	63·0	9·5	S. 79 W.	—	1·81	—	9·33
53	56 17 N.	2 05 W.	56 27 N.	2 16 W.	—	20.12.06	19.4.07	120	12·0	3·0	N. 30 W.	2·60	—	—	1·50
54	57 59 N.	2 41 W.	57 56 N.	3 32 W.	28	7.2.07	17.4.07	69	28·0	12·2	S. 84 W.	—	1·28	—	12·13
55	58 00 N.	2 54 W.	57 48 N.	3 06 W.	38	8.10.06	19.4.07	193	13·5	2·2	S. 28 W.	—	1·94	—	1·03
56	56 21 N.	1 37 W.	56 16 N.	1 50 W.	20	20.12.06	22.4.07	123	9·0	2·1	S. 53 W.	—	1·26	—	1·68
59	57 23 N.	0 50 E.	58 26 N.	2 18 E.	54	16.8.06	27.4.07	254	78·0	9·20	N. 37 E.	7·35	—	5·54	—
61	56 32 N.	0 32 W.	55 58 N.	1 04 W.	43	13.10.06	15.5.07	214	38·5	5·40	S. 28 W.	—	4·77	—	2·54
62	57 19 N.	1 02 W.	56 16 N.	1 50 W.	26	16.8.06	5.5.07	262	68·0	7·80	S. 22 W.	—	7·23	—	2·92
63	58 38 N.	1 42 W.	58 21 N.	0 12 W.	70	8.9.06	23.5.07	257	51·0	5·95	S. 70 E.	—	2·03	5·59	—
65	57 50 N.	0 49 W.	57 33 N.	1 00 E.	53	26.11.06	31.5.07	186	60·0	9·70	S. 73 E.	—	2·84	9·28	—
66	57 56 N.	0 48 W.	58 43 N.	1 23 E.	70	28.7.06	6.6.07	313	85·0	8·14	N. 57 E.	4·44	—	6·84	—
67	56 52 N.	1 06 W.	57 10 N.	1 19 W.	47	5.4.07	5.6.07	30	19·0	19·0	N. 22 W.	17·60	—	—	7·10
68	56 24 N.	1 21 W.	56 21 N.	1 33 W.	27	5.4.07	26.5.07	51	8·0	4·7	S. 66 W.	—	1·91	—	4·29
69	57 50 N.	0 54 W.	58 00 N.	0 14 E.	75	20.6.06	7.6.07	362	38·0	3·20	N. 74 E.	0·88	—	3·08	—
70	56 17 N.	2 03 W.	56 14 N.	1 48 W.	23	5.4.07	10.6.07	66	66·0	4·10	S. 70 E.	—	1·40	3·85	—
71	56 23 N.	1 16 W.	56 38 N.	1 14 W.	40	5.2.07	13.6.07	128	15·0	3·50	N. 4 W.	3·49	—	—	0·24
72	56 22 N.	1 37 W.	56 11 N.	2 07 W.	30	10.8.06	21.6.07	315	20·0	1·90	S. 57 W.	—	1·03	—	1·59
73	56 24 N.	1 21 W.	56 12 N.	2 20 W.	27	5.2.07	21.6.07	136	35·0	7·70	S. 70 W.	—	2·63	—	7·24
74	56 22 N.	1 32 W.	56 14 N.	2 13 W.	22	5.2.07	24.6.07	139	24·0	5·20	S. 71 W.	—	1·69	—	4·92
75	56 25 N.	1 07 W.	56 18 N.	1 32 W.	30	5.2.07	1.7.06	146	16·0	3·30	S. 63 W.	—	1·50	—	2·94
76	56 21 N.	1 34 W.	56 14 N.	2 13 W.	22	5.4.07	3.7.07	89	23·0	7·75	S. 72 W.	—	2·41	—	7·37
77	58 11 N.	1 31 W.	57 48 N.	1 43 W.	60	7.2.07	6.7.07	149	21·0	4·8	S. 16 W.	—	4·61	—	1·32
78	56 24 N.	1 21 W.	55 53 N.	1 32	40	10.8.06	23.6.07	317	31·5	3·0	S. 12 W.	—	2·90	—	0·60
79	58 17 N.	1 56 W.	58 0 N.	0 9 W.	65	20.6.06	21.7.07	396	59·0	4·5	S. 73 E.	—	1·32	4·30	—
80	59 23 N.	1 35 W.	59 25 N.	1 17 W.	57	10.5.07	27.7.07	78	9·0	3·5	N. 77 E.	0·79	—	3·41	—
81	58 22 N.	1 55 W.	58 17 N.	0 14 W.	70	25.2.07	27.7.07	152	54·0	10·7	S. 84 E.	—	1·12	10·64	—
82	59 10 N.	1 27 W.	58 04 N.	0 44 W.	52	12.6.06	29.7.07	412	70·0	5·1	S. 19 E.	—	4·82	1·66	—
86	56 29 N.	0 37 W	56 33 N.	1 43 W.	26	10.4.07	5.8.07	117	37·0	9·5	N. 84 W.	0·99	—	—	9·45
87	56 31 N.	0 24 N.	56 38 N.	0 53 W.	39	10.4.07	9.8.07	121	20·0	5·0	N. 70 W.	1·70	—	4·70	—
88	58 9 N.	1 50 W.	57 37 N.	1 33 W.	45	9.5.07	23.8.07	106	33·0	9·3	S. 16 E.	—	8·94	2·56	—
89	59 37 N.	1 23 W.	59 38 N.	1 05 W.	68	4.7.07	28.8.07	55	9·0	5·0	S. 84 E.	—	0·50	5·00	—
90	57 42 N.	0 57 W.	57 16 N.	0 20 W.	42	26.11.06	30.8.07	277	33·0	3·6	S. 38 E.	—	2·84	2·22	—
91	56 36 N.	0 06 E	56 28 N.	0 37 W.	40	6.2.07	10.9.07	216	25·0	3·5	S. 72 W.	—	1·08	—	3·33
92	56 28 N.	0 53 W.	56 02 N.	1 53 W.	30	5.2.07	13.9.07	220	42·5	5·8	S 52 W.	—	3·57	4·57	—
93	58 45 N.	1 42 W.	57 32 N.	1 30 W.	54	2.2.07	26.9.07	226	73·0	9·7	S. 5 E.	—	9·68	0·68	—
94	58 43 N.	1 39 W.	58 42 N.	0 35 W.	67	27.5.07	2.10.07	128	33·0	7·7	S. 89 E.	—	0·13	7·70	—
95	57 26 N.	0 47 W.	51 19 N.	1 14 W.	33	14.8.06	2.10.07	414	69·0	5·0	S. 13 W.	—	4·90	—	1·10
96	56 23 N.	0 53 W.	56 01 N.	1 35 W.	—	20.10.06	5.10.07	350	36·0	3·1	S. 41 W.	—	2·34	—	2·03
98	59 37 N.	0 12 E.	59 10 N.	0 16 W.	77	21.11.06	4.10.07	317	30·0	2·8	S. 27 W.	—	2·49	—	1·27
99	58 9 N.	1 50 W.	57 25 N.	0 24 E.	43	19.11.06	9.10.07	324	84·0	7·8	S. 58 E.	—	4·13	6·61	—
100	59 18 N.	1 24 W	58 48 N.	0 28 W.	64	12.6 06	10.10.07	519	42·0	2·6	S. 44 E.	—	1·87	1·81	—
101	56 59 N.	1 09 W.	57 07 N.	1 37 W.	46	5.4.07	10.10.07	188	17·0	2·7	N. 62 W.	1·27	—	—	2·38
102	57 56 N.	0 48 W.	58 04 N.	1 04 W.	63	2.9.07	14.10.07	42	11·5	8·2	N. 48 W.	5·49	—	—	6·09
103	59 47 N.	0 21 W.	59 24 N.	0 44 W.	74	24.2.07	27.10.07	245	26·0	3·2	S. 27 W.	—	2·85	—	1·45
104	56 37 N.	0 09 E.	56 12 N.	0 20 W.	44	13.8.06	27.10.07	440	30·0	2·0	S. 33 W.	—	1·70	—	1·10
105	56 35 N.	0 10 W.	56 12 N.	1 05 W.	36	24.7.07	25.10.07	93	38·5	12·4	S. 53 W.	—	7·46	—	9·90
106	59 36 N.	0 41 W.	59 32 N.	0 50 W.	70	13.2.07	26.10.07	255	6·0	0·7	S. 49 W.	—	0·46	—	0·53

TABLE I.—*continued.*

Reference Number.	Position.				Depth in Fathoms.	Date.		Number of Days Adrift.	Distance in (miles) between position in 30 days.	Mean Drift (in miles) in 30 days.	Direction True.	Difference of Latitude.		Departure.	
	Cast Out.		Recovered.			Cast Out.	Re-covered.					N.	S	E.	W.
	° ′	° ′	° ′	° ′							°				
109	60 06 N.	0 27 W.	59 38 N.	0 11 E.	66	1.9.07	6.11.07	66	34·0	15·5	S. 34 E.	—	12·85	8·67	—
110	56 21 N.	1 52 W.	56 09 N.	2 13 W.	28	10.8.06	18.11.07	465	17·0	1·1	S. 44 W.	—	0·79	—	0·76
111	61 30 N.	3 03 E.	60 22 N.	0 15 E.	85	20.5.07	20.11.07	184	10·8	17·6	S. 51 W.	—	11·1	—	13·7
112	58 02 N.	2 38 W.	57 49 N.	2 44 W.	39	8.10.06	30.10.07	387	13·5	1·1	S. 14 W.	—	1·07	—	0·27
113	57 45 N.	1 00 W.	56 45 N.	0 23 E.	90	23.7.06	24.11.07	484	75·0	4·6	S. 37 E.	—	3·67	2·77	—
114	57 07 N.	1 16 W.	57 09 N.	1 36 W.	35	5.4.07	28.11.07	237	11·0	1·4	N. 79 W.	0·27	—	—	1·37
115	59 33 N.	1 07 W.	59 27 N.	1 06 W.	64	3.2.07	2.12 07	292	11·0	1·1	S. 2 E.	—	1·10	0·04	—
116	60 06 N.	0 37 W.	59 47 N	0 48 W.	65	1.9.07	7.12.07	97	20·0	6·2	S. 16 W.	—	6·0	—	1·7
117	56 46 N	1 03 E.	57 27 N.	0 42 E.	46	20.12.06	13.12.07	358	42·0	3·5	N. 16 W.	3·36	—	—	0·96
118	58 30 N.	0 43 W.	58 32 N.	0 47 W.	70	9.4.07	22.12.07	257	12·0	1·4	N. 10 W.	1·38	—	—	0·24
119	58 32 N.	1 00 W.	58 24 N.	0 40 W.	68	2.9.07	20.12.07	109	13·0	3·6	S. 53 E.	—	2·17	2·88	—
120	58 20 N.	3 02 W.	57 47 N.	3 10 W.	50	15.9.06	20.12.07	461	33·0	2·1	S. 7 W.	—	2·08	—	0·26
121	57 57 N.	0 48 W.	58 01 N.	0 10 W.	75	20.6.06	22.12.07	550	21·0	1·1	N. 79 E.	0·21	—	1·08	—
122	57 24 N.	1 07 E.	58 24 N.	1 26 E.	67	12.10.06	21.12.07	435	61·0	4·20	N. 10 E.	4·14	—	0·73	—
124	58 15 N.	0 37 W.	57 50 N.	0 32 W.	63	2.9.07	28 12.07	117	25·0	6·40	S. 6 E.	—	6·36	0·67	—
125	56 28 N.	0 53 W.	56 22 N.	1 32 W.	32	24.7.07	30.12.07	159	23·0	4·30	S. 75 W.	—	1·11	—	4·15
126	58 36 N.	1 46 W.	57 45 N.	1 00 W.	63	12.2.07	28.12.07	329	57·0	5·20	S. 26 E.	—	4·67	2·28	—
127	58 30 N.	0 25 E.	58 35 N.	0 05 E.	79	23.7.07	31.12.07	161	12·0	2·20	N. 65 W.	0·93	—	—	1·99
128	58 47 N.	1 35 W.	57 57 N.	0 15 W.	62	25.2.07	2.1.08	311	65·0	6·20	S. 40 E.	—	4·75	3·99	—
129	59 34 N.	1 13 W.	59 20 N.	1 20 W	48	10.5.07	1.1.08	236	14·0	1·78	S. 4 W.	—	1·77	—	0·12
130	58 38 N.	1 42 W.	57 56 N.	0 53 W.	74	25.2.07	13.1.08	322	49·5	4·34	S. 32 E.	—	3·65	2·28	—
131	58 33 N.	1 47 W.	58 24 N.	0 23 W.	70	26.11.06	17.1.08	417	45·0	3·2	S. 79 E.	—	0·61	3·14	—
132	57 24 N.	1 07 E.	58 10 N.	3 10 E	77	6.2.07	23.12.07	320	80·0	7·5	N. 55 E.	4·30	—	6·14	—
133	58 27 N.	1 28 N.	58 10 N.	0 43 E.	78	9.4.07	21.1.08	287	29·0	3·0	S. 55 W.	—	1·70	—	2·50
134	58 08 N.	0 25 W.	58 04 N.	1 08 W.	63	2.9.07	24.1.08	144	18·0	3·70	S. 77 W.	—	0·83	—	3·61
135	57 45 N.	2 01 W.	57 41 N.	1 58 W.	—	16.7.07	30.1.08	198	4·5	0·70	S. 21 E.	—	0·65	0·25	—
136	58 34 N.	0 47 E.	58 10 N.	0 36 E.	82	9.4.07	25.1.08	291	24·0	2·47	S. 14 W.	—	2·43	—	0·60
137	59 26 N.	1 20 W.	58 45 N.	1 20 W.	60	6.8.07	4.2.08	182	41·0	6·75	South	—	6·75	—	—
139	58 47 N.	1 35 W.	58 40 N.	0 17 E.	—	8.9.06	4.1.08	438	59·0	4·04	S. 83 E.	—	0·50	4·00	—
140	58 14 N.	2 34 W.	57 47 N.	3 08 W	42	16.7.07	3.2.08	202	33·0	4·90	S. 34 W.	—	4·06	—	2·74
141	59 22 N.	1 22 W.	58 35 N.	1 30 W.	65	10.5.07	21.1.08	256	47·0	5·5	S. 5 W.	—	5·48	—	0·48
142	58 08 N.	2 00 W.	58 05 N.	2 07 W.	38	8.4.07	13.2.08	311	5·0	0·5	S. 51 W.	—	0·31	—	0·39
144	59 21 N.	1 22 W.	59 00 N.	1 35 W.	62	6.8.07	21.2.08	199	22·0	11·1	S. 17 W.	—	10·61	—	3·25
145	59 30 N.	0 28 W.	59 37 N.	0 40 W.	73	24.2.07	26.2.08	367	10·0	0·82	N. 41 W.	0·60	—	—	0·50
146	59 25 N.	0 36 E.	59 55 N.	0 25 W.	74	5.9.06	14.2.08	527	43·0	2·45	N. 45 W.	1·73	—	—	1·73
147	58 34 N.	0 47 E.	58 32 N.	1 40 E.	63	15.8.06	14.2.08	548	28·0	1·53	S. 86 E.	—	0·10	1·50	—
148	59 03 N.	1 34 W.	58 39 N.	1 36 W.	60	10.5.07	4.3.08	299	24·0	2·41	S. 2 W.	—	2·40	—	0·08
149	58 17 N.	1 03 W.	57 05 N.	3 25 W.	62	8.4.07	14.2.08	312	33·0	3·17	S. 38 E.	—	2·44	1·91	—
150	59 13 N.	1 24 W.	58 28 N.	1 27 W.	62	12.6.06	9.3.08	636	45·0	2·12	S. 2 W.	—	2·10	—	0·07
151	58 07 N.	0 37 W.	58 10 N.	1 05 W.	62	2.9.07	5.3.08	185	15·0	2·43	N. 79 W.	0·46	—	—	2·36
152	59 34 N.	0 52 W.	58 35 N.	0 52 W.	67	10.5.07	11.3.08	306	59·0	5·78	South	—	5·78	—	—
155	56 45 N.	1 23 W.	56 15 N.	2 15 W.	25	21.10.06	20.3.08	516	42·0	2·44	S. 44 W.	—	1·75	—	1·69
156	57 24 N.	1 06 E.	57 05 N.	3 36 E.	45	16.8.06	21.3.08	583	84·0	4·32	S. 77 E.	—	0·97	4·19	—
157	58 09 N.	1 50 W.	58 00 N.	2 08 W.	45	4.7.07	1.4.08	272	13·0	1·43	S. 46 W.	—	1·01	—	0·97
159	56 04 N.	1 12 E.	58 20 N.	2 00 E.	60	6.2.07	24.3.08	412	97·0	7·06	N. 15 E.	6·76	—	1·81	—
160	56 24 N.	1 21 W.	56 08 N.	2 18 W.	—	24.7.07	9.4.08	260	36·0	4·15	S. 63 W.	—	1·86	—	3·65
161	60 04 N.	0 33 E.	59 55 N.	0 11 E.	65	1.9.07	16.4.08	228	14·0	1·84	S. 51 W.	—	1·15	—	1·43
163	59 33 N.	1 35 W.	58 30 N.	1 37 W.	59	4.7.07	22.4.08	293	63·0	6·45	S. 1 W.	—	6·45	—	0·00
164	59 26 N.	1 21 W.	58 35 N.	1 20 W.	57	10.5.07	24.4.08	350	51·0	4·37	S. 1 E.	—	4·40	0·08	—
167	58 43 N.	1 41 W.	57 50 N.	1 00 W.	75	2.9.07	10.5.08	251	57·0	6·80	S. 23 E.	—	6·26	2·66	—
168	56 34 N.	0 16 W.	56 22 N.	0 48 W.	40	5.2.07	18.5.08	468	22·0	1·41	S. 56 W.	—	0·79	—	1·17
169	58 06 N.	0 37 W.	58 18 N.	1 23 E.	75	8.9.06	17.5.08	617	65·0	3·16	N. 79 E.	0·59	—	3·40	—
170	58 41 N.	1 40 W.	58 29 N.	0 04 W.	77	26.11.06	24.6.08	576	52·0	2·71	S. 77 E.	—	0·60	2·60	—
171	56 43 N.	0 45 E.	56 32 N.	0 42 W.	40	23.7.07	3.7.08	345	51·0	4·43	S. 77 W.	—	1·00	—	4·29
172	57 08 N.	0 16 E.	57 02 N.	0 15 W.	45	14.8.06	4.7.08	690	18·0	0·78	S. 71 W.	—	1·25	—	0·74
173	57 19 N.	0 00	56 41 N.	0 11 W.	42	16.8.06	10.7.08	693	38·5	1·69	S. 9 W.	—	1·68	—	0·27
174	56 26 N.	1 27 W.	56 05 N.	2 04 W.	28	10.8.06	7.7.08	696	30·0	1·29	S. 45 W.	—	0·91	—	0·91
176	56 44 N.	1 02 W.	56 48 N.	1 56 W.	30	5.4.07	10.7.08	461	30·5	1·98	N. 82 W.	0·27	—	—	1·96
178	56 40 N.	0 24 E.	56 35 N.	0 10 W.	41	10.4.07	18.7.08	464	20·0	1·29	S. 75 W.	—	0·33	—	1·24
185	56 49 N	1 20 E.	56 53 N.	1 45 E.	53	13.10.06	27.8.06	685	14·0	0·61	N. 74 E.	0·58	—	0·17	—
187	56 34 N.	0 12 W.	56 10 N.	0 18 W.	42	13.8.06	10.10.08	787	21·0	0·91	S. 8 W.	—	0·90	—	0·13
188	56 26 N.	1 06 W.	56 15 N.	1 30 W.	35	5.4.07	19.10.08	562	17·0	0·91	S. 50 W.	—	0·58	—	0·69
189	57 12 N.	0 05 E.	56 29 N.	1 19 W.	35	14.8.06	16.10.08	793	63·0	2·38	S. 47 W.	—	1·62	—	1·74
190	60 04 N.	0 33 E.	59 27 N.	1 08 W.	67	5.9.06	26.10.08	781	62·0	2·38	S. 54 W.	—	1·40	—	1·92
193	59 39 N.	0 35 E.	59 52 N.	0 35 E.	71	1.9.07	25.10.08	419	13·0	0·93	N.	0·93	—	—	—
194	58 32 N.	0 23 E.	59 03 N.	0 35 E.	82	27.7.06	30.11.08	856	31·0	1·09	N. 7 E.	1·08	—	0·13	—
196	58 45 N.	1 42 W.	57 10 N.	0 51 E.	51	21.8.06	5.12.08	836	125·0	4·49	S. 40 E.	—	3·45	2·89	—
197	58 13 N.	1 22 W.	58 10 N.	1 20 E.	63	15.8.06	11.12.08	849	86·0	3·03	S. 88 E.	—	0·10	3·00	—
199	57 54 N.	3 31 W.	57 56 N.	3 32 W.	27	22.7.07	16.1.09	543	2·0	0·10	N. 14 W.	0·10	—	—	0·02
202	58 38 N.	0 37 E.	58 55 N.	1 23 E.	75	27.7.06	26.1.09	914	31·0	1·02	N. 51 E.	0·64	—	0·79	—
203	58 36 N.	1 46 W.	58 23 N.	1 25 W.	65	12.6.06	29.1.09	962	17·0	0·53	S. 40 E.	—	0·41	0·34	—
204	58 00 N.	2 54 W.	57 56 N.	3 00 W.	40	8.4.07	23.1.09	655	5·0	0·23	S. 38 W.	—	0·18	—	0·14

TABLE II.—Trawled Drift-bottles. Summary of results.

Area.	Nos. of bottles whose tracks lie through the said area.	Resultant	
		Direction.	Mean Drift (in miles) per 100 days.
		°	
16	111	S. 51 W.	58·6
17	111	S. 51 W.	58·6
24	111	S. 51 W.	58·6
25	22	N. 20 E.	28·0
31	43, 109, 116	S. 8 E.	33·3
32	111, 161, 190	S. 52 W.	24·3
34	15	N. 36 E.	47·3
39	14, 28, 31, 89, 115, 129, 163	S. 22 W.	10·4
40	43, 103, 106, 116, 145, 146, 152, 190	S. 22 W.	11·26
41	35, 98, 109, 161, 190, 193	S. 20 E.	10·30
42	18, 35	S. 20 E.	5·80
48	13, 28, 42, 52, 80, 82, 100, 115, 129, 137, 141, 144, 148, 150, 163, 164, 190.	S. 22 W.	11·7
49	13, 52, 98, 103, 152	S. 74 W.	17·0
50	26, 52, 146, 194	N. 89 W.	9·7
57	42, 63, 82, 93, 94, 126, 128, 130, 131, 137, 139, 141, 148, 150, 163, 164, 167, 170, 196, 203.	S. 26 E.	11·5
58	94, 100, 118, 119, 139, 152, 170	S. 63 E.	10·0
59	127, 136, 139, 147, 194, 202	S. 86 E.	2·1
60	66, 147, 202	N. 66 E.	11·0
64	120	S. 7 W.	7·0
65	112, 140, 142, 157	S. 35 W.	6·3
66	2, 41, 77, 79, 81, 82, 88, 93, 99, 126, 130, 131, 134, 149, 150, 151, 157, 167, 196, 197, 203.	S. 32 E.	14·0
67	4, 6, 11, 63, 79, 81, 82, 118, 119, 124, 128, 131, 134, 151, 169, 196, 197.	S. 26 E.	10·3
68	36, 37, 66, 133, 136, 169, 197	S. 54 E.	12·3
69	59, 122, 133, 159, 169, 197	N. 34 E.	11·3
70	59	N. 37 E.	30·7
74	54, 55, 120, 140, 199	S. 62 W.	12·1
75	54, 55, 112, 135, 140, 204	S. 60 W.	10·3
76	2, 23, 77, 88, 93, 126, 135, 149	S. 18 E.	18·7
77	5, 27, 34, 36, 65, 66, 69, 90, 99, 113, 121, 124, 128, 130, 196	S. 40 E.	13·6
78	21, 65, 69	N. 58 E.	21·7
79	59, 122, 132, 159	N. 32 E.	22·0
80	132	N. 55 E.	25·0
81	132	N. 55 E.	25·0
86	16, 17, 27, 34, 62, 114	S. 28 W.	23·3
87	23, 25, 90, 95, 113, 172, 173	S. 57 E.	2·2
88	21, 59, 117, 172, 189, 196	S. 28 E.	11·0
89	122, 132, 156, 159	S. 42 E.	16·0
97	30, 32, 62, 67, 71, 101, 155, 176	S. 76 W.	9·5
98	40, 61, 87, 91, 95, 102, 168, 171, 173, 178, 187, 189	S. 65 W.	8·6
99	91, 104, 113, 171, 178	S. 43 W.	7·07
100	30, 117, 159, 185	N. 14 E.	1·80
107	7, 10, 29, 46, 53, 70, 73, 74, 105, 110, 155, 160, 174	S. 63 W.	12·30
108	32, 46, 49, 56, 62, 68, 71, 72, 73, 74, 75, 76, 78, 86, 92, 95, 104, 110, 125, 155, 160, 174, 188, 189.	S. 58 W.	13·60
109	61, 86, 92, 96, 104, 125, 168, 187	S. 61 W.	12·10
111	30	S. 3 W.	28·3

TABLE III.—Drifts of less than Thirty Days Duration.

Reference No. of Bottle.	Position.				Depth of Water.	Date.		Number of Days Adrift.	Distance between Positions.	Average Drift in Thirty Days.	Direction True.
	Where Put Away.		Where Recovered.			When Put Away.	When Recovered.				
	Lat.	Long.	Lat.	Long.							
	° ′	° ′	° ′	° ′	Fms.						
1	58 42 N.	0 48 W.	58 30 N.	0 20 W.	73	20.6.06	14.7.06	24	19	23·8	S. 51 E.
3	56 21 N.	1 42 W.	56 25 N.	1 07 W.	37	10.8.06	21.8.06	11	20	54·6	N. 77 E.
8	59 36 N.	0 57 W.	59 30 N.	1 02 W.	62	7.9.06	17.9.06	10	6·5	19·5	S. 22 W.
9	57 27 N.	1 19 W.	57 20 N.	1 33 W.	43	8.9.06	18.9.06	10	10·5	31·5	S. 43 W.
12	57 30 N.	1 12 W.	57 22 N.	1 40 W.	39	8.9.06	2.10.06	24	17	21·3	S. 63 W.
24	59 33 N.	0 41 W.	59 27 N.	0 59 W.	72	20.11.06	24.11.06	4	11	82·5	S. 54 W.
33	58 57 N.	0 08 E.	58 40 N.	1 10 E.	74	25.11.06	22.12.06	27	36	40·0	S. 63 E.
38	58 09 N.	1 50 W.	57 59 N.	1 48 W.	45	27.1.07	5.2.07	9	10	33·3	S. 5 E.
39	58 08 N.	2 00 W.	58 6 N.	2 08 W.	40	7.2.07	14.2.07	7	5	21·4	S. 70 W.
45	57 30 N.	1 12 W.	57 41 N.	1 16 W.	51	25.2.07	9.3.07	12	11	27·5	N. 14 W.
58	57 04 N.	1 15 E.	57 24 N.	0 52 E.	50	10.4.07	23.4.07	14	23	49·3	N. 31 W.
67*a*	57 40 N.	1 06 W.	57 42 N.	1 33 W.	46	27.5.07	29.5.07	2	15	—	N. 82 W.
84	58 17 N.	1 03 W.	58 08 N.	1 04 W.	60	23.7.07	27.7.07	4	9	67·5	S. 5 W.

TABLE IV.—Bottles Stranded on Scottish Coast.

Reference No. of Bottle.	Position.		Date.		Number of days.	Distance between Positions.	Direction True.
	Where Put Away.	Where Recovered.	When Put Away.	When Recovered.			
		GROUP I.					
108	2 miles East from Out Skerries.	Near Sumburgh Head, Shetland.	22.8.06	2.11.07	437	39	° S. 27 W.
200	9 miles E. ½ S. from Noss Head, Bressay Island.	Tresta Voe, Tetlar, Shetland.	10.5.07	21.1.09	621	30	N. 3 W.
97	4 miles South from Sumburgh Head.	Hamnavoe, Bussa Isle, Shetland.	4.7.07	7.10.07	95	20	N. 10 W.
		GROUP II.					
138	34 miles North from Kinnaird Head.	1 mile South of the River Ythan, Aberdeenshire.	27.5.07	5.2.08	254	57	S. 1 E.
107	11 miles N.E. ½ E. from Kinnaird Head.	½ mile North of the River Ythan, Aberdeenshire.	4.7.07	4.11.07	123	30	S. 16 W.
64	33 miles N. by E. from Kinnaird Head.	St. Andrew's Bay ...	20.11.06	1.6.07	193	117	S. 15 W.
19	2 miles East from Kinnaird Head.	Between Rattray Head and Scotston Head.	15.9.06	4.11.06	50	7	Southerly
83	1 mile off Kinnaird Head	Broadsea Shore, Fraserburgh.	16.7.07	24.7.07	8	2	South.
135	4 miles North from Kinnaird Head.	½ mile West of Kinnaird Head.	16.7.07	30.1.08	198	4	S. 21 W.
		GROUP III.					
57	2 miles from Tarbetness, Dornoch Firth.	1 mile from Ardmore Point, Dornoch Firth.	8.2.07	21.4.07	72	6	Westerly
153	Middle of Moray Firth, Lat. 57° 57′ N. Long. 2° 53′ W.	Brora, Sutherlandshire	7.2.07	12.3.08	399	31	N. 82 W.
		GROUP IV.					
20	1 mile West of May Island	2½ miles West of North Berwick Harbour.	9.8.06	8.11.06	91	10	S. 39 W.
51	31 miles East from Fifeness.	Foxton Burn, Alumouth Bay.	13.10.06	15.4.07	184	58	S. 3 E.
179	Aberdeen Bank. Lat. 57° 15′ N. Long. 0° 47′ W.	6 miles South from Dunbar.	16.8.06	19.7.08	703	95	S. 34 W.

TABLE IV.—*continued.*

Reference No. of Bottle.	Position.		Date.		Number of Days.	Distance between Positions.	Direction True.
	Where Put Away.	Where Recovered.	When Put Away.	When Recovered.			
			GROUP V.				
47	35 miles E. by N. from Fifeness.	Crail, Fifeshire	10.8.06	6.4.07	239	40	° S. 80 W.
177	10 miles E. ½ S. from Fifeness.	Tentsmoor Sands, St. Andrew's Bay.	9.8.06	18.7.08	709	18	N. 55 W.
165	37 miles E.N.E. from Fifeness.	Tentsmoor Sands, St. Andrew's Bay.	25.7.07	4.5.08	284	42	S. 87 W.
123	10 miles E. ½ S. from Fifeness.	Johnshaven, Kincardineshire.	25.7.07	28.12.07	156	42	N. 4 E.
48	13 miles E.S.E. from Fifeness.	Auchmithie, Forfarshire	13.10.06	6.4.07	175	25	N. 25 W.
154	49 miles East from Arbroath. Lat. 56° 35′ N. Long. 1° 07′ W.	Arbroath	26.7.07	17.3.08	235	48	S. 88 W.

TABLE V.—Long Distance Drifts.

Reference Number of Bottle.	Position.		Depth of Water.	Date.		Number of Days.	Distance between Positions.	Average Rate per day.
	Where Put Away.	Where Recovered.		When Put Away.	When Recovered.			
			GROUP I.					
44	° ′ ° ′ 58 02 N.; 2 43 W.	° ′ ° ′ 57 20 N.; 9 35 E. About midway between Hanstholm and Hirtshals, Denmark.	—	14.8.06	28.2.07	198	399	2·0
50	58 01 N.; 2 45 W.	59 13 N.; 10 30 E. West Coast of Tjonco, Tonsberg, Norway.	On the beach.	8.10.06	21.3.07	164	420	2·56
201	58 08 N.; 2 00 W.	58 16 N.; 11 25 E. Gåró–Bohuslan, Sweden.	On the beach.	8.10.06	18.1.09	833	404	0·48
184	58 32 N.; 1 42 W.	58 00 N.; 7 38 E. 4 miles east from Ryvingen Lighthouse, Norway.	On the beach.	4.7.07	23.9.08	446	296	0·67
					Average rate per day =			1·43
			GROUP II.					
85	57 09 N.; 0 38 W	57 19 N.; 9 37 E. Blokhüs, Denmark.	—	21.10.06	1.8.07	284	324	1·14
186	57 01 N.; 1 14 E.	57 36 N.; 10 00 E. Tannis Bay, 1 mile east from Hirtshals Lighthouse.	—	19.12.06	5.10.08	656	285	0·43
207	56 53 N.; 1 20 E.	57 45 N.; 10 34 E. On the north side of Skagen–Denmark.	On the beach.	19.12.06	16.2.09	790	305	0·39
					Average rate per day =			0·65

TABLE V.—*continued.*

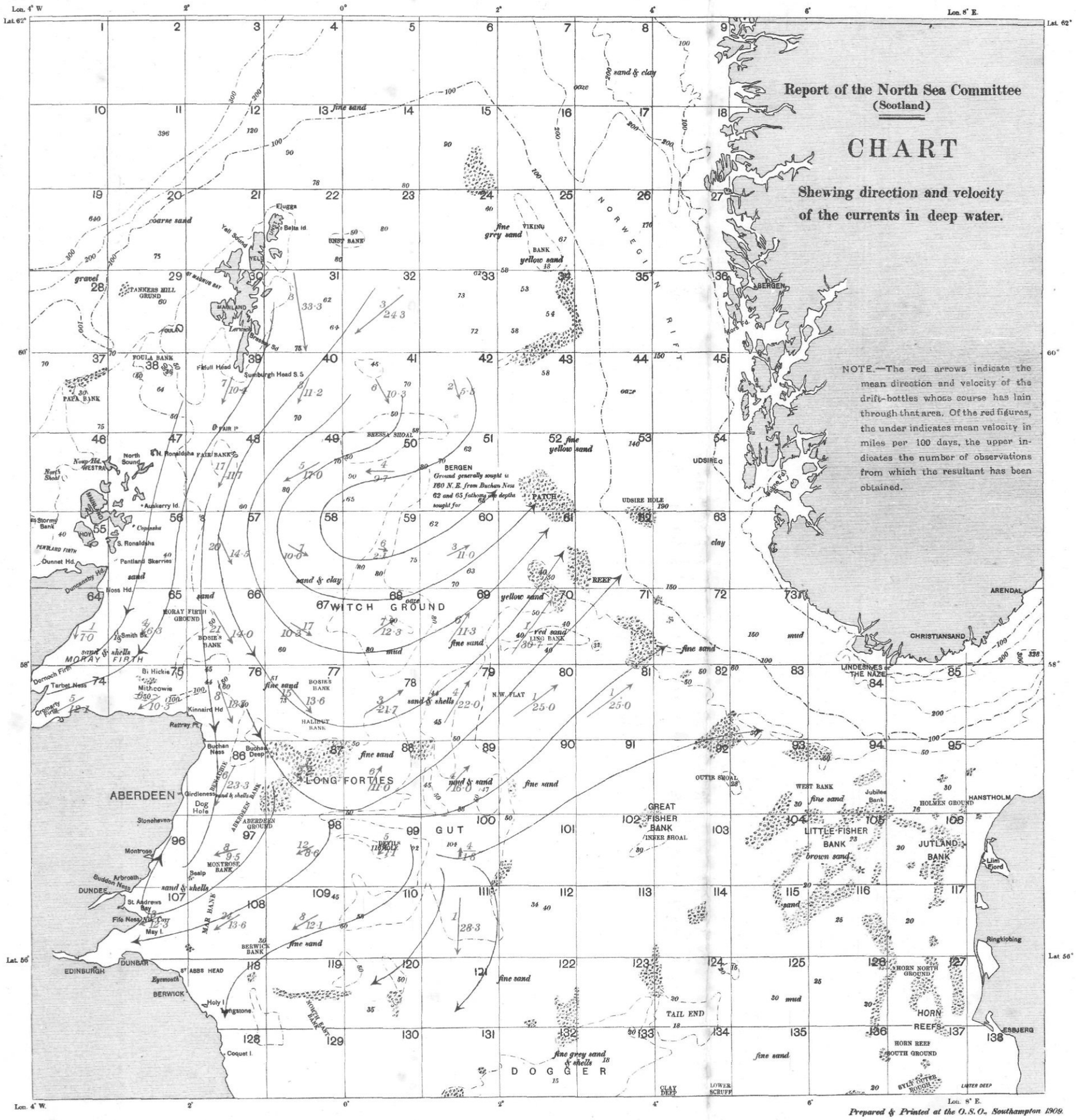
Reference No. of Bottle.	Position.		Depth of Water.	Date.		Number of Days.	Distance between Positions.	Average Rate per Day.
	Where Put Away.	Where Recovered.		When Put Away.	When Recovered.			
			GROUP III.					
	° ′ ° ′	° ′ ° ′						
162	58 22 N.; 1 45 W.	61 02 N.; 4 31 E. Utvaer Light, Norway.	70 fathoms.	20.11.06	15.4.08	511	248	0 48
192	58 17 N.; 1 04 W.	59 45 N.; 5 05 E. Melingsvaag, Norway.	On the beach.	15.8.06	11.11.08	818	210	0·26
205	57 24 N.; 0 11 E.	63 45 N.; 8 25 E. Homlingsvor Froien, near Kristiansund.	On the beach.	16.8.06	22.1.09	890	451	0·51
195	57 40 N.; 1 05 W.	59 08 N.; 5 17 E. Vigsnaes, Karmoën, Norway.	4 fathoms.	28.7.06	24.11.08	849	218	0·26
143	56 52 N.; 1 07 W.	61 46 N.; 4 53 E. Froien Island, Alansund, Norway.	—	21.10.06	11.2.08	478	346	0·73
					Average rate per day =			0·45
			GROUP IV.					
60	59 43 N.; 1 12 W.	70 40 N.; 22 38 E. 24 miles N.W. from Hammerfest.	(200 metres.)	12.6.06	25.4.07	317	883	2·78
175	58 15 N.; 1 09 W.	66 29 N.; 12 58 E. Indre Kvarö, Helqiland, Norway.	(400 feet.)	23.7.07	2.6.08	315	630	2·00
					Average rate per day =			2·39

Report of the North Sea Committee
(Scotland)

CHART

Shewing direction and velocity of the currents in deep water.

NOTE.—The red arrows indicate the mean direction and velocity of the drift-bottles whose course has lain through that area. Of the red figures, the under indicates mean velocity in miles per 100 days, the upper indicates the number of observations from which the resultant has been obtained.



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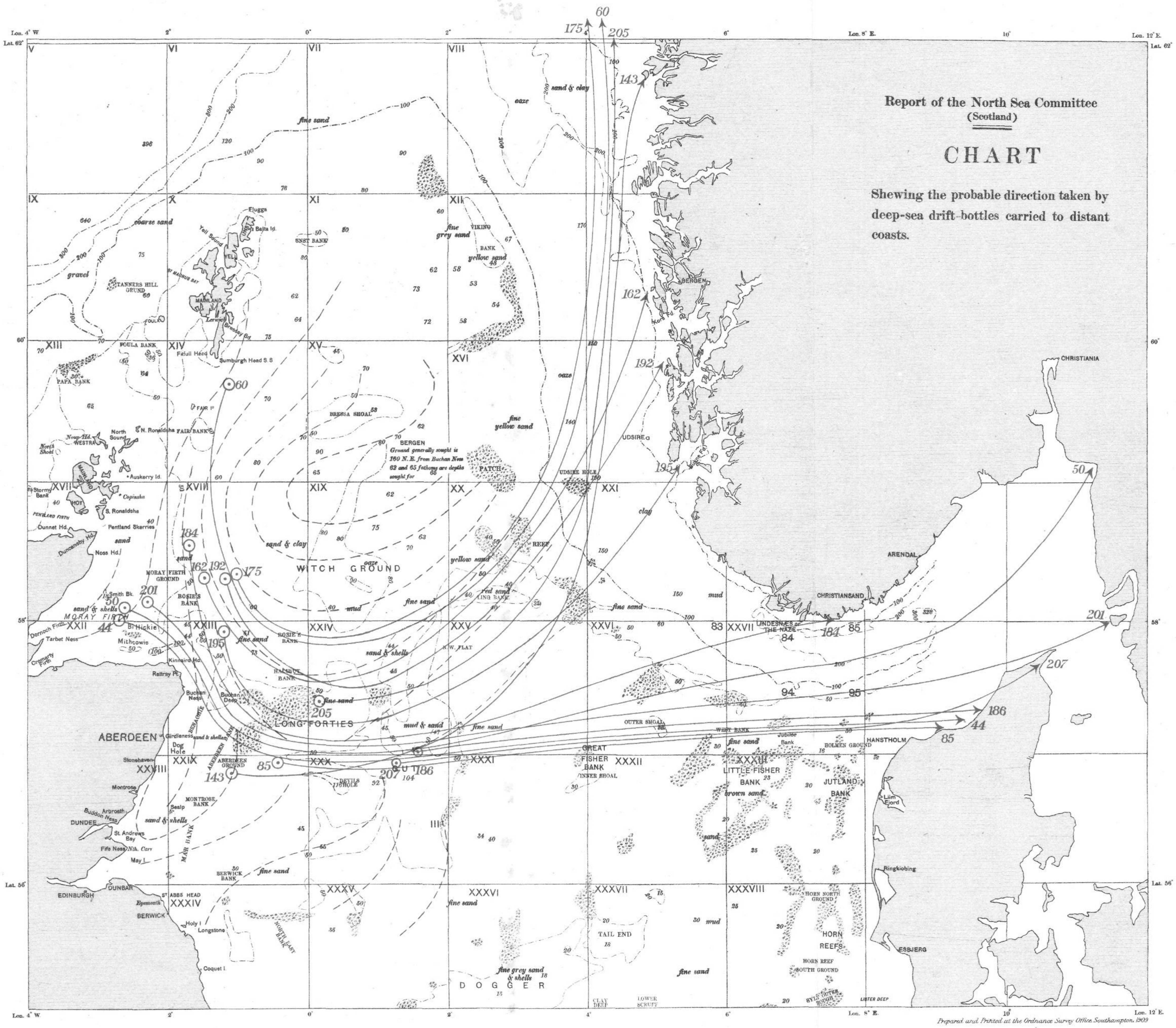
Report of the North Sea Committee
(Scotland)
CHART
Shewing the probable direction taken by deep-sea drift-bottles carried to distant coasts.
Prepared and Printed at the Ordnance Survey Office, Southampton, 1909.

Report of the North Sea Committee
(Scotland)

Chart of the NORTH SEA

Shewing the probable direction taken by drift-bottles washed up on to Scottish Coast

Prepared from Olsen's Chart of the North Sea (with additions)

Prepared and Printed at the Ordnance Survey Office Southampton. 1909.