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Recent Contributions to Oceanography

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having been filled in with the compass and plain-table. Advantage has been taken of positions previously fixed along the south coast by the Straits Government triangulation of the island of Singapore, and also of the Johore Government Surveys.

RECENT CONTRIBUTIONS TO OCEANOGRAPHY.

By H. N. DICKSON, F.R.S.E.

THE growth of knowledge concerning the depths of the great oceans is necessarily slow and irregular. In the shallower waters near land an expedition combining inquiries into different matters can be carried out with considerable thoroughness, at quite reasonable cost; but in "blue water" the expenditure of time and money involved is usually beyond what can be compassed by those most anxious to carry on the work: scientific research is impossible except to specially organized expeditions, and even these are seldom able to deal fully with more than one class of observations, the others being necessarily left to look after themselves.

Amongst the deep-sea expeditions of recent years, the "Plankton Expedition" of the *Humboldt-Stiftung* must be reckoned of special importance. The work of the s.s. *National* in the Atlantic during the summer and autumn of 1889, is now bearing fruit; and of the five large volumes of results announced, the sections already published include, besides zoological papers, a narrative of the cruise and a report on the meteorological and hydrographical observations, the two last being the work of Dr. Krümmel. The *National* sailed from Kiel on the morning of July 15th, and anchored in the same harbour on 7th November, having traversed a course of 15,000 miles—from the Butt of Lewis to Cape Farewell, Bermuda, Cape Verd Islands, Ascension, Para, Azores, and so home by the English Channel. As the primary object of the expedition was an examination of the Plankton or swimming organisms, the quantitative results of which are graphically exhibited on a map prefixed to the volume, physical investigations could only obtain a secondary place; and the narrative, where not concerned with the description of biological methods and apparatus, deals chiefly with incidents of the voyage and descriptions of the places visited. Of these latter, the accounts given of the Bermudas, of the Cape Verds, of Ascension, of Para and its neighbourhood, and of the Azores, are full of new facts; and the illustrations of persons, places, and things are characteristic to a degree.

In respect of oceanography, however, interest chiefly centres round the description and discussion of the position, form, and extent of the Sargasso Sea. After a review of the earlier accounts given by Theophrastus, Herodotus, and others, touching the existence of drift-weed

beyond the Pillars of Hercules, Dr. Krümmel concludes that the real sargasso was first encountered by Columbus, although the name (*salgazo*) is due to the Portuguese navigator, Oviedo. Various methods of estimating the amount of sargasso weed floating in different parts of the ocean were tried on board the *National*. On the outskirts of the main areas it was possible to obtain results by actually counting the floating bundles, but when these were aggregated by wind and wave into long bands, like stripes of cirrus cloud, it became necessary to make estimations from the amount of area covered and the average density at selected points. By calculating, from the records of sailing ships, the number of times the weed has been encountered in certain five-degree squares, and expressing these as percentages of total voyages across the squares, Dr. Krümmel has been able to draw lines representing the average frequency with which the sargasso occurs in different parts of the Atlantic at each season of the year. The results, reproduced diagrammatically in the following table, were first published in *Petermanns Mitteilungen*, in

	50° W.L.	45°	40°	35°	30°	
50°						
N.L.	0 0.4 — 0.3 — 0 0.6	0 0.3 — 0.3 — 0.1 1.0	0 0.1 — 0.2 — 0.1 0.7	0 0.8 — 0.3 — 0.1 0.1		
45°	0.9 3.0 — 1.9 — 1.2 2.4	0.5 2.8 — 2.5 — 2.0 4.8	0.2 2.2 — 1.7 — 1.8 2.6	0.4 1.1 — 1.1 — 1.7 1.2		
40°	1.2 4.8 — 4.2 — 4.4 6.5	1.3 4.5 — 3.8 — 2.6 6.6	2.1 3.1 — 4.3 — 3.0 9.1	1.6 0.6 — 1.7 — 2.0 2.4		
35°	9.1 8.2 — 9.6 — 11.6 8.7	11.1 9.1 — 10.5 — 12.3 9.6	5.7 7.4 — 7.5 — 6.7 10.2	1.9 2.7 — 3.7 — 4.8 5.6		
30°	The numbers show relative frequency of sargasso in 100 voyages at the following seasons:— <div><div>Spring Summer</div><div>— YEAR —</div><div>Winter Autumn</div></div>			9.5 7.8 — 9.4 — 9.1 11.83	6.1 2.4 — 4.4 — 5.3 4.0	
25°				8.4 6.0 — 5.6 — 6.1 1.8	5.7 2.9 — 3.0 — 2.4 0.8	
20°						

SARGASSO WEED IN THE NORTH ATLANTIC.

1891. They show conclusively that the bundles of weed are derived from the shores of the Gulf of Mexico, and that their concentration is at least partly due to the Gulf Stream bringing up supplies faster than the drift currents are able to carry them away.

Coming next to the purely physical and meteorological work, contained in the third part of the first volume, we have to regret that the limited time at the disposal of the expedition, and the comparatively slow steaming speed of the *National*, almost entirely prevented the taking of special soundings. A number of temperature observations were made at various depths with a reversing thermometer attached to the dredge rope just above the net, but apart from the inherent uncertainty as to the actual depth of the instrument below the surface, this method can scarcely be relied upon, and at best the result may be taken as merely confirming the work of previous expeditions. Zoological work and surface observations do not, however, mutually interfere, and between air and water the staff of the *National* left but little undone. An important series of observations with a standard anemometer affords, when compared with estimations of wind force, so strong a confirmation of the results of the *Gazelle* expedition, that we may accept the following table as a correct valuation of the numbers of Beaufort's scale:—

Force—Beaufort Scale	2	3	4	5	6	7	8
Wind velocity, miles per hour	7·6	11·4	15·9	21·0	26·2	31·8	36·2

Observations of the movements of the upper clouds in equatorial latitudes agree with those discussed by Dr. Gerhard Schott, in the paper noticed below, in showing that the motions of the upper atmospheric currents in those parts are by no means so simple as has been supposed. Between the equator and 10° N. lat. the prevailing direction is undoubtedly westwards, and during the summer months this holds good up to 20° N. lat. During winter, however, the most frequent direction in the higher latitude is with the anti-trade from south-west. Krümmel has shown that between 0° and 10° N. shallow depressions are met with at all times of the year, while between 10° and 20° N. they occur chiefly during the south-west monsoon, and as these depressions move almost invariably westward, he regards the deflection of the cirrus clouds as evidence that they are associated with such cyclonic disturbances. It seems necessary, without entering into a discussion of the question, to accentuate the fact that the true cirrus cloud of the high atmosphere is but seldom observed in low latitudes, and that, as Krümmel remarks, most of the cirriform clouds recorded really belong to the intermediate or anti-trade wind layers.

In another paper Dr. Krümmel discusses first the rain-squalls of the horse latitudes, showing that these are associated with local ascending currents; and second the sea-breeze at Para. In the estuary of the Para, as at Cadiz, the Camaroons, and elsewhere, it is noticed that the sea-

breeze attains remarkable strength at the beginning of flood tide, and especially during springs. As the normal sea-breeze moves considerably faster than any tidal current, it is evident that the increase of its speed cannot be due to a dragging action of the water, but rather to the change of pressure gradients caused by the raising up of the air lying on it. The phenomenon can therefore only occur in large estuaries, where the relative alteration with respect to the land is greatest. It is remarkable in this connection that at Campbeltown and other fishing stations near the entrance of the Clyde Sea Area, there is a popular belief that if the barometer falls quickly during flood tide, and the wind does not at the same time correspondingly increase, there will be no change during the succeeding ebb tide, and the storm may be looked for with the first of the second flood. This is recognized as a quite local peculiarity, and the belief is not current in any other part of the west coast of Scotland.

We may take it that for the present the chief aim of the oceanographer is to extend, and at the same time to simplify, the various methods of tracing the movements of bodies of water in the sea by means of physical or chemical peculiarities observable in the water itself; and the second half of the paper before us contains a masterly review of the present state of knowledge with regard to the examination of sea-waters, as well as important additions to the same. In the matter of temperature observations, Negretti and Zambra's reversing thermometer, especially when mounted in the "Scottish" frame, leaves little to be desired for accuracy or simplicity, and the water bottles of Sigsbee or Mill are trustworthy in action with reasonably smooth seas. Troubles may be said to begin with the examination of the samples collected, and where we are only concerned with means of identification, they centre chiefly round the determination of density or salinity. It may be seriously doubted if the very high degree of accuracy demanded by some investigators is really necessary; certainly any theory of circulation involving accuracy in density determinations to the fifth or sixth place of decimals may well be open to question, and in most cases the differences actually observed are much greater; but it must be admitted that we require to know the fourth place of decimals accurately, and ought to have at least some notion of the fifth, corresponding to about 0.10 part by weight of the total salts contained in 1000 parts of ordinary sea-water, or a difference of 0.1 per mille in the salinity. The method of weighing equal volumes of the sample under treatment and of distilled water in a "pycnometer" is certainly the most correct for direct determination of density, but its use involves considerable time and labour, and is, of course, impracticable at sea. Next in importance comes the hydrometer method, but here difficulties are endless. In order to obtain sufficient sensitiveness, and at the same time to include the whole range of densities met with, it is necessary to have either

some means of varying the weight of one hydrometer, as in Buchanan's *Challenger* type, or to employ a series of separate instruments, as in Dr. Kùchler's sets of Kiel hydrometers. In either case consistent results within the limit may be obtained, provided the temperature is fairly steady at the time of making the observations; sets of determinations made at about the same temperature with the same hydrometers give satisfactory comparative information, but considerable difficulty arises in ascertaining the absolute values, and it appears that whatever method is adopted for determining the instrumental constants, these should be fully controlled by experiments with waters of known density. The great source of uncertainty in hydrometer determinations is due to the fact that it is difficult to ascertain the temperature accurately, and almost impossible to keep it constant, and it is necessary to introduce corrections which require a knowledge of the change of volume with temperature of not only the hydrometer, but of the water under examination. The variations of specific gravity with temperature in waters of different salinities have been determined by various experimenters, whose results have recently been subjected to a very searching comparison and discussion by Dr. A. Schùck of Hamburg (*Ausland*, 1893, Nos. 40 and 41). Within reasonable limits of temperature and salinity, it seems unlikely that the volume corrections of the water introduce much error, but those of the hydrometer may be another matter. In passing, it seems again a duty to deplore the utter and hopeless confusion in the standards of temperature to which densities are to be referred: different methods undoubtedly adapt themselves best to different standards, and much is got over by the translation into terms of "salinity," but there are limits to the multiplication of results which cannot be compared. Fifteen degrees Centigrade is a convenient working temperature, and dynamical problems demand a recognition of the maximum density point of water—so why not adopt Prof. Pettersson's standard of sea-water at 15° C. referred to distilled water at 4° C.?

Of what may be called indirect methods, that of estimating the total halogen, usually spoken of collectively as chlorine, tends to supersede even the hydrometer in practical work. Amongst its many advantages, the facts that it can be carried out at sea, and that it requires but small quantities of the water samples, are specially in its favour. Given, however, the chlorine in a kilogramme or litre of sea-water, its density and salinity are still somewhat to seek; and here we come upon some of the most important recent work. From an examination of 133 samples, Forchhammer, who may be regarded as *fundator noster* in these matters, concluded that the salinity of any sea-water could be obtained from the chlorine in a kilogramme by simply multiplying the latter quantity by a constant coefficient, *i.e.* that the chlorine was, in all sea-waters, a constant fraction of the whole salts present. Forchhammer fixed the chlorine coefficient at 1.811, and Ekman, Tornøe, Dittmar, and

Jacobsen found approximately the same values. Pettersson, however, in revising Ekman's work, found that if the samples were arranged into groups according to their salinity, the chlorine coefficient was smaller with the higher salinities, and conversely. Dr. Krümmel gives an exhaustive review of existing material from this point of view, and shows that the chlorine coefficient increases with diminishing salinity, at first slowly, and then faster and faster, or, in other words, it is found that chlorine forms a smaller proportion of the total salts the fresher the water. This would indicate that the dilution of sea-water by rivers is accompanied by the addition of a fairly constant proportion of salts, amongst which chlorides occupy but a secondary place; but it may be doubted if this constancy can be sufficiently trusted to allow of the universal application of the new chlorine coefficients. So far, the greater number of determinations have been made with brackish waters from the Baltic, and it would be interesting to see if the same values hold good for estuarine waters generally. The recent analyses of bottom waters by Murray and Irvine (*Trans. R. S. E.* xxxvii. p. 481) certainly show that there are other influences at work tending to alter the ratio of the chlorine to other salts in sea-water, and great caution must be exercised in making any assumptions of a general nature.

In computing *density* from chlorine, we meet the familiar "Dittmar's D," but here in the new form of an equation of the second degree. The advantage of dealing with litres of sea-water instead of kilogrammes is undoubted where volumetric methods are concerned, but this seems to be more than neutralized by the fact that "Chlorine per litre" involves a standard temperature, about which differences of opinion have of course arisen, as well as by the quadratic equation required in any calculation. From the various values for the coefficients in this expression, Dr. Krümmel revises the values of the factor for computing the salinity direct from the density, using different sets of data, and obtains a number practically the same as that of Karsten generally used. It may be noted that the uncertainty in this value is greater than that affecting density determinations of even comparatively modest pretensions.

With the aid of the surface observations made during the cruise of the *National*, Dr. Krümmel has revalued the older data of the surface salinity of the North Atlantic, and a new map is appended to his paper, which he observes resembles Buchanan's *Challenger* chart more closely than it does that published by the Deutsche Seewarte. The most striking feature of the map is the manner in which it shows that the densest surface water is found where evaporation goes on most actively, not where the insolation is strongest.

Among new methods of determining density indirectly, Dr. Krümmel's modification of Abbe's differential refractometer, first tried on board the *National*, promises excellent results. The chief difficulty with this instrument lies in correcting the optical comparison of salt water with

fresh for temperature; a difficulty which, it would seem, might be got over by using salt water of known density as a standard instead of fresh. Practical workers in this field will be glad to know that Dr. Krümmel is developing further improvements in what we may expect to be an invaluable instrument for sea work.

Practically a new departure is made in the application of Forel's "Xanthometer" scale to the observation of the colour of the surface of the sea. Combining the observations of the *National* with those made by Dr. Schott in the voyage already referred to, a chart of the North Atlantic has been prepared, in which the surface is coloured according to the percentage of yellow in the corresponding colours of the scale. Comparing these, which obviously allow of more rigorous treatment than the usual purely descriptive colour observations, with the observations of transparency, Dr. Krümmel concludes that the more transparent the water the purer the blue colour of its surface, and the less transparent, the more the colour tends to green. Dense warm water would seem to be bluer and more transparent, other things being equal, than water not so warm or so dense; but the conditions are so complicated by the number and nature of the solid particles in suspension, that it is extremely difficult to establish any general relations.

In *Ergänzungsheft* No. 109 of *Petermanns Mitteilungen* Dr. Gerhard Schott gives an interesting, if somewhat diffuse, account of a voyage made by him in 1891 and 1892 to the East Indies and Japan. Dr. Schott's observations were also unfortunately confined to "between wind and water," and in the first half of his paper, which deals exclusively with hydrography, the work is of a similar scope to that of Dr. Krümmel. The chart showing the salinity of the surface waters of the South Atlantic fits in excellently with that of the North Atlantic noticed above, and that of the China Sea and the region between the Indian and Pacific Oceans affords new information of considerable importance. Dr. Schott's observations of surface currents in the higher southern latitudes are of extreme interest, and although some of his conclusions certainly require the support of observations at greater depths, they give further indications of drift currents from a great Antarctic anticyclone.

In the second part of his paper, Dr. Schott describes his meteorological observations, and gives an account of the working of Assmann's aspiration psychrometer on board ship. Some remarkable observations were made on the effects of tropical rains on the sea and air: it was found that even heavy continuous rain altered the temperature and salinity of the surface water but little, while the change of air-temperature was considerable. In a section devoted to the temperature relations of the air and surface water, Dr. Schott confirms the general conclusion that the water is on the whole slightly warmer than the air lying upon it. It would appear, however, that there are important exceptions to

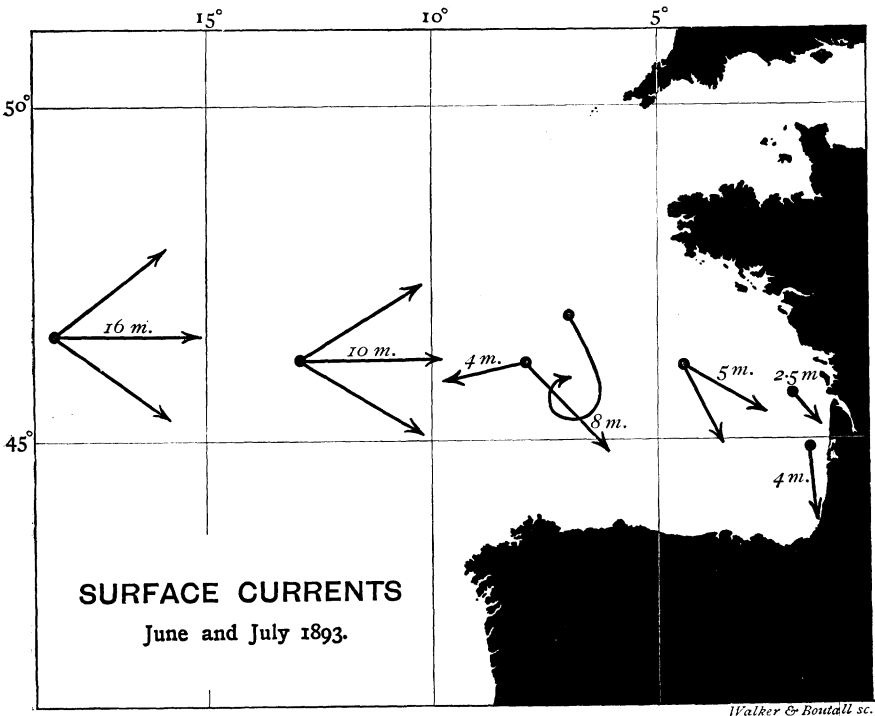
this rule, which Dr. Schott omits to notice. If, for example, we compare the air-temperatures for the North Atlantic in the *Challenger* Report on Atmospheric Circulation with the surface-temperature charts for the same area published by the British Meteorological Office, we find that the air is in many cases somewhat warmer than the sea, answering to the general condition that the usual state of things is reversed where the water is welling up or is part of a cold current. Toynbee, from 25,000 observations, concluded that in the North Atlantic the sea was on the whole warmer than the air in autumn, colder in summer, and that the temperatures were equal in spring.

Considering the numerous difficulties which arise in the course of identifying samples of sea-water from their chemical or physical peculiarities, and the pitfalls which beset any attempt to draw definite conclusions from such identifications, there is much to be said in favour of the old methods of mapping surface currents from the drift of floating objects, whether these be specially prepared floats, as in the investigations of H.S.H. the Prince of Monaco, or derelict ships as tracked by the Hydrographic Office of the United States. The most important recent application of this method is an extension of the Prince of Monaco's "Bottle-chart," by M. Hautreux, vice-president of the Society of Commercial Geography of Bordeaux, who publishes two short papers in the Society's *Bulletin* (Nos. 14-15 and 22, 1893). It has long been suspected that the accepted views concerning a steady northerly current, usually known as Rennell's, moving along the French coast in the Bay of Biscay, were erroneous; and, as M. Hautreux shows, recent research has brought forward no evidence of its existence. Bottles thrown overboard from the Prince of Monaco's yacht while following a course close to the meridian of 18° W. long. drifted invariably southwards of east, and were for the most part found on the Landes coast. To settle the matter, a first series of bottles, numbering thirty-five in all, were supplied to the fishing authorities at Arcachon and to the steamers of the Messageries Maritimes sailing from Bordeaux. These were put overboard at distances of 10 to 100 miles from land during June and July, and twenty-one were recovered, all on the Landes coast. Taking account of wind and tide, M. Hautreux found that the rate of motion diminished as the land was approached, varying from 5 to 6 miles per day 100 miles out to 1 mile and under close inshore, and that the motion was more southerly near the head of the gulf; also that the greatest number of bottles came ashore at spring tides. We reproduce a chart showing the general results. Continuing the investigation during August, September, and October, it was found that with the more variable winds the movements of the bottles were extremely erratic. Only about one-fifth of those put into the sea were recovered, and, although some were found to the north of their starting-point, their course had evidently been slow and tortuous. M. Hautreux' investigation has quite disposed of the northerly

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Rennell current, and shown that instead of an active division of the drift current from the Gulf Stream in the Bay of Biscay, the water simply loses its proper motion as it approaches the part of the coast bordered by sand-dunes, and follows the prevailing winds, just as it does, for example, on the east coast of Scotland. We may take M. Hautreux' paper as another striking illustration of the variability of surface drift cur-



rents, and of the danger incurred by navigators in trusting implicitly to current charts. One of the leading results of recent oceanographical research is to show that surface drift currents vary in direction and speed almost as widely as do the winds which cause them, and that in different years and different seasons the same parts of the sea may contain water derived from widely different sources.