Immigration of a Plankton Diatom into a quite new Area within recent years; Biddulphia sinensis in the North Sea Waters.

By

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With 9 text-figures.

In a newly published paper I have communicated the data concerning the immigration of the plankton diatom Biddulphia sinensis Grév. into the North Sea area.[1]) As this case seems to me of special interest with regard to the study of the wanderings of plankton organisms and for the understanding of the connection between plankton and sea currents, I shall here give a summary of my main results. —

One of the many problems taken up by the International Cooperation for the Study of the Sea has been to obtain a fuller knowledge of the plankton within the area investigated. For this purpose plankton has been collected during the quarterly hydrographical cruises carried out from all the participating states. The results of the examination of this vast material have been published in a periodical „Bulletin" in the form of large plankton lists or tables, but this material has not yet been worked out in a more comprehensive manner. From this „Bulletin" I have taken most of my data concerning the occurrence of Biddulphia sinensis.

It was when examining the plankton samples from the November 1903 cruise in Danish waters, that I found this large and peculiar plankton diatom (see fig. 1) which I knew well from the plankton of the Red Sea and the Gulf of Siam. The appearance of this Indo-Pacific species in the Skager Rak and that in great quantities seemed to me very strange and

[1]) On the Immigration of Biddulphia sinensis Grév. and its Occurrence in the North Sea during 1903—1907, and on its Use for the Study of the Direction and Rate of Flow of the Currents (with 4 charts and 5 text-figs.). — Meddelelser fra Kommissionen for Havundersögelser, Serie Plankton, I, 6, 1908, Köbenhavn.

well worthy a closer study. During the following years I paid attention to all accessible data concerning its distribution and its seasonal occurrence, hoping to get some interesting results. After the lapse of four years I decided to terminate the investigation and publish the results, as it seemed to me that the matter was definitely settled. —

According to the plankton tables from August 1903 published in the „Bulletin", Bidd. sinensis was nowhere found in the North Sea or the adjacent seas within an area reaching from the English Channel in

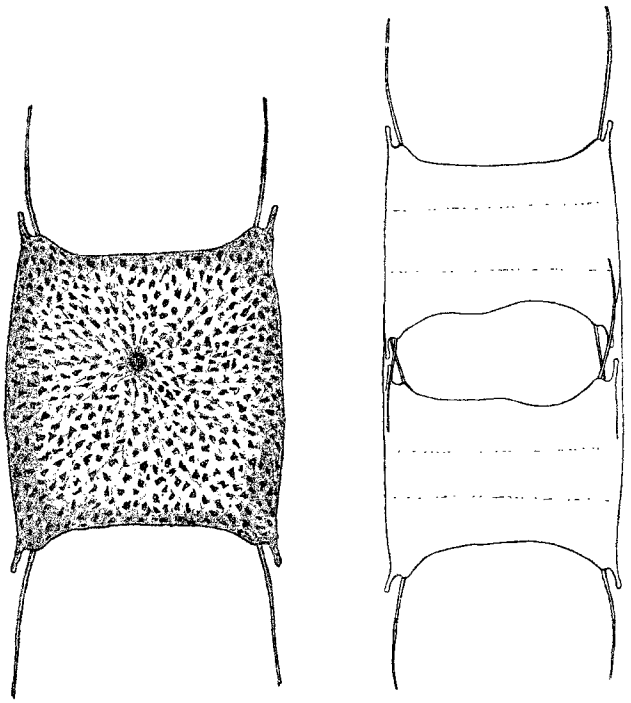

Fig. 1. Biddulphia sinensis Grev.
A fully developed specimen with chromatophores and nucleus; two new formed daughter cells (× 165).

the south through the southern, the south-eastern and the north-western North Sea to the Norwegian Sea in the north, and further through the Skager Rak and the Kattegat to the innermost part of the Baltic in the north-east. But in November the conditions were quite different, as illustrated on the chart (fig. 5). Bidd. sinensis was now present within a territory of the North Sea which extended westwards to ca. 4° E. Long., southwards to the mouth of the river Elbe and eastwards to the Skager Rak and Kattegat to ca. 56° 30′ N. Lat., and in many of the samples it was the dominant species. On the

other hand it was not recorded from the southern North Sea or the Channel, nor from the northern North Sea off Scotland, nor from the Baltic. The question then naturally arose: How can we explain this sudden and numerous appearance of a plankton diatom in regions where it was previously unknown? The first thing to do was to be sure that it had not been overlooked or mistaken in the samples from the parts of the North Sea from which it was not reported. This has been done, and I feel quite sure that it did not occur outside the above mentioned area. It was thus unlikely that it had been carried by the currents into the North Sea from the north or from the south. It would also have been difficult to understand, how this could have been the case, as Bidd. sinensis seems to be lacking in the whole Atlantic Ocean[1]) both on the American and on the African-European sides, — except for this new occurrence in the North Sea. Further, it would be unlikely to suppose that is was stationary in the North Sea earlier than 1903, as plankton investigations have been carried on here for many years, and it has never before been found. Finally it need hardly be said that it did not come from the brackisch water of the Baltic.

Thus, as for as I can judge, there is no other explanation of its sudden appearance than the following: It has been drawn in from afar by the aid of man, that is to say, carried along from distant oceans by ship, e.g. attached to the outside of a ship, or living in the water of the hold, or in the water of a used bucket or the like. Outside the Atlantic Ocean the species has been found in the coastal waters from the Red Sea eastwards through the Indian Ocean to Japan, i. e., it is a tropical (and subtropical) neritic Indo-Pacific form, and it will be most natural to suppose that it has been carried from the Indian Ocean or the Red

[1]) In my paper I quote Bidd. sinensis from the sea off Guyana upon the authority of the late Professor P. T. Cleve. In his paper „On the seasonal Distribution of Atlantic Plankton Organisms" (Göteborg 1900) he records it from two samples collected in March and June 1898 respectively, but only in small numbers. As I had some doubts as to this record, thinking that is might perhaps be some other species, I asked the zoological department of the Göteborg Museum where Cleve's material is kept, to lend me the two samples for examination. Through the kindness of the keeper Dr. L. A. Jägerskiöld, to whom I here tender my best thanks, I received the slides made from these two samples and found that the Biddulphia present there (in one of them I did not find any Biddulphia) was not B. sinensis, but a large form (f. tropica n. f.) of the related species B. regia (Schultze) Ostf., an inhabitant of the warmer coasts of the Atlantic. I give here two drawings (Fig. 2) of the form found in Cleve's material and add for comparison figures of the typical B. regia (Fig. 3) and of B. mobiliensis (Fig. 4) taken from my paper; all these together with B. sinensis (Fig. 1) form a natural group of species within the genus.

Sea by one of the many steamers which trade to Hamburg. In accordance with *this supposition* we have the fact that its first recorded occurrence in the North Sea is in the S. E. corner, consequently off Hamburg. The exact time

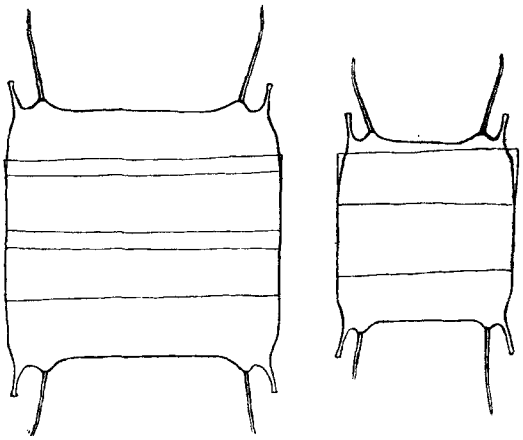

Fig. 2. Biddulphia regia (Schultze) Ostf., f. tropica n. f., from the Sea off Guayana (10° N. Lat.; 52′ 45′ W. Long). (Same magnification as in B. sinensis).

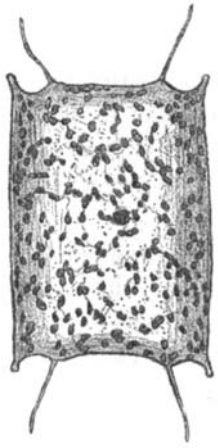

Fig. 3. Biddulphia regia (Schultze) Ostf. A fully developed specimen. (Same magnification as in B. sinensis).

for the immigration is not known, but it made its appearance — which nearly coincides whith its maximum development („flowering time") — at the Danish lightship Horns Rev (55° 34′ N. Lat., 7° 19′5 E. Long.) in October 1903 (not present on the 1st of Oct., main form of the plankton on the 15th), and supposing some time for development from the — probably — few introduced specimens to the enormous quantities found in the middle of October and in November, it would be reasonable to take September as the immigration time.

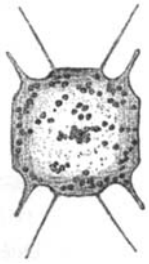

Fig. 4. Biddulphia mobiliensis (Bail.) Grun. A fully developed specimen. (Same magnification as in B. sinensis).

As far as I know, it is the first time that we have been in any way able to follow an immigration of a plankton organism so closely and to fixe the date approximately exactly. Such an introduction from afar is very strange and probably very rare. Nevertheless we know of some cases of immigrations of higher fixed Algae which have much resemblance to it. E. g. Bonnemaisonia hamifera whose home is the coasts of Japan and California, was some years ago found in the Channel on the coast of England and, later, on the coast of France. (Also other parallels are given in my paper).

The fortnightly plankton collections from Danish lightships enable us

to find, that Bidd. sinensis follows the north-going current along the Jutland peninsula. This can be seen from the following data: It was present, as mentioned above, at Horns Rev on Oct. 15th; at Skagens Rev (The Skaw; 57° 46′ N. Lat., 10° 43,3′ E. Long.) not on Oct. 15th, but for the first time on Nov. 2nd.

The water of this current had a salinity of 33—34 per mille and a temperature of 12—14° C; this is comparatively low for a tropical species: but that it thrives well under these conditions, is evident when we learn that Prof. C. Apstein[1]) has reckoned over 4 million specimens in 1 m^3 water at a station off the Jutland coast (ca. 55° N. Lat.) on Nov. 12th.

The symboles for frequency used in the plankton tables of the „Bulletin" show, that Bidd. sinensis within its distribution area in Nov. 1903 was one of the main forms of the plankton in the part of the North Sea close to the Jutland coast and in the whole Skager Rak from the south point of Norway to off Göteborg, while it was more rarely present in the samples taken in the North Sea west of the above area and in the Kattegat. In the chart (Fig. 5) the distribution and frequency are given in detail.

In my paper quoted 14 small charts show the distribution of our organism in February, May, August and November of the years 1904—07. In all charts the same series of marks (dots) gives the occurrence or non-occurrence, and — if present — the frequency of it at all places where plankton samples have been taken at that time. I may now give an abstract of the occurrence and the variations with regard to time and place observed in 1904—07 and laid down on these charts, five of which are reproduced in the present paper.

When we compare the conditions in February 1904 (Fig. 6) with those of Nov. 1903, we find that Bidd. sinensis is still present, but comparatively rare in the North Sea off Jutland. In the Skager Rak it is common as in November, and from there it has wandered with the under-current through the Kattegat, Great Belt and the Belt Sea into the Cadet Deep north of Warnemünde (Western Baltic). It occurs in this area only in the under-current and is only present in small numbers (most, probably all, specimens dying or dead). We have here a fine example of its serviceableness as indicator of the under-current from the Skager Rak southwards into the Baltic. At the same time our organism has wandered from the Skager Rak up along the west coast of Southern Norway (compare later, p. 373) and has reached ca. 61° 30′ N. Lat., here only occurring in the upper layers of the water, just where the influence

[1]) Apstein, C., Plankton in Nord- und Ostsee auf den deutschen Terminfahrten I. — Wissenschaftl. Meeresuntersuchungen, Abt. Kiel, 1905, N. F., Bd. IX, p. LIII.

of the coastal current could be marked on the salinity; another fine example of its importance for hydrographical questions.

It is very strange that it lives so well in spite of the low temperature ruling in February, but, although numerous, it is not so dominant as in November. Probably its best thriving period is over, and it is at

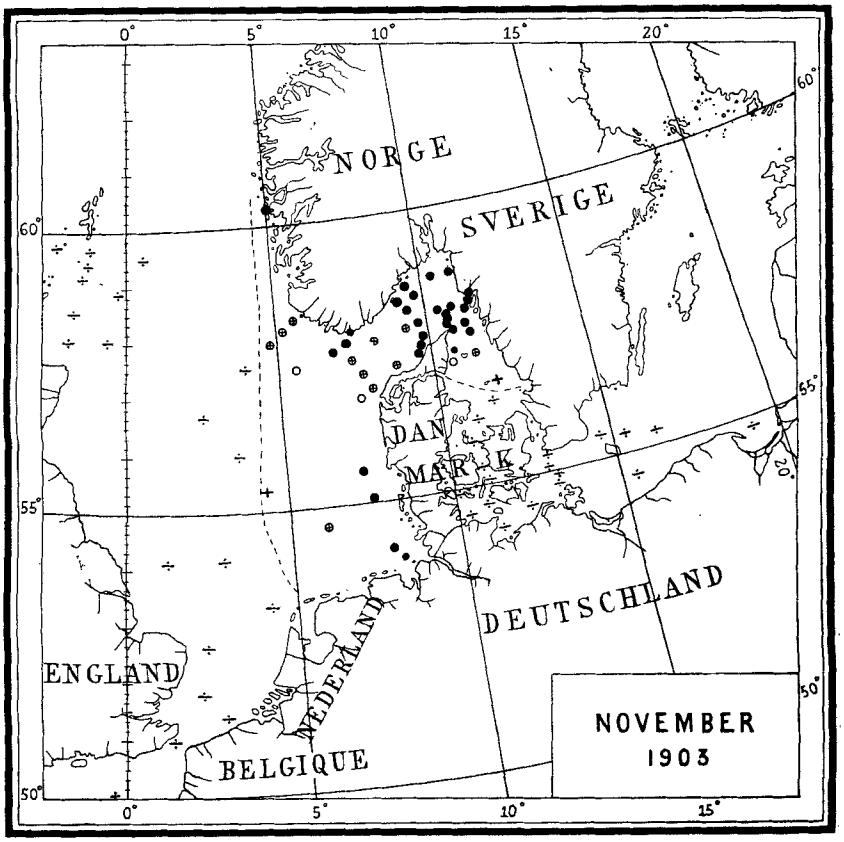

Fig. 5. Distribution of Bidd. sinensis in November 1903.

● = very common, • = common
⊕ = not uncommon ○ = rather rare
+ = very rare × = present
÷ = absent.

a kind of standstill, in the course of which most of the individuals die off. This becomes evident, when we look at the May chart (Fig. 7): here we find only few records of it, and all give it as rare. The same is the case in August (Fig. 8); but now a new flowering period begins again at the S.E. corner of the North Sea (Heligoland), and in November 1904 we get almost the same distribution and maximum development as in the

year before. Such is the seasonal cycle of Bidd. sinensis during its first year of occurrence in the North Sea. But in November 1904 there is one point more of interest, namely its appearance off the coast of Belgium. How it has come here, is now the question. And I must admit, that I have no definite answer, but I suppose that it has followed some reversed branch of the North Sea circular current, in spite of the

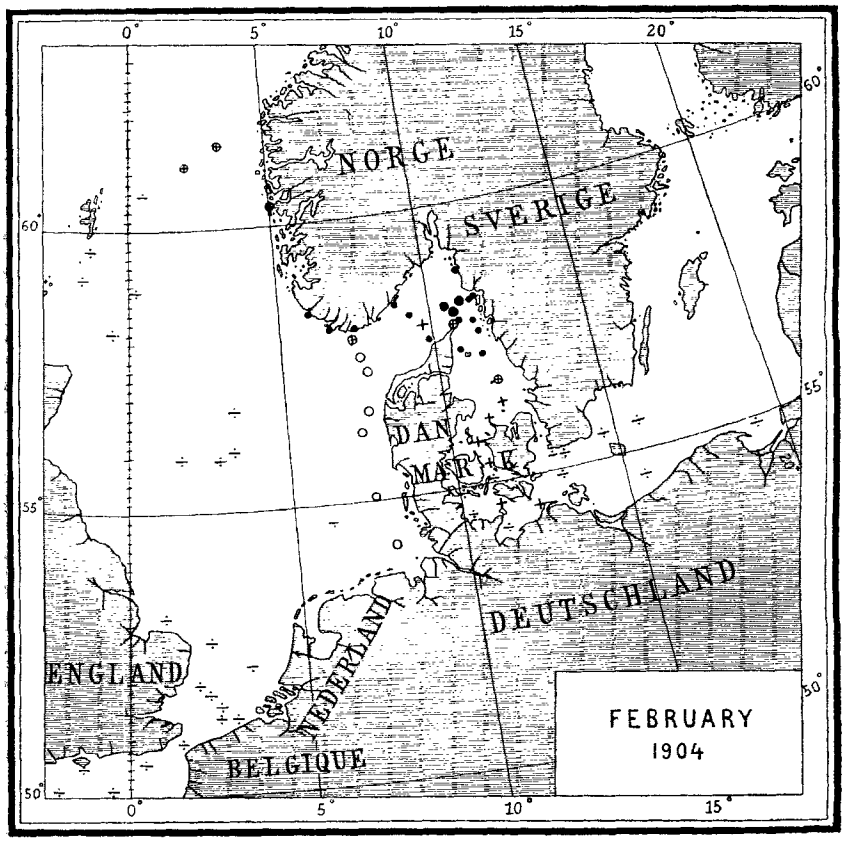

Fig. 6. Distribution of Bidd. sinensis in February 1904.

curious fact, that it does not occur at the Dutch stations north of the Belgian ones. (It is present not at the English Channel stations). Space does not allow me to explain this supposition here; I must refer to my paper (p. 15—17). Another supposition is that it has come to the Belgian coast by means of ships from those parts of the North Sea where it occurred earlier.

The distribution and the seasonal occurrence in 1905 and 1906 are almost as in 1904, and here is not the place to enter further upon the

details. Some few points deserve however to be mentioned. In February 1905 Bidd. sinensis occurs as far eastwards as in samples from Dantzig Bay at the S. E. corner of the Baltic; it must therefore have followed with the under-current as far as to this spot, thus showing that North Sea water penetrates during the winter time far into the Baltic and renews the bottom-water here.

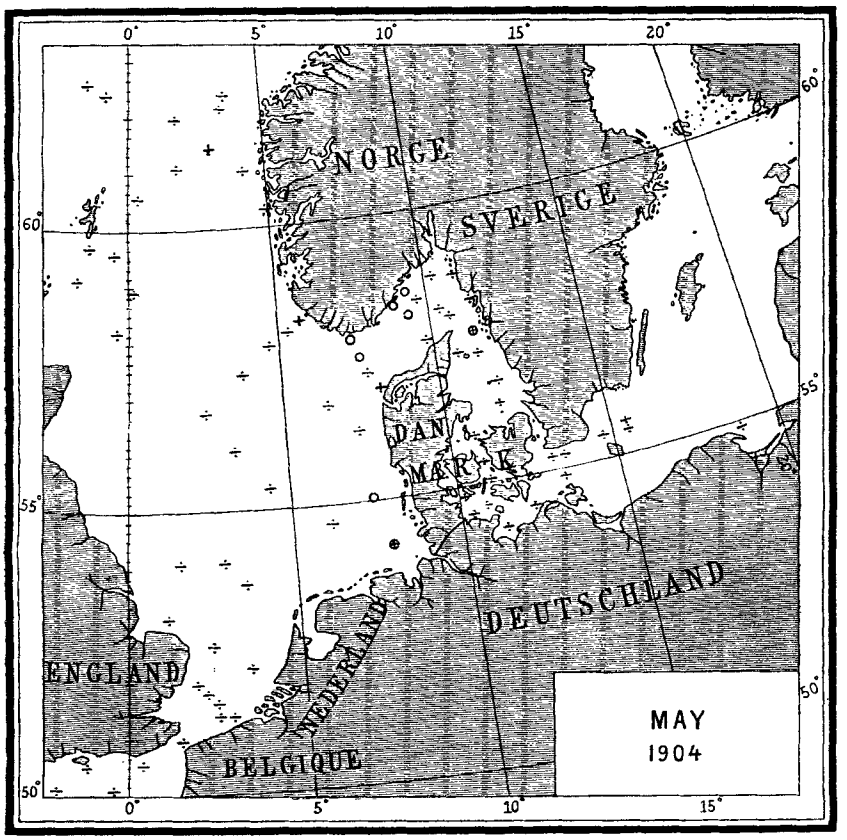

Fig. 7. Distribution of Bidd. sinensis in May 1904.

In the southern North Sea off Belgien and Holland our organism becomes quite stationary in 1905 and 1906 and a dominant feature in the autumn plankton; on the whole its distribution in the North Sea grows somewhat more extensive, but nevertheless it does not reach the western part (off Great Britain), and it has not yet been found in the Channel. The chart for Febr. 1907 is reproduced here (Fig. 9) to show the situation three and a quarter years after the immigration. It is sur-

prising how similar the situation now is with that of Febr. 1904 (Fig. 6). We learn that Bidd. sinensis has its principal occurrence in the Skager Rak. Towards the east we find it until north of Rügen in the western Baltic; towards the north it has an unusually advanced post north of Scotland, and towards the south its limit is just in the mouth of the Channel.

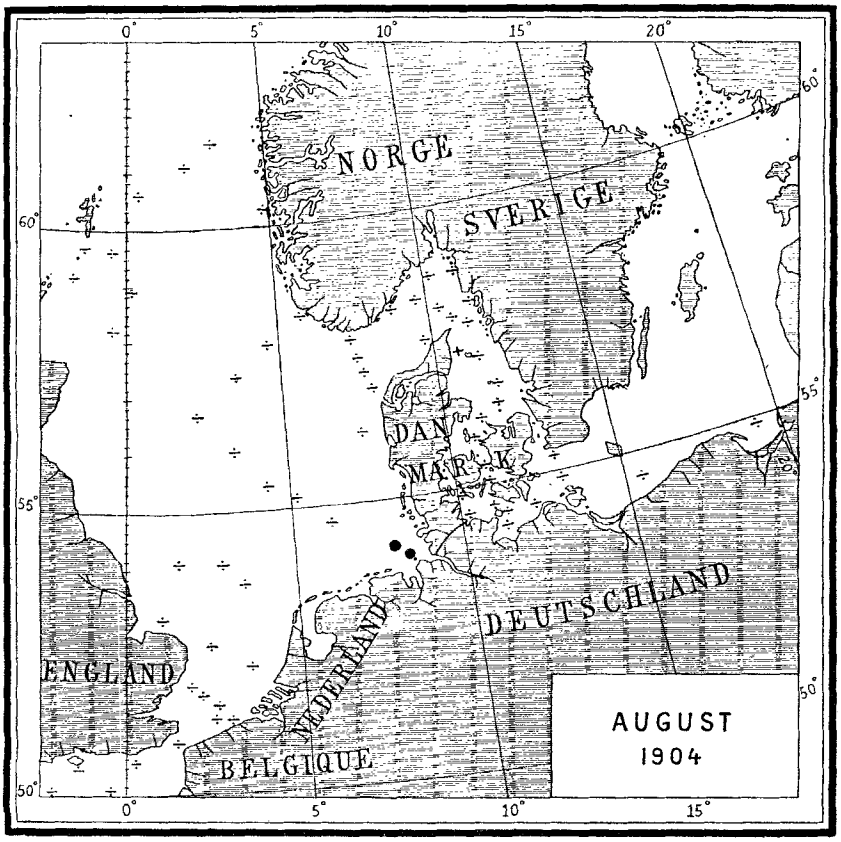

Fig. 8. Distribution of Bidd. sinensis in August 1904.

The result of our study is therefore that Bidd. sinensis in the autumn 1903 suddenly appeared in the south-eastern North Sea and in the Skager Rak; and that it since then hat got a new home here, reaching its maximum in November and its minimum in the early summer. From its new stationary area it has spread with the currents far beyond towards the north and east, but has not succeeded in fixing itself in wider regions, probably because the salinity and temperature have not been suitable for it.

Bidd. sinensis is an eurythermic and euryhaline organism. From the many samples taken in the North Sea area in 1903—07 I have found the following approximate figures: 1^0 for a numerous occurrence (i. e. it thrives well), and 2^0 for its occurrence at all (often the cells are then dying or dead):

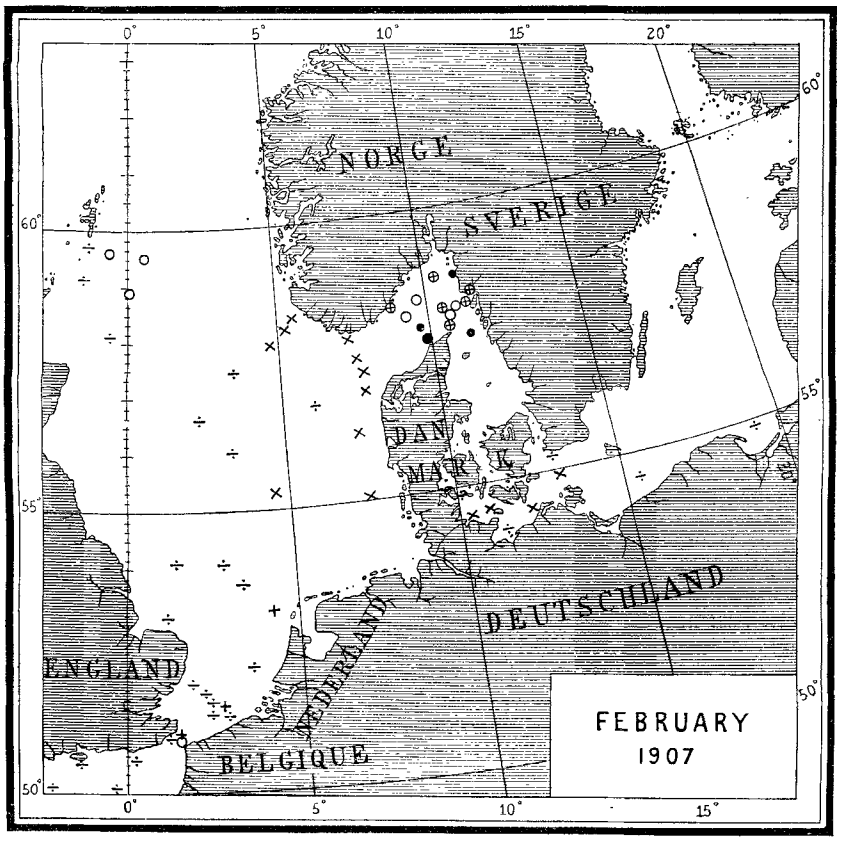

Fig. 9. Distribution of Bidd. sinensis in February 1907.

	Temperature (C°)		Salinity (‰)	
	Max.	Min.	Max.	Min.
Numerous occurrence	12,6°	2,2°	35,0	27,0 (30,0)
single occurrence	15,5°	1,0°	35,3	7,5

The maximum temperature (and perhaps also the salinity) is of rather small interest, as the limit is given a priori because higher figures do not occur in the area in question. No doubt Bidd. sinensis will thrive well

in higher temperatures and also in somewhat higher salinities, as the waters of its true home[1]) are both warmer and salter than those of the North Sea. On the other hand the minimum temperature (2,2° C) for numerous occurrence means only that it exists in considerable numbers in water of that temperature, probably because it has nos disappeared as quickly as the temperature sank.

From the facts here explained it is seen that Bidd. sinensis during its migrations in the North Sea area has been serviceable as an indicator of the direction of the sea currents. In one further respect it has proved to be of hydrographical importance. It hat been possible to utilise its first wanderings from the S. E. corner of the North Sea into the Skager Rak and then southwards into the Baltic to calculate approximately the rate of flow of the currents. The calculations are based upon the fortnightly collections from Danish lightships, and they give consequently only approximate figures which may differ by half a month. Their principal value is then to show that it is possible to study the rate of flow of the currents by means of plankton samples; but for more rational study it would be necessary to collect such samples at much smaller intervals, e. g. daily. As an example of the calculations, I may mention only, that two independent calculations coincide in the result, that the minimum rate of flow of the current running northwards along the Jutland coast and then turning southwards as under-current into the Kattegat was in October-November 1903 ca. 8 nautical miles per day (= ca. 17,2 cm per second).

The special value of using plankton organisms for current studies lies principally in this, that it is practicable to follow the under-currents which are much more difficult to study by ordinary hydrographical methods than the surface currents.

After the above was written I received the March number of the Norwegian periodical „Naturen“ in which Mr. E. Jörgensen[2]) of Bergen, after a review of my paper, adds several very interesting points to my observations by giving an account of the occurrence of our organism off Bergen on the west coast of Norway. As the Norwegian marine in-

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[1]) The water of a sample containing B. sinensis from the Red Sea had a temperature of 26,7° C, and the salinity must certainly be given as about 36‰ or a little more.

[2]) E. Jörgensen: Biddulphia sinensis ved Bergenskysten. Naturen, Mars 1909, p. 84—89, Bergen.

vestigations in connection with the international cooperation have been unable to contribute regularly to the plankton lists of the „Bulletin" — a shortcoming which I have deplored in my paper, as it prevented me from following the progress of Bidd. sinensis towards the north —, the data now given by Mr. Jörgensen fill a gap in our knowledge.

The first appearance of Bidd. sinensis off Bergen is Novemb. 26th 1903 in the open sea outside Herlöfjord. When calculating the rate of flow of the current from the Skager Rak northwards Mr. Jörgensen gets a minimum rate of flow of ca. 16 cm pr. sec. (distance from the Skaw to Bergen) or ca. 17 cm pr. sec. (distance from Bohuslän to Bergen), which comes very near to the minimum rate of flow given by me, viz. ca. 17,2 cm per sec. (see above).

In the sea round Bergen Bidd. sinensis was common in February 1904 and found sparingly as late as March 24th, but was absent from May to October. On the 7th Novemb. 1904 it appeared again in the open sea off Herlöfjord, thus about three weeks earlier than in the autumn of the foregoing year, and corresponding well with its earlier appearance during this year in the S. E. corner of the North Sea (comp. p. 367). Again, it was present during the winter and spring (recorded as late as April 1905), but absent from May until the beginning of October. It was then found sparingly a little S. of Bergen on Oct. 9th 1905 and in the open sea off Herlöfjord on Oct. 25th. It remained rare in November, but became common in December (7th—27th), rare again in January and February of 1906, and had disappeared in March. The explanation of this earlier immigration is perhaps due to this, that it had then been stationary in the Skager Rak and consequently had a much shorter way to Bergen than when coming from the neighbourbood of Heligoland. That it is less numerous during the winter (of 1905—06) may be caused by a smaller abundance of the Baltic-Jutland current.

In the summer of 1906 the plankton collections[1]) from which Mr. Jörgensen has his informations stopped, and later he has had only more occasionally collected samples at his disposal. We learn that Bidd. sinensis was present near Bergen in Jan. and Febr. of 1907, and that it was frequent in Bergensfjord in Nov. and Dec. 1908 and Jan. 1909, but rarer in Febr. 1909. The communication given by Mr. Jörgensen thus reach up to the present time, white my paper ended with May 1907. I have recently had access to the unpublished plankton lists of the „Bulletin" for Aug. and Nov. of 1907 and Febr. and May 1908, and from

[1]) The samples have been collected upon the initiative of Mr. O. Nordgaard, formerly director of the biological station of Bergen, now in Throndhjem.

them it appears that the occurrence during this time is the same as in the foregoing year, at least that it follows the same main lines as before; Bidd. sinensis has its maximum in Nov. and remains in considerable numbers in Febr. (in March reaching the N. W. part of the North Sea), while rare in May. This information together with the observations published by Mr. Jörgensen entitles us to say, that we are thus fairly sure of the regularity of the seasonal occurrence and, to some degree, of the distribution within our area of this new form among the plankton organisms of the North Sea.