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ON THE PHYTOPLANKTON OF THE SOUTH-WEST ATLANTIC AND THE BELLINGSHAUSEN SEA, 1929–31

By

T. JOHN HART, B.Sc.

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ON THE PHYTOPLANKTON OF THE SOUTH-WEST ATLANTIC AND THE BELLINGSHAUSEN SEA, 1929–31

By T. John Hart, B.Sc.

(Text-figs. 1–84)

INTRODUCTION

This paper forms the continuation of Prof. Hardy's pioneer work on the phytoplankton of South Georgia and gives, in addition, an account of extended work on similar lines over a much wider area, comprising the waters round the South Sandwich Islands, the South Orkneys, in the Bransfield Strait, and in the Weddell and Bellingshausen Seas. Mention is also made of work carried out in more northerly waters, particularly of collections showing the transition from Antarctic to sub-Antarctic phytoplankton.

A knowledge of the times and places where a rich phytoplankton development may be expected, and the factors governing both the seasonal variations in production and the larger fluctuations from year to year, is of obvious importance in considering the ecological relationships of the various organisms in any given sea area. Such knowledge is in its turn based upon a consideration of the hydrological conditions in the region in question. A clear understanding of the main features of the hydrology of the surface waters over the area dealt with in this paper is therefore essential before the distribution of the phytoplankton can be discussed. Papers now in course of preparation by Mr A. J. Clowes and Mr G. E. R. Deacon deal with this subject,[1] and another paper by Mr H. F. P. Herdman on bottom-relief has already appeared.[2] This last is of course important in the present connection as showing the regions in which upwelling and vertical mixing are likely to occur. I am greatly indebted to the above-named members of the hydrological staff for their advice and assistance.

GENERAL HYDROLOGICAL FEATURES

The surface waters of the South-west Atlantic may be divided into four main types: Antarctic, sub-Antarctic, sub-tropical and tropical.

The *Antarctic surface water* is a well-defined, cold, poorly saline layer from 100 to 250 m. in depth, lying over the warmer deep water. It is formed all round the Antarctic Continent and contains comparatively fresh water formed by the melting of the pack-ice in summer. At this season the upper layers become warmed and diluted, so that their stability is greatly increased, and shallow very strongly marked discontinuity layers tend to be set up. The cold nucleus of the layer, however, remains above the warmer deep

[1] Since the above was written, some of Mr Deacon's work has appeared in *Discovery Reports*, VII, pp. 171–238. This should be consulted for a fuller account of the hydrology.

[2] *Discovery Reports*, VI, pp. 205–36 (1932).

water. In the winter cooling and freezing at the surface leads to increased density, and consequently to vertical mixing and to the homogeneity of the whole layer. Generally speaking the Antarctic surface water streams away in a north-easterly direction all the way round the Antarctic Continent, although the configuration of the land and of the sea-floor may cause local modifications. Within the area with which we are immediately concerned there are two main currents of Antarctic surface water, derived from the Weddell and Bellingshausen Seas. These are described in detail below.

The temperature of the Antarctic surface water varies from about $-1 \cdot 0°$ C. in the south to $3 \cdot 5°$ C. at its northern boundary in summer, and from $-1 \cdot 8$ to about $0 \cdot 5°$ C. in winter. The salinity may be as low as $33 \cdot 00\,‰$ in the extreme south in summer, increasing to an average of $33 \cdot 80\,‰$ between $65\frac{1}{2}$ and $58\frac{1}{2}°$ S latitude. The salinity of the Weddell Sea water is slightly higher than that of the Bellingshausen Sea water.

The Antarctic surface water is extraordinarily rich in nutrient salts, the phosphate content ranging from 110 to 150 mg. P_2O_5 per m.^{3} in winter, and from about 80 to 100 mg. in summer. It is safe to say that the phosphate content never falls below 50 mg. per m.^{3}, from which it will be seen that there is nothing corresponding to the complete utilization of nutrient ions by the phytoplankton of north temperate latitudes in summer. The importance of this fact in considering phytoplankton problems in the south is obvious. The nitrate content is similarly high, ranging in summer from 350 to 500 mg. NO_3 per m.^{3}, while from 6 to 8 mg. of nitrite nitrogen per m.^{3} have been detected.

The oxygen content of the Antarctic surface water is of the order 90–95 per cent saturation in winter. In spring supersaturation has frequently been observed near the surface, the highest values working out at about 110 per cent saturation. The lowest values have been obtained in late summer, when, of course, the temperatures were at their highest.

The northern boundary of the Antarctic surface water is as a rule sharply defined at the surface, big differences in temperature and salinity being encountered within comparatively short distances when crossing it. The effect is particularly noticeable in the case of ships fitted with a distance thermograph as in the R.R.S. 'Discovery II'. The sharp definition of this boundary, which is called the Antarctic convergence, is due to the cold Antarctic surface water meeting and sinking below the sub-Antarctic surface water, which is much warmer, and therefore lighter. It is obvious that a convergence of this nature will profoundly influence the nature of the plankton population to be found on either side of it, though a certain amount of mixing of the water, and consequent overlapping of species, sometimes occurs. In other respects the Antarctic convergence may be said to have an effect upon the distribution of the plankton comparable to that exerted by one of the great mountain ranges on the flora and fauna of a land mass. The occasional mixing and consequent overlapping, and the rare presence of "cut-offs" (e.g. a section of sub-Antarctic water surrounded by Antarctic surface water) might be likened to the partial penetration rendered possible by passes through the mountains on land.

At the convergence the temperature range of the Antarctic surface water is approximately 0·5 to 3·0° C. in winter, and 3·0 to 5·5° C. in summer. The position of the convergence varies somewhat with the time of year, and also from season to season: in a heavy ice year the northward flow of the Antarctic surface water may be increased appreciably above normal. The effect of the land on the two main water masses concerned causes a considerable variation in the latitude of the convergence with longitude. Thus it will be seen from Fig. 1, in which the average position of the Antarctic convergence in the South Atlantic is shown, that it takes a big sweep southward as far as

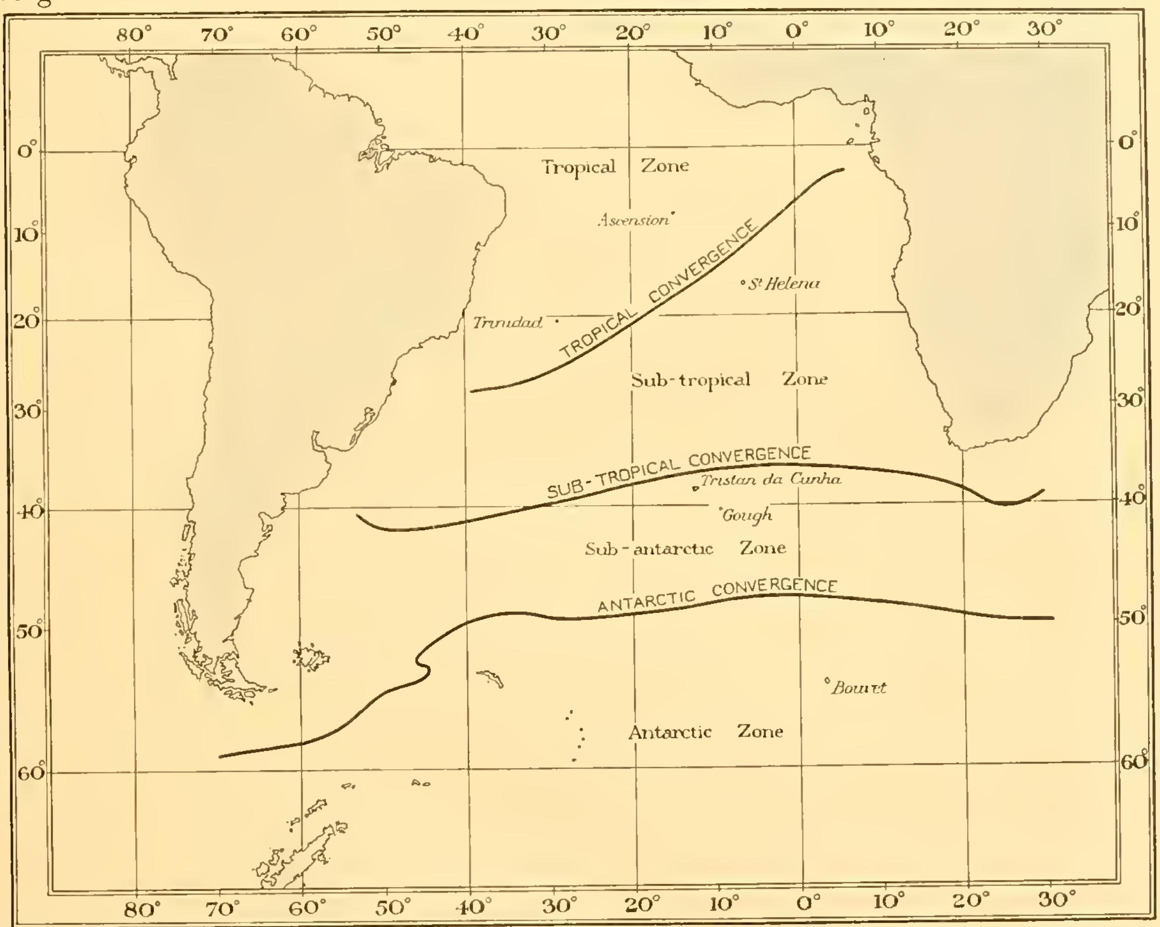

Fig. 1. Chart showing the probable average positions of the Antarctic, sub-tropical and tropical convergences in the South Atlantic (from information supplied by Mr Deacon).

$58\frac{1}{2}$° S on rounding the Horn, and begins to bend sharply northwards due south of the Falkland Islands. The northward trend becomes even more marked between 50 and 43° W longitude, where the convergence runs almost north-east and south-west, passing between the Falkland Islands and South Georgia well to the north of the latter island. Farther east the convergence continues to incline very gradually northwards, reaching 47° 40′ S in the meridian of Greenwich, but north of Bouvet Island it again begins to trend slightly southward. Recent work of the R.R.S. 'Discovery II' during her circumnavigation of the Antarctic Continent will probably enable the position of the convergence to be determined all the way round the world, but the above description covers the area dealt with in this paper. One important recent discovery is incorporated in the chart, in which it will be seen that the convergence takes an S-shaped course between the Falkland Islands and South Georgia. Phytoplankton samples from this area seem to indicate that this may be a permanent feature.

The *sub-Antarctic surface water* is a deep layer in which salinity and temperature decrease gradually with depth. This fact, coupled with vertical mixing and promoted by the almost continual bad weather of the latitudes in which it is found, renders the formation of shallow discontinuity layers, such as occur in the Antarctic surface water, impossible. Here we have an initial factor militating against a heavy phytoplankton production, as it is obvious that stability in the upper layers will tend to promote the growth of passively drifting holophytic organisms by keeping them within the zone of optimum light intensity, while instability will have the reverse effect.

The sub-Antarctic surface water receives a considerable amount of Antarctic surface water by mixing at and to the north of the Antarctic convergence, and its salinity is also reduced by the heavy precipitation. Its depth increases from about 200 m. at the Antarctic convergence to about 1450 m. at its northern boundary, the sub-tropical convergence, the distance in long. 30° W being about 550 miles. The temperature of the sub-Antarctic surface water ranges from 5·5° C. in the south to 14° C. in the north in summer, and from 3 to 11° C. in winter. The sub-tropical convergence is marked by a sudden increase in surface temperature from about 11·5 to 15·5° C. in winter, and from 14 to 18° C. in summer.

The salinity of the sub-Antarctic surface water increases gradually as one proceeds from south to north from about 34·00 to 34·50 ‰. The sub-tropical convergence is marked by a sudden increase to about 35·00 ‰. Its phosphate content is high as compared with that found in equivalent northern latitudes, being of the order of 60–80 mg. P_2O_5 per m.^{3} The sources of this rich supply of phosphate are the mixing with Antarctic surface water at the Antarctic convergence, and the vertical mixing caused by bad weather. The nitrate content is correspondingly high—about 200 mg. per m.^{3} of nitrate nitrogen in the upper layers—while from 3·5 to 5·5 mg. of nitrite nitrogen have been found in the upper 100 m., showing that more nitrate is being generated.

The average position of the sub-tropical convergence is shown in Fig. 1. It will be seen that in general it lies between 37 and 40° S across the Atlantic, reaching 42° S south of the Brazil current, and 42° 30′ S south of Cape Town, where it is forced southwards by the Agulhas current. The Falkland Islands' current is a local extension of sub-Antarctic water, strongest close in to the Patagonian coast, occasionally reaching as far north as the mouth of the River Plate.

The sub-tropical convergence is on the whole very well marked, but considerable mixing both in a northerly and a southerly direction occurs. Entire "cut-offs" of sub-tropical water surrounded by sub-Antarctic water are occasionally found, especially south of the Cape and south of the Brazil current, accompanied by rapid changes in temperature and salinity.

The *sub-tropical surface water* attains its greatest depth as a layer, about 500 m. in thickness, towards its northern boundary. Its surface temperature increases from 15·5 to 18° C. in the south to 23° C. in the north, when the tropical convergence is reached. On crossing this the surface temperature rapidly increases to 26 or 27° C., marking the appearance at the surface of the tropical layer next to be described. The sub-tropical water continues on below this very warm tropical layer, the vertical discontinuity also coinciding roughly with the 23° C. isotherm. The salinity of the sub-tropical surface water ranges from about 34·90 °/₀₀ in the south to 36·00 °/₀₀ in the north. The amount of nutrient ions present shows a striking decrease as compared with the sub-Antarctic water, the phosphate content falling to about 10 mg. per $m.^3$ north of the sub-tropical convergence. Here also the nitrate content falls abruptly from 200 to 50 mg. nitrate nitrogen per $m.^3$ and to 10 mg. only a little farther north. The oxygen content of the sub-tropical surface water is of the order of 93 per cent saturation, but north of the tropical convergence, where this same water persists as an under-layer to the very warm, shallow, tropical surface layer, its percentage saturation decreases from about 80 in 25° S, to 40 near the Equator, showing how very strongly marked is the discontinuity between it and the tropical surface water, vertical mixing being practically impossible.

This *tropical surface water* has a temperature range of from 23 to 28 or 29° C., the latter being recorded just north of the Equator. The salinity maximum of over 37·00 °/₀₀ is found in about 15° S and the minimum of about 35·50 °/₀₀ just north of the Equator. It contains no detectable phosphate and only from 0 to 5 mg. of nitrate nitrogen per $m.^3$ As we have seen that vertical mixing with the deeper layers is impossible, the probable source of this nitrate is the tropical thunderstorms.

The tropical convergence (see Fig. 1) is not so well defined as the other convergences, but, as stated above, its position coincides roughly with the 23° C. summer isotherm. It extends as far as 28° S in longitude 30° W, where the Brazil current is flowing southwards, but only to about 10–15° S in the east where the Benguela current is flowing northwards, its boundary probably lying between the islands of St Helena and Ascension.

One of the more deeply seated water masses may be of direct importance in considering the phytoplankton. This is the warm water found immediately below the surface layer within the Antarctic Zone. Previously this was thought to originate in the North Atlantic according to the theory of Brennecke and Wust, but while this may remain true of the more eastern portion of the South Atlantic, some recent hydrological information[1] suggests that the bulk of this water in the south-west may originate in the Pacific Ocean, and enter the Scotia Sea through Drake Passage. It is therefore no longer possible to regard this as a homogeneous water mass, though the similarity in temperature would seem to indicate that its ultimate mode of origin in the Pacific Ocean must resemble that of the "North-Atlantic deep water". Pending further hydrological information the provisional term "*warm deep water*" may be applied to it. Its nucleus is shown by a maximum temperature at a depth of about 400 m. off South Georgia: farther south it approaches the surface more closely.

[1] See Clowes, A. J., *Nature*, CXXXI, p. 189 (1933).

CURRENTS WITHIN THE ANTARCTIC ZONE OF THE SOUTH-WEST ATLANTIC

The Antarctic surface water flowing out from the Bellingshausen Sea follows a simple course (Fig. 2). It can be shown that there is a moderately strong set from the neighbourhood of Adelaide Island outside the Biscoe and Palmer Archipelagoes to the South Shetland Islands. The surface water in both the major portion of the Bransfield Strait and in the southern part of Drake Passage thus originates in the Bellingshausen Sea. It continues north-eastwards towards South Georgia, off the northern and western coasts of which island it can still be recognized, but farther east its identity becomes merged with that of the "old" Antarctic surface water from the Weddell Sea. In passing through the southern half of Drake Passage, this *Bellingshausen Sea surface water* constitutes the cold part of the "west-wind drift".

From the nature of the phytoplankton it would appear that water of this type was encountered round Elephant Island during the seasons studied, but at the South Orkneys, farther to the east, the surface water appears to be of Weddell Sea origin. This group must lie very near the junction of the two currents, where considerable mixing probably takes place. The Bransfield Strait appears to be occupied mainly by comparatively old Bellingshausen Sea water, except in the north-eastern corner, where, as can be clearly shown from both hydrological and plankton investigations, there is a comparatively small eddy of Weddell Sea surface water round Joinville Island. This does not extend farther north than the middle of the strait, and not beyond Astrolabe Island in a south-westerly direction. From the above it will be seen that the Antarctic surface water originating in the Bellingshausen Sea follows in the main the north-easterly trend common to all Antarctic surface waters, except in very high latitudes.

Conditions in the Weddell Sea are somewhat more complicated. To begin with it is a very deep bight penetrating farther to the southward than any other known indentation, with the exception of the comparatively shallow Ross Sea. Further, while its eastern boundary—Coats Land—does not extend north of the Antarctic Circle, the western limits of the Weddell Sea are continued north from Snow Hill Island through Graham Land to the north of Joinville Island in 63° S. Now, in high southern latitudes the prevailing winds are from the east, while the great west winds prevail at least as far as 60° S. Consequently a well-defined clockwise circulation is set up within the Weddell Sea surface water, entering round the coasts of Coats Land and farther north, and flowing round and out towards the South Sandwich Islands. This is roughly indicated in Fig. 2, where it will be seen that it is possible to subdivide the *Weddell Sea surface water* into two types. The water which flows in along the coasts of Coats Land penetrates far into the bight, and when it turns north is apparently confined to a comparatively narrow belt close against the Graham Land coast, finally issuing from the north-western corner of the sea. The eddy round Joinville Island into the Bransfield Strait is composed of surface water of this type. From Joinville Island the main body of the stream, during the seasons with which we are dealing, continued in a north-easterly direction, passing

Fig. 2. Chart showing the probable surface currents within the Antarctic Zone in the South-west Atlantic (partly after Hans H. F. Meyer). Broad arrows = eastern Weddell Sea water; fine arrows = western Weddell Sea water; dotted arrows = Bellingshausen Sea water. The size of the arrows is not intended to show the probable strength of the currents.

south of Elephant Island, but north of the South Orkneys. In the season 1930–1 it continued as far as the south-western coasts of South Georgia, but in normal seasons, except perhaps at the equinoxes, when the flow is strongest, it probably loses its identity some distance to the south-west of the island, becoming merged with old water from the Bellingshausen Sea. This type of Weddell Sea surface water is here provisionally termed the "*western*" *Weddell Sea water*, in order to distinguish it from the "eastern" Weddell Sea water next to be considered. The two types can be readily distinguished by the phytoplankton which they contain.

The *eastern Weddell Sea water* enters the sea in comparatively low latitudes. It does not penetrate so far into the Weddell Sea proper, nor remain there so long, as water of the western Weddell Sea type. On its north-easterly course when flowing out of the sea, it remains to the south of the western type water, and continues clearly recognizable by the character of its phytoplankton as far as the South Sandwich Islands. Here the arcuate ridge upon which these islands are situated apparently causes a north-westerly deflection of this water, which has been detected on several occasions in the form of a cold tongue projecting some distance along the north-east coast of South Georgia, at a distance of some 50 miles out from the island.

The individuality of the two types of surface water in the Weddell Sea was first clearly recognized by Mr D. Dilwyn John and his colleagues in the R.R.S. 'Discovery II' in 1932. It has been found to afford a valid explanation of the observed differences in the phytoplankton material collected in previous seasons. Mr John was able to divide the surface water into four types, the very cold water far to the south, water containing melting pack-ice, that in which pack-ice had recently melted, and "older" water. These types were found to be characterized by a certain definite range of surface temperature, and by the nature and bulk of the phytoplankton they contained. These limits probably apply only to the time of observation, mid-season 1931–2, as the range of seasonal variation is considerable. Nevertheless, this conception of the "age" of the surface water is of the first importance, and, generally speaking, Mr John's preliminary results agree very closely with those obtained at mid-season in previous years. One important difference between surface waters of the Bellingshausen and Weddell Seas was noted, that in the Bellingshausen water the heaviest phytoplankton hauls were obtained in water containing melting pack-ice, while in the Weddell Sea water the richest hauls were obtained in the old water which had travelled farthest from the pack. This is in good agreement with our mid-season results, but apparently does not hold earlier in the year, when very heavy catches have been obtained in Weddell Sea water, south of South Georgia and close up to the edge of the pack.

The *ice conditions* in the seas with which we have to deal are notoriously variable, and little is definitely known concerning them even by the seamen who use these waters most. Work in this direction is in progress, and when published should materially assist in explaining the distribution of the plankton. It is evident that some definite relation between the phytoplankton production and the position of the ice-edge exists, and the possible nature of this is discussed later.

Among the meteorological factors which may affect the phytoplankton, the prevalence of fogs, especially in the region of the Antarctic convergence, and farther south in summer when the ice is melting, should not be overlooked. The islands in the Southern Ocean are so few and far between, and mostly uninhabited, that our meteorological information is necessarily of the scantiest. A useful idea of the conditions experienced in certain localities may, however, be gathered from the tables in Appendix II of the first edition of *The Antarctic Pilot* (1930). The most valuable of these deal with the observations of the Argentine Government Meteorological Stations at South Georgia and the South Orkneys.

THE ECONOMIC IMPORTANCE OF THE PHYTOPLANKTON

The economic significance of the phytoplankton in Antarctic waters may be judged from the following considerations. It has long been known that the southward migration of the southern rorquals in summer is a feeding migration, and that within the zone of Antarctic surface water the food of these whales consists almost entirely of *Euphausia superba*, known to the whalers as "krill". The food of these Euphausians consists very largely, if not entirely, of diatoms and other phytoplankton organisms. Thus we have here one of the simplest food chains possible, the building up of the vast body of the whale being only one stage removed from the organic fixation of the radiant energy of the sun by the diatoms. From this it will be seen that some knowledge of the phytoplankton is essential to a proper understanding of the economic problems of these regions, and it is largely in the hope of providing a working background for other lines of enquiry that this paper has been written.

Examination of the stomach contents of adult and post-larval *E. superba* has been made on a number of occasions, though this line of investigation has not been followed up systematically as yet. Small diatoms appear to be ingested by some form of filtering mechanism, and the more typically oceanic species are evidently digested rapidly: recognizable fragments are rather rare even in the crop, the contents of which in krill from waters in which such species are dominant, presenting the appearance of a green porridge. Two forms that occurred constantly and remained clearly recognizable were *Fragilaria antarctica* and *Thalassiosira antarctica*. Torn fragments of the large species *Chaetoceros criophilum* indicated that the adults are capable of triturating and swallowing the larger forms in addition to possessing a filtering mechanism. In post-larval forms entire examples of large Foraminifera (*Globerigina* sp.) were frequently found. Possibly these are eaten for the sake of the contained calcium.

In working on the larval stages of *Euphausia superba* Mr F. C. Fraser made the interesting discovery that the distribution in numbers and size groups of the larvae showed a very fair degree of correlation with the distribution of the phytoplankton as described in this paper. The same stages were found to show an increase in size at those stations where a rich development of small diatom species was found (e.g. *Thalassiosira ant-*

arctica). The extent to which this correlation can be regarded as significant will doubtless appear when Mr Fraser's results are published.

The more important part of the area dealt with in this paper is known to the Norwegian whalers as the West Antarctic, comprising South Georgia and adjacent waters from about the longitude of the South Sandwich Islands in the east to the South Shetlands in the west. Whaling is also carried out in Bransfield Strait between the South Shetlands and Graham Land, and the collections from three plankton surveys in this area are described. Modern whaling has been carried out in the Dependencies of the Falkland Islands since 1904, and in recent years has spread to the ice-edge and far to the east—to Enderby Land and even beyond.

In addition to the results obtained within the Antarctic Zone mention is made of work carried out in more northerly waters, particularly collections showing the transition from Antarctic to sub-Antarctic phytoplankton. On the homeward passage at the end of her first commission the R.R.S. 'Discovery II' worked a line of stations from a point to the north-east of the South Sandwich Islands along the thirtieth meridian right up to $14\frac{1}{2}°$ N lat. This line passed through all the types of surface water met with in the South-west Atlantic, and opportunity has been taken to describe the phytoplankton material then collected, by way of introduction to the more detailed account of the southerly region of economic importance. Incidentally this material also affords a good illustration of the close relation existing between the character of the phytoplankton, and the major hydrological features of the surface water.

ACKNOWLEDGMENTS

With the exception of the paper by Hardy and Gunther[1] on plankton mainly from South Georgia, previous work on the Antarctic phytoplankton has been almost entirely of a systematic nature. The works which have been found of most value are Karsten's account of the material collected (to the east) by the 'Valdivia', Mangin's accounts of the material brought back by the 'Pourquoi Pas?' and the 'Scotia', and Van Heurck's report on the Belgica collections. Of these Van Heurck's and Karsten's are almost purely systematic accounts, though the latter contains some illuminating extracts from Schimper's field notebook. Mangin makes a notable effort to determine the leading forms and to give an idea of the seasonal succession. The Pourquoi Pas? material was, however, taken close in to the land for the most part, and probably for this reason our results do not show so close an agreement with Mangin's findings as might have been expected. These works are the principal sources of the identifications made in this paper. The small amount of material from sub-tropical and tropical waters here dealt with, has not been examined so thoroughly as that from the more important region farther south. However, the identification of as many species as possible from the warm seas has been attempted, the principal sources, in addition to Mangin, being the sections by Paulsen and Gran (1908 and 1905) in *Nordisches Plankton*, and the works of Dr

[1] *Discovery Reports*, in press.

M. V. Lebour. The order of the genera given in the tables of analyses is that adopted by the last-named in her works on the Dinoflagellates (1925) and the Planktonic Diatoms (1930) of northern seas. The species have been arranged alphabetically.

It should be obvious that work of the nature here described can only be accomplished with the co-operation of a large number of people. The entire scientific staff has been engaged at some time or another in the collection of the material at sea, and this is only rendered possible in the first place by the able co-operation of the marine staff. In addition useful ideas have often accrued from discussion with the other members of the scientific staff, which are acknowledged in the appropriate sections of the paper. Prof. A. C. Hardy, sometime second scientific officer of the Expedition, has given the benefit of his experienced advice, and I am also indebted to Dr W. H. Pearsall, of Leeds, and Mr H. W. Harvey, of Plymouth, for their opinions on some points. Thanks are due to Mr F. W. Mills for checking the references to the diatom species, to Miss E. C. Humphreys for preparing the figures for reproduction, and to the authorities of the British Museum (Natural History) for laboratory and library facilities.

MATERIAL

The material upon which this paper is based consists of a large number of vertical hauls of the Gran half-metre net, fished usually from 100 m. to the surface. At the majority of the stations full hydrological observations were taken. At a very few stations centrifuged water samples were also examined.

It will be seen that the material is considered in five sections, partly for the sake of convenience; but the division is also more or less a natural one.

The collections round South Georgia include two surveys made by the R.R.S. 'Discovery II' in January–February 1930 and in November 1930. In addition a line of stations worked to the north of the island later in the season 1930–1 by the R.R.S. 'William Scoresby' is dealt with, and the main evidence supported by the examination of material from isolated stations worked by both ships on arrival and departure from the island.

Seven lines of stations crossing the Antarctic convergence are examined in the section dealing with the transition from Antarctic to sub-Antarctic phytoplankton. These were taken at times of year varying from November to April. All cross the convergence to the west of South Georgia, some being worked on passage from the Falkland Islands, others across Drake Passage from the South Shetlands to Cape Horn, and the rest crossing the convergence at various points between these two extremes. Of these lines four were made by the R.R.S. 'Discovery II' and two by the R.R.S. 'William Scoresby', while on one both ships were employed.

The section dealing with the phytoplankton of the Weddell Sea area is based mainly on the season's work in 1930–1. A few stations worked by the R.R.S. 'Discovery II' in the neighbourhood of the South Sandwich Islands in February–March 1930 are, however, included. During the following season, a large amount of material was collected in the northern part of this region, in the Orkney-Sandwich-Georgia area and west as far as Elephant and Clarence Islands, by the R.R.S. 'Discovery II'. In January–February 1931 the R.R.S. 'William Scoresby', finding ice conditions favourable, was able to extend a most valuable series of observations from South Georgia south and east of the South Sandwich Islands to 68° 53′ S, 13° 03′ W. The phytoplankton collected on this cruise has proved of great value in interpreting the results obtained from the other material collected to the north and west during the same season. During this cruise the scientific work on the R.R.S. 'William Scoresby' was directed by Dr N. A. Mackintosh.

Three plankton surveys of the Bransfield Strait have been considered in this paper. The first was carried out by the R.R.S. 'William Scoresby' in February 1929, when Mr John was senior scientific officer, and the second by the same ship in November of that year, when Mr G. W. Rayner was in charge of the scientific work. In December 1930 a survey worked by the R.R.S. 'Discovery II' provided material showing the conditions prevailing at mid-season in this area. It is therefore probable that from this material valuable evidence as to seasonal changes will be obtained.

Some scattered stations were taken in the Bellingshausen Sea by the R.R.S. 'William Scoresby' during 1929–30, and a valuable line of close stations was worked off Adelaide Island, the phytoplankton material from which shows striking agreement with that found in the same locality the following year. Finally, in January 1931, the R.R.S. 'Discovery II' worked forty-eight stations in this area at which phytoplankton material was collected. Both ships have made a few stations, in the channels and outside the islands, on their way to and from the Bellingshausen Sea, but at these the phytoplankton appears to be of a rather local character.

The numbers and in most cases the positions of all these stations will be found at the top of the tables of analyses, for further information it is only necessary to refer to the Station Lists,[1] at the end of which charts will be found showing the positions of all the stations.

METHODS

The Gran net used for the capture of phytoplankton is made from the finest bolting silk with 200 meshes to the linear inch, and the circular ring is 50 cm. in diameter. A full description of this net will be found in *Discovery Reports*, vol. I, p. 183. A recent innovation of protecting the net with a loose outer covering of stronger material has not proved successful, owing to the ease with which small tears can develop unnoticed in the silk net if it is not constantly watched when fished in bad weather. The speed of hauling was as nearly as possible $\frac{1}{3}$ m. per second. In practice this was found to be almost exactly the slowest speed at which the deck engine could be persuaded to turn over without stopping on the top of a roll.

The catches having been brought on board were transferred to tall glass cylinders and fixed and preserved by the addition of the requisite proportion of strong formalin

[1] *Discovery Reports*, III, pp. 1–132, Pls. i–x and IV, pp. 1–232, Pls. i–v.

to the sea water. Having been allowed 24 hours to settle the superfluous liquid was decanted off and the catches transferred to $\frac{1}{2}$ lb. jars. Before these jars were available glass tubes plugged with cotton-wool wrapped in tissue paper were used: a number of these could be stored in a large jar. When very large catches were obtained, as in November 1930, it was found necessary to retain only a small portion, for it is obviously impracticable to preserve many successive catches of a litre or more of diatoms when working a large number of close stations.

For various reasons the volume of the settled sample does not give a trustworthy guide to the number of organisms contained. The most important of these lies in the fact that comparatively small numbers of spiny forms, such as large Chaetocerids, or species forming long robust chains, such as *Rhizosolenia styliformis*, occupy a large apparent volume, as compared with that taken up by quite large numbers of the more compact forms, such as *Coscinodiscus* spp. Further, an apparently small sample may contain millions of minute forms such as *Nitzschia* and *Fragilaria*. However, the volumes have been given at the top of the tables of analyses, as it has been found that where the proportions of the principal species remain fairly constant, they do show a fair agreement with the estimated numbers of organisms (see Fig. 3): also, in the case of very large samples, they afford some justification for the minute fractions examined. On the other hand, in the very rich and varied samples taken round South Georgia, it will at once be seen that the volumes do not possess any constant relation to the numbers of organisms (e.g. Tables X–XVI).

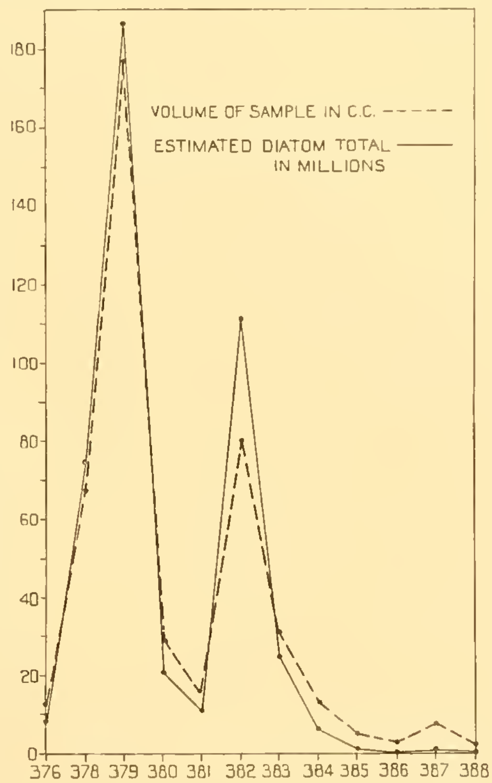

Fig. 3. Graph showing the close relation between volume of sample and estimated numbers of phytoplankton organisms, found only when the quality of the plankton remains fairly constant.

The actual estimations were made by Hensen's methods, as adopted by Prof. Hardy (in press). It was found that it was impossible to do this work at sea. Accordingly, as many samples as possible were worked up whenever the ship was in port, and the remainder while serving at the Marine Biological Station in South Georgia, and in England. Owing to the necessity of obtaining a preliminary idea of the nature of the phytoplankton, in some cases the practice was adopted while abroad of counting much smaller fractions of the larger samples than are justified by the limits of accuracy of the method, if a true quantitative analysis is aimed at. Two circumstances led to the retention of this rough comparative method, after consultation with Prof. Hardy and Dr W. H. Pearsall of Leeds.

Prof. Hardy found it necessary to work on fractions as small as one three-thousandth of the total sample in the case of his larger hauls, and even then it was impracticable to count more than a few squares in the case of the smaller colonial forms. The largest sample he examined occupied a settled volume of 290 cc., while many of those examined here were of twice or four times this bulk. Even with the smaller samples the probable range of error is large (see Hardy, in press), and these facts, coupled with the known "patchiness" of the phytoplankton as it occurs in the sea, made it evident that, practically speaking, a comparative estimation, as distinct from any attempt at a true quantitative analysis, was all that could be usefully aimed at.

It was found that in practice a settled volume of 20 cc. or so of plankton distributed through 150 cc. of liquid, was the greatest amount that could be used if counts were to be readily obtained after the ultimate fractionization with a 0·5 cc. Stempel pipette. Accordingly, all the larger samples were preliminarily fractionized to about this extent.

The mathematical errors involved in any such estimation must be enormous, but it may be pointed out that in practice differences of 100 per cent and over are the smallest that can be regarded as of much significance, owing to the unequal distribution of the phytoplankton in nature. The effect of this last factor may be judged from Table 1, which is based on the analyses of the material from St. 461. It will be seen that at seven hauls taken within a few miles of each other in the course of 24 hours, the estimated numbers of phytoplankton organisms deviated from the mean to the extent of − 54·7 and + 99·0 per cent, and here the samples were sufficiently small and uniform in character to warrant the assumption that the errors involved by the methods of estimation were not excessive. This may be seen from Table XXVI, p. 242, where the full analyses are to be found.

Table 1

Station No.	461 A	461 B	461 C	461 D	461 E	461 F	461 G
Position	56° 44′ S, 02° 23¾′ W	56° 44′ S, 02° 23′ W	56° 41′ S, 02° 24′ W	56° 41′ S, 02° 24′ W	56° 41′ S, 02° 24′ W	56° 44′ S, 02° 22′ W	56° 44¾′ S, 02° 21½′ W
Date	21.x.30	21.x.30	21/22.x.30	22.x.30	22.x.30	22.x.30	22.x.30
Time	1603	1956	2344	0355	0725	1130	1540
Volume cc.	12	12	8	12	6	5	10
Fraction	1 : 900	1 : 1080	1 : 1020	1 : 1260	1 : 1020	1 : 900	1 : 900
Estimated total	344,700	1,094,040	262,140	1,147,860	442,680	337,500	418,500
Deviation from mean as %	− 40·8	+ 89·7	− 54·7	+ 99·0	− 23·2	− 41·9	− 27·6

In extenuation of the rough methods adopted it may be urged that if any high degree of mathematical accuracy had been attempted, the analysis of the material would have occupied many years, as among other factors, the eye-strain involved in the counting is very considerable.

These counts, then, are to be taken as *roughly comparable*, *not* strictly quantitative, and the numbers in the case of the larger samples are to be regarded merely as a slightly more concrete expression of relative abundance than the "common", "very rare" and so on, of earlier plankton workers. With the smaller samples some approach to the actual numbers has probably been attained, as shown by Hardy. It may also be claimed that the counts show the relative proportions of the leading forms at each station with some accuracy. The personal error involved may be taken as the same all through, as care has been taken to repeat some of the earlier analyses after a higher degree of proficiency had been attained.

The centrifuge method evolved by Gran permits more accurate estimations to be made, but can only be employed with advantage when the dominant forms are known, and it is possible to arrange the method of investigation accordingly. Gran (1932, p. 343) has himself pointed out that the success attending the employment of this method in the northern hemisphere has been largely due to the knowledge of the general distribution of the more important forms gained during earlier work with nets.

Very little was known about the distribution of the leading forms in the south when these observations were begun, but by the examination of a large number of net hauls it has been possible to obtain a general view of the nature and extent of the principal associations. If the centrifuge method had been adopted it would not have been possible to make observations at so many different points during the same period of time, and for this reason alone it appears that net hauls are still the most valuable method in dealing with relatively unknown areas. At the few stations at which it was practicable to use the centrifuge method, excellent results were obtained on Gran's lines, and it is hoped to employ this method more frequently in the future.

One definite advantage presented by net hauls lies in the capture of the rarer forms. It is true that the numbers estimated are even more in error than those of the more numerous species, but at least their presence is noted, whereas they would almost certainly be missed by the centrifuge method. This in itself would be of small importance, were it not for the fact that some of the rarer forms seem to be confined to particular types of water, whose probable extent can thus in some measure be defined by their occurrence. The presence of small numbers of littoral forms also often provides a valuable clue as to the extent of inshore influences.

In making the analyses given in this paper, all the forms were identified down to species as far as possible, with the aid of the works already mentioned. There did not seem to be any new forms among the more important species. Two categories of organisms were less thoroughly dealt with: the diatoms belonging to the genus *Coscinodiscus*, and the smaller and less numerous dinoflagellates.

With regard to the genus *Coscinodiscus*, only one form, the large, easily recognized *C. bouvet*, was ever taken in large numbers at any distance from the land. On the occasion when other members of the genus reached their highest relative abundance round South Georgia, on the January–February 1930 survey, the combined numbers recorded formed only 1·2 per cent of the total phytoplankton. As regards species, this genus is extraordinarily richly represented, as will be seen from Van Heurck's list (1909, pp. 83–5), where over a hundred named species and varieties are recorded as occurring in the Antarctic. From the samples here examined it would appear that the majority of these are littoral and ice forms. Mangin (1915, pp. 51–2) has already remarked on the great difficulty of identifying these forms satisfactorily when working on a large series of plankton samples. Special mounting methods would be necessary to obtain the requisite definition of the fine striations and punctae of the valves, besides which it is often necessary to examine them in girdle view. This would be manifestly impossible when estimating the numbers in a large series of plankton hauls. It is evident that the systematics of the southern members of the genus are badly in need of overhaul, but this in itself would be a labour of years. Bearing in mind the fact that except at a few inshore stations they never form an important part of the phytoplankton, it has been considered justifiable to lump them together as *Coscinodiscus* spp. with the important exception of *C. bouvet*.

The smaller dinoflagellates at no time formed any appreciable proportion of the phytoplankton collected within the Antarctic Zone (cp. Mangin, 1915, p. 86, and Hardy, in press) and were not identified specifically. A few larger ones were sometimes important towards the northern limit of the Antarctic surface water, but their identification presents no difficulties.

One or two systematic points should perhaps be mentioned here. The first refers to a form which is perhaps the most numerous and widely distributed of all Antarctic phytoplankton organisms—*Corethron valdiviae*, Karsten. Both Mangin (1915, p. 51) and Hardy found it impossible to distinguish this form from the *C. inerme* of the same author, and in the course of the present work this difficulty has again been encountered, the range of individual variation, especially in size, being great. It is probable that this last character is due simply to alternate propagation by means of microspores and auxospores. For this paper the practice has been followed of referring to all single frustules with the double crown of spines as *C. valdiviae*. Two other forms of *C. valdiviae* were noted, those in process of forming auxospores, and a thin spineless chain form, which appears to be a vegetative phase derived from the smaller spiny individuals, as intermediates have been observed. These two forms have been estimated separately. In all the analyses, the estimated numbers refer to the individual frustules, not, in the case of colonial and chain forms, to the aggregates of individuals.

Mangin (1915, p. 62) has shown conclusively that Karsten's two species, *Eucampia balaustium* and *Moelleria antarctica*, should be referred to as types of one species, *Eucampia antarctica*, as he found both occurring in the same chains. This was also very apparent in our catches: it was frequently impossible to refer to the separate types, as so many intermediates occurred. In general, however, the type *moelleria* was the most abundant in all samples taken during the summer months, in agreement with Mangin's findings. The further subdivision of this species into two varieties, according as to whether the chains are straight or spirally curved, appears to be of doubtful value.

The tables of analyses in this paper have been constructed so as to show the station number, position and date, together with the (ship's) time when a series of hauls was made at one station. On the close lines worked round South Georgia, the positions have been omitted, and the stations arranged in sequence as they were situated, proceeding seawards from the points of origin after which the lines have been named. Next, mean values for the temperature, salinity, phosphate content, oxygen content and hydrogen-ion concentration of the upper 20 m. of the sea water are given. Where surface values only are available these have been denoted by an asterisk. The volume of the sample in cc. and the fraction examined (in practice the largest that could be got on to the squared slide without rendering counting impossible through overcrowding) are then quoted. The estimated numbers of diatoms follow with the genera arranged in order of Lebour's (1930) classification, and the species alphabetically. Dinoflagellates, other holophytic organisms, Protozoa and larger animal organisms follow in natural sequence. Where a large variety of dinoflagellates was present, as in the samples from warmer seas, Lebour's (1925) classification has again been followed. The estimated total of diatom frustules is also shown.

In constructing the various charts and diagrams, great difficulty has been experienced in devising suitable scales, as the differences in numbers are often very great. It is particularly important that the scale should be noted when referring to any of the figures, as it has been found impossible to adhere to the same scale throughout.

It is evident that in future work in the south, every effort must be made to obtain data on the vertical distribution of the phytoplankton by the centrifuge method as developed by Gran. The difficulties of carrying this out in the far south have already been mentioned, but with the gradual increase in our knowledge of the general distribution of the main associations it should be possible to arrange the method of investigation in such a way that centrifuge determinations can be carried out at a sufficient number of stations. Until such data are obtained it is impossible to extract the full value from the hydrological data now available.

In view of the fact that cultural methods, ever since their introduction by Allen and Nelson (1910), have been used with much success in unravelling the factors influencing phytoplankton production in European waters, it may be mentioned that attempts to obtain cultures of Antarctic plankton diatoms have been made, but these have so far failed owing to the extreme difficulty of maintaining the media at temperatures approaching those to which the organisms are subject in nature.

THE MAIN TYPES OF PHYTOPLANKTON MET WITH IN THE SOUTH ATLANTIC

A very fair idea of the main types of phytoplankton present in the South Atlantic may be gained by a study of the material collected at a series of stations at approximately equal intervals from $57\frac{1}{2}°$ S lat. to $14\frac{1}{2}°$ N lat., along the thirtieth west meridian. This was carried out in April–May 1931 on the homeward voyage, and was the last piece of work done during the first commission of R.R.S. 'Discovery II'. The time of year was somewhat unfortunate, as phytoplankton production was probably at its lowest on some of the more southerly stations, but in the light of previous work it is possible to interpret the results obtained quite intelligibly. The rich *Rhizosolenia* plankton, with *R. polydactyla* dominant, that we have found in sub-Antarctic water on other occasions, was not represented, and in the oceanic sub-tropical water the phytoplankton was extremely poor. It is probable that this water would have shown a richer phytoplankton at a more favourable time of year, but not, of course, anything approaching that found off the south-west coast of Africa in a similar latitude. There, with considerable upwelling caused by the offshore winds, the concentration of nutrient ions in the surface layers was at least three times as high as in the oceanic water with which we are immediately concerned (30–60 mg. P_2O_5 per m.^{3} as against 8–10), and a fairly rich mixed plankton was present. The state of affairs off the south-west coast of Africa may be likened to the conditions obtaining off the west coast of South America, in the Humboldt current, but on a much smaller scale.

The tremendous preponderance of diatoms and comparatively huge bulk of the phytoplankton of Antarctic surface waters is well illustrated by the more southerly stations, despite the fact that, owing to the time of year, production for the season was nearly over, and much phytoplankton had undoubtedly perished and sunk to the lower layers. This disparity between the numbers of organisms in Antarctic, sub-tropical and tropical surface waters is so great that it is not possible to represent it diagrammatically in the same figures, so that recourse must be had to the tabulated results of analyses. The relative proportions of the chief classes of phytoplankton organisms are also shown in tabular form.

The absence of Coccosphaeriales is to be explained by the method of collection, for vertical hauls with the Gran net were taken in the tropics as in our routine work in the far south. For the successful estimation of Coccosphaeriales prompt examination of centrifuged water samples is essential, and this is very difficult to accomplish on a small ship during a long sojourn at sea.

The results of the analyses made on the long line of stations in 30° W are given in Table I, which shows the hydrology of the surface waters together with the dates and positions of the stations; the estimated numbers of diatoms, dinoflagellates, Schizophyceae and other organisms follow. The positions of these stations are shown in the Station List (1932, pl. i).

From time to time in the account which follows mention is made of other work performed in sub-Antarctic waters. The analyses upon which these remarks are based will be found in Tables XVII–XXIII. At one or two points reference is made to the phytoplankton of South African waters. Forty stations were worked there during the winter and early spring of 1930–1; the material was briefly examined on board at the time but has not yet been worked up in detail.

THE PHYTOPLANKTON OF ANTARCTIC SURFACE WATERS

As will be seen from the more detailed consideration that forms the body of this paper the Antarctic surface water may have quite distinct floras, varying with the major current systems within the Antarctic convergence to which the particular tract of water belongs.

These distinctions, however, lie rather in the different proportions of the dominant forms than in the presence of distinct species, and signs are not wanting that as they approach the Antarctic convergence, the several types of Antarctic surface water tend to merge to a certain extent, or rather the floras of old, comparatively warm waters from the Weddell and Bellingshausen Seas respectively, approach one another much more closely than the floras of waters from the same two areas farther south, containing melting pack-ice. The chief feature of the phytoplankton of the Antarctic surface water, viz. the preponderance of diatoms and its great abundance as compared with that of all other seas in the world (apart from comparatively small isolated areas like the Humboldt current) is well brought out by the stations worked in long. 30° W.

In the description which follows, reference should be made to Table I, Sts. 661–6, and to Table 2 below showing the relative percentages of the major categories of phytoplankton organisms. It will be seen that at the two southernmost stations the total number of diatoms present was estimated at some millions, and that the percentage of dinoflagellates was negligible. The dominant forms were *Chaetoceros criophilum*, and in a lesser degree, *Corethron valdiviae*. Among the rarer forms *Rhizosolenia styliformis* was the most numerous, these conditions all pointing to the eastern Weddell Sea origin of the water.

St. 666 was worked only a few miles south of the convergence, and the phytoplankton found was comparatively scanty. The relative percentage of dinoflagellates was still very small, the dominant forms being the diatoms *Chaetoceros atlanticus* and *Nitzschia seriata*. Among the less numerous forms the chief were *Chaetoceros dichaeta* and *Dactyliosolen antarcticus*. The same dominant forms have been found in larger hauls obtained in close proximity to the convergence on lines of stations worked earlier in the season farther west.

The following list gives all the species recorded at these stations within the Antarctic convergence, those printed in heavy type not being found north of it. The reason for such a comparatively large number of typically Antarctic species being found (in most cases, in an apparently dying condition) to the north of the convergence is probably to be ascribed to the time of year, and to the fact that a certain amount of mixing of the surface waters takes place mainly to the north of the convergence. At this time of the year most of the *Chaetoceros criophilum* taken were in a dead or dying condition.

Coscinodiscus spp.
Asteromphalus regularis, Karst.
Dactyliosolen antarcticus, Castr.
Corethron valdiviae, Karst.
Rhizosolenia alata, Btw.
R. styliformis, Btw.
Chaetoceros atlanticus, Cleve
Ch. criophilum, Castr.
Ch. curvatus, Castr.
Chaetoceros dichaeta, Ehrb.
Ch. neglectus, Karst.
Fragilaria antarctica Castr.
Thalassiothrix antarctica, Schimp.
Nitzschia seriata, Cleve
Dinophysis sp.
Peridinium antarcticum, Schimp.
Peridinium sp.

This list gives but a poor idea of the rich variety, apart from the bulk, of the phytoplankton of Antarctic surface waters generally. This fact is to be attributed partly to the time of year at which the collections were made and partly, as will be shown later, to the fact that the eastern Weddell Sea water, which formed the representative of Antarctic surface waters at the southern end of this line, is characterized by marked predominance of a few large forms, notably *Chaetoceros criophilum*, *Rhizosolenia styliformis* and *Corethron valdiviae*.

Table 2

St. No.	Latitude	Diatomales		Dinoflagellata		Schizophyceae	
		Total	%	Total	%	Total	%
661	57° 36′ S	11,046,400	**99·88**	12,800	**0·12**	—	—
663	53° 34½′ S	6,249,200	**100·00**	—	—	—	—
666	49° 58¾′ S	354,600	**98·42**	5,700	**1·58**	—	—
670	44° 52′ S	14,700	**89·09**	1,800	**10·91**	—	—
671	43° 08′ S	52,200	**76·99**	15,600	**23·01**	—	—
673	38° 10½′ S	1,200	**26·67**	2,400	**53·33**	900	**20·00**
675	34° 08′ S	—	—	1,800	**100·00**	—	—
677	31° 16¼′ S	4,200	**35·00**	7,800	**65·00**	—	—
679	26° 06½′ S	22,500	**81·53**	5,100	**18·47**	—	—
681	21° 13′ S	2,000	**20·83**	7,600	**79·17**	—	—
684	15° 37′ S	400	**8·69**	3,600	**78·26**	600	**13·05**
687	09° 47′ S	2,600	**26·00**	7,400	**74·00**	—	—
690	03° 17¾′ S	800	**2·98**	6,000	**22·39**	20,000 +	**74·63**
693	02° 59′ N	5,400	**7·11**	4,600	**6·05**	66,000 +	**86·84**
699	14° 27¼′ N	1,600	**12·31**	9,000	**69·23**	2,400	**18·46**

THE PHYTOPLANKTON OF SUB-ANTARCTIC SURFACE WATERS

This was but poorly represented on the line of stations in 30° W, the small catches at the two stations 670 and 671 consisting mainly of an overlap of typically Antarctic forms. There was no trace of the comparatively rich *Rhizosolenia* plankton found earlier in previous seasons farther west, probably owing to the time of year. Most of the Antarctic forms recorded were in a dying condition, and the only noticeably dominant forms were an indeterminate species of *Nitzschia* and *Ceratium fusus* at St. 671.

The distribution of *C. fusus* (Table I) is very interesting. It will be seen that it occurred in small numbers at most of the stations north of the Antarctic convergence, but reached its maximum here in 43° S. Mangin, in his account of the Scotia material (1922, pp. 32 and 68), mentions the sub-species *seta* as particularly abundant in 40° 22′ S farther to the eastward. It has been found impossible to distinguish this variety or sub-species satisfactorily, owing to the number of apparently intermediate forms in our catches, a remark which applies to most of the named varieties of *Ceratium* found in warm seas; but apart from that the agreement as to the maximum occurrence of the species under consideration, towards the northern limit of the sub-Antarctic surface water, is striking. Mangin's statement concerning the distribution of this species (*loc. cit.*, p. 68) is somewhat misleading. He says it was taken at sixteen stations, always in the cold region. It must be realized that in his pioneer work Mangin had only the scantiest of hydrological data to assist him, and that he was not aware of the existence of the Antarctic convergence. He apparently took the extreme northern range of the majority of the southern forms as the limit of his cold region, and as we have seen that typically Antarctic species are often carried north of the convergence in small numbers, this limit naturally approaches the sub-Antarctic more closely than the Antarctic convergence. If one examines Mangin's actual analyses, one finds that the distribution of *C. fusus* is as shown in Table 3.

Table 3

Station No.	Position	Abundance, Mangin's scale	Surface temperature °C.	Type of surface water
119	52° 45′ S, 55° 16′ W	½	7·0	Sub-Antarctic
344	54° 55′ S, 57° 28′ W	1	—	,,
352	42° 30′ S, 59° 18′ W	½	10·0	,,
355	Off Mogotes Light,	2	16·7	Sub-tropical
355	Cape Corrientes	2	16·4	,,
359	39° 24′ S, 55° 02′ W	½	14·6	? Mixed
362	43° 33′ S, 55° 07′ W	1	15·5	,,
458	42° 57′ S, 08° 13′ W	1	10·4	Sub-Antarctic
462	39° 58′ S, 08° 36′ W	2	12·9	,,
463	40° 22′ S, 05° 45′ W	4	11·7	,,
506	08° 28′ S, 13° 32′ W	½	25·0	Tropical
510	02° 46′ S, 17° 14′ W	½	24·7	,,
511	00° 15′ S, 18° 32′ W	½	24·4	,,
519	04° 14′ N, 20° 11′ W	2	26·6	,,

It will be seen that at ten out of the fourteen stations at which it was found *C. fusus* occurred in either sub-Antarctic or sub-tropical water. The only justification for Mangin regarding it as a cold-water form was that he was unaware of the big sweep southwards, beginning approximately in long. 45° W, which the Antarctic convergence takes on rounding the Horn. Even so he has recorded it from four tropical stations which he does not mention in the text. The main point is that Mangin's findings, when reviewed in the light of modern hydrological work, confirm the fact that the maximum occurrence of *C. fusus* in the South Atlantic is reached in the vicinity of the sub-tropical convergence. A somewhat similar distribution in the North-east Atlantic, where the boundary between sub-polar and sub-tropical water is less well defined, owing to the action of the Gulf Stream, is suggested by Lebour's brief remarks (1925, p. 146) concerning this species. We agree with her that the warm-water forms are in general smaller and more slender than those of sub-polar waters, but as previously stated, owing to the presence of intermediate forms in our material, the retention of the sub-species *seta*, as by Mangin, seems hardly justified.

A similar distribution of *C. fusus* was found by the 'Valdivia' farther to the eastward in the South Atlantic, as is evident from the extracts from Schimper's notebook quoted by Karsten (1905, p. 35). These are considered later in relation to their bearing upon the part played by the "warm deep" water in the economy of the Southern Ocean.

The distribution of this particular form has been considered at length, partly because Mangin's perfectly sound observations are liable to misinterpretation in the light of his text, and partly because the occurrence of the species in large numbers may be of assistance in the interpretation of future work, its maximum being reached near the boundary between sub-Antarctic and sub-tropical surface waters. Its distribution in the material examined for this paper is shown in Table 4, which illustrates the points raised above.

Table 4

Station No.	Position	Estimated abundance	Surface temperature ° C.	Type of surface water
WS 468	55° 52′ S, 56° 53′ W	300	5·07	Sub-Antarctic
670	44° 52′ S, 30° W	600	8·10	,,
671	43° 08′ S, 30° W	12,600	9·56	,,
673	38° 10½′ S, 30° W	600	17·39	Sub-tropical
675	34° 08′ S, 30° W	600	18·95	,,
677	31° 16¼′ S, 30° W	1,200	21·43	,,
679	26° 06½′ S, 30° W	600	25·21	Tropical
684	15° 37′ S, 30° W	200	26·80	,,
687	09° 47′ S, 30° W	600	27·56	,,
690	03° 17¾′ S, 30° W	200	28·19	,,
693	02° 59′ S, 30° W	400	28·05	,,

Returning to a more general consideration of the phytoplankton of the sub-Antarctic surface water, there is no doubt that it is moderately rich at times, as described later (p. 73). Despite its comparative poverty on this occasion, the total number of organisms, very much smaller than in Antarctic surface water, was still higher than those found farther north in sub-tropical and tropical surface waters. Thus the relative abundance in the major types of surface water is quite fairly represented in Table 2. This table also shows very clearly the gradual increase in the proportion of dinoflagellates as one proceeds northwards.

The following is a list of all the species found at the stations worked in sub-Antarctic surface water in 30° W. Those printed in heavy type were exclusively confined to the sub-Antarctic Zone; of the others, all the diatom species were found also in the Antarctic surface water, to which they properly belong. The cosmopolitan species *Rhizosolenia alata*, *R. styliformis* and *Ceratium fusus* were also found in sub-tropical surface water.

Coscinodiscus sp.
Dactyliosolen antarcticus, Castr.
Corethron valdiviae, Karst.
Rhizosolenia alata f. *gracillima*
R. curva, Karst.
R. styliformis, Btw.
R. torpedo, Karst.
Chaetoceros atlanticus, Cleve
Ch. criophilum, Castr.
Chaetoceros ? concavicornis, Mangin
Nitzschia seriata, Cleve
Nitzschia sp.
Goniaulax polygramma, Stein
Peridinium elegans, Karst.
Peridinium spp.
Ceratium fusus, Ehrb.
C. tripos f. *truncata*, Lohm.

THE PHYTOPLANKTON OF SUB-TROPICAL SURFACE WATER

The phytoplankton of the sub-tropical surface water on this line of stations was extremely scanty (Table I, Sts. 673–7, also Table 2, p. 22). As already explained the time of year was probably responsible for this, and the method of collection for the absence of Coccosphaeriales. In normal circumstances one would expect the phytoplankton of sub-tropical surface water to be intermediate in bulk between the sub-Antarctic and the tropical phytoplankton, apart from local exceptions like that off the south-west coast of Africa. There, in the Benguela current, and also in the Agulhas current on the Indian Ocean side, a moderately rich phytoplankton was found in sub-tropical water; but the upwelling caused by the incidence of these currents with the continental shelf on their right hand, and by offshore winds, leads to a much richer supply of nutrient ions in the surface water than in the oceanic sub-tropical water we are considering here: the temperature is also relatively lower particularly in the Benguela current. It may be mentioned in passing that characteristic forms noted in some abundance round the Cape were: small *Chaetoceros*, notably *Ch. furca*, *Bacteriastrum varians*, *Stephanopyxis* sp., *Planktoniella sol*, *Corethron pelagicum*, and *Dinophysis tripos*, Gourret (= *D. homunculus* var. *tripos*, Paulsen), this last often in catena. Subsequently a species of *Stephanopyxis* has been found as the dominant form in phytoplankton collected off the coast of Patagonia by Mr John, and this was probably in sub-Antarctic water; but the distinction between sub-Antarctic and sub-tropical surface water between the Falkland Islands and the mainland would seem to be much less well defined than in the open ocean, and it is probable that *Stephanopyxis* will be found to be a typical dominant form near the southern boundary of inshore sub-tropical waters.

Among the species of dinoflagellates recorded from sub-tropical water by Mangin in his examination of the material collected during the homeward voyage of the 'Scotia', *Dinophysis tripos* (= *D. homunculus*) had a very significant distribution. It was found throughout the sub-tropical Zone, but reached its maximum in 39° 48′ S, 02° 33′ E, probably slightly to the south of the sub-tropical convergence (surface temperature 12·1° C.). This species was not encountered during our return voyage, but as the route followed by the 'Scotia' was much more easterly (8° W to 16° E longitude) in the southern half of the Atlantic, and as we found it in some abundance off the south-west coast of Africa, it is possible that it is confined to the eastern half of the South Atlantic. Some support for this view is furnished by the fact that these three series of observations were made at the same time of year (autumn).

The distribution of *D. tripos* as given by Mangin (1922, p. 72 and tables) in more northerly latitudes is very interesting. He records it as far north as 22° 38′ S in long. 02° 08′ E (under the synonym *D. homunculus*). There is then a complete gap in the Scotia material until it turned up again in 29° 54′ N, 34° 10′ W. It is evidently a temperate and sub-tropical species, and the above distribution is in agreement with the strong northerly trend of the tropical convergence in the eastern half of the South Atlantic which we have already briefly mentioned.

Returning to the scanty phytoplankton taken in 30° W in sub-tropical water, it will be seen that the more important forms were *Ceratium varians*, *Bacteriastrum varians*, and, to a small extent, *Ceratium fusus*. The species *C. varians* was not found south of the sub-tropical convergence, but occurred at several stations in tropical waters. Its maximum for the line was reached at St. 677 in latitude 31° 16¼′ S.

The following is a list of all the species recorded in sub-tropical water during the working of the stations in long. 30° W; those printed in heavy type were peculiar to this type of surface water.

Planktoniella sol, Wallich
Asteromphalus hepactis (Bréb.), Ralfs
Bacteriastrum varians, Lauder
Rhizosolenia alata, Btw.
R. ?styliformis, Btw.
Ornithocercus steinii, Mangin
O. magnificus, Stein
Goniaulax sp.
Peridinium tripos, Murr. and Whitt.
Peridinium spp.
Ceratium lineatum (Ehrb.), Cleve
C. fusus, Ehrb.
C. varians, Mangin
Ceratium spp.

A study of Table I in conjunction with the above list shows that the sub-tropical water passed through was poor as regards both the numbers of individuals and of species of phytoplankton organisms; on the other hand the greatly increased proportion of dinoflagellates is well brought out by Table 2 (Sts. 673–7, p. 22).

THE PHYTOPLANKTON OF TROPICAL SURFACE WATER

The general characteristics of the phytoplankton population of warm seas are clearly demonstrated by the catches obtained north of the tropical convergence in long. 30° W (Tables I and 2, Sts. 679–99). The more obvious features are the scarcity of diatoms, and the large variety of dinoflagellates, coupled with marked paucity of individuals.

At only three stations north of the tropical convergence did dinoflagellates fail to provide over 50 per cent of the phytoplankton estimated. At the first of these, St. 679, just within the zone of tropical surface water, which is characterized by complete absence of detectable phosphate in the surface layers, the tropical diatom *Hemiaulus hauckii* was dominant. At the two equatorial stations (690 and 693), the pelagic blue-green alga *Trichodesmium thiebautii* predominated, but this is not to be taken as indicating that it is confined to tropical seas. On the outward voyage it was met with in vast quantities two days sail south-east of the River Plate in a position which must have been very near the sub-tropical convergence. Darwin (1889, p. 11) describes the appearance of a similar dense swarm of the smaller, closely allied species, *Trichodesmium erythraeum*, encountered off the Brazilian coast in about 18° S lat. Our finding of *T. thiebautii* in quantity in about 40° S on the outward voyage apparently extends its known range considerably to the southward, for Wille (1903, p. 18) quotes C. H. Ostenfeld as giving its range in the Atlantic as from 59° N to 26° S latitude. At the few tropical stations at which it was taken on our return voyage it was very scarce, nothing being found remotely resembling the dense patches discolouring the seas, and earning the nick-name "sea-sawdust" from Cook's sailors. It was, however, very definitely dominant among the phytoplankton organisms taken at those stations.

Elsewhere on the homeward passage, as we have seen, dinoflagellates in great variety formed the majority of the sparse phytoplankton encountered in tropical surface waters. The variety was so great, and the number of individuals so small, that it is difficult to pick out any definite leading forms. The following species, however, occurred with some constancy and in fair numbers: *Ceratium lineatum*, *C. varians*, *C. fusus*, *Ornithocercus magnificus*, and, towards the northern end of the line, *Ceratium gibberum* f. *sinistrum*.

The occurrence (in very small numbers) of *Peridinium tripos* at the most northerly station on the line is of interest, as the only other recorded instance was at St. 677, south of the tropical convergence. St. 699, in lat. 14° 27¼′ N and with a surface temperature of 23·85° C., probably approaches the sub-tropical conditions of the northern hemisphere. From this it would appear that this species may be found to be peculiar to sub-tropical waters, as it was not present at any of the intervening stations. An interesting find amongst the tropical phytoplankton was that of *Richelia intracellularis* epiphytic upon frustules of *Rhizosolenia styliformis* at St. 693.

The following is a list of all the phytoplankton species recorded from the stations worked in tropical surface water on the homeward voyage, those peculiar to the tropical Zone being printed in heavy type:

Coscinodiscus spp.
Planktoniella sol, Wallich
Asterolampra sp.
Hemidiscus (***Euodia***) ***cuneiformis***, Wallich
Bacteriastrum varians, Lauder
Rhizosolenia castracanei, H. Perag.
R. ?styliformis, Btw.
Chaetoceros ?didymum, Ehrb.
Ch. peruvianum, Btw.
Hemiaulus hauckii, Grun.
Gymnodinium (***Pyrocystis***) ***lunula*** f. ***lunula***, Apstein
Gymnodinium (***Pyrocystis***) ***lunula*** f. ***globulus***, Apstein
Gymnodinium sp.
Noctiluca scintillans, Macartney
Phalacroma minutum, Cleve
P. rudgei, Murr. and Whitt.
Dinophysis schuettii, Murr. and Whitt.
Amphisolenia globifera, Stein
Ornithocercus magnificus, Stein
Goniodoma polyedricum (Pouch.), Jorg.
Peridinium tripos, Murr. and Whitt.
P. oceanicum, Vanh.
P. globulus, Stein
Peridinium spp.
Pyrophacus horologicum, Stein
Ceratium candelabrum (Ehrb.), Stein
C. lineatum (Ehrb.), Cleve
C. fusus, Ehrb.
C. bucephalum, Cleve
C. gibberum f. ***sinistrum***, Gour.
C. varians, Mangin
C. limulus, Gour.
Ceratium spp.
Podolampas bipes, Stein
Pelagothrix sp.
Trichodesmium thiebautii, Gomont
Richelia intracellularis, Schmidt

SUMMARY

The material collected on the long line of stations in 30° W affords a basis for a comparison of the main types of phytoplankton met with in the South Atlantic, but owing to the small number of the stations which fell in the sub-Antarctic and sub-tropical Zones it has been necessary to take other work into account in dealing with them.

The broad division into four zones based on the hydrology of the surface waters is reflected fairly closely in the quantity of the phytoplankton. The great abundance of the phytoplankton in the Antarctic Zone, with its rich supply of nutrient ions in the surface layers, and diatoms completely dominant over other forms, is well brought out. Proceeding northwards the rapidly diminishing numbers of organisms, running parallel with the average concentrations of nutrient ions in the surface layers, and the increasing proportion and variety of dinoflagellates, is also well shown. It must be borne in mind that the great disparity in bulk between the Antarctic phytoplankton and that of warmer seas is over-emphasized in this material, as the method employed did not permit of the Coccosphaeriales being taken into account, and these nannoplankton forms are undoubtedly among the most important producers in warm seas.

The collections from warmer waters did not show any novel features, but they serve to indicate the great richness of the Antarctic Zone, and the fact that in general the quantity of phytoplankton depends on the average nutrient salt content of the surface waters. Certain points of distributional interest also became evident. Among the more noteworthy of these were the facts that *Ceratium fusus* appears to find its optimum (in the southern hemisphere) near the northern limit of the sub-Antarctic surface water, and that *Dinophysis tripos* appears to be confined to the more easterly portion of the South Atlantic. Several dinoflagellates, notably *Ceratium gibberum* f. *sinistrum*, were only encountered at the northern end of the line.

The following list shows the species confined to each type of surface water in the material from the 30° W line. The hauls from the sub-Antarctic and sub-tropical waters were not fully representative, as already explained. An additional reason for the lack of distinctive forms in the sub-tropical water is the considerable overlap of several species, especially to the north of the tropical convergence—the least well defined of the three convergences.

Peculiar to the Antarctic surface water:

Asteromphalus regularis
Chaetoceros curvatus
Ch. dichaeta
Ch. neglectus
Fragilaria antarctica
Thalassiothrix antarctica
Dinophysis sp.
Peridinium antarcticum

Peculiar to the sub-Antarctic surface water:

Rhizosolenia curva
R. torpedo
Chaetoceros ?concavicornis
Nitzschia sp.
Goniaulax polygramma
Peridinium elegans

Peculiar to the sub-tropical surface water:

Asteromphalus hepactis
Ornithocercus steinii
Goniaulax sp.

Peculiar to the tropical surface water:

Asterolampra
Hemidiscus (*Euodia*) *cuneiformis*
Rhizosolenia castracanei
Chaetoceros didymum
Ch. peruvianum
Hemiaulus hauckii
Gymnodinium (*Pyrocystis*) *lunula* f. *lunula*
Gymnodinium (*Pyrocystis*) *lunula* f. *globulus*

Gymnodinium sp.
Phalacroma minutum
P. rudgei
Dinophysis schuettii
Amphisolenia globifera
Goniodoma polyedricum
Peridinium oceanicum
P. globulus
Pyrophacus horologicum
Ceratium candelabrum
C. bucephalum
C. gibberum sinistrum
C. limulus
Podolampas bipes
Richelia intracellularis

THE PHYTOPLANKTON OF THE SOUTH GEORGIA AREA

The phytoplankton of the area immediately surrounding South Georgia is in general very rich and varied, but the elucidation of the factors governing its quality and quantity is a matter of great difficulty, for a variety of reasons. Foremost among these is the impracticability of carrying out a series of observations over the whole area continuously throughout the year, so that in considering the seasonal variation in production one is forced to rely on inference from a number of surveys often taken in different seasons. As the conditions fluctuate considerably from season to season, and the phytoplankton crop with them, it will be seen that such inferences must be made with caution. Another factor introducing complicating features is the different origins of the types of surface water found off the island, and the considerable mixing which may take place between them.

Plankton surveys worked in January–February 1930 and in November 1930, together with some material collected later during the season 1930–1, are described here, and their probable significance discussed in the light of that already made known by Hardy. The positions of the stations made on these surveys are shown in Fig. 4.

THE PLANKTON SURVEY OF JANUARY–FEBRUARY 1930

On this survey phytoplankton samples were collected at fifty-seven stations arranged on seven lines radiating out from various points on the island. They were taken between January 20 and February 11, or roughly one month later in the year than the bulk of the material examined by Hardy. The analyses of these samples are contained in Tables II–VIII (Appendix II) in which the stations are arranged in order as they occur proceeding outwards from the island on each line. For the sake of convenience each line has been named after the salient point on shore from which the spacing of the stations was calculated beforehand, but for obvious reasons it was not always possible, or even desirable, to work the stations strictly in this sequence. The tables have been constructed to show the surface hydrology, and the estimated numbers of the several phytoplankton species, together with the totals for the major categories of organisms at each station. In addition, histograms (Figs. 5–11) have been constructed showing the total phytoplankton, and the percentages of the leading forms in the catch at each station. Owing to the very great range in total phytoplankton content of the water, it has been impossible to show the phytoplankton totals on the same scale for each line, but in each case the

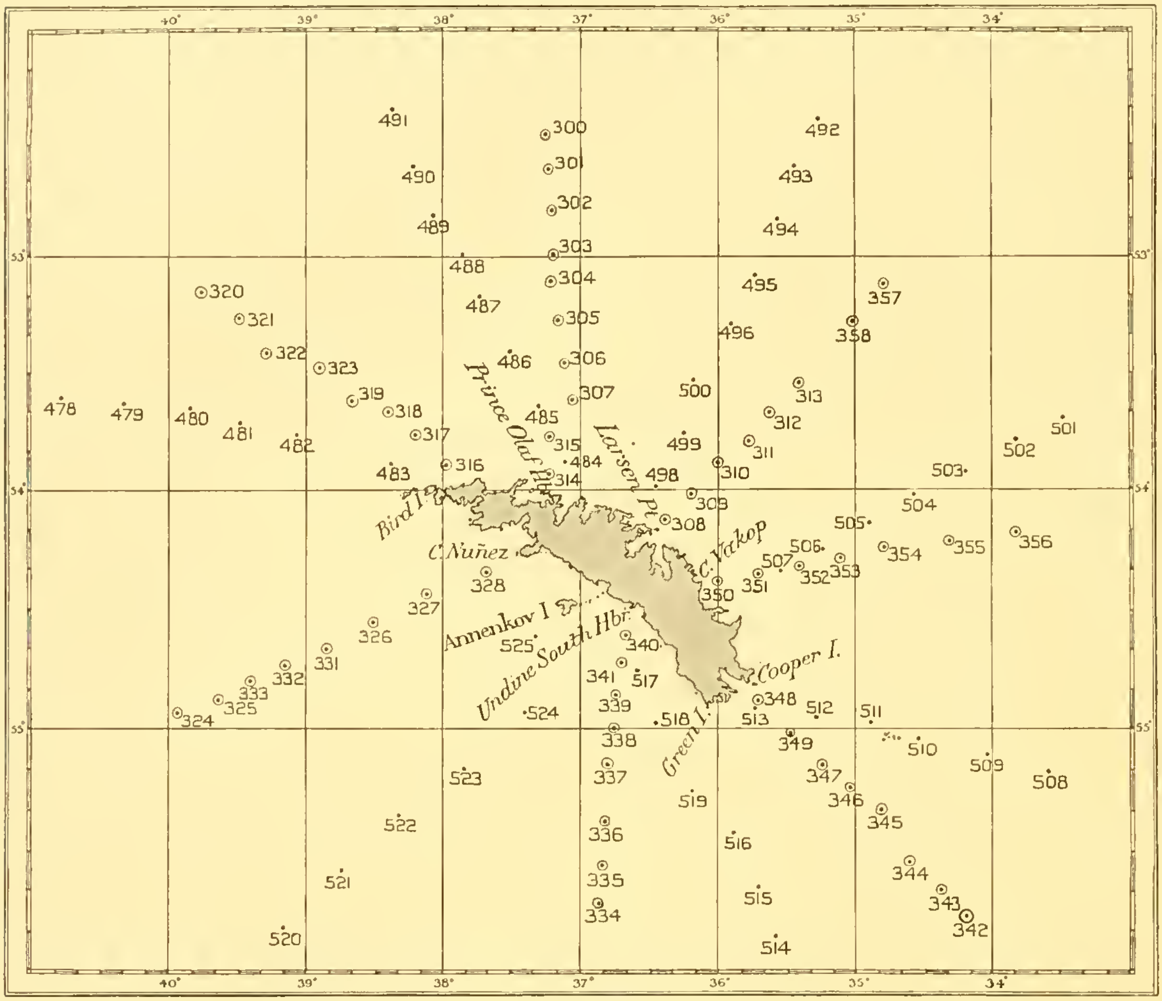

Fig. 4. Chart showing the positions of the stations worked on the two surveys round South Georgia, January–February 1930 open circles, and November 1930, black dots.

scale adopted is shown at the left-hand margin. Charts showing the distribution of each of the principal species, and also the total diatoms, are also given (Figs. 12–17) in an attempt to build up a picture of the conditions over the whole area. It may be mentioned that most of the lines consisted of eight stations worked at approximately 10-mile intervals.

The main features of the LARSEN LINE (Table II, Figs. 4, 5) were the almost complete absence of diatoms at the inshore stations, where the dinoflagellates *Peridinium antarcticum* and *Ceratium pentagonum* f. *grandis* were dominant, and the relative abundance of diatoms, principally *Corethron valdiviae* in the spineless chain form, and *Thalassiothrix antarctica* at the next two stations. The outermost stations on this line (Sts. 357 and 358) were perforce worked much later than the others when conditions were obviously different. The temperatures were higher, and the two large dinoflagellates mentioned above were more numerous than at any of the other stations worked during the survey. Diatoms were still fairly numerous, particularly *Corethron valdiviae* (spineless chains) and to a lesser extent *Eucampia antarctica* and *Nitzschia seriata*. The conditions on this line may be summarized as follows:

At the four inshore stations (Sts. 308–11) an extremely scanty phytoplankton with small numbers of dinoflagellates dominant, but fair numbers of *Corethron valdiviae*, alone among diatoms, present at Sts. 309 and 310. At the next two stations (Sts. 312 and 313) diatoms were completely dominant over dinoflagellates, with *Thalassiothrix antarctica* considerably in excess of *Corethron valdiviae*, and these two species far more numerous than all the other forms. At these two stations the temperatures were lower than those found closer inshore, and lower than at the two stations worked farther offshore on this line a fortnight later.

At St. 358, though the dinoflagellates *Peridinium antarcticum* and *Ceratium pentagonum* f. *grandis* reached their highest estimated numbers for the whole survey, it will be seen from Fig. 5 that they represented only 7·3 and 6·0 per cent respectively of the total phytoplankton, the diatom *Corethron valdiviae* in the spineless chain form being dominant with 80 per cent. It may be mentioned that throughout this survey the *C. valdiviae* present were entirely in the spineless chain form; the absence of the individual frustules, with their double crown of spines so characteristic of almost all Antarctic surface waters, was most marked, and apparently correlated in some way with the abnormal conditions prevailing round South Georgia at the time.

The outermost station on the Larsen line, St. 357, showed large numbers of the two dinoflagellates whose presence was such a feature of this survey, and with the percentage of *C. valdiviae* falling to 32·9 it will be seen that together they accounted for nearly half the total phytoplankton (Fig. 5). At both the outer stations small proportions of the diatoms *Eucampia antarctica* and *Nitzschia seriata* were found. *Thalassiothrix antarctica* was absent, in strong contrast to the conditions found farther inshore a short time earlier.

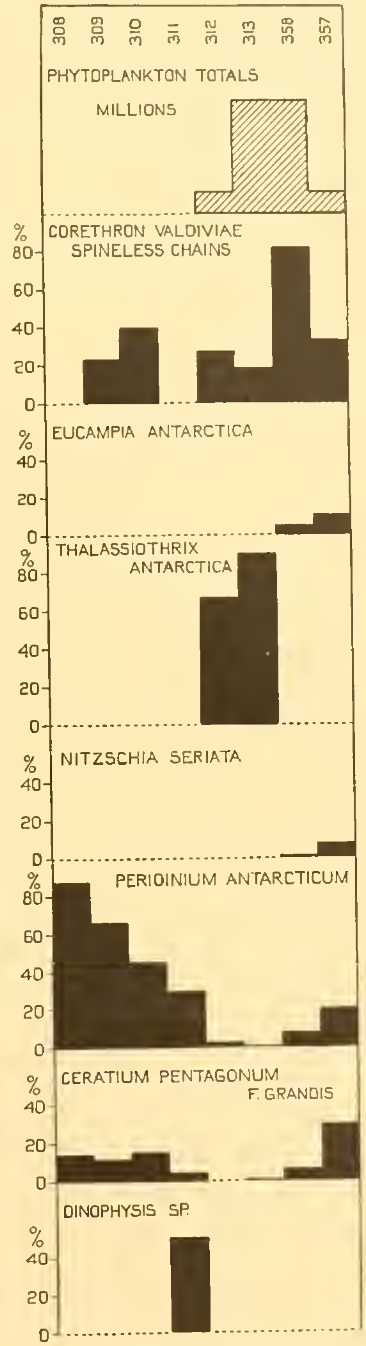

Fig. 5. Diagram showing the percentages of the principal species in the catches on the Larsen Line, South Georgia survey, January–February 1930.

On the Prince Olaf line the phytoplankton at the two inshore stations was almost non-existent (Table III, Figs. 4, 6). Proceeding seawards, that at St. 307 was comparatively rich with a fair variety of diatoms and *Corethron valdiviae* strongly dominant. At the next two stations the phytoplankton was comparatively thin, with *C. valdiviae* still dominant and a fair proportion of the two large dinoflagellates. These last showed a great increase in numbers at the succeeding stations, Sts. 304 and 303; but with greatly increased numbers of diatoms—*C. valdiviae* and *Thalassiothrix antarctica* dominant and fair numbers of *Fragilaria antarctica* at St. 304—they no longer formed such a large percentage of the phytoplankton. At the three outermost stations on this line the dinoflagellates disappeared and the diatoms *Thalassiothrix antarctica*, *Corethron valdiviae*, *Eucampia antarctica* and *Nitzschia seriata* predominated in that order of importance.

The main features of the phytoplankton collected on the Prince Olaf line may thus be summed up as follows: very general dominance of *Corethron valdiviae* inshore, and of *Thalassiothrix antarctica*, particularly at those stations worked farthest from the island. The dinoflagellates *Peridinium antarcticum* and *Ceratium pentagonum* f. *grandis* together formed more than 10 per cent of the total phytoplankton at all stations out as far as St. 303, with the single exception of St. 307.

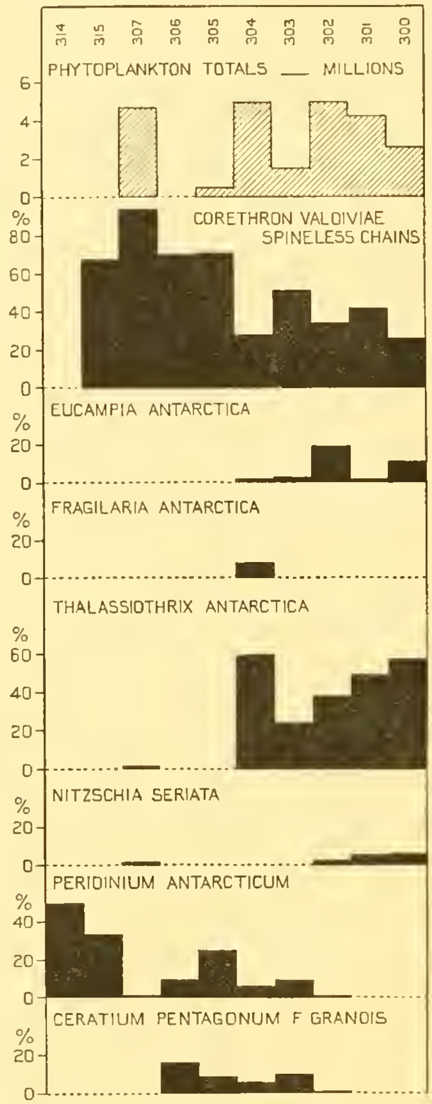

Fig. 6. Diagram showing the percentages of the principal species in the catches on the Prince Olaf Line, South Georgia survey, January–February 1930.

It will have been noted from the description given above that on the Larsen and Prince Olaf lines the phytoplankton was very scanty inshore, and comparatively abundant some distance away from the island. Similar conditions were also found on several of the lines still to be described, but on the next to be considered in detail, the Bird Island line, the reverse was the case. The phytoplankton at the three innermost stations on this line was rich in comparison with that found farther offshore, but without achieving such abundance as was found towards the seaward end of the two lines previously dealt with.

At the three inshore stations on the Bird Island line (Table IV, Figs. 4, 7) *Corethron valdiviae* was strongly dominant (entirely so at St. 318), and at the first two small proportions of *Eucampia antarctica* and *Melosira sphaerica* were also noted (Sts. 316 and 317). At St. 319 the phytoplankton was almost non-existent, but it became more plentiful though still sparse at the next station seawards, St. 323. Here *Corethron valdiviae* was still dominant, but the proportion of the two dinoflagellates *Peridinium antarcticum* and

Ceratium pentagonum f. *grandis* was much higher than at the inshore stations, and at the two succeeding stations to seaward (Sts. 322 and 321) these two species together predominated over *Corethron* to a marked extent, these three forms together comprising almost the whole of the catches (Fig. 7). At the last station of all, St. 320, *C. valdiviae* again predominated over the dinoflagellates.

The most striking feature of the phytoplankton on the Bird Island line was thus the relatively high proportion of dinoflagellates at the four outermost stations. They were in excess of the diatoms at Sts. 322 and 321, and formed 30 per cent of the total phytoplankton at Sts. 323 and 320. *C. valdiviae* was very generally present, and was the most numerous form at six of the eight stations. It was markedly dominant in the three comparatively rich hauls close in to the land. The other diatom species met with most frequently on this survey, *Thalassiothrix antarctica*, was entirely absent from the Bird Island line.

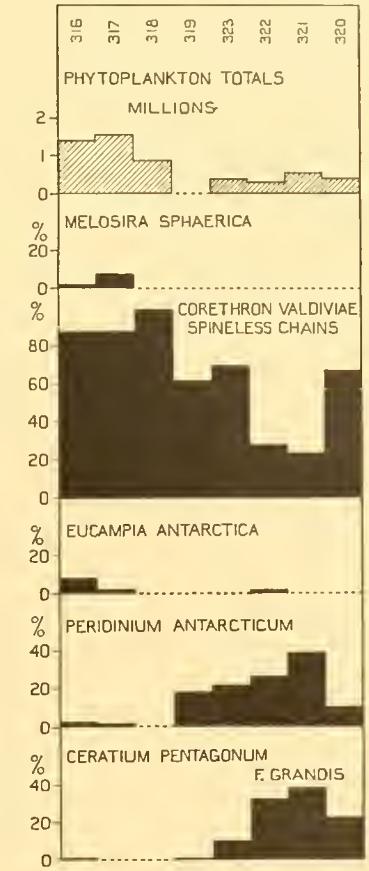

Fig. 7. Diagram showing the percentages of the principal species in the catches on the Bird Island Line, South Georgia survey, January–February 1930.

Again, upon the CAPE NUÑEZ LINE (Table V, Figs. 4, 8), the usual order of small samples inshore and richer phytoplankton offshore was reversed, but the phytoplankton was very poor throughout. At the innermost station, St. 328, *Peridinium antarcticum* predominated. Proceeding seawards, at St. 327, *Corethron valdiviae* with an estimated number of 1,200,000 frustules, or 88·9 per cent of the total phytoplankton, was the dominant form in the richest haul of the line. Still farther seaward the two large dinoflagellates, *Peridinium antarcticum* and *Ceratium pentagonum* f. *grandis*, the former usually being the more abundant of the two, predominated over diatoms at all the stations right out to the end of the line. The single exception was the very poor haul at St. 325, in which *Corethron* was again dominant.

The chief features of this line, apart from the poverty of the phytoplankton throughout, were the extreme scarcity of diatoms other than *C. valdiviae* and the general predominance of dinoflagellates.

On the line worked southwards from UNDINE SOUTH HARBOUR (Fig. 4) the phytoplankton hauls were uniformly small and of very much the same character throughout. The same two large dinoflagellates predominated, except at Sts. 338 and 337 (Table VI, Fig. 9). At the first of these a fair proportion of *C. valdiviae* and *Nitzschia seriata* led to the diatom total exceeding that of the dinoflagellates, though *Peridinium antarcticum* was still the most important individual form. At St. 337 *Corethron* was definitely dominant, and with a considerable proportion of *Thalassiothrix antarctica* also present, the dinoflagellates were less important at this station than anywhere else on the line. It will be seen from Fig. 14 that this small haul was the only one in which *Thalassiothrix* was taken off the south-west side of the island.

Of the two dinoflagellates, *Peridinium* was more important than *Ceratium* except at St. 340, close in to the land, and throughout the survey, with a few notable exceptions, *Peridinium* was as a general rule slightly the more numerous of the two.

The Cooper Island line (Table VII, Figs. 4, 10) trended away to the south-east,

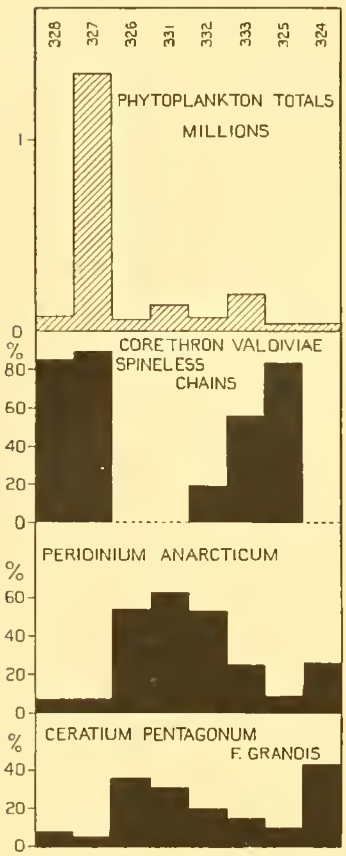

Fig. 8. Diagram showing the percentages of the principal species in the catches on the Cape Nuñez Line, South Georgia survey, January–February 1930.

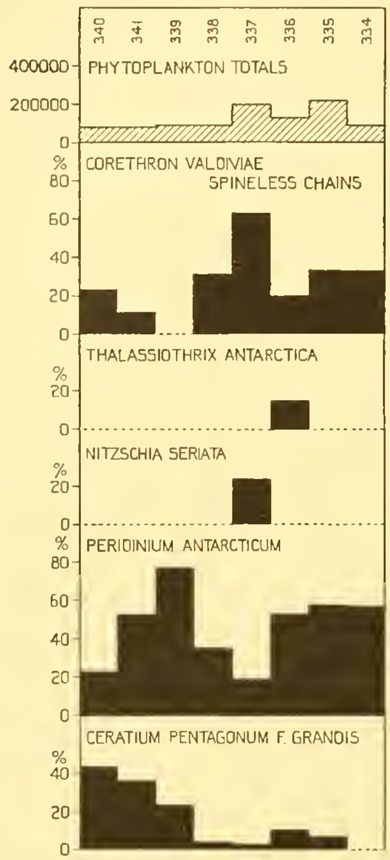

Fig. 9. Diagram showing the percentages of the principal species in the catches on the Undine South Line, South Georgia survey, January–February 1930.

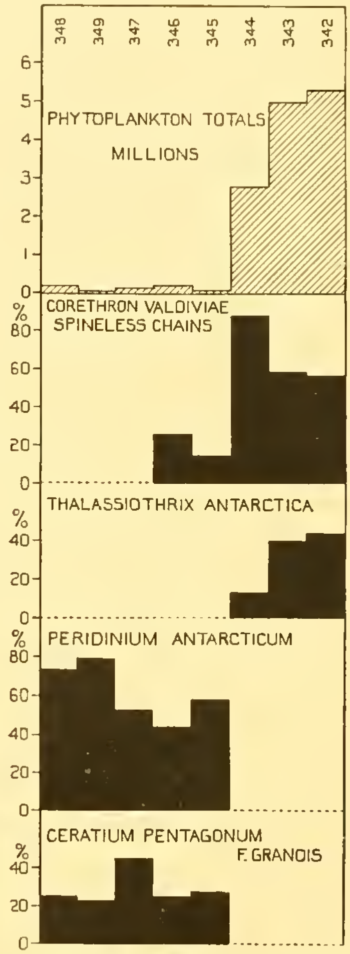

Fig. 10. Diagram showing the percentages of the principal species in the catches on the Cooper Island Line, South Georgia survey, January–February 1930.

and was therefore likely to cut into surface water of Weddell Sea origin, as distinct from that of Bellingshausen Sea or mixed origin which probably extended over most of the stations to the west and north of the island on this particular survey. The probable sources of the various types of surface water met with round South Georgia have already been briefly discussed (p. 8), and, as stated, the Weddell Sea water is generally speaking richer in phytoplankton than the surface water derived from the Bellingshausen Sea. Accordingly we should expect to find that the samples taken at the outer stations on the Cooper Island line, were richer than those obtained on the more westerly lines described above, and this was, in fact, the case.

At all the first five stations proceeding outwards from the land, the two large dinoflagellates so common on this survey predominated in small hauls taken in water of comparatively high temperature. Outside these, however, a fairly rich diatom plankton was found, and the dinoflagellates were of no appreciable importance. The three outer stations, 344, 343 and 342, all showed surface temperatures more than 0·5° C. lower than those at the inshore stations where dinoflagellates were dominant. The principal diatoms were *Corethron valdiviae* and *Thalassiothrix antarctica*, the proportion of the latter increasing as one proceeded offshore.

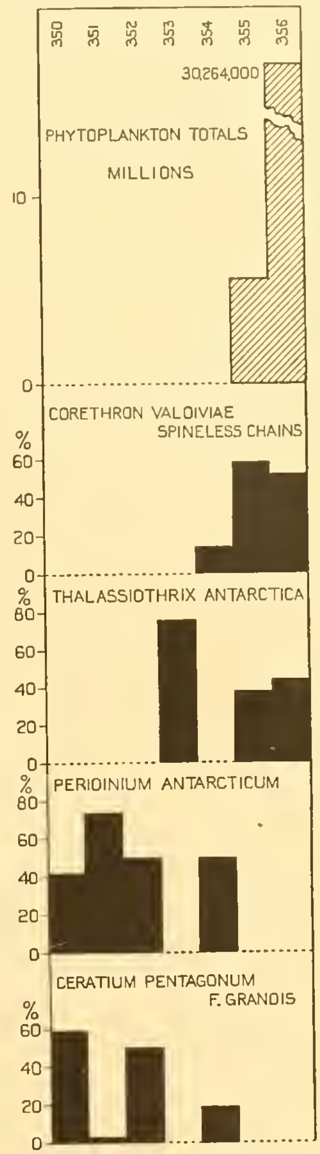

Fig. 11. Diagram showing the percentages of the principal species in the catches on the Vakop Line, South Georgia survey, January–February 1930.

The January–February 1930 survey of the South Georgia area was concluded by the VAKOP LINE (Table VIII, Figs. 4, 11), worked almost due east from the island. The conditions found on this line formed a close parallel to the results obtained on the Cooper Island line described above. At the five inshore stations temperatures were relatively high, and dinoflagellates dominant, except in the small sample obtained at St. 353, where the diatom *Th. antarctica* predominated. At the two outermost stations, worked at somewhat wider intervals than usual in order that the survey might be completed before weather conditions led to delay, the two diatoms *Corethron valdiviae* and *Thalassiothrix antarctica* became completely dominant, the change again being accompanied by a considerable drop in temperature to 2·01° C., the lowest value recorded in the surface waters examined on this survey. St. 356 provided the richest haul of the survey, over 30 million diatoms being estimated.

The last two lines worked on this survey thus cut into a comparatively rich zone of fairly homogeneous phytoplankton lying to the south and east of the island, further evidence of which was obtained at the first two stations worked on the way to the South Sandwich Islands a fortnight later (see pp. 88, 89 and Table XXIV).

The general distribution chart (Fig. 12) showing the total diatoms for January–February 1930 indicates clearly where the comparatively rich hauls were obtained, and when this is compared with the separate distribution charts (Figs. 13–17) upon which the five leading species are plotted individually, a very fair picture of the phytoplankton conditions prevailing over the whole area can be built up. From the general chart it can readily be seen that except at the northern end of the island, the phytoplankton inshore was very scanty, an observation which agrees with Hardy's findings; farther offshore on the eastern side the comparatively rich belt spreads up to the north, and the small inshore patch with moderately rich phytoplankton to the north was evidently not of the same origin, as it contained no *Th. antarctica.* To the east, south-east and north-east of the island, this species was found in very considerable

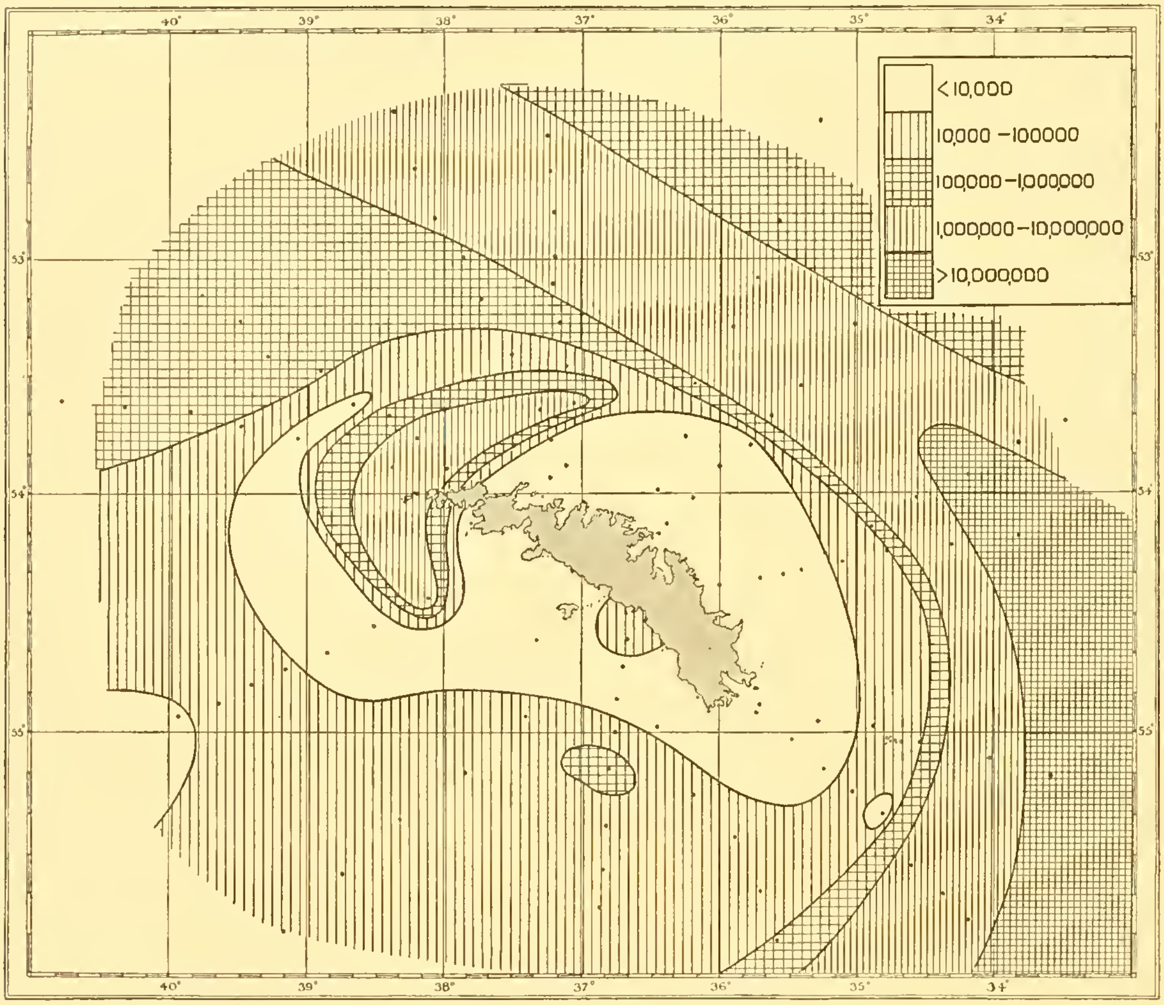

Fig. 12. Chart showing the general distribution of Diatomales (totals per 100–0 m. haul), South Georgia survey, January–February 1930. This chart is based on catches made at the positions indicated in Fig. 13.

abundance at some distance from the land, but was almost totally lacking on the west side and in the thin phytoplankton from the inshore stations (Fig. 13). The ubiquitous *Corethron valdiviae* in the spineless chain form was present among the scanty hauls close in to the land and to the west of the island, but its abundant occurrence coincided with that of *Thalassiothrix* with two important exceptions (Fig. 14). These were the small moderately rich patch round Bird Island, and the two late stations, worked at the end of the Larsen line, that completed the survey. As these temperatures were high, *Thalassiothrix* was absent, and dinoflagellates present in large numbers as previously described. In both these cases *Corethron* was the dominant form. Elsewhere it might be described as co-dominant with *Thalassiothrix* in a tongue of comparatively cold water reaching right up the eastern side of the island, and originating at an indeterminate distance to the south-east, as indicated by the first two stations worked on our way to the South Sandwich Islands a fortnight later.

The two dinoflagellates *Peridinium antarcticum* and *Ceratium pentagonum* f. *grandis*

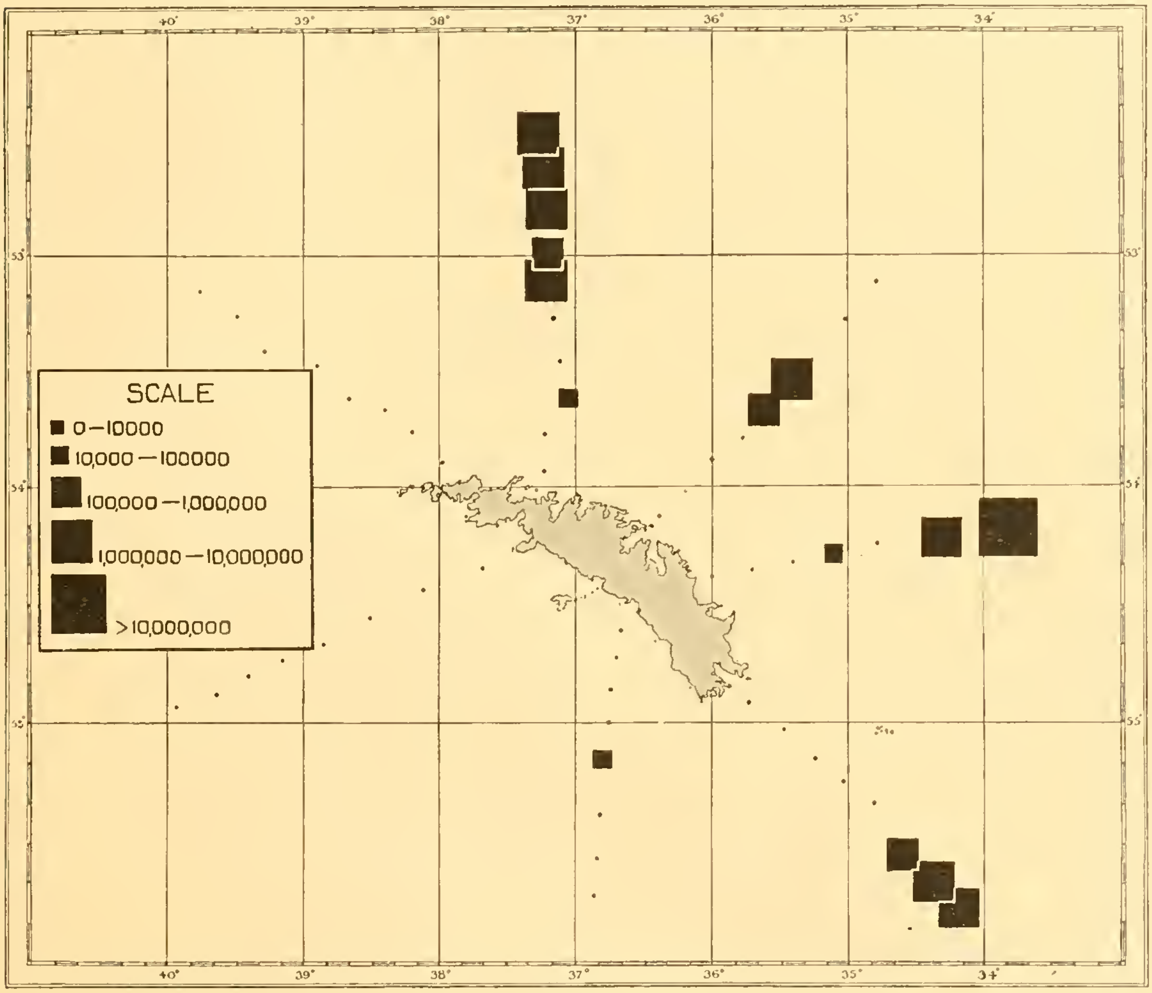

Fig. 13. The distribution of *Thalassiothrix antarctica*, South Georgia survey, January–February 1930.

were very similarly distributed throughout the area (Figs. 15 and 16). Present in moderate numbers at almost all the stations worked during the survey, they reached their greatest abundance to the north of the island. Generally speaking, their abundant occurrence was closely correlated with the highest surface temperatures, while the diatoms, more particularly *Thalassiothrix*, reached their maximum in comparatively cold water to the east.

The distribution of the diatom *Eucampia antarctica* is shown in Fig. 17. It will be seen that except for two stations just to the north of Bird Island, it was found almost

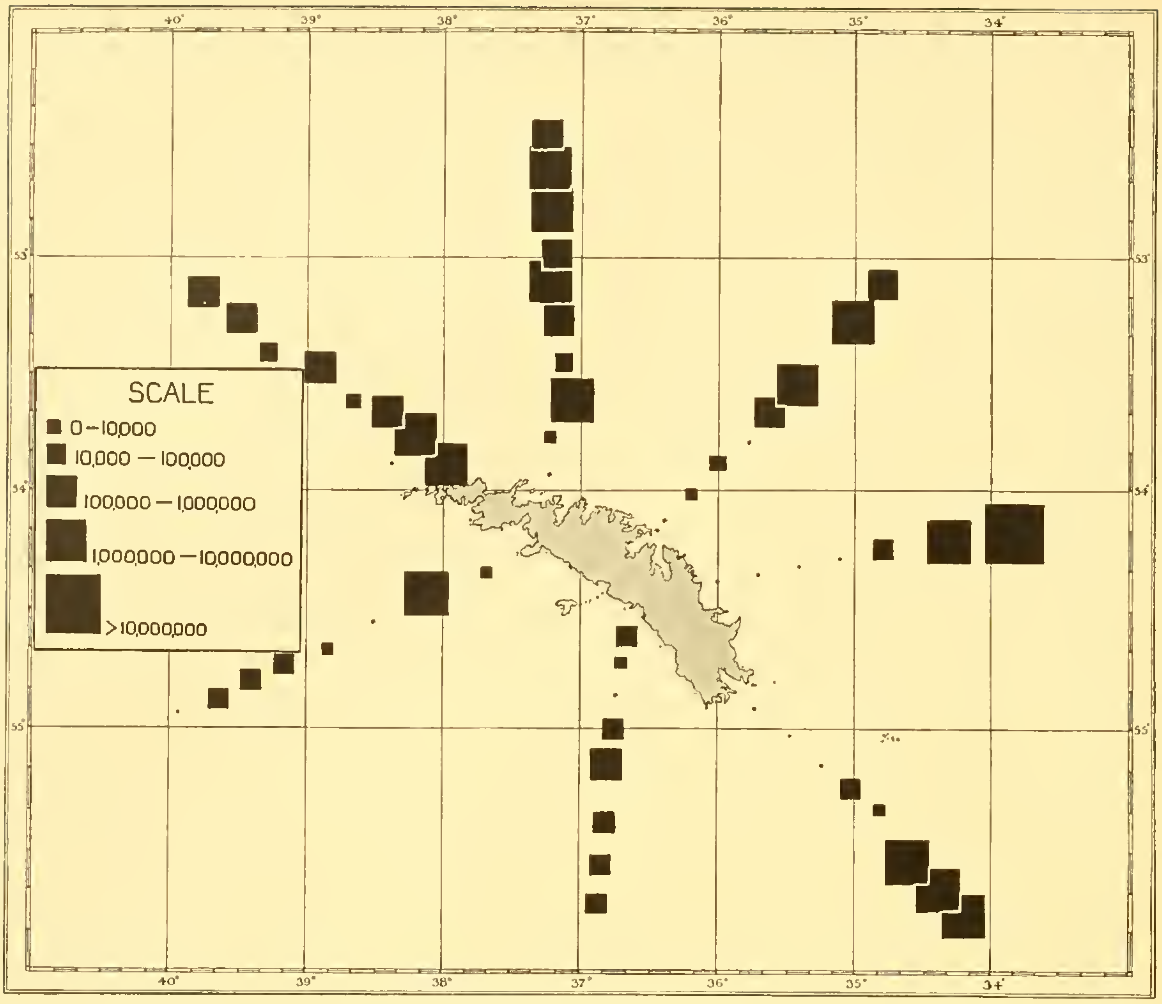

Fig. 14. The distribution of *Corethron valdiviae* (spineless chain form), South Georgia survey, January–February 1930.

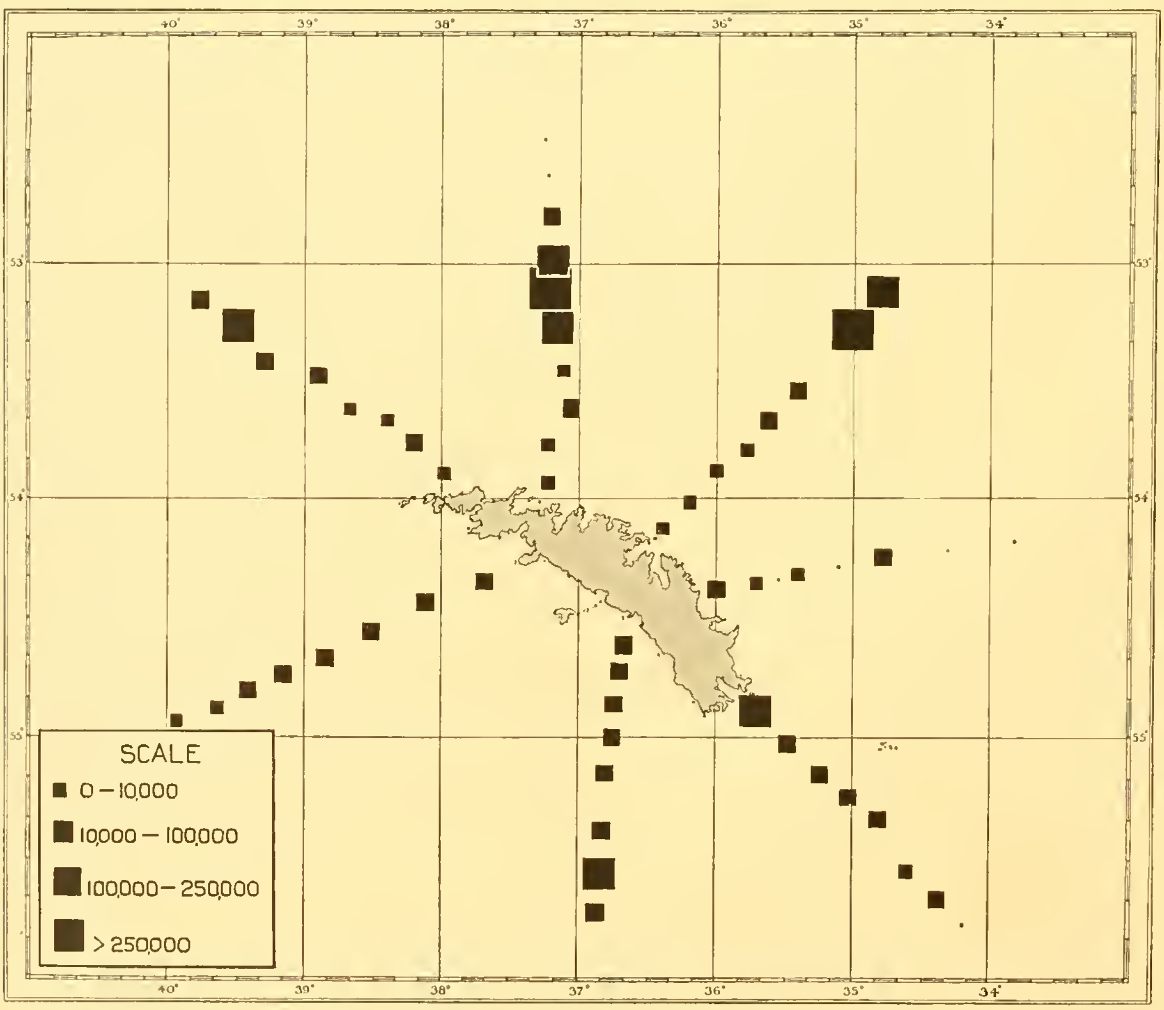

Fig. 15. The distribution of *Peridinium antarcticum*, South Georgia survey, January–February 1930.

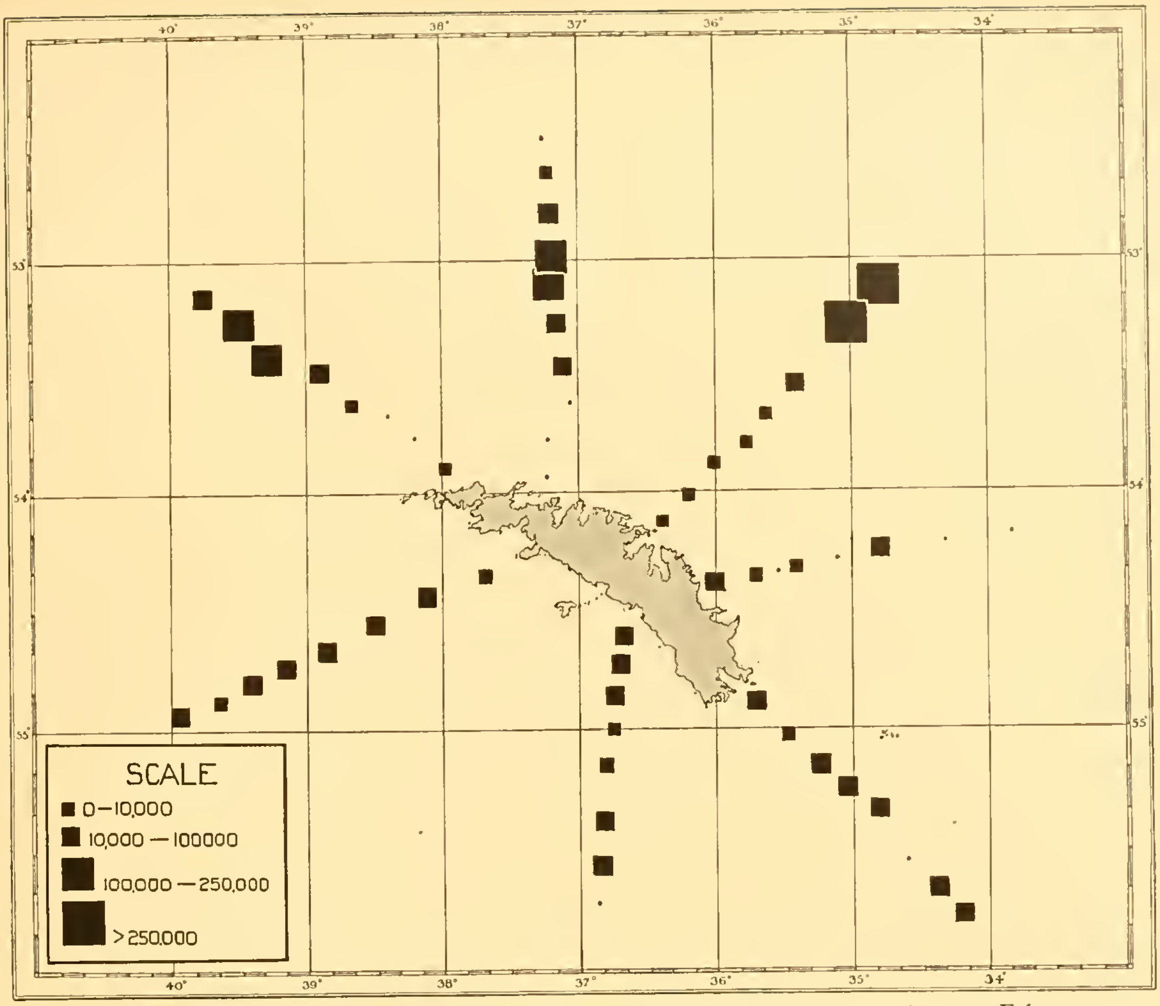

Fig. 16. The distribution of *Ceratium pentagonum* f. *grandis*, South Georgia survey, January–February 1930.

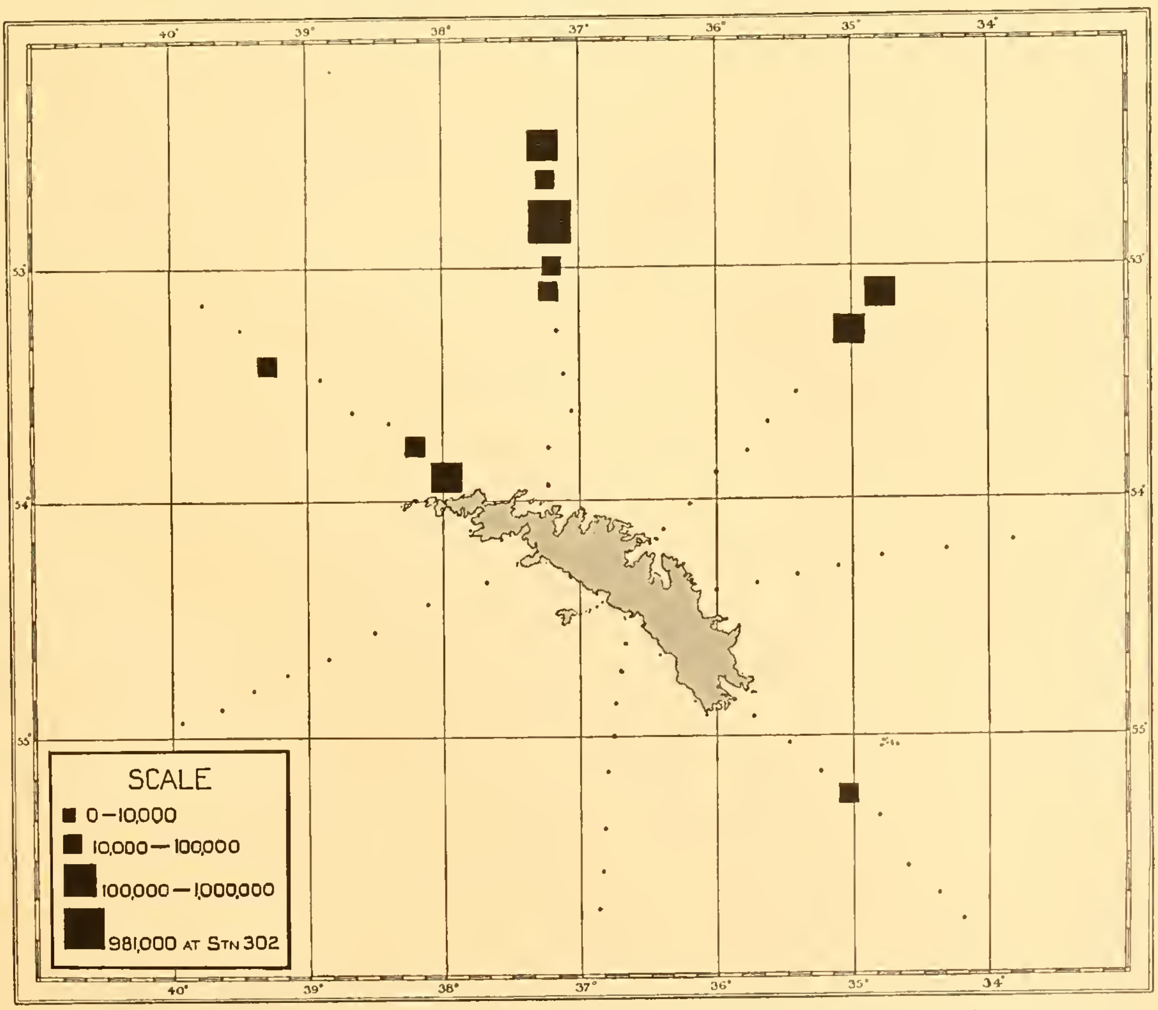

Fig. 17. The distribution of *Eucampia antarctica*, South Georgia survey, January–February 1930.

entirely towards the northern extremities of the Larsen and Prince Olaf lines. It seems quite probable that we have here an example of the normal seasonal effect. From subsequent work it appears that *Eucampia antarctica* reaches its maximum round South Georgia in the spring and perhaps early summer—it was very abundant to the south of the island in November 1930. Now, the general direction of the surface drift, apart from the circulation set up by the configuration of the land, which seems to be confined to within a comparatively short distance of the coast, is to the north-east. Hence it is quite natural to find the last traces of the *Eucampia* maximum away to the north and east of the island during the late summer and autumn.

SUMMARY

The main features of the survey as a whole, which will have become apparent from the above description, were the sameness of the phytoplankton throughout and its poverty in both species and individuals when compared with the earlier survey described by Hardy, and with other areas during the same season. There was also no comparison with the very abundant plankton found on a detailed survey over the same area worked early in the following season, when production was at its height. These differences are so great that there is little doubt that they should not be attributed to seasonal variation: the conditions in January–February 1930 should almost certainly be regarded as abnormal—an instance of one of the major fluctuations of which we know but little as yet beyond the bare fact that they occur. On this survey the conditions were much milder than any experienced in the South Georgia area since the Discovery investigations were begun, and it seems certain that the unusually poor phytoplankton encountered was in some way a resultant of these abnormal conditions.

Everywhere during the January–February 1930 survey when diatoms were at all numerous *Corethron valdiviae* and *Thalassiothrix antarctica* were the dominant forms, with occasionally smaller numbers of *Eucampia antarctica* and *Nitzschia seriata*. The very general presence, in comparatively large numbers, of the two large dinoflagellates *Peridinium antarcticum* and *Ceratium pentagonum* f. *grandis* was an unusual feature directly traceable to the abnormally mild conditions. Representatives of the genus *Chaetoceros*, usually abundant in nearly all types of Antarctic surface water, were almost entirely absent from the material collected on this survey.

The following is a list of all the forms recorded during the survey, arranged in order of their total abundance; the figures in brackets immediately after the specific names represent the number of stations at which each was recorded. In addition, the proportions of the more important forms to the total phytoplankton are expressed as percentages in the right-hand column:

	Total	%
Corethron valdiviae (spineless chains) (43)	32,735,200	53·4
Thalassiothrix antarctica (15)	19,868,900	32·4
Peridinium antarcticum (52)	2,088,550	3·4
Eucampia antarctica (11)	1,985,700	3·2

	Total	%
Ceratium pentagonum f. *grandis* (46) ...	1,776,300	2·9
Coscinodiscus spp. (25)	742,950	1·2
Nitzschia seriata (6)	557,300	
Fragilaria antarctica (2)	380,000	
Small plant cells (? diatom spores) (2) ...	360,000	
Rhizosolenia alata (13)	186,000	
Melosira sphaerica (2)	129,000	
Thalassiosira antarctica (2)	114,000	
Chaetoceros atlanticus (3)	86,400	
Silicoflagellata (7)	82,200	
Biddulphia striata (3)	71,400	
Rhizosolenia styliformis (8)	58,700	3·5
Melosira sol (2)	57,900	
Rhizosolenia antarctica (1)	19,200	
Dinophysis sp. (6)	18,550	
Dactyliosolen antarcticus (2)	13,000	
Rhizosolenia truncata (2)	12,000	
Navicula oceanica (1)	3,000	
Asteromphalus regularis (1)	200	
Gyrosigma (*Pleurosigma*) *directum* (1) ...	150	
Total phytoplankton	61,346,600	

THE PLANKTON SURVEY OF NOVEMBER 1930

On this survey forty-nine stations, arranged on seven lines radiating out to a distance of about 100 miles from the island, were made in the course of 15 days by the R.R.S. 'Discovery II'. The arrangement of the lines differed slightly from that adopted on the previous survey (see Fig. 4), but the area was equally well covered. The phytoplankton obtained was exceedingly rich and varied, the main spring diatom increase having apparently only just reached its maximum. At some stations the settled volume of the catches exceeded $1\frac{1}{2}$ litres, and as small colonial forms, notably *Chaetoceros socialis*, *Ch. neglectus* and the minute form of *Thalassiosira antarctica* which occurs in gelatinous colonies, were exceedingly abundant, it will at once be seen that it was utterly impossible to estimate their numbers with even the rough comparative degree of accuracy achieved with the larger species. The ordinary chain form of *Th. antarctica* was, however, always countable, though unfortunately small numbers of the closely allied *Coscinosira antarctica* were probably confused with it at a few stations on the Undine South and Cooper Island lines. The general practice adopted was to denote the presence of small colonial forms, when too numerous to be estimated satisfactorily, by a symbol such as + or ∞, and to count only those forms that could be clearly distinguished under a $\frac{1}{6}$ in. objective. By this means the expression of the relative abundance of the leading forms diagrammatically is ruled out of court, and tables have therefore been constructed showing both the actual numbers, and the percentages of the total estimated apart from the uncountable forms, which, however, are included in the tables with appropriate symbols so that their great importance can be clearly recognized.

On the Larsen line (Fig. 4), the catches were uniformly heavy, except for that at St. 494. From Table IX it will be seen that conditions on this line were very uniform, with the exception of the outermost station but one, St. 493, where the temperature was over 0·5° C. higher than at the stations worked on either side of it. This was reflected in the very different character of the phytoplankton present.

At the innermost station *Chaetoceros criophilum* was the dominant form, with nearly 50 per cent of the total of a very rich haul, and *Corethron valdiviae* was the only other form of note, while at the next station seawards, this state of affairs was reversed in a haul which, while still heavier than any obtained during the previous survey, was considerably smaller than that from the inshore station. At each of the next four stations *Chaetoceros criophilum* was strongly dominant, forming indeed over 75 per cent of the catch at the next station which, though not the richest in point of numbers, was the largest haul as regards volume taken on this line. At the next three stations, the dominant *Ch. criophilum* was accompanied by a moderate proportion of *Thalassiosira antarctica*. At St. 496 *Fragilaria antarctica* formed over 10 per cent of the estimated total, and *Rhizosolenia styliformis* showed an increase both in numbers and in proportion to the rest of the catch. At the two succeeding stations to seaward this species formed a trifle over 10 per cent of the phytoplankton estimated, and this in conjunction with the general dominance of *Chaetoceros criophilum* may be taken as good evidence of the eastern Weddell Sea origin of the water. This brings us to St. 493 where, as has already been shown from a consideration of the temperatures, it is evident that we have to deal with surface water of a different type. The large species were of little importance in the catch from this station, where, in marked contrast to the conditions elsewhere on this line, we find the small forms *Nitzschia seriata*, *Thalassiosira antarctica* and *Fragilaria antarctica* co-dominant. At the outermost station of all *Corethron valdiviae* predominated, with lesser numbers of *Chaetoceros criophilum* and *Thalassiosira*. This occurrence of *Corethron* in bulk at the two extremities of the line is paralleled on the Prince Olaf line next to be described.

The estimated numbers and percentages of the leading forms on the Larsen line are shown in Table 5.

Table 5

Station number Total phytoplankton	498 **80,640,000**	499 **41,112,000**	500 **74,304,000**	496 **41,593,200**	495 **65,995,200**	494 **15,192,000**	493 **40,116,000***	492 **77,956,800**
Thalassiosira antarctica	6,624,000 **8·2**	1,224,000 **3·0**	3,456,000 **4·7**	7,603,200 **18·3**	18,144,000 **27·5**	2,640,000 **17·3**	12,600,000* **31·4**	7,968,000 **10·2**
Corethron valdiviae	21,792,000 **27·0**	20,448,000 **49·7**	3,686,400 **5·0**	633,600 **1·5**	1,296,000 **2·0**	552,000 **3·6**	540,000 **1·3**	47,424,000 **60·8**
Rhizosolenia styliformis	1,920,000 **2·4**	864,000 **2·1**	1,382,400 **1·9**	3,916,800 **9·4**	7,056,000 **10·7**	1,752,000 **11·5**	270,000 **0·7**	864,000 **1·1**
Chaetoceros criophilum	38,976,000 **48·3**	13,176,000 **32·0**	56,217,600 **75·7**	21,024,000 **50·5**	31,536,000 **47·8**	8,160,000 **53·7**	7,200 **0·002**	14,784,000 **19·0**
Ch. neglectus	3,936,000 **4·9**	1,584,000 **3·9**	3,110,400 **4·2**	— —	— —	120,000 **0·8**	360,000 **0·9**	1,344,000 **1·7**
Fragilaria antarctica + f. *bouvet*	3,936,000 **4·9**	— —	2,304,000 **3·1**	5,535,600 **13·3**	3,320,000 **5·0**	— —	10,800,000 **26·9**	1,920,000 **2·5**
Nitzschia scripta	864,000 **1·1**	504,000 **1·2**	576,000 **0·8**	115,200 **0·3**	432,000 **0·7**	744,000 **4·8**	13,386,000 **33·4**	1,824,000 **2·3**
Other forms %	**3·2**	**8·1**	**4·6**	**6·7**	**6·3**	**8·3**	**5·4**	**2·4**

* Excluding uncountable gelatinous colonies.

The main features of the phytoplankton on this line are well brought out in the table. As will be seen later, the general character of the phytoplankton, which as compared with some others on this survey was rather poor in species and rich in individuals, particularly of the larger forms, all tends to show that the origin of the surface water was in the eastern Weddell Sea, except at the anomalous St. 493. The eastern Weddell Sea influence was almost certainly strongest at Sts. 496, 495 and 494, where a relatively high proportion of *Rhizosolenia styliformis* was observed. At the others the water was comparatively old, and at the inshore stations it is probable that considerable mixing had taken place. There seems to be a sort of eddy off the north-east coast of South Georgia at about this point where the surface water is checked in its normal northerly flow and develops a phytoplankton of a type characteristic of old mixed water although there may be comparatively "young" eastern Weddell Sea water to the north-east.

The striking difference in the character of the phytoplankton at St. 493 is well illustrated by the volumes of the catches (Table IX). It will be seen that the volumes exceeded 250 cc. at all the other stations on the line, but at this one the volume was only 60 cc. With small forms dominant the estimated total reached 40 millions, however, so that we have here a good example of the unreliability of volumes as a guide to the quantity of phytoplankton, whenever the quality is liable to abrupt changes.

The general character of the phytoplankton taken on the PRINCE OLAF LINE (Fig. 4) seems to indicate a development from comparatively old water of the eastern Weddell Sea type, with possibly a considerable degree of mixing from old Bellingshausen water from the west, especially towards the middle and outer end of the line. The numbers and percentages of the leading forms are shown in Table 6; the full analyses will be found in Table X.

Table 6

Station number Total phytoplankton	484 **10,087,800**	485 **55,440,000**	486 **5,415,000**	487 **7,335,000**	488 **8,047,800**	489 **25,185,600**	490 **43,318,800**	491 **41,492,000**
Thalassiosira antarctica	— —	7,470,000 **13·5**	870,000 **16·1**	1,545,000 **21·1**	1,209,600 **15·0**	172,800 **0·7**	151,200 **0·3**	812,000 **1·9**
Corethron valdiviae	9,715,200 **96·3**	40,860,000 **73·7**	390,000 **7·2**	390,000 **5·3**	1,722,000 **21·4**	8,179,200 **32·5**	18,068,400 **41·7**	24,480,000 **59·0**
Rhizosolenia styliformis	13,800 **0·1**	270,000 **0·5**	135,000 **2·5**	405,000 **5·5**	184,800 **2·3**	230,400 **0·9**	680,400 **1·6**	648,000 **1·6**
Chaetoceros criophilum	331,200 **3·3**	2,700,000 **4·9**	2,665,000 **49·2**	3,450,000 **47·0**	3,410,000 **42·4**	15,667,200 **62·2**	19,807,200 **45·7**	10,080,000 **24·3**
Ch. neglectus	— —	1,260,000 **2·3**	— —	— —	352,800 **4·4**	633,600 **2·5**	2,646,000 **6·1**	3,600,000 **8·7**
Fragilaria antarctica + f. *bouvet*	— —	1,440,000 **2·6**	735,000 **13·6**	840,000 **11·5**	201,600 **2·5**	— —	— —	648,000 **1·7**
Thalassiothrix antarctica	— —	270,000 **0·5**	45,000 **0·8**	150,000 **2·0**	201,600 **2·5**	64,800 **0·3**	982,800 **2·3**	144,000 **0·3**
Nitzschia seriata	— —	270,000 **0·5**	45,000 **0·8**	30,000 **0·4**	117,600 **1·5**	— —	907,200 **2·1**	432,000 **1·0**
Other forms %	0·3	1·5	8·8	7·2	8·0	0·9	0·2	1·5

From this table it will be seen that at the two inshore stations *Corethron valdiviae* was strongly dominant, with a moderate proportion of *Thalassiosira antarctica* at St. 485 as the only other form of much importance. At the next two stations seaward *Corethron* was not encountered in anything approaching these numbers. *Chaetoceros criophilum* was the dominant form, with lesser numbers of *Thalassiosira antarctica* and *Fragilaria antarctica*. At St. 488 a moderate proportion of *Thalassiosira* was found, but at the three succeeding stations out to the end of the line it became comparatively scarce. *Chaetoceros criophilum* was still dominant at St. 488 and the two succeeding stations, but at these increasing proportions of *Corethron* were found, and at the outermost station this form was again dominant.

It will be seen from the tables that except at St. 485 and the outermost stations on the line the quantity of phytoplankton collected was not so great as that found almost everywhere on the Larsen line previously described. The totals at Sts. 486, 487 and 488 were in fact among the smallest estimated on this survey.

The general character of the phytoplankton indicates that most of the stations on this line were worked in comparatively old water, mainly originating from the eastern Weddell Sea type. The high proportion of *Corethron* at the two inshore stations indicates that these were worked in the eddy off the north-east coast mentioned in connection with the inshore stations on the previous line. At the outermost stations on the Prince Olaf line the increase of *Corethron* and *Chaetoceros neglectus*, and the proportionate decrease of the large *Ch. criophilum*, are possibly indicative of mixing with old Bellingshausen Sea water from the west, but more probably to the fact that the phytoplankton of the Weddell Sea water loses some of its sharply defined character as the water gets older, so that the phytoplankton of all old Antarctic surface waters becomes very much the same.

The Bird Island line (Fig. 4) provided the smallest samples taken on this survey, which is not surprising in view of the fact that it apparently cut into the old Bellingshausen Sea surface water to the north-west of the island. This water must have travelled a great distance from its source of origin, and all our evidence goes to show that except perhaps in autumn, the phytoplankton of the Bellingshausen Sea water reaches its maximum when that water is comparatively young, an observation which has been confirmed by Mr John during the following (1931–2) season.

From Table XI, in which the full analyses of the material collected on this line are given, it will be seen that the flora encountered, though much smaller quantitatively, was richer in species than that of the lines previously described. The numbers and proportions of the leading forms are shown in Table 7.

From this table it will be seen that at the inshore station *Corethron valdiviae* was entirely dominant in the smallest catch, in point of numbers, obtained during this survey. Probably this station was worked in surface water similar to that found at the innermost stations on the previous line. At the next three stations proceeding offshore the influence of old eastern Weddell Sea surface water mixing with old Bellingshausen Sea surface water approaching from the west was very clearly indicated. The dominant forms *Corethron*, *Chaetoceros criophilum* and *Thalassiosira antarctica*, whose abundant development is characteristic of the old eastern Weddell Sea type, show a steady decrease in proportion, while the percentages of the small forms *Fragilaria antarctica*, *Nitzschia seriata* and *Chaetoceros neglectus*, characteristic of the older Bellingshausen Sea water, show a progressive increase. At the four outer stations on the line these small forms were dominant with the single exception of St. 477, where *Ch. criophilum* was the most numerous diatom. This may be taken as almost conclusive evidence of the presence of old Bellingshausen Sea water. The nature of the phytoplankton taken on the Bird Island line thus affords good evidence of mixing of the two types of surface water to the north of South Georgia at this time, while farther out to the north-west old Bellingshausen Sea water was to be found.

Table 7

Station number Total phytoplankton	483 **1,001,700**	482 **12,832,800**	481 **13,020,000**	480 **36,128,000**	479 **11,048,000**	478 **2,470,000**	477 **1,710,000**	475 **4,627,400**
Thalassiosira antarctica	18,900	3,456,000	2,580,000	4,248,000	577,500	16,200	28,500	85,800
	1·9	**26·9**	**19·8**	**11·8**	**5·2**	**0·6**	**1·7**	**1·9**
Corethron valdiviae	951,300	3,420,000	3,120,000	7,184,000	172,000	48,600	152,000	85,800
	95·0	**26·7**	**24·0**	**19·9**	**1·6**	**2·0**	**8·9**	**1·9**
Rhizosolenia chunnii	12,600	4,200	210,000	1,728,000	22,500	—	—	—
	1·2	**0·03**	**1·6**	**4·8**	**0·2**	—	—	—
R. styliformis	—	504,000	360,000	720,000	—	24,300	57,000	23,400
	—	**3·9**	**2·8**	**2·0**	—	**1·0**	**3·3**	**0·5**
Chaetoceros criophilum	6,300	3,312,000	2,820,000	7,344,000	127,500	105,300	617,500	109,200
	0·5	**25·8**	**21·7**	**20·3**	**1·2**	**4·5**	**36·1**	**2·4**
Chaetoceros spp. (small)	—	252,000	630,000	3,168,000	1,072,500	437,400	247,000	702,000
mainly *neglectus*	—	**2·0**	**4·8**	**8·8**	**9·7**	**17·7**	**14·4**	**15·2**
Eucampia antarctica	—	10,200	810,000	504,000	210,000	129,600	38,000	23,400
	—	**0·1**	**6·2**	**1·4**	**1·9**	**5·2**	**2·2**	**0·5**
Fragilaria antarctica	—	792,000	1,470,000	5,472,000	5,460,000	826,200	389,500	1,801,800
	—	**6·2**	**11·3**	**15·1**	**49·4**	**33·4**	**22·8**	**38·9**
Thalassiothrix antarctica	—	216,000	—	864,000	352,500	72,900	38,000	85,800
	—	**1·7**	—	**2·4**	**3·2**	**2·9**	**2·2**	**1·9**
Nitzschia seriata	—	252,000	720,000	3,456,000	2,205,000	275,400	—	922,400
	—	**2·0**	**5·5**	**9·6**	**20·0**	**11·1**	—	**19·9**
Other forms %	**1·4**	**4·7**	**2·3**	**4·9**	**7·6**	**21·6**	**8·4**	**16·9**

The next line of stations to be described was worked roughly south-westwards from Annenkov Island (Fig. 4); actually it was the last line worked on this survey, but as the whole survey was accomplished in a very short space of time, and the phytoplankton lends itself to natural explanation in this sequence, the order in which the lines are described seems well justified.

The full analyses of the hauls taken on the Annenkov Island line are shown in Table XII. From this it will at once be seen that the hauls were extremely heavy, with a vast profusion of small forms. The value of the percentages, which could only be calculated apart from the forms which defied estimation, is thus vitiated. Nevertheless, Table 8 gives some idea of the main features of the phytoplankton taken on this line.

The hauls obtained here show such a marked difference from those taken to the north and north-east of the island during this survey that it is probable that we have to deal with an entirely different type of surface water. As far as one can judge from the character of the phytoplankton alone this is indeed the case, the dominant species here pointing to the western Weddell Sea origin of the bulk of the water, especially inshore, with a certain amount of mixing with old Bellingshausen Sea water, more particularly at the middle and outer end of the line.

Table 8

Station number Total phytoplankton	525 **35,251,200***	524 **58,392,000***	523 **107,382,000***	522 **57,840,000***	521 **132,300,000***	520 **108,136,800**
Thalassiosira antarctica	22,075,200† **62·6**	32,040,000† **54·9**	19,180,800† **17·9**	8,280,000† **14·3**	19,278,000† **14·6**	28,648,800 **26·5**
Rhizosolenia styliformis	— —	144,000 **0·2**	1,209,600 **1·1**	840,000 **1·5**	8,694,000 **6·6**	1,573,200 **1·5**
Chaetoceros criophilum	648,000 **1·8**	2,592,000 **4·4**	21,081,600 **19·6**	11,280,000 **19·5**	35,910,000 **27·1**	17,636,400 **16·3**
Ch. neglectus	+ —	+ —	11,923,200 **11·1**	4,200,000 **7·3**	6,615,000 **5·0**	1,987,200 **1·8**
Ch. socialis	∞ —	∞ —	— —	— —	— —	— —
Eucampia antarctica	5,659,200 **16·1**	8,568,000 **14·7**	691,200 **0·6**	1,080,000 **1·9**	2,268,000 **1·7**	1,159,200 **1·1**
Fragilaria antarctica	2,505,600 **7·1**	7,632,000 **13·1**	24,192,000 **22·5**	13,320,000 **23·0**	31,941,000 **24·1**	30,336,400 **28·1**
Thalassiothrix antarctica	1,036,800 **2·9**	2,376,000 **4·1**	10,195,000 **9·5**	4,080,000 **7·1**	3,780,000 **2·9**	3,394,800 **3·1**
Nitzschia seriata	734,400 **2·1**	1,728,000 **3·0**	5,011,200 **4·7**	7,920,000 **13·7**	8,694,000 **6·6**	7,617,600 **7·0**
Other forms %	**7·4**	**5·6**	**13·0**	**11·8**	**11·4**	**14·6**

* Excluding uncountable colonies. † Excluding gelatinous colonies.

From the above table it will be seen that at the two inshore stations the dominant forms were *Chaetoceros socialis*, *Ch. neglectus* and *Thalassiosira antarctica*, with lesser numbers of *Eucampia antarctica* and *Fragilaria antarctica*. It will be seen that besides the normal chain form that can be readily estimated, large numbers of minute gelatinous colonies of *Thalassiosira* were present, as indicated by the asterisk after the estimated numbers. It is at these two stations that the influence of the western Weddell Sea water is most strongly exhibited. In all the material examined for this report *Chaetoceros socialis* has only twice been recorded in any other type of surface water. The pronounced dominance of *Thalassiosira antarctica* over the other countable forms may also be taken as typical of western Weddell Sea conditions, as this species, though undoubtedly a spring form, was still numerous in water of this type near Joinville Island later in the season, whereas at the stations worked towards the Bellingshausen Sea it never reached anything like the same prominence.

At the four outer stations on the Annekov Island line it will be seen that the general character of the phytoplankton remained very much the same throughout. *Chaetoceros socialis* did not occur, and it will be noted later on how extremely sporadic is the distribution of this form. The dominant forms were *Fragilaria antarctica*, *Thalassiosira* and *Chaetoceros criophilum* and lesser numbers of *Thalassiothrix antarctica* and *Nitzschia seriata*, indicative of slight admixture with Bellingshausen Sea water. It will be noted that the percentage of *Fragilaria* increased steadily towards the south-west; pack-ice was present in that direction at the time, and as will be noted on many subsequent occasions, the abundant occurrence of this species in the plankton at any distance from land appears to be closely correlated with the presence of melting pack-ice. The probable significance of this is discussed later.

Heavy hauls containing large numbers of species, with small colonial forms dominant, were the feature of the line worked in a direction slightly east of south from UNDINE SOUTH HARBOUR (Fig. 4). The general character of the phytoplankton was similar to that described at the two inshore stations of the previous line, the influence of western Weddell Sea surface water being marked throughout. The full analyses of the phytoplankton catches on this line are to be found in Table XIII. The proportions of the leading forms are shown, so far as is possible, in Table 9.

Table 9

Station number Total phytoplankton	517 **87,552,000***	518 **85,823,800***	519 **76,416,000***	516 **109,440,000***	515 **32,529,600***	514 **26,799,200***
Thalassiosira antarctica	38,016,000†	38,707,000†	25,536,000†	68,352,000†	7,192,800†	6,917,400†
	43·4	**45·1**	**33·4**	**62·5**	**22·1**	**25·6**
Dactyliosolen laevis	960,000	2,073,600	672,000	864,000	939,600	340,200
	1·1	**2·4**	**0·9**	**0·8**	**2·9**	**1·3**
Corethron valdiviae	2,496,000	2,073,600	1,344,000	576,000	680,400	340,200
	2·9	**2·4**	**1·8**	**0·5**	**2·1**	**1·3**
Chaetoceros atlanticus	2,496,000	345,600	576,000	384,000	518,400	—
	2·9	**0·4**	**0·8**	**0·4**	**1·6**	—
Ch. criophilum	11,328,000	6,336,000	3,360,000	9,888,000	1,717,200	3,628,800
	12·9	**7·4**	**4·4**	**9·0**	**5·3**	**13·5**
Ch. dichaeta	—	—	3,744,000	576,000	810,000	1,134,000
	—	—	**4·9**	**0·5**	**2·5**	**4·2**
Ch. neglectus	∞	+	7,488,000	6,816,000	4,082,400	3,780,000
	—	—	**9·8**	**6·2**	**12·5**	**14·1**
Ch. socialis	∞ ∞	∞	+	Present	+	∞
	—	—	—	—	—	—
Eucampia antarctica	13,056,000	3,686,400	2,304,000	1,920,000	810,000	264,600
	14·9	**4·3**	**3·0**	**1·8**	**2·5**	**1·0**
Fragilaria antarctica	9,216,000	23,616,000	19,392,000	11,616,000	10,335,600	4,951,800
	10·5	**27·5**	**25·4**	**10·6**	**31·8**	**18·5**
Thalassiothrix antarctica	2,880,000	3,801,600	4,128,000	1,824,000	2,203,200	2,381,400
	3·3	**4·4**	**5·4**	**1·7**	**6·8**	**8·9**
Nitzschia seriata	3,072,000	1,267,200	5,760,000	2,016,000	2,106,000	1,398,600
	3·5	**1·5**	**7·5**	**1·8**	**6·5**	**5·2**
Other forms %	**4·6**	**4·6**	**2·7**	**4·2**	**3·4**	**6·2**

* Excluding uncountable colonies. † Excluding gelatinous colonies.

It will be seen that *Chaetoceros socialis* and *Thalassiosira antarctica* were dominant throughout, accompanied by *Chaetoceros neglectus* inshore and with lesser numbers of *Fragilaria antarctica* farther south. A very large number of species were recorded, this line being surpassed only by that off Annenkov Island, where, as we have seen, a certain amount of mixing with old Bellingshausen Sea surface water had probably taken place. It will be noted that *Chaetoceros atlanticus* and *Ch. dichaeta* here reached their maximum both in numbers and importance for the survey, while *Corethron valdiviae*, as on the Annenkov Island line, was comparatively scarce. This is in strong contrast to the hauls taken at this time in water originating in the eastern Weddell Sea, to the east and north of South Georgia. *Eucampia antarctica* again reached its maximum inshore, as on the Annenkov Island line. It will be noted also that at the two southernmost stations on the Undine South line the phytoplankton was somewhat scantier than at those worked nearer the island, though the hauls were still very large.

Thus the general character of the phytoplankton on this line closely reflected the western Weddell Sea origin of the surface water. There is a possibility of slight mixture with old Bellingshausen Sea water away to the south-west, which is perhaps indicated by the moderate numbers of *Nitzschia seriata* and *Thalassiothrix antarctica*. However, both these forms do occur in surface water of western Weddell Sea origin, and it seems more probable that their presence here, in rather higher proportions than usual for water of this type, may be due merely to the seasonal influence, the species concerned possibly showing a more strongly marked vernal increase in western Weddell Sea water.

Again, on the line worked eastwards from Cooper Island (Fig. 4) heavy catches with immense numbers of small forms were obtained. The inshore station showed a comparatively small catch, which was not so rich in species as those taken farther offshore. Even here the volume of the sample reached 250 cc., and in the very minute sub-sample it was possible to examine no organisms other than diatoms were seen. The full analyses of the material from this line will be found in Table XIV; the proportions of the leading forms are indicated in Table 10.

Table 10

Station number Total phytoplankton	513 **24,631,200***	512 **124,082,000***	511 **59,478,000**	510 **126,836,000***	509 **54,856,800***	508 **76,752,000***
Thalassiosira antarctica	12,513,600 **50·8**	37,200,000† **30·0**	10,800,000 **18·2**	33,696,000† **26·6**	26,370,000 **48·1**	24,624,000† **32·1**
Dactyliosolen laevis	39,600 **0·2**	960,000 **0·8**	576,000 **1·0**	810,000 **0·6**	180,000 **0·3**	1,152,000 **1·5**
Corethron valdiviae	118,800 **0·4**	480,000 **0·4**	1,296,000 **2·2**	1,458,000 **1·1**	1,260,000 **2·3**	576,000 **0·8**
Rhizosolenia styliformis	79,200 **0·3**	1,680,000 **1·4**	1,152,000 **1·9**	2,430,000 **1·9**	1,350,000 **2·5**	1,008,000 **1·3**
Chaetoceros criophilum	6,613,200 **26·8**	11,522,000 **9·3**	33,126,000 **55·7**	22,518,000 **17·8**	7,920,000 **14·4**	16,416,000 **21·4**
Ch. neglectus	— —	24,960,000 **20·1**	432,000 **0·7**	20,726,000 **16·3**	4,725,000 **8·6**	— —
Ch. socialis	∞ —	∞ —	— —	∞ —	+ —	∞ —
Biddulphia striata	— —	1,440,000 **1·2**	144,000 **0·2**	1,134,000 **0·9**	675,000 **1·2**	1,440,000 **1·9**
Eucampia antarctica	435,600 **1·8**	18,240,000 **14·7**	864,000 **1·5**	8,100,000 **6·4**	1,935,000 **3·5**	4,608,000 **6·0**
Fragilaria antarctica	2,772,000 **11·3**	21,120,000 **17·0**	7,488,000 **12·6**	29,808,000 **23·5**	6,345,000 **11·6**	22,752,000 **29·6**
Thalassiothrix antarctica	1,900,800 **7·7**	4,080,000 **3·3**	2,160,000 **3·6**	2,592,000 **2·0**	1,620,000 **3·0**	2,304,000 **3·0**
Nitzschia seriata	— —	2,160,000 **1·7**	576,000 **1·0**	2,106,000 **1·7**	1,035,000 **1·9**	— —
Other forms %	**0·7**	**0·1**	**1·4**	**1·2**	**4·9**	**2·4**

* Excluding uncountable colonies. † Excluding gelatinous colonies.

It will be seen that the general character of the phytoplankton was very similar to that taken on the previous line, with *Chaetoceros socialis* dominant and *Thalassiosira antarctica*, *Fragilaria antarctica*, *Chaetoceros criophilum* and more rarely *Ch. neglectus* also numerous, in that order of importance. At the one station where *Ch. socialis* was not found, St. 511, the large *C. criophilum* was strongly dominant, and the percentage of *Thalassiosira* and other forms whose abundant occurrence is characteristic of surface water derived from the western Weddell Sea, showed a marked decrease in comparison with the other stations on the line. This suggests mixing with eastern type Weddell Sea surface water. Apart from this one station the phytoplankton encountered was typical of old western Weddell Sea surface water, with *Corethron valdiviae* nowhere important. *Eucampia antarctica* formed nearly 15 per cent of the countable forms at St. 512, and *Thalassiothrix antarctica* was most important relatively at the inshore station. Of the less numerous forms it will be seen that *Chaetoceros atlanticus*, *Ch. dichaeta*, *Dactyliosolen laevis* and *Nitzschia seriata* were not so plentiful as on the Undine South line, while on the other hand *Biddulphia striata* reached its maximum for the survey on this line and small numbers of *Rhizosolenia styliformis* were again encountered.

The line worked eastwards from Cape Vakop (Fig. 4) completes this account of the second survey. The phytoplankton was still very rich, though it will at once be seen that there was a big falling off in numbers at the offshore stations. Table XV gives the full analyses of the material collected on this line, and from it the reason for this falling off in numbers, although the catches did not by any means show a proportionate decrease in bulk, will at once be apparent. The inshore half of the line was evidently worked in old surface water of western Weddell Sea type, with the forms mentioned on the previous two lines strongly dominant. Farther out the line cut into the cold tongue of eastern Weddell Sea surface water sweeping up the north-east coast of South Georgia some 50 miles out from the land, where the characteristic plankton association, with one or two large species very strongly dominant, was encountered. The proportions of the leading forms on the Vakop line are indicated in Table 11.

Table 11

Station number Total phytoplankton	507 **18,906,000***	506 **63,170,000***	505 **69,016,800***	504 **32,472,000**	503 **34,290,000**	502 **31,392,000**	501 **19,856,000**
Thalassiosira antarctica	9,936,000† **52·6**	17,664,000† **28·0**	26,460,000† **38·3**	2,736,000 **8·4**	9,720,000 **28·3**	2,448,000 **7·8**	720,000 **3·6**
Dactyliosolen laevis	55,200 **0·3**	480,000 **0·8**	2,116,800 **3·1**	— —	— —	— —	48,000 **0·2**
Corethron valdiviae	1,380,000 **7·3**	2,496,000 **4·0**	1,058,400 **1·5**	1,440,000 **4·4**	630,000 **1·8**	864,000 **2·8**	336,000 **1·7**
Rhizosolenia styliformis	55,200 **0·3**	576,000 **0·9**	1,134,000 **1·6**	4,320,000 **13·3**	5,040,000 **14·7**	9,576,000 **30·5**	6,464,000 **32·6**
Chaetoceros criophilum	3,091,200 **16·4**	14,112,000 **22·3**	2,721,000 **3·9**	14,904,000 **45·9**	15,210,000 **44·4**	14,328,000 **45·6**	9,744,000 **49·1**
Ch. dichaeta	— —	1,344,000 **2·1**	1,058,400 **1·5**	— —	— —	360,000 **1·1**	144,000 **0·7**
Ch. neglectus	— —	8,544,000 **13·5**	7,030,800 **10·2**	2,664,000 **8·2**	270,000 **0·8**	— —	— —
Ch. schimperianus	220,800 **1·2**	3,744,000 **5·9**	907,200 **1·3**	— —	— —	— —	— —
Ch. socialis	∞ —	— —	— —	— —	— —	— —	— —
Biddulphia striata	82,800 **0·4**	768,000 **1·2**	1,360,800 **2·0**	— —	— —	72,000 **0·2**	48,000 **0·2**
Eucampia antarctica	1,849,200 **9·8**	192,000 **0·3**	2,570,400 **3·7**	288,000 **0·9**	— —	— —	— —
Fragilaria antarctica	1,876,800 **9·9**	6,720,000 **10·6**	13,980,000 **20·3**	720,000 **2·2**	720,000 **2·1**	432,000 **1·4**	192,000 **1·0**
Thalassiothrix antarctica	193,200 **1·0**	3,840,000 **6·1**	3,553,200 **5·1**	1,080,000 **3·3**	540,000 **1·6**	576,000 **1·8**	432,000 **2·3**
Nitzschia seriata	— —	1,920,000 **3·0**	2,419,200 **3·5**	3,240,000 **10·2**	1,530,000 **4·5**	1,944,000 **6·1**	1,344,000 **6·8**
Other forms %	**0·8**	**2·2**	**4·0**	**3·2**	**1·8**	**2·7**	**1·8**

* Excluding uncountable colonies. † Excluding gelatinous colonies.

It will be seen that inshore *Chaetoceros socialis* and *Thalassiosira antarctica* were dominant, with lesser numbers of *Chaetoceros criophilum*, *Ch. neglectus* and *Fragilaria antarctica*. Among the rarer forms *Eucampia antarctica* reached its maximum for the line at the innermost station, as on the lines worked farther west. *Chaetoceros schimperianus* and *Dactyliosolen laevis* reached their maximum for the survey at Sts. 506 and 505 respectively. The transition to the eastern Weddell Sea surface water evidently began at St. 504. Here the large *Chaetoceros criophilum* was dominant with lesser numbers of *Rhizosolenia styliformis*, and the percentage of these two forms, more especially the latter, increased steadily towards the seaward end of the line. All the less numerous forms characteristic of the western Weddell Sea water show a decrease from this station outwards, with the exceptions of *Nitzschia seriata* and, at St. 503, *Thalassiosira antarctica*.

It will be noted that on this line *Corethron valdiviae* was still rare, as on the lines worked in almost purely western Weddell Sea water, in strong contrast to the conditions obtaining in the older eastern Weddell Sea water which was examined on the earlier lines to the north-east, where it was one of the dominant forms. It seems that in the eastern Weddell Sea surface water one encounters successive zones in which first *Corethron* and then *Rhizosolenia styliformis* accompany *Chaetoceros criophilum* as the dominant forms, and that where *Rhizosolenia* is present in any numbers, as on this line, *Corethron* is relatively scarce. This can be seen on the Larsen line at Sts. 495 and 494 (Tables IX and 5). It was even more clearly illustrated on the line worked south-east from South Georgia later in the season, which is described in the Weddell Sea section (pp. 101, 102). On this line zones in which either *Corethron*, *Chaetoceros* or *Rhizosolenia* were completely dominant were met with, divided by transitional areas in which either *Corethron* and *Chaetoceros*, or *Chaetoceros* and *Rhizosolenia*, were more or less codominant.

Having given some account of the nature of the phytoplankton encountered on the several lines of the November 1930 survey, it remains to give a general view of the flora over the whole area at this time. Separate distribution charts (Figs. 19–30) of the more important species have been constructed, which, coupled with the chart showing the estimated diatom totals, should give a clearer picture of the situation than many pages of detailed description. Some of the rarer forms are of course very instructive in their distribution, but space precludes a detailed consideration of these.

The general distribution chart (Fig. 18) shows that the heaviest phytoplankton hauls were obtained to the south and south-west of the island in water of western Weddell Sea origin. The cold tongue of eastern Weddell Sea surface water projecting up the north-east coast was not so rich in individuals. The local eddy off the north-east coast fairly close in had a moderately rich flora, and also the water sampled to the extreme north-east. The poorest hauls were obtained to the north-west in old Bellingshausen Sea water, and to the north, where this water was probably mixing with old water of the eastern Weddell Sea type.

Turning to individual species, reference to the list given on p. 65 shows that the most important of these were:

Chaetoceros socialis	*Fragilaria antarctica* f. *bouvet*
Thalassiosira antarctica	*Nitzschia seriata*
Chaetoceros neglectus	*Eucampia antarctica*
Ch. criophilum	*Thalassiothrix antarctica*
Corethron valdiviae	*Rhizosolenia styliformis*
Fragilaria antarctica	*Dactyliosolen laevis*

in that order of total abundance.

Fig. 18. General distribution of Diatomales (totals per 100–0 m. haul), South Georgia survey, November 1930. This chart is based on catches made at the positions indicated in Fig. 19.

The distribution of *Chaetoceros socialis* is shown in Fig. 19. It will be seen that it was taken at fourteen stations only, all of which were grouped round the southern extremity of the island, some close inshore, and the others in the neighbourhood in which the pack-ice lingered longest during this spring, and all in water which from the general nature of the phytoplankton as a whole, almost certainly originated in the western Weddell Sea.

Thalassiosira antarctica also reached its greatest abundance in the western Weddell Sea surface water round the southern end of the island (Fig. 20) and was comparatively rare to the north and north-west. It was, however, very widely distributed, being taken at all but six stations on this survey. It occurred in the eastern Weddell Sea water in considerable numbers. The minute form growing in gelatinous colonies which defied

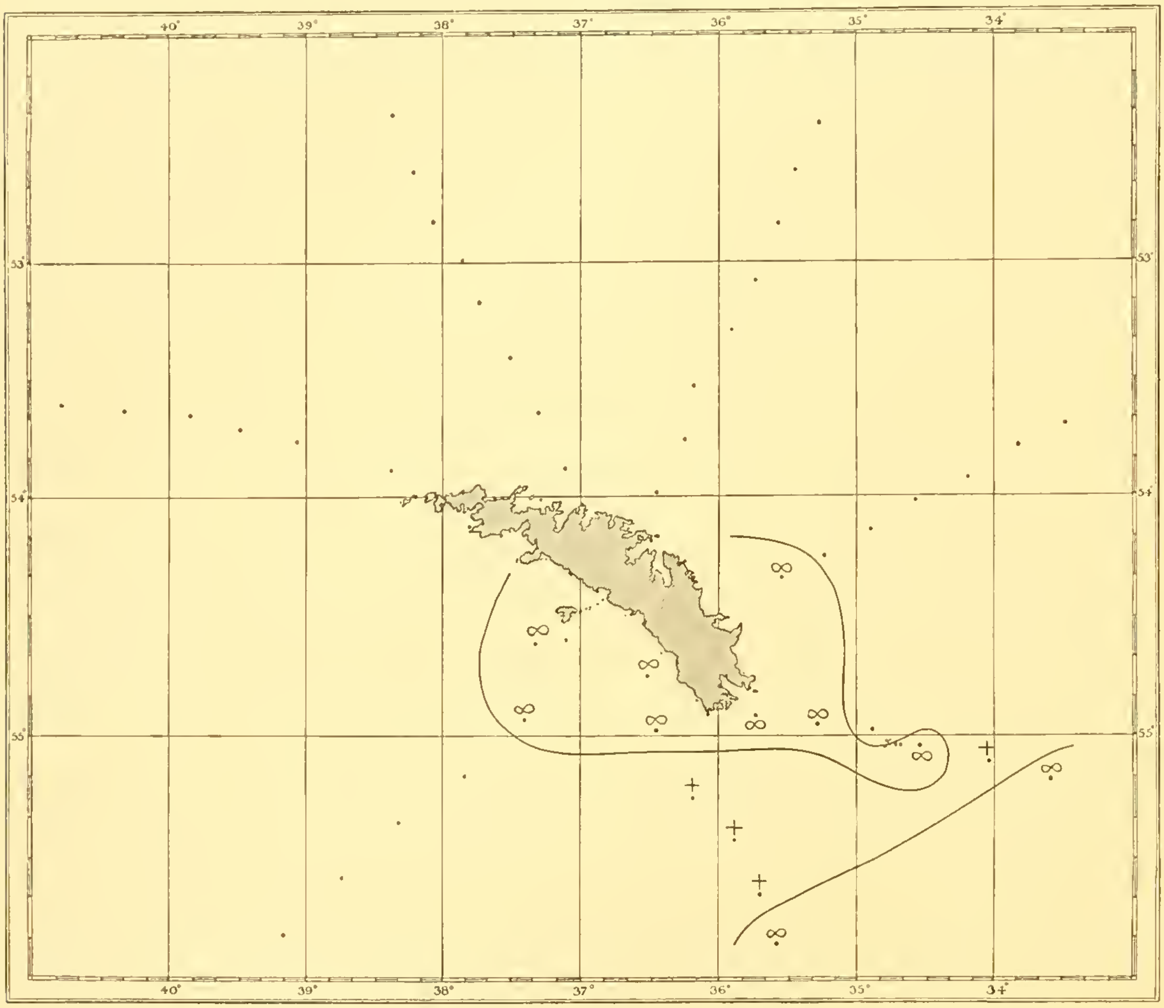

Fig. 19. The distribution of *Chaetoceros socialis*, South Georgia survey, November 1930.

estimation was, however, confined to the densely populated region to the south-west with the single exception of the anomalous St. 493 on the Larsen line.

Chaetoceros neglectus (Fig. 21) was another widely distributed form, showing, however, a strong maximum to the south-west and south, where at some of the inshore stations it occurred in such numbers as to render estimation impossible. This was due chiefly to the presence of *Ch. socialis* at the same stations, as when this species was absent it was found to be possible to count very large numbers of *Ch. neglectus*. Here again this species reached its maximum in water of western Weddell Sea origin; to the east and north-east, where stations were worked in water originating in the eastern Weddell Sea, it was almost entirely absent.

The large species *Ch. criophilum*, on the other hand (Fig. 22), was equally abundant in both types of Weddell Sea water and least numerous to the north and north-west where the influence of surface water from the Bellingshausen Sea made itself felt. Whereas in the extremely rich hauls in the western Weddell Sea water, *Ch. criophilum*, though abundant, was surpassed in numbers by the small forms mentioned

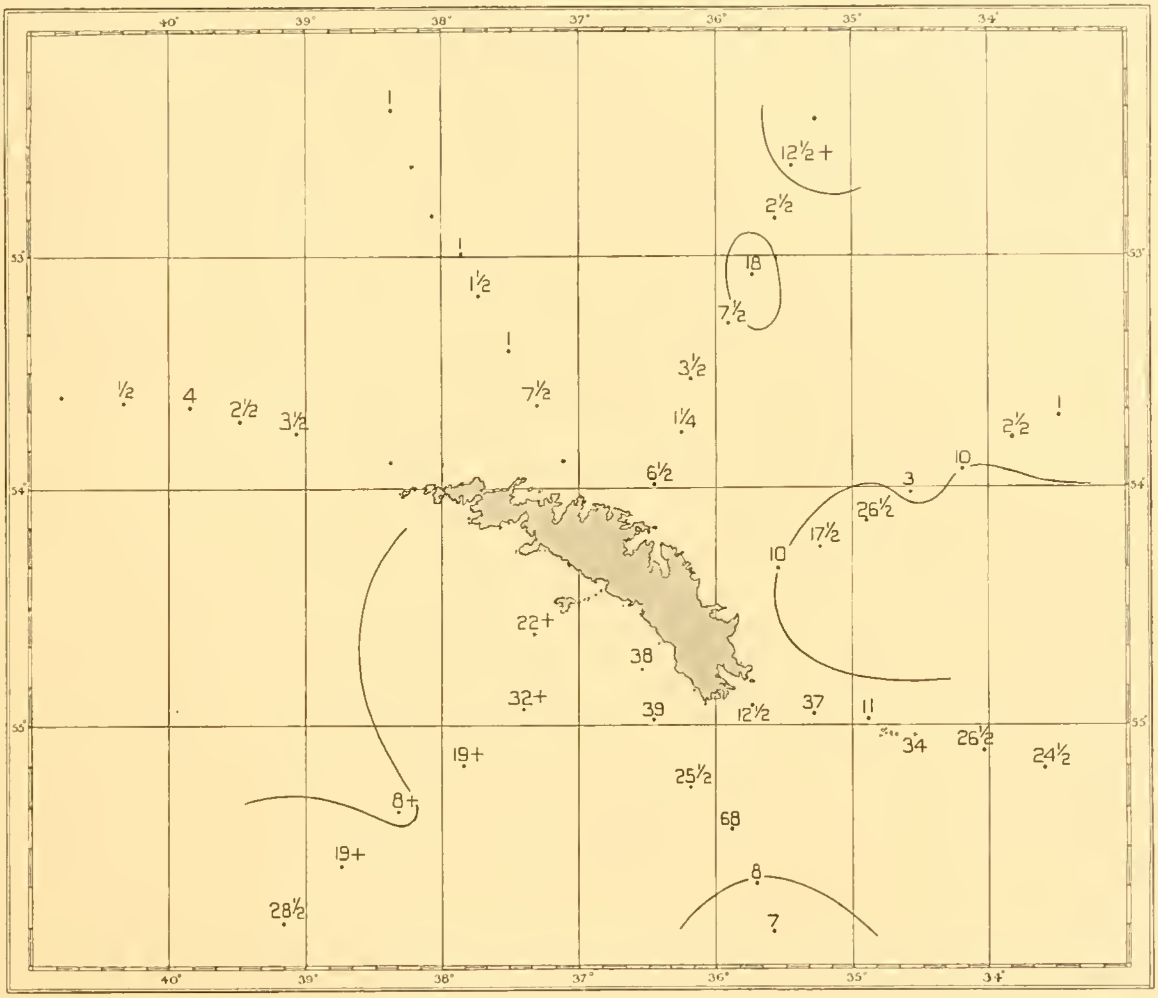

Fig. 20. The distribution of *Thalassiosira antarctica*, South Georgia survey, November 1930. 1 = one million.

above, in the moderately heavy catches in surface water of the eastern Weddell Sea type it was the dominant form, as will have been seen from the percentages already discussed. This form reached its maximum for the survey in the comparatively old eastern Weddell Sea water on the Larsen line.

The distribution of *Corethron valdiviae* (Fig. 23) on this survey was very interesting. In strong contrast to the summer survey previously described, the spineless chain form was comparatively rare, the normal spiny form being present in moderate numbers in all three types of surface water, and very abundant in the old mixed water to the extreme north, and in the eddy close inshore off the north-east coast. Most of the individual

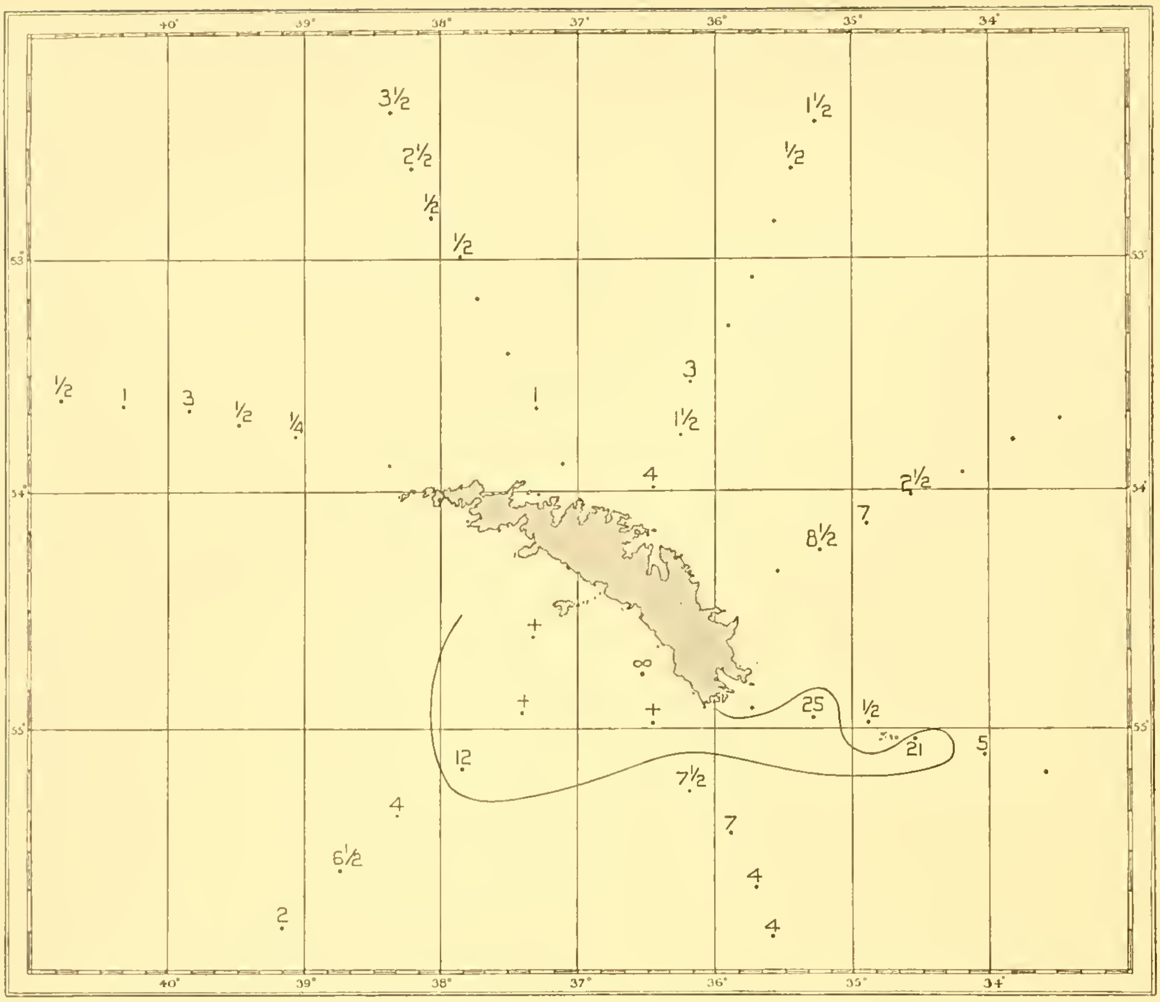

Fig. 21. The distribution of *Chaetoceros neglectus*, South Georgia survey, November 1930. 1 = one million.

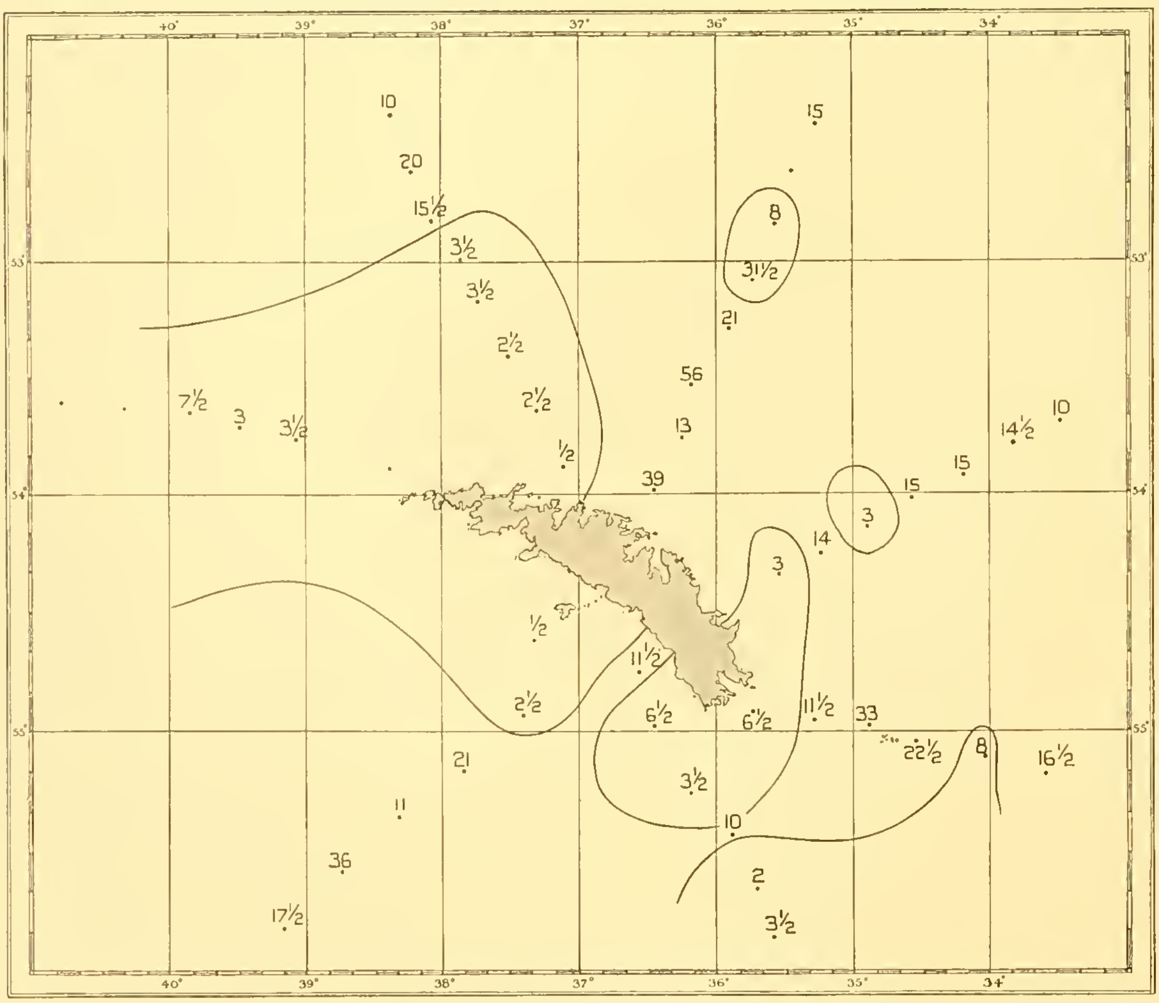

Fig. 22. The distribution of *Chaetoceros criophilum*, South Georgia survey, November 1930. 1 = one million.

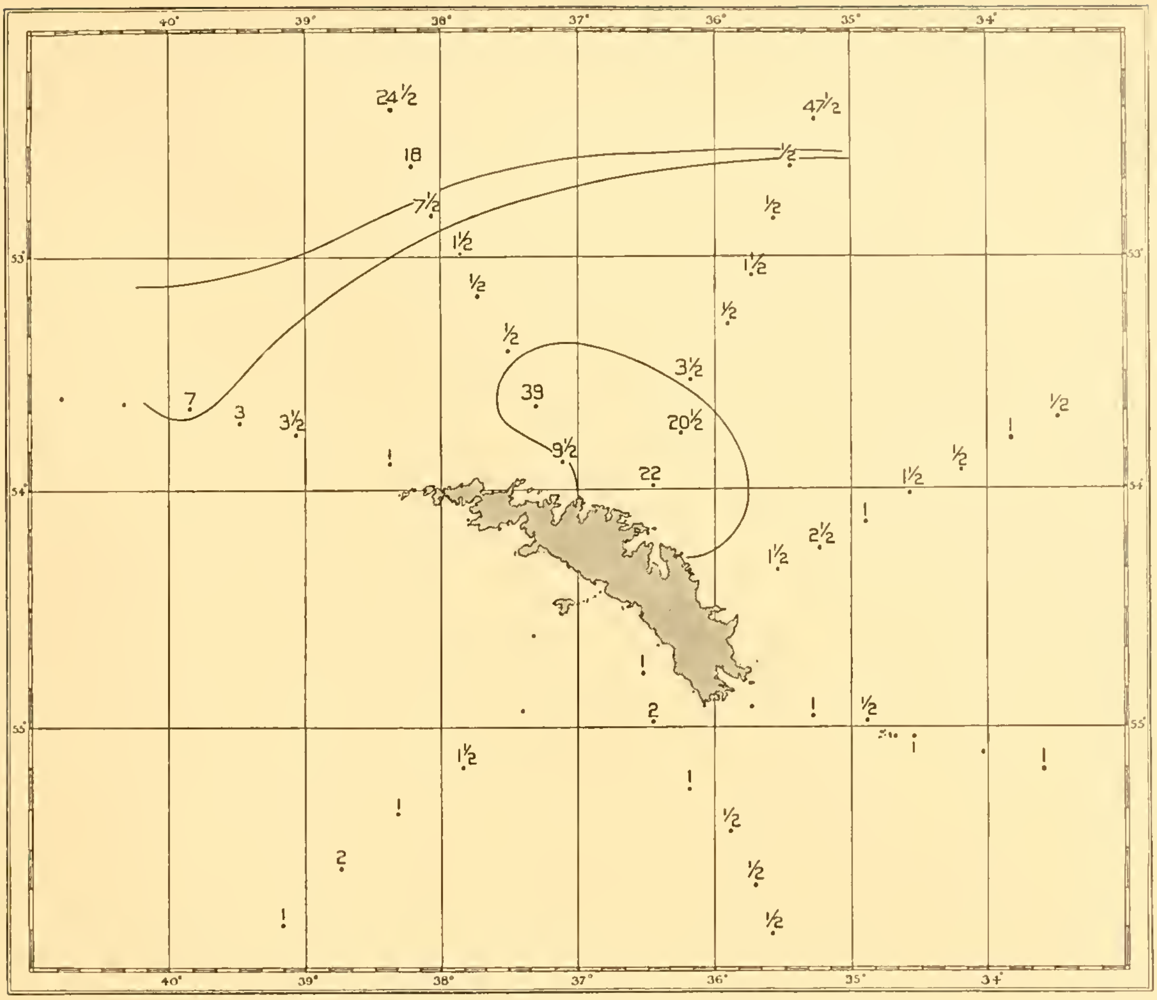

Fig. 23. The distribution of *Corethron valdiviae*, South Georgia survey, November 1930. 1 = one million.

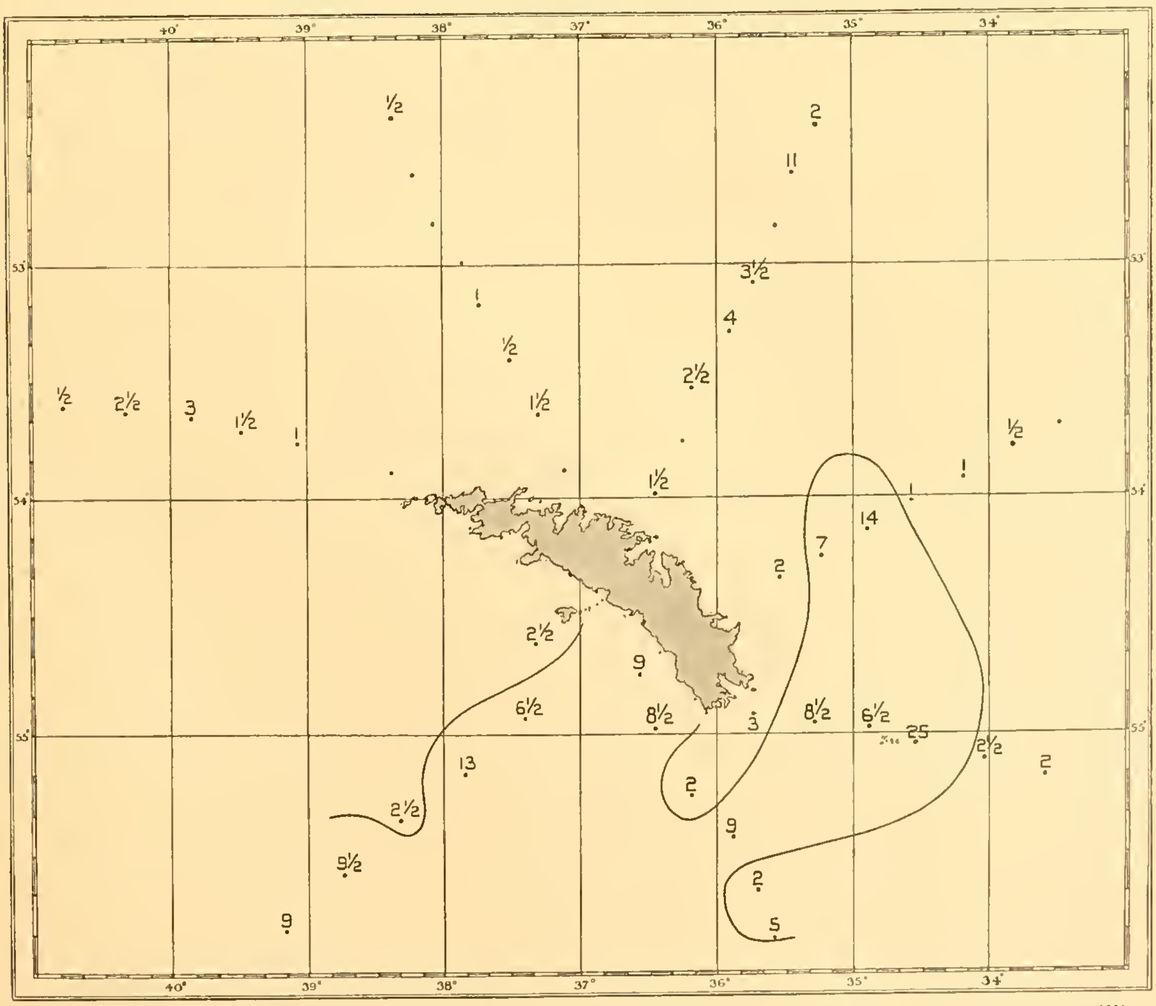

Fig. 24. The distribution of *Fragilaria antarctica*, South Georgia survey, November 1930. 1 = one million.

frustules were large, and auxospore formation was observed at comparatively few stations, while microspore formation was quite common. It is reasonable to suppose that the first maximum of production for this species had already passed, and that the large form was about to be succeeded by a wave of smaller frustules derived from microspores, such as had been found in the Bellingshausen Sea at mid-season. These in their turn would in normal circumstances doubtless have given way to the spineless vegetative form towards the end of the season. This season, however, was if anything unusually cold, and from work done by the R.R.S. 'William Scoresby' later in the year it seems that a succession of waves of the normal spiny form of *Corethron* invaded South Georgian waters, their chief source of origin being the eastern Weddell Sea. The only stations worked during this season, at which the spineless chain form was markedly dominant were away to the north-west, in the vicinity and to the north of the Antarctic convergence. While odd individuals have been taken in the far south in late summer, it seems that the abundant occurrence of this form is limited by the water temperature, which reached 3·0° C. or over at all the stations at which it has been abundantly recorded during this investigation, except for the southernmost portion of the dense patch recorded to the south-east of the island during the previous season.

Fragilaria antarctica (Fig. 24) was another form reaching its greatest abundance in the western Weddell Sea water round the southern end of the island. It also occurred in moderate numbers in the eastern Weddell Sea water, and in the small hauls in the Bellingshausen Sea water to the north-west, where it formed an important part of the comparatively scanty phytoplankton. The minimum for this form was apparently in the oldest surface water in the extreme north of the area investigated.

This distribution is closely paralleled by *F. antarctica* f. *bouvet* (Fig. 25), except that it was much rarer in the eastern Weddell Sea water than the type species. Very large catches of this form were obtained to the south and west, while it formed quite a large proportion of the small hauls obtained in the Bellingshausen Sea water to the north-west.

Next in order of total abundance on this survey comes *Nitzschia seriata*, which evidently reaches its maximum for the area somewhat later in the year than the other species; on the survey dealt with by Hardy it totalled over 200 millions, while on this occasion only about 88 millions were recorded. It will be seen from Fig. 26 that though widely distributed in all three types of surface water, this species showed a maximum of abundance to the south-west in western Weddell Sea surface water. But from the description of the catches on the Bird Island line (p. 44) it will have been seen that it reached its highest proportions in the catches towards the outer end of that line, in water of Bellingshausen Sea origin. At the anomalous St. 493 on the Larsen line, *N. seriata* reached its maximum in numbers for the whole survey, and was one of the dominant forms. As it was comparatively poorly represented in the catches from the old eastern Weddell Sea water to the south and to the west this fact requires some explanation. From the Station List (1932, pp. 87–9) it will be seen that this line was worked some two days later than the Bird Island line on which Bellingshausen Sea

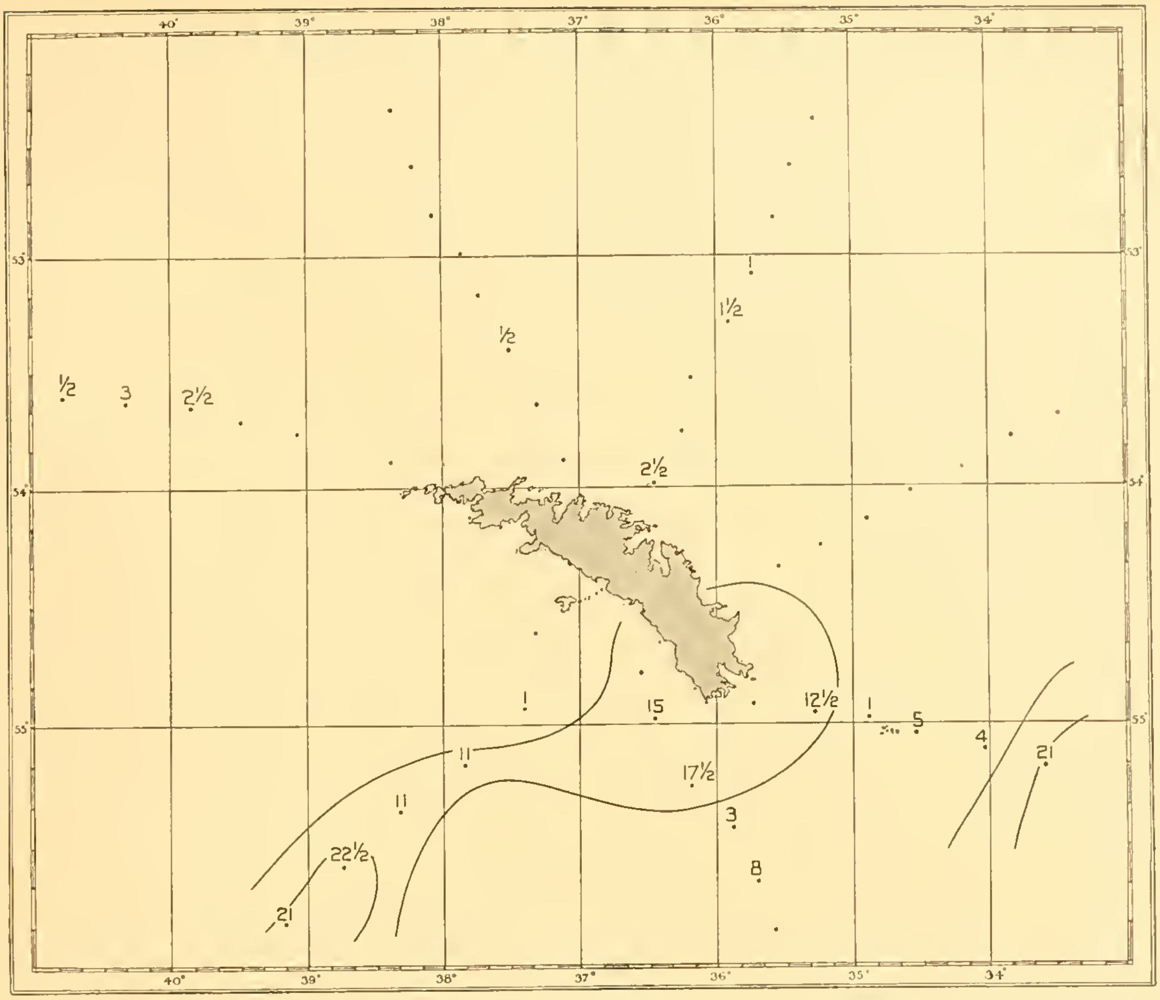

Fig. 25. The distribution of *Fragilaria antarctica* f. *bouvet*, South Georgia survey, November 1930. 1 = one million.

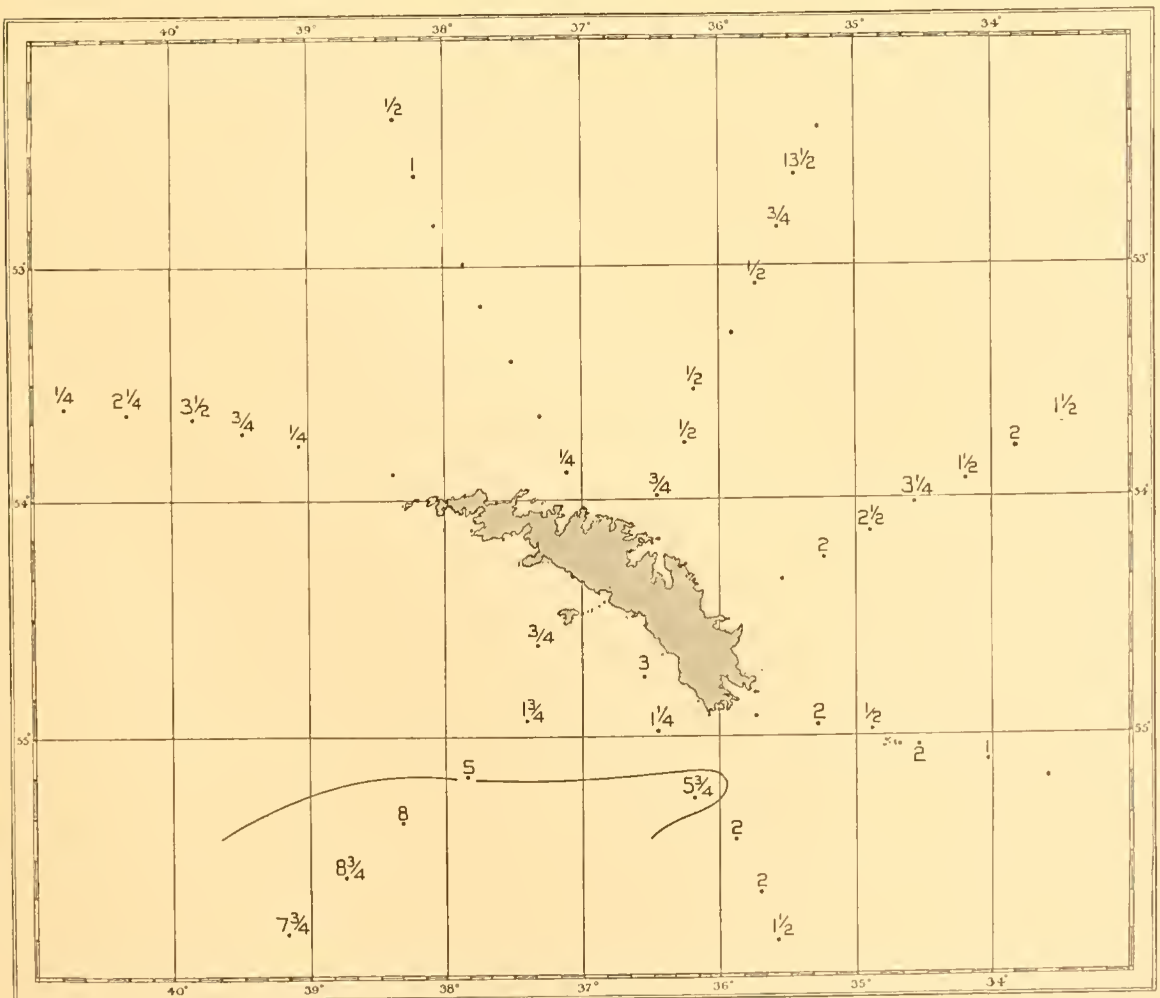

Fig. 26. The distribution of *Nitzschia seriata*, South Georgia survey, November 1930. 1 = one million.

water was found, and that the Prince Olaf line, on which the mixing of Bellingshausen with old eastern Weddell Sea type water was not much in evidence, was worked in the interim. For the first part of these two lines the wind was mainly light and from the south, but half-way out on the Prince Olaf line it backed to the west and blew hard, and continued to do so while the outer stations on the Larsen line were being worked. It is just possible that this caused a strong flow of Bellingshausen Sea water across from the

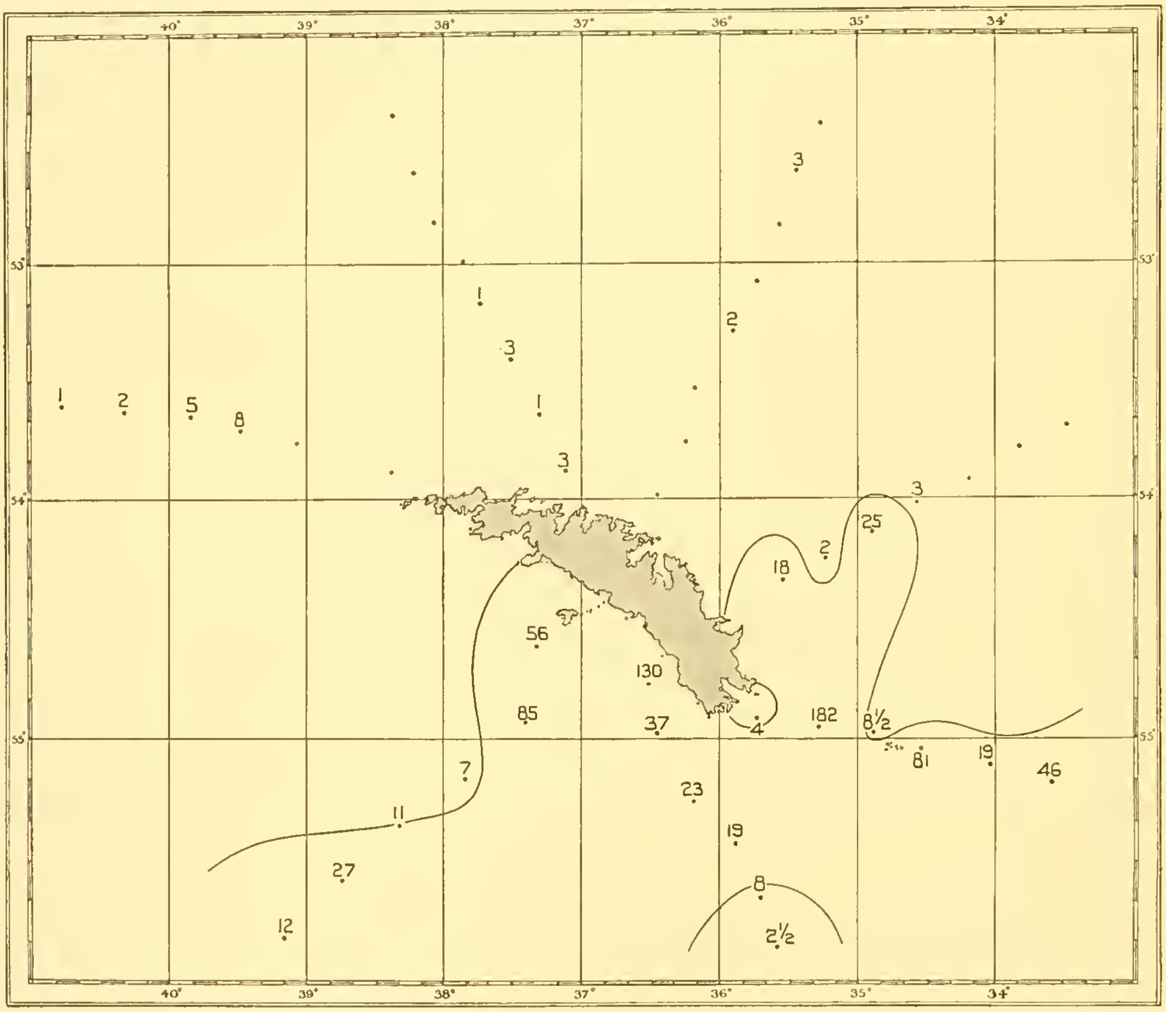

Fig. 27. The distribution of *Eucampia antarctica*, South Georgia survey, November 1930. 1 = one hundred thousand.

neighbourhood of the Shag Rocks to the station in question. Unless one presupposes the existence of some comparatively rapid surface current of this nature, the high surface temperature and peculiar nature of the phytoplankton at St. 493 remain inexplicable; surface temperatures were much lower, and *N. seriata* rare or absent, at the stations on the Prince Olaf line immediately to the westward.

Eucampia antarctica was another form which reached its maximum in the water of western Weddell Sea origin to the south of the island at this time, where, as will be seen from Fig. 27, it was particularly numerous close inshore. Small numbers of this species were also found in the old Bellingshausen Sea water to the north-west, and at a few of the stations worked in the older water derived from the eastern Weddell Sea.

On this survey *Thalassiothrix antarctica* was widely distributed in all three types of surface water, but again showed a maximum to the south in the western Weddell Sea water (Fig. 28). The seasonal distribution of this species presents some very interesting features, which admit only hypothetical explanation until further data are available.

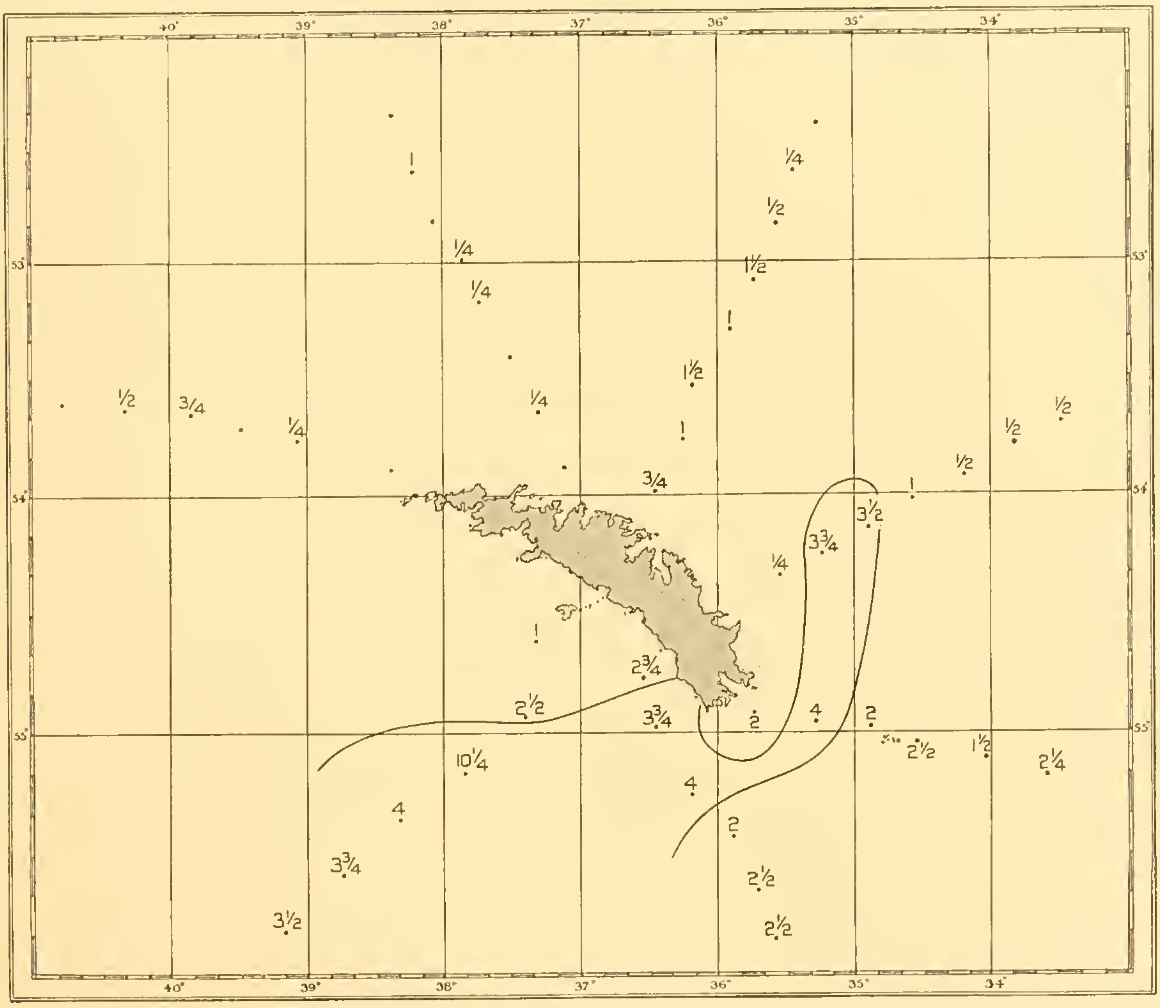

Fig. 28. The distribution of *Thalassiothrix antarctica*, South Georgia survey, November 1930. 1 = one million.

On the present survey (late spring) it totalled some $77\frac{1}{2}$ millions, on the survey described by Hardy (midsummer) only half a million, but on the January–February (late summer) survey of 1929–30 nearly 20 millions. This gives the appearance of a species with a big spring and comparatively small autumnal maximum, such as is found among many of the better known forms in north temperate latitudes; but it may very well be that this unequal distribution is due, at least in part, to variation in the extent and intensity of the surface currents, as this same species was found abundantly to the west of the Bellingshausen Sea at mid-season 1930–1 but was by no means so plentiful in that locality in February of the preceding year. Thus it is just possible that the comparatively rich occurrence of this species around South Georgia in February 1930 was due to the overflow, as it were, from an earlier maximum down towards the Bellingshausen Sea itself. The fact that these hauls were obtained to the east of the island does not detract from this, as there was little phytoplankton in the Bellingshausen water to the west, so that the mixing with eastern Weddell Sea water may well have brought out the last

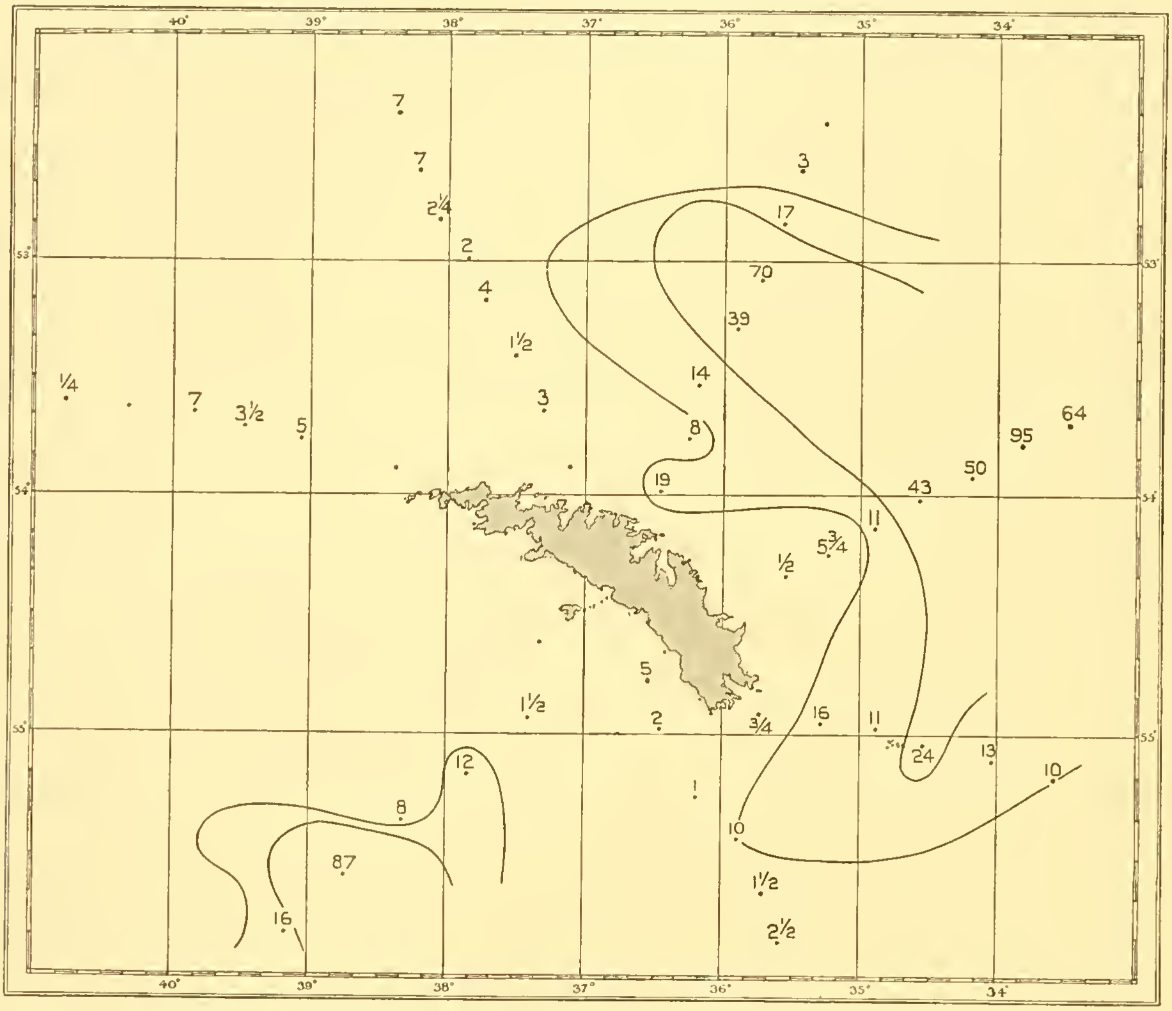

Fig. 29. The distribution of *Rhizosolenia styliformis*, South Georgia survey, November 1930. 1 = one hundred thousand.

resources of this surface water. On this survey, it will be remembered, the western Weddell Sea current was apparently at a minimum, and was almost certainly dissipated before it reached South Georgia, and all the surface water round South Georgia at that time was comparatively "old" and mixed. More recently Mr John's preliminary investigations of samples collected during 1931–2 confirm the possibility of *Thalassiothrix* being transported to the neighbourhood of South Georgia in old surface water of Bellingshausen Sea origin.

The next species in order of total abundance on the November 1930 survey was

Rhizosolenia styliformis. This species was widely distributed and present in all three types of surface water, but its abundant occurrence closely coincided with the limits of the Weddell Sea influence (Fig. 29), and it was particularly abundant in the cold tongue of eastern Weddell Sea water off the east coast, the position of which could be clearly demonstrated from the distribution of this species alone.

Dactyliosolen laevis (Fig. 30) was an example of yet another species which attained its

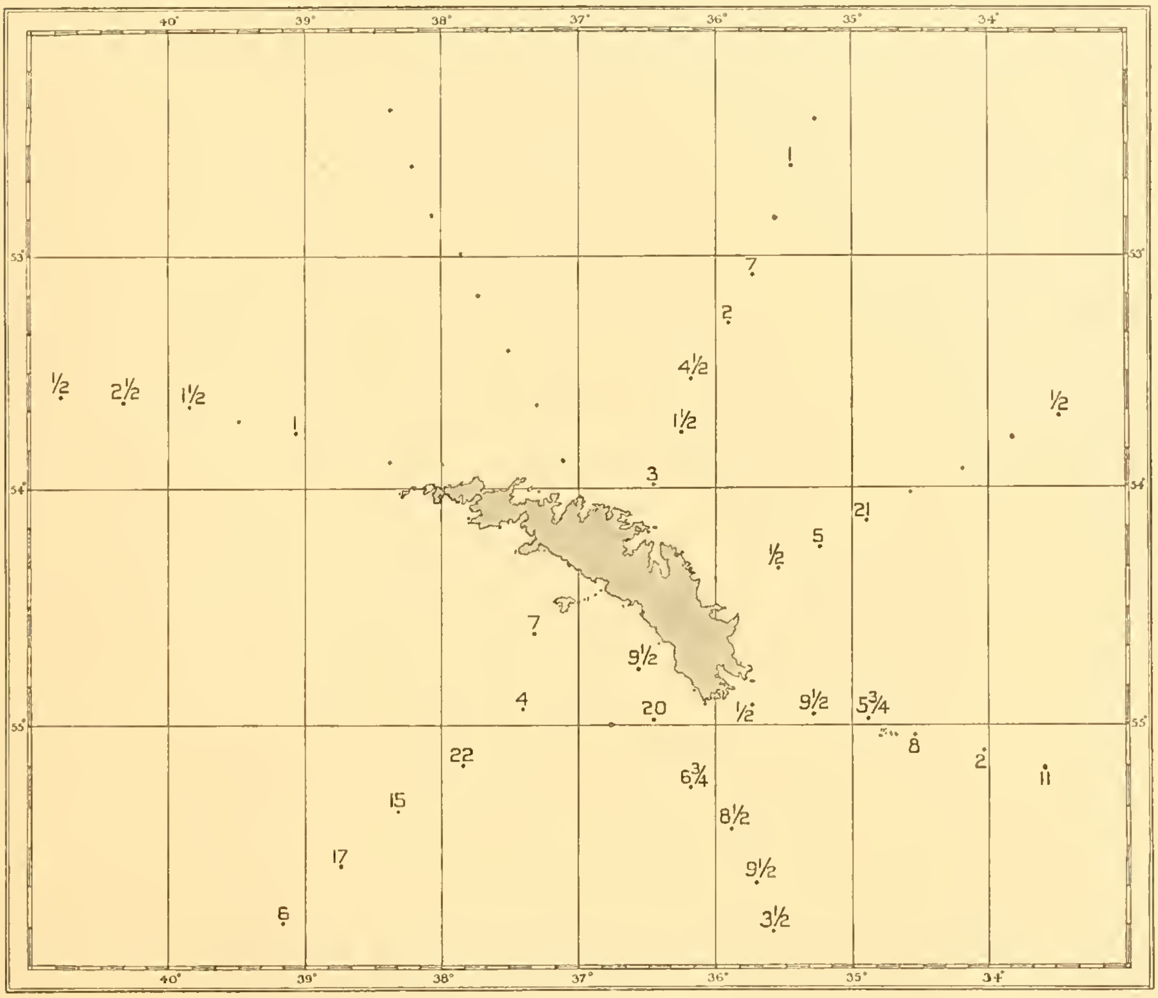

Fig. 30. The distribution of *Dactyliosolen laevis*, South Georgia survey, November 1930. 1 = one hundred thousand.

maximum development for this survey in the western Weddell Sea water to the south and south-west of the island. Many more might be cited from the less numerous forms, for example *Nitzschia* sp. A, a minute colonial form closely resembling the *N. rigida* of northern waters.

On this second survey two series of water samples for examination by means of the centrifuge were taken. The first of these was at St. 483, where analysis of the net haul had shown the phytoplankton to be poorer than anywhere else on the survey, with *Corethron valdiviae* completely dominant. From the centrifuged samples it was estimated that there were 55 *Corethron* cells per litre at the surface, and 14 per litre at a depth of 5 m. Below that depth the samples did not contain sufficient organisms to obtain a count.

At St. 501 a much better series was obtained. This station was worked at the outer end of the Vakop line in eastern type Weddell Sea water. Large forms were dominant, and as will be seen from the analysis of the net haul (Table XV), the sample was not nearly so rich either in species or individuals as many of the others obtained at this time, particularly those from western Weddell Sea water. The chief results of the centrifuge determinations are shown in Fig. 31. It will be seen that the phytoplankton as a whole reached its maximum at a depth of from 5 to 10 m. and thereafter diminished steadily as the depth increased. From the estimations of the three leading forms it appears that while *Thalassiosira antarctica* reached its maximum at the surface, *Chaetoceros criophilum* was most abundant at a depth of 5 m., which is perhaps significant in view of the fact that members of this genus have been shown by Marshall and Orr (1928, p. 337) to be peculiarly susceptible to systrophe. *Rhizosolenia styliformis* showed two well-defined maxima at 10 m. and at 30 m. It is probable that the lower of these two was caused by older frustules sinking, as this species was not so abundant on the Larsen line, and the surface current here was flowing to the north-west. On the other hand this double maximum perhaps represented a parallel to that described by Gran (1929 *a*, p. 18) for the same species in the northern hemisphere—off the south-west coast of Greenland in August.

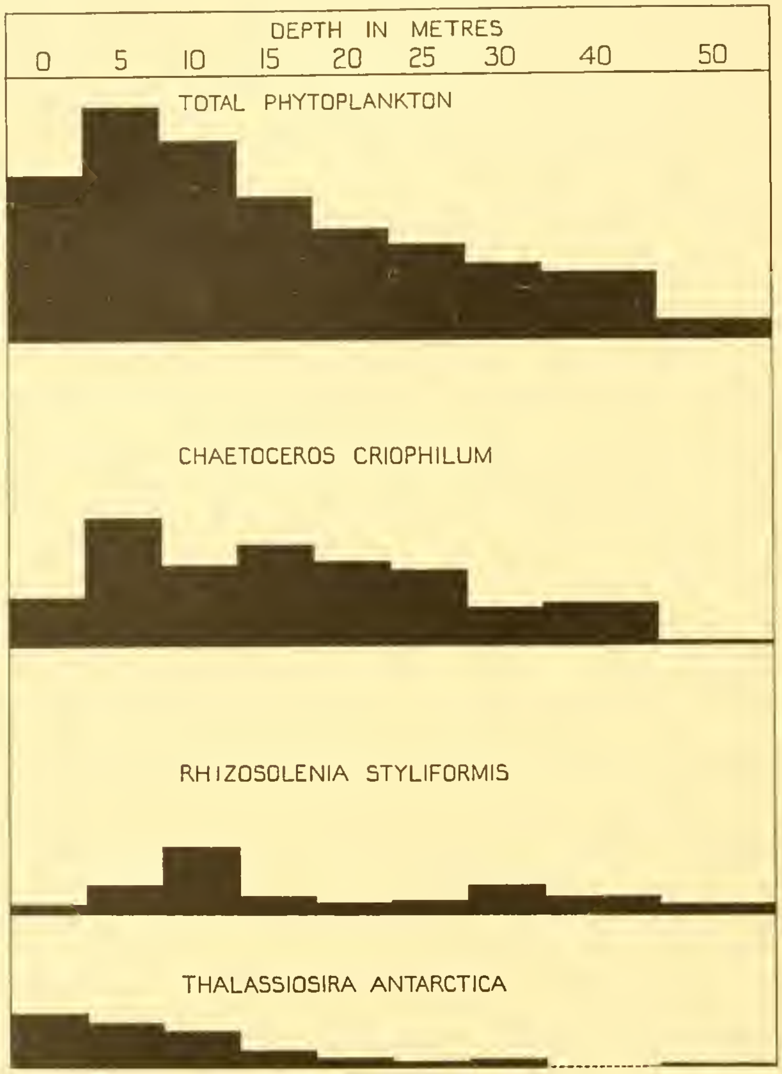

Fig. 31. Diagram showing the distribution of the total phytoplankton organisms, and of the dominant species with depth, from centrifuge determinations at St. 501.

Table 12 contains the full results of the centrifuge determinations from St. 501, from which it will be seen that besides *Thalassiosira*, three of the less numerous forms, *Corethron valdiviae*, *Fragilaria antarctica* and *Rhizosolenia alata*, reached their maximum at the surface, while other forms even more rare at this particular station attained their highest numbers at depths of 5 and 10 m.

Table 12

Depth in m. ...	0	5	10	15	20	25	30	40	50
Chaetoceros criophilum	250	646	416	524	438	392	200	223	8
Rhizosolenia styliformis	42	154	348	92	61	69	146	92	54
Thalassiosira antarctica	283	231	193	85	54	31	39	—	15
Corethron valdiviae	50	46	42	31	8	8	15	15	8
Fragilaria antarctica	117	54	—	15	—	—	—	—	—
Thalassiothrix antarctica	17	23	25	15	15	8	8	8	15
Rhizosolenia alata	83	23	—	—	—	—	—	—	—
Navicula oceanica	17	31	25	—	—	—	—	—	—
Nitzschia seriata	8	23	—	—	—	—	—	—	—
Rhizosolenia truncata	—	—	—	—	15	—	—	—	—
Dactyliosolen laevis	8	—	—	—	—	—	—	—	—
Silicoflagellates	—	8	—	—	—	—	—	—	—
Total cells per litre	875	1239	1049	762	591	508	408	338	100

OTHER MATERIAL

One piece of work in the South Georgia area during the 1930–1 season remains to be discussed, namely a repetition of the Prince Olaf line, worked by the R.R.S. 'William Scoresby' in March. As will be seen from Table XVI, in which the full analyses of the material then collected are given, these stations were worked in two periods, with a considerable interval between. This was caused by very bad weather, sufficiently severe to cause damage to shipping in the locality.

The stations worked during the first week of March 1931 comprised the three inshore stations on this line, and the outermost. At St. WS 567 close in to the land, the phytoplankton was almost non-existent, *Corethron valdiviae* being dominant in a very poor catch. This was explicable on the grounds of inshore influences, as was clearly shown by the presence of a small Tintinnid, which has been found to be very characteristic of inshore waters at South Georgia and in the Bransfield Strait. At the two succeeding stations moderate hauls were obtained, in which *C. valdiviae* and *Chaetoceros criophilum* were dominant. At the outermost station on the line, the estimated diatom total was over 12 millions, *Ch. criophilum* and *Nitzschia seriata* being strongly dominant, with lesser numbers of *Dactyliosolen antarcticus*, *Chaetoceros neglectus* and *Corethron*. Turning now to the stations worked towards the end of the month (Sts. WS 572–5 inclusive) we find *Nitzschia seriata* and *Chaetoceros criophilum* dominant in moderately rich hauls, with lesser numbers of *Ch. atlanticus*, *Corethron*, *Chaetoceros neglectus* and *Dactyliosolen antarcticus*, in that order of importance, at the three outermost stations. At St. WS 572 *Chaetoceros criophilum* formed roughly two-thirds, and *Corethron valdiviae* one-third of a sample in which only two other diatom species were observed.

The comparative scarcity of species towards the end of the season is indeed well shown by the material from this line as a whole, only nineteen different phytoplankton organisms being encountered as against twenty-seven earlier in the year in the same area. Moreover, it would seem, from a few stations worked on the arrival and departure of the research ships on more extensive investigations, that towards the end of this season the phytoplankton elsewhere round South Georgia was even scantier. The remnant of the formerly abundant flora apparently persisted longest in the old mixed water, mainly of eastern Weddell Sea origin, to the east and north of the island.

One other feature of this repetition of the Prince Olaf line was interesting—the presence of *Peridinium antarcticum* in numbers which, though insignificant as compared to the rest of the phytoplankton present, still amounted to over one-third of the numbers recorded for the same species over the whole of the survey worked earlier in the year. Here we have a suggestion of the usual slight increase in dinoflagellates towards the end of the season, which reached such exceptionally large proportions on the survey conducted in the late summer of the previous abnormally warm year.

SUMMARY

On the plankton survey of November 1930, the spring diatom increase was at its height, and very heavy catches were obtained. The influence of the three types of surface water on the character of the phytoplankton was very clearly shown, and the richest and most varied flora was found in the water, mainly of western Weddell Sea origin, to the south and south-west of the island. Here the dominant forms were *Chaetoceros socialis*, *Thalassiosira antarctica* and *Chaetoceros neglectus*. The cold tongue of eastern Weddell Sea water running up the north-east coast of the island, was populated mainly by the large forms *Ch. criophilum* and *Rhizosolenia styliformis*, and in the older water farther north by *Corethron valdiviae*. The poorest hauls on the whole survey were obtained in the old Bellingshausen Sea water to the north-west.

There is also evidence that during the latter half of the 1930–1 season, the phytoplankton did not decrease to anything like the same extent as in previous years. The season was an exceptionally cold one with a lot of ice about. There was pack around the island only a week before the survey was begun, and throughout the season ice was reported in comparatively low latitudes to the southward.

An idea of the richness of the phytoplankton encountered on the November survey may be gathered from the following list, in which the species are arranged in order of their total abundance. The figures in brackets immediately after the specific names denote the number of stations at which each occurred.

Thus, taking the survey as a whole, sixty separate forms were recognized, including eight species of *Chaetoceros*, *Coscinodiscus bouvet* and others that were not taken at all in the scanty phytoplankton of the previous summer, when only twenty-four forms were distinguished. The striking disparity between the two surveys, as regards the quality apart from the quantity of the phytoplankton, was also shown by the fact that the normal spiny form of *Corethron valdiviae* was present at every station, while the

spineless chain form was rare. Only one species was recorded on the previous survey that was not found early in the following year—*Melosira sol*—and that had been found at only two stations in comparatively small numbers.

	Total	%		Total	
Chaetoceros socialis (14)	∞ uncountable	—	*Coscinodiscus bouvet* (3)	453,600	
Thalassiosira antarctica (48)	∞+612,612,300	26·2+	*Asteromphalus parvulus* (6)	426,300	
Chaetoceros neglectus (38)	∞+145,799,800	6·2+	*Chaetoceros tortissimus* (1)	408,000	
Ch. criophilum (49)	554,064,600	23·7	*Peridinium* sp. (small) (7)	386,100	
Corethron valdiviae (49)	236,429,100	10·1	*Asteromphalus challengerensis* (3)	319,800	
Fragilaria antarctica (43)	187,903,000	8·0	*Thalassiothrix ? longissima* (2)	306,000	
F. antarctica f. *bouvet* (21)	164,977,900	7·0	*Asteromphalus hookeri* (7)	253,100	4·1%
Nitzschia seriata (36)	87,952,200	3·8	*Coscinosira antarctica* (3)	230,400	
Eucampia antarctica (35)	83,601,200	3·6	*Rhizosolenia truncata* (1)	216,000	
Thalassiothrix antarctica (46)	77,589,000	3·3	*R. bidens* (1)	192,000	
Rhizosolenia styliformis (44)	72,088,000	3·1	*Nitzschia delicatissima* (1)	171,600	
Dactyliosolen laevis (34)	22,102,300	0·9	*Dinophysis* sp. (5)	171,000	
Biddulphia striata (31)	16,038,200		*Coscinodiscus centralis* (2)	165,000	
Chaetoceros dichaeta (17)	14,049,600		*Dactyliosolen flexuosus* (2)	160,800	
Rhizosolenia alata (41)	11,033,800		*Peridinium antarcticum* (5)	147,900	
Chaetoceros schimperianus (13)	10,609,800		*Rhizosolenia torpedo* (2)	128,400	
Ch. atlanticus (14)	9,657,000		*Melosira sphaerica* (2)	120,000	
Silicoflagellata (30)	8,878,500		*Hyalodiscus kerguelensis* (2)	114,300	
Corethron valdiviae (spineless chains) (10)	6,455,700		*Rhizosolenia antarctica* (2)	105,900	
Coscinodiscus spp.	5,570,000		*Gyrosigma directum* (3)	103,500	
Rhizosolenia chunnii	4,856,700		*Rhizosolenia simplex* (4)	96,900	
Asteromphalus regularis	2,882,500		*Dactyliosolen antarcticus* (2)	79,800	
Corethron valdiviae (auxosporenbildung) (4)	2,672,400		*Tropodoneis antarctica* (1)	72,000	
Nitzschia sp. A. (12)	1,730,400		*Hyalodiscus chromatoaster* (1)	45,000	
Navicula pellucida (8)	1,460,700		*Synedra spathulata* (1)	45,000	
Achnanthes sp. (1)	1,209,600		*Nitzschia closterium* (1)	32,400	
Chaetoceros curvatus (2)	765,000		*Leptocylindrus* sp. (2)	30,600	
Spores (3)	744,000		*Rhizosolenia crassa* (1)	30,000	
Navicula oceanica (7)	619,800		*Actinocyclus* sp. (1)	7,800	
Navicula spp. (5)	591,000		*Ceratium pentagonum* f. *grandis* (3)	3,000	

Total phytoplankton organisms estimated: 2,341,067,800.

The contrast in bulk between the two series of catches is also strikingly brought out by the above list, and by the estimated totals—61 millions as against 2341 millions. The relative proportions of the small colonial forms on the second survey are of course problematical, but their position at the head of the list is undoubtedly justified. In calculating the percentages of the various leading forms it has only been possible to take the estimated numbers into consideration, those forms that defied any method of estimation being perforce left out of account.

CONCLUSIONS

COMPARISON WITH THE RESULTS OBTAINED IN 1926–7

The results obtained on the two strikingly contrasted surveys described above may be usefully compared with those for the December–January 1926–7 survey described by Hardy (in press). On this occasion, as on the rich spring survey of November 1930, the western Weddell Sea current again provided the richest samples, though it would seem that the rich belt had undergone considerable mixing with old Bellingshausen Sea water, and that the whole system had been pushed round and up the western side of the island. It is probable that the extent of the influence of the western Weddell Sea current, after the manner of certain better known water movements in the northern hemisphere,[1] may be found to oscillate considerably from year to year in correlation with extensive climatic changes farther south, where this current has its origin. The operation of some such factor, perhaps augmented by strong south-easterly winds, appears to afford the most reasonable explanation of the unusual northerly extension of the dense belt of phytoplankton up the western side of the island at this time.

On this survey the total number of phytoplankton organisms was estimated by Hardy at 1,930,948,760. From his lists it would appear that the principal species were:

Chaetoceros socialis	*Fragilaria antarctica*
Nitzschia seriata	*Rhizosolenia styliformis*
Halosphaera viridis (at three stations only)	*Chaetoceros atlanticus*
Corethron valdiviae	*Ch. criophilum*

in that order of importance. All these, with the exception of *Halosphaera viridis*, were also abundant in the spring of 1930–1, and generally speaking the first survey appears to have been worked under more normal conditions than the later summer survey of 1929–30. The major differences between the three surveys are summed up in Table 13, in which the estimated numbers of the twenty leading forms upon each of them have been tabulated. The species here have been arranged systematically, in order to avoid repetition, and the dashes do not necessarily indicate that a species was entirely absent, but merely that it was not one of the twenty leading forms on the given survey.

From this list it will be seen that at mid-season 1926–7, most of the species were considerably less abundant than in the spring of 1930, but that two—*Nitzschia seriata* and *Halosphaera viridis*—were more so. Of the eight principal species encountered by Hardy, all except the two just mentioned show some falling off in numbers compared with the catches obtained in spring. This was doubtless due to the normal seasonal effect, most of the southern forms showing a marked spring maximum.

On the other hand several forms encountered in abundance on the spring survey were definitely rare on the mid-season survey, notably *Thalassiosira antarctica*. Hardy (in press) has already shown that this species was abundant early in the season he studied and the collections here described fully confirm his suggestion that it is very definitely a spring form. In this respect its behaviour resembles that of *Th. nordenskjoldii* in north temperate latitudes (Johnstone, Scott and Chadwick, 1924, pp. 62, 138).

The differences in both the quality and quantity of the phytoplankton obtained on the January–February 1930 survey, and on that described by Hardy are so great that there can be no doubt of the abnormality of the conditions during the latter part of the 1929–30 season. We have already remarked on the unusual mildness of this season, which was accompanied by marked poverty of the phytoplankton, in which dinoflagellates were much more numerous than is usual in Antarctic surface waters. The 1929–30 season presented conditions clearly constituting one of the major fluctuations, as distinct from the normal seasonal variations. The most probable explanation of the unusually poor phytoplankton and high surface temperatures that prevailed over the

[1] E.g. the incursion of Atlantic water into the North Sea. See Hardy, *Publ. de Circ.*, No. 78, 1923.

South Georgia area during the latter part of that summer lies in the fact that the currents from the Weddell Sea appeared to be unusually slack, so that the greater part of the area was occupied by old water of Bellingshausen Sea origin. It was only to the east of the island, where the Weddell Sea influence was shown by higher salinities and lower temperatures at the surface, that moderately rich phytoplankton hauls were obtained on this survey.

Table 13

	November 1930 (spring)	December–January 1926 (midsummer)	January–February 1930 (late summer)
Melosira sol	—	—	57,900
M. sphaerica	—	—	129,000
Coscinodiscus bouvet	—	114,000	—
Coscinodiscus ?oppositus	—	517,020	—
Coscinodiscus spp.	5,570,000	—	742,950
Thalassiosira antarctica	∞ + 612,612,300	184,500	114,000
Dactyliosolen antarcticus	—	—	13,000
D. laevis	22,102,300	381,600	—
Corethron valdiviae	236,429,100	23,839,560	—
C. valdiviae, spineless chains	6,455,700	—	32,735,200
Rhizosolenia alata	11,033,800	—	186,000
R. antarctica	—	—	19,200
R. curva	—	168,150	—
R. obtusa	—	171,900	—
R. styliformis	72,088,000	9,806,220	58,700
R. truncata	—	—	12,000
Chaetoceros atlanticus	9,657,000	6,379,200	86,400
Ch. criophilum	554,064,600	6,160,050	—
Ch. curvatus	—	214,000	—
Ch. dichaeta	14,049,600	444,600	—
Ch. neglectus	∞ + 145,799,800	—	—
Ch. socialis	∞ uncountable	1,492,817,000	—
Ch. schimperianus	10,609,800	442,400	—
Biddulphia striata	16,038,200	237,900	71,400
Eucampia antarctica	83,601,200	447,800	1,985,700
Fragilaria antarctica	187,903,000	10,362,010	380,000
F. antarctica f. *bouvet*	164,977,900	—	—
Thalassiothrix antarctica	77,589,000	517,900	19,868,900
Gyrosigma directum	—	155,750	—
Nitzschia seriata	87,952,200	211,395,000	557,300
Dinophysis sp.	—	—	18,500
Peridinium antarcticum	—	—	2,088,550
Ceratium pentagonum f. *grandis*	—	—	1,776,300
Silicoflagellata	8,878,500	420,250	82,200
Halosphaera viridis	—	83,866,000*	—
Total phytoplankton	∞ + 2,341,067,800	1,930,848,760	61,264,400

* At only three stations.

In considering the work done in the South Georgia area as a whole, it has become very evident that the different origin of the three main types of surface water, and the extent to which mixing takes place between them, exerts a profound influence upon the nature of the phytoplankton. Consequently the seasonal variation in the strength of the surface currents and the degree to which their influence extends into the South Georgia area in different years will be reflected in the phytoplankton crop. It seems probable that as regards the seasonal variation the flow will be strongest in spring and early summer, when the pack-ice begins to melt and break up. This is particularly true of the western Weddell Sea current, which, as we have seen, produces the heaviest phytoplankton. Of the yearly fluctuations in the flow little can be said until more is known concerning the hydrology of the currents, beyond the fact that they occur on a large scale with a correspondingly marked effect upon the phytoplankton.

THE PROBABLE SEASONAL SUCCESSION

The main diatom increase takes place in late spring, when almost all the species attain their maximum. Some of these forms persist in more moderate numbers throughout the summer, to an extent which varies from year to year; a few almost certainly have a small secondary autumnal maximum, though on this point further observations are required. The great outburst of diatom growth in the spring is an almost universal feature in cold temperate and higher latitudes, and this fact leads to the consideration of another way in which the surface currents probably affect the plankton population off South Georgia. From the writings of Gran, and others who have studied the production of marine phytoplankton in the northern hemisphere, it has been clearly shown that the date of the main spring increase, in any comparatively small area, falls within certain fairly narrow limits from year to year. Further, the higher the latitude, the later is the time of this increase, until in very high latitudes there is just a single prolonged period of rapid growth, in some cases after midsummer. Now the surface water round South Georgia originates in high latitudes, as we have seen, so that if the flow is prolonged, there is the possibility of the production due to the main increase farther south being apparent in comparatively rich hauls off South Georgia after the large-scale production in that area has ceased. Something of this sort was evidently taking place during the latter half of the 1930–1 season, when comparatively large hauls of *Chaetoceros criophilum*, many in a dying condition, were obtained to the east of the island.

The normal succession off South Georgia is thus probably somewhat as follows: A big spring increase, with the dominants found on the November 1930 survey, the following species remaining important up to mid-season in years in which much ice drifts north and the currents are strong: *Chaetoceros socialis*, *Ch. criophilum*, *Ch. atlanticus*, *Corethron valdiviae*, *Fragilaria antarctica*, *Eucampia antarctica*, *Rhizosolenia styliformis*, and more constantly *Nitzschia seriata*. To these in years in which the influence of Bellingshausen Sea water predominates, a second wave of *Thalassiothrix antarctica* should be added. A minimum appears to be reached in February–March.

The larger forms encountered in some abundance at mid-season appear to be renewed by successive waves of production farther south, drifting up into the area mainly by way of the eastern Weddell Sea current.

The scanty evidence of an autumnal increase off South Georgia at present available may be summarized as follows:

Hardy (in press) states that phytoplankton catches in May 1927 were larger than in March 1926, though still much smaller than those obtained in December and January. Secondly, as regards the two main sources of the surface water in this area, a moderately rich phytoplankton was observed in the southern half of Drake Passage in April 1930, as described in the next section, with *Chaetoceros atlanticus*, *Nitzschia seriata* and *Fragilaria antarctica* the most numerous forms. Some of this old Bellingshausen Sea water would presumably reach the neighbourhood of South Georgia before this phytoplankton was completely dissipated. On the Weddell Sea side Mangin's analyses of the Scotia material indicate a slight autumnal increase with *Chaetoceros criophilum*, *Ch. atlanticus*, *Ch. dichaeta*, *Dactyliosolen antarcticus* and *Nitzschia seriata* dominant; and the later March stations of the 'William Scoresby' in 1931, and the other stations taken late in March and in the April of that year, indicated that phytoplankton of this nature was to be found to the east and north of South Georgia. Of the autumn forms, small Chaetocerids were the most important in both areas, as had already been observed in the case of the Weddell Sea by Lohmann (1928, p. 16). *Chaetoceros atlanticus* reaches its maximum farther north than *Ch. dichaeta*, which is a species preferring very cold temperatures. It is therefore probable that round South Georgia *Ch. atlanticus* will be much the more important of the two towards the latter end of most years.

In abnormally mild open seasons, like 1929–30, it is probable that all the *Corethron valdiviae* will go over to the spineless chain form. The latter would seem to propagate vegetatively and it has also been found in sub-Antarctic surface water. There is probably always a slight increase in dinoflagellates after mid-season when the diatoms are on the wane, but except in abnormally mild seasons this will not be very noticeable, as the diatoms remain completely dominant.

The factors that may determine the succession indicated are discussed in the general conclusions.

THE TRANSITION FROM ANTARCTIC TO SUB-ANTARCTIC PHYTOPLANKTON

The material collected during the two seasons studied which bears on this part of the problem is not very complete, as most of the lines of stations did not extend far into the sub-Antarctic Zone. The majority of them also were worked towards the end of the season; information on conditions at midsummer is unfortunately lacking as at this time of year the research ships were engaged farther south. The effect of the Antarctic convergence and the extent to which overlapping of species takes place is, however, well brought out by the lines of stations about to be described, so that on this account alone the material is of considerable value.

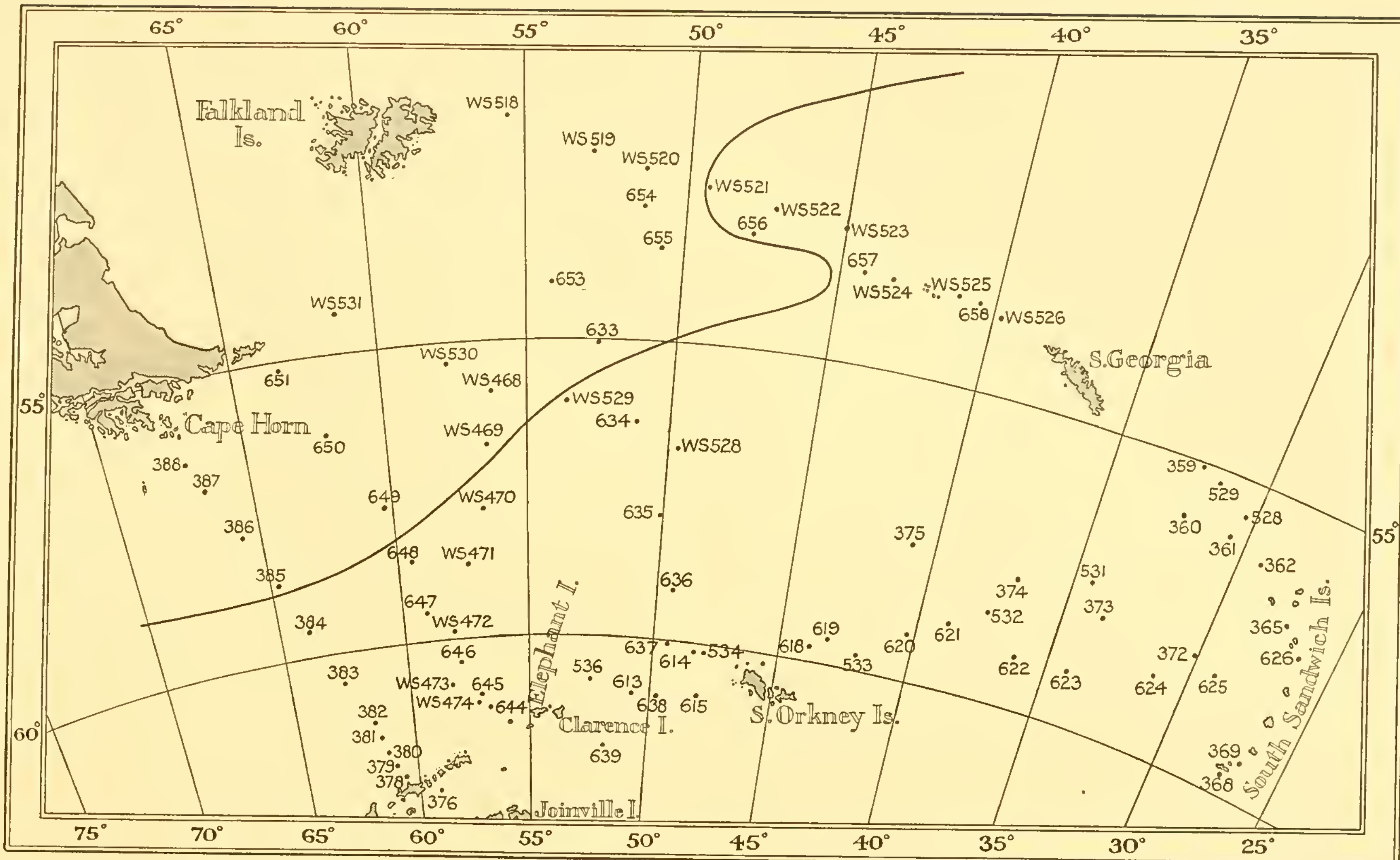

Fig. 32. Reference chart showing the positions of the stations on the lines crossing the convergence, and in the northern part of the Weddell Sea area. The probable position of the Antarctic convergence is also shown.

The stations worked on these lines were necessarily far apart, and it would therefore be inadvisable to attempt any such detailed account as has been given of the close lines of stations worked in the South Georgia area. For purposes of comparison, the material may be divided naturally into the collections from the two seasons 1929–30 and 1930–1, though it must be noted that the line worked early in the 1929–30 season shows little relation to the others worked later in the year. All these lines, with the possible exception of those worked between the Falkland Islands and South Georgia, extend much farther to the south and east of the convergence than to the north of it, traversing old Antarctic surface water both from the Weddell and the Bellingshausen Seas.

THE SEASON 1929–30

The first piece of work to be considered, was a line of stations (WS 468–74) worked by the R.R.S. 'William Scoresby' in November, from 55° 52′ S, 56° 53′ W to 61° 03′ S, 56° 42′ W, that is from a point south of the Burdwood Bank to a point west of Elephant Island. Seven stations were worked on this line; their positions are shown in Fig. 32. The full analyses will be found in Table XVII, and the percentages of the leading forms in each catch are shown in Fig. 33, together with the temperature mean for the upper 20 m., and the total estimated numbers of phytoplankton organisms. From these it will be seen that the phytoplankton was very poor to the north of the convergence, and showed a marked increase with the decreasing temperature gradient as one proceeded southwards. The first station, definitely to the north of the convergence, was St. WS 468, and it furnished the poorest haul on the line. *Fragilaria antarctica* was dominant, and other Antarctic stragglers were present in very small numbers. Only two species were recorded that were not also found farther to the southward, *Chaetoceros decipiens* and *Ceratium fusus*. At the next station to the south, worked in the immediate vicinity of the convergence itself, the phytoplankton was appreciably richer and several common Antarctic forms made their appearance, *Corethron valdiviae* and *Nitzschia seriata* being the most important. The spineless chain form of *Corethron*, which has been found to be an important member of the phytoplankton both in sub-Antarctic and Antarctic surface waters (in abnormally warm seasons) reached its highest relative proportion here, though larger numbers were actually encountered farther south on this line. This station, WS 469, was also noteworthy for the only occurrence of *Rhizosolenia polydactyla* on this line, a species which has been found as a dominant form of the sub-Antarctic phytoplankton later in the season, and only occasionally farther south in very small numbers.

St. WS 470, with a mean temperature of 1·59° C. in the upper layers, and nearly 17 million estimated phytoplankton organisms besides uncountable colonies of *Chaetoceros neglectus*, brings us fairly into the Antarctic Zone. Other important species at this station were *Nitzschia seriata*, *Chaetoceros atlanticus*, and a comparatively scarce form whose occurrence has been found to be very sporadic throughout all the material examined—*Ch. castracanei*. Farther south on this line minus temperatures were recorded, and a very rich phytoplankton was present at all but the southernmost station. The main features of these catches may be briefly summarized for the sake of the light that they throw on conditions in this water of Bellingshausen Sea origin at this time of year.

At St. WS 471 the dominant species in a fairly rich haul were *Nitzschia seriata*, *Chaetoceros dichaeta* and *Ch. neglectus* in that order of importance, while at the next station to the south the richest haul of the whole line was obtained, this catch being also characterized by a large variety of species. Here the dominant forms were *Thalassiosira antarctica*, *Fragilaria antarctica* and *Nitzschia seriata*. The next station south also showed a fairly heavy catch, but here the dominant forms were *Nitzschia seriata* and *Chaetoceros neglectus*. At the most southerly station the phytoplankton was relatively thin, and the presence of *Rhizosolenia alata* f. *gracillima* points to possible mixing with Bransfield Strait water: other important forms were *Nitzschia seriata* and *Thalassiosira antarctica*.

Summing up this survey of the line as a whole, the main feature was undoubtedly the close general resemblance to the type of phytoplankton one has learnt to expect in late autumn, with small Chaetocerids, *Nitzschia seriata* and *Fragilaria antarctica* dominant; though the presence of the spring form of *Thalassiosira* in moderate numbers at all the stations south of the convergence, and dominant at St. WS 472, showed that the spring increase had definitely begun. The bulk of the samples was also somewhat greater than that of the autumn catches, but in other respects the resemblance is most marked. This is possibly to be explained by the fact that as the north-easterly flow of the Antarctic surface water is at a minimum (sometimes even apparently at a standstill) in winter, the autumn forms will probably persist in small numbers in the older water just to the south of the convergence, and so be the first to multiply in spring. The small catch at the southernmost station may have been due to the spring increase not having started farther south, but conditions in the Bransfield Strait only a short time later render this highly improbable. This station (WS 474) was worked just to the north of the submarine ridge connecting King George Island and Elephant Island, and from other work carried out later in the following seasons it would seem that there is usually an area to the east and north of King George Island where phytoplankton is scanty. This may be due to constant vertical mixing over the ridge preventing the

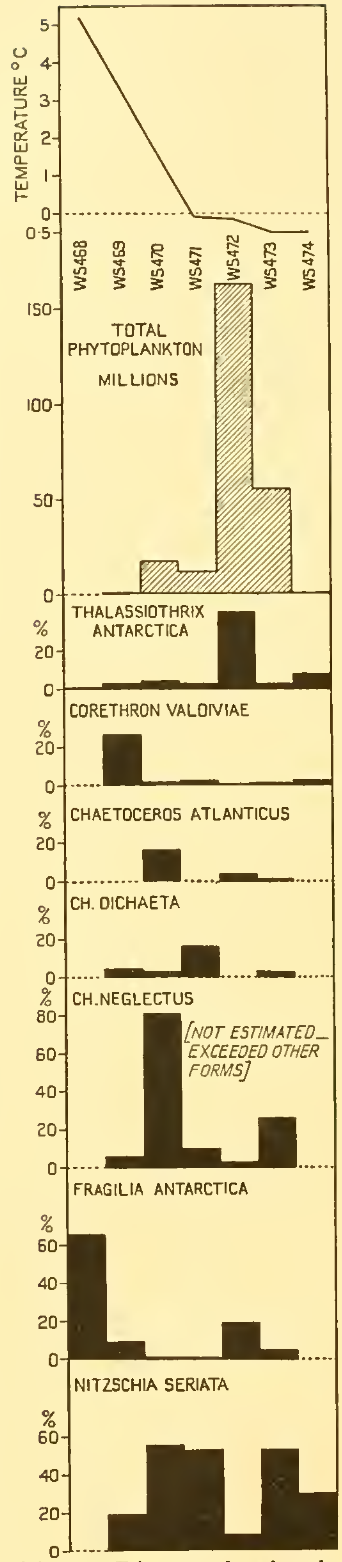

Fig. 33. Diagram showing the percentages of the principal species in the catches on a line of stations worked southwards across the Scotia Sea, November 1929.

organisms from remaining in the optimum light zone long enough for extensive proliferation. The presence of *Rhizosolenia alata* f. *gracillima* at this particular station is interesting, as this form has been encountered in abundance only in the northern part of the Bellingshausen Sea at midsummer, and just outside the South Shetlands later in the year, and in Bransfield Strait. In this last locality it evidently comes in with the old Bellingshausen Sea water from the western end, and its appearance here to the east quite early in the season may be due to multiplication of the remnant of the autumn invaders of the previous season.

On the line just described, the great increase in phytoplankton with decreasing temperature to the south of the Antarctic convergence was very well illustrated, but on a series of observations taken between the Falkland Islands and South Georgia at the end of February 1930 (WS 518–36), the normal state of affairs was reversed, there being a fairly rich phytoplankton in the sub-Antarctic surface water, while that to the south-east was comparatively poor. On this line also the convergence was much less sharply defined than usual, the probable reasons for this being mixing caused by the newly discovered bend or curve in the convergence immediately to the west of the centre of this line, and as already noted, the abnormal warmth of the old Antarctic surface water in the vicinity of South Georgia towards the end of this season.

It will be seen from Table XVIII, in which the full analyses of the hauls on this line are given, that proceeding east by south from the Falkland Islands, fairly heavy catches were obtained at the first three stations in definitely sub-Antarctic water. This is perhaps rendered even clearer by Fig. 34, where the proportions of some of the leading forms are also shown as percentages of the catch at each station. It will be seen that few species were represented, and that the phytoplankton was of a very distinctive type, with *R. polydactyla* dominant, and *R. styliformis* and *Corethron valdiviae* (spineless chains) as the other more numerous forms.

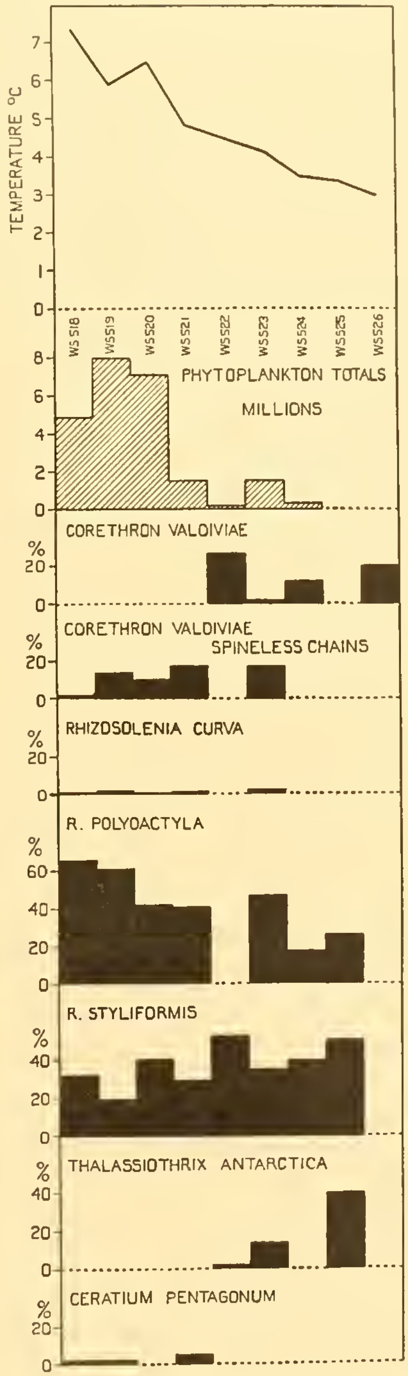

Fig. 34. Diagram showing the percentages of the principal species in the catches on a line of stations from the Falkland Islands to South Georgia, February 1930.

A few rarer forms were also of very constant occurrence: *Rhizosolenia alata*, *Ceratium pentagonum* with intermediates between forms *grandis* and *longisetum*, and the large easily recognized *Rhizosolenia curva*, which in many ways closely resembles the *R. robusta* of the northern hemisphere. This type of oceanic phytoplankton with *Rhizosolenia* spp. dominant was taken on several other occasions during this season just to the north and west of the convergence. It might perhaps be compared to the styli-plankton of the north temperate zone (see Gran, in Murray and Hjort, 1912, p. 347), except that Dinoflagellata were much rarer; but as several observers have noted, this class of organism is noticeably unimportant in the Antarctic, and it is possible that this scarcity extends to the southern part of the sub-Antarctic Zone as well. It may be mentioned that two of the above-named *Rhizosolenia* spp., *R. alata* and *R. styliformis*, are apparently ubiquitous. They are subject to a large range of individual variation, and apparently occur at some time of the year in almost all seas, though very rare in the tropics. The *R. styliformis* found in the warmer water on this line consisted of small thin individual frustules very different from the robust chains met with in water of the eastern Weddell Sea current farther south, although a small proportion of thin forms, presumably derived from microspores, was observed there also. Speaking of the distribution of this species in the northern hemisphere, Gran (1929 *a*, p. 18) describes it as an oceanic form reaching its maximum development where Atlantic water abuts on colder water masses, and also shows how it occasionally invades areas as far north as Davis Strait. In the south, as we see here, it seems moderately abundant where the sub-Antarctic water approaches the colder Antarctic surface water, but it was much more abundant away to the south in the eastern Weddell Sea water, where even in late summer the surface temperatures rarely rise above 1·5° C. The summer temperatures in the southern hemisphere are in fact so much lower that little can be gained from the comparison. One fact, however, is noteworthy: most workers in the northern hemisphere agree that *R. styliformis* is a form requiring high salinity to reach its optimum, and the eastern Weddell Sea water in which we have found it so abundant has a higher salinity than any other Antarctic surface water so far as is known at present.

To revert to conditions between the Falklands and South Georgia, at St. WS 521 the *Rhizosolenia* plankton was still present, but with a marked falling off in numbers, correlated with a considerable drop in temperature, and this was continued at the next station to the eastward where the catch was extremely small. Here *R. styliformis* was the only member of the genus observed, dinoflagellates were absent, and the typically Antarctic spiny form of *Corethron valdiviae* made its appearance in small numbers. At the very next station, however, despite a further drop in temperature the *Rhizosolenia* plankton cropped up again and traces of it persisted until the last station but one on the line. On the last four stations small numbers of the Antarctic forms *Corethron valdiviae* and *Thalassiothrix antarctica* made their appearance. The only obvious explanation of this gradual transition, and the paucity of the phytoplankton near South Georgia, is that the S-shaped curve in the convergence lying between 45 and 50° W long. must have led to mixing of the surface waters, encouraged by the abnormal warmth of the old Antarctic surface water during the latter half of this season. Diatom production round South Georgia at the time must have been at a standstill, from the prolongation of the generally unfavourable conditions described on the plankton survey slightly earlier in the year.

That diatom production was at a minimum in the older Antarctic surface water in March 1930 is also shown by the south-easterly stations on the next line (Sts. 372–5), which was worked from a point near the South Sandwich Islands west-north-west to the Burdwood Bank. The full analyses of the catches taken on this line are shown in Table XIX. It will be seen that in the small catches to the south-east, *Coscinodiscus bouvet* was of fairly constant occurrence, and that at St. 374 *Rhizosolenia styliformis* was dominant. Both these species had been taken in much greater numbers in the neighbourhood of the South Sandwich Islands a short time before. The comparatively rich hauls on this line were all taken to the north-west, on either side of the Antarctic convergence, which was evidently crossed between Sts. WS 529 and 530 (Fig. 32). The dominant forms in the old Antarctic surface water examined at Sts. WS 528, 529, were small Chaetocerids, mainly *Chaetoceros atlanticus*, *Nitzschia seriata* and *Fragilaria antarctica*. The plankton at St. WS 529 appears to indicate that the autumnal maximum observed a fortnight later in the southern half of Drake Passage, in old Bellingshausen Sea water, had already begun. At St. WS 530, over the convergence, a hint of the *Rhizosolenia* plankton met with on the previous line was encountered, with *R. polydactyla*, *R. styliformis* and *R. alata* prominent in that order of importance. Here also *Ceratium pentagonum* reached its maximum for the line. At the last station, WS 531, on the tail of the Burdwood Bank itself, the phytoplankton was quite different from anything else encountered during this season, apparently owing to violent vertical mixing transporting bottom forms into the surface layers. *Coscinodiscus* spp. were dominant with moderate numbers of *Fragilaria antarctica*, small Chaetocerids, *Hyalodiscus kerguelensis* and *Rhizosolenia polydactyla*. The apparent mixing of oceanic forms and bottom forms at this station is to be expected in view of the fact that it was worked on the only extensive area of shoal water known in the southern ocean, just to the north-west of the Antarctic convergence. The relation between the bulk of the phytoplankton samples taken on this line and the position of the convergence, as indicated by the temperature of the upper layers, is shown diagrammatically in Fig. 35.

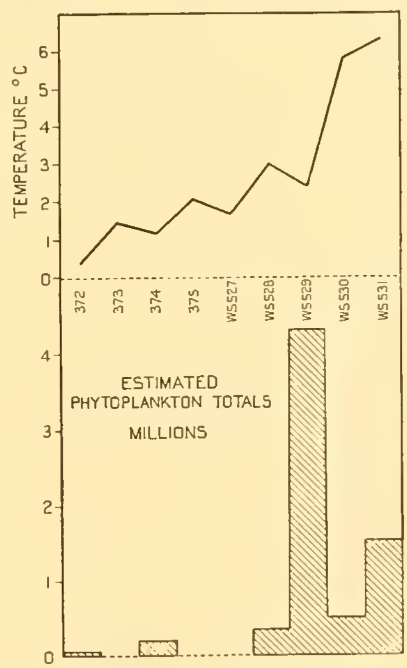

Fig. 35. Diagram showing the surface temperatures and phytoplankton totals on a line of stations from the South Sandwich Islands to the Burdwood Bank, March 1930.

This brings us to the consideration of the last piece of work accomplished in the south during the 1929–30 season, the line worked across Drake Passage in April from Livingston I. to a point near Cape Horn (Sts. 377–88, Fig. 32). In Table XX, in which the full analyses of the phytoplankton hauls taken on this line are given, that from St. 376 worked inside the Bransfield Strait has been included, as the phytoplankton was essentially similar to that found outside the South Shetlands at this time. Owing to the ice conditions this was the only station that could be worked in the Bransfield Strait on this occasion, so that the results from it are most logically considered here. Towards the southern end of this line a rich phytoplankton was encountered, hence the working of the extra stations, Sts. 379, 380 and 381, at closer intervals. At these stations diatom nets and surface-water samples only were worked. The rich phytoplankton in the southern half of Drake Passage at this time evidently represented an autumnal increase in water of Bellingshausen Sea origin. This increase led to a more normal disposition of the phytoplankton totals with regard to the position of the Antarctic convergence, than that seen on the previous lines (Figs. 33–5). The Antarctic phytoplankton encountered here was so much richer than that taken in the sub-Antarctic surface water to the northern end of the line, that the latter does not show up at all when the totals are plotted diagrammatically beneath the temperature curve (Fig. 36). This is so despite the fact that at these more northerly stations a distinct remnant of a *Rhizosolenia* plankton was present, such as was found in the fairly rich hauls near the Falkland Islands a month earlier. The relative proportions of the leading forms on the Drake Passage line will be seen from Table 14, in which their numbers, and their percentage of the total estimated catch at each station are given.

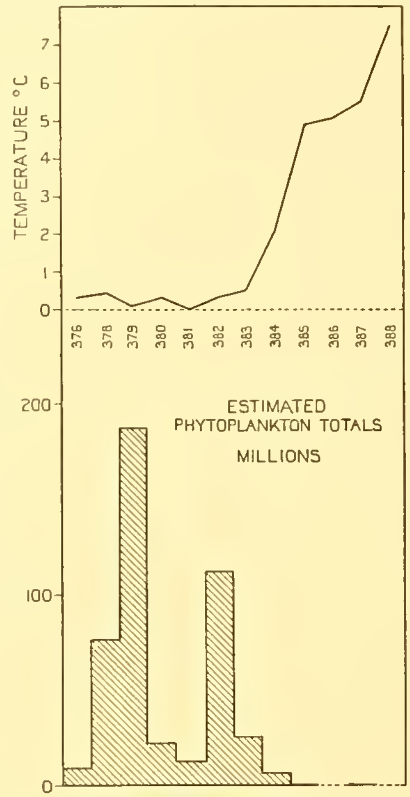

Fig. 36. Diagram showing the surface temperatures and total Diatomales on a line of stations worked across Drake Passage from south to north, April 1930.

From the temperatures quoted in Table XX it is evident that the convergence was crossed between Sts. 384 and 385: this is also clearly shown by the rise in salinity and fall in the phosphate values. The distribution of the principal forms, which is shown in detail in Table 14, may therefore be briefly summarized as follows:

South of the convergence in the comparatively rich hauls which represented an autumnal increase in old Antarctic surface water of Bellingshausen Sea origin, the dominant forms were small Chaetocerids, *Nitzschia seriata* and *Fragilaria antarctica*, and there was a falling off in the bulk of the catches as the convergence was approached (see also Fig. 36). At St. 384, immediately to the south of the convergence, *Nitzschia seriata* was very strongly dominant.

North of the convergence *Chaetoceros atlanticus* was still important, but various species of the genus *Rhizosolenia* accounted for a large proportion of the comparatively scanty phytoplankton. At these four stations, 385–8, *Ceratium pentagonum* was present in small numbers, various individuals showing all stages of variation between forms *grandis* and *longisetum*. The positions of all the stations on the lines crossing the con-

Table 14

Station number Total phytoplankton	376 **8,826,000**	378 **75,006,000**	379 **187,320,000**	380 **20,667,000**	381 **12,177,200**	382 **111,655,000**	383 **25,047,000**	384 **6,990,000**	385 **611,200**	386 **120,600**	387 **269,100**	388 **43,600**
Corethron valdiviae	60,000 **0·7**	33,000 **0·04**	60,000 **0·03**	27,000 **0·1**	54,000 **0·4**	1,260,000 **1·1**	180,000 **0·7**	510,000 **7·3**	60,600 **9·9**	23,200 **19·2**	— —	— —
Rhizosolenia alata	120,000 **1·4**	60,000 **0·1**	— —	27,000 **0·1**	17,200 **0·1**	129,000 **0·1**	— —	— —	90,000 **14·7**	800 **0·6**	36,900 **13·7**	1,200 **2·8**
R. polydactyla	— —	— —	— —	— —	— —	— —	— —	— —	150,000 **26·2**	— —	26,400 **9·8**	— —
R. styliformis	60,000 **0·7**	— —	— —	12,000 **0·06**	— —	360,000 **0·3**	33,000 **0·1**	— —	— —	9,200 **7·6**	149,000 **55·4**	2,800 **6·4**
Small Chaetocerids mainly *Ch. atlanticus*	1,950,000 **22·1**	50,190,000 **66·9**	150,000,000 **80·1**	16,240,000 **78·6**	6,570,000 **54·0**	84,540,000 **75·7**	21,930,000 **87·5**	990,000 **14·2**	100,000 **16·4**	65,200 **54·1**	16,000 **5·9**	21,200 **48·6**
Ch. criophilum	570,000 **6·5**	750,000 **1·0**	1,620,000 **0·9**	28,500 **0·1**	144,000 **1·2**	363,000 **0·3**	540,000 **2·2**	60,000 **0·8**	— —	— —	— —	— —
Eucampia antarctica	— —	30,000 **0·04**	840,000 **0·4**	135,000 **0·7**	864,000 **7·1**	40,000 **0·03**	— —	— —	— —	— —	18,900 **7·0**	— —
Fragilaria antarctica + f. *bouvet*	1,320,000 **15·0**	4,530,000 **6·0**	4,500,000 **2·4**	990,000 **4·8**	3,204,000 **26·3**	2,820,000 **2·5**	1,080,000 **4·3**	690,000 **9·9**	— —	9,600 **8·0**	— —	— —
Thalassiothrix antarctica	420,000 **4·8**	600,000 **0·8**	720,000 **0·4**	— —	27,000 **0·2**	1,140,000 **1·0**	— —	— —	— —	— —	2,100 **0·8**	— —
Nitzschia seriata	4,170,000 **47·2**	18,510,000 **24·7**	28,920,000 **15·4**	3,088,000 **14·9**	864,000 **7·1**	19,500,000 **17·5**	810,000 **3·2**	4,650,000 **66·5**	80,000 **13·1**	— —	— —	9,600 **22·0**
Ceratium pentagonum	— —	— —	— —	— —	— —	— —	— —	— —	10,000 **1·6**	4,000 **3·3**	4,200 **1·6**	3,600 **8·3**

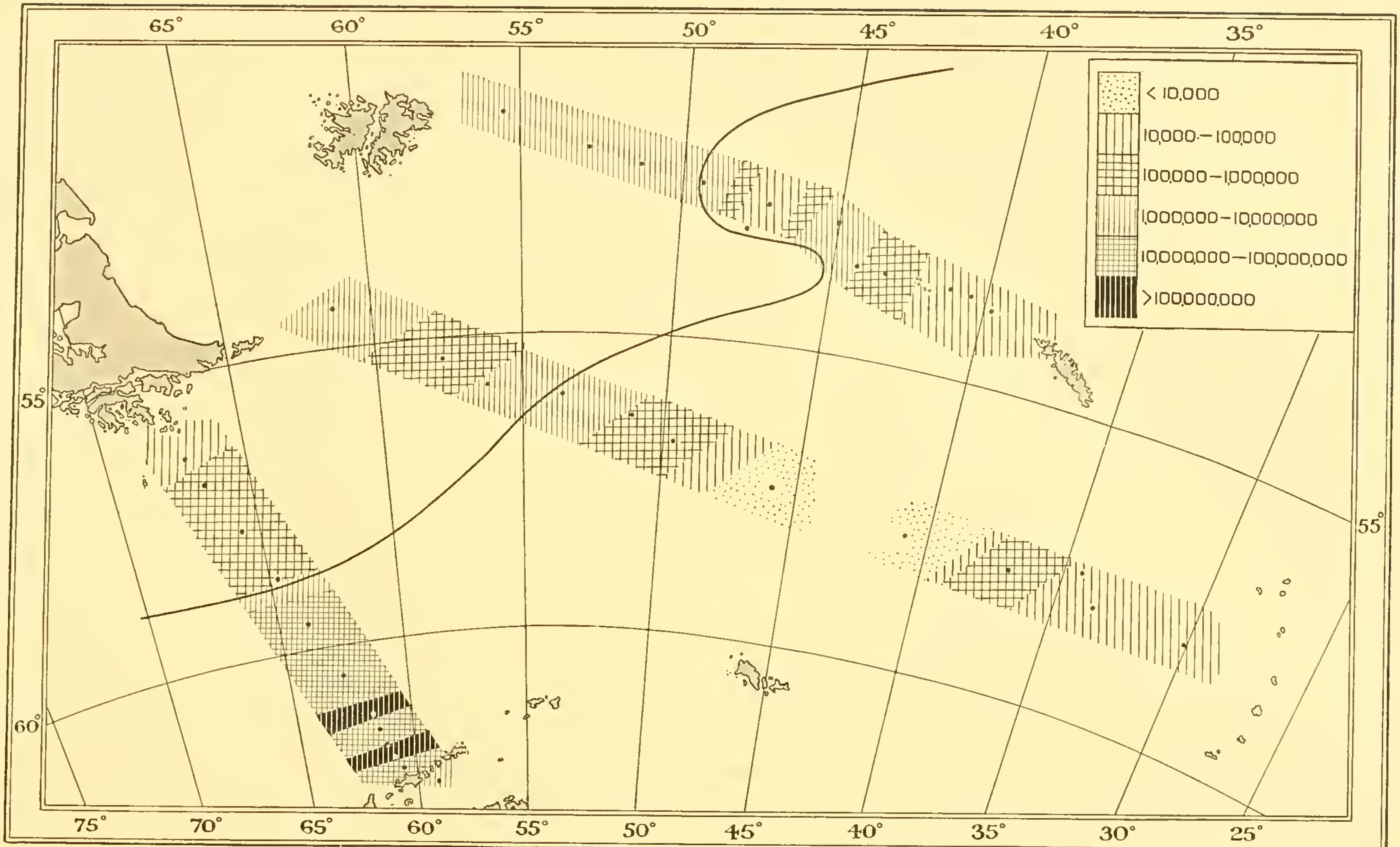

Fig. 37. Chart showing the distribution of phytoplankton (totals per 100–0 m. haul) on the lines of stations crossing the convergence, February–April 1930.

vergence in the Scotia Sea are shown in Fig. 32, along with those worked in the northern part of the Weddell Sea area.

The total abundance of the phytoplankton on three lines of stations worked across the Antarctic convergence in March–April 1930 is indicated in Fig. 37, where the probable position of the convergence is also shown. The conditions on the line worked in the spring of the year (November 1929) have not been charted with the autumnal results as this would confuse the issue. In Fig. 38 the distribution of the typically sub-Antarctic species *Rhizosolenia polydactyla* has been plotted separately, along with the probable position of the convergence, and from this figure it will readily be seen how the curve in the convergence to the west of the Shag Rocks helps to account for the unexpected occurrence of this species at the eastern stations on the Falkland Islands-South Georgia line.

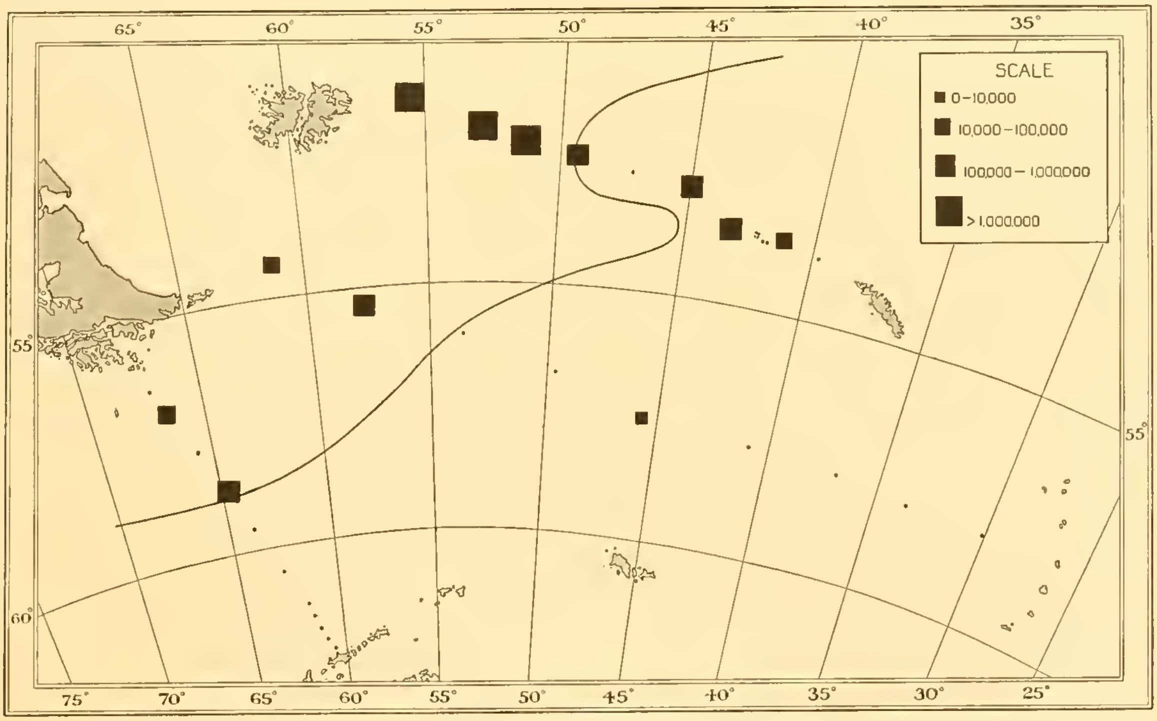

Fig. 38. Chart showing the distribution of *Rhizosolenia polydactyla*, February–April 1930.

Summing up the points raised by the lines crossing the Antarctic convergence in 1929–30, it will at once be seen that they indicate that in early March the phytoplankton in the old Antarctic surface water to the south was at a minimum, but that at that time a fairly rich *Rhizosolenia* plankton was to be found immediately to the north of the Antarctic convergence. In spring there was very little phytoplankton at the station worked just to the north of the convergence, and the hauls showed a large but irregular increase as one proceeded southwards, production in the Antarctic surface water having just begun. The April (late autumn) line showed somewhat similar conditions, from which it seems fairly certain that there is a slight autumnal increase very late in the year in the older Antarctic surface water. At the northernmost stations on this line a trace of the March *Rhizosolenia* plankton of the sub-Antarctic surface water still remained.

It will be remarked that very few species entirely confined to the sub-Antarctic Zone were recorded, and that many Antarctic stragglers were found to the north of the convergence. The chief reason for this was that as one of the main purposes of these lines was to determine the position of the convergence, they were not carried very far north and west into the sub-Antarctic Zone; other lesser reasons for this have already been discussed. If we take the stations worked in what may be considered as the extreme south of the sub-Antarctic Zone, we find that only three species were recorded that did not occur sporadically farther south: *Chaetoceros decipiens*, *Hyalodiscus kerguelensis* and *Ceratium fusus*; but if we consider the forms found dominant to the north of the convergence, but rarely or sporadically farther south, we have besides *Hyalodiscus*, the spineless chain form of *Corethron valdiviae* and *Rhizosolenia polydactyla*. Next in importance are the two very variable cosmopolitan forms *R. styliformis* and *R. alata*, and to these can be added a list of definitely Antarctic immigrants, sometimes found in comparatively large numbers to the north of the convergence, where, however, they have frequently been observed in an apparently dying condition: *Dactyliosolen antarcticus*, *Chaetoceros atlanticus*, *Ch. criophilum*, *Fragilaria antarctica* and *Nitzschia seriata*. The occurrence of these forms in numbers in the sub-Antarctic Zone is normally confined to the region in the immediate vicinity of the convergence itself, or only a short distance north of it. Among the rarer forms the following may be regarded as typically sub-Antarctic, though occurring sporadically to the south of the convergence, *Rhizosolenia curva*, *R. torpedo* and *Ceratium pentagonum* (f. *lineatum* and intermediates). The form *grandis* of the last-named species normally shows a maximum right on the convergence or, as in this unusually mild season, slightly farther south.

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Towards the end of this season, in the month of March, three series of observations crossing the Antarctic convergence were obtained. The positions of these stations are shown in Fig. 32. The distribution of the phytoplankton species differed somewhat from that found towards the latter end of the previous abnormally warm season, as would be expected from the striking contrast between the meteorological and ice conditions obtaining during the two years.

The first line of stations (Sts. 633–9) was worked from 54° 58¼′ S, 52° 16½′ W on a course leading down to the neighbourhood of the South Orkney Islands and then southwestwards as far as 61° 57¾′ S, 51° 59′ W. The full analyses of the phytoplankton collected on this line will be found in Table XXI. At the northernmost station, definitely to the north of the convergence, it will be seen that a rich phytoplankton was encountered, indeed, the haul at this station, the earliest in the year of the series under consideration, was appreciably heavier than any of the others to the north of the convergence taken later in the month. The chief forms present in this haul, however, were for the most part

Antarctic stragglers. *Nitzschia seriata* was strongly dominant, and the other principal species were *Corethron valdiviae* in the spineless chain form, *Dactyliosolen antarcticus*, *Chaetoceros atlanticus* and *Rhizosolenia alata* in that order of importance. Among the rarer forms, indicative of sub-Antarctic influence, *R. curva*, *R. polydactyla* and *Ceratium pentagonum* were present.

The temperature at the next station to the southward was still high, although the position given is normally definitely to the south of the convergence. The phytoplankton at this station was very rich, and in general closely similar to that taken on the first station. *Nitzschia seriata* was again strongly dominant, and the other more numerous species, in order of their importance were: *Corethron valdiviae* (spineless chains), *Fragilaria antarctica*, *Dactyliosolen antarcticus* and *Ceratium pentagonum*. The dinoflagellates here reached their maximum for the line, and the typically sub-Antarctic species *Rhizosolenia curva* and *R. polydactyla* were both present.

At St. 635, the next in order as one proceeded south on this line, the quantity of the phytoplankton was moderate, only a trifle over 1 million organisms being estimated to be present, as against 14 and 40 millions respectively at the first two stations. The quality was also markedly different, *Chaetoceros atlanticus* being strongly dominant, and *Nitzschia seriata* the only other species recorded in appreciable numbers. The dinoflagellates formed but a small proportion of the phytoplankton at this station, and farther south they were not met with on this line. At the next station to the southward, St. 636, the phytoplankton was rich again; *Nitzschia seriata* and *Chaetoceros neglectus* were co-dominant with only a slightly smaller quantity of *Ch. atlanticus*. Other important forms were *Ch. dichaeta* and *Fragilaria antarctica* f. *bouvet*.

The three succeeding stations (637–9) were worked roughly south-south-west from the South Orkney Islands; the temperatures in the upper layers were much lower and the phytoplankton showed an abrupt falling off. At the first of these the high salinity possibly indicates the influence of western Weddell Sea water. *Chaetoceros atlanticus*, *Fragilaria antarctica* and *Chaetoceros neglectus* were the principal forms here among a poor phytoplankton. The two last stations showed minus temperatures and the low salinities suggest that ice had recently melted in the water in which they were worked. At both the phytoplankton was very poor, with the normal spiny form of *Corethron valdiviae* dominant.

The next line of stations crossing the Antarctic convergence during this second season (Sts. 644–51), was worked from a point to the north-west of Elephant Island northwards to Staten Island—across Drake Passage, but farther to the eastward and a month earlier than the corresponding line of the preceding year. The analyses of the phytoplankton collected on this line are given in Table XXII.

At the southernmost station *C. valdiviae* was the most numerous form in an exceedingly poor catch. This station was apparently worked within the "desert" area to the north and east of King George Island which has been noted on other occasions (see p. 72). Proceeding northwards the phytoplankton was somewhat richer at the next two stations, the dominant forms being *Chaetoceros neglectus*, *Nitzschia seriata* and

Chaetoceros atlanticus. Still farther north, at St. 647, the phytoplankton was found to be very rich, with *Ch. neglectus* strongly dominant, and *Nitzschia seriata*, *Fragilaria antarctica*, *Chaetoceros atlanticus* and *Ch. dichaeta* next in order of importance. This haul was by far the heaviest obtained on the whole of this line.

The considerable rise in temperature at the next station, 648, indicates that it was worked only a short distance to the south of the Antarctic convergence. The phytoplankton here showed a great falling off in bulk, but was still rich numerically owing to the pronounced dominance of the minute *Nitzschia seriata*. The only other forms of much importance were the spineless chain form of *Corethron valdiviae* and *Fragilaria antarctica*. Among the rarer forms more typical of sub-Antarctic conditions *Rhizosolenia curva* and *R. polydactyla* made their first appearance, together with various dinoflagellates. In point of fact these species were actually more numerous here than at the definitely sub-Antarctic stations farther north on this particular line, so that despite their more abundant occurrence in sub-Antarctic water at other times it should be recognized that under certain conditions they may show a maximum in the comparatively warm, old Antarctic surface water immediately to the south of the convergence. A somewhat similar circumstance seems to have been noted by Schimper, when he recorded *R. curva* as the dominant species in a surface haul some distance to the south of the convergence, north-west of Bouvet Island, comparatively early in the year (Karsten, 1905, p. 37).

At St. 649 the much higher temperature and salinity indicates clearly that the Antarctic convergence had been crossed. The phytoplankton was poor, with the spineless chain form of *Corethron valdiviae*, *Nitzschia seriata* and *Dactyliosolen antarcticus* the most numerous species. *Rhizosolenia curva* was present in small numbers. Again at St. 650 the phytoplankton was very scanty. Here *Nitzschia seriata* was dominant, and among the other forms *Corethron valdiviae* (spineless chains), *Ceratium pentagonum* and *Dactyliosolen antarcticus* were slightly the more numerous. The two typically sub-Antarctic species of *Rhizosolenia* were both present in small numbers. At the northernmost station on the line *Chaetoceros atlanticus* was the most numerous species in an extremely poor catch of Antarctic stragglers.

As the ship proceeded eastwards from Staten Island to South Georgia, a few stations were worked, mainly to the north of the Antarctic convergence and in the area of the abrupt curve which it makes to the westward of the Shag Rocks. The analyses of the phytoplankton material collected on these stations are given in Table XXIII. It will be seen that at all of them the phytoplankton was very scanty, and consisted for the most part of Antarctic stragglers. Of these the most important were *Dactyliosolen antarcticus*, *Corethron valdiviae*, *Chaetoceros atlanticus* and *Nitzschia seriata*. At the eastern end of this line *Chaetoceros criophilum* also made its appearance. *Rhizosolenia curva* was taken in small numbers at almost all of these stations, including the most easterly one, St. 658, which was worked in Antarctic surface water.

In attempting to epitomize the main features of the results obtained during March 1931, recourse has been had to distribution charts rather than to a more detailed con-

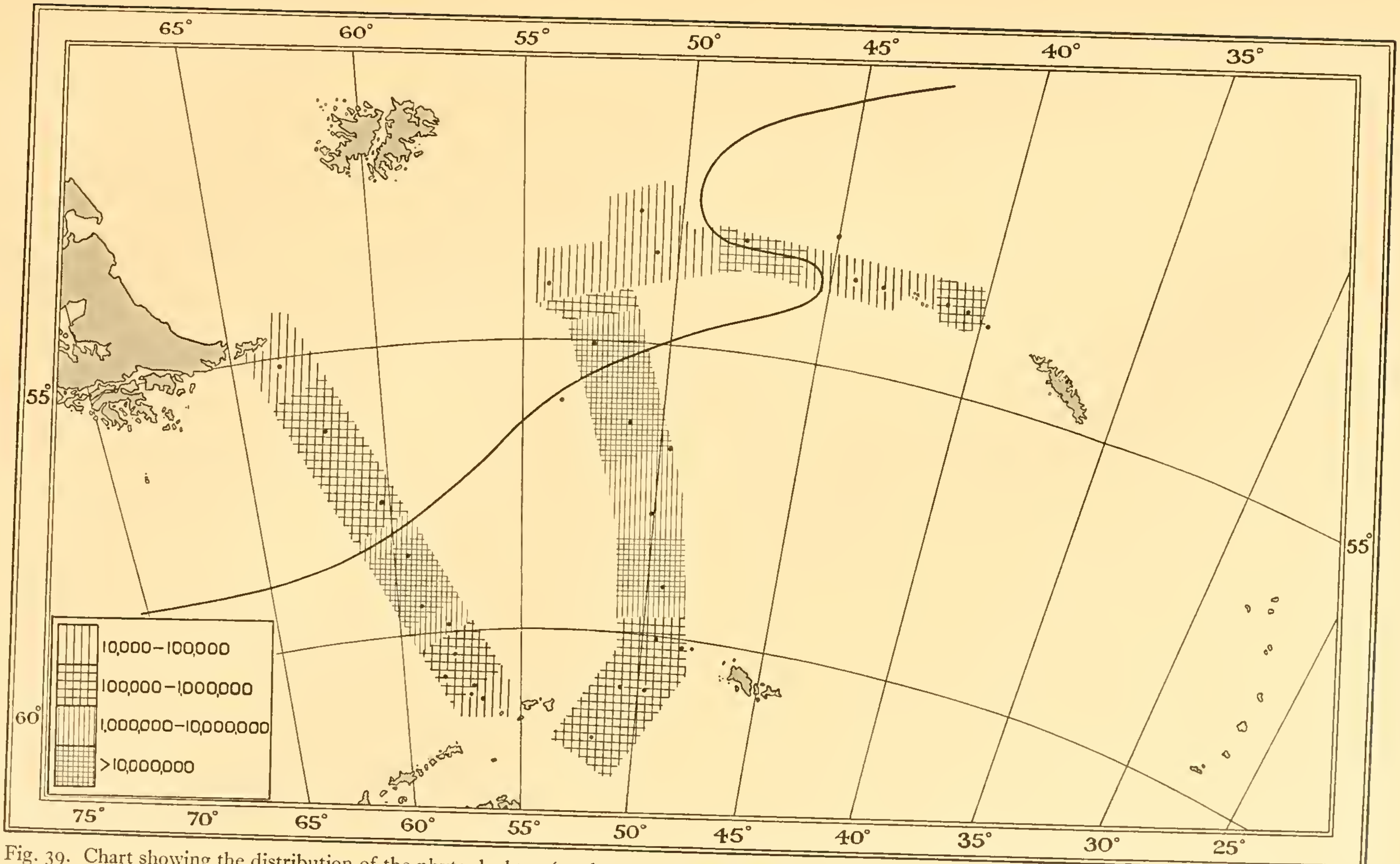

Fig. 39. Chart showing the distribution of the phytoplankton (totals per 100–0 m. haul) on the lines of stations crossing the convergence in the Scotia Sea, February–March 1931.

sideration of the actual analyses, as it is evident that the observations were not sufficiently numerous to yield results of much value from the latter method of treatment. From the account already given it will have been seen that the characteristic *Rhizosolenia* plankton in the sub-Antarctic surface water, which had been such a feature of the first week in March of the previous year, and of which traces were still observed as late as April, did not occur in 1931, the phytoplankton at the comparatively few stations worked within the sub-Antarctic Zone on this occasion consisting mainly of Antarctic stragglers. On the other hand, while in 1930 the comparatively rich phytoplankton with small Chaetocerids and *Nitzschia seriata* dominant was not encountered until April, and then on the westernmost line, in 1931 a similar phytoplankton was encountered already half-way across the Scotia Sea early in March. In Fig. 39 the phytoplankton totals are

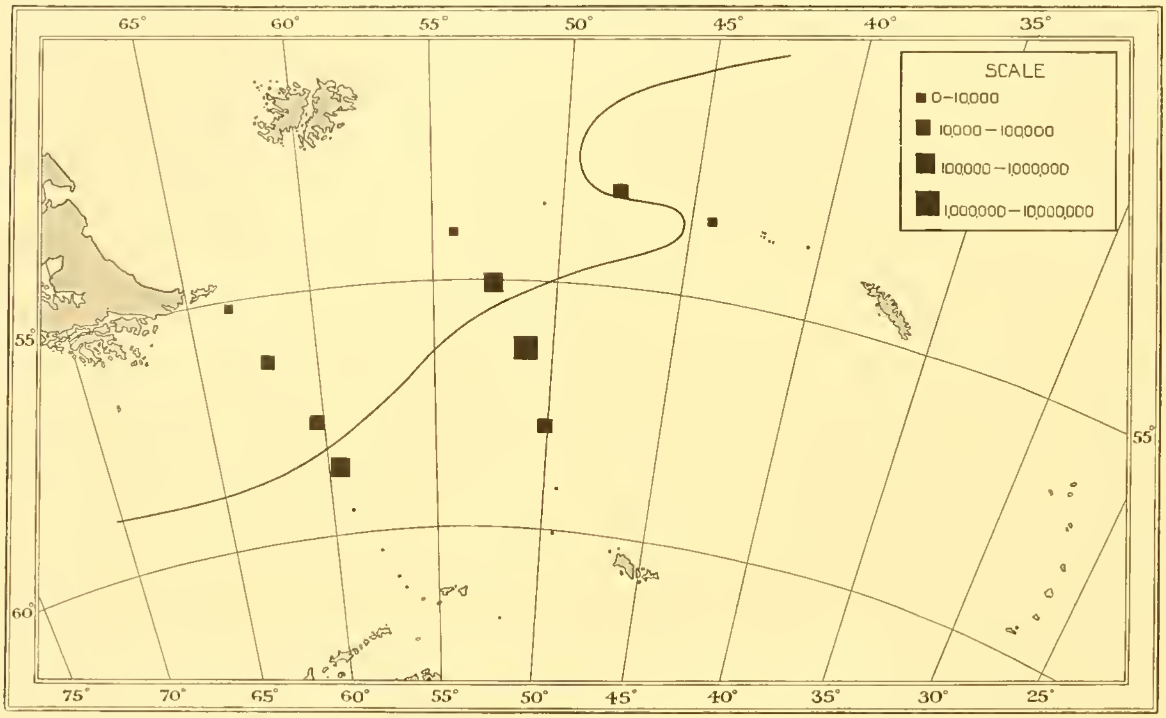

Fig. 40. The distribution of *Corethron valdiviae* (spineless chain form) in the Scotia Sea, February–March 1931.

indicated by shading, and the presence of this comparatively rich phytoplankton to the south of the Antarctic convergence is clearly shown. The distributions of the more important species of diatom have also been plotted individually in Figs. 40–45. Fig. 40 shows the distribution of the spineless chain form of *Corethron valdiviae*, which as we have endeavoured to show in the preceding pages, may be regarded as a dominant form of the phytoplankton in the southern sub-Antarctic waters, and also in old Antarctic water, in abnormally warm seasons, in late summer. This is well borne out by the distribution observed during this particular piece of work. It will be seen that it occurred at five out of the six comparatively poor stations worked to the north of the convergence, and at four only of the stations immediately to the south, where the phytoplankton was richer and this species of less relative importance, though the actual numbers in one case were higher. It may be mentioned that this form has occasionally been found in very small numbers in the cold water much farther south, in both the Weddell and Bellingshausen Seas, but only late in the season, and never forming any large proportion of the total phytoplankton.

In Fig. 41 the distribution of *Nitzschia seriata* has been plotted. It will be seen that this form, perhaps the most abundant of all those encountered during this piece of work, was most numerous in the old Bellingshausen Sea water approaching from the westward, immediately to the south of the Antarctic convergence. It was also exceedingly abundant at one station (633) worked immediately to the north of the convergence, and was the most numerous and widespread of the Antarctic forms found in the scanty phytoplankton in the sub-Antarctic water on this occasion, so much so that it might almost be described as an invader, rather than a straggler.

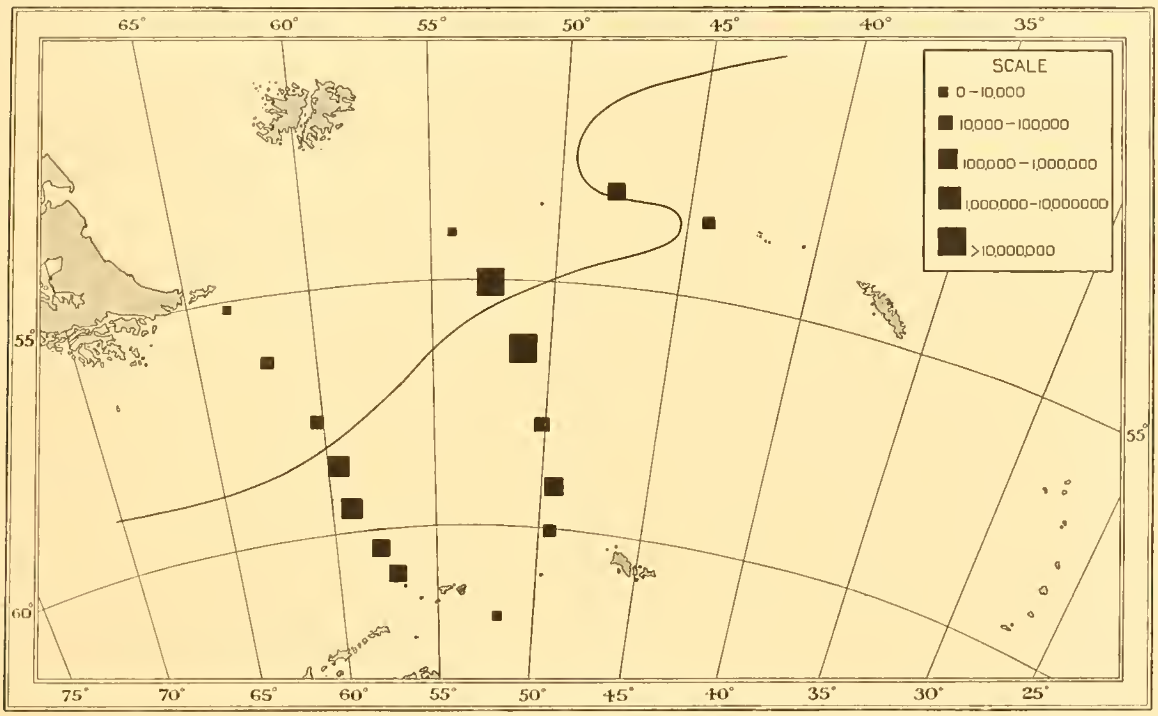

Fig. 41. The distribution of *Nitzschia seriata* in the Scotia Sea, February–March 1931.

Fig. 42 shows the distribution of *Chaetoceros neglectus*, the most numerous of the small species of *Chaetoceros* which seem to have been percolating through the southern half of Drake Passage at this time. The definitely Antarctic character of this species is well evidenced by the fact that it was only observed to the south of the Antarctic convergence.

Ch. atlanticus, on the other hand, the distribution of which is shown in Fig. 43, was almost as frequent in the sub-Antarctic Zone as *Nitzschia seriata*. Like the preceding species, however, it reached its greatest abundance in the old Bellingshausen Sea water approaching from the west. There is considerable evidence that *Chaetoceros atlanticus* may be regarded as one of the principal forms of the autumnal increase in both Weddell and Bellingshausen Sea water, and since it has about the most northerly distribution of

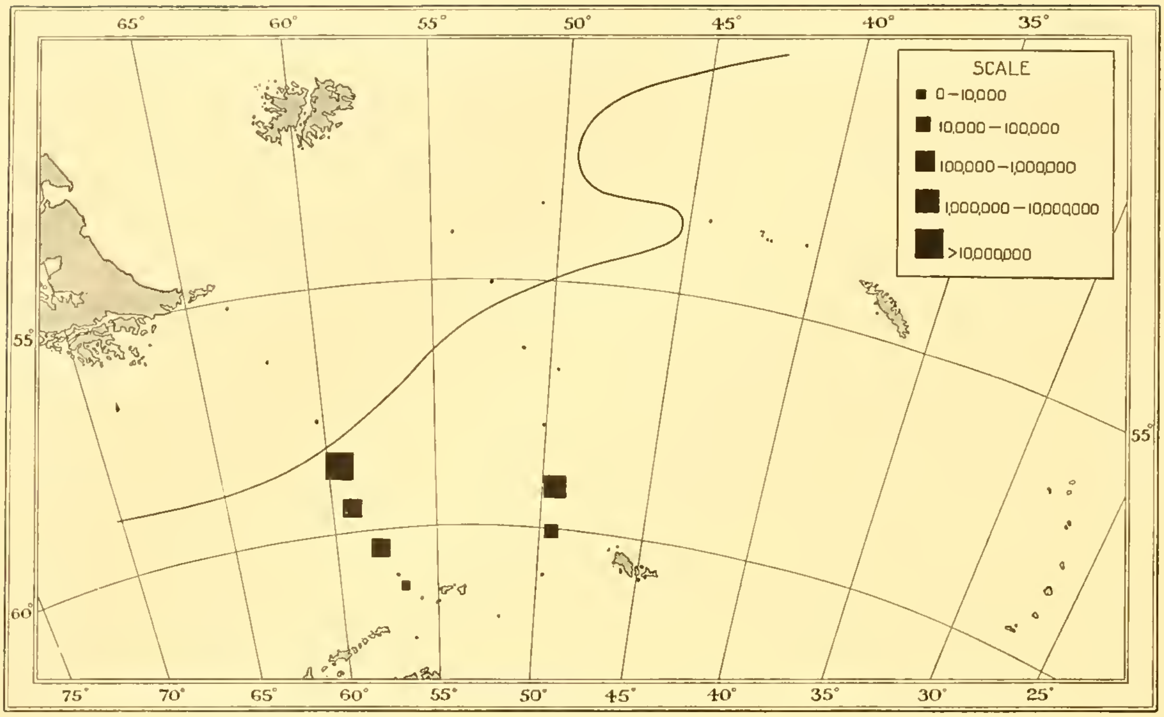

Fig. 42. The distribution of *Chaetoceros neglectus* in the Scotia Sea, February–March 1931.

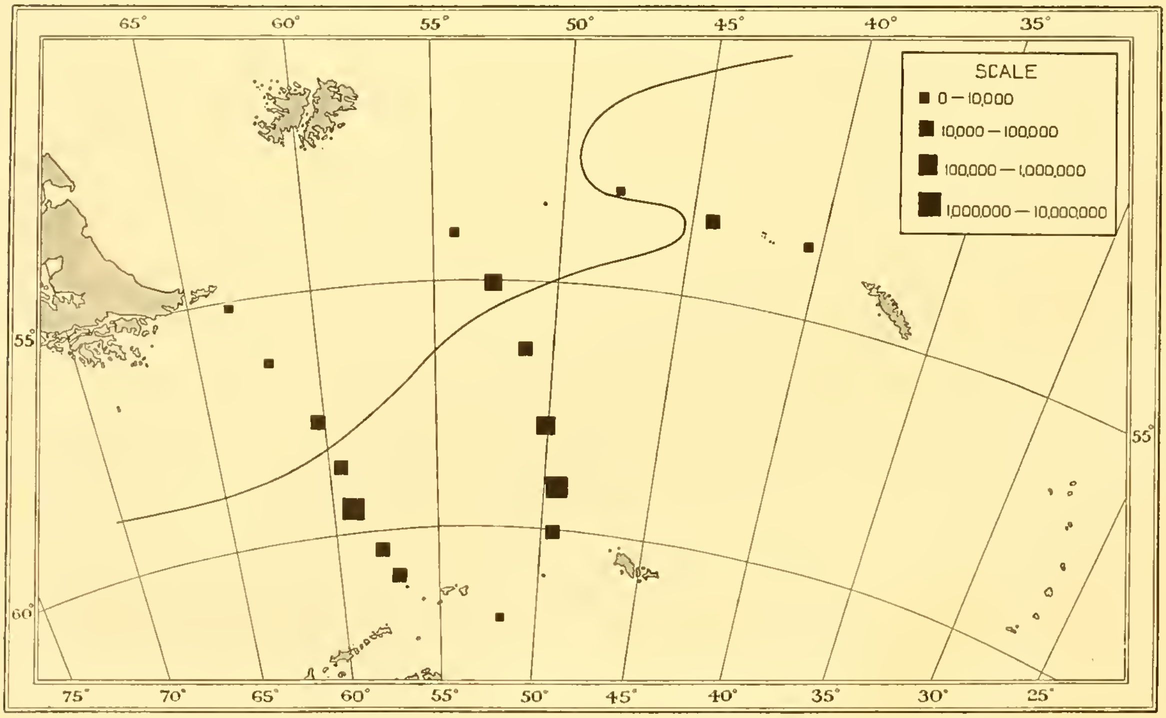

Fig. 43. The distribution of *Chaetoceros atlanticus* in the Scotia Sea, February–March 1931.

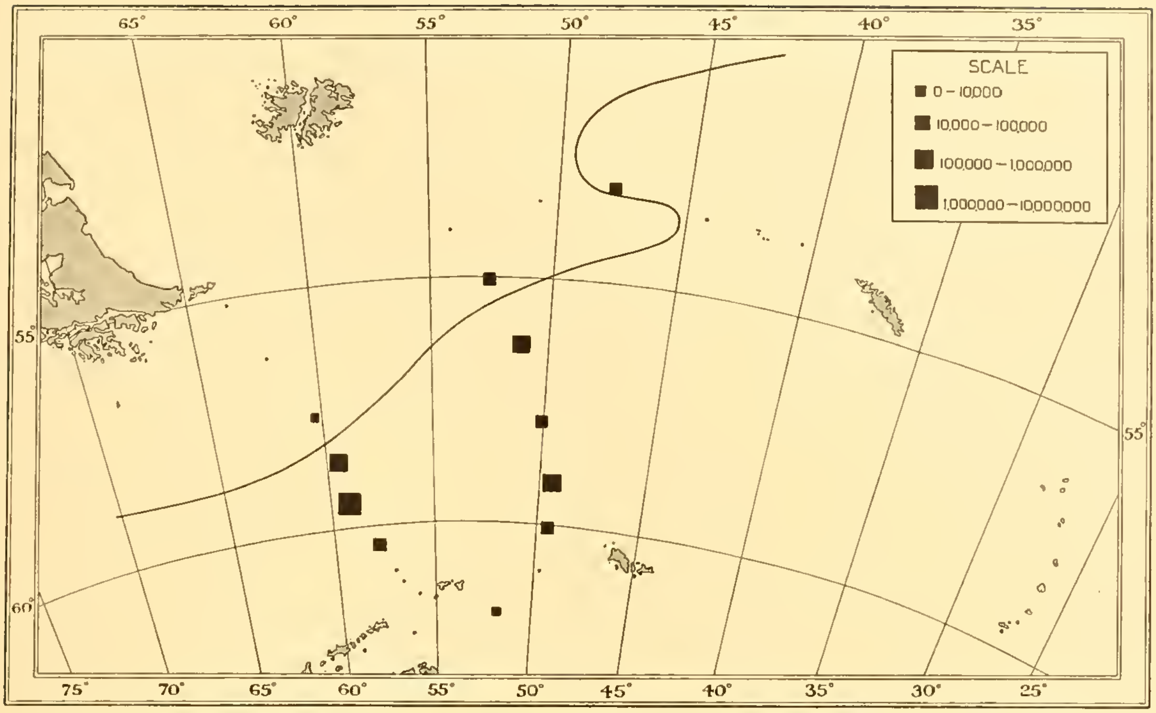

Fig. 44. The distribution of *Fragilaria antarctica* in the Scotia Sea, February–March 1931.

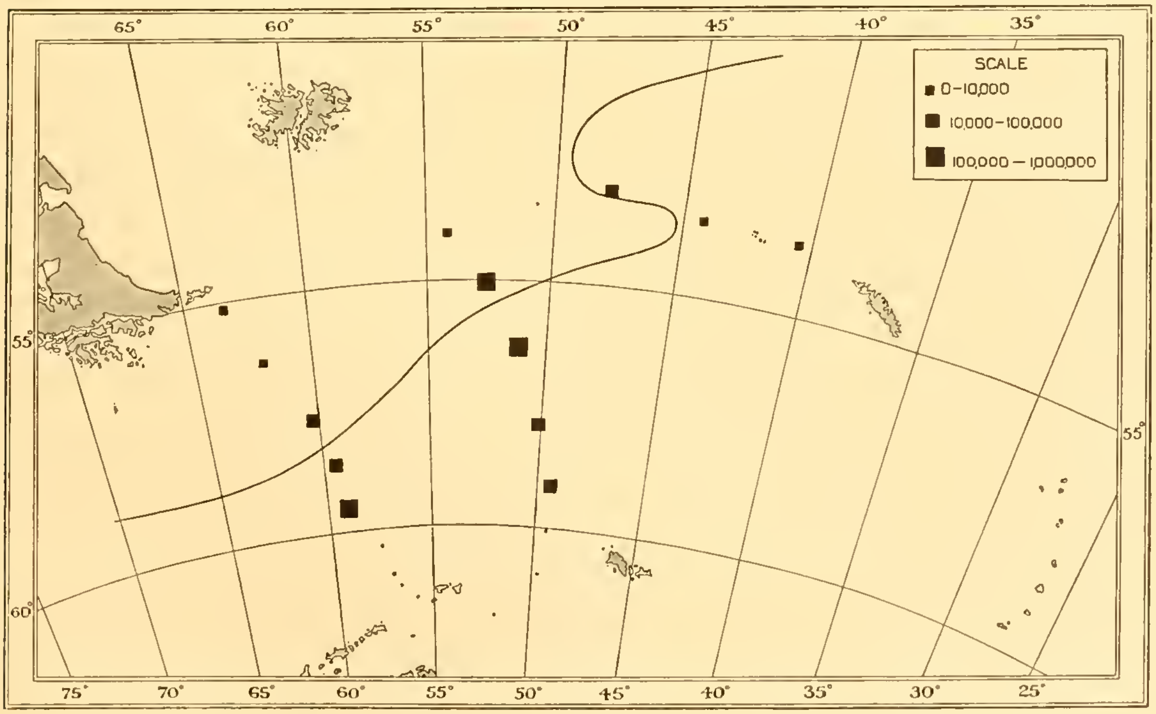

Fig. 45. The distribution of *Dactyliosolen antarcticus* in the Scotia Sea, February–March 1931.

all the species of the genus commonly found in Antarctic surface waters, it is not surprising to find it prominent among the Antarctic stragglers into the sub-Antarctic Zone.

The distribution of *Fragilaria antarctica* observed on these stations is shown in Fig. 44. Like most of the other Antarctic forms it was evidently coming through the southern half of Drake Passage into the Scotia Sea. North of the convergence it occurred at two stations only, all so close to the convergence as to lie most probably with the zone of great vertical mixing which is found immediately to the north. The occurrence of this species in sub-Antarctic surface waters may therefore reasonably be regarded as fortuitous.

Fig. 45 shows the distribution of *Dactyliosolen antarcticus*, a species whose occurrence especially to the north of the convergence closely agrees with that of *Chaetoceros atlanticus*. Like the latter it may be regarded as an autumn form of northerly range (see also p. 69).

THE PHYTOPLANKTON OF THE WEDDELL SEA AREA

A brief account of the stations worked in this area has already been given (pp. 13, 14). As stated, the material obtained during the first season's work was very scanty, being confined to a few stations worked rather late in the season in the extreme north-east of the Weddell Sea proper, in the vicinity of the South Sandwich Islands. This material has been treated separately, small as it is, with a view to avoiding confusion and bringing out the abnormality of the conditions obtaining to the north-east during the latter half of the season 1929–30.

The positions of all the stations worked in the northern part of this area are shown on the same reference chart (Fig. 32) as that used for the previous section (p. 70).

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On the completion of the plankton survey round South Georgia, course was laid for the South Sandwich Islands, and while on this passage phytoplankton samples were collected at four stations, at which full hydrological data were also obtained. The first of these, St. 359, was worked in the lee of a very large tabular berg, over 60 miles in length. At this station a first attempt to employ the centrifuge method of estimating the phytoplankton was made, but beyond gaining useful experience the results were not of much value, as the phytoplankton appeared to be homogeneous in both quality and quantity down to a depth of 80 m. This was doubtless due to violent vertical water movements caused by the presence of this vast mass of ice. The analysis of the net haul from this station, together with those of the others obtained en route to the South Sandwich Islands, will be found in Table XXIV. It will be seen that the results from St. 342 of the South Georgia survey have also been included, as by this means it becomes possible to show that the moderately rich belt of phytoplankton met with to the east of South Georgia on that occasion extended for a considerable distance to the south-east.

At St. 359 a rich phytoplankton was encountered, with the spineless chain form of *Corethron valdiviae* strongly dominant. Other forms estimated to run into millions in the net haul were: *Fragilaria antarctica*, *Thalassiothrix antarctica* and *Nitzschia seriata*. St. 342, the next in the table, was the outermost station on the Cooper Island line of the South Georgia survey. Here *Corethron valdiviae* (spineless chains) and *Thalassiothrix antarctica* were co-dominant in a moderately rich phytoplankton. The comparatively high temperature of the upper layers at this station, together with the low salinity and phosphate content, indicate that old Bellingshausen Sea water from the westward may, by mixing with the old water of eastern Weddell Sea origin, have been responsible for the localization of the moderately rich phytoplankton to the east of South Georgia.

A similar phytoplankton was encountered at St. 360, with *Corethron* dominating over *Thalassiothrix*, and very few other organisms present; but at the next station to the eastward, St. 361, the phytoplankton became extremely poor, and it was evident that the limit of the spineless-*Corethron* and *Thalassiothrix* belt had been reached. At the succeeding station it was even poorer, though the falling temperature indicated that more typically Weddell Sea conditions were being approached. Here the normal spiny form of *Corethron valdiviae* was encountered for the first time among the hauls taken on board the 'Discovery II', though in very small numbers.

During the running survey of the South Sandwich Islands it was only found possible to make phytoplankton collections from three full stations. The material obtained, however, was very interesting, as it showed a phytoplankton which may possibly be taken as typical of old surface water of the eastern Weddell Sea type in late summer. It may be that during this mild open season the remnants of a formerly rich phytoplankton hung round the immediate neighbourhood of the islands, like the numerous small bergs that were encountered, as the catches obtained in the open sea to the westward on the long line previously described (Table XIX) were very much poorer. This South Sandwich phytoplankton bore a close general resemblance to that normally found in the tongue of eastern Weddell Sea water to the east of South Georgia in the latter half of the season, in strong contrast to that actually present in the latter region on this occasion. The analyses of the net hauls made at the South Sandwich Islands are contained in Table XXV, where they are arranged in north to south order.

It will be seen that at St. 365 between Visokoi Island and the Candlemas Islands small Chaetocerids, notably *Chaetoceros dichaeta*, were numerically dominant, but the most remarkable feature of the catch was the presence of *Coscinodiscus bouvet* in large numbers. This form was also taken in the larger closing nets down to the unusual depth of 750–500 m. Similar findings of this large heavily silicified form at great depths have already been described by Hardy (in press), who noted that as the depth increased the number of "living" individuals, as estimated by taking the percentage of the frustules containing chloroplasts, decreased. This observation led to the formulation of the important theory that the diatom population of Antarctic surface waters might be kept up by the return of resting spores in the upper layers of the warm deep water. The formation of minute microspores has been observed in the genus by Pavillard (1924), so that in the present instance the theory might apply very well, even though spore formation was not actually observed. The upper limit of the warm deep water at this station lay at a depth of only 200–300 m. Lohmann (1928, p. 16) has described a maximum for this genus in January in the Weddell Sea proper, and one would therefore expect to find the species sinking in numbers late in February in the older water farther to the north-east. On the few occasions when this and other *Coscinodiscus* spp. were encountered in numbers (which, apart from *C. bouvet*, was almost always under neritic or ice conditions) it was noted that they seemed to have a very limited reproductive period, and once this was over, with their heavily silicified skeletons and small surface-volume ratio, they appeared to sink with great ease. In addition to *C. bouvet* a form was encountered in some quantity at St. 365 which is to be regarded as an essentially neritic species—*Melosira sol.*

A rather similar phytoplankton was encountered at St. 369 between Bristol Island and Southern Thule, though here the approach to typically eastern Weddell Sea conditions was more complete, as instanced by the still lower temperature and high salinity. Small Chaetocerids, principally *Chaetoceros dichaeta*, were again numerically dominant, but the following also occurred in considerable numbers: *Rhizosolenia styliformis*, *Coscinodiscus bouvet*, *Chaetoceros criophilum* and *Ch. castracanei*, in that order of importance. The *Rhizosolenia styliformis* found here consisted of large robust individuals in long chains, and it is to the presence of this form, both here and at the following station, that the apparent disproportion between the estimated numbers of organisms and the bulk of the samples is to be ascribed.

At the most southerly of these stations (St. 368), worked in Douglas Strait in Southern Thule, *R. styliformis*, *Chaetoceros dichaeta* and *Coscinodiscus bouvet* were co-dominant, and other forms of some importance were *Chaetoceros criophilum* and *Fragilaria antarctica*. At all these stations the phytoplankton was moderate in quantity, the estimated numbers ranging from 24 to 32 hundred thousand individual organisms. Except for the rich belt to the south-east of South Georgia, however, the hauls might fairly be described as rich in comparison with the majority obtained round that island on the survey of the preceding month.

It will be obvious from the small number and isolated nature of these stations that little could be gained by discussing them further except in conjunction with other more extensive data from the same area, and accordingly it is proposed to defer consideration of their significance until the results obtained during the following season have been described.

THE SEASON 1930–1

The earliest hauls bearing upon conditions in the Weddell Sea during the second season, were taken in the vicinity of Bouvet Island and at a continuous series of observations lasting 24 hours (St. 461) about one-third of the distance between Bouvet Island and the South Sandwich Islands, in October. That the Weddell Sea influence extends as far eastwards as Bouvet Island is shown by the fact that the Antarctic convergence reaches its most northerly latitude in about that meridian. However, these stations are too remote from the more intensively studied area to do more than indicate the conditions obtaining along the ice-edge in early spring. The analyses of the hauls from these stations are contained in Table XXVI.

It will be seen that at St. 453, worked a short distance to the north-west of Bouvet Island, which was free from pack-ice at this time, the phytoplankton was very scanty, with *Corethron valdiviae* dominant, and *Fragilaria antarctica* the most numerous among the other forms present. A similar poor phytoplankton was encountered at St. 460 which was worked at a considerable distance west-south-west of Bouvet Island. In addition to the above-named species *Nitzschia seriata* was of some importance here. The scanty phytoplankton at these two stations in the old Antarctic surface water that had travelled a long way from the Weddell Sea, shows how the minimal winter conditions persist into early spring. This is probably rendered possible by the retardation of the north-easterly flow of the water during winter. In conjunction with the observations round South Georgia during the next few weeks of this season the conditions at these stations also serve to show how sudden the spring increase must be when it does begin.

In the series of observations made still farther to the west in a lane in the pack-ice (St. 461), seven hauls with the Gran net were taken. The analyses of the material from these hauls indicate that while the quality of the phytoplankton remained fairly constant, its quantity varied very considerably (see p. 16). The hauls provide a good illustration of the extent of this variability in nature, as the discrepancies observed were too large to be due merely to errors in estimation. These hauls may probably be taken as giving a good picture of the phytoplankton present along the ice-edge in the older eastern Weddell Sea immediately before the great spring increase. Though poor in comparison with catches obtained during the height of that phenomenon, it will be seen that they were very much richer in species and individuals than the two previous hauls to the north-east. The principal species met with were: *Chaetoceros neglectus*, *Nitzschia seriata*, *Fragilaria antarctica* f. *bouvet* and normal form, *Synedra spathulata*, *Corethron valdiviae* and *Thalassiosira antarctica*, in that order of importance. It is an interesting fact that this association resembles that found far to the south later in the season, in surface water of a different type, more closely than that found to be typical of the eastern Weddell Sea water at the height of the season. It was evident that the ice here had scarcely begun to melt, and the small proportion of *Th. antarctica* was alone sufficient to show that the spring increase proper had yet to begin. *Th. antarctica* was found to show a very strong spring maximum in all types of Antarctic surface water round South Georgia less than a month later. The time of the spring increase in the older eastern Weddell Sea water during the 1930–1 season may thus be laid down with some certainty as occurring about the first week in November.

The next piece of work in this area consisted of a line of stations worked from a point to the south-east of South Georgia, westwards past the South Orkney Islands to the vicinity of Elephant and Clarence Islands in December 1930. The positions of these stations will be found in Fig. 32. Phytoplankton collections were made at only seven of these stations, but general information obtained at the others has aided the interpretation of the results. The detailed analyses of the phytoplankton will be found in Table XXVII. From previous descriptions it will at once be realized that the phytoplankton at the three easternmost stations belonged mainly to the eastern Weddell Sea type, the unusually low salinity for this type of surface water being undoubtedly due to the extensive melting of pack-ice which was known to have covered a large part of the area concerned only a short time before these observations were made. In order to render the main features of the phytoplankton clearer than in the detailed analyses the relative proportions of the leading forms at each station are shown in Table 15, as it is important that intermediate conditions should be easily recognized in this region of complicated surface currents.

Table 15

Station number Total phytoplankton	529 **27,995,200**	528 **7,556,200**	531 **106,848,000**	532 **11,692,800**	533 **15,145,200**	534 **2,322,000**	536 **4,605,000**
Thalassiosira antarctica	268,800 **1·0**	124,800 **1·7**	3,936,000 **3·7**	720,000 **6·2**	1,285,200 **8·5**	72,000 **3·1**	150,000 **3·3**
Corethron valdiviae	2,822,400 **10·1**	67,200 **0·9**	1,536,000 **1·4**	403,200 **3·4**	3,049,200 **20·1**	189,000 **8·1**	3,412,500 **74·1**
Rhizosolenia styliformis	4,233,600 **15·1**	4,052,200 **53·6**	9,120,000 **8·5**	2,260,000 **19·3**	1,260,000 **8·3**	693,000 **29·8**	— —
Chaetoceros criophilum	11,961,600 **42·8**	— —	64,992,000 **60·8**	1,324,800 **11·3**	1,045,800 **6·9**	486,000 **20·3**	45,000 **1·0**
Ch. dichaeta	1,008,000 **3·6**	345,600 **4·6**	2,304,000 **2·2**	201,600 **1·7**	138,600 **0·9**	90,000 **0·4**	210,000 **4·6**
Ch. neglectus	3,427,200 **12·3**	— —	3,648,000 **3·4**	2,577,600 **22·0**	3,591,000 **23·7**	135,000 **5·8**	262,500 **5·7**
Fragilaria antarctica	806,400 **2·9**	172,800 **2·3**	13,728,000 **12·8**	1,267,200 **10·8**	756,000 **5·0**	306,000 **13·2**	105,000 **2·3**
Nitzschia seriata	1,276,800 **4·6**	2,572,800 **34·0**	2,112,000 **2·0**	1,656,000 **14·2**	2,318,400 **15·3**	216,000 **9·3**	— —
Other forms %	**7·6**	**2·9**	**5·2**	**11·1**	**11·3**	**10·0**	**9·0**

It will be seen that at St. 529, which was worked some distance to the south-east of South Georgia, the eastern Weddell Sea character of the surface water is strongly indicated by the dominance of *Chaetoceros criophilum*, and the position occupied among the other more numerous species by *Rhizosolenia styliformis* and *Corethron valdiviae*. Among the small forms so characteristic of surface water of the western Weddell Sea type, which was found within about 30 miles of this position during the South Georgia survey the month before, only *Chaetoceros neglectus* was of sufficient importance to give any indication of mixing of the two types of surface water. It will be seen that among the other smaller forms listed above *Nitzschia seriata* and *Chaetoceros dichaeta* were the most numerous at this station, where, however, they were of quite subordinate importance. These two species have been found to be the most frequent of the smaller species in surface water of the eastern Weddell Sea type, in which the three large species first mentioned normally predominate to a marked extent, although their numbers relative to one another vary enormously.

At the very next station to be considered, St. 528, worked still farther to the south-east, a good demonstration of this was given. The surface water here was certainly of eastern Weddell Sea origin, and *Rhizosolenia styliformis* was strongly dominant. Both

Corethron valdiviae and *Chaetoceros criophilum* were almost completely lacking however, and among the small forms *Nitzschia seriata* and *Chaetoceros dichaeta* were again the most important, the former especially so. From the tables it will be seen that the phytoplankton at this station was considerably poorer than at St. 529, which might fairly be described as rich in any season. All through this series of observations the hauls were large, with some falling off at the south-western end of the line. This general abundance of the phytoplankton was of course to be expected, as the main spring increase was evidently in full swing round South Georgia less than a month before.

An extremely rich phytoplankton was encountered at St. 531, which was situated about 150 miles due south of South Georgia. Here *Ch. criophilum* was strongly dominant, with *Fragilaria antarctica* and *Rhizosolenia styliformis* the only other forms of much importance. Among the rarer species at this station *Thalassiosira antarctica*, *Chaetoceros neglectus*, *Ch. dichaeta* and *Nitzschia seriata* were the most numerous, in that order. It is evident that this phytoplankton was mainly the product of water of the eastern Weddell Sea type, but the presence in some numbers of *Fragilaria antarctica* and more particularly of *Thalassiosira antarctica* so far to the north indicates the possibility of some slight admixture with water of western Weddell Sea origin.

At St. 532 a catch of a more normal size was obtained, about one-tenth as rich as that at the last station but still moderately heavy. Here *Chaetoceros neglectus* was the dominant form, and the other principal species were *Rhizosolenia styliformis*, *Nitzschia seriata*, *Chaetoceros criophilum*, and *Fragilaria antarctica* in that order of importance. With this considerable increase in the percentage of the smaller forms it is evident that mixing between the two types of Weddell Sea water had taken place to an appreciable extent, the results indeed suggesting that the western type was most strongly represented. This was still more evident at the next station to the south-west (St. 533). Here *Chaetoceros neglectus* was again dominant, and the order of importance of the other principal species was: *Corethron valdiviae*, *Nitzschia seriata*, *Thalassiosira antarctica*, *Rhizosolenia styliformis*, and *Chaetoceros criophilum*. The phytoplankton at this station was richer than that at St. 532.

Conditions at St. 534, to the north-west of the South Orkney Islands, present something of an anomaly. From its position one would expect the surface water to be either of definitely western Weddell Sea type, or the latter affected by some degree of admixture with old surface water from the Bellingshausen Sea passing through the southern half of Drake Passage. Yet analysis of the phytoplankton haul, which was considerably smaller than any of those dealt with above, reveals the fact that among the four species of most importance *Rhizosolenia styliformis* and *Chaetoceros criophilum* dominated to a marked extent over *Nitzschia seriata* and *Fragilaria antarctica* f. *bouvet*, conditions which one would normally associate with surface water of eastern Weddell Sea origin. It would appear that the most probable explanation of this would lie in the supposition that as the age of the western Weddell Sea water increases, the nature of the phytoplankton supported by it changes, the proportion of large to small forms becoming greater. Further observations may show this to be a more probable explanation of the nature of the phytoplankton at Sts. 532 and 533 described above, than mixing between the two types of Weddell Sea water. This series of observations is insufficient to settle the point definitely.

The last station worked on this line, St. 536 to the north-east of Clarence Island,

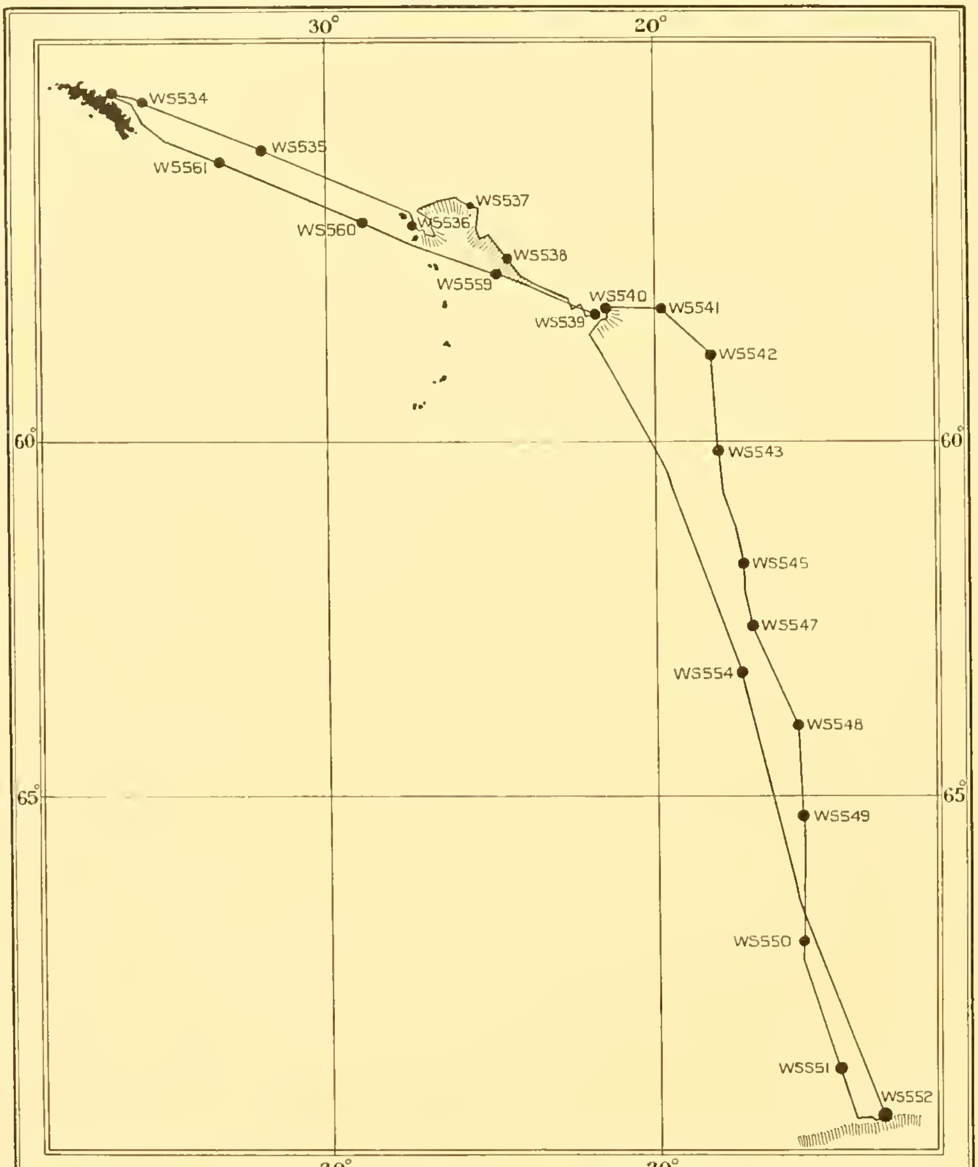

Fig. 46. Track chart showing the positions of the stations worked in the eastern Weddell Sea by the R.R.S. 'William Scoresby', January–February 1931.

presented a flora characteristic of the peculiar type of old surface water from the Bellingshausen Sea which flows through Bransfield Strait. Towards the western end and middle of the strait this flora seems fairly constant, being only slightly modified by littoral and seasonal influences, but at the eastern end there is some degree of mixing with Weddell Sea water in the eddy round Joinville Island. This, however, has but a slight effect on the water passing out through the northern half of the strait; during the seasons studied this water appeared to invest Elephant and Clarence Islands with a practically unchanged flora typical of Bransfield Strait. This was characterized by the very pronounced dominance of *Corethron valdiviae*, such as was encountered at the station here considered.

After the completion of the line from South Georgia to Elephant Island, the 'Discovery II' proceeded on a plankton survey of Bransfield Strait and the next piece of work in the Weddell Sea proper was a very valuable series of observations obtained by the 'William Scoresby' working south-east from South Georgia in January–February and returning upon very nearly the same course. The positions of the stations worked during this cruise are shown in Fig. 46. The full analyses of the phytoplankton hauls are given in Tables XXVIII–XXXI, in which the stations have been grouped together in four areas arbitrarily chosen for the sake of convenience. As the numbers of species and individuals recorded was large, the relative proportions of the leading forms at each station have been calculated and tabulated separately so as to render the description more easy to follow.

The first group of stations comprises those worked between 54 and 57° S, 25 and 36° W. From Fig. 46 it will be seen that they include the three worked between South Georgia and the northern end of the South Sandwich Islands on the outward voyage, and two stations worked to the west of this track on the return some eighteen days later, and also St. WS 537, to the east of Zavodovski Island. As indicated on the chart Visokoi Island was found to be surrounded by pack-ice on the outward voyage, and this last station was worked while skirting the pack to the east. On returning a fortnight later all this pack had disappeared. From the hydrological data given in Table XXVIII, it will be seen that while the conditions at these stations varied considerably, as would be expected from the wide range in space and time covered by them, the salinities were uniformly low for water of eastern Weddell Sea origin. The temperatures at the surface were also somewhat low for the latitude and time of year, and the probable reason for both these facts was the melting of the pack-ice mentioned above. The quantity of the phytoplankton at these stations varied enormously, and though at all but one of them *Chaetoceros criophilum* was the most numerous form, the quality also varied considerably, as Table 16, giving the numbers and percentages of the more important forms, clearly shows.

Taking these stations individually, it will be seen that at the first, worked off the north-east coast of South Georgia, the phytoplankton was exceedingly poor, the bulk of the sample being due to numbers of large Copepoda, as may be seen from Table XXVIII: the following station, St. WS 535, on the contrary, furnished one of the richest hauls in our experience. Here *Chaetoceros criophilum* was the dominant form, and *Nitzschia seriata*, *Rhizosolenia styliformis* and *Fragilaria antarctica* were also present in very large numbers. The immense haul was obtained almost exactly midway between South Georgia and the northernmost of the South Sandwich Islands. Evidently there was still a rich production in the moderately old water of eastern Weddell Sea type at this time. Apart from the species named above, the only particular feature of this haul apart from its bulk, was the occurrence of the spineless chain form of *Corethron valdiviae* in comparatively small numbers. It will be remembered that this was the form found so abundantly in this area at the same time during the previous abnormally warm season, and farther north close up to the Antarctic convergence and in sub-Antarctic water on other occasions. From this and other observations farther south, it would seem that there is a tendency towards the production of this vegetative form especially after mid-season, but this tendency does not reach large dimensions unless favoured by comparatively high temperatures.

Table 16

Station number Total phytoplankton	WS 534 **21,900**	WS 535 **224,532,000**	WS 561 **27,331,200**	WS 536 **4,341,000**	WS 537 **13,737,600**	WS 560 **50,937,600**
Thalassiosira antarctica	—	1,944,000	230,400	6,000	—	33,600
	—	**0·9**	**0·8**	**0·1**	—	**0·1**
Corethron valdiviae	5,100	2,916,000	1,123,200	2,913,000	1,490,400	8,232,000
	23·3	**1·0**	**4·1**	**67·1**	**10·8**	**16·2**
C. valdiviae (spineless chains)	—	3,078,000	—	—	—	—
	—	**1·3**	—	—	—	—
Rhizosolenia styliformis	—	23,814,000	4,896,000	117,000	5,788,000	9,945,600
	—	**10·6**	**17·9**	**2·7**	**42·1**	**19·5**
Chaetoceros criophilum	16,500	108,702,000	20,044,800	612,000	6,393,600	28,123,200
	75·3	**48·4**	**73·3**	**14·1**	**46·5**	**55·2**
Ch. neglectus	—	1,944,000	230,400	372,000	—	3,460,800
	—	**0·9**	**0·8**	**8·6**	—	**6·8**
Fragilaria antarctica	—	16,848,000	—	144,000	—	403,200
	—	**7·5**	—	**3·3**	—	**0·8**
Nitzschia seriata	—	44,388,000	—	51,000	—	—
	—	**19·8**	—	**1·2**	—	—
Other forms %	**1·4**	**9·6**	**3·1**	**2·9**	**0·6**	**1·4**

St. WS 561 was worked slightly to the west of the very rich station described above on the return trip eighteen days later. The very rich phytoplankton had evidently drifted farther to the north during this time and only a moderately rich haul was obtained. The nature of the phytoplankton was also rather different, but still very characteristic of old eastern type Weddell Sea surface water. *Chaetoceros criophilum* was strongly dominant, and *Rhizosolenia styliformis* the only other form of much importance.

As will be seen from the chart, the next station to be dealt with, St. WS 536, was worked on the fringe of the transient belt of pack-ice between Zavodovski and Visokoi Islands. The phytoplankton haul from this station was nothing like so rich in individuals as those obtained at the two stations previously described. Here the normal spiny form of *Corethron valdiviae* was dominant, which would appear to indicate an affinity with two stations worked farther to the south-east, Sts. WS 538 and WS 559, to be described shortly, and also with St. 626 worked in this neighbourhood by the 'Discovery II' some three weeks later. At St. WS 536, though the haul was fairly rich in species, the only forms besides *Corethron* that attained much importance were *Chaetoceros criophilum* and *Ch. neglectus.*

As we have seen, St. WS 537 was worked to the north-east when a way was being sought round the pack-ice. Here the nature of the moderately rich phytoplankton was very distinctive, as the catch consisted almost entirely of the three large forms whose extensive development has been found to be such a feature of the older surface water of eastern Weddell Sea origin, namely, *Ch. criophilum*, *Rhizosolenia styliformis* and *Corethron valdiviae*, in that order of importance.

The last station dealt with in this table was worked a long way to the westward on the return voyage a fortnight later, after the pack-ice had cleared away. The phytoplankton here was rich, with *Chaetoceros criophilum* dominant, and *Rhizosolenia styliformis* and *Corethron valdiviae* also present in large numbers. Very few species were present in this catch, which closely resembled those in surface water of the same type obtained nearer South Georgia during the plankton survey worked earlier in the year: of the smaller species present, only *Chaetoceros neglectus* occurred in large numbers.

Besides the selected leading forms dealt with in Table 16, certain other species occurred in large numbers in the vast haul at St. WS 535, as may be seen from the full analysis in Table XXVIII. The relative proportions of the more noteworthy of these were *Ch. dichaeta*, 3 per cent of the total; *Thalassiothrix antarctica*, 2·5 per cent; and *Rhizosolenia alata*, 1·3 per cent.

Continuing this general survey of the stations worked during this southern voyage of the 'William Scoresby', the next group to be considered includes all those stations between 57 and 60° S, 15 and 25° W. The full analyses of the phytoplankton hauls from these stations are given in Table XXIX. Of the six stations thus included, reference to Fig. 46 shows that the first three in point of time were worked while skirting the pack to the south-east, one (St. WS 559) in the same neighbourhood on the return voyage, and the last two after the pack had been successfully rounded to the eastwards and course altered to approximately due south. As will be seen from the analyses the phytoplankton hauls, while moderately rich in individuals, were poor in species, all being characterized by the pronounced dominance of a single large species as we have learnt to expect in surface water of the eastern Weddell Sea type. The relative proportions of the leading forms are shown in Table 17.

Table 17

Station number Total phytoplankton	WS 538 **4,104,000**	WS 559 **3,654,000**	WS 539 **15,696,000**	WS 540 **7,790,400**	WS 541 **7,414,400**	WS 542 **59,611,200**
Thalassiosira antarctica	—	—	12,000	7,200	—	5,649,600
	—	—	**0·1**	**0·1**	—	**9·5**
Corethron valdiviae	2,260,800	3,574,200	672,000	360,000	403,200	105,600
	55·1	**97·8**	**4·3**	**4·6**	**5·4**	**0·2**
Rhizosolenia styliformis	432,000	21,000	936,000	561,600	5,465,600	50,371,200
	10·5	**0·6**	**6·0**	**7·2**	**73·7**	**84·5**
Chaetoceros criophilum	676,800	37,800	14,004,000	6,796,800	940,800	—
	16·5	**1·0**	**89·2**	**87·2**	**12·7**	—
Ch. neglectus	525,600	—	—	—	246,400	—
	12·8	—	—	—	**3·3**	—
Fragilaria antarctica	—	—	48,000	57,600	89,600	211,200
	—	—	**0·3**	**0·7**	**1·2**	**0·4**
Nitzschia seriata	158,400	—	—	—	190,400	—
	3·8	—	—	—	**2·6**	—
Other forms %	**1·3**	**0·6**	**0·1**	**0·1**	**1·1**	**5·4**

It will be seen that these stations lend themselves to consideration in pairs, both from their positions and the nature of the phytoplankton observed. At St. WS 538, worked at the edge of the pack-ice some 60 miles east of Candlemas Island, *Corethron valdiviae* was the dominant species, with lesser numbers of *Chaetoceros criophilum*, *Ch. neglectus* and *Rhizosolenia styliformis*, the phytoplankton agreeing closely with that already described from St. WS 536, between Zavodovski and Visokoi Islands. At St. WS 559, worked some 15 miles to the south of this position twelve days later, *Corethron valdiviae* constituted almost the whole of the catch, and thus the phytoplankton was evidently of the same nature as that found by the 'Discovery II' slightly farther south a fortnight later. Evidently a zone of phytoplankton characterized by the dominance of this species invested the more northerly islands of the South Sandwich group during this second season.

The next two stations, Sts. WS 539 and WS 540, were worked some distance to the south-east from St. WS 538, and at the edge of the pack-ice, just before the 'William Scoresby' succeeded in working round it to the east. This proximity to the ice is reflected in the low salinities and surface temperatures recorded. The phytoplankton hauls were richer as regards numbers than the two described above, and again characterized by the pronounced dominance of a single large species, in this case *Chaetoceros criophilum*. From Table 17 it will be seen that at both these stations the phytoplankton was almost of identically the same constitution, as would be expected from their close proximity, but the haul obtained at the first was nearly twice as big as at the second station, yet another instance of the great variability of the plankton in nature, as the difference is too large to be due to experimental error alone. Besides the dominant form, *Rhizosolenia styliformis* and *Corethron valdiviae* were the only species occurring in large numbers at these two stations.

Having rounded the pack-ice to the east, at St. WS 541 a haul was obtained which showed yet another great change in the constitution of the phytoplankton, though the number of individual diatom frustules recorded was nearly the same as at the preceding station. Here *Rhizosolenia styliformis* was strongly dominant, although *Chaetoceros criophilum* and *Corethron valdiviae* persisted in moderate numbers, while at the last station of this set of tables, worked some 50 miles to the southward, the change was complete, *Rhizosolenia styliformis* forming the bulk of an extremely rich catch in which the only other form of note was *Thalassiosira antarctica* in the small gelatinous colonial form. The occurrence of two of the rarer forms at this station is also of interest, namely *Rhizosolenia bidens* and *Thalassiothrix antarctica*. The former because although large and easily recognized it has been found to be extremely sporadic in its occurrence, and the latter because it was not found farther to the southward during this piece of work. Each of these species formed roughly 2·1 per cent of the total phytoplankton at St. WS 542.

The remainder of the stations worked during this cruise followed at varying intervals between 59 and 69° S, the general direction of the course steered being slightly to the east of south. The time interval being naturally much smaller, the few stations worked on the return voyage within these limits can be considered along with those of the outward passage without further explanation. The southernmost station was worked at the edge of pack-ice, encountered when the 'William Scoresby' had penetrated to a point within about 100 miles of the probable position of Coats Land. Lack of fuel prevented further progress, but as by this time the ship had penetrated into the region of the distinctive type of plankton found in the water which flows round the inside of the bight of the Weddell Sea, the observations obtained are just as valuable, from the point of view of plankton investigations, as they would have been had an even higher latitude been attained.

Proceeding southwards from St. WS 542, the hauls from the next five stations show yet another great change in the nature of the phytoplankton. The full analyses of this material are contained in Table XXX, and in addition the relative proportions of the leading forms are shown in Table 18.

Table 18

Station number Total phytoplankton	WS 543 **128,342,400**	WS 545 **4,550,400**	WS 547 **4,238,000**	WS 554 **3,715,200**	WS 548 **14,179,200**
Thalassiosira antarctica	3,369,600 **2·6**	— —	24,000 **0·6**	18,900 **0·5**	— —
Corethron valdiviae	6,912,000 **5·4**	72,000 **1·5**	22,000 **0·5**	8,100 **0·2**	33,600 **0·2**
C. valdiviae (spineless chains)	— —	— —	— —	— —	8,400 **0·05**
Rhizosolenia styliformis	92,534,400 **71·7**	1,605,600 **35·3**	66,000 **1·6**	13,500 **0·4**	42,000 **0·3**
Chaetoceros criophilum	259,200 **0·2**	352,800 **7·8**	30,000 **0·7**	24,300 **0·7**	29,400 **0·2**
Ch. neglectus	2,332,800 **1·8**	108,000 **2·4**	8,000 **0·2**	195,750 **5·3**	667,800 **4·7**
Fragilaria antarctica	3,456,000 **2·7**	864,000 **19·0**	240,000 **5·6**	324,000 **8·7**	268,800 **1·9**
Nitzschia closterium	1,296,000 **1·0**	— —	— —	4,050 **0·1**	— —
N. seriata	14,342,400 **11·1**	1,008,000 **22·2**	3,702,000 **87·4**	3,029,400 **81·5**	12,839,400 **90·6**
Other forms %	**3·5**	**11·8**	**3·4**	**2·6**	**2·05**

These five stations were worked between 60 and 65° S, 15 and 20° W and are arranged in north to south order. It will be seen that the very rich phytoplankton with *Rhizosolenia styliformis* dominant, which was encountered at the southernmost of the last described series of stations, culminated in an enormous catch of this type at St. WS 543. The next great change in the character of the phytoplankton was, however, foreshadowed in the fairly large numbers of *Nitzschia seriata* recorded at this station. Another interesting species which occurred here was *N. closterium*. Except in the immediate vicinity of ice or close to the Antarctic Continent this form has rarely been encountered during the course of the investigations. Its occurrence here in open water in about 60° S, to the extent of 1 per cent of this very rich haul, was probably a legacy of pack-ice which had recently passed away to the north.

At the next station to the southward, St. WS 545, *Rhizosolenia styliformis* was still the most numerous of the phytoplankton organisms, but it is evident that the catch at this station represented the transition between two strongly contrasted types of plankton. To begin with, the total number of organisms estimated here was very much smaller than that at the preceding station, and besides *Rhizosolenia* the small species *Nitzschia seriata* and *Fragilaria antarctica* were of considerable importance. This station also marked the most southerly point at which *Chaetoceros criophilum* was taken in large numbers, and as will be seen from the comparatively large percentage of "other forms" in the table, certain species which were comparatively unimportant in considering this series of observations as a whole, occurred at this station in some abundance. The more noteworthy of these were *Synedra spathulata* (7 per cent of the total), *Rhizosolenia alata* (1·1 per cent) and *R. truncata* (1·1 per cent).

Proceeding southwards the transformation was complete, the minute species *Nitzschia seriata* being strongly dominant at each of the next three stations. At the first two of these the catches were relatively small, but at the southernmost, though the constitution of the phytoplankton remained much the same, it was appreciably richer. The only other species present in any abundance at these stations were *Fragilaria antarctica* and *Chaetoceros neglectus*.

The last series of observations to be considered here consisted of phytoplankton hauls from three more stations to the south of those described above, and four hauls from a twenty-four-hour station worked at the most southerly position of all on the edge of the pack-ice. The full analyses of this material will be found in Table XXXI; in addition, the relative proportions of the principal species are shown in Table 19.

Table 19

Station number Total phytoplankton	WS 549 **12,915,000**	WS 550 **8,020,800***	WS 551 **24,534,000***	WS 552 A **3,718,050***	WS 552 B **3,620,250***	WS 552 C **3,398,400***	WS 552 D **2,786,400***
Thalassiosira antarctica	75,000	172,800	216,000	24,150	33,750	24,000	21,600
	0·6	**2·2**	**0·9**	**0·6**	**0·9**	**0·7**	**0·8**
Corethron valdiviae	300,000	374,400	3,348,000	105,000	173,250	360,000	270,000
	2·3	**4·7**	**13·6**	**2·8**	**4·8**	**10·6**	**9·7**
C. valdiviae (spineless	60,000	86,400	—	—	—	—	—
chains)	**0·5**	**1·1**	—	—	—	—	—
Rhizosolenia styliformis	60,000	115,200	162,000	3,150	4,500	4,800	21,600
	0·5	**1·4**	**0·7**	**0·1**	**0·1**	**0·1**	**0·8**
Chaetoceros criophilum	120,000	475,200	216,000	19,950	24,750	19,200	27,000
	0·9	**5·9**	**0·9**	**0·5**	**0·7**	**0·6**	**1·0**
Ch. neglectus	1,050,000	∞	∞	+	+	+	+
	8·1	—	—	—	—	—	—
Ch. socialis	—	—	—	+	+	+	+
	—	—	—	—	—	—	—
Fragilaria antarctica	—	921,600	2,520,000	254,100	378,000	460,800	151,200
	—	**11·5**	**10·3**	**6·8**	**10·4**	**13·6**	**5·4**
Nitzschia closterium	—	1,080,000	3,312,000	1,568,700	900,000	753,600	999,000
	—	**13·5**	**13·5**	**42·2**	**24·9**	**22·2**	**35·9**
N. seriata	10,440,000	3,153,600	12,528,000	1,575,000	1,887,750	1,430,400	1,107,000
	80·8	**39·3**	**51·1**	**42·4**	**52·1**	**42·1**	**39·7**
Other forms %	**6·3**	**20·4**	**9·0**	**4·6**	**6·1**	**10·1**	**7·7**

* Excluding uncountable colonies.

It will be seen that the phytoplankton at the first of these stations leads on naturally from that encountered at St. WS 548, *Nitzschia seriata* still being markedly dominant, and the only noticeable differences being a slight increase in the proportion of *Chaeto-*

ceros neglectus and a further decrease in the proportion of the large forms found dominant farther north. This evidently represented the first stage in the transition to yet another distinctive phytoplankton, as at the next two stations *Ch. neglectus* became dominant, being present in such numbers as to defy adequate estimation. Of the forms of which good counts could be obtained *Nitzschia seriata*, *N. closterium* and *Fragilaria antarctica* were the most abundant in that order of importance, and *Corethron valdiviae* was the most numerous of the larger forms, though by no means so important relatively as in the richer hauls farther north. As will be gathered from the high percentage of other forms, certain species of less constant occurrence than those tabulated reached a comparatively high degree of importance at these two stations. Chief among these were *Dactyliosolen antarcticus* (7·4 per cent of the total), *Synedra spathulata* (4·7 per cent), *Rhizosolenia* spp. other than *styliformis* (3·9 per cent) and *Chaetoceros dichaeta* (3·4 per cent) at St. WS 550, and the same species to a lesser extent at St. WS 551. At the most southerly station of all (St. WS 552 A–D), worked at the edge of the pack within about 100 miles of the Antarctic mainland, the phytoplankton was very similar, with the exceptions that *Ch. socialis* made its only appearance amongst the material collected during this cruise, and that the minute species *Nitzschia closterium* was of greater relative importance. The hauls at this station were also consistently smaller than those obtained in the ice-free water slightly farther north. Clear counts of the two minute species of *Chaetoceros* could not be obtained, but they were certainly the dominant forms, followed by *Nitzschia seriata*, *N. closterium*, *Fragilaria antarctica*, and *Corethron valdiviae* in that order of importance. The occurrence of *Nitzschia closterium* in bulk at this station is of interest, as it bears out the view already expressed that in the south it is only found in numbers in the vicinity of the Antarctic mainland, or of pack-ice. Mr J. W. S. Marr has informed me that he has observed it close in to the land at several points round Antarctica while serving with Sir Douglas Mawson, particularly in the neighbourhood of Enderby Land.

This phytoplankton found far south near the eastern side of the Weddell Sea bears a close general resemblance to that found during the same season in corresponding latitudes in the Bellingshausen Sea, as will be seen from the description of the material from that locality described later (p. 153). One important difference should be noted, however. In the Bellingshausen Sea *Thalassiothrix antarctica* was found in large numbers far to the south-west, whereas it was absent from the more southerly catches on the Weddell Sea side. In the Weddell Sea the allied and closely similar form *Synedra spathulata* was found in moderate numbers in the more southerly hauls, but it was of rare occurrence and little importance in corresponding latitudes in the Bellingshausen Sea. This important difference will be referred to again later.

The main features of the phytoplankton observations during this cruise are illustrated in Figs. 47 and 48, which indicate the total estimated numbers of phytoplankton organisms, and the dominant species at each station respectively. From these it will be seen that seven well-defined types of phytoplankton were encountered.

Proceeding south-eastwards from South Georgia, an extremely rich phytoplankton was encountered on passage to the northernmost of the South Sandwich Islands, with *Chaetoceros criophilum* dominant and *Rhizosolenia styliformis* the most abundant of the other forms present. The surface water in this area should undoubtedly be regarded as of the comparatively old eastern Weddell Sea type. Around the western fringes of

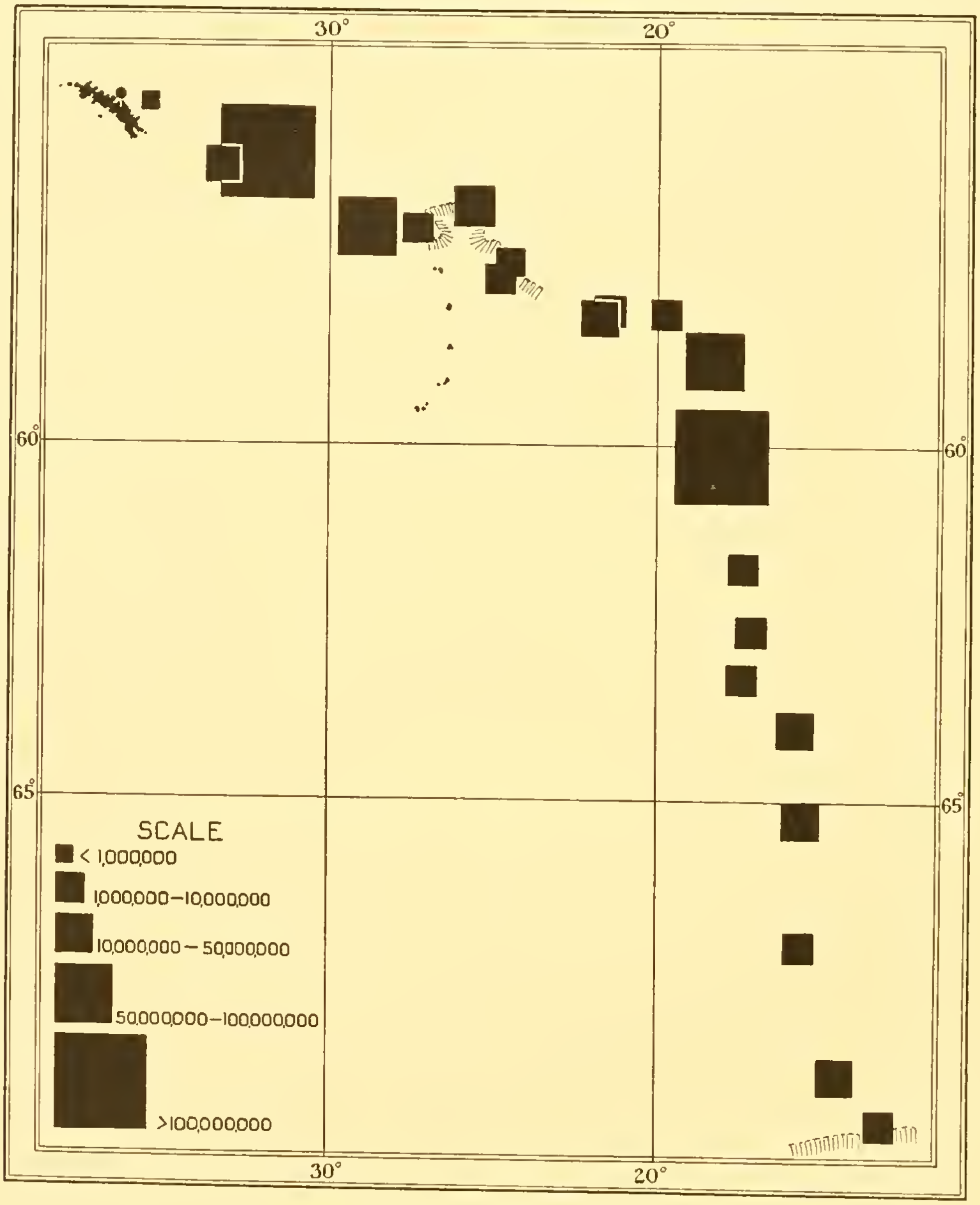

Fig. 47. Distribution of phytoplankton (totals per 100–0 m. haul) in the eastern Weddell Sea, January–February 1931.

the pack-ice encountered in the neighbourhood of the South Sandwich Islands the catches were much smaller, and here *Corethron valdiviae* was dominant. A further development of this phytoplankton, with the other forms becoming more and more subservient to *Corethron*, is known to have persisted in this area for a considerable time after this pack-ice had cleared away. In skirting the pack-ice to the east yet another type of phytoplankton was encountered, with *Chaetoceros criophilum* very strongly dominant in moderate hauls.

Having rounded the pack-ice to the east an entirely different association was encountered when proceeding on a more southerly course. *Rhizosolenia styliformis* became

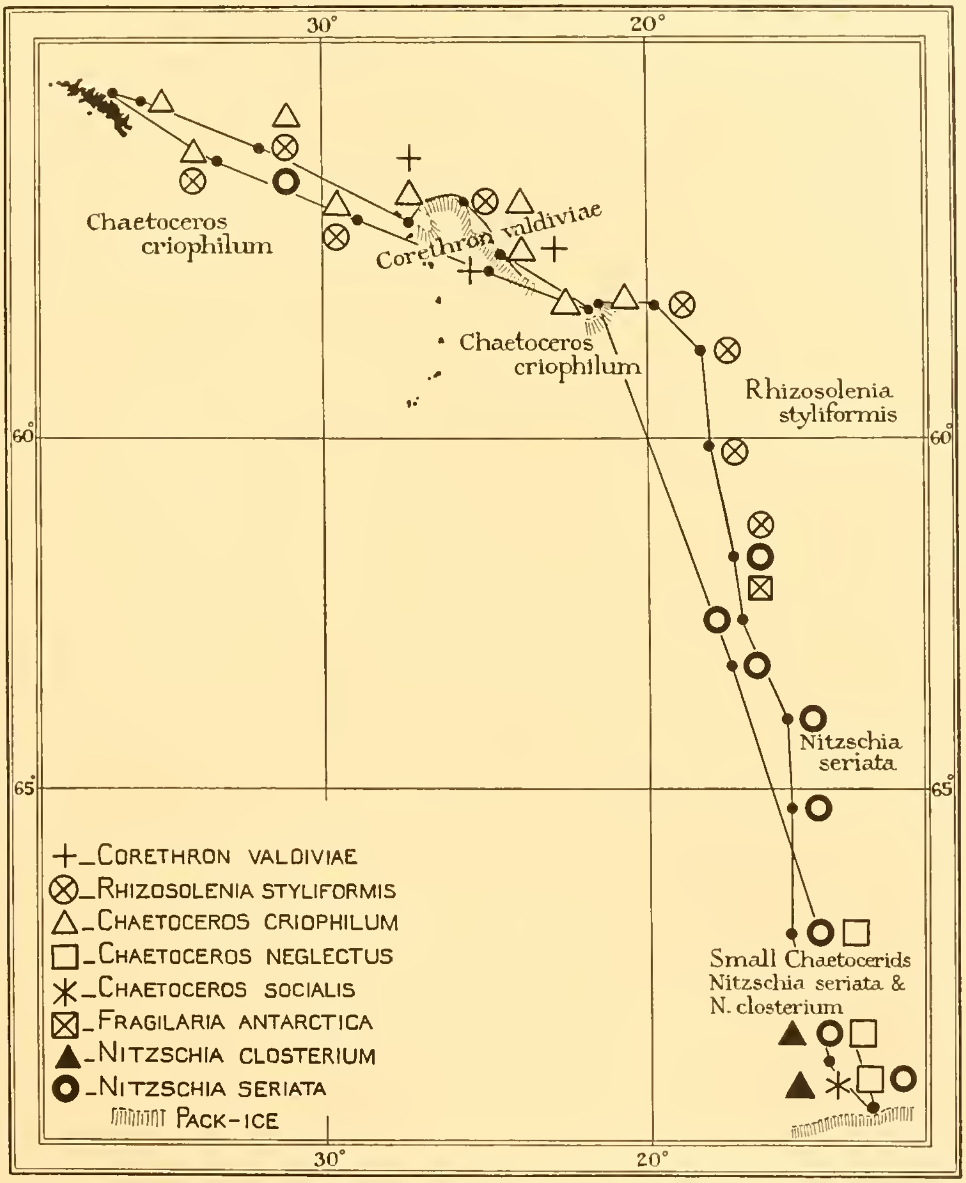

Fig. 48. Distribution of the principal phytoplankton species in the eastern Weddell Sea, January–February 1931.

by far the most abundant species in an exceedingly rich phytoplankton. This in its turn gave way to a series of moderate hauls with the minute form *Nitzschia seriata* predominating in about 63° S, and finally in the region of the Antarctic circle small Chaetocerids became dominant in hauls in which *Nitzschia seriata* was still prominent, accompanied by the Antarctic-littoral and ice-form *N. closterium*.

The last series of observations obtained from the Weddell Sea area during this season consisted of a series of thirteen stations (Sts. 613–26) worked from the neighbourhood of Elephant and Clarence Islands on an approximately east-north-easterly course past the South Orkneys to a point between Saunders Island and the Candlemas Islands in the South Sandwich group, in late February 1931. The full analyses of the phytoplankton material collected will be found in Table XXXII and the positions of the stations on reference to Fig. 32. The very variable salinities and temperatures recorded at the surface during this series of observations indicate that conditions were greatly influenced by melting of pack-ice at no great distance to the southward. The relative proportions of the more important phytoplankton organisms at these stations are shown in Table 20.

From the phytoplankton totals it will be seen that to the west the catches were very poor, but that they became slightly richer near the South Orkneys, and after a further falling off, increased steadily as the South Sandwich Islands were approached, in which region some of the catches might fairly be described as rich despite the lateness of the season.

The three westerly stations first dealt with, at which the phytoplankton was comparatively poor, showed a phytoplankton indicative of old Bellingshausen Sea water of the type commonly met with in Bransfield Strait, and, at certain times of the year, in the southern half of Drake Passage also. At these stations *Corethron valdiviae* was the dominant form, with *Fragilaria antarctica* the most numerous of the few other species present at St. 613, and *Thalassiothrix antarctica* at the two following stations. To the west of the South Orkneys, at Sts. 617 and 618, *Fragilaria antarctica* was of practically equal importance to *Corethron*, and a relatively large proportion of the poor catches obtained was made up of moderate numbers of a variety of small forms which were of little significance elsewhere during this series of observations. This may be seen from the large percentage of "other forms" at these stations in Table 20, and reference to the full analyses (Table XXXII) shows that while individually of small account, such species as *Thalassiosira antarctica*, *Biddulphia striata*, *Chaetoceros atlanticus* and *Ch. schimperianus* were of greater importance here than anywhere else on the line. These indications all point to the western Weddell Sea origin of the surface water at these stations, though the distinction was by no means so clear as in the catches to the south-west of South Georgia early in the season. This is probably to be ascribed to the operation of one or all of the following factors: a slackening in the flow of the current out of the Weddell Sea after mid-season, mixing with Bellingshausen Sea surface water from the west, and to a change in the nature of the phytoplankton of western Weddell Sea surface water as the season advanced, the large forms characteristic of eastern Weddell Sea conditions earlier in the year attaining greater prominence. This last factor may help to explain the character of the phytoplankton observed at Sts. 619 and 620, which was of the type we have come to associate with eastern Weddell Sea conditions, although from the positions one would have expected some sign of mixing with water of the western Weddell Sea type. The haul from St. 619 was rather poor, that at St. 620 slightly richer, and from St. 621 onwards a fairly rich phytoplankton of definitely

Table 20

Station number Total phytoplankton	613 **264,000**	614 **66,300**	615 **718,800**	617 **509,580**	618 **132,000**	619 **232,200**	620 **1,004,400**	621 **9,882,000**	622 **7,164,800**	623 **3,993,000**	624 **37,620,000**	625 **6,747,300**	626 **10,777,200**
Corethron valdiviae	174,000	43,500	524,400	183,540	29,700	72,600	628,800	3,618,000	367,200	415,800	3,100,800	2,041,200	10,029,600
	65·9	**65·6**	**73·0**	**36·0**	**22·5**	**31·3**	**62·6**	**36·6**	**5·1**	**10·4**	**8·2**	**30·3**	**93·1**
Rhizosolenia styliformis	—	300	8,400	—	6,600	9,000	10,800	1,134,000	720,000	864,600	3,556,800	1,115,100	109,200
	—	**0·4**	**1·2**	—	**5·0**	**3·9**	**1·1**	**11·5**	**10·0**	**21·6**	**9·5**	**16·5**	**1·0**
Chaetoceros criophilum	4,800	5,400	27,600	34,200	31,500	102,600	261,600	4,428,000	5,716,800	2,052,600	29,366,400	3,074,400	277,200
	1·8	**8·1**	**3·8**	**6·7**	**23·9**	**44·2**	**26·0**	**44·8**	**79·8**	**51·4**	**78·1**	**45·6**	**2·6**
Ch. neglectus	—	—	9,600	—	—	17,400	39,600	—	—	343,200	592,800	252,000	67,200
	—	—	**1·3**	—	—	**7·5**	**3·9**	—	—	**8·6**	**1·6**	**3·7**	**0·6**
Fragilaria antarctica	62,400	—	16,800	176,700	39.000	9,600	—	216,000	—	66,000	—	100,800	67,200
	23·6	—	**2·3**	**34·7**	**29·5**	**4·1**	—	**2·2**	—	**1·7**	—	**1·5**	**0·6**
Thalassiothrix antarctica	—	14,700	114,000	—	900	—	—	162,000	—	13,200	319,200	18,900	16,800
	—	**22·2**	**15·9**	—	**0·7**	—	—	**1·6**	—	**0·3**	**0·8**	**0·3**	**0·2**
Nitzschia seriata	—	—	—	—	4,500	3,000	—	—	259,200	—	364,800	18,900	75,600
	—	—	—	—	**3·4**	**1·3**	—	—	**3·6**	—	**0·9**	**0·3**	**0·7**
Other forms %	8·7	3·6	2·5	22·6	15·0	7·7	6·4	3·3	1·5	6·0	0·9	1·8	1·2

eastern Weddell Sea type was encountered. This is shown by the greatly increased proportions of *Ch. criophilum* and *Rhizosolenia styliformis* in the catches. The other important species at all these stations was *Corethron valdiviae*. This last was of less importance at Sts. 622 and 624 than at the others, *Chaetoceros criophilum* being very strongly dominant. The catch at St. 624 was a particularly large one for the time of year. At the two most easterly stations the proportion of *Corethron valdiviae* again increased, this species being completely dominant at St. 626, worked close to the positions at which a similar plankton had been observed during the 'William Scoresby's' cruise a fortnight earlier. From these stations it becomes very obvious that a fairly rich phytoplankton of the eastern Weddell Sea type persisted in the older surface water until well into the second half of the cold 1930–1 season.

CONCLUSIONS

In attempting to gain a picture of the phytoplankton production of the Weddell Sea as a whole, a few stations worked within the eddy of western Weddell Sea water at the northern end of Bransfield Strait in December 1930, should be considered along with those described in this section. A full description of the phytoplankton at these stations is given on p. 126, for the present purpose it is sufficient to state that they showed a phytoplankton of similar type to that found to the south-west of South Georgia earlier in the season, but by no means so rich. This would seem to indicate that the very rich phytoplankton with small forms dominant, notably *Chaetoceros socialis* and *Ch. neglectus*, is only found in this type of water during the late spring increase, when the northerly flow of Antarctic surface water is at its strongest. This is in good agreement with the more extensive observations to the north of the Weddell Sea, mostly obtained towards the middle and end of summer. As we have seen, these indicate that as the season advanced and the currents slackened, the distinction between the two types of surface water so sharply defined earlier in the season was very largely lost as far as the outflow from the north-western corner of the Weddell Sea was concerned. On the other hand the changes in the phytoplankton in the water flowing into the Sea, far to the south-east, were still well marked as one proceeded southwards in February.

One of the most obvious facts brought out in the preceding description was the comparative poverty of the phytoplankton in the South Georgia–South Sandwich Islands area during the mild open season 1929–30, and its great abundance during the cold 1930–1 season, the latter a heavy ice year. Despite the large numbers of the spineless chain form of *Corethron valdiviae* recorded at a few stations during the earlier of these two years, the total numbers of phytoplankton organisms estimated in the catches were of the order of one-tenth of those found in the same locality during the following season. This poverty of the 1929–30 season appeared to be a very general phenomenon, but the material obtained was too scanty to permit of any statement regarding the Weddell Sea as a whole. However, it remains fairly certain that the phytoplankton of the surface water flowing out of it to the north-east was unusually poor.

It seems, then, that while the phytoplankton of the two types of surface water known to occur in the Weddell Sea remains fairly distinctive in the far south, where the water flows in from the east, the degree to which this distinction is retained as the water flows out to the north-west is subject to both seasonal changes and to considerable fluctuations from season to season. This being so, a consideration of all the sixty-one hauls examined from the area should form a better basis of comparison with other areas studied during the same period than any of the individual series of observations previously described. The following list of all the categories of phytoplankton organisms recognized at these stations, arranged in order of their total abundance, and showing also the number of stations at which each occurred, should render such a comparison possible, always provided that certain minor anomalies due to the different seasons at which the collections were made are carefully borne in mind. The more important of these are indicated subsequently.

	Total	%
Chaetoceros criophilum (53)	313,881,540	32·8
Rhizosolenia styliformis (51)	227,578,770	23·8
Nitzschia seriata (38)	124,824,870	13·0
Corethron valdiviae (56)	69,100,870	7·2
Fragilaria antarctica (45)	48,588,320	5·1
*Corethron valdiviae** (9)	45,656,400	4·8
Chaetoceros neglectus (38)	26,970,330+	2·8
Thalassiosira antarctica (43)	18,759,000	2·0
Chaetoceros dichaeta (48)	18,729,330	2·0
Thalassiothrix antarctica (26)	14,980,100	1·6
Nitzschia closterium (11)	10,162,950	1·1
Rhizosolenia alata (47)	7,230,620	0·8
Dactyliosolen antarcticus (16)	4,841,700	0·5
Synedra spathulata (19)	4,300,500	0·4
Chaetoceros atlanticus (14)	3,045,600	0·3
Silicoflagellata (28)	2,368,600	0·2
Biddulphia striata (16)	2,204,580	
Eucampia antarctica (23)	1,788,840	
Coscinodiscus bouvet (16)	1,788,120	
Chaetoceros schimperianus (21)	1,674,710	
Rhizosolenia bidens (1)	1,267,200	
Coscinodiscus spp. (24)	830,680	
Chaetoceros ? didymum (1)	810,000	
Fragilaria antarctica f. *bouvet* (8)	705,360	
Rhizosolenia truncata (20)	702,600	
Dactyliosolen laevis (5)	553,200	
Peridinium antarcticum (10)	388,500	
Rhizosolenia chunnii (2)	351,000	
Navicula oceanica (1)	324,000	
Leptocylindrus sp. (15)	281,240	
Asteromphalus regularis (13)	262,890	
Melosira sol (1)	237,600	
Peridinium spp. (12)	206,900	

	Total
Navicula pellucida (8)	205,650
Chaetoceros curvatus (5)	192,120
Rhizosolenia rhombus (1)	172,800
Dinophyis spp. (10)	164,600
Chaetoceros castracanei (1)	126,000
Asteromphalus hookerii (6)	125,020
Navicula spp. (3)	121,080
Nitzschia sp. "A" (2)	115,200
Asteromphalus parvulus (4)	104,100
Rhizosolenia antarctica (1)	100,800
Nitzschia ? sigmoidea (1)	86,400
Rhizosolenia crassa (3)	82,200
Chaetoceros radiculum (6)	73,440
Gyrosigma (*Pleurosigma*) *directum* (1)	60,000
Chaetoceros cruciatum (1)	37,800
Ceratium pentagonum f. *grandis* (2)	36,100
Amphora sp. (1)	36,000
Rhizosolenia torpedo (3)	28,800
Chaetoceros tortissimus (1)	26,400
Dactyliosolen flexuosus (2)	19,350
Cymbella sp. (1)	18,000
Dinophysis ellipsoidea (1)	15,000
Coscinodiscus ? stellaris (1)	14,400
Actinocyclus sp. (1)	12,600
Rhizosolenia simplex (1)	12,600
Peridinium turbinatum (1)	7,200
P. elegans (4)	4,200
Actinocyclus corona (1)	6,300
Asteromphalus challengerensis (2)	5,250
Rhizosolenia spp. (2)	2,900
Actinocyclus bifrons (1)	2,100
Rhizosolenia polydactyla (1)	900
Dinophysis rotundata (1)	900

Total phytoplankton, 957,415,830

* Spineless chains.

In addition to the forms listed *Chaetoceros socialis* was taken in four hauls in uncountable colonies, and would certainly have occupied an important position in the list had it been possible to work more stations in the first half of the season. This also applies to a lesser extent to certain other forms with a well-marked spring maximum, e.g. *Biddulphia striata*. Apart from the forms listed above, the following additional species were encountered in the eddy of western Weddell Sea water at the north-eastern end of Bransfield Strait: *Chaetoceros flexuosus* at two stations, and the littoral forms *Biddulphia* (*Triceratium*) *arcticum* and *Lycmophora* sp. at one station at which the influence of in-shore water flowing northwards through Antarctic Sound was very apparent.

From the list it can be seen that despite their wide distribution, such species as *Rhizosolenia alata*, *R. truncata* and *Coscinodiscus* spp. were of quite minor importance, while some forms would certainly take a higher place if it had been possible to estimate their numbers satisfactorily and if ice conditions had allowed more hauls to be taken early in the season. From the account already given of the phytoplankton round South Georgia in November 1930, it will be remembered that among the small forms present in vast quantities in old surface water, mainly of western Weddell Sea origin, *Chaetoceros socialis*, *Thalassiosira antarctica* and *Chaetoceros neglectus* took pride of place. There is thus little doubt that in order to make the list fully representative of the phytoplankton of the Weddell Sea as a whole, throughout the year, these three species should be included in the first half-dozen or so, their precise position relative to the others being, of course, problematical. As it stands, however, the list gives a fairly true picture of the conditions from mid-season onwards, at which time of year most of the observations were taken. The large forms *Ch. criophilum*, *Rhizosolenia styliformis*, and *Corethron valdiviae* reached an enormous maximum in the older water of the eastern Weddell Sea type in the vicinity of the South Sandwich Islands, while the minute species such as *Nitzschia seriata* and *Fragilaria antarctica* owe their high place to their almost complete dominance in the water entering the sea far to the south-east. The comparatively high position of the spineless chain form of *Corethron valdiviae* is, of course, entirely due to its complete dominance in the old water between South Georgia and the South Sandwich Islands in the late summer of the abnormally warm year 1929–30.

From this summary, coupled with the facts previously mentioned of the great increase in quantity of the phytoplankton as one proceeded east-north-east across the mouth of the Weddell Sea in late summer (Table XXXII), one is forced to the following important conclusions. In the region of the South Sandwich Islands and to the east of South Georgia, a rich phytoplankton development takes place lasting on well into the second half of the season in a cold year, and that a rich phytoplankton tends to persist longer in old surface water of the eastern Weddell Sea type than in any of the other types of Antarctic surface water with which we are at present acquainted.

THE PHYTOPLANKTON OF BRANSFIELD STRAIT

During the period studied three surveys of this area were undertaken. The first two, each consisting of eighteen stations on three lines crossing the strait in a north and south direction, were made by the 'William Scoresby' in February and in November 1929, i.e. in autumn and spring. The third, consisting of seventeen stations on three lines disposed somewhat farther to the eastwards than on the preceding surveys, was made by 'Discovery II' in December 1930, and in addition six stations at the western end of the strait were worked later in that season. From the times of year at which these observations were carried out it will be seen that this material should give a useful idea of the seasonal changes taking place, the collections having been obtained in late spring, midsummer and in early autumn. Except for minor complications at the eastern end of the strait due to Weddell Sea influence, the phytoplankton was found to be of very much the same character throughout and much less varied than that of either of the two large oceanic areas studied during the same period.

THE SURVEY OF FEBRUARY 1929

The first line to be considered was that worked farthest to the east, from a point off Admiralty Bay, King George Island, southwards to a point off Graham Land. The full analyses of the phytoplankton material collected on this line are given in Table XXXIII and the positions of the stations, Sts. WS 382–WS 388, in Fig. 49.

Fig. 49. Reference chart showing the positions of the stations worked in Bransfield Strait, February 1929.

It will be seen that at St. WS 382 a very moderate haul was obtained, in which *Corethron valdiviae* was dominant, and *Thalassiosira antarctica* was present in fairly large numbers. The littoral character of the surface water here was well shown by the presence of a small species of Tintinnidae, which was found throughout the season in Cumberland Bay, South Georgia, and has been frequently encountered elsewhere in inshore waters. This may account for the comparatively large proportion of *Th. antarctica* found here so late in the season, as it would appear that this species persisted in the inshore waters on the northern side of the strait, though practically absent elsewhere during the present survey.

At each of the next four stations to the southward *Corethron valdiviae* was very strongly dominant, in moderately rich hauls that showed a decrease as one proceeded south. Other forms were present only in entirely subordinate numbers, and but few species were recorded. The fairly high temperature of the upper layers, and the low salinity at Sts. WS 385 and WS 386 indicate that the surface water here was of Bellingshausen Sea origin. At St. WS 387 a slight fall in temperature with a rise in salinity indicated a slight degree of admixture with surface water from the Weddell Sea, and this feature was more pronounced at the most southerly station, St. WS 388. The only reflection of this change in the nature of the surface water in the phytoplankton was a slight increase in the small numbers of *Chaetoceros criophilum* present, otherwise the hauls were very similar to those obtained farther north, being moderate in quantity and with *Corethron valdiviae* very strongly dominant.

On the two subsequent surveys worked earlier in the year the influence of the eddy of western Weddell Sea surface water round Joinville Island was most marked, a considerable increase in the number of species recorded, and in the proportion of small forms to *Corethron*, being found in the vicinity of these last two stations, especially on the December survey. The absence of any marked Weddell Sea influence on this autumn survey bears out the observation made in the preceding section, that after mid-season the flow of the western Weddell Sea current slackens and the nature of the phytoplankton in areas previously affected by it undergoes just such a change as is indicated here (see p. 104).

Among the rarer species present on this line *Rhizosolenia alata* f. *gracillima* was only recorded from the two northernmost stations. This form is hereinafter referred to as *Rh. gracillima* for the sake of brevity. It has been observed abundantly to the north-west of the Bellingshausen Sea slightly earlier in the year, in surface water which apparently invades the Bransfield Strait from the west somewhat over a month later. Its occurrence at these two stations only on the eastern line, and in small numbers, indicates that this invasion was not complete at the time of the survey during the season in question.

The next line of stations was worked from a point south of Macfarlane Strait to a point north-west of Astrolabe Island, forming a section across the middle of the deepest basin of Bransfield Strait. At the most northerly station, St. WS 393, *Corethron valdiviae* was again very strongly dominant in a moderate haul, but five other species of diatoms were recorded, as against two on the more southerly stations, albeit in very small numbers, a fact which lends support to the view that the remnants of a formerly more varied phytoplankton persisted longest on the northern side of the strait. The three stations in the middle of this line furnished by far the richest catches of the whole survey, with *C. valdiviae* again predominating, the numbers at the richest of them (St. WS 391) being estimated at over 37 millions. The surface salinity and temperatures at the four northerly stations on this line are rather higher than those commonly met with to the north-west of the Bellingshausen Sea; yet there is little doubt that this surface water originated there, the apparent anomaly being explicable on the grounds of vertical mixing as the water enters the Bransfield Strait over the comparatively shoal stretches between the islands across its western end. At the most southerly station on this line the marked fall in temperature and higher salinity again indicated the influence of the Weddell Sea eddy; but, as on the eastern line, this was apparently without effect upon the nature of the phytoplankton, *C. valdiviae* still being entirely dominant in a more moderate haul. Indeed, it would almost appear that the peculiar type of old Bellingshausen Sea surface water filling the greater part of the strait was here diluted, as it were, by admixture with old Weddell Sea water, itself almost devoid of plankton.

The full analyses of the phytoplankton material collected on this line will be found in Table XXXIV, from which it will be seen that of the rarer forms *Rhizosolenia gracillima* was again most frequent on the northern side of the strait.

This survey was concluded with a series of six stations between the islands at the western end of the strait. Actually the majority were worked in south to north order, but the order adopted in Table XXXV appears to facilitate the consideration of the survey as a whole. The positions are shown in Fig. 49, from which it will be seen that the first of these stations, St. WS 394, was worked just to the north of Deception Island, between it and Livingston Island. Here *Corethron valdiviae* and *Thalassiosira antarctica* predominated in a very poor catch.

At St. WS 399, worked in the comparatively deep channel between Smith and Snow Islands in the extreme north-west of the Bransfield Strait, a moderate haul was obtained; in it *Corethron valdiviae* was again the most numerous form, but there was also a larger variety of species than at any other station worked during this survey. Chief among these were *Nitzschia seriata* and *Rhizosolenia gracillima*, with *Chaetoceros atlanticus*, *Ch. dichaeta*, *Ch. neglectus* and *Ch. schimperianus*, forms which were rarely or never encountered elsewhere in the area at this time. Farther south, between Smith and Low Islands at St. WS 398, the poorest catch of the whole survey in point of total number was obtained. Here there was still a fair variety of species, but *Corethron* was again strongly dominant, the other forms occurring only in very small numbers.

At each of the three more southerly stations, bridging the gap across the western end of the strait from Low Island to the northern end of Brabant Island, a closely similar phytoplankton was encountered, with *C. valdiviae* very strongly dominant. The size of these hauls decreased steadily towards the southward, indicating that the main influx of Bellingshausen Sea water into the Bransfield Strait takes place at the north-western corner. The fine bathymetric chart based on some thousands of echo-soundings (Herdman, 1932, p. 231, pl. xlvii), favours this view as it shows clearly that the deeper inlets are all in the direction one would expect from the plankton hauls.

The obvious features of this survey were the very pronounced dominance of *C. valdiviae* to the exclusion of almost all other phytoplankton forms, the small number of species recorded, and the absence of any marked effect from the eddy of Weddell Sea water round Joinville Island on the phytoplankton. The hydrological results, however, showed that this eddy was still present, if not so clearly distinguishable as on subsequent surveys worked earlier in the season. The first two of these three main features are well shown by the following list of all the species recorded during the survey, arranged in order of their estimated total abundance, and showing the number of stations at which each occurred:

Corethron valdiviae (18)	83,493,600	*Rhizosolenia styliformis* (4)	16,350
Thalassiosira antarctica (10)	387,450	Silicoflagellata (1)	12,600
Chaetoceros criophilum (11)	365,000	*Dactyliosolen laevis* (1)	8,400
Rhizosolenia alata f. *gracillima* (11)	202,800	*Synedra* sp. (1)	8,400
Nitzschia seriata (8)	183,000	*Thalassiothrix antarctica* (2)	7,800
Fragilaria antarctica (4)	141,400	*Biddulphia striata* (2)	6,000
Chaetoceros atlanticus (2)	71,700	*Eucampia antarctica* (2)	4,200
Ch. neglectus (1)	58,800	*Coscinodiscus* spp. (1)	3,000
Ch. schimperianus (1)	29,400	*Peridinium antarcticum* (1)	3,000
Ch. dichaeta (1)	25,200	*Dactyliosolen antarcticus* (1)	600
Leptocylindrus sp. (1)	16,800	*Corethron valdiviae* (spineless chains) (1)	300
Synedra spathulata (4)	16,500	*Lycmophora* sp. (1)	300

Estimated total phytoplankton 85,081,600.

From this it will be seen that *Corethron valdiviae* dominated over all the other species to such an extent that it formed over 98 per cent of the phytoplankton.

The distribution of *Corethron valdiviae* itself is indicated in Fig. 51. By comparison with Fig. 50, which gives the phytoplankton totals, it will be seen that it was completely dominant at all stations except the three in the extreme north-west. The richest hauls of this survey, in the middle of the strait and at St. WS 383 to the north-east, consisted almost entirely of this species. On subsequent surveys the richest hauls were obtained farther to the east, so that it was fairly evident that on this occasion the phytoplankton was being renewed by the influx of Bellingshausen Sea water into the western end of the strait. The work carried out in the north-east of the Bellingshausen Sea itself during subsequent seasons showed that a considerable increase of *Corethron* took place fairly close in to Adelaide Island in early autumn, while farther to the north-east the remnant of the more varied phytoplankton of the earlier months no doubt persisted. This may furnish an explanation of the conditions found in Bransfield Strait on this occasion, as it is clear from the distribution charts that little but *Corethron* was entering through the broad, comparatively shallow gap between Low and Hoseason Islands, while a more varied phytoplankton was encountered in the narrower, deeper channels to the north-west. It would seem reasonable to regard this as the resultant of the north-easterly drift from what might be termed the extreme north of the Bellingshausen Sea in January,

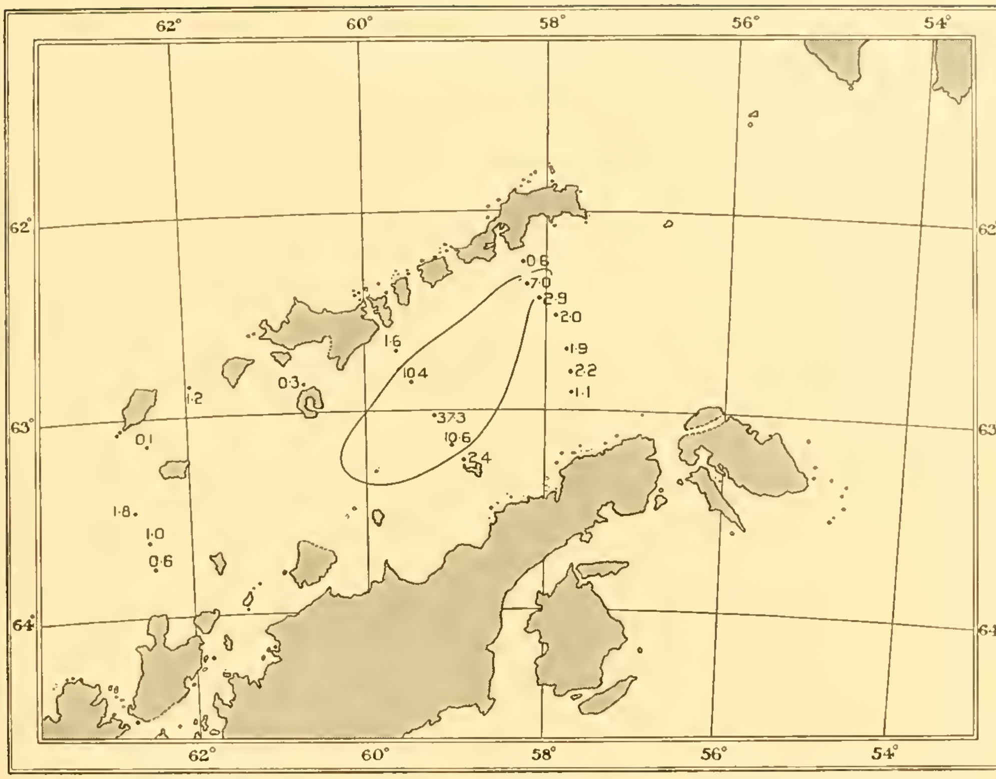

Fig. 50. Phytoplankton distribution (totals per 100–0 m. haul) in Bransfield Strait, February 1929. 1 = one million.

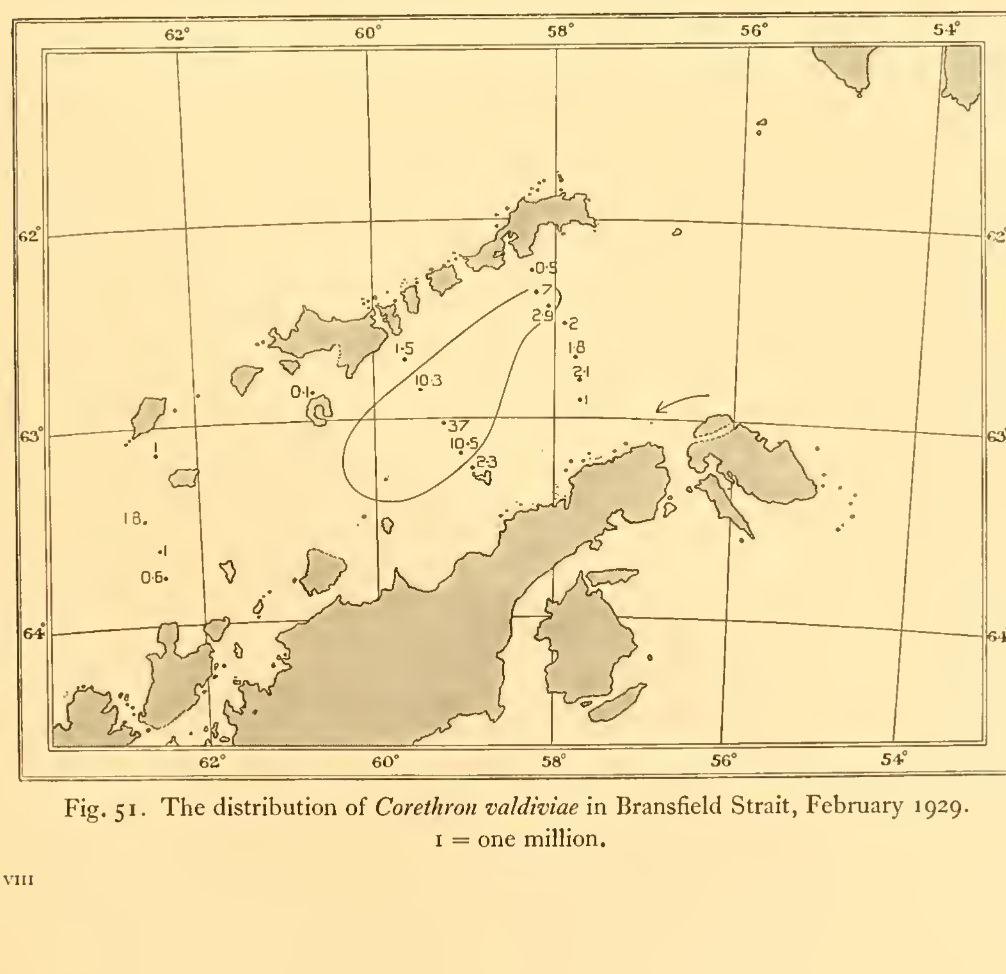

Fig. 51. The distribution of *Corethron valdiviae* in Bransfield Strait, February 1929. 1 = one million.

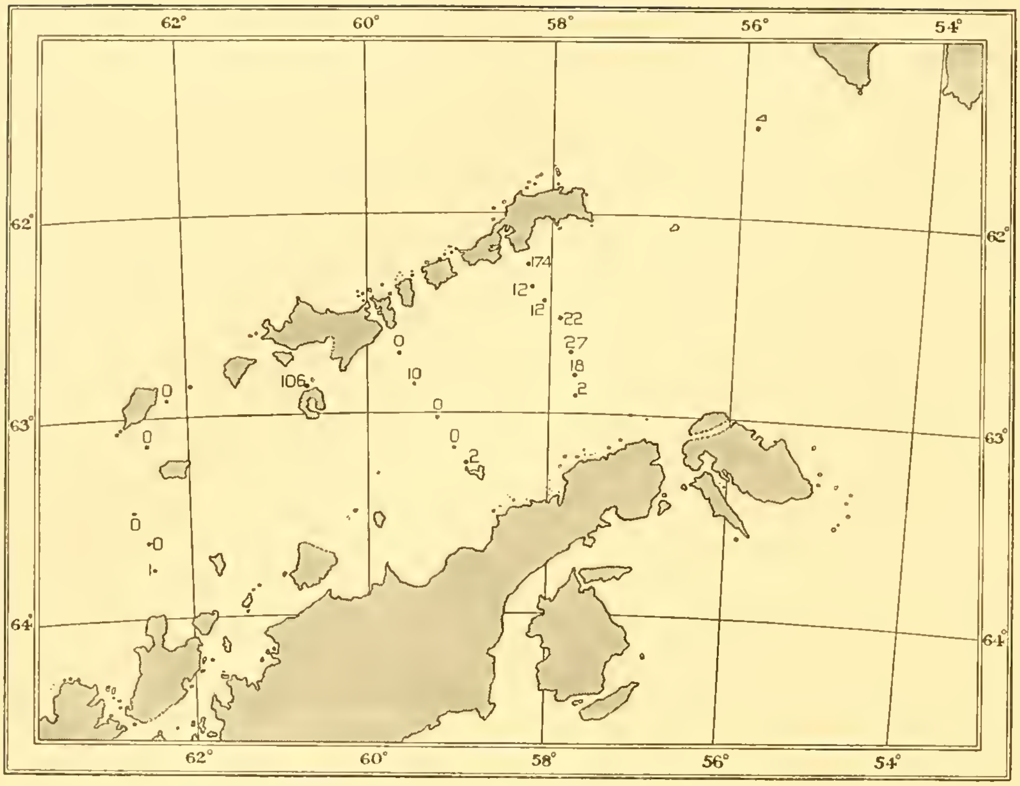

Fig. 52. The distribution of *Thalassiosira antarctica* in Bransfield Strait, February 1929. 1 = one thousand.

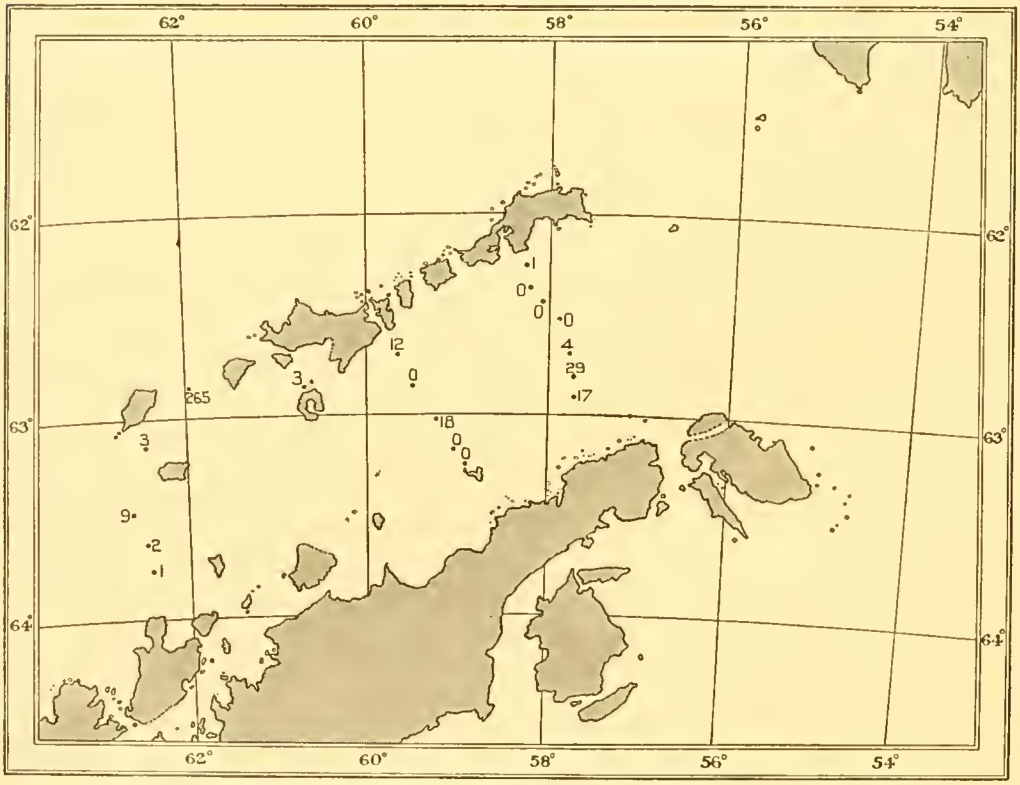

Fig. 53. The distribution of *Chaetoceros criophilum* in Bransfield Strait, February 1929. 1 = one thousand.

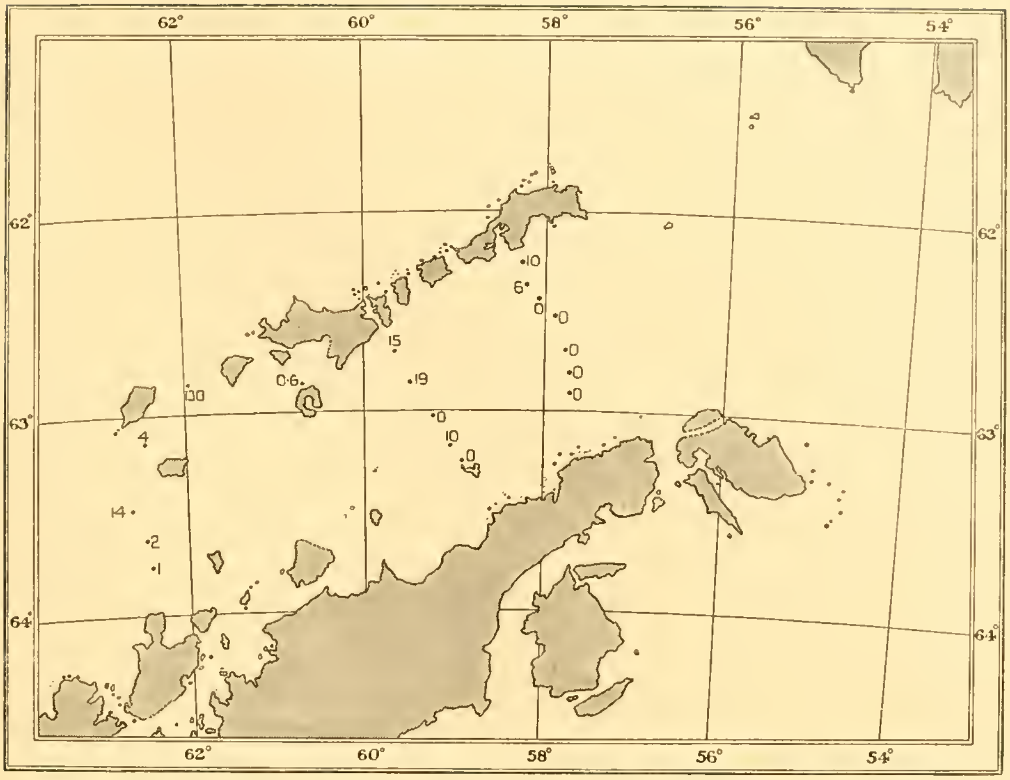

Fig. 54. The distribution of *Rhizosolenia alata* f. *gracillima* in Bransfield Strait, February 1929. 1 = one thousand.

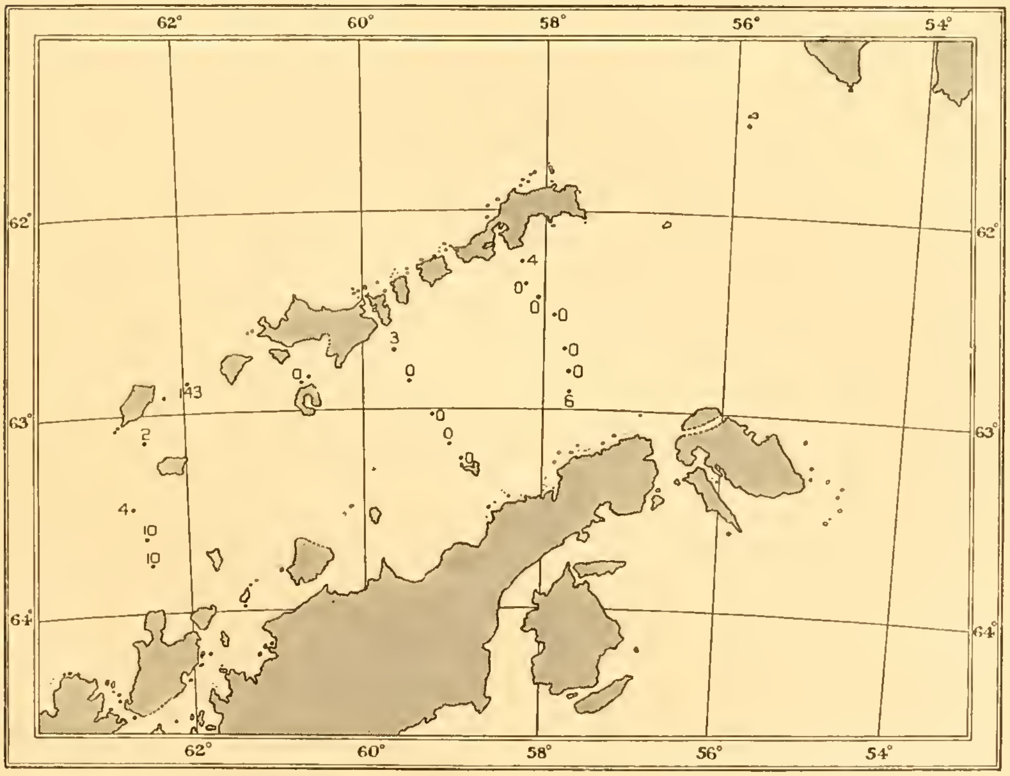

Fig. 55. The distribution of *Nitzschia seriata* in Bransfield Strait, February 1929. 1 = one thousand.

while the *Corethron* entering farther to the south was probably the vanguard of an invasion due to the increase off Adelaide Island which has been observed in February. It is fairly certain, and is consistent with this view, that the north-easterly set from the vicinity of Adelaide Island immediately outside the Biscoe and Palmer Archipelagos, is stronger than that over the whole of the Bellingshausen Sea.

Compared with *Corethron* the species totalling over one hundred thousand are insignificant; but those most widely distributed may be considered further, as they serve to show the probable sources of the surface water. These were *Thalassiosira antarctica*, *Chaetoceros criophilum*, *Rhizosolenia gracillima* and *Nitzschia seriata*.

The distribution of *Thalassiosira antarctica* is shown in Fig. 52. It will be seen that it occurred in small numbers at all the stations on the eastern line, and in moderate plenty at two stations well to the north just inside the South Shetland Islands. This is in fair agreement with the view that the almost pure *Corethron* plankton found over most of the Bransfield Strait at this time, was the result of recent incursion from the Bellingshausen Sea, the hauls at which *Thalassiosira* was found in some quantity including the last traces of the slightly more varied phytoplankton which had been found earlier in the year.

Fig. 53 shows the distribution of *Chaetoceros criophilum*. The species was fairly generally distributed in small numbers, with a slight indication of greater abundance to the south of the eastern line, correlated with the Weddell Sea influence. Its maximum, however, was reached at St. WS 399 to the north-west. This species is widely distributed in the Bellingshausen Sea, but does not appear to be of much importance there. It would therefore seem that conditions at St. WS 399 point to an influx of comparatively old surface water from the north of the Bellingshausen Sea area.

The only other species of much significance on this particular survey were *Rhizosolenia gracillima* and *Nitzschia seriata*. Their closely parallel distribution is shown in Figs. 54 and 55. It will be seen that both showed a maximum at St. 399, where it is thought that the bulk of the more northerly Bellingshausen Sea water was entering. Otherwise they were present in small numbers at all the stations at the western end of the strait, but were confined to the northern ends of the more easterly lines.

THE SURVEY OF NOVEMBER 1929

The positions of the stations worked on this survey were almost exactly the same as on that described above, so that in order to avoid confusion of the numbers they have been plotted on a separate reference chart, Fig. 56. The first and most easterly line was worked from a point off Admiralty Bay southwards, as before. The full analyses of the phytoplankton hauls obtained on this line (Sts. WS 476–81) are given in Table XXXVI together with that from one isolated station, St. WS 475, still farther to the north-east (at a point north-east of Bridgman Island). It will be seen that at this station a rich haul was obtained, again with *Corethron valdiviae* strongly dominant, but with *Fragilaria antarctica*, *Thalassiosira antarctica* and *Rhizosolenia gracillima* also present in considerable numbers. Turning to the northernmost station on the line, St. WS 476, the inshore character of the surface water was indicated by the presence of the small species of Tintinnid previously referred to (p. 110). The catch here was not so large, less than five million phytoplankton organisms being estimated to be present; *Corethron valdiviae* was again dominant, but *Thalassiosira antarctica* accounted for nearly 25 per cent of the catch. At the next station to the southward, *Corethron* again predominated in a much richer haul, in which *Fragilaria antarctica*, *Thalassiosira antarctica*, *Rhizosolenia gracillima*, *Biddulphia striata* and *Coscinodiscus bouvet* were all more abundant than has been found usual in this area.

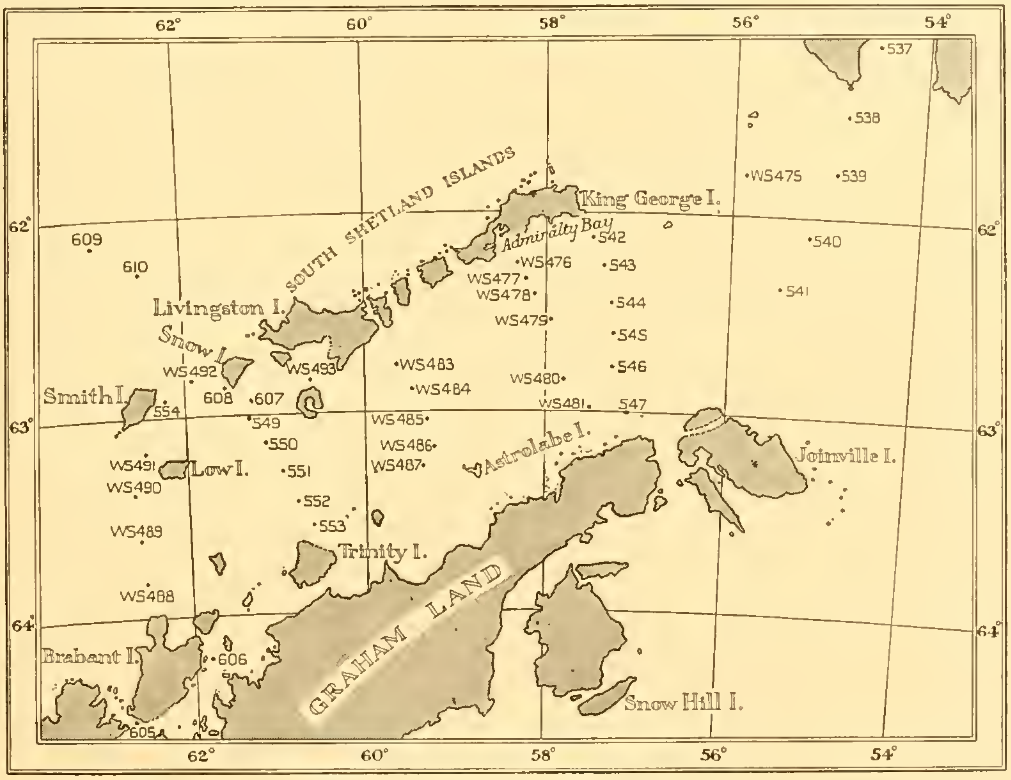

Fig. 56. Reference chart showing the positions of the stations worked in Bransfield Strait in November 1929, and in December 1930.

Still farther to the southward, at St. WS 478, a much smaller catch was obtained, more comparable to that from the inshore station, except that *Corethron* was more markedly dominant. Local current systems have been encountered in this vicinity on other occasions, and it is possible that this break in the continuity of rich hauls is to be ascribed to some such cause, as the phytoplankton at the succeeding station, St. WS 479, closely resembled that at St. WS 477 both in character and bulk, the only notable difference being that *Thalassiosira antarctica* and *Fragilaria antarctica* were not so numerous. As before, *Corethron* was strongly dominant, a statement which also applies to the catch at the next station, St. WS 480, where the proportion of the smaller forms decreased still further, despite the fact that the rise in salinity indicates that the region of the Weddell Sea influence was being approached.

At the most southerly station on the line the high surface salinity and low temperature show clearly that the surface water was in the main of Weddell Sea origin, and the analyses of the phytoplankton haul revealed notable differences from those obtained farther to the north. *C. valdiviae* was still dominant in a rather poor catch (the time was early for the spring increase to have got far advanced in Weddell Sea water thus far south), but to nothing like the same extent as over the rest of the Bransfield Strait at this time. Sixteen species of diatoms were recorded as against a maximum of ten (St. WS 476) at any one station in the rest of the strait on this survey. Here also *Eucampia antarctica* showed a strong maximum and other species forming a considerable proportion of the catch were *Thalassiosira antarctica* and *Fragilaria antarctica*. *Chaetoceros atlanticus*, *Ch. dichaeta* and the normal form of *Rhizosolenia alata* made their only appearance of the survey at this station, which also furnished our only records in the Bransfield Strait of the littoral species *Melosira sol* and *Biddulphia* (*Triceratium*) *arcticum*. The presence of these last-named species indicates the possibility of a strong current flowing northwards through Antarctic Sound.

The next line of stations on this survey (Sts. WS 483–7) was worked from a point south of Macfarlane Strait to the vicinity of Astrolabe Island. The analyses of the phytoplankton material then collected are given in Table XXXVII. It will be seen at once that little in the way of detailed description is necessary, as *Corethron valdiviae* was strongly dominant throughout, very few other species being recorded and these in entirely subordinate numbers. The hauls from the two northernmost stations on the line were moderate in quantity, as also was that from the southernmost station, while those from the two stations in the middle of the strait were considerably richer. The increase in salinity at the two southernmost stations on this line probably indicated some slight degree of mixing with Weddell Sea surface water, but this was apparently without influence on the nature of the phytoplankton on this occasion.

The analyses of the catches at the various stations worked at the western end of the strait on this survey (Sts. 488–93) are shown in Table XXXVIII. It will be seen that though *Corethron* was strongly dominant throughout, a much larger number of species was recorded than on the line in the middle of the strait. The occurrence of species other than *Corethron* was, however, both scattered and scanty, as might be expected from the fact that the surface water in which they were taken was certainly of Bellingshausen Sea origin, in the course of percolating through the various western openings of the Bransfield Strait proper. The pronounced dominance of *Corethron* in water of this type occupying the greater part of the strait indicates that some factor in the local conditions must be strongly unfavourable to the development of other forms.

The most notable of the rarer species at these stations were *Rhizosolenia gracillima* and *Thalassiosira antarctica*. *Nitzschia seriata* was present in considerable numbers at St. WS 489. All these forms have been encountered in much greater abundance in the Bellingshausen Sea somewhat later in the year.

The phytoplankton hauls obtained at the western end of the strait on this survey were very considerably poorer in quantity than those taken farther to the east, as may be seen from Fig. 57 in which the estimated phytoplankton totals have been plotted. Comparison of this chart with Fig. 50 brings out one of the most interesting features of this survey, namely that the centre of the richest phytoplankton production appears to lie farther to the east than on the previous autumn survey. This is also well shown by the distribution of the dominant species, *Corethron valdiviae* (Fig. 58).

Summing up the other more noteworthy features it will be seen that while *C. valdiviae* was still strongly dominant, the proportion of other species was considerably greater than on the autumn survey, especially at the eastern end of the strait. The hauls were on the average much richer, as would be expected in the spring, and the influence of the eddy of Weddell Sea water round Joinville Island was more clearly marked. The following is a list of the species recorded with the number of occurrences and estimated total abundance. It will be seen that the number of species was still small, despite the more favourable time of year, a fact which serves to illustrate the local character of the phytoplankton of Bransfield Strait.

Corethron valdiviae (18)	124,987,200	*Thalassiothrix antarctica* (6)	47,400
Fragilaria antarctica (6)	5,692,200	*Melosira sol* (1)	42,000
Thalassiosira antarctica (12)	5,032,200	*Peridinium* spp. (2)	33,600
Rhizosolenia alata f. *gracillima* (13)	1,248,000	*Rhizosolenia alata* (1)	21,000
Eucampia antarctica (7)	852,600	*Peridinium antarcticum* (1)	18,000
Biddulphia striata (13)	619,800	*Chaetoceros atlanticus* (1)	16,800
Nitzschia seriata (7)	581,400	*Ch. dichaeta* (1)	12,600
Chaetoceros criophilum (8)	272,400	*Ch. ? didymum* (1)	7,200
Coscinodiscus bouvet (4)	184,200	*Lycmophora lyngbyei* (1)	4,800
Ch. neglectus (3)	129,600	*Cocconeis ? costata* (1)	4,800
Rhizosolenia truncata (2)	85,800	*Chaetoceros schimperianus* (1)	3,600
Fragilaria antarctica f. *bouvet* (1)	81,600	*Biddulphia* (*Triceratium*) *arcticum* (1)	1,200
Coscinodiscus spp. (4)	65,400	*Rhizosolenia styliformis* (1)	600

Estimated total phytoplankton 140,045,800.

Comparing this with the previous survey it will be seen that here *Corethron* formed 89 per cent of the total phytoplankton, as against 98 per cent; but when the distribution of the other more important species is considered, it is seen that the increase in their number was chiefly confined to the eastern end of the strait.

The most widely distributed, though not the most numerous, species after *Corethron* was *Rhizosolenia gracillima*. From Fig. 59 it will be seen that it reached its maximum at the north-eastern end of the strait, that it was absent from the more northerly stations on the middle line, but was encountered fairly constantly in more moderate numbers to the west. In considering the distribution of this species during the survey here described it is necessary to enquire how far the associations met with in different areas may be attributed to transportation by currents. The great planktologist Cleve carried this concept to such lengths that there has been a tendency to ignore it in recent work; but the surface currents over the greater part of the area here treated are so strong and persistent (except perhaps in winter) that they must certainly play a great part in determining the character of the phytoplankton. As will be seen, this view has permeated the accounts of the different associations described in this report. The observed distribution of *R. gracillima* in Bransfield Strait during this spring survey, however, brings

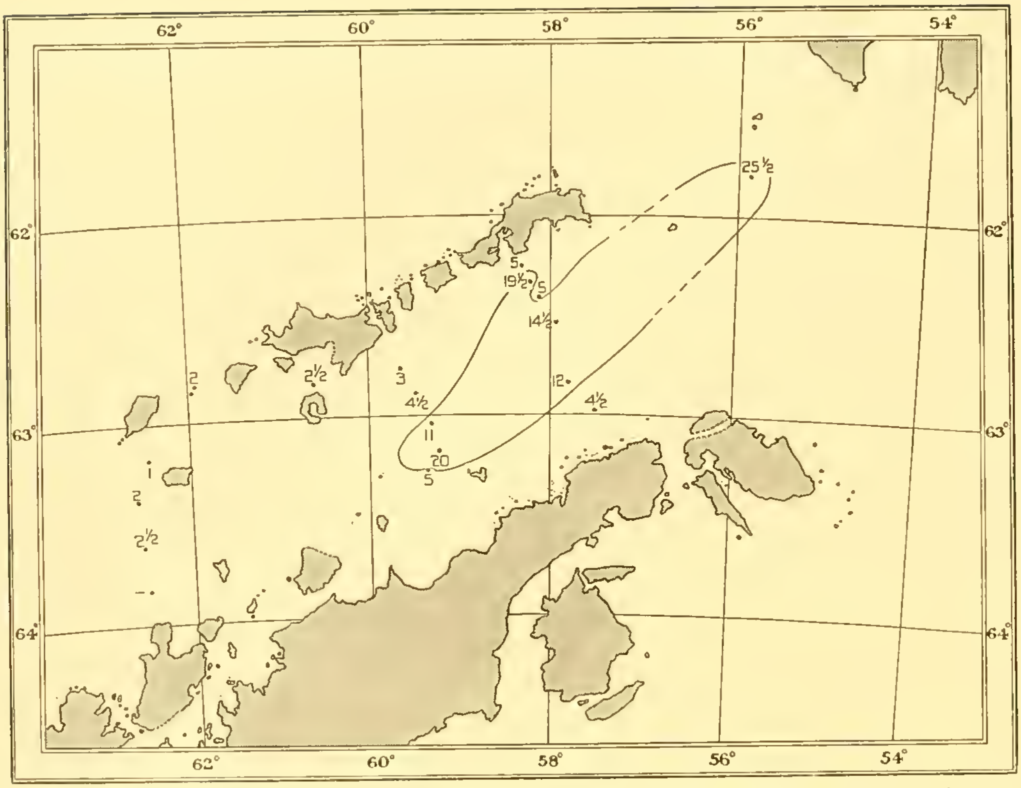

Fig. 57. Phytoplankton distribution (totals per 100–0 m. haul) in Bransfield Strait, November 1929.
1 = one million.

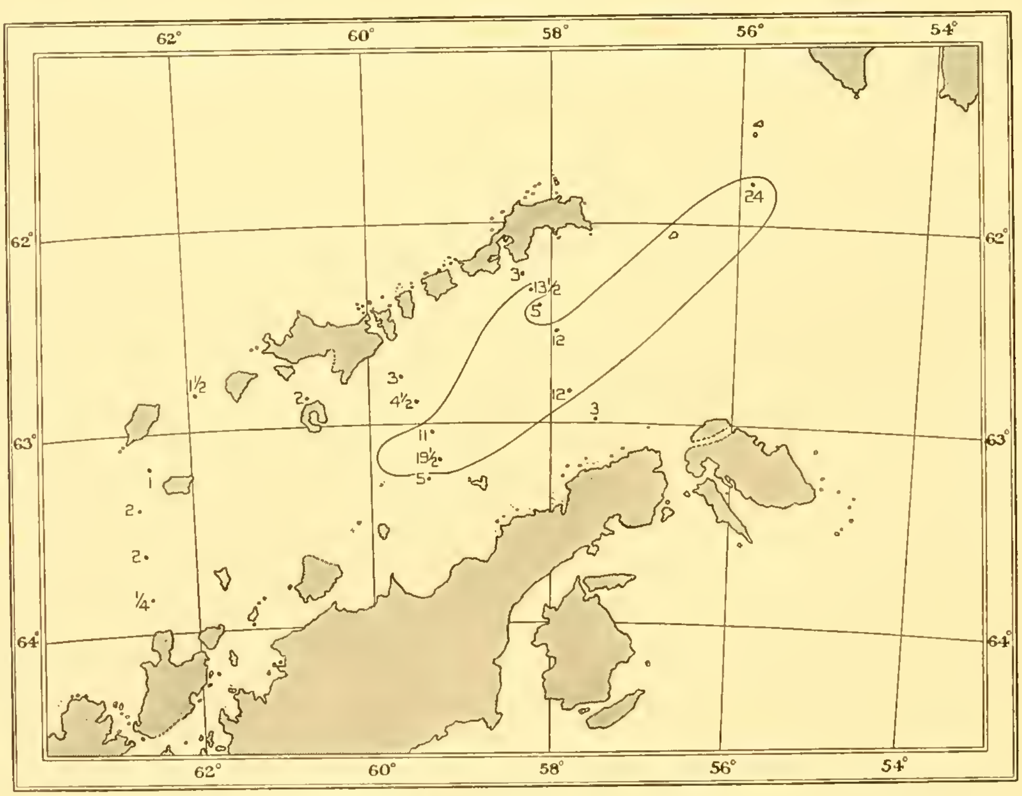

Fig. 58. The distribution of *Corethron valdiviae* in Bransfield Strait, November 1929.
1 = one million.

us face to face with another equally important concept due to Gran—that of the regeneration of an association on the spot. It can be shown that the form in question has a strong autumnal maximum in the Bellingshausen Sea (p. 133), at which season it penetrates into the Bransfield Strait in small numbers as shown by the February survey. On this spring survey moderate numbers coming up from the south-west were again found at the western end of the strait, but there was a very definite gap between them and the maximum observed to the north-east. It is known that the general north-easterly drift of the Antarctic surface water is at a minimum during the winter months, so that it would seem that the most rational explanation of the observed distribution would be as follows: sufficient individuals remain from the autumnal invasion to give rise within Bransfield Strait to a marked spring increase, that drifts away to the north-east as the strength of the current again increases. A similar increase probably takes place somewhat later in the northern part of the Bellingshausen Sea, and this was probably represented here by the re-invasion apparent at the western end of the strait.

The distribution of *Biddulphia striata* is shown in Fig. 60. It will be seen that its maximum was reached at the eastern end of the strait, and that while it was present in small numbers to the west and north-west it was almost entirely absent from the middle line. As this and certain other species were plentiful at the station worked within the eddy of western Weddell Sea water, it might be thought that their presence in large numbers to the northern end of the eastern line was due to mixing of the two types of surface water, which would be promoted by large masses of pack-ice farther east, always a probability at this time of the year. However, the salinities given in Table XXXVI are alone sufficient to show that on this survey the Weddell Sea influence most certainly did not extend north beyond the middle of the eastern end of the strait, so that the most reasonable explanation of the large numbers of *B. striata* at Sts. WS 477 and WS 479 appears to be regeneration on the spot, as in the case of *Rhizosolenia gracillima*. This is not, as might at first appear, in contradiction to the distinctions between the phytoplankton of the various types of surface water drawn throughout this paper. From the first (pp. 20, 21) it has been pointed out that all the more important phytoplankton species appear to be common to all types of Antarctic surface water. It is in the relative proportions of the dominant forms that the distinction lies, and it will be seen that while *Biddulphia striata* was twice as numerous at St. WS 477 as at St. WS 481, its proportion of the total catch was 2·2 per cent at the latter as against 1·1 per cent at the former.

The distribution of *Thalassiosira antarctica*, shown in Fig. 61, closely parallels that of *Biddulphia striata*. It reached its maximum estimated numbers to the north-east and was generally present in fairly large numbers at the eastern end of the strait, reaching by far its greatest relative abundance (16·2 per cent) at St. WS 481 in the eddy of Weddell Sea water. Yet another species of some importance, having a distribution of this type, was *Eucampia antarctica*, as will be seen from Fig. 62. Though by no means so widely distributed as the two species described above, it showed an even more pronounced maximum at St. WS 481. This species was entirely absent from the middle

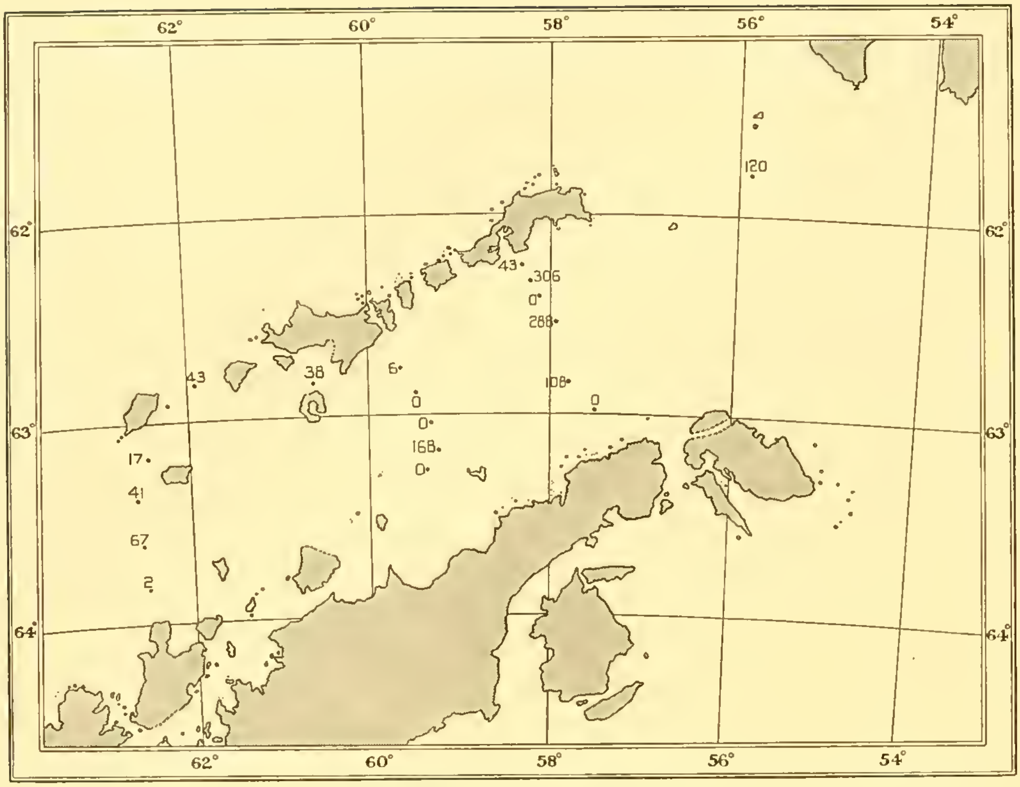

Fig. 59. The distribution of *Rhizosolenia alata* f. *gracillima* in Bransfield Strait, November 1929. 1 = one thousand.

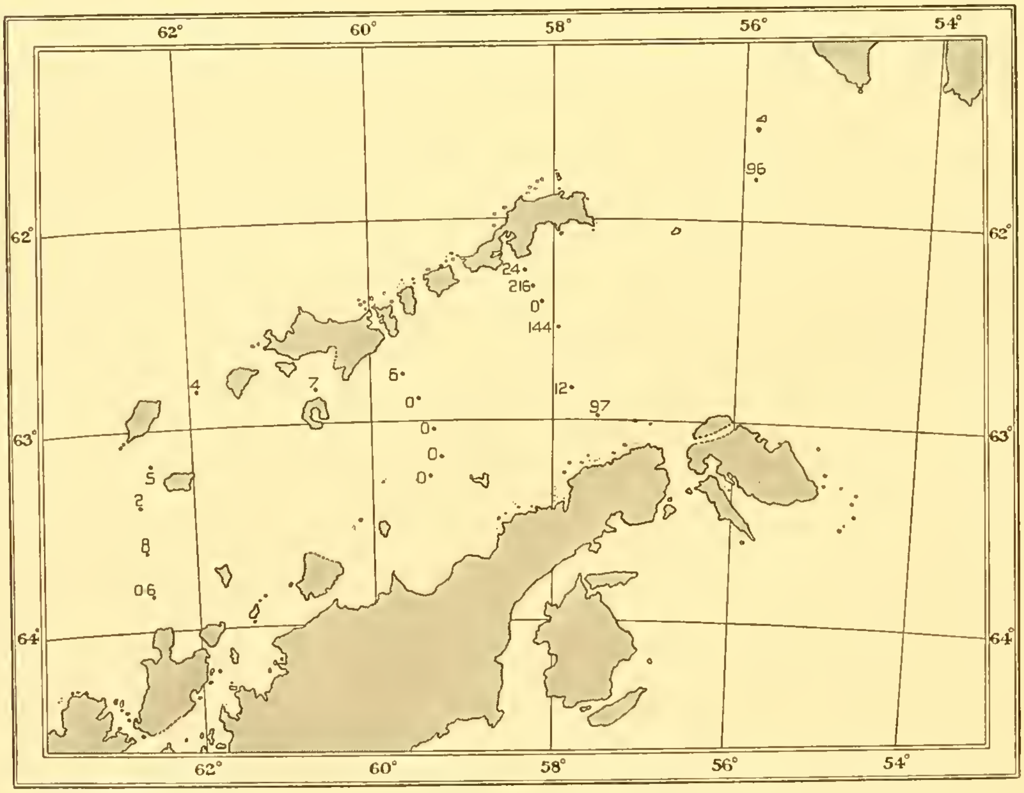

Fig. 60. The distribution of *Biddulphia striata* in Bransfield Strait, November 1929. 1 = one thousand.

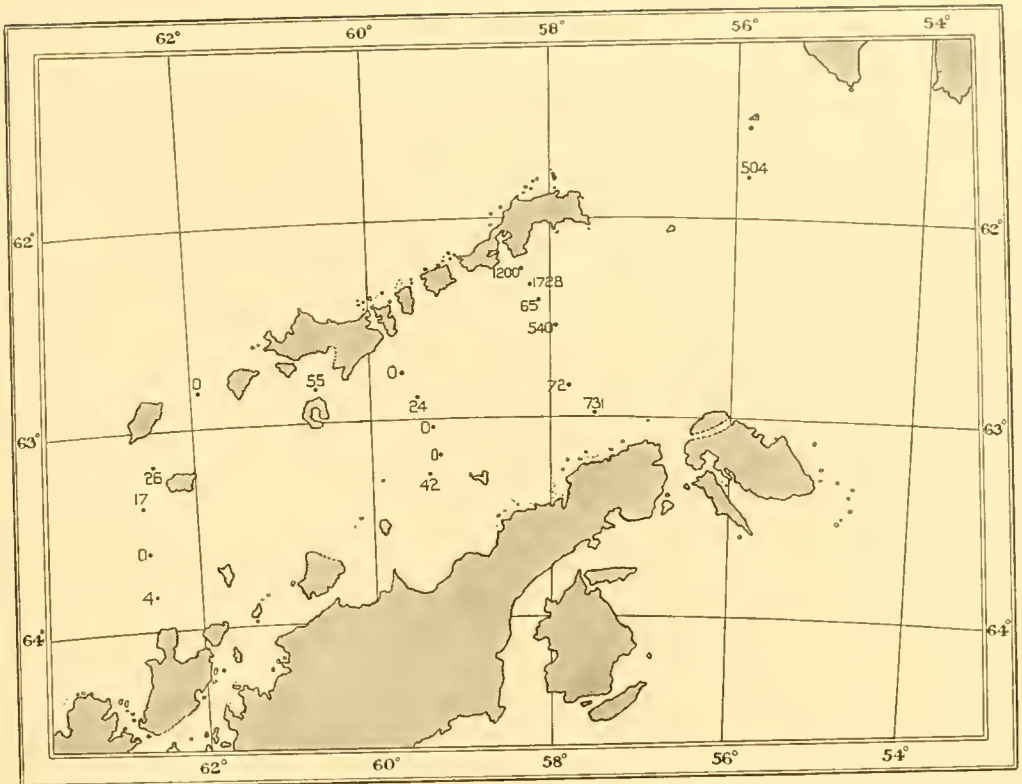

Fig. 61. The distribution of *Thalassiosira antarctica* in Bransfield Strait, November 1929. 1 = one thousand.

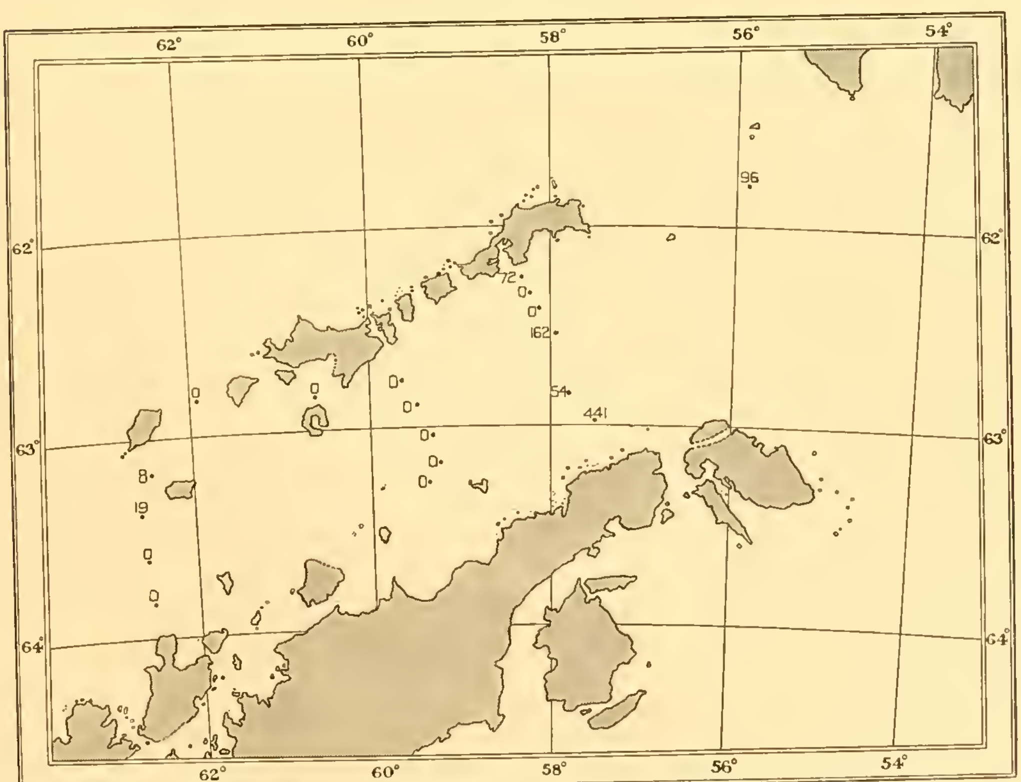

Fig. 62. The distribution of *Eucampia antarctica* in Bransfield Strait, November 1929. 1 = one thousand.

line, and on the western line occurred in small numbers only at the two stations on either side of Low Island.

The small species *Nitzschia seriata* showed a much more scattered distribution on this survey, as will be seen from Fig. 63. It was only abundant at one station, St. WS 489, at the western end of the strait, and elsewhere was confined mainly to the north-western stations. It occurred at three stations on the eastern line, two at the north in the old Bellingshausen Sea water, and at the southernmost station in the eddy of Weddell Sea water, but it was absent from St. WS 475 still farther to the north-east, and at all the more easterly stations where it occurred it was present only in relatively

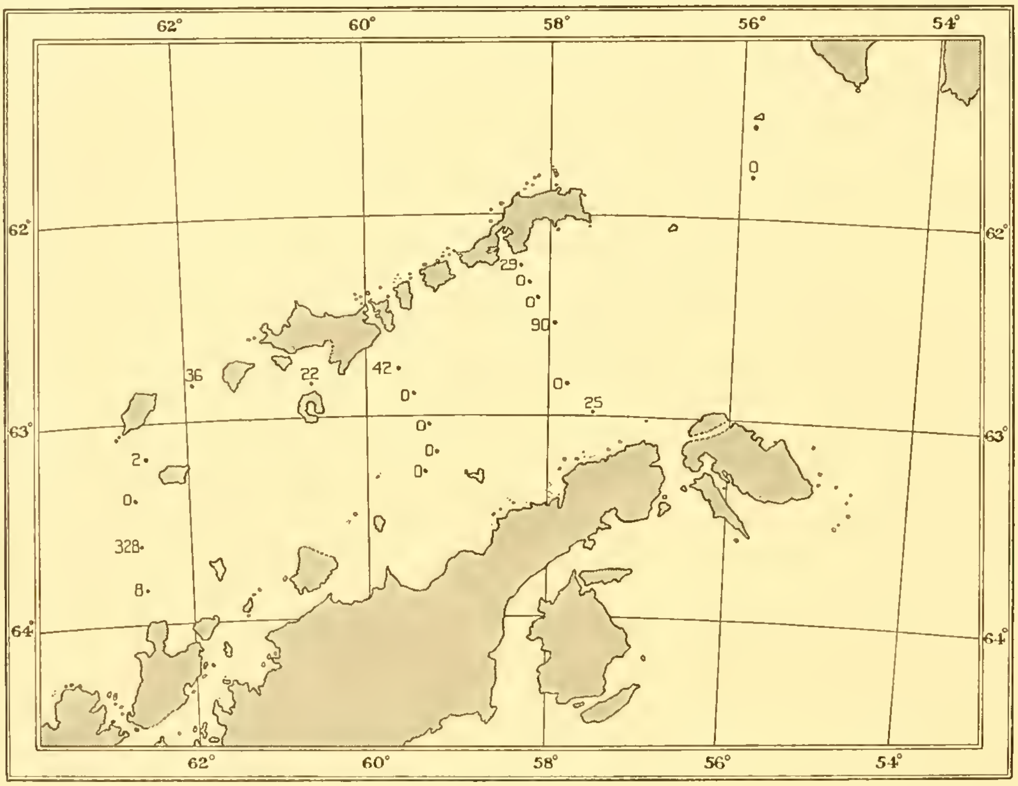

Fig. 63. The distribution of *Nitzschia seriata* in Bransfield Strait, November 1929. 1 = one thousand.

small numbers. From these facts it would seem that there is no extensive regeneration of this species in the old Bellingshausen Sea water in the Bransfield Strait in early spring, but that there is a certain amount of invasion from the west. *N. seriata* has been found to be a most cosmopolitan species, present in abundance at some time or other in almost every type of Antarctic surface water. Later in the year, when the influx of Weddell Sea water into Bransfield Strait was at its strongest, it was found to have its maximum there, but not approaching its abundance in the more oceanic areas studied. The reason for the scarcity of this species in the Bransfield Strait at most seasons of the year would appear to lie in the origin of the old Bellingshausen Sea surface water that fills the greater part of the strait. This, as the dominance of *Corethron valdiviae* and the invasion of *Rhizosolenia gracillima* clearly show, comes from the north-east of the

Bellingshausen Sea, whereas the more westerly parts of the Bellingshausen Sea have been found to support a more varied association in which *Nitzschia seriata* was prominent (see pp. 148, 177). The drift from the more westerly parts of the Bellingshausen Sea will in the normal course of events pass to the north of the South Shetlands, scarcely influencing the Bransfield Strait at all. This was the probable source of the rich flora of Chaetocerids, *Nitzschia seriata*, etc., observed in the southern half of Drake Passage in April 1930, in old surface water of Bellingshausen Sea origin, a flora which was evidently the outcome of a secondary autumnal diatom increase (see p. 76, Table XX). On this occasion we were unfortunately able to work only one station in

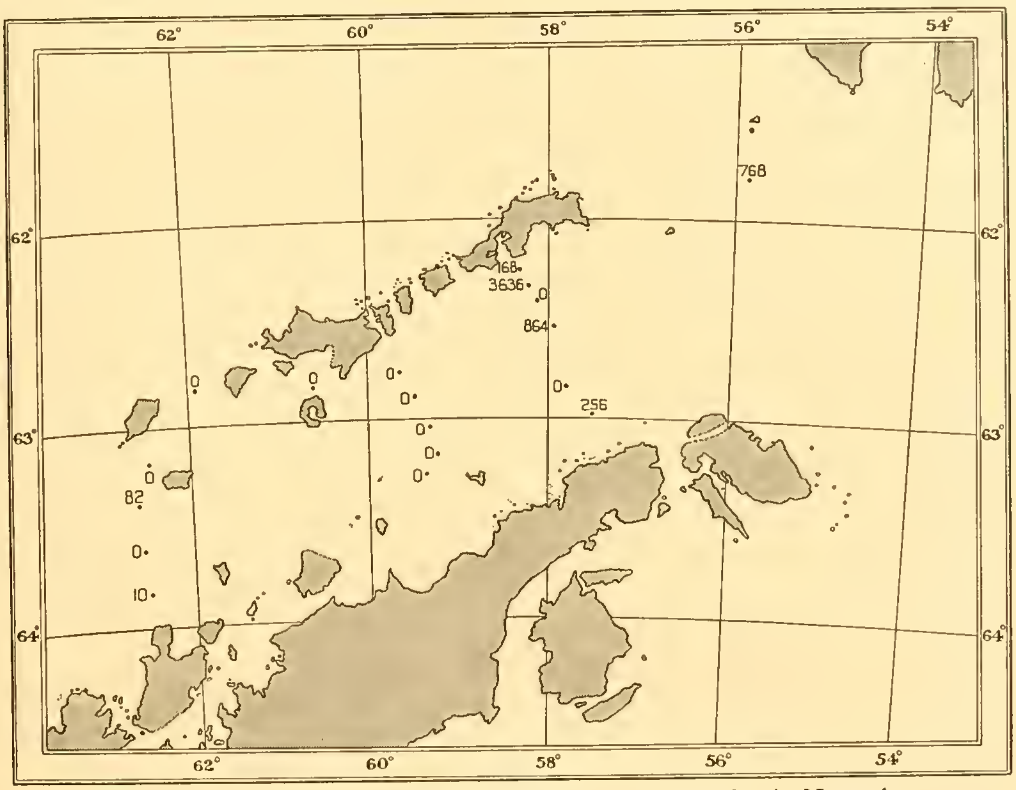

Fig. 64. The distribution of *Fragilaria antarctica* in Bransfield Strait, November 1929. 1 = one thousand.

Bransfield Strait owing to ice conditions. This station showed, however, a similar flora to that found outside Livingston Island, though not so rich. It seems, therefore, that if *N. seriata* ever reaches great abundance in Bransfield Strait, it does so in late autumn.

The only other species of much importance in the phytoplankton community of the strait on this November survey was *Fragilaria antarctica*. As can be seen from Fig. 64, this species was fairly abundant to the north-east and also in the eddy of Weddell Sea water. It was absent from the middle line and present at two stations only to the westward (at St. WS 490 as f. *bouvet*). The distribution of this species is thus obviously to be explained on the same lines as that of *Thalassiosira antarctica* and *Biddulphia striata*, namely regeneration from the remnant that had survived the winter within the strait, or from their spores.

THE SURVEY OF DECEMBER 1930

During the 1930–1 season a plankton survey of seventeen stations was made in Bransfield Strait by the 'Discovery II'. The first two lines of this survey were disposed somewhat farther to the eastward than on those previously described, as can be seen from Fig. 56.

It will be seen that the first line, of five stations, was worked from the strait between Elephant and Clarence Islands—south-westwards in the direction of Joinville Island. The full analyses of the phytoplankton material collected on this line are given in Table XXXIX. At all four stations to the north-east, Sts. 537–540 inclusive, it will be seen that *Corethron valdiviae* was strongly dominant, with *Rhizosolenia gracillima* present in moderate numbers at Sts. 538 and 539, and increasing numbers of small forms such as *Fragilaria antarctica* and *Chaetoceros neglectus* at Sts. 539 and 540. At Sts. 537 and 540 the phytoplankton was moderate in quantity, and at the two middle stations it was rich. The findings on the next line worked to the west served to make it fairly clear that this flora represented the last of the dense *Corethron* plankton of the spring increase within the Bransfield Strait drifting away to the north-east. A noteworthy feature of these stations was the large number of *Corethron* cells in process of forming auxospores, thereby more than doubling their size. The increased proportion of small forms at the two more southerly stations in this case undoubtedly indicated slight admixture with Weddell Sea surface water, as the rising salinities with falling surface temperatures are sufficient to show.

At the southernmost station on this line a phytoplankton of an entirely different nature was encountered, as can be seen from the fact that though it occupied barely half the volume of the catch at the preceding station, the total diatoms, exclusive of minute, uncountable colonial forms, exceeded the estimated total at St. 540 by some eight hundred thousand. This was primarily due to a great falling off in the proportion of *Corethron valdiviae*, and to the presence of a much greater variety of small forms, sixteen species being recorded against nine at the preceding station to the north-east. That this station, St. 541, was worked well within the sphere of Weddell Sea influence is clearly shown by the sharp rise in salinity and fall in temperature at the surface. The dominant form here was *Chaetoceros socialis* in minute uncountable colonies, and other leading species were *Thalassiosira antarctica*, *Chaetoceros tortissimus*, *Corethron valdiviae* and *Chaetoceros neglectus*, in that order of importance. A precisely similar phytoplankton was found at the two southernmost stations on the line next to be described, which were evidently worked within the eddy of Weddell Sea water round Joinville Island. In examining the catch from St. 541 unusually large numbers of faecal pellets of Euphausians were observed, many of large size being obviously attributable to *Euphausia superba*. This may indicate that the feeding was good.

The next line of this midsummer survey was worked very slightly to the east of the lines south from Admiralty Bay of the previous surveys, from Cape Melville on King George Island southwards. The full analyses of the phytoplankton hauls from the six full stations worked on this line are given in Table XL. From this table it will be seen that at the inshore station to the north *Thalassiosira antarctica* predominated in a small catch. The inshore character of the surface water here was clearly indicated by the presence of a large species of *Lycmophora* in the phytoplankton. It is thus probable that this catch represents the surviving remnant of the previous association to the north of the strait. It has already been noted, in the account of the February survey, that the typically spring form, *Thalassiosira antarctica*, appears to persist in small numbers just within the South Shetland Islands.

At the next station to the southward, St. 543, another very poor catch was obtained, this time with *Corethron valdiviae* dominant, as we have learnt to expect in the more open waters in Bransfield Strait, though the poverty of the catch may have been due in part to inshore influence, as the presence of a *Lycmophora* sp. shows. In the course of these investigations the phytoplankton of littoral areas occupied by old Antarctic surface water has been frequently found to be much poorer than that present farther offshore. The possible reasons for this, in the case of South Georgia, are discussed in Appendix I.

At both of the succeeding stations to the southward on this line *Corethron valdiviae* was very strongly dominant in hauls of moderate quantity, the phytoplankton thus being typical of the old Bellingshausen Sea surface water occupying the bulk of the strait, but still farther south, at Sts. 546 and 547, it was very evident that the surface water was of Weddell Sea origin. Indeed these stations are the best illustration yet obtained of the pronounced effect of the eddy round Joinville Island, for not only was the different character of the surface water clearly shown by the marked rise in salinity and fall in temperature, but the phytoplankton was totally different, being of the same nature as that described from St. 541, the southernmost on the preceding line farther to the eastward. The phytoplankton at these three stations was moderately rich, and composed of a much greater variety of species than that found at the other stations. The dominant forms in this western Weddell Sea surface water were *Chaetoceros socialis*, *Ch. neglectus* and *Ch. tortissimus*, and other important species were *Corethron valdiviae, Fragilaria antarctica, Thalassiosira antarctica*. At the end of this section, when the phytoplankton collected on this December survey is considered as a whole, it will be seen that the proportion of other species to *Corethron* was considerably higher than in the surveys made in November and February, but it is important that it should be recognized that this was entirely due to the relatively large numbers of other species taken at the three stations in the eddy of Weddell Sea surface water. This applies to all the species other than *Corethron* totalling over one hundred thousand, with the sole exception of the typically Bellingshausen Sea form *Rhizosolenia gracillima*. Several species did not occur at any of the other stations on the survey, the more noteworthy of these being the normal form of *Rhizosolenia alata*, *Chaetoceros dichaeta*, *Ch. flexuosus*, *Ch. socialis* and *Ch. tortissimus*. It may be noted in passing that this is our only record of the rather rare *Ch. flexuosus* occurring in surface water of Weddell Sea origin.

On this survey the line of stations across the middle of the strait was omitted, and the line at the western end was brought slightly to the eastward of its old position. The analyses of the phytoplankton material collected on this line are given in Table XLI, together with the analysis of the haul from St. 555, worked slightly to the westward of the middle of the line a week later.

It will be seen that on this line the phytoplankton was poor, and that *Corethron valdiviae* was dominant throughout. The haul at St. 549 at the northern end close in to Snow Island was somewhat richer and more varied than the others, but even here none of the species other than *Corethron* reached any high degree of importance. One would have expected a more varied phytoplankton at this station owing to its proximity to the deepest western inlet into the Bransfield Strait—that between Snow and Smith Islands. It was very evident throughout this survey that the influx of Bellingshausen Sea surface water was at a minimum and that the spring maximum within the body of the strait was over. The hauls from the more southerly stations on this line fully bear out this view. One hint of a possible renewal of the invasion from the Bellingshausen Sea was afforded by a richer haul, with *Corethron* dominant, at the very last station of the survey, St. 555, mentioned above.

The additional isolated stations worked off the western end of the strait somewhat later in the year have been included on the distribution charts for the sake of convenience. Their consideration is better left until conditions on the survey proper have been summarized.

The following is a list of all the species recorded on the whole of the survey, with their total abundance and the number of stations at which each occurred. The letter W after the figures indicates that the numbers of the species were mainly due to a strong maximum at the three stations, Sts. 541, 546 and 547, worked in surface water of Weddell Sea origin:

Corethron valdiviae (17)	59,810,200	*Chaetoceros criophilum* (5)	219,000
Chaetoceros neglectus (9)	(∞ +) 4,329,100 W	*Coscinodiscus* spp. (5)	130,700
Ch. socialis (3)	∞ W	*Thalassiothrix antarctica* (5)	53,200
Thalassiosira antarctica (14)	3,882,600 W	*Rhizosolenia styliformis* (5)	50,500
Chaetoceros tortissimus (3)	3,873,000 W	Silicoflagellata (2)	50,400
Fragilaria antarctica (9)	2,095,500 W	*Coscinodiscus bouvet* (2)	27,600
Biddulphia striata (9)	1,184,400 W	*Synedra spathulata* (2)	21,600
Eucampia antarctica (6)	1,050,800 W	*Peridinium* spp. (2)	12,800
Rhizosolenia alata f. *gracillima* (12)	461,850	*Navicula pellucida* (1)	12,000
R. alata (3)	360,600 W	*Navicula* spp. (4)	2,800
R. truncata (6)	338,540 W	*Lycmophora* sp. (2)	2,100
Nitzschia seriata (6)	300,000 W	*Thalassiothrix* sp. (1)	1,200
Chaetoceros flexuosus (3)	246,000 W		
Ch. dichaeta (2)	207,000 W		

Estimated total phytoplankton 78,723,790.

The total estimated phytoplankton taken on this survey (17 stations) of course excludes the minute uncountable Chaetocerids. The proportion of "other species" was 31·6 per cent of the total, *Corethron valdiviae* forming 68·4 per cent. The proportion of other species was thus much greater than that found during the spring or autumn surveys, but, as we have seen, this was almost entirely due to the three hauls obtained in Weddell Sea surface water. It will be evident that, if we consider only the stations in the old Bellingshausen Sea water, the proportion of *Corethron* will be as large as that found on the autumn survey, and larger than on the spring survey.

The estimated total phytoplankton was also lower than on the other two surveys, and though it would be very much higher had it been possible to count the small colonial forms at the three stations in the Weddell Sea eddy, it may be said that there was a decrease over the strait as a whole, well shown by conditions on the two more westerly lines (see Fig. 65).

The distribution of the more important species serves to emphasize the points made above. *Chaetoceros socialis* and *Ch. tortissimus* are not considered here, as they were

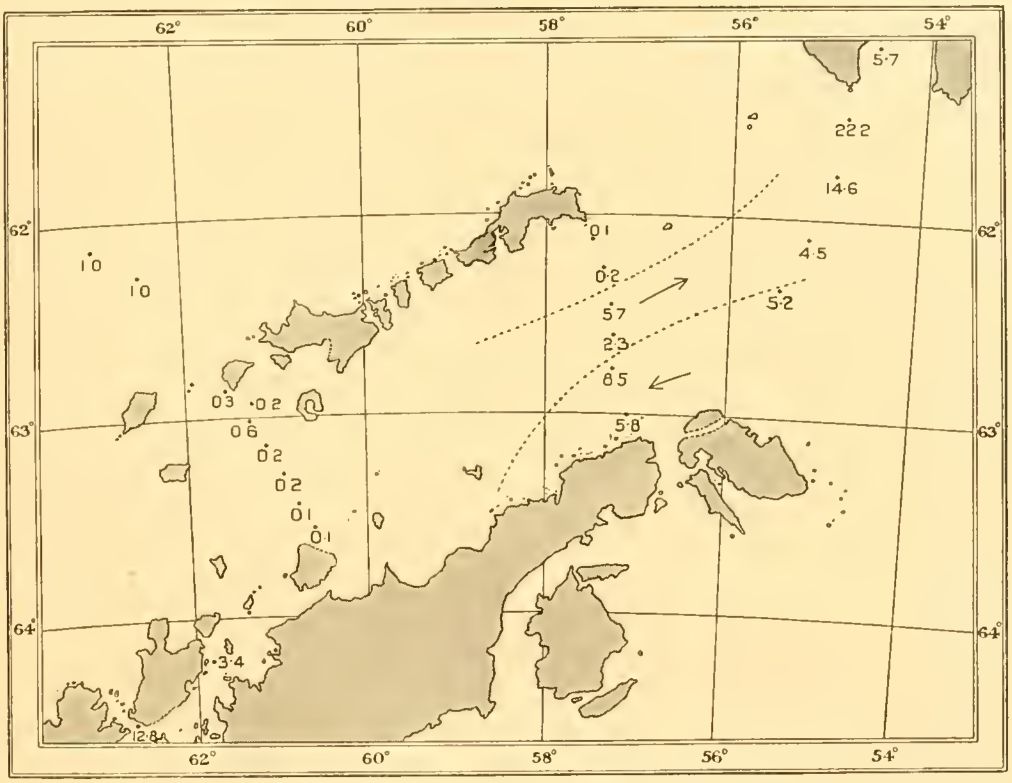

Fig. 65. Phytoplankton distribution (totals per 100–0 m. haul) in Bransfield Strait, December 1930. 1 = one million.

confined to the three Weddell Sea stations, as the tables clearly show. Fig. 66 shows the distribution of the dominant species *Corethron valdiviae*. It will be seen that it reached its maximum to the north-east at Sts. 538 and 539, suggesting that the eastward movement of the phytoplankton association regenerated in the old Bellingshausen Sea water within the strait, observed during the spring of the previous season, had on this occasion advanced still farther. This view is strongly upheld by the distribution of *Rhizosolenia gracillima* (Fig. 67), whose maximum development here coincided with the *Corethron* maximum. As we have previously tried to show, this form is apparently regenerated in moderate abundance in the old Bellingshausen Sea surface water in the spring (see p. 121). Comparison of Fig. 65, where the phytoplankton totals are given, with Fig. 66, showing the distribution of *Corethron*, also shows the relatively small proportion of that

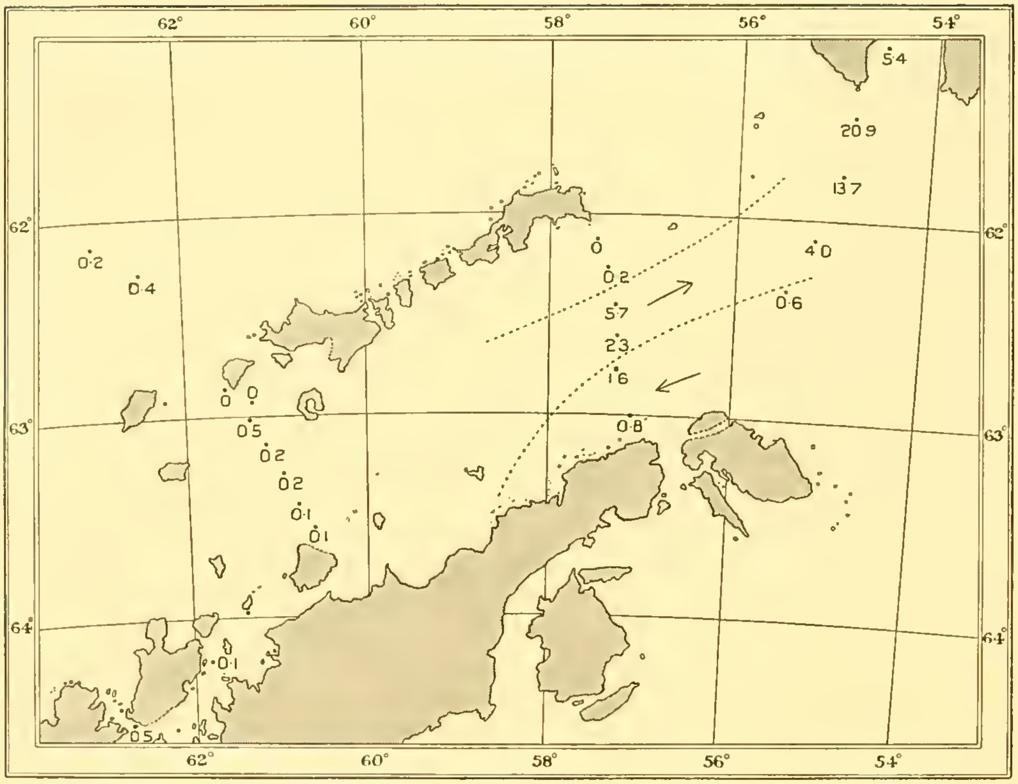

Fig. 66. The distribution of *Corethron valdiviae* in Bransfield Strait, December 1930. 1 = one million.

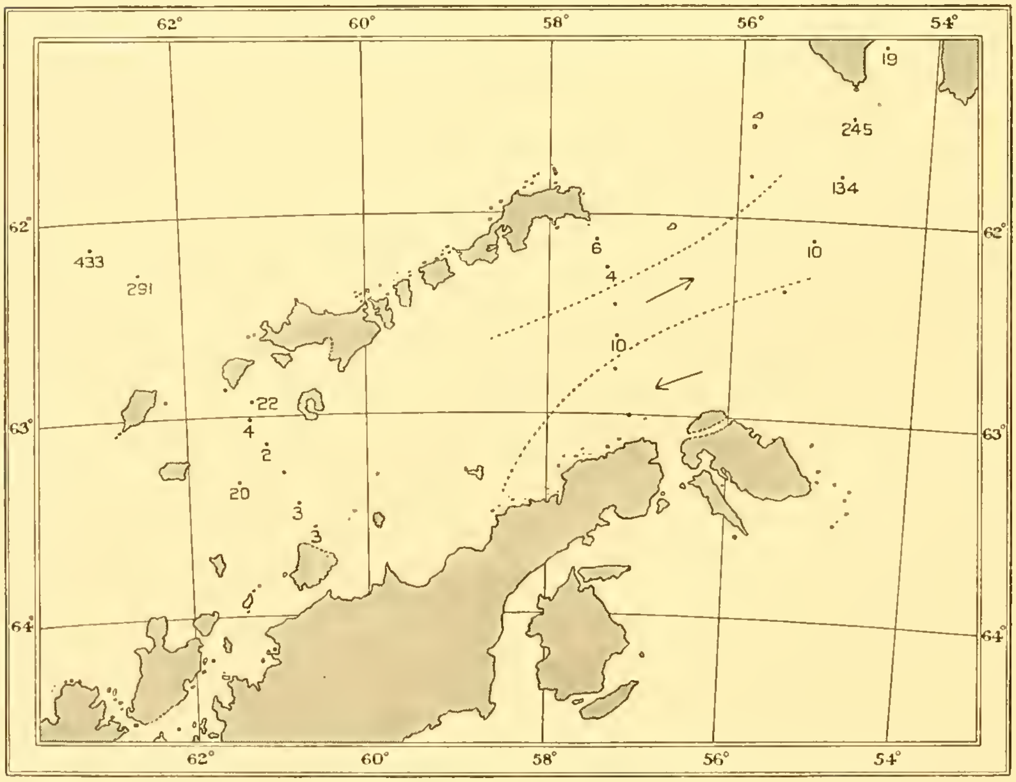

Fig. 67. The distribution of *Rhizosolenia alata* f. *gracillima* in Bransfield Strait, December 1930. 1 = one thousand.

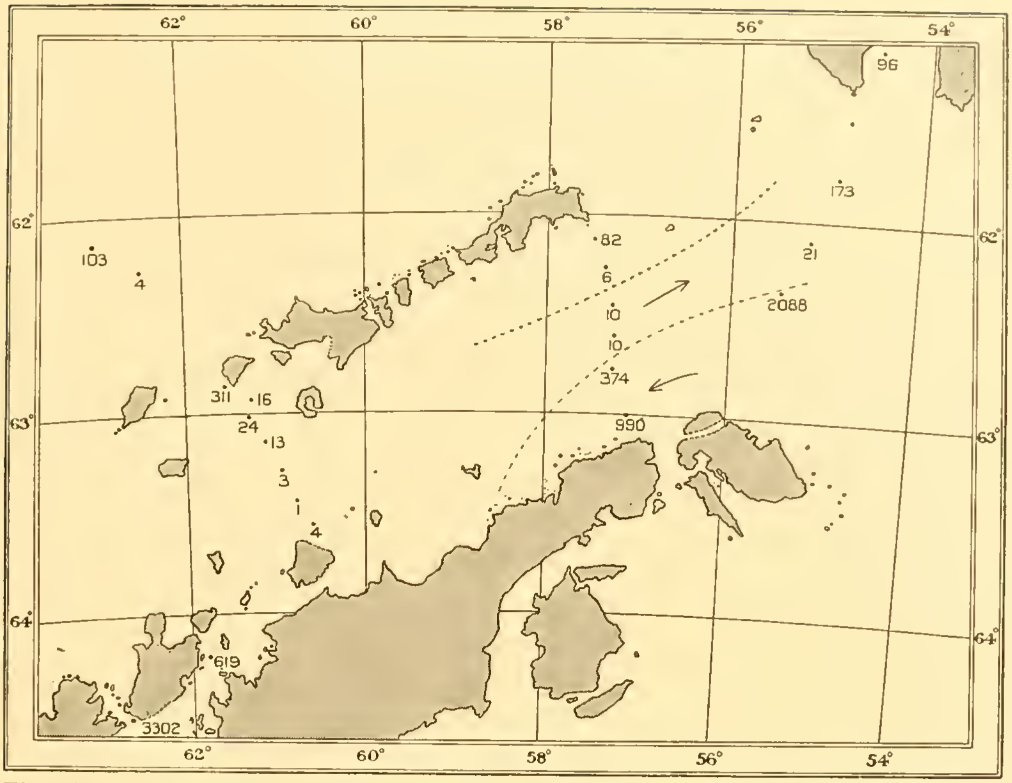

Fig. 68. The distribution of *Thalassiosira antarctica* in Bransfield Strait, December 1930.
1 = one thousand.

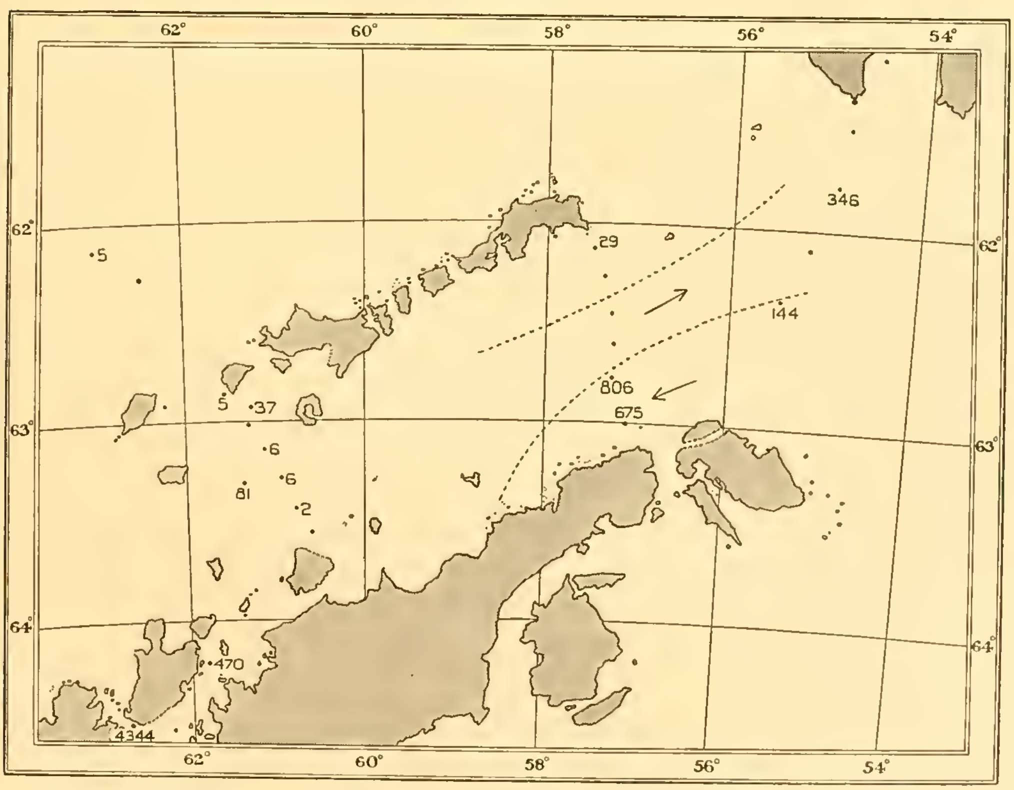

Fig. 69. The distribution of *Fragilaria antarctica* in Bransfield Strait, December 1930.
1 = one thousand.

species within the eddy of Weddell Sea surface water. At the western end of the strait both *Corethron* and *Rhizosolenia* were comparatively scanty.

The distribution of *Thalassiosira antarctica* is shown in Fig. 68. This species showed a very strong maximum in the Weddell Sea eddy, and was elsewhere most numerous in the extreme north-east as one would expect if the remnant of the spring increase within the strait had indeed drifted off in that direction.

The distribution of both *Fragilaria antarctica* (Fig. 69) and *Chaetoceros neglectus* (Fig. 70) at the eastern end of the strait was very similar to that of *Thalassiosira*, except

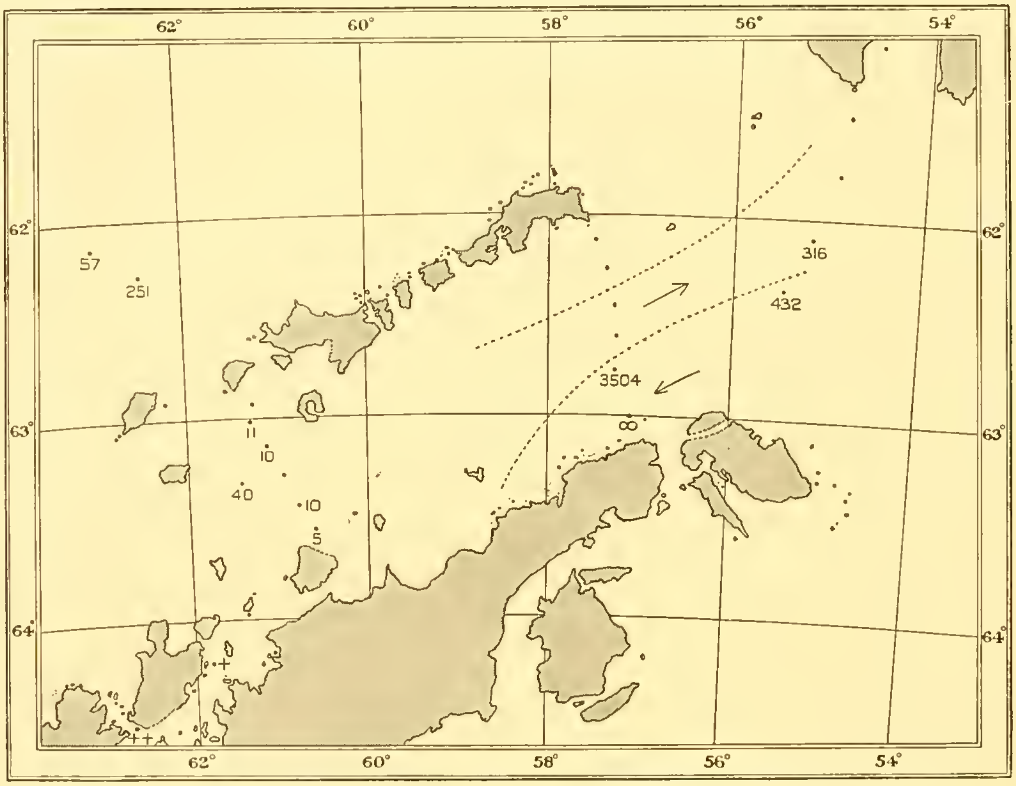

Fig. 70. The distribution of *Chaetoceros neglectus* in Bransfield Strait, December 1930. 1 = one thousand.

that *Chaetoceros neglectus* was almost entirely confined to the Weddell Sea water. The only exception was at St. 540 where mixing may have occurred. At this time *Ch. neglectus* was evidently re-entering the strait in the old Bellingshausen Sea water to the westward, as it was present at Sts. 550–552 in small numbers, and at St. 555 a week later in considerably greater numbers. It will have been noted that the numbers of *Corethron* present in this haul were also considerably greater, which points to the end of December being the time of the beginning of the reinvasion of the Bransfield Strait by phytoplankton associations from the Bellingshausen Sea, as distinct from the spring increase in the old water within the strait.

ADDITIONAL STATIONS TO THE WESTWARD, JANUARY–FEBRUARY 1931

The full analyses of the phytoplankton hauls from the six stations (Sts. 605–610) worked to the west of Bransfield Strait later in the 1930–1 season are given in Table XLII. It will be seen that in the table they have been arranged in north to south (i.e. reverse) order, partly for the sake of consistency and partly because by this means the stations bearing more directly upon conditions within the strait are considered first. The distribution of most of the more important species is included in Figs. 66–70.

It will be seen that at the two stations outside the strait to the north-west of Snow Island, two hauls moderate in quantity and fairly similar in quality were obtained. At the more northerly of the two, St. 610, well out in Drake Passage, the leading forms were *Corethron valdiviae*, *Rhizosolenia gracillima* and *Chaetoceros neglectus*. At the inner station *Rhizosolenia gracillima* dominated over *Corethron*, and other important species were *Thalassiosira antarctica* and *Chaetoceros dichaeta*. It seems fairly certain from observations in the Bellingshausen Sea described in the next section that this phytoplankton had drifted to the southern side of Drake Passage from the vicinity of Adelaide Island.

At two stations worked inside Snow Island, Sts. 608 and 607, two small hauls of peculiar quality were obtained. The surface salinities at the stations were remarkably high, and the temperatures rather low, for this locality and time of year. These facts point strongly to the probability of vertical mixing, and may well explain the peculiar nature of the phytoplankton observed. An interval of more than a week elapsed between the working of these stations, which is probably in itself sufficient to account for the dissimilarity between them. At the later and more northerly station (St. 608), *Thalassiosira antarctica* was strongly dominant, a most unusual feature for this typically spring form during the second half of the season, but showing a possible source of the undoubted regeneration of this species in the north of the Bransfield Strait in early spring. In the very small catch from St. 607 *Corethron valdiviae*, *Fragilaria antarctica* and *Nitzschia closterium* were the most numerous forms, the presence of the last named, in the absence of ice, being indicative of littoral conditions.

The conditions at the two stations to the southward, St. 606 in the mouth of de Gerlache Strait and St. 605 in Schollaert Channel, remain to be discussed. From the analyses in Table XLII it will at once be seen that the phytoplankton at these stations was entirely different from anything encountered in the old Bellingshausen Sea surface water occupying the greater part of the Bransfield Strait, but that it closely resembled the association found earlier in the year in the eddy of Weddell Sea water to the eastward. *Chaetoceros socialis*, *Ch. neglectus* and *Ch. tortissimus* were the dominant forms in uncountable colonies, and other important species were *Thalassiosira antarctica*, *Biddulphia striata*, *Eucampia antarctica*, *Fragilaria antarctica*, *Nitzschia seriata* and *N. closterium*. The presence of this last-named species furnished the only notable difference from the Weddell Sea association, apart from the expected occurrence of the littoral form *Lycmophora* in small numbers. At first sight it would seem as if the current from the Weddell Sea had proceeded down the south shore of Bransfield Strait and penetrated the channels of the Palmer Archipelago. The low surface salinities and rather high temperatures at these stations render this explanation improbable, however, and hydrological results obtained within the Bransfield Strait itself all point to the probability that the Weddell Sea influence does not extend much beyond Astrolabe Island in a south-westerly direction. The only parallel we have encountered to this rich and varied phytoplankton association, with so many typically spring forms persisting in large numbers late in the summer in water that must have ultimately originated in the Bellingshausen Sea, was at St. WS 501 worked just to the south of Anvers Islands near the southern entrance to Neumayr Channel at midsummer of the previous year. It seems possible that a rich local association may persist among the channels of the Palmer Archipelago throughout the major part of the season. Mangin has described a somewhat similar association from material collected in Scotia Bay at the South Orkneys, where *Chaetoceros socialis* was dominant throughout the season (see Mangin, 1922, pp. 94, 95), though this was in Weddell Sea water. If a localized phytoplankton rich in small forms does in fact persist within the channels, further investigations there may prove very interesting, as I am informed by Mr F. C. Fraser that the abundance of those species included here under the general term "small forms" shows some degree of correlation with the abundance and the size of the developmental stages of *Euphausia superba*.

CONCLUSIONS

If the observations described above represent an approach to the normal conditions in the strait, we may conclude that the course of the phytoplankton development proceeds somewhat as follows.

Early in the year, when the western end of the strait is still blocked up by pack-ice, a moderate development takes place in the old Bellingshausen Sea surface water within the strait. The dominant species of this spring increase is *Corethron valdiviae*, but the other more important forms, *Thalassiosira antarctica*, *Rhizosolenia gracillima*, *Biddulphia striata* and *Fragilaria antarctica* are all more abundant in proportion than at any other time of the year in surface water of this nature. The influence of the Weddell Sea current round Joinville Island does not reach its maximum until December, but is already apparent in the greatly increased proportions of *Thalassiosira antarctica*, *Eucampia antarctica*, etc., to be found in that locality. The maximum for the year in the old Bellingshausen Sea water occupying the greater part of the strait is probably reached about the last week of November or first of December.

As the season advances the pack at the western end tends to break up, the influx of Bellingshausen Sea water into the western end of the strait is increased, the phytoplankton formed by the spring increase drifts away to the north-east in the direction of Elephant and Clarence Islands, and is not immediately replaced. About the second week in December the phytoplankton development in the eddy of Weddell Sea water reaches its height. This is characterized by the pronounced dominance of small Chaetocerids, continued importance of the smaller species mentioned above, and by the much larger variety of species than are present in the old Bellingshausen Sea water. Another notable feature is the much smaller proportion of *Corethron valdiviae* than elsewhere in the strait at this season, and the absence of auxospore formation of this species, whereas in the rich *Corethron* plankton drifting to the north-east with the old Bellingshausen Sea water, auxospore formation is proceeding apace at this time. But little phytoplankton is present in the water entering the western part of the strait at mid-season, probably owing to the lateness of the spring increase in the ice-bound Bellingshausen Sea whence this surface water originates.

Still later in the year a moderately rich phytoplankton, with *Corethron* very strongly dominant, and *Rhizosolenia gracillima* the only other form of constant occurrence, develops in the middle of the strait as a result of the invasion of Bellingshausen Sea water from the westward. Up to the time when it enters the labyrinth of islands, and comparatively shoal water which guards the western entrance, this Bellingshausen Sea water possesses a much more varied flora, which leads one to suppose either that these other species fail to survive the violent vertical mixing consequent upon the passage of the current through the various obstructions, or that conditions within the Bransfield Strait itself at this time may be inimical to their extensive development. So far as they have been studied, the chemical and physical properties of the surface water within the strait do not, however, present any features sufficiently striking to account for such a big difference. The first of the two factors mentioned is thus more likely to be responsible for the peculiar nature of the phytoplankton in Bransfield Strait. While other species, such as *Thalassiosira antarctica*, penetrate in small numbers to the extreme north-west (where the deepest opening, between Smith and Snow Islands, lies), nothing corresponding to the pronounced dominance of *Corethron valdiviae* over the greater part of Bransfield Strait throughout the year has been observed in any other area. In the present state of our knowledge the most probable reason for this phenomenon is that a large number of the other species fail to survive the violent vertical mixing consequent upon the passage of the Bellingshausen Sea drift through the chain of shoals and islands guarding the western entrance. Direct evidence of this mixing is furnished by the high surface salinities at some of the stations in the gaps (e.g. at Sts. 607 and 608 already quoted). The surface water to the south-west coming up from the Bellingshausen Sea rarely exceeds 33·90, whereas at these two stations the salinities were 34·17 and 34·24 ‰ respectively, at the surface. As a definite set from the westward is a well-established fact (vide *Antarctic Pilot*, 1930, p. 72) it follows that considerable mixing with the more saline, deeper-seated water layers must have taken place.

By early autumn the strongly defined character of the phytoplankton within the area affected by the eddy of Weddell Sea water has entirely disappeared, though traces of Weddell Sea influence are still clearly apparent in the hydrological features of the surface water. The reason for this lies probably in the rapid waning and change in character of the phytoplankton after mid-season, a feature that has also been noted at certain stations between Clarence Island and the South Orkney Islands.

In years when the autumnal increase in old Bellingshausen Sea water is unusually rich, as it seemed to be in April 1930, it is possible that there is a considerable invasion of small Chaetocerids, *Nitzschia seriata*, etc., into the northern half of Bransfield Strait quite late in the year. An association of this type was found at St. 376 (pp. 75, 76 and Table XX). Apart from this there is little doubt that the maximum phytoplankton development is in late spring, though the disparity between the quantities present at the different seasons is by no means so marked as in the other areas investigated.

THE PHYTOPLANKTON OF THE BELLINGSHAUSEN SEA

The interpretation of our results from this area must necessarily be more speculative than that placed upon the material collected in the Bransfield Strait, for observations in spring and early summer are not available, and we have little direct evidence as to the phytoplankton to the north of this rather ill-defined area. All our observations were obtained south of the 64th parallel, and conditions in the older water between that latitude and the Antarctic convergence remain unknown, apart from such conclusions as can be drawn from the material collected in the southern half of Drake Passage in surface water that undoubtedly originated in that area.

In the Bellingshausen Sea proper, phytoplankton material was collected at twenty stations, worked mostly in February, by the 'William Scoresby' during the 1929–30 season, and at forty-seven stations worked mostly in January by the 'Discovery II' in the following year.

THE SEASON 1929–30

On her voyages to the Bellingshausen Sea during this season the 'William Scoresby' was mainly engaged in other work, and apart from the valuable line worked off Adelaide Island, material is available only from a small number of widely scattered stations. It has been found impossible to group the latter into strictly logical sequence, though their significance can be made out fairly well when the results obtained during the following season are taken into consideration: a purely arbitrary grouping has perforce been adopted in the tables. The positions of the stations are shown in Fig. 71. The dominant species are indicated by symbols in Fig. 72, and the phytoplankton totals, to the nearest hundred thousand, in Fig. 73.

Table XLIII gives the full analyses of the phytoplankton hauls at St. WS 495 worked to the west of Adelaide Island late in December, and at three other stations to the south-west worked in February. Conditions at St. WS 495 were interesting, as this station was worked earlier in the year than any of the others in this area. Here the littoral or ice-form *Nitzschia closterium* was dominant in a haul of moderate size, in which a fair number of species were recorded, the other more numerous forms being *Corethron valdiviae*, *Rhizosolenia gracillima* and *Chaetoceros neglectus*, all of which have been found to be of the first importance in this area somewhat later in the year.

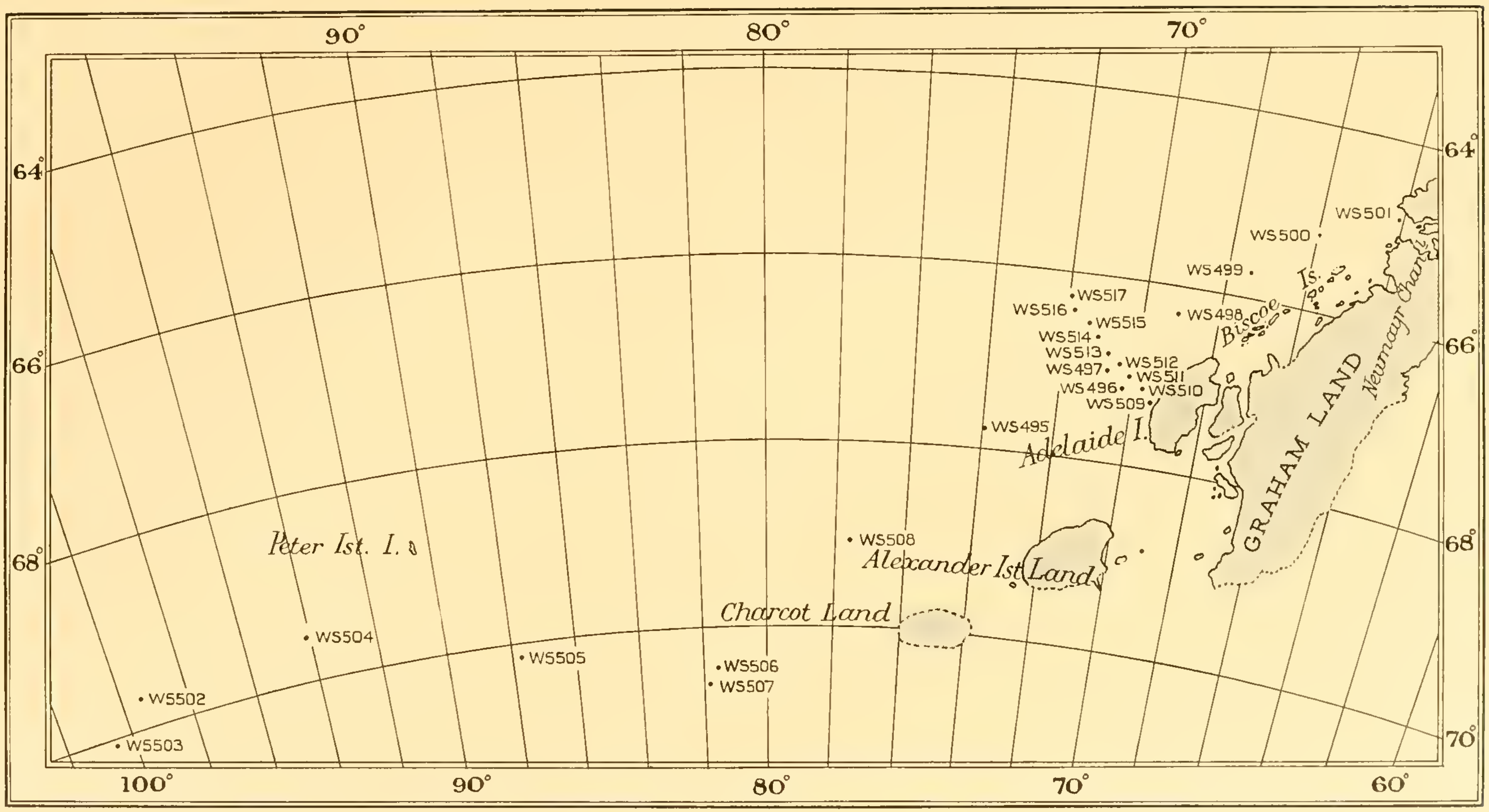

Fig. 71. Reference chart showing the positions of the stations worked by the R.R.S. 'William Scoresby' in the Bellingshausen Sea during 1929–30.

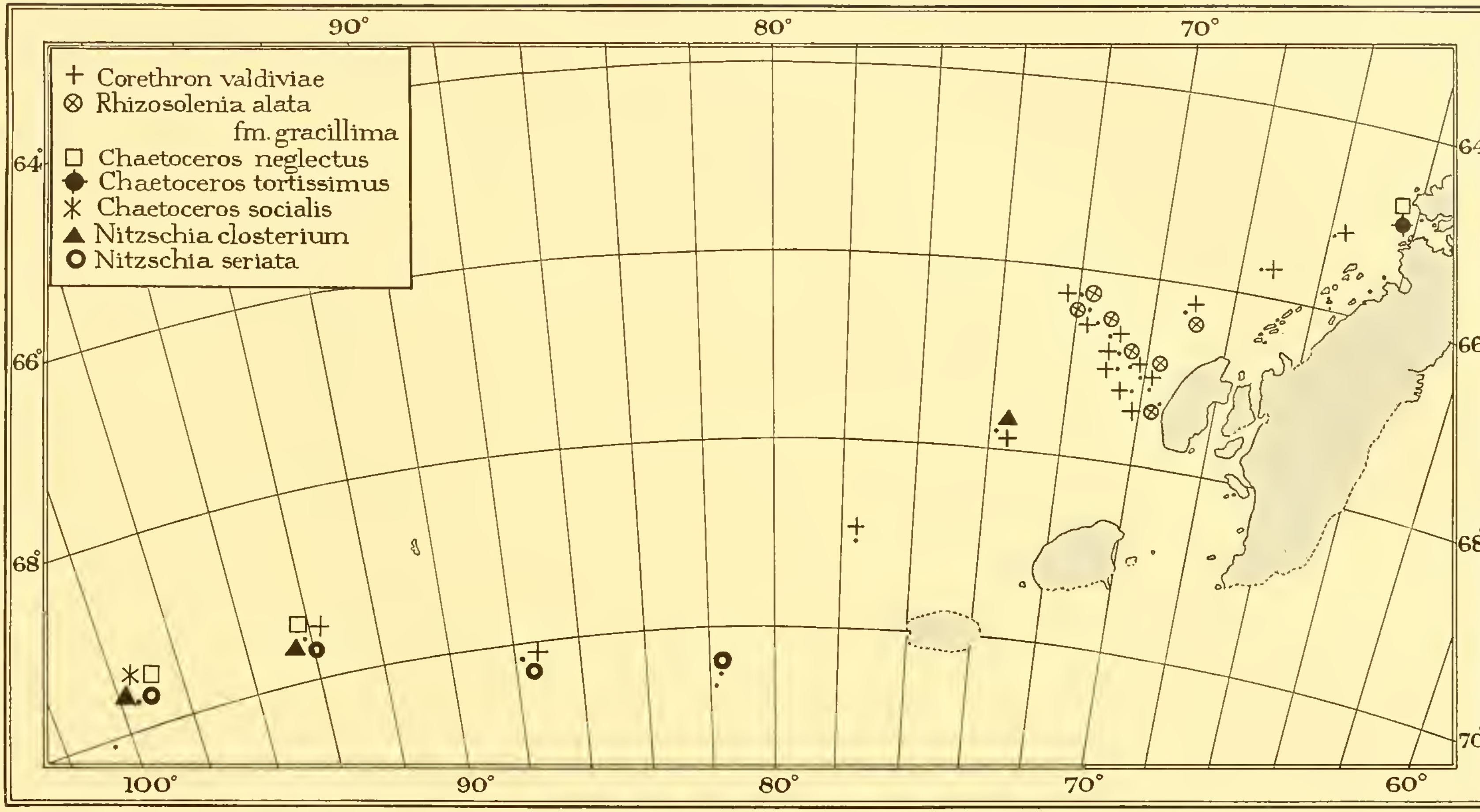

Fig. 72. The distribution of the principal phytoplankton species in the Bellingshausen Sea, December–February 1929–30.

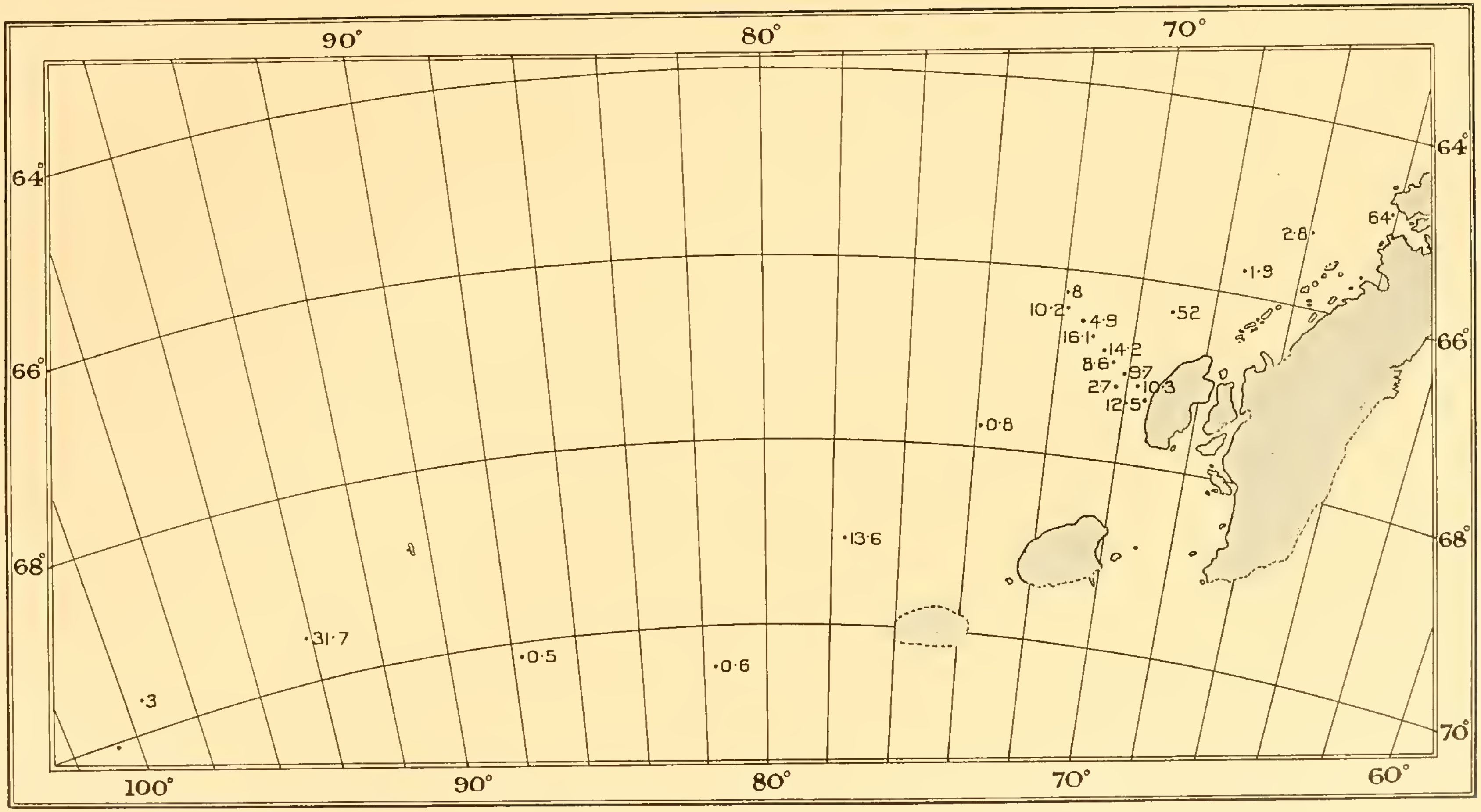

Fig. 73. Phytoplankton distribution (totals per 100–0 m. haul) in the Bellingshausen Sea, December–February 1929–30. 1 = one million.

Of the three stations worked to the south-westward in February, the most easterly, St. WS 508, showed a fairly rich phytoplankton with *Corethron valdiviae* strongly dominant; but at the two others, so far the most southerly stations worked during the course of these investigations, the phytoplankton was scanty. At St. WS 506 it was also of a most peculiar nature, but St. WS 505 showed a phytoplankton of quite a usual type, with *Corethron valdiviae* dominant, and a large variety of other forms present in very small numbers, *Nitzschia seriata* being the only one of much significance. In the peculiar catch from St. WS 506, the principal species were *Nitzschia seriata*, *Rhizosolenia truncata*, *Biddulphia striata*, *Corethron valdiviae*, *Nitzschia closterium*, and *Chaetoceros neglectus*. Despite the time of year it will be noted that the temperature of the surface water was extremely low, and the partial resemblance to the association met with farther to the north-east earlier in the year will be noted. The most important difference lies in the absence of *Rhizosolenia gracillima* at the more southerly station. As the sequel will show, this form appears to have a well-marked centre of distribution in the extreme north-east of the Bellingshausen Sea proper, off Adelaide Island.

In Table XLIV are shown the analyses of Sts. WS 496 and WS 498–501. It will be seen from Fig. 71 that these stations, worked on the return from the first voyage into the Bellingshausen Sea that season, form a line running from off Adelaide Island north-eastwards outside the Biscoe Islands to the mouth of Neumayr Channel. At all four of the southernmost stations on this line a very similar phytoplankton was encountered in moderate quantity, with *Corethron valdiviae* strongly dominant throughout, and a fair variety of other forms present, mostly in small numbers. At one station only, St. WS 498, *Rhizosolenia gracillima* was important, but was even then outnumbered by *Corethron* by more than two to one. Conditions at this station strongly suggest, however, that we have here the first beginnings of the development of the richer association with these two species co-dominant, observed to the north and east of Adelaide Island later in the year. At the most northerly station on this line (St. WS 501), worked almost in the mouth of Neumayr Channel, a rich local phytoplankton of the type described from two stations in de Gerlache Strait and Schollaert Channel was encountered. The development of this rich local flora probably takes place within the channels of the Palmer Archipelago, and bears little direct relation to conditions in the Bellingshausen Sea. Despite the comparatively small volume, the catch at this station was by far the richest in point of numbers from the whole of this area. The reason for this apparent anomaly will be readily understood by the enumeration of the leading forms: *Chaetoceros neglectus*, *Ch. tortissimus*, *Thalassiosira antarctica*, *Fragilaria antarctica*, *Biddulphia striata*, *Nitzschia closterium*, *Rhizosolenia truncata* and *Nitzschia seriata*, the majority of these being minute species.

Before passing on to a description of the line of close stations taken off Adelaide Island, two isolated stations worked far to the south-west, some three weeks later in the year than those worked in the same locality by the 'Discovery II' during the following season, may be considered. The analyses of the phytoplankton hauls from these two stations are given in Table XLV. At St. WS 502, the more southerly of the two, it will be seen that a rich variety of species was present in a haul of moderate quantity, with two small species, *Chaetoceros socialis* and *Ch. neglectus* predominating in uncountable colonies. This is the only occasion on which the colonial form of *Ch. socialis* has been observed in the open water of the Bellingshausen Sea during the course of these investigations, though it is possible, but not probable, that the single chains have occasionally been confounded with those of *Ch. neglectus*. The only other species present in large numbers at this station were *Nitzschia seriata* and *N. closterium*, although, as can readily be seen from the analysis, many other species were present in subordinate quantities.

At St. WS 504 a much richer haul was obtained, though the larger volume was mainly accounted for by the larger numbers of *Corethron valdiviae* present. *Chaetoceros socialis* was not observed here, but *Ch. neglectus* and the two species of *Nitzschia* were present in large numbers, and *Ch. dichaeta* was taken in much greater quantity than at any other station in the Bellingshausen Sea during this season.

The phytoplankton at these two stations presented important differences from that collected in the same locality during the following year, when the large species *Thalassiothrix antarctica* was one of the leading forms, and *Fragilaria antarctica* and *Chaetoceros dichaeta* formed much larger proportions of the catches. It would appear that these differences are too great to be accounted for by the three weeks difference in time of year, and constitute one of the fluctuations from year to year for which we are only able to offer hypothetical explanations at present.

On the line of stations worked off Adelaide Island in the north-eastern corner of the Bellingshausen Sea in February (WS 509–17), we find a rich development of the association with *Corethron valdiviae* and *Rhizosolenia gracillima* dominant; this association was encountered in this area on other occasions, and it evidently invades the Bransfield Strait during the latter half of the season. The full analyses of the phytoplankton hauls from these nine stations (Figs. 71–73), which were worked at 10 mile intervals outwards from Adelaide Island on an approximately north-westerly course, are given in Table XLVI. From this table it will be seen that the phytoplankton encountered was fairly uniform throughout, though with a considerable fluctuation in the relative proportions of the two dominant species, and some falling off in the bulk of the catches towards the northern extremity of the line. At the three inshore stations *Corethron* predominated over *Rhizosolenia gracillima* to a marked degree, and other forms present in considerable numbers were *Nitzschia seriata* and *Fragilaria antarctica*. Farther offshore the phytoplankton presented a smaller variety of species, and the only form apart from the two dominants that consistently occurred in moderate numbers was *Chaetoceros criophilum*. This form, which has been found as a dominant species in the Weddell Sea area, was of fairly constant occurrence in the Bellingshausen Sea also, but always in subordinate numbers. Its maximum for the sixty-seven stations we have examined from the latter area occurred at Sts. WS 513 and WS 514 on this line. Among the less important forms, *Dactyliosolen laevis*, *Chaetoceros dichaeta*, *Synedra spathulata* and *Thalassiothrix antarctica* were confined to the outermost stations on this line. From the description of the other work in this area, it will be gathered that these species were not frequent in the east of the Bellingshausen Sea, but were often abundant in the rich and varied associations to the south-west. Their occurrence at the outermost stations on this line is therefore in good agreement with the general idea of the north-easterly drift of the surface water.

SUMMARY

The general character of the phytoplankton from the twenty stations worked in the Bellingshausen Sea during the season 1929–30 is summed up in the following list, which gives the twelve leading forms in order of their total abundance, with the number of stations at which each was observed, and their percentage of the total phytoplankton. *Chaetoceros socialis* in uncountable colonies was dominant at St. WS 502 and is not included in this list.

	Total	%
Corethron valdiviae (20)	88,522,800	40·0
Chaetoceros neglectus (7)	40,250,400 + ∞*†	18·2
Rhizosolenia alata f. *gracillima* (18)	34,737,600	15·7
Chaetoceros tortissimus (2)	17,076,000*	7·7
Nitzschia closterium (6)	8,714,100*†	3·9
N. seriata (16)	8,011,300	3·6
Thalassiosira antarctica (15)	7,613,700*	3·4
Eucampia antarctica (8)	3,670,200*	1·7
Biddulphia striata (11)	2,536,500*	1·1
Chaetoceros criophilum (15)	2,221,200	1·0
Rhizosolenia truncata (6)	2,203,500*	1·0
Fragilaria antarctica (8)	2,028,000	0·9
Other forms		1·8

Total phytoplankton estimated 221,084,600.

* Due mainly to St. WS 501. † Due in part to St. WS 504.

It will be seen that the position of many of these forms is due mainly to the very rich haul taken at St. WS 501 in the mouth of Neumayr Channel, which was of the special type found at a few other stations among the Palmer Archipelago, and by no means characteristic of conditions in the Bellingshausen Sea proper. Leaving these forms out of consideration, it is apparent that *Corethron valdiviae* and *Rhizosolenia gracillima* were very markedly dominant in the north-eastern Weddell Sea at this time. If we leave St. WS 501 out of account the estimated total phytoplankton becomes 157,033,400 for nineteen stations or an average of 8,264,900 organisms per station. Bearing in mind that the hauls obtained at the few stations worked early in the year were comparatively poor, it becomes very evident that a rich development of what may be called the *Corethron—Rhizosolenia gracillima* association was taking place late in the summer, as this average considerably exceeds that obtained for stations in the same area, worked in the January of the following year. This increase to the north-east of the Bellingshausen Sea may be the precursor of the autumnal development in older surface water of Bellingshausen Sea origin farther to the northward.

THE SEASON 1930–1

During this season forty-seven stations, at which phytoplankton material was collected, were worked by the 'Discovery II' in the Bellingshausen Sea, mostly during the first three weeks of January. Considerable difficulty has been experienced in grouping the stations for tabulation. The analyses of the phytoplankton hauls are given in Tables XLVII–LII. Of these the first two consist of two definite lines worked north of Adelaide Island, the third treats of all the stations worked between the Palmer Archipelago and 70° W long., excluding those dealt with in the first two tables, and the remaining three deal with the stations worked farther to the westward grouped between necessarily arbitrary limits. The positions of all the stations at which phytoplankton material was collected are shown in Fig. 74. To the westward it became apparent that the time difference between the outward and homeward bound passages was not sufficiently great to be reflected in marked changes in the nature of the phytoplankton, but at a few of the more easterly stations the conditions had changed considerably, the interval being nearly three weeks.

The long line worked on an approximately north-westerly course from Adelaide Island may be described first, as it affords the best grounds of comparison with that worked by the 'William Scoresby' during the previous season. On this occasion ten stations were worked at somewhat greater intervals, the line being carried up to 64° 17′ S, 75° 35′ W (Table XLVII). At the innermost station (St. 584), it will be seen that although small in volume, the catch contained millions of the minute species *Chaetoceros neglectus* and *Ch. tortissimus*, the former strongly dominant and the association generally bearing a close resemblance to that found in the Palmer Archipelago. Farther offshore, at St. 583, *Corethron valdiviae* predominated in a small haul in which the only other form of much importance was *Chaetoceros neglectus*. At all three of the succeeding stations to seaward (Sts. 585–587), very poor catches were obtained, with *Corethron valdiviae* the most numerous form of a phytoplankton poor in both species and individuals. A possible explanation of this extreme poverty lies in the fact that the area was known to have been completely covered by pack-ice just prior to the working of the stations. The conditions at the earliest stations worked in this area indicate that a considerable interval is necessary, after the ice begins to break up, before extensive phytoplankton development can take place. It was round the position of these inshore stations in the following month of the preceding year that such a rich development of the *Corethron—Rhizosolenia gracillima* association had been found. On this occasion the line was spread over double the distance to the northward, and this association was not encountered until St. 588 was reached. It persisted in varying degrees at the three succeeding stations to the northward, Sts. 589–591, but with an increasing proportion of *Chaetoceros neglectus* and with *Nitzschia seriata*, actually the most numerous organism at St. 591, whereas in the preceding year the dominance of *Corethron valdiviae* and *Rhizosolenia gracillima* had been most marked. It is evident that the development of this association had not proceeded so far on this occasion, and it seems probable that open water is an

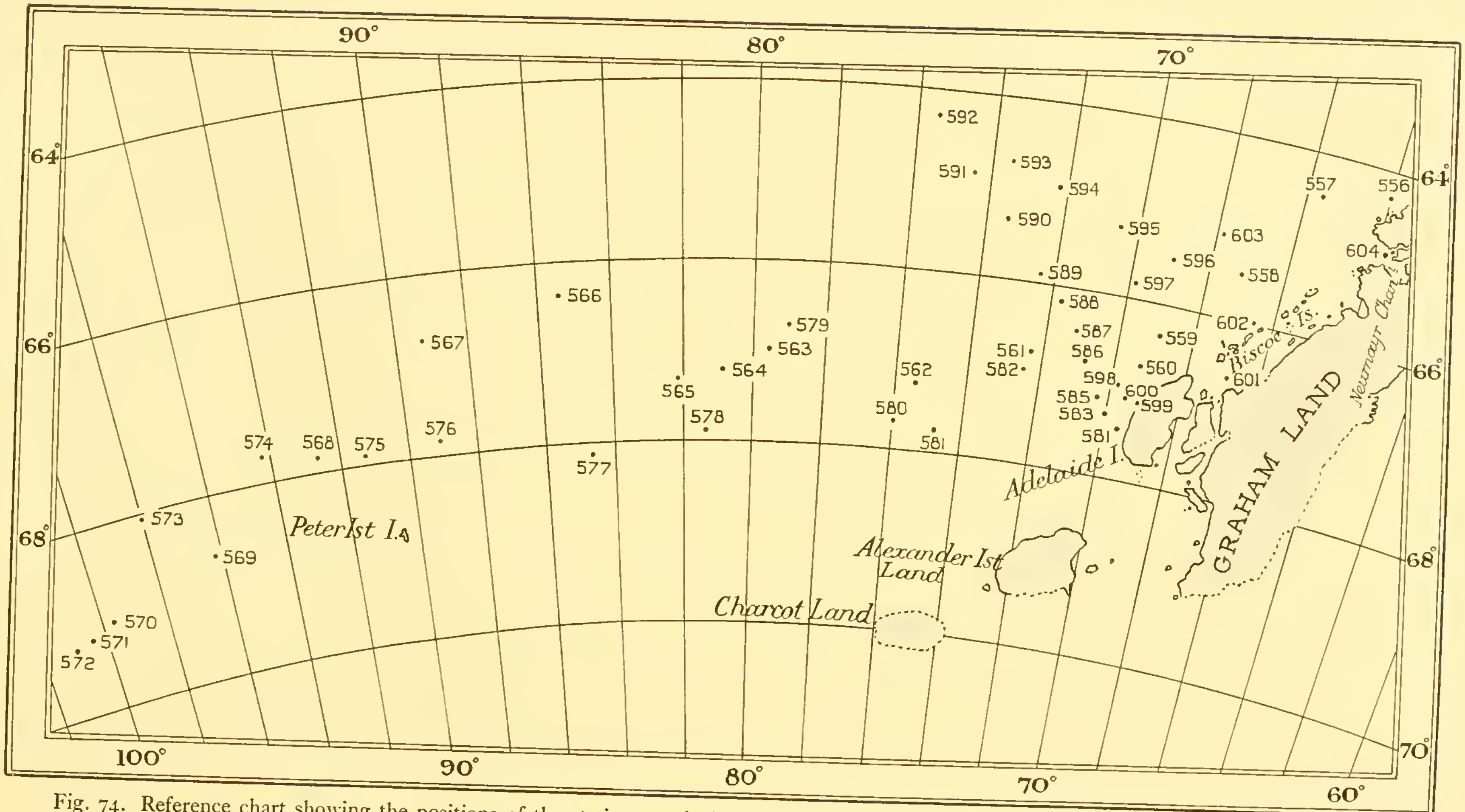

Fig. 74. Reference chart showing the positions of the stations worked in the Bellingshausen Sea by the R.R.S. 'Discovery II', January 1931.

essential factor. This would explain its absence from the innermost stations on this line, as it was known that pack-ice had been present for a considerable distance to the northward of Adelaide Island at the beginning of January. At the northernmost station on this line, St. 592, a moderately rich and varied phytoplankton was encountered, with *Nitzschia seriata* strongly dominant. The other leading species at this station were: *Fragilaria antarctica*, *Corethron valdiviae*, *Chaetoceros neglectus*, *Ch. dichaeta*, *Thalassiosira antarctica* and *Thalassiothrix antarctica* in that order of importance. When the catches obtained in the far south-west of the Bellingshausen Sea a little earlier are considered, it seems highly probable that the surface water at this station had originated in that region, and drifted to the north-east fairly rapidly. It will be noted that the phytoplankton became moderately rich only at the five more northerly stations on this line. There is thus some support for the view that the persistence of the pack-ice in the Bellingshausen Sea throughout spring and early summer has a strong retarding effect upon the development of the phytoplankton.

From the position of the outermost station on this line, four stations were worked on an approximately south-easterly course, in the direction of the Biscoe Islands. The analyses of the phytoplankton hauls from these stations are given in Table XLVIII. It will be seen that at the three outermost stations *Nitzschia seriata* predominated in a fairly rich mixed plankton, which became less varied and showed a stronger tendency to develop into the *Corethron—Rhizosolenia gracillima* association, as one proceeded in a south-easterly direction. The varied plankton at St. 593 contained species giving good evidence of the origin of the surface water far to the south-west, for example *Thalassiothrix antarctica*, and the high proportion of *Chaetoceros dichaeta* at the succeeding station also indicated that the surface water was largely of similar origin. At St. 595 it was evident that a transition stage between the three major types of phytoplankton development observed in the Bellingshausen Sea on this occasion was being reached; the large numbers of *Nitzschia seriata* and *Fragilaria antarctica* afforded good evidence of the origin of some of the surface water far to the south-west, the high proportion of *Chaetoceros neglectus* suggested mixing with water drifting up from the region of Alexander the First Island, and finally there was an obvious increase in the tendency towards the development of the *Corethron—Rhizosolenia gracillima* association. It would seem probable from the conditions on this line that there is a general tendency towards the development of this association in the older surface water of the whole of the Bellingshausen Sea as it drifts north-eastward, and that the reason for the observed maximum of this type of development to the north of Adelaide Island will be found in the comparatively early breaking up of the pack-ice in that region. At the most southerly station (St. 596) on this line a rich development of this association was encountered, and other species prominent at the three more northerly stations in more mixed water were either absent or present only in much smaller relative proportions.

Table XLIX shows the analyses of the phytoplankton material from all stations worked on this survey between 64 and 70° W, excluding any from the two definite lines already dealt with that fall within this area (Sts. 584 and 596). From the route followed these stations naturally included the first and the last worked in the Bellingshausen Sea during that season, and accordingly the conditions will be seen to have varied considerably. At the first station (St. 556) worked to the north of Anvers Island in December, a moderate phytoplankton very poor in species was encountered. *Corethron valdiviae* was strongly dominant and *Chaetoceros neglectus* the only other species of much importance. It will be noted that an association of this type was encountered at several stations in the more ice-bound portions of the Bellingshausen Sea farther to the south-west, and also at the western end of the Bransfield Strait early in the season. It would seem that it is the first association to develop when the ice begins to clear away, except perhaps in the extreme west, where, as will be seen from Table LII, a phytoplankton of quite a different type was encountered only a week later.

The next station in east to west order was St. 604, worked near the mouth of Neumayr Channel towards the end of January. Here a catch of small proportions but rich in minute species was obtained, of the same type that we have learnt to associate with the channels of the Palmer Archipelago and the littoral waters of the islands farther south. *Chaetoceros neglectus* was dominant, and the other more numerous species were *Fragilaria antarctica*, *Thalassiosira antarctica*, *Corethron valdiviae*, *Nitzschia seriata*, *Rhizosolenia truncata* and *Nitzschia closterium*, in that order of importance.

A phytoplankton of rather similar type but much poorer in quantity was found at St. 557 worked well out to sea three weeks earlier. Here the most numerous species were *Fragilaria antarctica*, *Chaetoceros neglectus*, *Thalassiosira antarctica*, and a small branching colonial form of *Nitzschia* closely resembling the northern *N. frigida*, which we have never observed far from land or extensive pack-ice. The striking difference between the phytoplankton observed at this station, and that from its near neighbour St. 556, appears to be explicable on the grounds of the deflection of the inshore current along the islands to the southward by the extensive masses of pack-ice surrounding them, though we have no direct evidence of such deflection. It is, however, certain that an essentially neritic association was present at St. 557, of a type clearly distinguishable from the associations sometimes met with along the ice-edge which have a certain general resemblance to neritic floras.

At St. 603, the next to be considered from Table XLIX, it will be seen that a rich phytoplankton of the *Corethron—Rhizosolenia gracillima* type was encountered, with a higher proportion of *Fragilaria antarctica* than had been observed at the stations worked later in the previous year, and *Corethron* greatly in excess of *Rhizosolenia*. However, the phytoplankton observed at this station and at St. 596 made it fairly evident that surface water bearing the *Corethron—Rhizosolenia gracillima* association was drifting away from about the middle of the Adelaide Island line to the north-east, and as we have already seen (p. 133) a similar phytoplankton was observed as far north as the southern half of Drake Passage some three weeks later.

At St. 558 on the outward voyage, worked near the pack-ice to the north of the Biscoe Islands, *Corethron valdiviae* was very strongly dominant in a fairly rich haul in which the only other species of much importance were *Fragilaria antarctica* and *Thalassiosira* *antarctica*. The absence of neritic forms here renders the conditions at St. 557 even more difficult to understand. Again, at St. 602, a precisely similar though poorer phytoplankton was encountered even closer to the Biscoe Islands, the only obvious neritic feature being the presence of *Biddulphia polymorpha* in small numbers, and this despite the presence of typical neritic associations both to the south (Sts. 598, 599) and east (St. 601).

Perhaps the richest haul of this survey in the Bellingshausen Sea proper was obtained at St. 597, some distance to the north of Adelaide Island. The phytoplankton here was of the *Corethron—Rhizosolenia gracillima* type, and, as at St. 603, the proportion of *Corethron* was high, much higher than at some of the stations worked later during the previous year, when on some occasions *Rhizosolenia gracillima* was present in equal numbers, or even in excess, in phytoplankton of this type. The next station dealt with in Table XLIX furnishes the probable explanation. It will be seen that at St. 559 worked earlier in the year closer in to the land, a rather similar haul was taken, not so rich in quantity, and with *Chaetoceros neglectus* and *Fragilaria antarctica* both present in considerable numbers in addition to the two dominants. Now, in the eastern portion of the Bellingshausen Sea, it seems that the first association to develop is one with *Corethron valdiviae* and *Chaetoceros neglectus* dominant, succeeded at times (e.g. St. 602) by almost pure *Corethron*. This may pass on to an association of the *Corethron—Rhizosolenia gracillima* type, which as we have already tried to show has been found most abundantly late in the year in comparatively open water. It seems that the proportion of *Rhizosolenia gracillima* increases with the age of the surface water—*up to a point*. Stations worked in Bransfield Strait always showed *Corethron* to be strongly dominant, but others worked in the southern half of Drake Passage (Sts. 609, 610) showed the two species in approximately equal numbers, as in the late hauls farther south in 1930.

At St. 601 between the Biscoe Islands and the Fallières coast, a neritic plankton essentially similar to that found at the Palmer Archipelago was encountered. The more numerous species were *Corethron valdiviae*, *Chaetoceros neglectus*, *Thalassiosira antarctica*, *Fragilaria antarctica*, *Nitzschia* sp. (branching colonies), and *Rhizosolenia truncata*, in that order of importance. Several of the rarer forms at this station were never met with far from land, for example, *Biddulphia polymorpha* and *Lycmophora* sp.

The very poor catch with *Corethron valdiviae* and *Fragilaria antarctica* dominant obtained at St. 560 is possibly representative of conditions before the ice has dispersed sufficiently for phytoplankton production to make much headway, as it was taken right up against the heavy pack to the north and west of Adelaide Island on the outward voyage. The last two stations analysed in Table XLIX were both made on the return trip some three weeks later, close in to the land after most of the ice had cleared away. At these stations, Sts. 598 and 599, a neritic association strongly resembling that found at the Palmer Archipelago was observed, the dominant species being: *Chaetoceros tortissimus*, *Ch. neglectus*, *Corethron valdiviae*, *Fragilaria antarctica* and *Thalassiosira antarctica*.

The analyses of the phytoplankton hauls from the stations worked between 66 and

68° S, 70 and 80° W, are given in Table L. From this it will be seen that they were of very moderate size and of such uniform composition that detailed description is unnecessary. All the stations were worked in or near the pack. *Corethron valdiviae* and *Chaetoceros neglectus* were dominant throughout, and there is a hint of grading off into the associations found still farther west in the increasing numbers of *Nitzschia seriata* and *Fragilaria antarctica* f. *bouvet* found at the more westerly of these stations.

Table LI gives the analyses of the hauls taken between 66° and 68° 10′ S, 80° and 90° W. Here the transition between the *Corethron valdiviae—Chaetoceros neglectus* association and the more varied plankton found farther west was even more clearly shown. At the two more easterly stations, near pack-ice, the above two species still predominated, and at the following station, St. 565, the catch was extremely scanty. From then on *Nitzschia seriata*, *Fragilaria antarctica* and f. *bouvet*, *Thalassiothrix antarctica*, *Chaetoceros dichaeta* and *Thalassiosira antarctica* became increasingly important, with the first-named species dominant, except at the last station, St. 576, where *Corethron valdiviae* and *Chaetoceros neglectus* were again the most numerous forms. This is perhaps significant in view of the fact that pack-ice was again present, though still farther west the rich *Nitzschia—Fragilaria—Thalassiothrix* association was encountered at two stations in the ice. Table LI also illustrates the interesting fact that by far the richest hauls were obtained at the two most northerly stations in comparatively old warm surface water of relatively high salinity. Apart from these two stations the hauls were of moderate and fairly uniform quantity, except for the very poor catch at St. 565.

The analyses from the most westerly stations included in Table LII complete this survey of the phytoplankton of the Bellingshausen Sea. It will be seen that the eight stations were situated between 67° 45′ and 69° 15′ S, 90° and 102° W, and that the phytoplankton was of a uniform and distinctive character throughout. Almost all the stations yielded richer catches than the generality of those to the eastward, and a much greater variety of species was present. At the first two stations *Chaetoceros neglectus* and to a less extent *Corethron valdiviae* were still of some importance. Otherwise the dominant forms in this rich and varied association were: *Thalassiothrix antarctica*, *Nitzschia seriata*, *Fragilaria antarctica* and more especially f. *bouvet*, and *Chaetoceros dichaeta*. Among the less numerous forms *Thalassiosira antarctica* and *Rhizosolenia truncata* were prominent, and *Chaetoceros criophilum* occurred in moderate numbers at all the stations. Fair numbers of *Ch. atlanticus* were also present at some stations, this being the only occasion on which this species was observed in quantity in the far south. Generally speaking it appears to find its optimum in the older, warmer Antarctic surface water just to the south of the convergence. The only other remarkable feature of these stations was the large number of *Ch. schimperianus* recorded at St. 568. The phenomenon of rafting of *Thalassiothrix antarctica* was very noticeable at these stations, groups of four and eight individuals, with similar poles adherent, being common. This was first noted by Schimper in material from the South-east Atlantic during the voyage of the 'Valdivia'.

SUMMARY

Summing up the conditions observed in the Bellingshausen Sea during this survey, it will be seen that several distinct associations were encountered. In the far south-west the rich *Nitzschia—Fragilaria—Thalassiothrix* association held sway, and evidently persisted to some extent as the water drifted away to the north-east, as the catches at the more northerly stations farther east (e.g. Sts. 566, 567 and 592) bear witness. This association provided catches rich in both species and individuals (owing to the predominance of small forms). Farther east along the ice-edge a poor phytoplankton was encountered, development having evidently only just begun in earnest with the break up of the ice. Here the dominant species were *Corethron valdiviae* and *Chaetoceros neglectus*. To the north-east, off Adelaide Island and the Biscoe Islands, a similar association was encountered at the earlier stations worked among the ice, but was evidently passing over into the *Corethron—Rhizosolenia gracillima* association as seen farther offshore on the return voyage. At a few of the later stations worked close inshore off Adelaide Island and farther north, an additional neritic association similar to that observed at the Palmer Archipelago was met with. If due allowance is made for this localization of the abundance of some of the more prominent species, the following list, together with Figs. 75 and 76, which show the total estimated numbers of organisms, and the dominant species at each station, should enable a fairly clear picture of the conditions over the whole area to be obtained. The list gives the twelve most numerous species in order of their total abundance at all forty-seven stations, together with the number of stations at which each occurred and their percentage of the estimated total of phytoplankton organisms. This estimate naturally leaves out of account the occasional presence of minute forms in uncountable colonies, but this was fortunately a rare occurrence in the Bellingshausen Sea.

	Total	%
Corethron valdiviae (46)	71,941,400	25·9
Nitzschia seriata (32)	52,609,000	19·0
Chaetoceros neglectus (40)	38,894,100 + ∞	14·0 +
Thalassiothrix antarctica (23)	33,962,500	12·3
Fragilaria antarctica f. *bouvet* (16)	22,689,800	8·2
F. antarctica (37)	14,552,300	5·2
Rhizosolenia alata f. *gracillima* (33)	8,759,850	3·2
Chaetoceros tortissimus (8)	7,800,000 +	2·8
Ch. dichaeta (31)	6,814,600	2·5
Thalassiosira antarctica (41)	5,197,700	1·9
Chaetoceros atlanticus (16)	2,239,300	0·8
Rhizosolenia truncata (30)	1,736,450	0·6
Other forms		3·6

Total estimated phytoplankton 277,193,350.

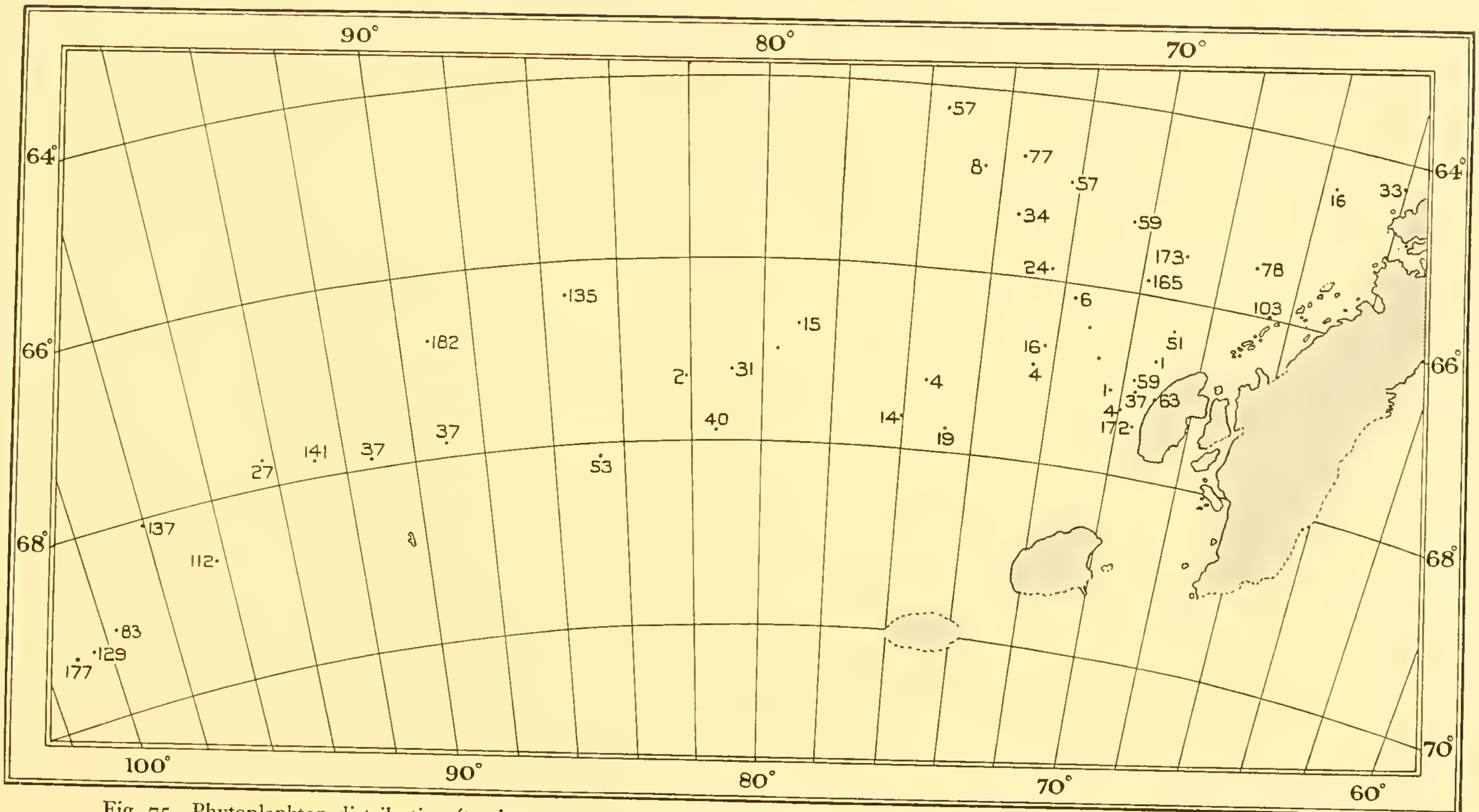

Fig. 75. Phytoplankton distribution (totals per 100–0 m. haul) in the Bellingshausen Sea, January 1931. 1 = one hundred thousand.

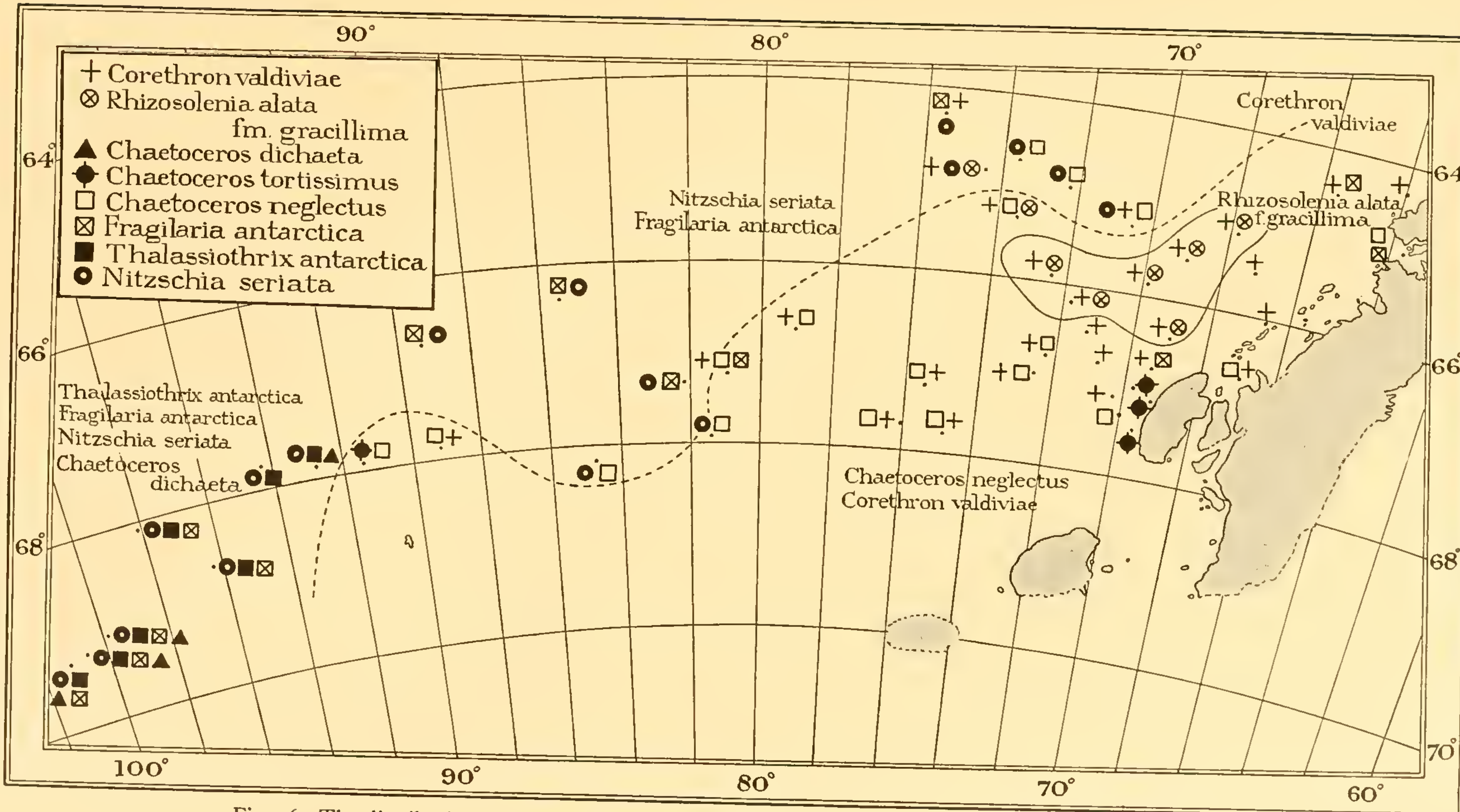

Fig. 76. The distribution of the principal phytoplankton species in the Bellingshausen Sea, January 1931.

CONCLUSIONS

If the above list is compared with that obtained from the results of the stations worked later in the previous year (p. 142), several differences will be remarked. These are in part due to the localization previously noted; thus the increased importance of forms like *Fragilaria antarctica*, *Nitzschia seriata* and *Thalassiothrix antarctica*, was obviously due to the rich association met with in the far south-west. The greater number and more even distribution of the stations are also partly responsible—if more stations had been worked in the localized *Corethron—Rhizosolenia gracillima* patch north of Adelaide Island these two forms would doubtless have formed a higher proportion of the whole. Nevertheless when full allowance has been made for these factors, the seasonal differences indicated in the description were very evident. The average number of organisms per station works out at 5,897,000 as against 8,264,900 for the previous survey, a difference sufficiently great to indicate a real comparative poverty despite the enormous errors to which such estimations are subject.

It seems, then, that the spring increase in the Bellingshausen Sea itself takes place very late in the year, and probably merges imperceptibly with the autumnal increase. So far as the evidence goes there is probably no minimum in March, as would appear to be the case in the Weddell Sea and in the older water farther north. In old water of Bellingshausen Sea origin farther north a spring increase undoubtedly occurs, though we have little evidence of that as yet.[1] The *Corethron—Rhizosolenia gracillima* association which was such a feature of the north-eastern portion of the Bellingshausen Sea, and has been observed to invade the western end of Bransfield Strait late in the season, very evidently develops late in the year in comparatively open water. In fact the retardation of the usual cycle in the Bellingshausen Sea would seem to be due chiefly to the persistence of the pack-ice up to comparatively low latitudes until the summer is far advanced. In the Weddell Sea pack-ice is equally abundant, but it appears to break up somewhat earlier in most years and passes away to the north-east in dense belts, traces of which often persist throughout the season round the South Orkney and the South Sandwich Islands. This is due to the more definite circulation induced by the northward prolongation of Graham Land. As a result comparatively open water is left behind the ice, thus permitting phytoplankton production to begin earlier in the higher latitudes, at any rate in the south-eastern portion of the Weddell Sea.

Further comparison between the Bellingshausen and Weddell Seas reveals striking differences in both the quality and quantity of the phytoplankton, though this is due in part to the fact that some of the observations from the Weddell Sea area were obtained in comparatively low latitudes. If all the sixty-seven analyses from the Bellingshausen Sea over the two seasons are lumped together, and compared with the sixty-one from the Weddell Sea area over the same period, it will be found that the average estimated number of organisms in the Bellingshausen Sea was only 8,475,000 against some 15,695,000, a sufficiently striking difference despite the many obvious factors that tend

[1] See however p. 72.

to invalidate such a comparison. The major qualitative differences between the floras can be seen from the following list of the dominant forms in the two areas arranged in order of importance.

Weddell Sea area:	Bellingshausen Sea:
Chaetoceros criophilum	*Corethron valdiviae*
Rhizosolenia styliformis	*Chaetoceros neglectus*
Nitzschia seriata	*Nitzschia seriata*
Corethron valdiviae	*Rhizosolenia alata* f. *gracillima*
Fragilaria antarctica	*Thalassiothrix antarctica*
Corethron valdiviae (spineless chains)	*Chaetoceros tortissimus*
Chaetoceros neglectus	*Fragilaria antarctica* f. *bouvet*
Thalassiosira antarctica	*F. antarctica*
Chaetoceros dichaeta	*Thalassiosira antarctica*
Thalassiothrix antarctica	*Nitzschia closterium*
Nitzschia closterium	*Eucampia antarctica*
Rhizosolenia alata	*Chaetoceros dichaeta*

It will be realized that there was a fairly close resemblance between the association met with far south in the Weddell Sea, and that in the extreme south-west of the Bellingshausen Sea. *Nitzschia seriata*, *Chaetoceros neglectus* and *Fragilaria antarctica* were prominent at both, together with *Rhizosolenia truncata*, one of the less important species not listed above. The Bellingshausen Sea association was distinguished by the abundant occurrence of *Thalassiothrix antarctica* and *Fragilaria antarctica* f. *bouvet*. The general similarity in the floras of old Antarctic surface waters immediately to the south of the convergence, irrespective of their history, has already been noted; it is in the rich intermediate zone lying roughly between 65 and 55° S that the differences are most marked. The possible reasons for this will become apparent when the problems of dispersal come to be discussed.

NOTES ON THE SPECIES

In these notes the species identified during the course of the work are arranged systematically, with a brief account of their distribution within the area and references to the more important literature. It is hoped that the latter will be sufficient to establish the identity of the species concerned. I am greatly indebted to Mr F. W. Mills for checking the references to all the diatom species, for providing some useful additional references, and for advice on various taxonomic points. Both the Antarctic plankton diatoms and the dinoflagellates of the warmer seas are obviously in need of thorough systematic revision, but to do this adequately would be a labour of years. It would, moreover, be outside the scope of the present paper, which merely attempts to describe the more important associations in the different areas, and by correlation with hydrological and other data to give some explanation of their distribution and seasonal abundance.

The Dinoflagellata were poorly represented within the more important Antarctic Zone, the greater number of the species recorded being obtained at the few stations worked farther north. From the material at our disposal it has therefore not been possible to do more than identify most of the species roughly and note the stations at which they occurred. The analyses upon which this paper is based were all made before the recent important paper of N. Peters (1932), on the Ceratia of the South Atlantic, was published. Some of his findings will doubtless lead to a clearer conception of the distribution of this group, notably his observations on their relation to the concentrations of nutrient salts present in the sea water.

In compiling the references, preference has been given where possible to works to which plankton workers are likely to have access. In many cases where more than one reference has been given, this has been done for the sake of the figures. Thus Mangin has usually little to add to the earlier descriptions, but his simple line drawings are often much more useful in working through large samples preserved in bulk, than other more elaborate figures. It will be realized that the distributional notes are based on material collected prior to 1932, and that further work may lead to considerable modifications.

Class DIATOMALES

Family MELOSIRACEAE, Schröder, 1911

Genus **Melosira**, Agardh, 1824

Melosira sol, Ehrb.

Karsten, 1905, pp. 70–72, pl. i, figs. 3–9.

A littoral Antarctic form observed in moderate numbers on one occasion at the South Sandwich Islands, and elsewhere only occasionally in Bransfield Strait and off Adelaide Island, close inshore. In Bransfield Strait it was present in the eddy of Weddell Sea water round Joinville Island, having apparently drifted north with other littoral forms, in the current through Antarctic Sound.

Melosira sphaerica, Karst.

Karsten, 1905, p. 70, pl. i, fig. 2.

Rarely and in small numbers in old Antarctic surface water.

Genus **Hyalodiscus**, Ehrenberg, 1845

Hyalodiscus chromatoaster, Karst.

Karsten, 1905, p. 74, pl. ii, figs. 4, 5.

Observed at one station only during the spring survey round South Georgia.

Hyalodiscus kerguelensis, Karst.

Karsten, 1905, p. 74, pl. ii, figs. 6, 7.

At two stations on the spring survey round South Georgia, abundant at St. WS 531 on the Burdwood Bank, just to the north of the Antarctic convergence; rare and sporadic farther south.

Family COSCINODISCACEAE, Schröder, 1911

Genus **Coscinodiscus**, Ehrenberg, 1839

Coscinodiscus bouvet, Karst.

Karsten, 1905, p. 83, pl. iii, fig. 9; Mangin, 1915, p. 52, fig. 36.

By far the most important member of the genus in southern waters at any distance from land. Recorded off South Georgia at a few spring stations, and more plentifully by Hardy (in press) later in previous years. Abundant at the South Sandwich Islands in February 1930 where it was found to be sinking to great depths as observed by Hardy. Consistently present in small numbers inshore on the southern side of Bransfield Strait, at the Palmer Archipelago, the Biscoe Islands and off Adelaide Island. Much more common in the Weddell than in the Bellingshausen Sea.

Coscinodiscus centralis, Ehrb.

Lebour, 1930, p. 39, figs. 16–18.

Forms apparently referable to this northern species were recorded at two stations of the spring survey round South Georgia, where it had previously been recorded by Hardy.

Coscinodiscus stellaris, Roper.

Gran, 1905, pp. 37, 38, fig. 40; Lebour, 1930, p. 49, pl. iii, fig. 9.

A form identical with the figures of European workers in all respects save that the stellate arrangement of the central punctae was not quite so definite was found abundantly in the inshore plankton round South Georgia, and at one station in the Bellingshausen Sea. Its determination rests principally on the highly characteristic girdle view.

Coscinodiscus spp.

Occurred at a majority of the Antarctic stations, but in entirely subordinate numbers. The difficulties of their identification being great, it was manifestly impossible to determine all the species in working through such a large number of plankton hauls (see pp. 17, 18).

Genus **Planktoniella**, Schütt, 1893

Planktoniella sol, Wallich.

Lebour, 1930, p. 50, pl. i, fig. 5.

An oceanic species of temperate and tropical seas. Recorded at four stations on the homeward voyage along the 30th W meridian, one in sub-tropical water, the other three in tropical surface water from 03° $17\frac{3}{4}'$ S to 14° $27\frac{1}{4}'$ N, i.e., at the extreme northern end of the line. Abundant in material from the Agulhas and Benguela streams which has not been described in detail for this paper.

Genus **Asterolampra**, Ehrenberg, 1845

Asterolampra sp.

A single individual was observed just north of the Equator in long. 30° W. It resembled *A. marylandica* in all respects but for the possession of eight radii instead of seven.

Genus Asteromphalus, Ehrenberg, 1844

The species of this genus encountered in our material are most easily distinguished by the number of radii, omitting the obsolete radius; thus *A. hepactis* is referred to as a "six-rayed" form.

Asteromphalus challengerensis, Castr.

Castracane, 1886, p. 134, pl. v, fig. 2.

This handsome eight-rayed form was present in moderate numbers at a few stations off South Georgia in spring. Farther south it was rare, occurring at only two stations in the Weddell and one in the Bellingshausen Sea. It was not observed in Bransfield Strait, but was present in small numbers at several stations in older Antarctic surface water farther north, apparently finding its optimum just to the south of the Antarctic convergence. Maximum in spring.

Asteromphalus hepactis (Bréb.), Ralfs.

Karsten, 1905, pl. viii, fig. 11; Lebour, 1930, p. 52, fig. 28 *a*.

An oceanic six-rayed form characteristic of warmer seas. Present at two stations on the 30th meridian in 31° 16¼′ S and 21° 13′ S, in sub-tropical and tropical surface waters respectively.

Asteromphalus hookerii, Ehrb.

Karsten, 1905, pl. viii, fig. 9; Rattray, 1888–89, p. 656.

An oceanic Antarctic species widely distributed in small numbers, absent from Bransfield Strait.

Asteromphalus parvulus, Karst.

Karsten, 1905, p. 90, pl. viii, fig. 14.

A five-rayed oceanic Antarctic species, which with *A. hookerii* has a more southerly distribution than other members of the genus. Present in moderate numbers round South Georgia at a few spring stations. Rare farther south in the Weddell Sea, but fairly frequent in the Bellingshausen Sea.

Asteromphalus regularis, Karst.

Karsten, 1905, p. 90, pl. viii, fig. 12.

This oceanic seven-rayed form was by far the commonest member of the genus in the material from the spring survey round South Georgia and in the northern part of the Weddell Sea area, where it was observed in moderate numbers at many stations. It was only recorded once in the Bellingshausen Sea itself, and was rare in older water of Bellingshausen Sea origin. Like *A. challengerensis* it appears to find its optimum in the older Antarctic surface water not far south of the convergence in spring, but it has a much wider range to the southward, especially in the Weddell Sea.

Genus Actinocyclus, Ehrenberg, 1839

Actinocyclus bifrons, Karst.

Karsten, 1905, p. 92, pl. ix, fig. 8.

Rare and sporadic in Antarctic surface water, chiefly in old water in comparatively low latitudes.

Actinocyclus corona, Karst.

Karsten, 1905, p. 92, pl. ix, fig. 6.

Observed in small numbers at one station only, near the South Sandwich Islands, also at one of the inshore stations in East Cumberland Bay, South Georgia.

Actinocyclus spp.

Indeterminate species of this genus were encountered in small numbers at a very few stations, all within the Antarctic Zone.

Genus **Hemidiscus**, Wallich, 1860

Hemidiscus (Euodia) cuneiformis, Wallich.

Gran, 1905, p. 45, fig. 51.

This, the *Euodia cuneiformis* of Schütt, 1896, was encountered at one station just north of the Equator, in long. 30° W.

Family THALASSIOSIRACEAE, Lebour, 1930

Genus **Thalassiosira**, Cleve, 1873

Thalassiosira antarctica, Comber.

Cleve, 1900, p. 919; Karsten, 1905, p. 73, pl. ii, figs. 2, 3; Mangin, 1915, p. 77, figs. 56, 57.

Mangin has already drawn attention to the fact that the name of this species was preoccupied by Cleve (1900), who described it from the manuscript with photograph sent to him by Comber. Karsten described it as a new species—under the same name! It was very widely distributed in all types of Antarctic surface water, and particularly abundant in the older mixed water, mainly of western Weddell Sea origin, to the south-west of South Georgia in spring. The spring maximum was very clearly shown by this species in all regions for which we have any seasonal data. It is a very variable form sometimes occurring in vast masses of gelatinous colonies, as depicted by Mangin, which render its numerical estimation impossible.

Genus **Coscinosira**, Gran, 1900

Coscinosira antarctica, Mangin.

Mangin, 1915, pp. 55–7, fig. 39.

Observed at a few stations to the south-west of South Georgia in spring only. Very difficult to distinguish from the last named when it occurs in bulk.

Family SKELETONEMACEAE, Lebour, 1930

Genus **Stephanopyxis**, Ehrenberg, 1844

Stephanopyxis spp.

Frequent round South Africa and to the east of Patagonia, referred to incidentally on p. 25.

Family LEPTOCYLINDRACEAE, Lebour, 1930

Genus **Dactyliosolen**, Castracane, 1886

Dactyliosolen antarcticus, Castr.

Castracane, 1886, p. 75, pl. ix, fig. 7; Karsten, 1905, p. 93, pl. ix, fig. 10.

An important species in spring and autumn just to the south of the Antarctic convergence. Frequently abundant farther south in the Weddell Sea after mid-season, but rare in the Bellingshausen Sea. A species with a well-marked secondary autumnal maximum.

Dactyliosolen flexuosus, Mangin.

Mangin, 1915, p. 57, fig. 40.

Similarly distributed but very much rarer than *D. antarcticus*.

Dactyliosolen laevis, Karst.

Karsten, 1905, p. 93, pl. ix, fig. 11.

Moderately abundant on the spring survey round South Georgia, particularly in the cold mixed water, mainly of western Weddell Sea origin, to the south-westward. Also met with at several stations farther south, much more commonly in the Bellingshausen than in the Weddell Sea.

Genus **Leptocylindrus**, Cleve, 1889

Leptocylindrus sp.

A small form closely resembling *L. minimus*, Gran, of the northern hemisphere. It was present at several stations far to the southward in both the Weddell and the Bellingshausen Sea, always in small numbers, but was rare in the older Antarctic surface water farther north. However, at one station to the north of Elephant Island it was moderately abundant, and roughly one-ninth of the individuals appeared to be parasitized by *Solenicola* sp.

Family CORETHRONACEAE, Lebour, 1930

Genus **Corethron**, Castracane, 1886

Corethron pelagicum, Brun.

Hustedt, 1930, p. 547, fig. 312.

Present in sub-tropical water round South Africa in material not yet worked up in detail; only referred to incidentally in the present paper.

Corethron valdiviae, Karst.

Castracane, 1886, p. 85, pl. xxi, figs. 12, 14, 15; Karsten, 1905, p. 101, pls. xii, xiii; Mangin, 1915, p. 50, fig. 54; Hustedt, 1930, p. 546.

Mangin found it impossible to distinguish satisfactorily between this species and *C. inerme*, Karst., owing to the presence of intermediate forms, and this is fully borne out by our abundant material. Hustedt draws attention to the inadequacy of Castracane's description and figures of the genotype *C. criophilum*, and concludes that what he really saw was *C. valdiviae*. However, he decides to retain Karsten's name for the species, on account of his being the first to describe it in accurate detail, and this seems to be the best course in view of the frequent references to *C. valdiviae* in subsequent literature.

The size variation within this species is enormous; in spring it has frequently been seen to be reproducing by both microspore and auxospore formation in the same samples. The spineless chain form encountered so abundantly round South Georgia during the abnormally warm season 1929–30, in sub-Antarctic surface water, and rarely farther south, should, we think, be regarded as a vegetative phase of this species, as intermediates with the terminal frustules bearing the characteristic whorl of bristles, have been observed in Bransfield Strait. Possibly this form of growth is induced by a temporary shortage of silica.

This is one of the most important of Antarctic plankton diatoms, being almost universally present, and only surpassed in numbers by the vast swarms of small Chaetocerids, *Thalassiosira antarctica* and *Nitzschia seriata*, met with in old water of the western Weddell Sea type, and, less noticeably, in old Bellingshausen Sea water; and by the large masses of *Chaetoceros criophilum* and *Rhizosolenia styliformis* present in the eastern Weddell Sea. All these have a much more localized distribution in time and space. Taking the year as a whole, *Corethron valdiviae* formed over 90 per cent of the phytoplankton in Bransfield Strait. It was the dominant form in the Bellingshausen Sea, except in the extreme west, and also at several stations in water of the eastern Weddell Sea type. In common with most of the other species it appears to reach its maximum in late spring, but maintains a high level of abundance throughout the greater part of the season.

Family BACTERIASTRACEAE, Lebour, 1930

Genus **Bacteriastrum**, Shadbolt, 1854

Bacteriastrum varians, Lauder.

Pavillard, 1924, p. 1086.

In his revision of this genus based mainly upon material collected in the Mediterranean and North Atlantic, Pavillard has shown that the forms there met with should not be referred to this species. He goes on to say that it is characteristic of the Indian Ocean and eastern tropical waters generally, and probably does not occur in the Atlantic at all. While this is almost certainly correct so far as the North Atlantic is concerned, we believe it to be present in the South Atlantic. Forms agreeing with the revised description of this species were met with in small numbers at three stations in sub-tropical and tropical surface waters, between 31 and $21\frac{1}{2}°$ S in long. 30° W. It was abundantly present in waters of the Agulhas stream, which is, of course, of Indian Ocean origin, and was also observed to the west of Saldanha Bay in the Benguela current. It would therefore seem quite possible for this species to spread into the tropical and sub-tropical South Atlantic via the Agulhas, the Benguela, and westwards in the south equatorial current.

Family RHIZOSOLENIACEAE, Schröder, 1911

Genus Rhizosolenia (Ehrb.), Brightwell, 1858

Rhizosolenia alata, Btw.

This ubiquitous and very variable species was very constantly present in all types of Antarctic surface water, without ever forming any large proportion of the phytoplankton. It was also fairly frequent in sub-Antarctic water, and was encountered more rarely farther north.

Rhizosolenia alata f. **gracillima**, Cleve.

Mangin, 1915, p. 70, fig. 51; Lebour, 1930, p. 90, fig. 59.

This attenuated variety was found to be very characteristic of the north-eastern portion of the Bellingshausen Sea, and also of the north-easterly drift from that region into the Bransfield Strait and the southern half of Drake Passage. In these waters the more normal forms were rare or absent.

Rhizosolenia antarctica, Karst.

Karsten, 1905, p. 95, pl. xi, fig. 1.

A rare species observed at two spring stations in the old eastern Weddell Sea water to the north-east of South Georgia, and at one station only to the westward in water of Bellingshausen Sea origin. Present in moderate numbers at one station far to the south-east in the Weddell Sea.

Rhizosolenia bidens, Karst.

Karsten, 1905, p. 98, pl. ix, fig. 13; Castracane, 1886, p. 73, pl. xxiv, fig. 14.

Abundant at one station in eastern Weddell Sea water, to the south-east of the South Sandwich Islands. Rare in the old water in the southern half of Drake Passage and on the spring survey round South Georgia. Karsten concludes that this was the problematical form observed by Castracane. He himself figures the peculiar form assumed by this species when in process of auxospore formation, but owing to the scale gives no idea of its large size as compared with other members of the genus.

Rhizosolenia castracanei, H. Péragallo.

Lebour, 1930, p. 103, fig. 75.

Observed at one station almost on the tropical convergence in 26° 06½′ S, 30° W.

Rhizosolenia chunnii, Karst.

Karsten, 1905, p. 99, pl. xi, fig. 5.

This small Antarctic form, which typically occurs in long chains and closely resembles the northern form *R. faröense*, Ostenf., was observed in the southern half of Drake Passage in April, and was subsequently found to be of moderately frequent occurrence in the Bellingshausen Sea. It was fairly abundant round South Georgia during the spring survey, showing a maximum where the Bellingshausen Sea influence was strongest. In the Weddell Sea area it was observed at two stations only, both in low latitudes (57 and 59° S), in moderately large numbers.

Rhizosolenia crassa, Schimp.

Karsten, 1905, p. 99, pl. xi, fig. 6.

Rare in this material, being recorded from three stations far to the south in the Weddell Sea in small numbers, and from one station to the north-west of South Georgia. Some of Schimper's notes (Karsten, 1905, p. 68) and recent reports by Mr John indicate that it may occur more abundantly in sub-Antarctic water at certain times of year.

Rhizosolenia curva, Karst.

Karsten, 1905, p. 97, pl. xi, fig. 2; *R. curvata*, Zacharias, 1905, p. 121, phot. in text.

Karsten's manuscript was received in April 1905, and Zacharias' paper appeared in July, so that it seems that Karsten's name for this species should be given priority. The figure given by Zacharias is very good, illustrating clearly the large size of this species, and the association in which we have found it most abundantly. The only peculiar point in his account is that the sample was said to have been collected some 300 sea miles south of the Horn, i.e. well within the Antarctic Zone, whereas the association so clearly illustrated in the photomicrograph is precisely the same as that which we encountered in sub-Antarctic waters to the south-east of the Falkland Islands. The forms included have, however, been seen rarely to the south of the convergence, so that it is perhaps unwise to stress this point unduly, particularly as to the south-west of the Horn the convergence may lie as far south as 59°.

In our collections this was a typically sub-Antarctic species, found rarely south of the convergence, usually in an apparently dying condition. Karsten's extracts from Schimper's field notes indicate a similar distribution in the South-eastern Atlantic.

Rhizosolenia polydactyla, Castr.

Castracane, 1886, p. 71, pl. xxiv, fig. 2; Mangin, 1915, pp. 73-5, fig. 52.

This form is distinguished from *R. styliformis* by the closeness of the rings, the more bluntly rounded apexes of the frustules, their shorter mucron, and their greater diameter in proportion to their length. Often the frustules, united in pairs, are slightly curved as depicted by Mangin. This was found to be the dominant form in the sub-Antarctic association to the south-east of the Falkland Islands in March 1930, and it was observed in the vicinity of the Antarctic convergence on several other occasions. It was also encountered rarely farther south, particularly in the Bellingshausen Sea, whence Mangin had previously reported it, the frustules being in most cases devoid of contents. A reason for this apparently anomalous distribution is suggested in the discussion of the possible effect of sub-surface currents as transporting agents on p. 188.

Rhizosolenia rhombus, Karst.

Karsten, 1905, p. 95, pl. x, fig. 6.

Observed in moderate numbers at two stations only, in about 60° S latitude, one to the south-east of the South Sandwich Islands, the other in long. 58° W.

Rhizosolenia simplex, Karst.

Karsten, 1905, p. 95, pl. x, fig. 1.

A rather rare species widely distributed in small numbers in the older Antarctic surface water in the Scotia Sea, and round South Georgia. Very rare farther south, occurring at only three stations in the Bellingshausen and one in the Weddell Sea.

Rhizosolenia styliformis, Btw.

Karsten, 1905, p. 96, pl. x, fig. 5.

Great size variation is exhibited by this species, which appears to be almost cosmopolitan, occurring in all the types of surface water investigated. The specific identity of the individuals from warm seas with those obtained in the Antarctic is doubtful, but the resemblance in form is so close as to justify their inclusion until further evidence is forthcoming.

This species formed an important part of the association in water of the eastern Weddell Sea type, in which it was sometimes strongly dominant, being present in enormous numbers. It was also abundant in the older mixed water, mainly of western Weddell Sea origin, to the south of South Georgia during the spring survey. *R. styliformis* was very generally present in the Bellingshausen Sea, and in sub-Antarctic waters during March, but in much smaller numbers. A few individuals apparently referable to this species were observed at one sub-tropical and three tropical stations.

Rhizosolenia torpedo, Karst.

Karsten, 1905, p. 95, pl. x, fig. 2.

A rather rare species distributed very similarly to *R. simplex* but absent from the Bellingshausen Sea.

Rhizosolenia truncata, Karst.

Karsten, 1905, p. 97, pl. x, fig. 3.

The most important member of the genus in the far south, near the fast ice and at the Palmer Archipelago. Moderately abundant at many stations in the Bellingshausen and Weddell Seas. Confined almost entirely to the eddy of Weddell Sea water in Bransfield Strait. Found rarely and in small numbers farther north at the beginning and end of the season.

Family CHAETOCERACEAE, Schröder, 1911

Genus **Chaetoceros**, Ehrenberg, 1844

Chaetoceros atlanticus, Cleve.

Mangin, 1915, pp. 28–34, figs. 9–11.

A very common species of the older Antarctic surface water of comparatively low latitudes, and one of the most frequent invaders of the sub-Antarctic Zone (it is well known from temperate seas in the northern hemisphere). Found also far to the southward in both the Weddell and Bellingshausen Seas after mid-season, but in much smaller numbers, being largely succeeded by *Ch. dichaeta* in higher latitudes.

Chaetoceros castracanei, Karst.

Karsten, 1905, p. 116, pl. xv, fig. 1.

Rather rare and very sporadic in its occurrence; in all types of Antarctic surface water but as a rule not very far south.

Chaetoceros concavicornis, Mangin.

Lebour, 1930, p. 122, fig. 88.

A few individuals apparently referable to this species were observed at one station just to the south of the sub-tropical convergence.

Chaetoceros criophilum, Castr.

Mangin, 1915, pp. 34–6, figs. 13, 14; Hustedt, 1930, p. 667.

Hustedt is satisfied that Mangin's distinction between this species and the northern *Ch. criophilus*, Castr., of Gran, is correct. The name should properly be applied exclusively to the Antarctic form (Mangin, 1917).

This is one of the most widespread and abundant of all the Antarctic plankton diatoms. It was often dominant in water of the eastern Weddell Sea type, and was abundant also in the mixed water south and west of South Georgia during the spring survey. It was of frequent occurrence in the Bellingshausen Sea also, but was not nearly such an important constituent of the phytoplankton there. It appears to reach its optimum in somewhat lower latitudes, and late in the season has often been observed north of the Antarctic convergence, in an apparently dying condition.

Chaetoceros cruciatum, Karst.

Karsten, 1905, p. 116, pl. xv, fig. 5.

Rarely, in old Antarctic surface water.

Chaetoceros curvatum, Castr.

Mangin, 1915, p. 36, figs. 15, 16.

Present at a few stations in all types of Antarctic surface water, always in small numbers.

Chaetoceros decipiens, Cleve.

Lebour, 1930, p. 126, fig. 91.

A few individuals, agreeing exactly with this northern form, were observed at one station in sub-Antarctic water.

Chaetoceros dichaeta, Ehrb.

Mangin, 1915, pp. 37–45, figs. 17–26.

This variable species was found to be very characteristic of the phytoplankton far to the south in the Weddell Sea, and in the extreme south-west of the Bellingshausen Sea. It was also abundant on the spring survey round South Georgia, and at a few other stations in comparatively old water in the Scotia Sea. In no case was it found to be the most numerous species, but at the stations indicated was present in uniformly large numbers.

Chaetoceros didymus, Ehrb.

Lebour, 1930, p. 103, fig. 97.

Forms apparently referable to this species, which has hitherto been regarded as characteristic of warmer seas, were from time to time recorded in all types of Antarctic surface water. Undoubted *Ch. didymus* was observed at one station near the tropical convergence.

Chaetoceros flexuosus, Mangin.

Mangin, 1915, p. 45, fig. 27, pl. i, fig. 7.

A rather rare species mainly confined to a few stations to the north-east of the Bellingshausen Sea, reaching its maximum abundance near land. Present also in the eddy of western Weddell Sea water round Joinville Island into Bransfield Strait, but not observed elsewhere in the Weddell Sea. Moderately abundant at one station in the Scotia Sea, in old water of Bellingshausen Sea origin very early in the season.

Chaetoceros neglectus, Karst.

Karsten, 1905, p. 119, pl. xvi, fig. 5; Mangin, 1915, p. 47, fig. 29.

This minute species was found very abundantly in all types of Antarctic surface water, the only areas in which it was comparatively unimportant being the eastern Weddell Sea, and Bransfield Strait. It was outnumbered by larger species in the former, and mainly confined to the eddy of Weddell Sea water at the eastern end of the latter area. *Ch. neglectus* was most abundant on the spring survey round South Georgia, being one of the dominant forms in the rich phytoplankton to the south-west, where it was frequently present in such numbers as to defy estimation. More common in the Bellingshausen than in the Weddell Sea farther southward, but frequently abundant in both areas.

Chaetoceros radiculum, Castr.

Castracane, 1886, p. 79; Karsten, 1905, p. 117, pl. xv, fig. 3; Mangin, 1922, pp. 59–61, fig. 7.

Mangin holds that this species should be regarded as a form of *Ch. schimperianus*, Karst., as in the chain form only the bristles on the distal valves of the terminal frustules are swollen into the characteristic bulbous projections upon which the species was founded, the individuals in the middle of the chains resembling *Ch. schimperianus* very closely. Both the previous workers had noted this fact, however, though Karsten does not refer to the resemblance to the other species. Though we have found chains showing the "intermediate" stage and agreeing with Mangin's figures very closely, it is not at all clear that the species are really one and the same. In the first place, the bristles on the middle cells of the chains, though variable, were always shorter and less strongly curved than those of typical *Ch. schimperianus*, and in the second, chains of the latter were frequently present in samples in which prolonged examination failed to reveal any *Ch. radiculum*. The question is one requiring detailed examination such as is not possible when working through large series of plankton samples. For the present we think it best to retain the two species as distinct. Our intermediates were all found at St. 461 to the north-east of the South Sandwich Islands, early in spring. The only other stations at which *Ch. radiculum* was observed were in the old water of Bellingshausen Sea origin in the western part of the Scotia Sea. There it occurred at one early spring station and at three worked in late autumn.

Chaetoceros schimperianus, Karst.

Karsten, 1905, p. 117, pl. xv, fig. 2; Mangin, 1915, p. 48, figs. 30–2.

Abundant on the spring survey round South Georgia, mainly to the south-west. Fairly frequent, but in much smaller numbers, farther south in both the Weddell and the Bellingshausen Seas. Rare in Bransfield Strait.

Chaetoceros socialis, Lauder.

Lebour, 1930, p. 166, fig. 128; Gran, 1905, p. 96, fig. 123.

Extremely sporadic in its occurrence, but usually dominant when present. The colonies in rich samples are so closely intermingled that counting is impossible even at great dilutions, and they frequently render the counting of the other species present very difficult. Dominant to the south-west of South Georgia during the spring survey, in the eddy of Weddell Sea water round Joinville Island in December, in the far south of the Weddell Sea, at two stations at the Palmer Archipelago and at one in the Bellingshausen Sea.

Chaetoceros tortissimus, Gran.

Mangin, 1915, p. 49, fig. 33.

Very local in its distribution, but one of the dominant forms in inshore waters to the north-east of the Bellingshausen Sea and at the Palmer Archipelago. Abundant also in the eddy of Weddell Sea water into the eastern end of Bransfield Strait. Present at only one station off South Georgia, and one (far south) in the Weddell Sea.

Family BIDDULPHIACEAE, Lebour, 1930

Genus **Biddulphia**, Gray, 1832

Biddulphia (Triceratium) arcticum, Btw.

Karsten, 1905, p. 121, pl. xvi, fig. 7.

This littoral form was observed at one station to the north of Joinville Island, where there was apparently a current flowing northward through Antarctic Sound.

Biddulphia polymorpha, Mangin.

Mangin, 1915, pp. 23–7, figs. 2–5.

Another littoral form, observed on only three occasions, twice in the vicinity of the Biscoe Islands and once in East Cumberland Bay, South Georgia.

Biddulphia striata, Karst.

Karsten, 1905, p. 122, pl. xvii, figs. 2, 3; Mangin, 1915, p. 22, fig. 1.

Widely distributed in all types of Antarctic surface water, but rare in the eastern Weddell Sea. Abundant round South Georgia on the spring survey, mainly to the south, also at the eastern end of Bransfield Strait from spring to midsummer, and still later in the year at the Palmer Archipelago. Off South Georgia it shows a definite spring maximum.

Genus **Hemiaulus**, Ehrenberg, 1844

Hemiaulus hauckii, Grun.

Lebour, 1930, p. 183, fig. 143.

Observed at three stations in the tropical Zone on the homeward voyage. Most numerous at St. 679 in the immediate vicinity of the tropical convergence.

Family EUCAMPIACEAE, Schröder, 1911

Genus **Eucampia**, Ehrenberg, 1839

Eucampia antarctica, Mangin.

Mangin, 1915, pp. 58–64, figs. 41–4.

Mangin has shown that the two species *Moelleria antarctica*, Castr., and *Eucampia balaustium*, Castr., should be united, as he observed both forms and intermediates in the same chains; and he found that *E. balaustium* was merely the winter form. Numerous examples in our abundant material fully bear this out. The majority of the stations being worked during the southern summer the *moelleria* form was naturally much the more common of the two, and the long spiral chains to which Mangin assigns varietal rank were observed only in spring. Our own view, subject to further investigation, is that the torsion is a mechanical effect of the extreme length of the chains during the period of rapid vegetative growth in spring. This species was abundant in all types of Antarctic surface water, and particularly so on the spring survey round South Georgia when it reached its maximum to the south-west of the island. Other regions in which it was important were at the eastern end of Bransfield Strait up to mid-season, and at the Palmer Archipelago even later.

Family FRAGILARIACEAE, Schröder, 1911

Genus **Fragilaria**, Lyngbye, 1819

Fragilaria antarctica, Castr.

Karsten, 1905, p. 122, pl. xvii, fig. 7.

This is not the *F. antarctica* of Schwartz which should probably be referred to *F. striatula*, Lyng., and not to Castracane's species as Karsten has done.

One of the most important of Antarctic phytoplankton organisms. Abundant in all types of surface water within the Antarctic convergence, more particularly in front of the advancing ice-edge in spring and farther south later in the season. Principal concentrations observed: South Georgia (spring survey, south-west), south-west Bellingshausen Sea, Weddell Sea eddy in Bransfield Strait, and far south in the Weddell Sea.

Fragilaria antarctica f. bouvet, Karst.

Karsten, 1905, p. 123, pl. xvii, fig. 10.

More localized than the last named but generally even more abundant when present, and showing an even closer relation to pack-ice. Abundant along with the type-form in the areas indicated above.

Genus **Synedra**, Ehrenberg, 1830

Synedra spathulata, Schimp.

Karsten, 1905, p. 124, pl. xvii, fig. 11.

Widely distributed but never common in this material. Present in moderate numbers at several stations in the Bellingshausen Sea, especially in 1929–30, more rarely in the Scotia Sea and southern Weddell Sea.

Genus **Thalassiothrix**, Cleve and Grun, 1880

Thalassiothrix antarctica, Schimp.

Karsten, 1905, p. 124, pl. xvii, fig. 12.

Abundant to the south-west of the Bellingshausen Sea, 1930–1, where bundles of four and eight frustules were common. These rafts of frustules attached at similar poles were first observed by Schimper. Moderately frequent in older water farther north, but not observed far south in the Weddell Sea. Moderately abundant on both surveys round South Georgia, in spring mainly to the west, and in the later survey of the abnormally warm season 1929–30, to the east. On this occasion the frustules were of uniformly small size and occurred only singly or in pairs.

Thalassiothrix spp.

A few individuals, mostly bearing a strong resemblance to *Th. longissima*, Cleve and Grun., were encountered at one or two stations round South Georgia and in Bransfield Strait.

Family TABELLARIACEAE, West, 1927

Genus **Lycmophora**, Agardh, 1832

Lycmophora lyngbyei (Kutz.), Grun.

Lebour, 1930, p. 203, fig. 165.

This littoral form grows abundantly on the kelp round South Georgia and on the *Coronula* shells on Humpback whales. It is also occasionally found in the inshore plankton and in the film of *Cocconeis ceticola*, Nelson, on the skins of the southern rorquals.

Lycmophora sp.

A large and probably distinct species was observed in the plankton at a few inshore stations in Bransfield Strait and the Bellingshausen Sea. This may prove to be *L. reichardtii*, recorded (but not figured) by Mangin from the same region.

Family ACHNANTHACEAE, West, 1927

Genus **Achnanthes**, Bory, 1822

Achnanthes spp.

Observed at a very few inshore stations and on pack-ice.

Genus **Cocconeis**, Ehrenberg, 1838

Cocconeis costatum, Greg.

Gregory, 1855, p. 39.

A small form probably referable to this inshore species was observed at one inshore station in Bransfield Strait.

Family NAVICULACEAE, West, 1927

Genus **Navicula**, Bory, 1822

Navicula oceanica, Karst.

Karsten, 1905, p. 126, pl. xviii, fig. 4.

Present in moderate numbers at seven stations round South Georgia during the spring survey, and at a few other stations, all in comparatively old Antarctic surface water, in the Bellingshausen Sea.

Navicula pellucida, Karst.

Karsten, 1905, p. 126, pl. xviii, fig. 12.

More numerous than the last named round South Georgia in spring and present in moderate numbers at a few stations farther south in both the Weddell and Bellingshausen Seas.

Navicula spp.

Small indeterminate members of this genus occurred with some frequency in small numbers, especially close up to the ice-edge.

Genus **Tropodoneis**, Cleve

Tropodoneis antarctica (Grun.), Cleve.

Karsten, 1905, p. 128, pl. xviii, fig. 7.

At one station only, on the spring survey round South Georgia.

Genus **Amphora**, Ehrenberg, 1840

Amphora spp.

Observed on one or two occasions in the vicinity of pack-ice.

Genus **Cymbella**, Agardh, 1822

Cymbella spp.

Observed on pack-ice and rarely in the plankton in close proximity to pack-ice. One species occurs constantly on the baleen of southern rorquals at South Georgia.

Genus **Amphiprora**, Ehrenberg, 1830

Amphiprora sp.

Another ice form observed rarely in the plankton.

Family NITZSCHIACEAE, Schröder, 1911

Genus **Nitzschia**, Hassal, 1845

Nitzschia closterium (Ehrb.), Wm. Sm.

Mangin, 1915, p. 69, fig. 48.

Confined to the far south in the Bellingshausen and Weddell Seas, close in to the land or the fast-ice. Very rarely observed in small numbers in the older water farther north.

Nitzschia seriata, Cleve.

Lebour, 1930, p. 213, fig. 178.

One of the most abundant of all the phytoplankton organisms in Antarctic surface water of all types. A dominant species south of 63° in the Weddell Sea, and at several stations in the western part of the Bellingshausen Sea. Frequently abundant in older water farther north, especially just to the south of the Antarctic convergence in the Scotia Sea at the beginning and end of the season.

Nitzschia ? sigmoidea (Nitzsch), Wm. Sm.

Schütt, 1896, fig. 259, p. 142.

A form corresponding very closely to Schütt's figure was encountered at one station to the south-east of the South Sandwich Islands.

Nitzschia sp. "A."

This form occurred at several stations to the south-west of South Georgia in spring, when the pack-ice lay far to the north, and also near the ice-bound Biscoe Islands to the north-east of the Bellingshausen Sea. It formed branching colonies closely resembling *N. frigida*, Grun., of the northern hemisphere.

Nitzschia sp.

An indeterminate form assigned to this genus was encountered at one station in sub-Antarctic water.

Class FLAGELLATA

Sub-Class **DINOFLAGELLATA**

Family GYMNODINIIDAE, Kofoid

Genus **Gymnodinium**, Stein (emended Kofoid and Swezy)

Gymnodinium (Pyrocystis) lunula f. lunula, Apstein.

Paulsen, 1908, p. 111, figs. 154, 155.

Observed at two stations in the tropical South Atlantic.

Gymnodinium (Pyrocystis) lunula f. globulus, Apstein.

Paulsen, 1908, p. 110, fig. 152.

Also observed at two tropical stations.

Gymnodinium spp.

Observed at one tropical station. The "red-water" sometimes seen near the Cape of Good Hope is probably due to vast swarms of this genus.

Family NOCTILUCIDAE, Saville Kent

Genus **Noctiluca**, Suriray

Noctiluca scintillans, Macartney.

Lebour, 1925, p. 69, fig. 17.

Observed in small numbers at tropical stations between $15\frac{1}{2}°$ S and $14\frac{1}{2}°$ N on the 30th meridian, also in water of the Benguela current of Saldanha Bay.

Family DINOPHYSIDAE, Kofoid and Michener

Genus **Phalacroma**, Stein

Phalacroma minutum, Cleve.

Lebour, 1925, p. 78, fig. 20 *d*.

Observed at the two most northerly tropical stations in 30° W long.

Phalacroma rudgei, Murr. and Whitt.

Paulsen, 1908, p. 20, fig. 22.

At one tropical station north of the Equator.

Genus **Dinophysis**, Ehrenberg

Dinophysis ellipsoidea, Mangin.

Mangin, 1922, p. 72, fig. 15.

Noted at one station far south in the Weddell Sea.

Dinophysis ovum, Schütt.

Paulsen, 1908, p. 17, fig. 16.

Observed at several stations in the Bellingshausen Sea: probably many of the *Dinophysis* spp. recorded in the Antarctic Zone should be referred to this species.

Dinophysis rotundata, Clap. und Lachm.

Paulsen, 1908, p. 17, fig. 18.

At a few stations in the Bellingshausen Sea.

Dinophysis schuettii, Murr. and Whitt.

Paulsen, 1908, p. 18, fig. 19.

Observed at one tropical station on the homeward voyage.

Dinophysis tripos, Gourret.

Lebour, 1925, p. 82, fig. 22.

This is the *D. homunculus* var. *tripos* of Paulsen. It was not observed in the material examined in detail for this paper, but has a very significant distribution in the South Atlantic (see p. 25), being apparently confined to the eastern portion. It was moderately abundant in the phytoplankton collected round the Cape of Good Hope, often in catena, which rendered it one of the most conspicuous species during the preliminary examinations on board.

Dinophysis spp.

Present in very small numbers at about half the stations worked in the Antarctic Zone. As they never formed any important proportion of the phytoplankton their identification has been deferred.

Genus **Amphisolenia**, Stein

Amphisolenia globifera, Stein.

Paulsen, 1908, p. 20, fig. 23.

Observed at one tropical station.

Genus **Ornithocercus**, Stein

Ornithocercus steinii, Mangin.

Mangin, 1922, p. 75, fig. 17.

Observed at one station in sub-tropical water, in long. 30° W.

Ornithocercus magnificus, Stein.

Mangin, 1922, p. 74, figs. 18, 19.

Very generally present in small numbers in the tropics.

Family PERIDINIIDAE, Kofoid

Genus **Goniodoma**, Stein

Goniodoma polyedricum (Pouch.), Jorg.

Lebour, 1925, p. 90, fig. 26.

At one station in the tropical Zone, in long. 30° W.

Genus **Goniaulax**

Goniaulax polygramma, Stein.

Lebour, 1925, p. 94, pl. xiii, figs. 4 *a–c*.

A form apparently referable to this species was observed at one station in sub-Antarctic water in long. 30° W.

Goniaulax sp.

Observed at one sub-tropical station in long. 30° W.

Genus Peridinium, Ehrenberg

Peridinium tripos, Murr. and Whitt.

Paulsen, 1908, p. 63, fig. 82.

Observed at one sub-tropical station, and at the northernmost station on the homeward voyage when sub-tropical conditions were again being approached.

Peridinium antarcticum, Schimper.

Karsten, 1905, p. 131, pl. xix, fig. 1.

The only common member of the genus within the Antarctic Zone. Abundant round South Georgia during the abnormally warm 1929–30 season, and frequent just to the south of the Antarctic convergence in the Scotia Sea. Rare farther south.

Peridinium elegans, Karst.

Karsten, 1905, p. 132, pl. xix, fig. 5.

Present in very small numbers to the north of the Weddell Sea area early and late in the season.

Peridinium turbinatum, Mangin.

Mangin, 1922, p. 78, fig. 20.

At one station east of the South Sandwich Islands.

Peridinium oceanicum, Vanh.

Lebour, 1925, p. 120, fig. 26 *b*.

Observed at one tropical station in long. 30° W.

Peridinium globulus, Stein.

Lebour, 1925, p. 129, fig. 40.

At one tropical station.

Peridinium spp.

Minute species belonging to this genus were present at a number of stations in the Antarctic Zone in very small numbers.

Genus Pyrophacus, Stein

Pyrophacus horologicum, Stein.

Lebour, 1925, p. 139, pl. xxix, figs. 4 *a–c*.

Observed at three stations in the tropics on the homeward voyage.

Genus Ceratium, Schrank

Ceratium candelabrum (Ehrb.), Stein.

Lebour, 1925, p. 143, pl. xxx, fig. 2.

At one tropical station in long. 30° W.

Ceratium lineatum (Ehrb.), Cleve.

Lebour, 1925, p. 145, fig. 45.

One of the more numerous forms in the sparse phytoplankton of warm seas, observed at two sub-tropical and five tropical stations in long. 30° W.

Ceratium pentagonum, Gourret.

Mangin, 1922, p. 67, fig. 12.

Intermediates between the southern f. *grandis* and f. *longisetum* (or *robustum*) were common just to the north of the Antarctic convergence, and at some stations in sub-Antarctic water f. *longisetum* definitely predominated.

Ceratium pentagonum f. grandis, Mangin.

Abundant round South Georgia during the abnormally warm summer of 1929–30 and frequently encountered in the extreme north of the Antarctic Zone. It was also met with very rarely farther south.

Ceratium fusus, Ehrb.

Lebour, 1925, p. 146, pl. xxxi, figs. 1, 46 *a*.

This species showed a well-marked maximum in sub-Antarctic water, but attenuated forms were also found fairly frequently in tropical and sub-tropical water (see p. 23).

Ceratium tripos f. truncata, Lohm.

Paulsen, 1908, p. 79, fig. 106.

Observed at two stations in sub-Antarctic water.

Ceratium bucephalum, Cleve.

Lebour, 1925, p. 151, fig. 47 *b*, *c*.

Present at the three most northerly tropical stations in long. 30° W.

Ceratium gibberum f. sinistrum, Gourret.

Lebour, 1925, p. 153, fig. 49 *b*.

Present at the five most northerly stations in long. 30° W, which probably tend to fall in the comparatively rich zone round the Cape Verde Islands (cf. Peters, 1932).

Ceratium varians, Mangin.

Mangin, 1922, p. 70, fig. 14.

Present at several sub-tropical and tropical stations.

Ceratium limulus, Gourret.

Karsten, 1905, p. 133, pl. xix, fig. 11.

Observed at three tropical stations.

Ceratium spp.

Small indeterminate members of this genus were recorded at several stations; those in the sub-Antarctic Zone appeared to be mainly *C. fusus* which had recently divided.

Genus **Podolampas**, Stein

Podolampas bipes, Stein.

Lebour, 1925, p. 160, fig. 52 *b*.

At three tropical stations.

Sub-Class SILICOFLAGELLATA

These were not identified specifically, but were of tolerably constant occurrence in the more oceanic areas within the Antarctic Zone, frequently in moderately large numbers. Most of them appeared to be referable to the well-known forms *Dictyocha fibula*, Ehrb., and *Distephanus speculum* (Ehrb.), Haeckel.

SCHIZOPHYCEAE, etc.

Pelagothrix spp.

Observed in very small numbers at one tropical and at one sub-tropical station.

Trichodesmium thiebautii, Gomont.

Wille, 1903, p. 17, fig. 13.

Observed sparsely at four stations towards the northern end of the line worked in long. 30° W. Vast swarms discolouring the surface of the sea were encountered in about 40° S between Montevideo and South Georgia (see p. 26).

Richelia intracellularis, Schmidt.

Wille, 1903, p. 26, fig. 23.

Endophytic in *Rhizosolenia styliformis* at one tropical station.

Coccosphaeriales.

These are known to be important producers in the warm and temperate seas in the South Atlantic. The method of collection employed was that most suitable for obtaining a working knowledge of the almost entirely diatomaceous phytoplankton of Antarctic surface waters—viz. vertical net hauls. Unfortunately nets do not capture these organisms, and as our work in warmer waters was not extensive, other methods were not employed. At one tropical station small numbers of *Coccolithophora leptopora*, Murr. and Blackm., were observed.

Phaeocystis brucei, Mangin.

Mangin, 1922, p. 82, figs. 25–7.

This species is known to occur in our southern area, and was abundant in the pack-ice to the east of South Georgia in October 1930 (early spring), where it formed the food of post-larval *Euphausia superba*. Not observed at any of the phytoplankton stations. Undoubtedly very sporadic in its occurrence.

Halosphaera viridis, Schmitz.

Lemmermann, 1903, p. 38, fig. 128.

Also known to occur in our southern area, but not observed in this material. Possibly confounded with the numerous microspores of *Chaetoceros criophilum* and *Corethron valdiviae* at some stations round South Georgia in spring.

GENERAL CONCLUSIONS

SUMMARY OF OBSERVATIONS

Full summaries of the observations within each area will be found at the ends of the several sections; the following brief synopsis of the more important features is designed to facilitate the consideration of the section on limiting factors which follows.

During the survey round South Georgia in the warm summer of 1929–30 a very poor phytoplankton association was encountered with the following species dominant: *Corethron valdiviae*, entirely in the spineless chain form, *Peridinium antarcticum*, *Ceratium pentagonum* f. *grandis*, and, more numerous than the dinoflagellates but much less widely distributed, *Thalassiothrix antarctica*. On this occasion the richest hauls were all obtained to the east and south-east of the island at some distance from the land.

In the following season, an unusually cold one, the survey was made in spring just after the pack-ice had disappeared from the neighbourhood of the island, and an extremely rich phytoplankton was met with. Species as well as individuals were exceedingly numerous, but it was possible to recognize three definite associations. In the tongue of eastern Weddell Sea surface water the large species *Chaetoceros criophilum*, *Corethron valdiviae*, and *Rhizosolenia styliformis* predominated over smaller forms. To the north of the island, and inshore off the north-east coast, older mixed water with an association in which *Corethron valdiviae* was strongly dominant was evidently in the main derived from this source.

To the south and south-west of the island the phytoplankton reached its maximum in water mainly of western Weddell Sea origin with a slight admixture from the Bellingshausen Sea. Here there was a vast profusion of small forms, *Chaetoceros socialis*, *Thalassiosira antarctica*, *Chaetoceros neglectus*, and *Fragilaria antarctica* being the most important, and *Corethron* present only in small numbers. To the north-west a few stations with a comparatively poor phytoplankton, with small species dominant, were worked in water of Bellingshausen Sea origin.

Dinoflagellata were extremely rare round South Georgia on this survey. Other work later in the season indicated a slight increase in their number, but nothing approaching the abundance of the previous abnormally warm summer. Moreover the diatom plankton never deteriorated to anything like the same extent.

Of the Scotia Sea little can be said for want of observations at mid-season, when the research ships were engaged farther south. South of the convergence in Drake Passage a rich phytoplankton with *Nitzschia seriata* and small Chaetocerids dominant was found in April (autumn), and a similar association, with in addition a large proportion of *Thalassiosira antarctica*, was found slightly farther east in November. In March a poor phytoplankton was usually encountered in this area. In the sub-Antarctic water between the Falkland Islands and South Georgia, at the end of February 1930, a highly characteristic *Rhizosolenia* plankton was found, with *R. polydactyla* dominant and *R. curva* very conspicuous.

Work in the Weddell Sea revealed several distinctive associations closely correlated with the history and movements of the surface waters. To the north-east work along the ice-edge in early spring showed that the main increase had not begun in October. Development in the eastern Weddell Sea water apparently reached its maximum about mid-season, as Gran (1932, p. 352) has already placed on record. Early in January 1931 vast numbers of the three large species previously mentioned were encountered between South Georgia and the South Sandwich Islands, and thence south-eastwards as far as 63° S. *Rhizosolenia styliformis* had the most southerly distribution of the three, *Corethron valdiviae* predominated near the old pack-ice in about 57° S, and *Chaetoceros criophilum* was less regular in its distribution. South of lat. 63° a poorer phytoplankton with *Nitzschia seriata* dominant was found up to the circle, and south of that again a still poorer phytoplankton, somewhat similar to that found in the far south of the Bellingshausen Sea, was found close up against the fast ice within about 100 miles of the Antarctic mainland. Here the dominant species were *Chaetoceros socialis, Ch. neglectus, Nitzschia seriata* and *N. closterium.*

The water issuing from the north-western corner of the Weddell Sea, which probably passes through the last stage described above about two years previously, and which forms the eddy round Joinville Island into the Bransfield Strait, was found in December to be supporting a phytoplankton precisely similar in quality to that found to the south-west of South Georgia a month earlier, but by no means so rich. Later in the season work farther to the westward showed that the phytoplankton in this type of surface water had lost its distinctive character, merging imperceptibly with that of the eastern Weddell Sea and Bransfield Strait. Towards the end of the season the phytoplankton to the north-west of the Weddell Sea area became poor, while to the north-east it remained rich, partly owing to the drift of the aftermath of the main increase farther west. In the abnormally warm 1929–30 season a very poor phytoplankton prevailed over the whole of the northern part of the Weddell Sea area in March.

In Bransfield Strait an association of almost pure *Corethron valdiviae* was found at all seasons in the old water of Bellingshausen Sea origin that occupies the greater part of the strait. Other species were most frequent in this water in spring, when the association is probably regenerated within the strait itself, but they never formed any notable proportion of the total numbers. The phytoplankton of Bransfield Strait was poor in comparison with that of other areas in the same latitude, and though by far the richest hauls were obtained in November, signs are not wanting that in most years the main increase begins somewhat later than at South Georgia, as one would expect from its more southerly latitude. The phytoplankton tended to be richer at the eastern end of the strait; but the eddy of Weddell Sea water contained a very different phytoplankton during the first half of the season, and this appeared to reach its maximum somewhat later in the year than that of the *Corethron* plankton which occupied most of the strait. An autumnal maximum due to invasion from the Bellingshausen Sea probably occurs in most years.

The material from the Bellingshausen Sea was obtained in higher latitudes than that from the other areas, which accounts for the absence of seasonal data. In this area four distinct associations could be recognized: (i) a rather poor phytoplankton with *Corethron valdiviae* and *Chaetoceros neglectus* dominant, which appears to be the first to develop as the ice breaks up; (ii) a rich neritic flora resembling that of the western Weddell Sea water, with the addition of *Nitzschia closterium* and a larger proportion of *Chaetoceros tortissimus*, found among the Biscoe Islands and at the Palmer Archipelago; (iii) the *Corethron—Rhizosolenia gracillima* association developing in comparatively open water to the north-east; and (iv) a moderately rich association developing along the ice-edge far to the south-west, in the vicinity of Peter I Island, with *Nitzschia seriata*, *Fragilaria antarctica*, *Thalassiothrix antarctica* and *Chaetoceros dichaeta* among the more prominent species.

THE FLORAS OF THE MAIN TYPES OF WATER

From the consideration of the material as a whole, the four main types of surface water in the area investigated were distinguishable by the proportions of the principal species found within them, and by the general nature of the floras they supported. These features may be summarized as follows:

Eastern Weddell Sea water. **Chaetoceros criophilum, Rhizosolenia styliformis,** and **Corethron valdiviae**, strongly dominant. *Nitzschia seriata* and *Thalassiosira antarctica* the most numerous of the smaller forms. Moderately rich in species, very rich in quantity.

Western Weddell Sea water. **Chaetoceros socialis, Thalassiosira antarctica** and **Chaetoceros neglectus** the principal dominants, followed by *Fragilaria antarctica* and *Nitzschia seriata*. Very rich in species with minute forms dominant. Very rich in quantity early in the year, but falling off more rapidly than the eastern Weddell Sea water in this respect.

Bellingshausen Sea water. *Corethron valdiviae*, *Thalassiothrix antarctica*, *Nitzschia seriata*, *Fragilaria antarctica* and *Chaetoceros neglectus* all important, with *Rhizosolenia alata* f. *gracillima* a characteristic species. Very rich in species and more variable in quality than either of the types discussed above. Moderate in quantity.

Bransfield Strait water. This should be regarded as a special development of the last named. **Corethron valdiviae** very strongly dominant. *Rhizosolenia gracillima*, *Thalassiosira antarctica* and *Biddulphia striata* sometimes important. Rather poor quantitatively and with few species.

Where intermediate conditions obtained hydrological evidence frequently indicated that mixing between the bodies of water concerned was probable. Anomalies due to littoral conditions, the seasonal succession, and the "age" of the water (cf. p. 10) were not infrequent, but the cause was generally obvious. Broadly speaking, the above distinctions held good during the seasons studied, and were found to form a suitable basis for the description of the more local associations met with.

THE PROBABLE SEASONAL SUCCESSION

The probable seasonal succession of the more important species within our area is indicated in Figs. 77–9. For obvious reasons it has only been possible to include a few of the leading forms in the charts. Two factors that tend to complicate the question must be borne in mind: (i) while almost all the species reach their maximum during the great spring increase, the time of this increase falls later in the year as one proceeds

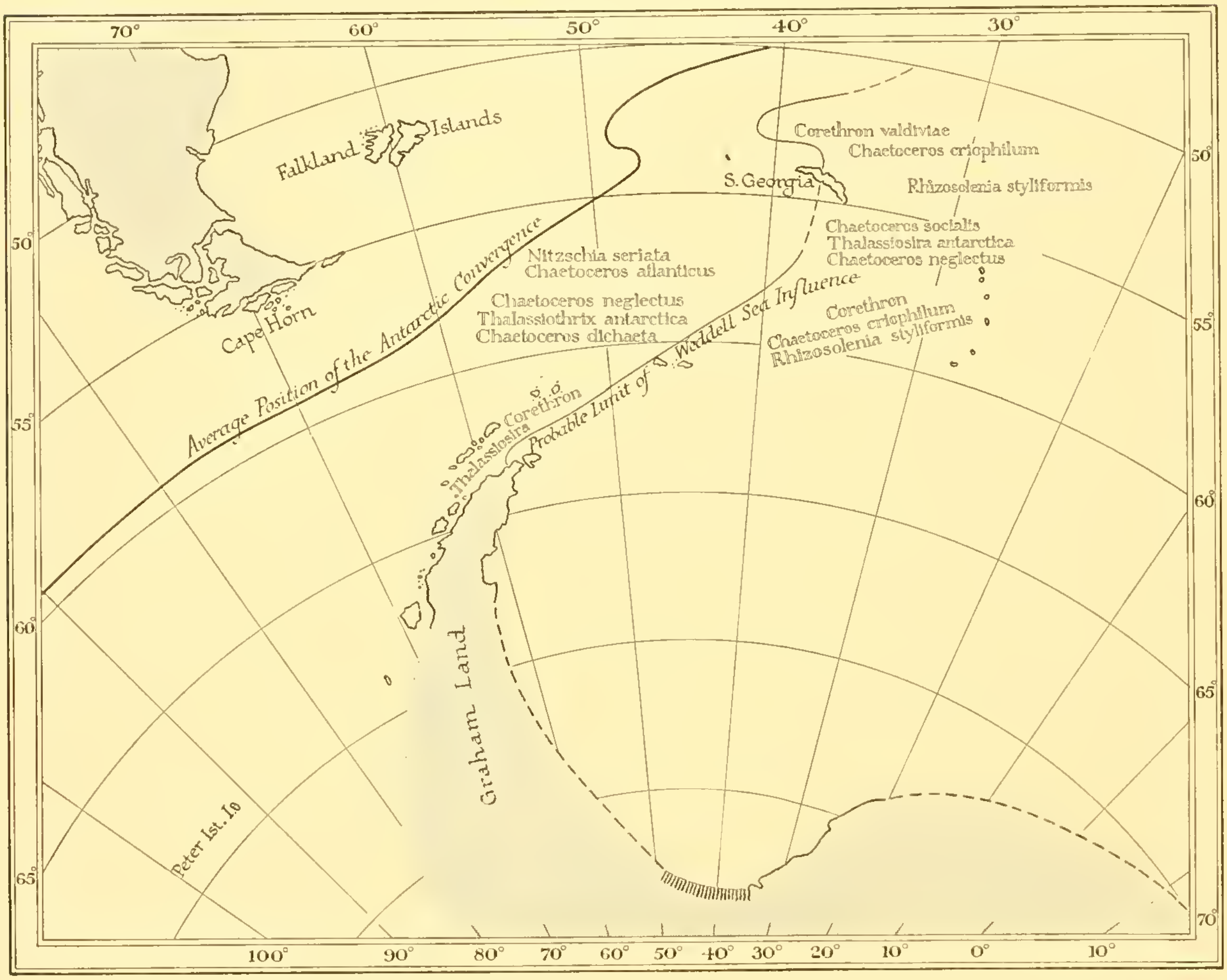

Fig. 77. The probable distribution of the dominant species over the area studied in late spring.

southwards; and (ii) transportation of the aftermath of the increase farther south by surface currents may lead to an apparent increase later in the season in the more northerly part of the region studied. Round South Georgia it seems fairly certain (cf. p. 91) that the main increase takes place in late spring; in the Weddell Sea it appears to take place at mid-season, and in the Bellingshausen Sea (doubtless in the far south of the Weddell Sea also) even later—about the end of January.

It should be realized that it is mainly to the more northerly parts of the region that these remarks apply—the South Georgia area, the Scotia Sea, and Bransfield Strait. Farther south seasonal data are scarce, owing to ice conditions, and it is probable that there is a short continuous period of production, rather than any well-marked succession of forms.

While nearly all the species reach their maximum during the main outburst, some persist throughout the summer to a much more marked degree than others. Others again, after falling off in January and February, show from the few observations obtainable at that season a definite tendency towards a secondary autumnal maximum. Thus it is possible to classify the more important species roughly into four groups:

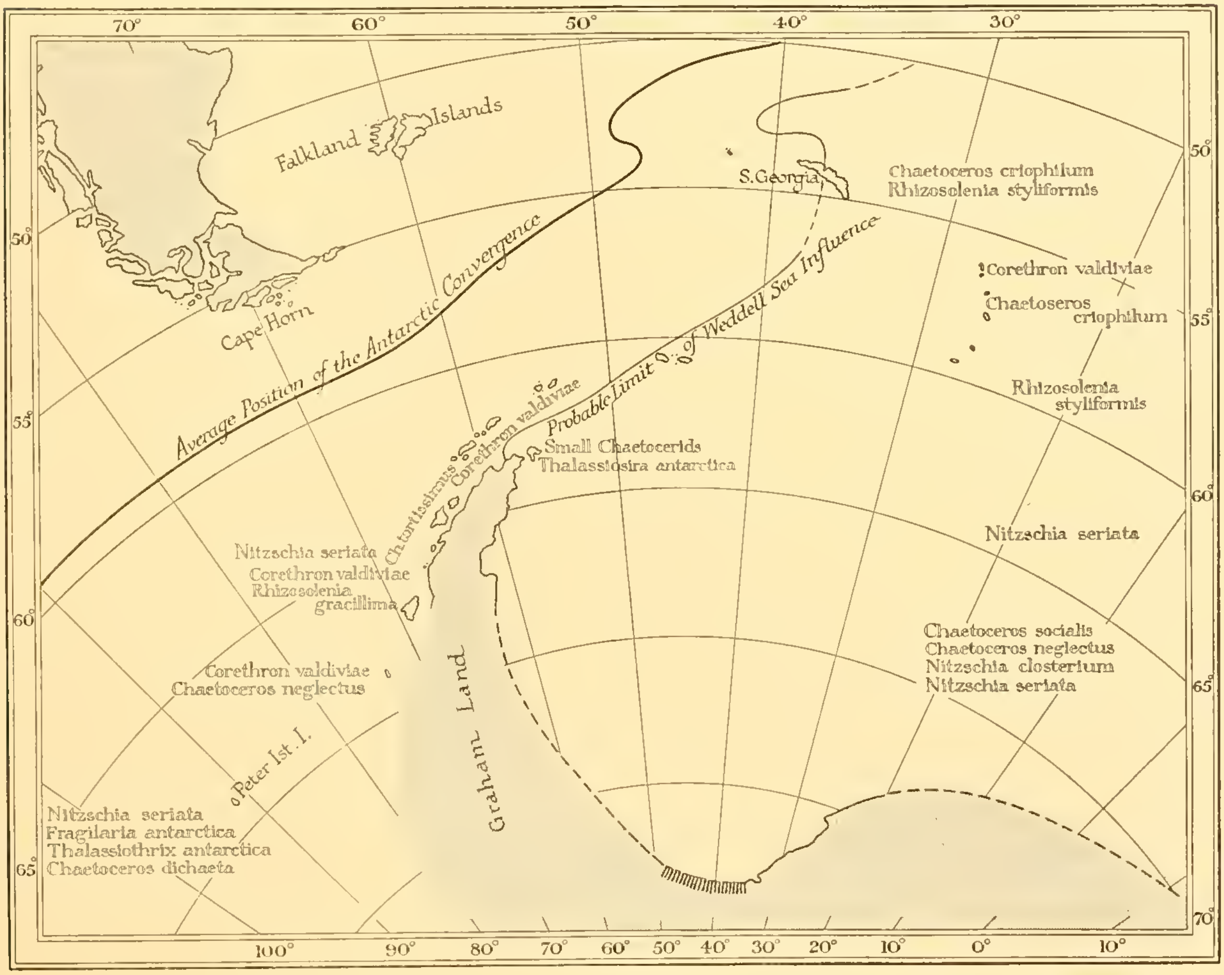

Fig. 78. The probable distribution of the dominant species over the area studied at mid-season.

(i) spring forms, (ii) forms with a spring maximum but which remain more or less important throughout the season, (iii) forms with spring and autumn maxima, and (iv) a few comparatively unimportant forms found most frequently in late summer and autumn.

One or two important forms do not fall into the grouping very well and may be mentioned separately:

The minute species *Chaetoceros socialis*, which has been found to be such an important constituent of the phytoplankton in water of the western Weddell Sea type, evidently has its maximum round South Georgia in spring, but as Hardy has shown (in press) may retain its importance up to mid-season. Later in the year it has not been recorded in quantity, except at one station far to the south in the Bellingshausen Sea.

Nitzschia seriata apparently finds its optimum later in the year than the other important species in the more northerly part of the area investigated. Though abundant round South Georgia in spring, it was even more so at mid-season on the survey described by Hardy. There is probably some falling off in February, but we have good

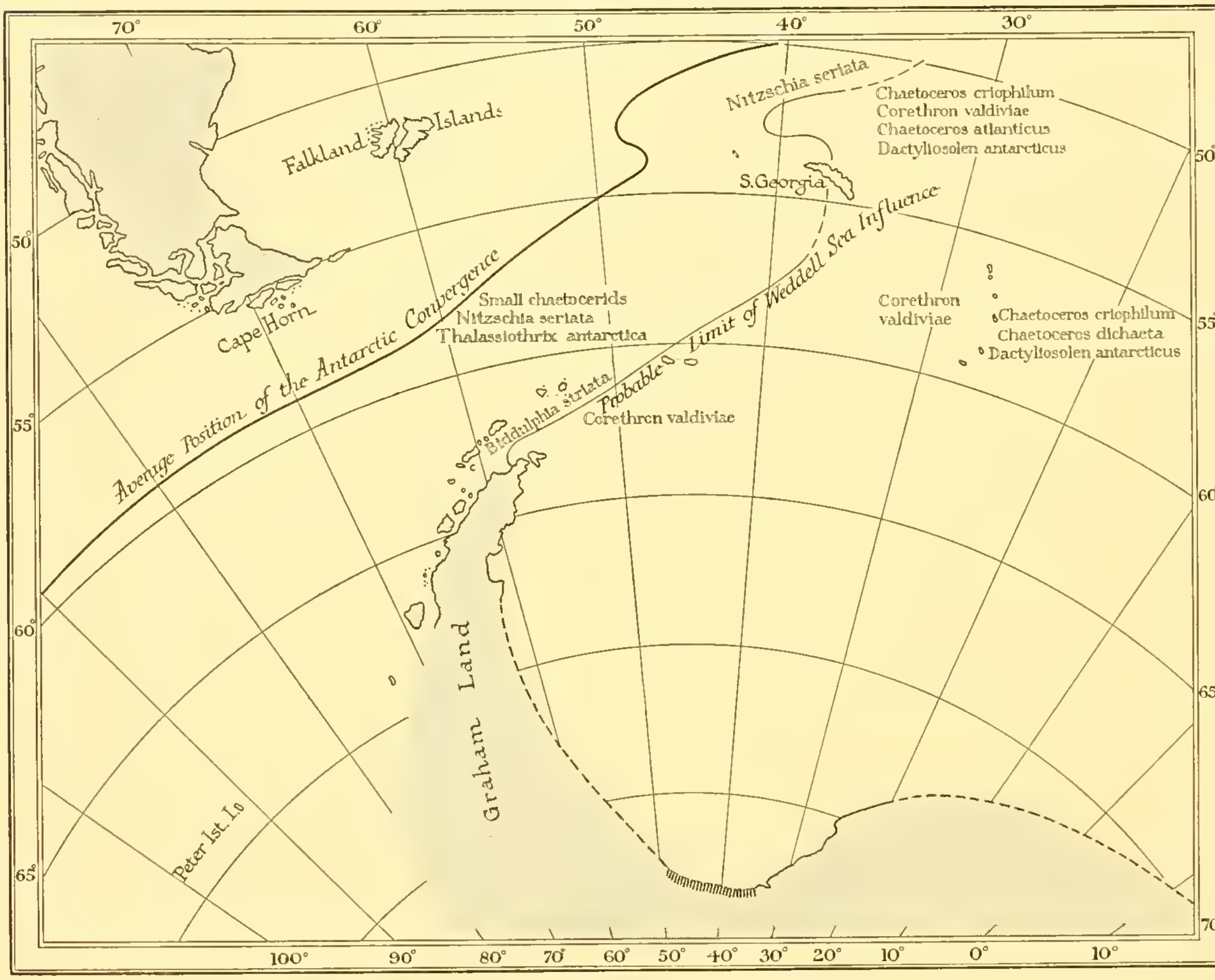

Fig. 79. The probable distribution of the dominant species over the area studied in autumn.

evidence that this is one of the dominant forms in the Scotia Sea during March and April.

As far as the evidence collected for this paper goes, *Biddulphia striata* would appear to be essentially a spring form, its abundant occurrence at a few stations far to the south later in the year being explained by the lateness of the main increase in those latitudes. A single instance during an earlier commission, of a rich haul with this species dominant as late as April in the Bransfield Strait, points to the probability of its belonging to the group of species with both spring and autumn maxima.

Apart from these three, all the other important species fall readily into the grouping previously outlined, so that their seasonal distribution can be conveniently summarized without further detailed discussion.

(i) Spring forms: *Thalassiosira antarctica*, *Dactyliosolen laevis* and *Chaetoceros schimperianus*.

(ii) Forms with a spring maximum remaining numerous throughout the season: *Corethron valdiviae*, *Rhizosolenia styliformis*, *Chaetoceros criophilum*, and *Thalassiothrix antarctica*.

(iii) Forms with spring and autumn maxima: *Chaetoceros atlanticus*, *Ch. dichaeta*, *Ch. neglectus*, and *Fragilaria antarctica*.

(iv) Forms with a maximum in late summer and autumn: *Dactyliosolen antarcticus*, and, in exceptionally mild years, the dinoflagellates *Peridinium antarcticum* and *Ceratium pentagonum* f. *grandis*, with the spineless chain form of *Corethron valdiviae*. In normal years these last are probably only of importance in the very oldest and warmest of Antarctic surface waters just to the south of the convergence; they do not reach South Georgia except in warm seasons. It is only in such years, with the mid-summer diatom minimum strongly marked, that the dinoflagellates become important, as they almost invariably do in corresponding latitudes in the northern hemisphere. Even in the warm years the dinoflagellates are outnumbered by the diatoms in the area investigated, and they are not numerous more than about 200 miles south of the Antarctic convergence.

AREAS OF LOCAL CONCENTRATION

From the conditions described on the November 1930 survey and the survey dealt with by Hardy, it would appear that the very rich phytoplankton, with small forms dominant, found off South Georgia during the first half of the season, is confined to the region to the south and south-west of the island. It is here that considerable mixing probably takes place between water from the western Weddell Sea, and old water of Bellingshausen Sea origin. Both Ruud (1932, p. 99) and Hardy have commented on the fact that regions with converging currents tend to encourage a rich production of plankton, and Hardy has suggested that this is due to the stimulus to growth consequent upon slight changes in the external conditions of the environment.

The tongue of eastern Weddell Sea water reaching up the eastern side of the island some distance offshore also supported a very rich flora during the survey of November 1930. Here large forms predominated, so that while the average volumes of the catches were as great or even greater than those obtained to the south-west, the numerical estimations indicate that the region was poorer. This may be so in actual fact from the point of organic production, as the proportionate bulk of the chloroplasts to the whole frustule is evidently very much smaller in the large species. It is to the east and south-east of the island that a comparatively rich phytoplankton persists longest throughout the season.

In the Weddell Sea area the only definite localizations were observed in the vicinity of the South Sandwich Islands, and westwards across the north of the sea towards the South Orkney Islands. Here again the influence of the mixing of the currents may be the determining factor, but the concentration to the east of the South Sandwich Islands appears to be of purely eastern Weddell Sea type. Doubtless the hindrance to the surface drift afforded by the chain of islands and the submarine ridge connecting them is involved. Although we have as yet no direct evidence, it is possible that upwelling, which brings spores within the photic zone, is the primary cause. On this point further hydrological evidence is awaited.

In Bransfield Strait the richest phytoplankton was found mainly to the east. Stations just inside the chain of islands guarding the western end of the strait yielded scanty hauls at all seasons of the year. Outside the South Shetland Islands to the north, in the southern half of Drake Passage, a rich phytoplankton was found in autumn, and there are indications that this locality may be a comparatively rich one at other seasons, more particularly in spring.

In the channels of the Palmer Archipelago, and farther to the south-west close inshore along the Biscoe Islands and Adelaide Island, a rich neritic association was found after mid-season. Here several species were abundant which commonly attain their maximum in spring farther north. In the Bellingshausen Sea itself the phytoplankton tended to be uniformly moderate in quantity. The nearest approaches to any local concentration observed were the moderately rich *Corethron—Rhizosolenia gracillima* association developing to the north of Adelaide Island and the slightly richer mixed plankton far to the south-west. The former evidently had its centre of distribution to the north of Adelaide Island during the seasons studied, and increased in that region as the season advanced, at the same time invading other areas farther to the north-east in a lesser degree.

COMPARISON OF THE FERTILITY OF THE DIFFERENT AREAS

Table XX shows the average estimated numbers of the catches in the several areas. The numerous large sources of error in such estimations have already been referred to, but most of the differences recorded are sufficiently large to leave little doubt that they have a real significance, and provide a useful basis for discussion of the probable limiting factors.

From this table the great quantity of phytoplankton present around South Georgia in spring, and its almost equally great scarcity in the late summer of the abnormally warm season 1929–30, will at once be noted. The evidence for the late spring maximum in Bransfield Strait is also well shown, and the poverty of this region as compared with others investigated. It will be seen that the mean value obtained from the Weddell Sea area, was more than twice that from the Bellingshausen Sea. This is not altogether a fair comparison, as many of the Weddell Sea stations were worked in relatively low latitudes. This source of distortion is, however, very largely compensated by the very poor catches obtained to the north-west of the Weddell Sea area in the second half of the season.

Table 21

Area	No. of analyses	Estimated total phytoplankton organisms	Approximate average per 100–0 m. haul
South Georgia, February 1930	57	61,264,400	1,076,000
South Georgia, November 1930	49	2,341,067,800	47,958,000*
Weddell Sea area (all stations)	61	957,415,830	15,695,000
Bransfield Strait, February 1929	18	84,817,000	4,726,700
Bransfield Strait, November 1929	18	140,045,800	7,780,300
Bransfield Strait, December 1930	17	78,723,790	4,630,800*
Bransfield Strait (all stations)	53	303,586,590	5,728,050
Bellingshausen Sea, February 1930	19	157,033,400	8,264,900
Bellingshausen Sea, January 1931	47	277,193,350	5,897,000
Bellingshausen Sea (all stations)	66	434,226,750	6,579,200

* Exclusion of uncountable colonies makes these values too low.

Taking the material as a whole, it appears to afford a good illustration of facts already well known as regards the northern hemisphere: that the time of the spring increase falls later in the year as one proceeds polewards, until in the highest latitudes there is a continuous period of production after midsummer. This is well shown by the figures from the Bellingshausen Sea. Thus the impression is gained that the phytoplankton of the older Antarctic surface water in comparatively low latitudes shows more marked seasonal variation, and fluctuates from year to year to a much greater extent, than that produced farther south. In the higher latitudes phytoplankton was never observed in anything like such quantities as around South Georgia (53–56° S) in late spring, and to the north-east of the Weddell Sea area (56–63° S) at midsummer. The more southerly phytoplankton was, however, very much more uniform in quantity.

THE POSSIBLE LIMITING FACTORS

CHEMICAL FACTORS

The factors governing phytoplankton production in north European waters have been intensively studied during the past ten years. An authoritative survey of the present state of our knowledge on this subject has recently been published by Gran (1932). As he has pointed out (p. 343), this study has been largely stimulated by the discovery of practicable methods of determining the quantities of nutrient salts present in the sea water by Atkins and Harvey at Plymouth. Accordingly, in considering conditions in the south, the nutrient salts may be dealt with first.

In north temperate waters Brandt's hypothesis, that the phosphates and nitrates essential for plant life would be periodically exhausted to such an extent as to put a stop to further production, has been well established. This phenomenon, which is most marked in waters such as the English Channel after the great vernal diatom increase, was not manifest in the south. In the more northerly parts of the Antarctic Zone the phosphates in the upper layers showed a considerable decrease at mid-season, but were never depleted below a minimum of *ca.* 50 mg. P_2O_5 per m.[3] Thus if we are to assume that the falling off in production after mid-season is due to lack of these substances, we must also assume that the Antarctic plankton diatoms are incapable of utilizing concentrations of phosphate and nitrate considerably above the winter maximum in the English Channel. This is extremely improbable, and it would seem fairly certain that generally speaking nutrient salts are not at any time limiting for phytoplankton growth within the Antarctic surface water. This is doubtless the main reason for the extremely rich production, which will probably be found to exceed that of any other large area in the world, apart perhaps from such local effects as in the Benguela and Humboldt currents, where upwelling from the deeps gives rise to a continuous supply of nutrient materials at the surface.

The numerous analyses for phosphate, nitrate, and to a lesser extent nitrite, made during the course of the work are given in full in the Station Lists (1930 and 1932); in addition, the mean phosphate values for the surface layer have been included at the head of the phytoplankton tables in this paper. In only two cases has it been found possible to draw any comparison between the amount of phosphate present and the abundance or otherwise of the plankton. These occurred on the two surveys round South Georgia. On the first of these, worked in the abnormally warm summer 1929–30 when phytoplankton was scanty, it was observed that the phosphate minimum was regularly found at 20 m. depth at all stations where the phytoplankton was appreciable. This has an obvious bearing on the effect of light penetration. On the second spring survey, when production was at its height, the phosphate minimum occurred at 10 m. or at the surface, and there was some correlation between the heaviest catches and relatively low phosphate values. Taking the mean for the upper 20 m. on the two surveys, however, we find 79 mg. P_2O_5 per m.^{3} in summer and 83 mg. per m.^{3} in the spring. It is obvious that so small a difference cannot have much bearing upon the immense disparity between the phytoplankton observed on the two surveys.

Clearly the comparatively rapid movements of the surface layers off South Georgia prevent the phosphate content of the water from showing any continual relation to the production on the spot, as in areas forming a practically closed system like the English Channel (Cooper, 1933, p. 678). A clear instance of this was encountered during the plankton survey of January–February 1930 at the outer end of the Larsen line. Here, at St. 313, the mean phosphate value for the upper 20 m. was 105 mg. per m.^{3}, and some six million phytoplankton organisms were present in the net haul. At St. 358, worked 10 miles farther to the eastward only a fortnight later, it was very evident that water of an entirely different type was present (see Table II). The phosphate value was 60 mg. per m.^{3} and some five million phytoplankton organisms were present in the net haul. With one exception, however, the dominant species were not the same at the two stations. Evidently the phosphate content of the surface waters round South Georgia does not reflect the changes in production in that locality at all closely, but is rather the resultant of the production over the large indefinite area farther to the south and west, where the various types of water have their origin. Even if sufficient seasonal data were obtainable, therefore, it would hardly be possible to calculate the minimum production for the South Georgia area from the consumption of phosphate.

The possibility that silica may be a limiting factor cannot be dismissed, for diatoms are entirely dominant in the phytoplankton of Antarctic surface waters. Analyses for silica content were not made during the period studied, but have been undertaken as part of the programme of work that is being carried out by Mr Deacon in the far south at the time of writing. It is extremely improbable that this factor would be limiting except in localized areas under special conditions, as Cooper (1933, Pt. II, p. 752) has recently shown that of all the essential salts this is probably the most rapidly regenerated. For all that, the absence of the usual abundant diatom flora, and the dominance of the small thin-walled spineless chain form of *Corethron valdiviae* on the exceptionally warm summer survey round South Georgia leads one to think that this may sometimes be a factor in limiting production. Some pertinent remarks by Cooper (*loc. cit.*, p. 697) show how this may have come about. He quotes Miss Stanbury's (1931) observations that in diatom cultures the skeletons of the dead frustules disappear very rapidly, owing to the highly alkaline media attacking the silica, and also refers to the recent observations of Bachrach and Lefèvre (1928, 1929) that a similar phenomenon may occur in living diatoms, the skeletons of several littoral genera degenerating in cultures until the cells, though still living, became scarcely recognizable. Unfortunately these workers did not discuss the *p*H of their media. Cooper goes on to give an actual instance in which an observed fall in silicate content was correlated with the succession of thick-walled by thin-walled diatoms in the plankton. The analogy of the unusual phytoplankton observed off South Georgia on the occasion in question is very striking, as on that survey the *p*H values were high, averaging 8·12 as against an average of 8·08 on the spring survey when diatoms were abundant. I consider, therefore, that it is at least possible that temporary reduction of silicate (complete exhaustion is not necessary, *vide* Cooper), in conjunction with a high *p*H, may occasionally limit phytoplankton production in the more northerly part of our area, and that in reaction to this some of the usual oceanic species may disappear, while others loose their spines and assume a thin-walled form of growth. The increased abundance of dinoflagellates in these conditions is according to expectation.

The silicate requirements of diatoms in the southern ocean raise several points of interest. Castracane (1886, p. 15) doubted the continuity of the broad belt over which the bottom deposits consist mainly of diatom ooze. This apparently encircles the globe some distance to the north of the Antarctic Circle, and its probable existence was first recognized by Murray (1876). The numerous bottom samples obtained by recent expeditions leave little doubt that it is practically continuous, and is the true homologue of the similar tract in the North Pacific. The action of the warm Atlantic current flowing past Iceland, the greater amount of terrigenous debris, and the comparatively shoal water are probably responsible for the absence of a similar belt in the North Atlantic. It would seem that in the Southern Ocean the northern edge of this belt coincides roughly with the Antarctic convergence, or the extreme northern limit of pack-ice; its southern limits are less well defined, but may very probably be found to coincide with the northern limits of the pack in *winter* (cf. Schott, 1926, Taf. VI). A glance at Schimper's notes on the numerous bottom samples obtained by the 'Valdivia', quoted by Karsten (1905), reveals the fact that in almost every sample *Fragilaria antarctica* predominated, and the only other important species were *Thalassiothrix antarctica* and discoid forms, mainly *Coscinodiscus* spp. With this our own preliminary observations in the South Atlantic are in entire agreement. Now it is precisely these forms that are found unchanged in crustacean stomachs and in the guano of sea-birds, and it seems natural to suppose that they have much more strongly silicified skeletons than the more typical plankton forms. Direct evidence of this is forthcoming for *Coscinodiscus*: Wailes (1929, p. 25) says: "...half-a-dozen nearly pure gatherings of plankton diatoms,...dried for one hour at 110° C., proved on analysis to contain an average of 40 per cent of silica, these were mostly small species of *Chaetoceros* [the predominant planktonic genus in the south].... Gatherings composed mostly of large *Coscinodiscus* gave...around 55 per cent; if dried until there was no further loss in weight, the percentage of silica is about 75 per cent of the dry weight". From our numerous plankton gatherings in the south we know that apart from local swarms of *Coscinodiscus bouvet*, *Coscinodiscus* spp. rarely form more than 1–2 per cent of the phytoplankton, and that such dominant forms as *Chaetoceros*, *Corethron* and *Rhizosolenia styliformis* are but rarely represented in the bottom samples. It follows that opinions, based on examination of bottom samples and guano, that *Coscinodiscus* is dominant in certain areas, stand in need of revision.

Among the other chemical constituents of sea water which have recently come under review as possibly limiting phytoplankton production, iron may be mentioned (Gran, 1932, p. 353). Little is known of this subject at present, but it has been suggested that it may help to explain the observed richness of the neritic plankton in north temperate waters, and the fact that this plankton frequently begins its main increase some time before that of the oceanic plankton offshore, the land being regarded as a source of iron in organic combination akin to the humic substance in soil. The preliminary results of both Gran (*loc. cit.*) and Harvey (personal communication) indicate that the most minute traces of iron and of soil washings may exercise a pronounced beneficial effect upon the growth of diatom cultures. It is thus conceivable, though it can hardly be thought probable, that the large number of morainic bergs observed in the Weddell Sea as compared with the Bellingshausen Sea, may have some bearing upon the fact that the phytoplankton of the former is richer.

PHYSICAL FACTORS

It is when we come to consider the physical features of the environment that the factors exerting the strongest influence upon phytoplankton production in the far south appear. These factors are closely interrelated, and this makes it difficult to assess their individual importance. The strongest influences appear to be due to weather, currents, light, ice conditions and temperature.

Of the weather, which has been used as a general term to include a number of meteorological factors, it is impossible to say much. The prevailing winds, in concert with the earth's rotation, are responsible for the course and strength of the surface currents, and variations in the meteorological system will be reflected in the yearly fluctuations of these currents. There is an obvious relation between weather and ice conditions, but it is difficult to say which is the prime mover. Prevalence of fogs will hinder phytoplankton production by cutting down the light intensity, while the short periods of fine calm weather experienced far to the south in the pack will promote it, as shallow strongly marked discontinuity layers tend to be set up, keeping the contained diatoms within the zone of optimum light intensity. Moreover, there is evidence that, when melting, the southern sea-ice liberates resting spores in a suitable internal condition for rapid growth. The continuous westerly gales of the northern part of the Antarctic Zone probably exert a strongly unfavourable influence by incessant mixing of the surface layers, but enough has been said to indicate how closely the more concrete physical factors are bound up with the meteorology, about which our information is necessarily scanty.

The surface currents are of such obvious importance throughout this area that their action has been dealt with at length in the body of this paper. The stimulus to growth provided by the convergence of currents has already been mentioned (p. 181); among their other important effects the transportation into the South Georgia area of the aftermath of the main increase farther south, after production on the spot had practically ceased, is possibly the most noteworthy. The effect of the north-easterly drift out of the Bellingshausen Sea into the Bransfield Strait, and through Drake Passage into the Scotia Sea, has also been emphasized. It is very probable that the individuality of the phytoplankton of the eastern Weddell Sea water is due to the fact that the whirl forms a partially closed system[1]; but the most important effect of the surface currents, acting in concert with the winds, is undoubtedly the northerly movement of the pack-ice in spring, a movement which is followed by such a tremendous production in the northern part of the Antarctic Zone.

It will have been noted that in addition to the typically oceanic species, the abundant flora developing along the advancing ice-edge in late spring presents in many respects a neritic facies. A similar oceanic development of neritic forms in the vicinity of ice has long been known in the northern hemisphere (Gran, in Murray and Hjort, 1912, p. 342). In the southern area it is most marked by the abundant occurrence of such forms as *Fragilaria antarctica*, *Thalassiothrix antarctica*, *Nitzschia seriata* and *Thalassiosira antarctica*. It will be noted that the majority of these forms belong to the Pennatae, as do the majority of littoral and ice forms. This is extremely interesting in view of the phylogenetic speculations of Lloyd (1926, pp. 105–10). Having pointed out that the majority of plankton diatoms belong to the Centricae, she refers to the above genera, which almost alone among marine pennate forms are of importance in the oceanic plankton, as "reversionary plankton forms". Her views are thus strongly sup-

[1] Cp. Clowes, A. J., *Nature*, CXXXI, p. 189 (1933).

ported by the observations that these forms find their optimum in polar waters, under conditions most closely approaching the littoral, i.e. along the ice-edge; and that they still possess strongly silicified skeletons as instanced by their remaining recognizable in diatom ooze. Certainly their spores seem to be carried by the ice, as Blessing found long ago in the Arctic. Fluctuations in the strength of the surface current bringing ice from the Weddell Sea up into the vicinity of South Georgia in spring will obviously play a large part in determining the quantities of these forms present in the plankton.

Apart from the importance of surface currents as transporting agents, it may be profitable to consider the possible influence of more deeply seated water movements. It is well established that the Antarctic surface drift has a distinct northerly component, and that when it sinks below the sub-Antarctic water at the convergence a tremendous mortality amongst the phytoplankton ensues, instanced by the presence of abundant diatom ooze in the bottom deposits in the vicinity. Doubtless eddies and the ice help to maintain a number of spores within the Antarctic Zone, but it seems improbable that the supply could be kept up by these means alone in the face of such an enormous drain. This obviously applies with even greater force when animal organisms are considered. A suggestion arising out of Hardy's observations on the rapid sinking of *Coscinodiscus bouvet* to great depths, and from the work of Mr Fraser on larval Euphausians, shows how this difficulty may be overcome, but it should be understood that this explanation is as yet hypothetical. Notwithstanding the great influx of Pacific water flowing east into the Scotia Sea, which Clowes[1] has recently demonstrated, there is little doubt that the warm intermediate layer of water which is so marked a hydrological feature in southern latitudes must have a well-defined southerly component. It replaces the water flowing northwards at the surface and along the bottom.

It is thus at least possible that resting spores derived from diatoms sinking near the northern limits of the Antarctic Zone might ultimately be carried southwards through the agency of this intermediate layer. On the analogy of the seeds of certain higher plants, which require a long sojourn under uniformly low temperature conditions,[2] before they will germinate, there appears to be no physiological obstacle to some such supposition. A few concrete facts also appear to support this hypothesis, notably the occurrence of typically sub-Antarctic forms such as *Rhizosolenia curva* and *R. polydactyla* to the south of the convergence, in dying condition, over the bank to the north-west of South Georgia. If these forms had died and sunk to the north-westward in the vicinity of the Antarctic convergence, and become involved in the warm intermediate layer, this bank of comparatively shoal water, where violent vertical mixing is known to occur, is just the position in which one would expect their dead frustules to come to light. If dead diatoms properly belonging to other habitats can be brought into the Antarctic Zone by this means, it is likely that Antarctic forms will be brought back also, and may very probably form resting spores that survive. Another instance, from the

[1] Cp. Clowes, A. J., *Nature*, CXXXI, p. 189 (1933).

[2] The average temperature of the "warm" nucleus of the intermediate layer is *ca.* 1·8° C. in the latitude of South Georgia.

south-eastern Atlantic, may be cited. It is reasonably well established that *Ceratium fusus* has its optimum, in the south, in the sub-Antarctic Zone, and if we examine the extracts from Schimper's working notes (quoted by Karsten, 1905, pp. 34 *et seq.*) we find a most significant distribution of this species. Proceeding south-westwards from Cape Town, the 'Valdivia' first encountered it in $41\frac{1}{2}°$ S at the surface. At the 'Valdivia' St. 120 in 42° 17′ S it was present in addition in the deep haul (450 m.). A similar vertical distribution was noted at the next station to the southward, but at St. 123 in 49° 07′ S, 08° 40′ E, i.e. well south of the Antarctic convergence in this longitude, the species was present in the deep haul only. It will be realized that in the south-west Atlantic, where Clowes' results indicate that the main component of this water is easterly, this hypothesis would involve the replenishment of the plankton of the Weddell Sea area, by the residue of the production in the north of the Bellingshausen Sea. Thus there may be a continuous cycle of alternate vegetative and resting forms travelling round the world on a course similar to that of a sailing ship running before the westerlies and bringing the wind alternately on either quarter (supposing that the direction of the wind remained constant). This would be in accordance with the fact that the majority of Antarctic plankton forms appear to have an almost completely circumpolar distribution, for it is in the relative proportions of the different forms, and not in their presence or absence, that the populations of the various areas within the Antarctic Zone chiefly differ.

This hypothesis might explain many of the more marked fluctuations and anomalies in the distribution of the plankton.

Light is obviously a factor of the first importance in considering phytoplankton production at any distance from the tropics. First Atkins (1928, p. 192) and latterly Marshall and Orr (1930, pp. 870 *et seq.*) have maintained that it is the initial limiting factor, determining the time of the start of the spring increase in north temperate waters. Gran (1929 *b*, p. 50) held the view that off the Norwegian coast, the increase in inshore waters began with the melting of the snows in spring, which washed down nutrient materials from the land into the productive upper layers; but the more recent work of Braarud and Klem (1931, pp. 68 and 77) in the same area has shown that light is almost certainly the initial limiting factor there also, and that the correlation between the main diatom increase and the spring thaw is incidental, though it may lead to a smaller secondary increase close inshore somewhat later (*loc. cit.*, p. 69). The fact that the midsummer cessation of phytoplankton production in temperate waters could be clearly demonstrated to be due to the depletion of the nutrient salts appears to have led to an over-estimation of their importance as a limiting factor at other times and in other places.

In the south it is certain that light is the limiting factor during winter, but this does not account for the relatively late beginning of the spring increase off South Georgia. November in the south is equivalent to May in the northern hemisphere and South Georgia is situated in a latitude corresponding to that of the north of England. The retardation must be due to a combination of adverse factors as yet imperfectly understood, though it seems fairly certain that the continual mixing of the surface layers during the more than usually violent gales of the spring equinox, and the fact that the northward moving pack-ice does not begin to melt and disperse much before November, will be largely responsible. It is a notable fact that the great differences in climate of the two hemispheres, with the Antarctic summer very much colder than the Arctic, and the south polar influence extending much farther towards the Equator, are closely reflected in the hydrological and plankton conditions. The commencement of the spring increase off South Georgia in November corresponds exactly with Vanhöffen's (1897, pp. 264, 289) observation that the main diatom increase in Karajak Fjord, North Greenland, some fifteen degrees farther from the Equator, occurred in May.

The details of the influence of light on phytoplankton production have been intensively studied by Marshall and Orr (1928 and 1930), who have succeeded in establishing the compensation point (balance depth of Gran), or depth at which gain by photosynthesis is balanced by loss in respiration, for the latitude of the Clyde at different times of year. By happy chance this latitude is almost directly comparable with that of the southern end of South Georgia, so that from their findings we may assume that production in the northern part of the Antarctic Zone proceeds actively only above a depth of some 35 m. in summer and considerably less in autumn and spring. In making this estimate due account has been taken of the facts that the almost continuous rough weather lessens the penetration of light, but that conversely, in the Southern Ocean, owing to the inconsiderable extent of the land, the adverse factor of inorganic particles decreasing the penetration of light will only be felt in extremely localized areas (e.g. Bays of South Georgia, see Appendix I). The above authors have also shown that at the surface in winter, and to a somewhat greater depth at midsummer, direct sunlight slows down synthesis in diatoms, inducing systrophe, or contraction of the endochrome (1928, p. 325). Proceeding southwards from South Georgia the level of both these critical points will obviously rise with the increasing obliquity of the sun's rays. With the narrowing of the depth range over which diatoms can actively reproduce and the more stable conditions prevailing in the far south after mid-season we have a plausible explanation of the observed differences in the phytoplankton from the more northerly and the more southerly parts of the area. To the south it was moderately rich and uniform, while to the north it was sometimes extremely rich and much more variable. It may be noted that there is some ground for believing that the phenomenon of systrophe near the surface is due not so much to the total light intensity being harmful to the diatoms, as to the action of the *shorter* ultra-violet rays.[1] When the sun is at a low altitude, the proportion of long to short wave-length light falling upon the surface of the water is increased (Harvey, 1928, pp. 155, 160), and hence we may conclude that if systrophe is induced by the shorter ultra-violet rays this adverse effect will be much reduced in high latitudes. This would further accentuate the value of shallow discontinuity layers, such as are found near melting ice, and may be the explanation of the preponderance of

[1] The shorter ultra-violet rays are absorbed rapidly, the longer penetrate farther than light of any other quality.

the pelagic genus *Chaetoceros* in polar seas, for Marshall and Orr (1928, p. 337) have found that genus to be peculiarly susceptible to systrophe.

Mention of the discontinuity layers formed as the ice melts leads to the consideration of a complex factor, the resultant of meteorological and ice conditions, which perhaps plays the most important part of all in promoting phytoplankton production within the area. This is the stabilization of the surface layers consequent upon the melting of the ice and the cessation of the convection effects of the southern winter, which will tend to keep the contained diatoms within the zone of optimum light intensity. Obviously this factor can only exercise a beneficial effect in waters with a superabundance of nutrient salts. Elsewhere it will tend to promote the rapid depletion of the surface layers, though even then it is possible that the most marked production will take place after the spring temperature overturn (cf. Marshall and Orr, 1930, p. 870). The possible importance of stabilization in the south has already been recognized by Gran (1932, pp. 351, 352) from a few stations worked in about 57° S between the South Sandwich Islands and Bouvet Island, and in about 61° S in the Weddell Sea, from the whaling factory 'Vikingen'. He observed that extensive proliferation did not begin until the water layers became stratified by the melting of the ice. Pelagic whaling factories are dependent on a certain amount of shelter from the ice for working conditions, so that we may assume that the adverse factor of instability was in this case due entirely to the prolongation of the convection effect characteristic of winter conditions, and not to the violent storms apparently responsible for a similar effect slightly farther north in the South Georgia area. Further examples of the adverse effect of instability are given by the "desert areas" observed over shoal water where constant vertical mixing takes place. It would seem that the favourable influence of upwelling in bringing resting spores up into the photic zone is nullified in these turbulent areas by downward movements carrying the organisms out of the zone again too rapidly to permit of extensive proliferation. The chief of these areas observed were at the western end of Bransfield Strait, to the east of King George Island (South Shetlands), and to the north-west of South Georgia.

Ice, important as an agent favouring temporary stabilization of the surface layers in summer, may affect phytoplankton production in other ways. Its possibilities as a carrier of resting spores have already been noted, together with the early references to this fact as regards the polar ice of the northern hemisphere. Mr R. E. Priestley of the Scott Expedition has noted (in correspondence) the presence of abundant living diatoms on Antarctic sea-ice, and the examination of samples of ice diatoms collected during the period dealt with by this paper revealed the presence of numerous plankton forms (e.g. *Corethron valdiviae*) in addition to those which appear to be peculiar to this habitat (e.g. *Amphiprora* spp.). It seems certain that by supporting diatoms and their spores in a resting condition—notably those species that find their optimum in its immediate vicinity, such as *Fragilaria antarctica*—the Antarctic pack-ice plays an important rôle in maintaining the rich flora of the Southern Ocean.

Another way in which ice may assist in promoting phytoplankton development, and which also involves the effect of temperature, is in the degree of polymerization of the water molecules. The higher this is, the greater will be the viscosity of the water, and viscosity is obviously an important factor for organisms whose continued existence is dependent upon their ability to maintain their level. Bayliss (1927, pp. 233 *et seq.*) gives a succinct account of the polymeric system of water and remarks that the degree of polymerization is roughly inversely proportional to the temperature, a fact which may well be of immense significance in the polar waters of the southern hemisphere with its low summer temperatures.

Yet another way in which the degree of polymerization may affect the phytoplankton has been suggested recently, but appears hitherto to have escaped the attentions of plankton workers. The first hint was given by H. T. Barnes (1928, p. 16) when he followed up the well-known exposition of the fact that water is to be regarded as a system of three polymers, monohydrol (steam), dihydrol, and trihydrol (ice), with the statement that it is highly probable that the higher polymer only is utilizable by living organisms. This found its natural sequel in the work of T. Cunliffe Barnes (1932, pp. 136, 137) when he showed that the growth of the fresh-water green alga *Spirogyra* markedly increased when trihydrol was the predominant polymer in the culture medium, under equal conditions of light and temperature. Among other biological phenomena which may be explicable in terms of this trihydrol effect he mentions "the anomalous increase in the plankton following the melting of the ice", and the "unexplained richness of microorganisms in Arctic waters...". These are rather naïve statements in view of the many other factors known to be involved, but the possible importance of his work should not be overlooked.

In a recent contribution to *Nature*,[1] H. T. and T. C. Barnes state that the *Spirogyra* filaments grown in water containing less of the active polymer trihydrol resemble plasmolysis forms with the chloroplasts badly twisted, and that the reduced macroscopical appearance of the cultures, compared with those grown in water with an abundant proportion of trihydrol, is due to collapse of the protoplasts. These workers are now engaged upon similar experiments with Protozoa.

More recently still H. W. Harvey[2] of Plymouth has investigated the effect of varying the proportion of trihydrol on cultures of the marine diatom *Nitzschia closterium*, by the addition of water from newly melted ice. I am greatly indebted to him for the personal communication of his preliminary results, which, though not yet complete, serve to show that this factor may be extremely important in polar seas. It appeared that an increased proportion of trihydrol greatly stimulated the growth of the cultures *during days with long daylight*, and provided that the growth was initially strong; but that earlier in the year, with short days and slow growing cultures, no appreciable effect was observed.

From the considerations outlined above, it will be realized that not only the melting of the ice but the temperature of the water is involved in the operation of this factor,

[1] May 7, 1932, p. 691.

[2] See Harvey, H. W., 1933. *On the rate of Diatom Growth.* Journ. Mar. Biol. Assoc., n.s., XIX, pp. 253–75: published since the above was written.

low temperatures favouring the persistence of a high proportion of trihydrol. This may well be a partial explanation of the poverty of the phytoplankton observed during the abnormally warm season 1929–30, and of the fact that the positions of the richer diatom hauls frequently showed a closer correlation with low temperatures than any other hydrological feature, particularly during the South Georgia survey of that year.

Apart from these physiological considerations, pack-ice may also exert a locally beneficial effect by damping down the sea and swell. Atkins (1926, p. 456) has pointed out that in rough water much of the light available is scattered and reflected at the surface and the quantity entering is correspondingly reduced.

These considerations give the impression that such seasonal variations and yearly fluctuations in phytoplankton production, as have been observed within the area discussed, are influenced mainly by the following four factors (or complexes of factors):

(1) Stabilization of the upper layers when the ice melts, a factor which is markedly beneficial; and conversely, instability, whether due to convection or wind action.

(2) Transportation by surface currents and the possible return of resting spores by sub-surface currents followed by upwelling. The probable importance of the transportation factor (in the Norwegian Sea) has been well expressed in a recent paper by Gran (1930, p. 72).

(3) The action of ice, which may promote phytoplankton production (i) by harbouring resting spores, (ii) by assisting stabilization, (iii) by shelter from sea and swell, and (iv) by the increase in viscosity and (possibly) by the increased physiological value of water rich in trihydrol. This last is obviously bound up with the temperature effect.

(4) Light intensity and duration, which is doubtless limiting during the southern winter and will determine the vertical as well as the horizontal range over which production is possible so long as the other factors remain favourable.

It cannot be too strongly emphasized that in all probability phytoplankton production is always governed by a complex of inter-dependent factors, rather than by one or two which are clearly definable. To this there are two obvious exceptions. In latitudes higher than about 45° light will be the main limiting factor during winter, and in some north temperate waters the complete exhaustion of the small quantities of nutrient salts present, combined with increasing stratification of the upper layers in summer, undoubtedly leads to the temporary stoppage of production, more or less prolonged, after the great vernal increase. At the two more critical periods, spring and autumn, it would appear that a combination of several factors has to be taken into consideration even in north temperate waters.

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APPENDICES

CONTENTS

APPENDIX I. ON FACTORS LIMITING PHYTO-PLANKTON PRODUCTION IN EAST CUMBERLAND BAY, SOUTH GEORGIA

(Text-figs. 80–4)

INTRODUCTION

The aim of this work was to endeavour to determine the factors limiting phytoplankton production throughout the season in the inshore waters round South Georgia, and, if possible, to keep sufficient check on the inshore conditions to permit of some comparison being made with those obtaining offshore.

The great difficulty in the interpretation of phytoplankton periodicity in the south lies in the fact that there appears to be a superabundance of nutrient salts, even at the surface layer, at all seasons. Particular attention was given, therefore, to other factors that might prove to be limiting; but as the locality investigated was an inshore one, it was felt that some check should be kept upon the amount of nutrient materials present. Samples from all the depths worked were analysed for phosphate but, owing to pressure of other work, it was impossible to attempt the analysis for nitrate as well. Gran (1929) has emphasized the possible importance of land drainage as a source of nutrient materials in the northern hemisphere, but later workers have shown that it is probably not so important a factor as was at first supposed. Owing to the relatively cold summer climate, and the singular barrenness and inconsiderable extent of the land in the latitudes in question, it would seem that this factor does not operate in the south.

A station was chosen in the deep water in the middle of the bay (*ca.* 90 fathoms) at which good cross-bearings could be obtained, and routine observations were carried out, as nearly as possible at weekly intervals, from November 12, 1930, to March 29, 1931. At each station water samples were taken with a Nansen-Pettersen bottle at depths of 0, 5, 10, 20, 30, 40, 50 and 75 m. These were analysed for salinity, hydrogen-ion concentration, and phosphate and oxygen content by the standard methods employed in the expedition. The analyses for phosphate content and hydrogen-ion concentration were always carried out within twenty-four hours of the completion of each station.

At the outset it was hoped to investigate the phytoplankton by the centrifuge method. Unfortunately the inshore plankton proved so scanty that this was impossible, and it was necessary to rely on two hauls with the Gran $\frac{1}{2}$ m. vertical net (N 50 V), from 25 to 0, and from 50 to 0 m. The samples were estimated by the usual Hensen methods.

We were very fortunate in having the use of the motor-boat 'Alert', a powerful, beamy, decked-in craft, 25 ft. long over all, and ideally suited to the work in hand. Thanks to her seaworthy qualities we were able to work on one or two occasions towards the end of the season in conditions previously thought impossible. In high winds drift was excessive owing to the very considerable freeboard of the boat, but it was still possible to work stations by going slow astern into the wind the whole time. For obvious reasons this method was only resorted to as a last expedient. It was unfortunately impossible to work more than one station per week, and occasionally this interval was exceeded owing to stress of weather.

Through the courtesy of the meteorologist in charge of the Argentine Government Station on King Edward Point, records of the sunshine, precipitation, wind force, etc., for the period in question were obtained. The station is badly placed, being closely shut

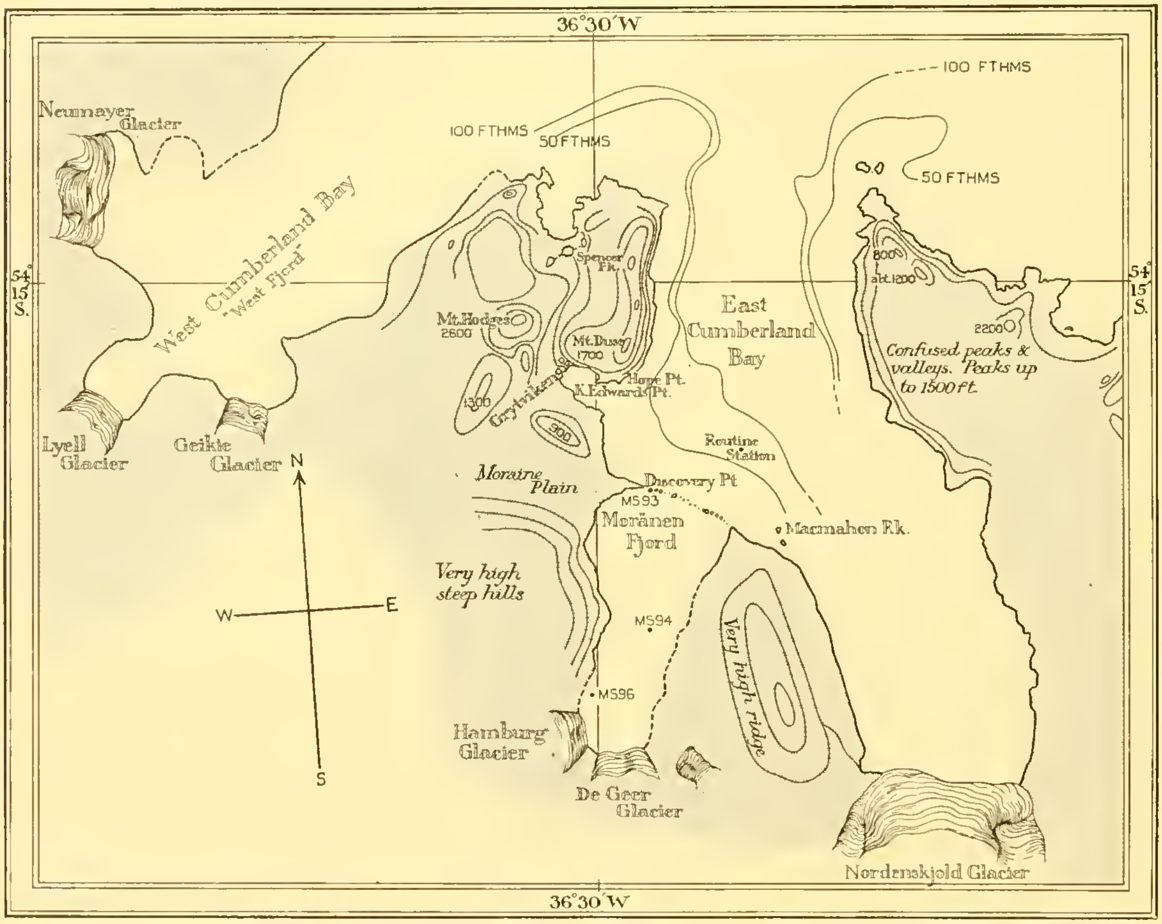

Fig. 80. Chart of East Cumberland Bay showing the positions of the routine station and the stations worked in Moränen Fjord.

in to the north and west by high mountains, but in general the records have shown a very fair degree of correlation with the hydrological and plankton conditions in the bay.

As will be seen from the chart, East Cumberland Bay is a deep inlet surrounded for the most part by very high, steep hills. Its main axis lies roughly north-north-west to south-south-east. The main southern extremity terminates in the very large Nordenskjöld glacier, and the lesser branch, Moränen Fjord, is also fed by three considerable glaciers. The conditions in Moränen Fjord are interesting, as it is a typical "threshold" fjord, a very deep basin with a shallow reef extending right across its mouth. A few observations were made there in addition to the routine stations.

There is no appreciable extent of low-lying land draining into the bay, and as all considerable vegetation ceases at a height of about 500 ft., even on the most sheltered slopes, it will be seen that the land drainage is, for the most part, very poor in nutrient materials such as could be utilized by the phytoplankton. Further, even the blackest pieces of morainic ice were found to be poorer in phosphate than the surface water. The results of phosphate analyses also indicate that pollution from the whaling station at Grytviken does not extend far beyond King Edward Cove. It may be mentioned here that the mean phosphate value for the upper 20 m. of water at the routine station throughout the season was 82·6 mg. per $m.^3$, as against an average of about 85 mg. in the open sea off South Georgia.

The climate at Grytviken is typically sub-Antarctic. Features of the summer season are strong variable winds, often deflected by the surrounding mountains, occasional heavy falls of rain and snow, and periods of dense fog, the whole interspersed with a few fine, calm, bright sunny days. The season 1930–1 was an unusually cold one, more particularly towards the end of December and throughout the month of January. The effect of this was to prolong the thawing of the snow on the lower slopes for over a month after its usual date.

The minimum salinity for the year normally coincides with maximum sea and air temperature in January, according to Clowes' (unpublished) investigations of shore water at Hope Point. At the station out in the bay, one would naturally expect a more considerable lag after maximum air temperature before this point was reached; but the above-mentioned abnormalities in the weather during the season in question were probably responsible for the fact that the mean salinity fell, while the temperature remained high until the middle of March: indications of the recommencing of the cycle were not apparent until the very last station. This retardation was augmented by heavy falls of rain and snow in February and March.

It is improbable that the main spring diatom increase was much affected by these conditions, as it appeared to be in full swing when observations were begun on November 12 and probably always takes place before thawing is nearly complete in the locality under consideration.

Thanks are due to Messrs H. F. P. Herdman, A. J. Clowes and G. E. R. Deacon for advice on chemical points, and to the two last-named for the opportunity of consulting their hitherto unpublished results. The attempted explanation of the relation between hydrological and meteorological features owes much to discussion with Mr Deacon. Throughout the season Mr A. H. Laurie rendered invaluable help with the boat work.

THE NATURE AND SEASONAL ABUNDANCE OF THE PHYTOPLANKTON

The analyses of the plankton samples taken at the various stations are shown in Tables LIII and LIV. It will be seen that they were not only very poor in bulk and numbers but in species also. In all only fourteen species of diatoms were recorded.

Dinoflagellates were present occasionally, but in such small numbers as to be altogether negligible when the phytoplankton as a whole is considered, and they have not been included in the tables.

The diatoms fall very readily into three groups, neritic forms, immigrants and occasional stragglers. Of the three neritic forms, *Fragilaria* sp., *Coscinodiscus stellaris* and *Lycmophora lyngbyei*, the first two are by far the most important, *Lycmophora* being typically a bottom form growing very plentifully on the kelp. *Fragilaria* sp. occurred on kelp also, growing in very long chains, but it was the chief and most constant constituent of the phytoplankton, where it occurred in relatively short chains averaging sixteen frustules each. *Coscinodiscus stellaris* was of fairly constant occurrence also, but its maximum development was reached at a time when the bay was invaded by a mass of high salinity water of extraneous origin, and in considering the phytoplankton in relation to hydrological and other changes, *Fragilaria* sp. has alone been taken as the typical inshore form.

Fig. 81 gives the total diatoms as histograms, *Fragilaria* sp. being shown in black; above are plotted curves for the various meteorological and other features that appear to exert an influence on the phytoplankton. Broadly speaking it will at once be seen that the heaviest catches of diatoms were obtained during the first half of the season, with a very marked falling off after mid-January. Three maximum periods are clearly definable with a sharp decline between each. The first, covered by Sts. MS 84, 85 and 86 (November 12–25), consisted of a fair proportion of *Fragilaria* sp. with an increasingly large number of immigrants, notably *Chaetoceros criophilum* and *Corethron valdiviae*. The next, at Sts. MS 89 and 90, consisted almost entirely of *Fragilaria* sp., and the last (St. MS 95) of *Coscinodiscus stellaris* of extraneous origin. At the end of the season there were slight indications of what might have become a small secondary autumnal maximum, but conditions at that time had become generally unfavourable for phytoplankton growth.

From the consideration which follows, of the meteorological and hydrological factors that appear to exert the most influence in determining this seasonal distribution of the phytoplankton, it seems that the principal reasons for its great scarcity in Cumberland Bay are two in number: firstly, the constant and often rapid movements of the surface layers consequent upon the high variable winds, and secondly, the amount of fine inorganic material, largely morainic in origin, in suspension. The wind has the effect of carrying the diatoms out of the area investigated too quickly to permit of extensive proliferation, while the suspended matter greatly decreases penetration of light, and may also interfere directly with the gaseous interchange of the organisms.

In early attempts to investigate the phytoplankton by means of the centrifuge, which failed in their main object by reason of the small numbers of organisms present, the great amount of inorganic material was at once apparent. A rough indication of the opacity of the water was obtained by noting the depth at which the polished metal top of the Nansen-Pettersen bottle disappeared from view. Unfortunately Secchi-disc readings were not taken, as the importance of this factor was not at first realized.

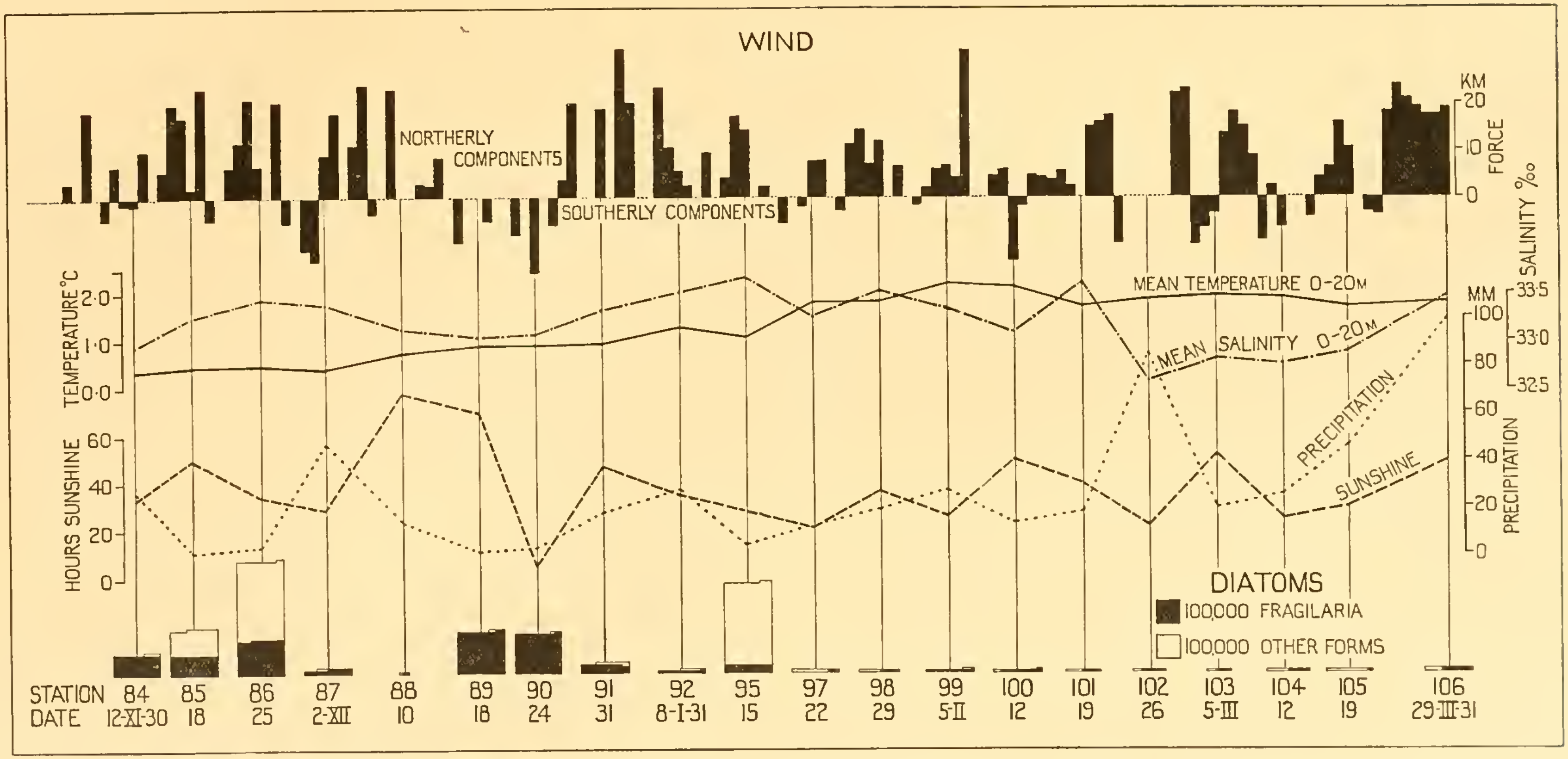

Fig. 81. Diagram showing the daily north and south components of the wind, the mean salinity and temperature of the upper 20 m., the sunshine and precipitation for the intervals between stations, and the diatom totals as histograms, for the season's work in East Cumberland Bay.

The whole situation becomes complicated when this effect of suspended inorganic matter is considered, as one of the most favourable factors for diatom growth is prolonged sunshine. This, however, leads to high air and surface temperatures and so increases the amount of thawing, and incidentally the amount of inorganic mud carried into the bay.

METEOROLOGICAL FACTORS

WIND

When investigating the movement of shore water at Hope Point, Mr Deacon found that its relation to the wind was similar to that found by Gran and Gaarder (1918) on a much larger scale in the surface layers of Oslo Fjord. With onshore winds surface water was piled up inside and the salinity reduced, while with offshore winds this state of affairs was reversed, the surface water being driven out, while the deeper-lying water of higher salinity was brought to the surface.

At our station out in the bay this simple relation was not manifest, and in the account which follows it should be borne in mind that the depth out in the bay is great, and the shoaling where it does take place is very abrupt, so that there is nothing corresponding to the shallow ridge across Oslo Fjord at Dröbak.

Owing to the configuration of the surrounding mountains the prevailing winds are usually deflected so that they blow somewhat from the north, and when the north and south components of the wind are plotted against the mean salinity for the upper 20 m. of water (see Fig. 81) it appears that with northerly winds the salinity is raised, while with southerly winds it is lowered. It seems that when northerly winds pile up the surface water inshore, outside surface water of high salinity moves in over the heavier, still more saline water of the lower layers, so that the salinity of the upper layers at the station position 2 miles out is raised.

With southerly winds, as Deacon found, the surface water of low salinity is driven offshore, and the salinity inshore rises as the deeper layers come to the surface. This apparently leads to the lowering of the salinity of the upper layers out at the station position, where the effect of the shore water drifting out is felt. The two contrasting sets of conditions may be represented diagrammatically as in Fig. 82.

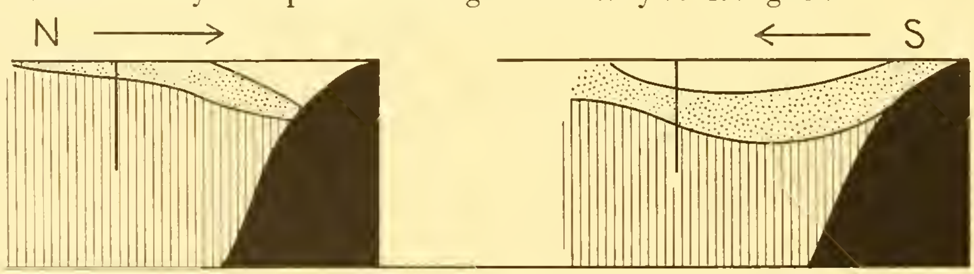

Fig. 82. Schematic diagram illustrating the apparent effect of wind on the surface layers in East Cumberland Bay.

In practice, of course, conditions are often complicated by the extreme variability of the wind, and at times by the presence of ice. Moreover, when the northerly component of the wind is negligible, heavy precipitation may lower the salinity very considerably without the aid of wind of a definite southerly trend, as at St. MS 102. South-easterly winds bringing water (and often floating ice as well) over from the Nordenskjöld glacier produced the lowest surface salinities of all.

Conditions in the bay change so rapidly that observations at much closer intervals would be necessary in order to keep track of all the changes going on, and as other work was in progress at the same time it was not possible to attempt more than one station per week. However, the broad outlines of the above argument seem to hold good, and to render the changes in the nature of the plankton observed during the first half of the season intelligible.

With strong winds of a pronounced northerly or southerly trend, the changes were so rapid as to necessitate only the wind on the day of the station itself being considered, but with light winds the conditions set up by the winds prevailing during the preceding days may still persist when the station is worked in the morning. Thus at Sts. MS 97 and 101, which furnish apparent exceptions to the general rule above enunciated, reference to the diagrams and to the Station List shows that at both of them the wind on the day of the station was slight, that they were worked early in the day, and that the conditions conform to theory when the prevailing winds of the preceding days are taken into account.

In the following account of the effect of the wind throughout the season, it is necessary to make constant reference to Figs. 81, 83 and 84, and occasionally to the Station List. Fig. 81 gives the total diatoms as histograms, *Fragilaria* sp., the principal neritic form, being shown in black; above are given the north and south components of the wind, curves for the mean salinity and temperature of the upper 20 m., the hours of sunshine, and the precipitation in mm., for the interval between each station. Fig. 83 shows the probable distribution of the isohalines with depth throughout the season, based on the salinity determinations from depths down to 75 m. at each station, and the wind components above.

It will be seen that at St. MS 84 (November 12) a light south-easterly breeze prevailed, the salinity in the upper layers was low, and *Fragilaria* sp., the typical neritic form, predominated in the plankton. At the next two stations with northerly winds, there was a rise in the mean salinity value for the upper 20 m. and a considerable invasion of oceanic diatoms, while *Fragilaria* sp. showed but slight increase in numbers. The richest diatom catch of the season was obtained at St. MS 86, the immigrant *Chaetoceros criophilum* being dominant. This form was exceedingly abundant in the open sea off South Georgia at that time.

At St. MS 87, despite a moderate northerly breeze with high salinity, there was a great falling off in diatoms, and in the scanty material obtained *Fragilaria* sp. again predominated. This is explicable on the grounds that during the interval between the two stations wild weather from the south-east prevailed, effectively driving out the comparatively rich phytoplankton found at St. MS 86. This change was also reflected in the drop in temperature of the upper layers.

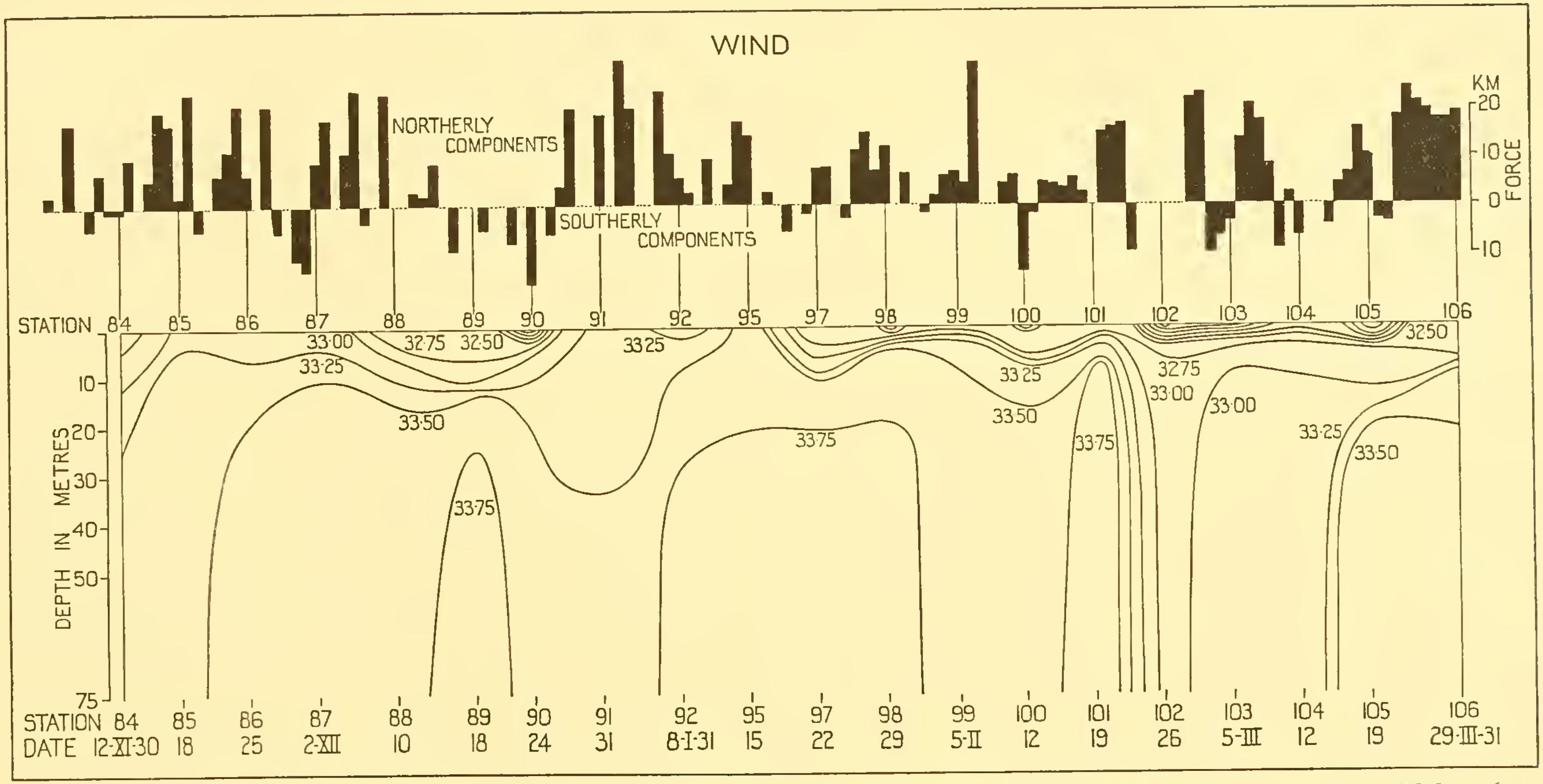

Fig. 83. Diagram showing the daily north and south components of the wind and the distribution of the isohalines with depth at Sts. MS 84–106.

By the time St. MS 88 was worked the phytoplankton was practically non-existent, violent fluctuating winds during the preceding week being responsible. Otherwise, with a fall in salinity correlated with an easterly wind one would have expected an increased development of neritic diatoms. Such an increase did in fact take place at the very next station, when, on December 18, *Fragilaria* sp. attained its maximum for the season. The salinity and intermediate wind conditions were very similar to those at the previous station, though, as might have been expected, the sharpest discontinuity layer occurred at a somewhat greater depth. Conditions during the following week were fairly stable and at St. MS 90 *Fragilaria* sp. still predominated over all other forms. A fresh south-easterly breeze was accompanied by a sharp fall in the salinity at the surface and in the temperature of the upper layers (Fig. 84), points that emphasize the influence of the large Nordenskjöld glacier and the ice which is nearly always present in the south-eastern portion of the bay.

Prior to the next station, St. MS 91, strong variable winds were experienced, and the salinity values and more gradual temperature gradient furnish strong evidence that mixing of the water layers above 40 m. had taken place. On the day of the station itself it was blowing nearly half a gale from the north-north-west. In agreement with this the salinity of the upper layers was considerably raised, and the diatom catch, though poor, showed an increased proportion of *Coscinodiscus stellaris*. This form is of constant occurrence inshore, but in small numbers, and it is probable that at this period its presence was due to invasion from outside (pp. 213, 214).

Throughout the ensuing week northerly winds prevailed and at St. MS 92 the salinity was found to be still higher in the upper layers. A slight fall at the extreme surface was due to the presence of ice, apparently brought over from the Neumayer glacier in West Fjord by the strong north-westerly wind of the two preceding days. The phytoplankton was similar to that obtained at the previous station, but not so rich, a fact that may be explained by further mixing—during this period the salinity of the whole column down to 75 m. was considerably raised, and the amount of phosphate also increased, strong evidence of the influx of outside water in bulk. These conditions reached their height on January 15 (St. MS 95) when the maximum salinity observed during the season was attained, with increased phosphate values. This was accompanied by a fresh northerly wind and a comparatively rich phytoplankton, *Coscinodiscus stellaris* being dominant (Figs. 81 and 84).

During the remainder of the season the diatom hauls were very poor, but, as the sequel should show, this was probably due to a combination of adverse factors, rather than water movements caused by wind alone. The interesting relation between the wind and the salinity of the upper layers, however, continued. Thus at St. MS 97 there occurred a sharp fall in salinity, and although the wind was working round to the north on the morning of the station, reference to the diagrams shows that easterly and south-easterly weather had prevailed during the previous four days. At the next two stations northerly winds were again correlated with increased salinity.

At St. MS 100 (February 12) surface salinities were lowered although the values for the deeper layers remained high, a fresh south-easterly breeze having followed on a period of northerly and variable winds. Throughout the ensuing week northerly winds were experienced and at the next station the salinity was greatly increased in spite of a slight easterly breeze on the day of the station itself. This station was worked in the morning, and it would seem that there had not been sufficient time for the easterly wind to affect the existing northerly conditions.

Forty-eight hours of heavy rain, with light variable winds and a very heavy northerly swell, preceded and accompanied St. MS 102, and the salinity was found to be reduced at all depths. South-easterly weather maintained this condition until March 12 (St. MS 104) with a very slight rise in the lower layers.

At the last two stations the mean salinity value for the upper layers rose, for in spite of heavy rain, snow and ice causing low surface values, that of the lower layers was considerably increased. Strong northerly winds prevailed at the time, and it is to them that this rise in salinity was doubtless due.

Summing up then, it seems to be generally true that with a pronounced northerly wind the salinity of the upper layers in the middle of East Cumberland Bay is raised, while with southerly and easterly winds it is lowered. The changes when the winds are light are slower, and conditions at stations taken at such a time may be modified by the winds prevailing during the preceding days, by heavy precipitation, and by the presence of glacier ice (cf. surface values of St. MS 105). During the first half of the season studied, the quality and quantity of the phytoplankton showed a close relation to the water movements so set up. Later it became uniformly scanty as other adverse factors came into play.

PRECIPITATION

The effect of precipitation in lowering salinity, mainly by increased land drainage, has already been described in considering the effect of wind. Unless the wind be light, the effect of increased precipitation is not at once apparent out at the station position.

The most important effect of heavy precipitation is to cut down the light available for phytoplankton growth by increasing the amount of fine inorganic particles carried into the bay by land drainage. From Fig. 81 it will be seen that the general level of precipitation was higher during the second half of the season than the first. It is to the increased opacity of the water, due both to precipitation and to thawing from the glaciers and snow-slopes, that the abrupt decline in diatom catches from January 22 onwards is ascribed. It is interesting to note that the five richest diatom hauls of the season were obtained at stations following the only weeks in which the precipitation was below 10 mm., as is well shown by Table II.

In time heavy precipitation leads naturally to dilution at the surface, and to the formation of a discontinuity layer at a depth varying with the extent of the dilution and limited by the mixing effect of the wind. Should the wind be light or offshore therefore, a layer of turbid water of low salinity will tend to form in the upper 10 m. or so, effectively cutting off the light from any diatoms remaining in the colder water of more normal salinity below, though the upper layer may show a slight development of neritic forms. These conditions were well shown by Sts. MS 99 and 100 (Figs. 81 and 83).

SUNSHINE

In general it may be said that the amount of sunshine varied inversely with the precipitation, as might be expected. Thus the general level of the sunshine curve was highest during the first half of the season when diatoms were most plentiful (Fig. 81).

This figure also brings out the interesting fact that the two highest peaks in the sunshine curve are associated with the first two diatom maxima, in November and December, when the typical neritic form, *Fragilaria* sp., was an important constituent of the phytoplankton. It is true that there was a lag in the second instance, the sunshine during the week preceding St. MS 88 being the highest recorded during the season though diatoms were practically absent at that time and did not turn up in force until the week following, the sunshine during the interval being again very high. This was probably due to the unfavourable wind conditions during the week preceding St. MS 88, which undoubtedly led to rapid movements in the upper layers. Apart from this the agreement is so close as to leave no doubt that it has a real significance.

It is noteworthy that this association of diatom abundance with sunshine occurred comparatively early in the season, before thawing was complete. In fact it was the second sunny period that finally began to clear the lower slopes of snow, a process normally completed at least three weeks earlier. After St. MS 90 (December 24) no more heavy catches of *Fragilaria* sp. were obtained, and indeed the only other catch of note was due to the invasion of *Coscinodiscus stellaris* with high salinity water from outside in January.

It would seem that this falling off was due in part to the amount of inorganic material brought down by the belated thaw. In normal seasons a spring increase would be expected with the first periods of reasonably sunny weather in October, before thawing on a large scale began; but this increase would only attain significant proportions during relatively calm periods.

PENETRATION OF LIGHT

During the first half of the season the polished metal top of the Nansen-Pettersen bottle was as a rule visible at a depth of 5 m., and transparency was logged "moderate" and "water opaque" as the limit became only 4 m. From St. MS 97 onwards it was barely visible at 2–3 m. and transparency was logged "water very opaque".

It was unfortunate that the importance of this effect of inorganic particles in suspension was not recognized sooner, or efforts would have been made to obtain more exact data on light penetration. It was felt that with diatoms so scarce that the centrifuge method could not be worked, this point could safely be left to analogy with results obtained offshore, which showed that the optimum light zone lay between the surface and 10 m. Actually, when the "sediment" factor is taken into consideration, it becomes almost certain that the optimum light zone must lie much closer to the surface inshore. It may be noted that although the two net hauls can give no detailed idea of the distribution with depth, at all stations where a comparatively rich phytoplankton was found, nearly all the diatoms appeared to be in the upper 25 m.

TIDE

The rise and fall of the tide in King Edward Cove is only $3\frac{1}{2}$ ft., so that it was not surprising to find that the tide had but little effect on the waters of the deep open bay. On one occasion only the effects of an ebbing spring tide were felt as far out as the routine station position. This was at St. MS 104 when the salinity at the surface was low. The wind on the day of the station was south-east, aiding the ebb over the reef at the mouth of Moränen Fjord, but while on station it suddenly flew round to the north-east and blew freshly for half an hour. A steep chop immediately got up, which, under-run by the northerly swell rendered work very difficult. In general there did not appear to be any correlation between the tide and hydrological and plankton conditions. Wind was the most potent agent in moving the water masses.

HYDROLOGICAL FACTORS

The temperature in the upper layers naturally showed considerable fluctuation in relation to wind, sunshine, the presence of glacier ice, and so on. From Fig. 81 it will be seen that there was a gradual rise up to St. MS 99 (February 5), after which the temperatures remained fairly high with no very marked falling off until the end of the season. At the early stations minus temperatures were recorded in the deeper layers which naturally took longer to get warmed.

The maximum observed at the surface was 2·9° C. at St. MS 97 (January 22) and the minimum 0·60° C. at St. MS 105 (March 19) with much glacier ice about. At the lowest depth worked, 75 m., the maximum was 1·55° C. at St. MS 104 (March 12) and the minimum, − 0·88° C., at the first full station worked. At this station the mean for the whole column (Fig. 84) was also at its lowest, − 0·10° C., the maximum, 1·86° C., being reached at St. MS 99 (February 5). It is to be noted that the means for the whole column (Fig. 84), 75–0 m., give a better idea of the falling off towards the extreme end of the season than the more variable means for the surface layers (Fig. 81).

The general nature of the temperature curve, together with the scanty phytoplankton, indicates that temperature is the main factor in determining the oxygen content of the water in the bay (Fig. 84). The initial value was high with supersaturation at the surface during the first diatom maximum, otherwise the temperature appeared to regulate the amount of oxygen very closely. The peak in the oxygen curve at St. MS 97 should not be considered as due to the activity of the comparatively rich phytoplankton of the week before, as the water of the upper layers was of quite different origin at the two stations. It seems highly probable that this is to be explained by the influence of water driven out of Moränen Fjord by the south-easterly winds preceding that station. The surface water

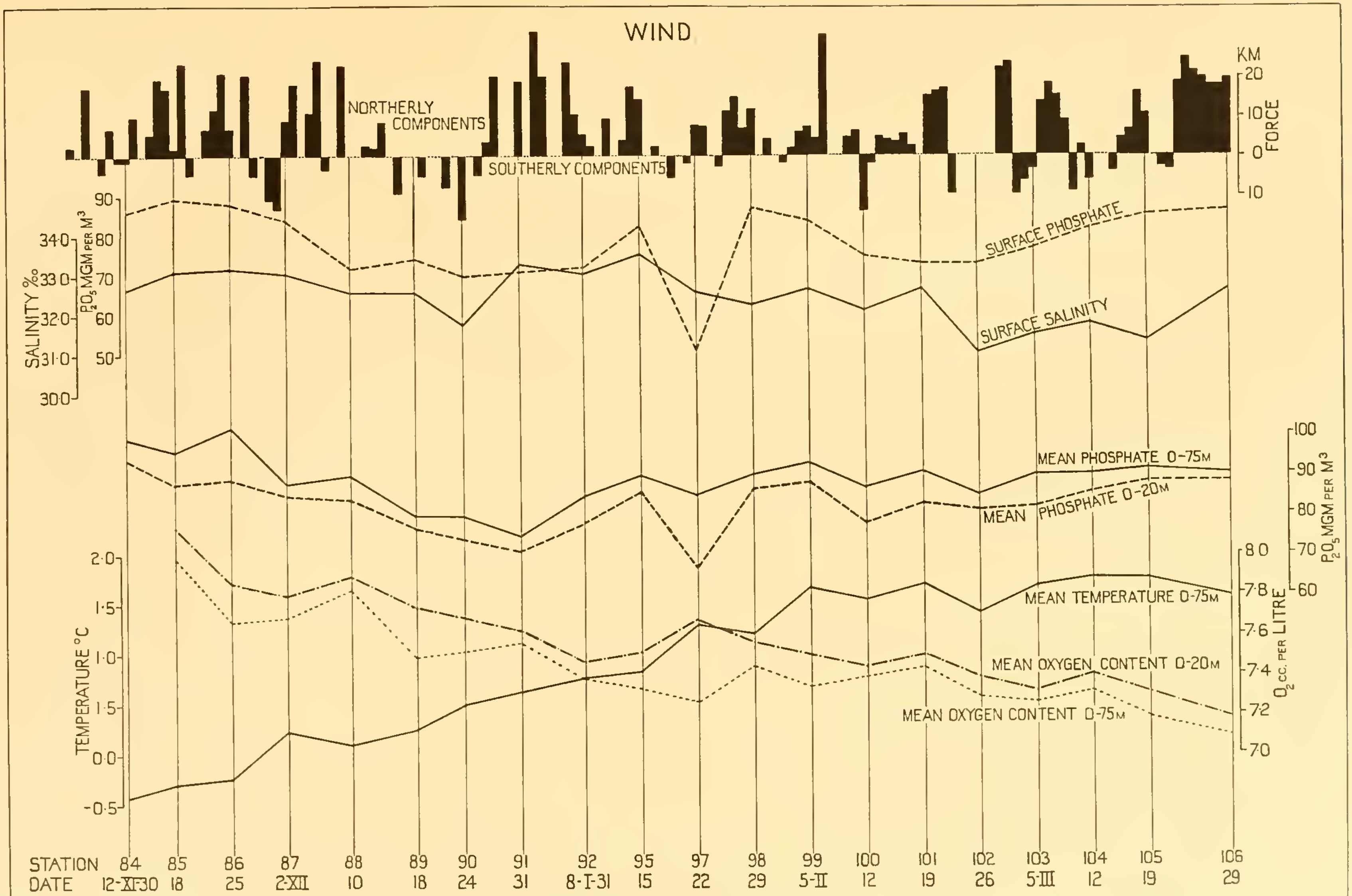

Fig. 84. Diagram showing the daily north and south components of the wind, salinity and phosphate at the surface, mean phosphate and oxygen values for 20–0 and 75–0 m. and the mean temperature for 75–0 m., at Sts. MS 84–106.

27-2

of the fjord was known to have a high oxygen content at that time (Table LV, Sts. MS 94 and 96). The abnormally low surface phosphate at St. MS 97 also lent support to this view, as the surface water of Moränen Fjord was also found to be comparatively poor in phosphate. It is possible that conditions in the fjord are much more stable than those in the open bay, permitting the development of a richer phytoplankton. Some support for this view was furnished by the *p*H values, which were much higher in the surface water of the fjord than any observed in the bay. However, there was no evidence of the efflux of such phytoplankton at St. MS 97, so that if the conditions in the fjord were, in part, the product of a rich phytoplankton development, as the diatom hauls at St. MS 94 suggested, it is fairly certain that this development must have ceased by the time St. MS 97 was worked.

The falling off of the diatom catches after mid-season coincided with a considerable rise in the mean value of the temperature. This again indicates land drainage as an unfavourable factor, but it is also possible that higher temperatures in themselves have a deleterious effect upon diatom growth. Rise in temperature will greatly increase the rate of respiration, whereas the rate of photosynthesis, limited by the amount of carbon dioxide available, cannot rise to the same extent. Thus the condition is obtained that extensive accumulation of food reserves is only possible at the lower limits of the organisms' temperature range (Dr W. H. Pearsall in correspondence). With the inshore plankton so extremely scanty it is probable that this factor would never be of the first importance in an area like East Cumberland Bay, but it is highly probable that temperature plays an important part in the open sea off South Georgia, either in some such way as is outlined above, or by its action on the degree of polymerization of the water molecules as outlined in the main part of this paper (pp. 191, 192).

Returning to East Cumberland Bay, the mean phosphate content of the upper layers showed a steady fall during the first half of the season (Fig. 84), similar to that observed by Clowes when working on the shore water at Hope Point. During this time the production of neritic diatoms was at its height (Fig. 81). This diatom production, however, never approached in extent that found offshore, so that it is probable that other factors besides utilization by phytoplankton were at work in bringing about this reduction of phosphates. From the consideration which follows it appears that the gradually increasing amount of thaw water from the glaciers and snow-slopes discharging into the bay may be responsible.

In Fig. 84 the salinity and phosphate values at the surface are plotted below the wind components. It will be seen that up to St. MS 98 the relation between surface salinity and wind was very close. The change in phosphate values was not so pronounced, and the slight falling off at St. MS 86 when the salinity was still rising with a northerly wind was due to the relatively large amount of outside plankton present at the time. The anomalous conditions apparent at St. MS 98 and some subsequent stations, were due to intervention of other factors. Chief among these were the effect of wind during the interval between stations, and, occasionally, the presence of drifting glacier ice.

At St. MS 98 phosphate was high after northerly winds, but the surface salinity was low. The wind on the previous day had been blowing hard from the west-north-west, and it is possible that low salinity water had been driven out from the region of the Neumayer glacier in West Fjord, over the top of the water of higher salinity present in the deeper layers at both Sts. MS 98 and 97. At any rate it is obvious that the low salinity surface water with high phosphate at St. MS 98 was of different origin from that at the previous station, which contained less phosphate than any other sample examined throughout the season. The sharp fall in surface salinity at St. MS 97 was consequent upon wild south-easterly weather during the preceding days, although the wind on the morning of the station itself was northerly. Prior to this easterly period, northerly winds had prevailed for a considerable time, culminating in the high salinity values obtained at St. MS 95, when there was high phosphate and a marked invasion of *Coscinodiscus stellaris* also. During this time the surface water piled up inshore would undergo dilution by land drainage, and also tend to be deprived of its phosphate by the kelp. This appears to be the probable explanation of the extremely low phosphate value (for this area) of the surface water at St. MS 97, when this diluted water had been driven out again by the south-easterly winds of the preceding four days.

From Fig. 84 it appears that at St. MS 100, with northerly wind and rising phosphate, there was still a fall in salinity at the surface. This was due to the melting of much glacier ice which drifted past while the station was in progress, causing dilution of the inflowing water comparatively rich in phosphate.

It appears, then, to be generally true that dilution of the surface layers by land drainage tends to reduce not only the salinity but the phosphate content also. This is precisely the reverse of the suggestions of some plankton workers in the northern hemisphere (cf. Gran, 1929). It must be remembered, however, that the initial phosphate value in the upper layers in East Cumberland Bay (*ca.* 90 mg. P_2O_5 per m.^{3} when these observations were begun) is probably very much greater. The valuable detailed investigations of Marshall and Orr (1927) in Loch Striven indicate *ca.* 50 mg. P_2O_5 per m.^{3} as the maximum ever attained in the upper layers there, while those of Atkins (1930) show that even less phosphate is regenerated in the English Channel. Obviously the conditions at South Georgia, where the phytoplankton, despite the abundance of nutrient salts, is very poor, are entirely different.

In support of this argument, that here the land drainage actually lowers the amount of nutrient salts, the comparatively low phosphate values found in the upper layers of the enclosed basin of Moränen Fjord (Table LV) may be cited. This fjord is fed by three large glaciers and cut off from Cumberland Bay by a reef over which there are only 2–7 m. of water. Inside it shoals very steeply and becomes very deep. About two hundred yards inside the reef soundings were obtained in 24 m., and farther up no bottom could be reached with a 40-fathom (73 m.) hand line. Returning later with another line, a sounding was obtained in 146 m. about three cables from the northern edge of the Hamburg glacier face. Owing to the reef, the larger fragments of glacier ice tend to drift round inside the fjord, in which the shores are mostly free from kelp, while on the outside of the reef kelp grows very luxuriantly. The formation of this fjord would seem to be due to the rapid recession, in comparatively recent times, of the glacier which formerly filled it. A somewhat similar condition may be seen in the hinterland of this portion of the island, where some of the glaciers have receded leaving moraine-dammed lakes.

As will be seen from Table LV, the salinity and phosphate values in the upper layers of Moränen Fjord were low, while deep down they were high and the temperatures very low, minus temperatures being found at depths of 75 and 100 m. as late as January 22.

Water obtained by melting a piece of very black morainic ice appeared to contain only 40 mg. P_2O_5 per $m.^3$ as against the 54 mg. of the surface water of Moränen Fjord, so that the diminution of phosphate in the surface waters of Cumberland Bay by land drainage becomes readily understandable.

The water at St. MS 94 was rendered turbid by melting morainic ice, yet a heavy catch of *Coscinodiscus stellaris* was obtained, the conditions being entirely different from those at the routine station in the bay a week later, when the same species again occurred in bulk. A possible explanation is that some internal biological factor determines the period for its maximum, within narrow limits during the month of January, and that being everywhere present inshore in small numbers, it so happened that the maximum in Moränen Fjord became apparent earlier than in the bay where conditions at the time were less favourable. That *Coscinodiscus stellaris* is nearly always present in inshore waters around South Georgia could be seen from the samples taken at the innermost stations on the lines worked by the R.R.S. 'Discovery II', but conditions in Cumberland Bay on January 8, the day of the Moränen Fjord maximum, were unstable, and the outburst of *Coscinodiscus* due to outside invasion came a week later. A more probable explanation, therefore, is that being a form with a heavily silicified skeleton it requires fairly stable conditions as regards density in order to develop in large numbers. At the station in Moränen Fjord it was present in large numbers *below* 35 m., and since there appeared to be a sharp discontinuity layer between 40 and 50 m. it may be that this prevented the heavy frustules from sinking farther. Many of those obtained in the deeper haul, 50–0 m., were dead. Its abundance in the bay with the invasion of outside water of much greater density a week later, was confined almost entirely to the upper 25 m., and here (see Station List, St. MS 95) the most marked difference in density occurred between 20 and 30 m.

It thus appears probable that *Coscinodiscus stellaris* is a form requiring stable conditions as regards density in order to attain its maximum development, that a sharp discontinuity layer tending to keep its heavy frustules within the zone of optimum light intensity is necessary, and that in the absence of such layering the frustules sink rapidly, It is also probable that mid-season is the normal time for this species to attain its maximum, as with the thawing of the lower slopes just complete, it is at that time that the most marked layering is liable to occur, always provided that wind conditions render this possible. In this connection it is interesting to note that there is evidence that other southern members of the genus *Coscinodiscus*, notably *C. bouvet*, show a strong tendency to sink unless conditions near the surface are ideal for them. They are frequent among pack-ice, near which shallow discontinuity layers are set up in calm weather. Father south in the Weddell Sea Lohmann (1928) gives January as the maximum period for this genus.

CONCLUSIONS

It has been shown that the phytoplankton in East Cumberland Bay is very scanty, and that a species of *Fragilaria* is the dominant neritic form. The principal factors preventing extensive production are the rapid mass movements of the water brought about by the wind, and the amount of fine inorganic particles in suspension brought down by drainage from land. Early in the season prolonged sunshine appears to be favourable to diatom growth, but will not promote any marked increase unless wind conditions are also favourable.

Meteorological conditions during the season studied were somewhat abnormal, but it seems probable that in the ordinary course of events there would be:

Firstly, a spring increase with *Fragilaria* sp. dominant, coincident with the first periods of prolonged sunshine before thawing on the lower slopes is considerable; and secondly, a mid-season increase with *Coscinodiscus stellaris* dominant, dependent upon a short period of calm weather.

Following periods of prolonged northerly winds there is likely to be a considerable invasion of outside forms, especially *Chaetoceros criophilum* and *Corethron valdiviae* These are large species which frequently dominate the phytoplankton community in the open sea east of South Georgia, and find their optimum conditions near the surface.

It has been shown that the phosphate content of the water in these regions is always very much higher than in corresponding latitudes in the northern hemisphere, so that it is unlikely that the amount of nutrient salts available influences phytoplankton periodicity in the south. In East Cumberland Bay, the concentration of phosphate fell during the first half of the season, during which time the richest hauls of diatoms, comparatively speaking, were obtained. Since these diatoms were not at any time present in sufficient quantity to warrant the assumption that this was due to their activity alone, it is concluded that dilution of the inshore water consequent upon the thawing of glaciers and snow-slopes was partly responsible for this decrease in phosphate. This dilution causes at the same time a marked reduction in the salinity at the surface, so that this effect can be distinguished from the depletion in phosphate caused by the rich phytoplankton development offshore, the influx of outside water being marked by a rise in salinity. This view is also supported by the fact that the mean phosphate content at the routine station position was lower than that found at corresponding depths in the open sea offshore during the season studied.

Gran (1929) and his co-workers, notably Mrs Ruud-Foyn, have held that off the Norwegian coast thaw water is responsible for the onset of the great vernal diatom increase by increasing the amount of nutrient salts present. This is precisely the reverse of the effect observed in Cumberland Bay, where, however, conditions are very different.

The hydrological work of Braarud and Klem (1931) in the area investigated by Gran, has shown that the apparent correlation of the spring thaw with the main spring diatom increase is probably incidental (*ibid.*, p. 77), and that in any case the former does not add to the nutrient salt content of the surface layers appreciably. It is therefore easily understandable that at South Georgia, where the land is much more barren and the initial phosphate content of the surface water higher, the thaw water appears to lead to an actual decrease in the amount of phosphate available.

Conditions in East Cumberland Bay do not permit of any comparison with those obtaining far offshore. However, the reasons to which the poverty of the inshore phytoplankton is attributed probably hold good all round the island. It is thus highly probable that the falling off in quantity of the phytoplankton often observed at the innermost stations of the lines worked on numerous surveys round the island by the research ships is to be explained by the prevalence of the same adverse factors, namely, rapid movements of the surface layers caused by wind, and the large amount of fine inorganic material in suspension brought down by land drainage. This last factor greatly hinders the penetration of light, and may also interfere directly with the gaseous interchanges upon which the vital processes of the organisms depend.

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TABLES I—LV

APPENDIX II. TABLES I–LV

Table I. *Analyses of samples taken on a line of stations along the 30th W meridian. The positions of the stations are charted on Plate I, Discovery Reports,* IV.

Station	661	663	666	670	671	673	675	677	679	681	684	687	690	693	699
Latitude	57° 36′ S	53° 34½′ S	49° 58¾′ S	44° 52′ S	43° 08′ S	38° 10½′ S	34° 08′ S	31° 16¼′ S	26° 06½′ S	21° 13′ S	15° 37′ S	09° 47′ S	03° 17¾′ S	02° 59′ N	14° 27½′ N
Date	2. iv. 31	4. iv. 31	17/18. iv. 31	22. iv. 31	22/23. iv. 31	24/25. iv. 31	26. iv. 31	27/28. iv. 31	29. iv. 31	1. v. 31	3. v. 31	5. v. 31	7/8. v. 31	10. v. 31	14. v. 31
Temp. ° C. (mean of 0–20 m.)	−0·80	0·52	2·70	8·10*	9·56	17·39	18·95	21·43	25·21	27·20	26·80	27·56	28·19	28·05	23·85
Salinity ‰ (mean of 0–20 m.)	33·33	33·60	33·84	34·18*	34·32	35·16	35·44	35·68	36·56	37·34	37·24	36·56	36·01	35·84	36·33
P_2O_5 mg./m.³ (mean of 0–20 m.)	106	99	107	74*	72	10	10	8	0	0	0	0	0	0	0
NO_3 mg./m.³ (mean of 0–20 m.)	505	490	475	—	—	48	7	5	5	1	2	3	4	2	2
O_2 cc. per l. (mean of 0–20 m.)	7·45	7·37	7·12	6·21*	6·12	5·21	5·05	4·89	4·59	4·40	4·33	4·28	4·33	4·35	4·63
*p*H (mean of 0–20 m.)	7·97	7·98	7·96	8·09*	8·09	8·17	8·16	8·18	8·25	8·30	8·28	8·28	8·28	8·28	8·26
Volume of sample cc.	620	340	6	6	3	2	2	4	3	3	2	4	4	4	5
Fraction examined	1 : 12,800	1 : 6,800	1 : 300	1 : 300	1 : 300	1 : 300	1 : 300	1 : 300	1 : 300	1 : 200	1 : 200	1 : 200	1 : 200	1 : 200	1 : 200
Diatomales:															
Coscinodiscus spp.	12,800	—	5,100	300	1,200	—	—	—	—	—	—	200	200	400	800
Planktoniella sol	—	—	—	—	—	900	—	—	—	—	—	—	600	200	600
Asterolampra sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	200	—
Asteromphalus hepactis	—	—	—	—	—	—	—	900	—	200	—	—	—	—	—
A. regularis	12,800	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Euodia cuneiformis	—	—	—	—	—	—	—	—	—	—	—	—	—	2,000	—
Dactyliosolen antarcticus	—	—	17,400	300	—	—	—	—	—	—	—	—	—	—	—
Corethron valdiviae	1,164,800	210,800	4,500	4,800	1,500	—	—	—	—	—	—	—	—	—	—
Bacteriastrum varians	—	—	—	—	—	—	—	1,800	600	400	—	—	—	—	—
Rhizosolenia alata	—	—	2,700	—	—	—	—	—	—	—	—	—	—	—	—
Rhizosolenia alata f. *gracillima*	—	—	—	900	1,200	300	—	—	—	—	—	—	—	—	—
R. castracanei	—	—	—	—	—	—	—	—	600	—	—	—	—	—	—
R. curva	—	—	—	300	—	—	—	—	—	—	—	—	—	—	—
R. styliformis	140,800	136,000	1,200	1,200	300	—	—	1,500	—	—	400	600	—	800	—
R. torpedo	—	—	—	600	—	—	—	—	—	—	—	—	—	—	—
Chaetoceros atlanticus	153,600	—	202,200	1,800	—	—	—	—	—	—	—	—	—	—	—
Ch. criophilum	9,228,800	5,868,400	10,800	900	—	—	—	—	—	—	—	—	—	—	—
Ch. concavicornis	—	—	—	—	4,500	—	—	—	—	—	—	—	—	—	—
Ch. curvatus	—	—	1,200	—	—	—	—	—	—	—	—	—	—	—	—
Ch. didymum	—	—	—	—	—	—	—	—	1,500	—	—	—	—	—	—
Ch. dichaeta	51,200	20,400	21,000	—	—	—	—	—	—	—	—	—	—	—	—
Ch. neglectus	140,800	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ch. peruvianum	—	—	—	—	—	—	—	—	600	—	—	1,800	—	—	200
Hemiaulus hauckii	—	—	—	—	—	—	—	—	19,200	1,400	—	—	—	1,800	—
Fragilaria antarctica	102,400	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Thalassiothrix antarctica	38,400	13,600	—	—	—	—	—	—	—	—	—	—	—	—	—
Nitzschia seriata	—	—	88,500	3,600	—	—	—	—	—	—	—	—	—	—	—
Nitzschia sp.?	—	—	—	—	43,500	—	—	—	—	—	—	—	—	—	—
Dinoflagellata:															
Gymnodinium lunula	—	—	—	—	—	—	—	—	—	200	—	200	—	—	—
Gymnodinium lunula f. *globulus*	—	—	—	—	—	—	—	—	—	400	—	—	—	200	—
Gymnodinium sp.	—	—	—	—	—	—	—	—	—	—	—	200	—	—	—
Noctiluca scintillans	—	—	—	—	—	—	—	—	—	—	200	200	200	—	200

Phalacroma minutum	—	—	—	—	—	—	—	—	—	—	—	—	—	200	400
P. rudgei	—	—	—	—	—	—	—	—	—	—	—	—	—	400	—
Dinophysis spp.	—	—	300	—	—	—	—	—	—	—	—	—	—	—	—
D. schuettii	—	—	—	—	—	—	—	—	—	400	400	—	—	—	—
Amphisolenia globifera	—	—	—	—	—	—	—	—	—	—	200	—	—	—	—
Ornithocercus steinii	—	—	—	—	—	300	—	—	—	—	—	—	—	—	—
O. magnificus	—	—	—	—	—	—	—	300	900	1,200	—	400	400	400	400
Goniodoma polyedricum	—	—	—	—	—	—	—	—	—	—	200	—	—	—	—
Goniaulax polygramma	—	—	—	300	—	—	—	—	—	—	—	—	—	—	—
Goniaulax sp.	—	—	—	—	—	—	—	300	—	—	—	—	—	—	—
Peridinium tripos	—	—	—	—	—	—	—	300	—	—	—	—	—	—	600
P. antarcticum	12,800	—	3,000	—	—	—	—	—	—	—	—	—	—	—	—
P. elegans	—	—	—	—	300	—	—	—	—	—	—	—	—	—	—
P. oceanicum	—	—	—	—	—	—	—	—	—	200	—	—	—	—	—
P. globulus	—	—	—	—	—	—	—	—	—	800	—	—	—	—	—
Peridinium spp.	—	—	2,400	—	300	600	900	—	—	—	800	400	—	200	200
Pyrophacus horologicum	—	—	—	—	—	—	—	—	600	—	—	600	—	—	400
Ceratium candelabrum	—	—	—	—	—	—	—	—	—	—	—	400	—	—	—
C. lineatum	—	—	—	—	—	—	—	300	1,500	800	—	1,000	2,800	1,400	400
C. fusus	—	—	—	600	12,600	600	600	1,200	600	—	200	600	200	400	—
C. tripos f. *truncata*	—	—	—	900	2,400	—	—	—	—	—	—	—	—	—	—
C. bucephalum	—	—	—	—	—	—	—	—	—	—	—	—	200	200	1,600
C. gibberum f. *sinistrum*	—	—	—	—	—	—	—	—	—	—	1,600	1,000	1,200	200	1,600
C. varians	—	—	—	—	—	900	300	4,800	1,500	3,200	—	1,200	800	800	3,000
C. limulus	—	—	—	—	—	—	—	—	—	200	—	200	—	—	200
Ceratium spp.	—	—	—	—	—	—	—	600	—	—	—	1,000	—	—	—
Podolampas bipes	—	—	—	—	—	—	—	—	—	200	—	—	200	200	—
Silicoflagellata	—	—	—	300	—	—	—	—	—	—	—	—	—	—	—
Schizophyceae etc.															
Pelagothrix sp.	—	—	—	—	—	900	—	—	—	—	—	—	—	400	—
Trichodesmium thiebautii (colonies)	—	—	—	—	—	—	—	—	—	—	—	—	200	200	—
Trichodesmium thiebautii (loose strands)	—	—	—	—	—	—	—	—	—	—	600	—	20,000	65,400	2,400
Richelia intracellularis	—	—	—	—	—	—	—	—	—	—	—	—	—	200	—
Coccolithophora leptopora	—	—	—	—	—	—	—	—	—	—	1,000	—	—	—	—
Protozoa															
Radiolaria	—	—	1,800	—	300	900	—	2,100	900	600	1,600	7,000	1,000	3,200	2,000
Foraminifera	—	—	—	1,800	4,200	5,100	1,500	600	—	1,200	600	1,400	1,800	1,200	1,800
Tintinnus lusus-undae	—	—	—	—	—	—	—	—	600	800	600	—	—	1,400	600
Other Tintinnidae	38,400	34,000	10,800	9,000	29,400	1,800	300	1,200	300	200	—	1,600	2,200	8,000	1,600
Copepoda	25,600	—	1,800	2,100	4,500	1,800	600	5,100	7,800	2,000	1,400	2,800	7,200	2,600	6,600
Nauplii	12,800	—	7,500	10,800	9,300	13,800	2,700	12,900	11,400	3,600	3,200	9,600	11,200	10,800	11,800
Diphyids	—	—	—	—	—	—	—	300	—	—	—	—	200	—	—
Chaetognatha	—	—	—	—	—	—	—	—	600	600	200	—	800	—	600
Pteropoda	—	—	—	—	—	300	—	600	—	—	—	400	200	—	400
Total Diatomales	11,046,400	6,249,200	354,600	14,700	52,200	1,200	—	4,200	22,500	2,000	400	2,600	800	5,400	1,600
Total Dinoflagellata	12,800	—	5,700	1,800	15,600	2,400	1,800	7,800	5,100	7,600	3,600	7,400	6,000	4,600	9,000
Total Schizophyceae	—	—	—	—	—	900	—	—	—	—	600	—	20,000 +	66,000 +	2,400
Total Protozoa	38,400	34,000	11,400	10,800	33,900	7,800	1,800	3,900	1,800	2,800	2,800	10,000	5,000	13,800	6,000

* Surface samples only.

Table II. *Analyses of samples collected on a line of stations north-eastwards from Cape Larsen, South Georgia. Survey of Jan.–Feb.* 1930. *The positions of the stations are charted in Fig.* 4.

Station ...	308	309	310	311	312	313	358	357
Date ...	24. i. 30	24. i. 30	24. i. 30	24. i. 30	24/25. i. 30	25. i. 30	11. ii. 30	10. ii. 30
Temp. °C. (mean of 0–20 m.)	3·15	3·34	3·30	3·13	2·45	2·52	3·63	3·26
Salinity ‰ (mean of 0–20 m.)	33·72	33·77	33·77	33·76	33·85	33·85	33·81	33·82
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	82	87	87	73	86	105	60	53
O_2 cc. per l. (mean of 0–20 m.)	6·99	—	6·86	—	6·29*	—	6·90	—
*p*H (mean of 0–20 m.)	8·12	8·10	8·12	8·11	8·09	8·10	8·11	8·11
Volume of sample cc....	12	3	2	1	10	23	19	15
Fraction examined ...	1 : 300	1 : 200	1 : 300	1 : 150	1 : 3,000	1 : 14,100	1 : 15,600	1 : 14,100
Diatomales:								
Melosira sol	—	—	—	300	—	—	—	—
Thalassiosira antarctica	—	—	—	—	—	42,500	—	—
Corethron valdiviae (spineless chains)	—	2,000	2,400	—	309,000	1,128,000	4,824,000	380,700
Rhizosolenia alata	—	—	—	—	6,000	45,000	15,600	—
R. truncata	—	—	—	—	3,000	—	—	—
Eucampia antarctica	—	—	—	—	—	—	286,400	112,800
Thalassiothrix antarctica	—	—	—	—	719,000	4,765,800	—	—
Navicula oceanica	—	—	—	—	3,000	—	—	—
Gyrosigma directum	—	—	—	150	—	—	—	—
Nitzschia seriata	—	—	—	—	—	—	93,600	98,700
Dinoflagellata:								
Dinophysis sp.	—	—	—	1,800	—	—	—	—
Peridinium antarcticum	6,000	5,800	2,700	1,050	24,000	30,000	440,400	239,700
Ceratium pentagonum f. *grandis*	900	1,000	900	300	3,000	28,200	358,800	324,300
Silicoflagellata	—	—	—	—	3,000	14,100	—	—
Protozoa:								
Radiolaria	—	—	2,400	—	3,000	42,300	—	—
Foraminifera	—	—	—	600	—	—	—	—
Tintinnidae	—	1,200	300	1,950	12,000	—	187,200	155,100
? *Sticholonche* sp.	—	—	—	—	—	—	15,600	—
Copepoda	36,000	6,000	1,600	1,500	9,000	14,100	16,000	56,400
Nauplii	27,000	4,800	3,300	2,250	18,000	14,100	78,000	211,500
Pteropoda: *Limacina* juv.	—	—	900	5,250	3,000	28,200	—	—
Total Diatomales	—	2,000	2,400	450	1,040,000	5,981,100	5,219,600	592,200
Total Dinoflagellata	6,900	6,800	3,600	3,150	27,000	58,200	799,200	564,000
Total Protozoa	—	1,200	2,700	2,550	15,000	42,300	202,800	155,100

* Sample at 10 m.

Table III. *Analyses of samples collected on a line of stations northwards from Prince Olaf Harbour, South Georgia. Survey of Jan.–Feb. 1930. The positions of the stations are charted in Fig. 4.*

Station	**314**	**315**	**307**	**306**	**305**	**304**	**303**	**302**	**301**	**300**
Date	29. i. 30	29. i. 30	22. i. 30	22. i. 30	21/22. i. 30	21. i. 30	21. i. 30	21. i. 30	20/21. i. 30	20. i. 30
Temp. °C. (mean of 0–20 m.)	2·35	3·06	3·20	3·20	3·25	3·05	2·94	2·77	2·74	2·88
Salinity ‰ (mean of 0–20 m.)	33·79	33·78	33·76	33·78	33·78	33·82	33·84	33·84	33·84	33·84
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	111	72	75	87	81	84	72	69	74	75
O_2 cc. per l. (mean of 0–20 m.)	—	7·37	8·16	—	7·35	—	—	—	7·38	—
*p*H (mean of 0–20 m.)	8·09	8·12	8·07	8·06	8·08	8·08	8·09	8·08	8·08	8·07
Volume of sample cc.	2	2	17	20	33	34	5	23	20	16
Fraction examined	1 : 300	1 : 300	1 : 5,100	1 : 7,200	1 : 5,500	1 : 9,000	1 : 8,550	1 : 9,000	1 : 9,600	1 : 9,000
Diatomales:										
Melosira sol	—	—	—	—	—	—	—	—	57,600	—
Coscinodiscus spp.	600	—	—	—	—	18,000	25,650	18,000	19,200	18,000
Thalassiosira antarctica	—	—	102,000	—	—	—	—	—	—	—
Dactyliosolen antarcticus	—	—	—	—	—	—	—	—	—	9,000
Corethron valdiviae (spineless chains)	—	2,400	4,324,800	64,800	286,000	1,350,000	735,300	1,719,000	1,708,000	630,000
Rhizosolenia alata	—	—	10,200	7,200	—	18,000	17,100	—	9,600	45,000
R. antarctica	—	—	—	—	—	—	—	—	19,200	—
R. styliformis	—	—	—	—	—	9,000	17,100	—	—	—
R. truncata	—	—	—	—	—	9,000	—	—	—	—
Chaetoceros atlanticus	—	—	—	—	—	—	—	18,000	57,600	9,000
Biddulphia striata	—	—	20,400	—	—	—	—	—	—	27,000
Eucampia antarctica	—	—	—	—	—	45,000	34,200	981,000	48,000	288,000
Fragilaria antarctica	—	—	—	—	—	378,000	—	—	—	—
Thalassiothrix antarctica	—	—	61,200	—	—	3,015,000	342,000	1,872,000	2,006,400	1,503,000
Nitzschia seriata	—	—	81,000	—	—	—	—	72,000	192,000	—
Small plant cells*	—	—	—	—	—	—	—	225,000	—	135,000
Dinoflagellata:										
Peridinium antarcticum	600	1,200	40,800	7,200	99,000	261,000	119,700	54,000	—	—
Ceratium pentagonum f. *grandis*	—	—	—	14,400	22,000	234,000	136,800	36,000	9,600	—
Silicoflagellata	—	—	—	—	—	—	17,100	18,000	—	18,000
Protozoa:										
Radiolaria	—	—	—	—	—	—	8,550	—	—	—
Tintinnidae	—	—	51,000	36,000	253,000	144,000	128,250	54,000	48,000	27,000
Copepoda	3,600	3,300	20,400	51,400	56,500	27,000	—	9,000	9,600	9,000
Nauplii	6,600	3,900	61,200	57,600	132,000	45,000	8,550	9,000	9,600	18,000
Pteropoda: *Limacina* juv.	300	—	—	14,400	11,000	18,000	—	—	9,600	—
Total Diatomales	600	2,400	4,599,600	72,000	286,000	4,542,000	1,171,250	4,905,000	4,104,200	2,664,000
Total Dinoflagellata	600	1,200	40,800	21,600	121,000	495,000	256,500	90,000	9,600	—
Total Protozoa	—	—	51,000	36,000	253,000	144,000	136,800	54,000	48,000	27,000

* ? Diatom spores.

Table IV. *Analyses of samples collected on a line of stations north-westwards from Bird Island, South Georgia. Survey of Jan.–Feb.* 1930. *The positions of the stations are charted in Fig.* 4.

Station ...	316	317	318	319	323	322	321	320
Date ...	29. i. 30	29. i. 30	29. i. 30	29/30. i. 30	31. i. 30	31. i. 30	30. i. 30	30. i. 30
Temp. ° C.	2·45	2·84	2·83	3·38	3·36	3·59	3·95	3·81
Salinity ‰	33·81	33·85	33·85	33·85	33·82	33·81	33·82	33·80
P_2O_5 mg./m.³ (mean of 0–20 m.)	83	69	90	74	78	71	50	68
O_2 cc. per l.	7·45	—	7·00	—	6·82	—	6·33	—
*p*H	8·12	8·20	8·16	8·18	8·17	8·17	8·19	8·19
Volume of sample cc. ...	16	14	4	6	2	8	11	6
Fraction examined ...	1 : 3,000	1 : 3,000	1 : 200	1 : 300	1 : 200	1 : 1,000	1 : 300	1 : 1,000
Diatomales:								
Melosira sphaerica	21,000	108,000	—	—	—	—	—	—
Coscinodiscus spp.	12,000	12,000	2,400	1,200	2,000	4,000	1,200	—
Corethron valdiviae (spineless chains)	1,254,000	1,374,000	864,000	6,600	270,000	100,000	132,000	252,000
Biddulphia striata	—	24,000	—	—	—	—	—	—
Eucampia antarctica	114,000	24,000	—	—	—	40,000	—	—
Fragilaria antarctica	—	—	—	—	—	2,000	—	—
Dinoflagellata:								
Peridinium antarcticum	27,000	24,000	3,600	1,800	81,000	88,000	216,000	36,000
Ceratium pentagonum f. *grandis*	9,000	—	—	1,200	36,000	118,000	216,000	81,000
Silicoflagellata	—	—	—	—	—	—	3,000	9,000
Protozoa:								
Radiolaria	—	—	—	2,100	—	4,000	—	—
Foraminifera	—	—	—	—	—	—	300	—
Tintinnidae	3,000	—	600	5,400	88,000	26,000	12,000	54,000
Copepoda	15,600	300	18,000	11,700	1,200	3,000	2,400	9,000
Nauplii	27,000	12,000	3,000	6,900	9,000	36,000	4,800	27,000
Pteropoda:	3,000	—	—	3,000	—	8,000	—	—
Total Diatomales	1,401,000	1,542,000	848,400	7,800	272,000	146,000	133,200	252,000
Total Dinoflagellata	36,000	24,000	3,600	3,000	117,000	206,000	432,000	117,000
Total Protozoa	3,000	—	600	7,500	88,000	30,000	12,300	54,000

Table V. *Analyses of samples collected on a line of stations south-westwards from C. Nuñez, South Georgia. Survey of Jan.–Feb.* 1930. *The positions of the stations are charted in Fig.* 4.

Station ...	328	327	326	331	332	333	325	324
Date ...	2. ii. 30	2. ii. 30	2. ii. 30	2. ii. 30	3. ii. 30	3. ii. 30	1. ii. 30	1. ii. 30
Temp. ° C.	3·13	3·25	3·35	3·35	3·00	3·00	3·32	3·10
Salinity ‰	33·72	33·85	33·86	33·87	33·89	33·91	33·87	33·86
P_2O_5 mg./m.³ (mean of 0–20 m.)	87	81	86	84	96	98	95	100
O_2 cc. per l.	7·22	—	6·59	—	—	—	6·96	—
*p*H	8·14	8·13	8·11	8·13	8·12	8·12	8·12	8·14
Volume of sample cc. ...	12	15	9	10	5	6	2	3
Fraction examined ...	1 : 3,000	1 : 7,500	1 : 250	1 : 1,000	1 : 200	1 : 200	1 : 100	1 : 100
Diatomales:								
Coscinodiscus spp.	—	—	—	4,000	—	4,800	—	3,000
Asteromphalus regularis	—	—	—	—	—	200	—	—
Dactyliosolen antarcticus	—	—	—	4,000	—	—	—	—
Corethron valdiviae (spineless chains)	6,000	1,200,000	—	—	12,000	52,800	27,000	—
Rhizosolenia styliformis	—	—	—	—	2,000	—	—	3,000
Dinoflagellata:								
Dinophysis sp.	—	—	5,250	—	2,000	—	—	6,000
Peridinium antarcticum	72,000	97,500	31,500	80,000	33,000	24,000	3,000	9,000
Ceratium pentagonum f. *grandis*	6,000	52,500	21,000	40,000	13,200	14,400	3,000	15,000
Protozoa:								
Radiolaria	—	—	—	8,000	—	9,600	6,000	9,000
Foraminifera	—	—	5,250	—	—	14,400	3,000	6,000
Tintinnidae	—	—	—	—	2,000	9,600	6,000	9,000
Copepoda	38,000	15,000	89,250	68,000	20,000	28,800	27,000	30,000
Nauplii	132,000	187,500	63,000	68,000	26,400	67,200	15,000	51,000
Pteropoda: *Limacina* juv.	3,000	—	—	—	—	—	—	—
Total Diatomales	6,000	1,200,000	—	8,000	14,000	57,800	27,000	6,000
Total Dinoflagellata	78,000	150,000	57,750	120,000	48,200	38,400	6,000	30,000
Total Protozoa	—	—	5,250	8,000	2,000	33,600	15,000	24,000

Table VI. *Analyses of samples collected on a line of stations southwards from Undine South Harbour, South Georgia. Survey of Jan.–Feb.* 1930. *The positions of the stations are charted in Fig.* 4.

Station	340	341	339	338	337	336	335	334
Date	5. ii. 30	5/6. ii. 30	5. ii. 30	5. ii. 30	5. ii. 30	5. ii. 30	4/5. ii. 30	4. ii. 30
Temp. ° C. (mean of 0–20 m.)	3·86	3·57	3·61	3·29	2·78	2·81	2·81	3·01
Salinity °/₀₀ (mean of 0–20 m.)	33·78	33·83	33·84	33·86	33·88	33·83	33·82	33·89
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	73	87	73	78	86	83	72	82
O_2 cc. per l. (mean of 0–20 m.)	6·80	—	6·83	—	—	—	7·04	—
*p*H (mean of 0–20 m.)	8·14	8·13	8·13	8·13	8·11	8·12	8·13	8·11
Volume of sample cc.	9	9	13	5	20	19	15	10
Fraction examined	1 : 1,500	1 : 1,000	1 : 1,000	1 : 1,000	1 : 300	1 : 200	1 : 150	1 : 400
Diatomales:								
Coscinodiscus spp.	—	—	—	—	1,500	13,400	—	—
Corethron valdiviae (spineless chains)	22,500	8,000	—	28,000	125,400	27,000	67,500	28,800
Rhizosolenia alata	—	—	—	—	—	—	300	—
R. styliformis	—	—	—	4,000	—	9,000	—	9,600
Thalassiothrix antarctica	—	—	—	—	28,500	—	—	—
Nitzschia seriata	—	—	—	20,000	—	—	—	—
Dinoflagellata:								
Dinophysis sp.	—	—	—	—	—	—	6,750	—
Peridinium antarcticum	22,500	42,000	68,000	32,000	39,000	72,000	122,500	52,800
Ceratium pentagonum f. *grandis*	34,000	28,000	16,000	4,000	5,700	13,400	13,500	—
Protozoa:								
Radiolaria	—	—	4,000	4,000	17,100	13,400	13,500	4,800
Foraminifera	—	4,000	—	—	11,400	4,400	—	4,800
Tintinnidae	—	—	—	—	28,500	22,000	6,750	19,200
Copepoda	54,000	90,000	96,000	20,000	79,800	85,400	74,250	29,000
Nauplii	94,500	43,000	112,000	60,000	256,500	166,400	30,000	129,600
Pteropoda	4,500	4,000	12,000	—	39,900	13,400	30,000	9,600
Total Diatomales	22,500	8,000	—	52,000	155,400	49,400	67,800	38,400
Total Dinoflagellata	56,400	70,000	84,000	36,000	44,700	85,500	142,750	52,800
Total Protozoa	—	4,000	4,000	4,000	57,000	39,800	20,250	28,800

Table VII. *Analyses of samples collected on a line of stations south-eastwards from Cooper Island, South Georgia. Survey of Jan.–Feb.* 1930. *The positions of the stations are charted in Fig.* 4.

Station	348	349	347	346	345	344	343	342
Date	8. ii. 30	8. ii. 30	8. ii. 30	8. ii. 30	8. ii. 30	7. ii. 30	7. ii. 30	7. ii. 30
Temp. ° C. (mean of 0–20 m.)	3·11	3·01	3·08	2·77	2·88	2·37	2·34	2·24
Salinity °/₀₀ (mean of 0–20 m.)	33·71	33·82	33·75	33·84	33·85	33·81	33·84	33·82
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	62	68	73	78	77	84	80	85
O_2 cc. per l. (mean of 0–20 m.)	—	—	6·71	—	6·91	—	—	—
*p*H (mean of 0–20 m.)	8·11	8·13	8·13	8·13	8·13	8·13	8·13	8·10
Volume of sample cc.	5	4	22	3	1	14	15	17
Fraction examined	1 : 2,100	1 : 200	1 : 300	1 : 300	1 : 200	1 : 9,600	1 : 1,200	1 : 2,000
Diatomales:								
Coscinodiscus spp.	4,200	—	4,200	—	—	—	60,000	40,000
Corethron valdiviae (spineless chains)	—	—	—	43,500	9,000	2,428,800	2,880,000	4,080,000
Rhizosolenia alata	—	—	—	—	—	—	—	12,000
Eucampia antarctica	—	—	—	12,300	—	—	—	—
Thalassiothrix antarctica	—	—	—	—	—	384,000	1,980,000	3,192,000
Dinoflagellata:								
Dinophysis sp.	—	—	—	—	2,000	—	—	—
Peridinium antarcticum	123,200	32,200	47,100	74,700	35,200	9,600	24,000	—
Ceratium pentagonum f. *grandis*	42,400	9,200	40,500	43,500	17,000	—	24,000	16,000
Protozoa:								
Radiolaria	—	—	—	—	9,000	—	36,000	6,000
Foraminifera	—	—	6,600	—	—	—	12,000	—
Tinitinnidae	—	—	—	12,300	8,800	19,200	12,000	16,000
Copepoda	21,200	36,800	183,300	2,400	2,200	28,800	4,800	8,000
Nauplii	68,000	50,600	108,000	63,000	5,200	67,200	36,000	24,000
Pteropoda: *Limacina* juv.	4,200	—	—	27,000	4,400	—	24,000	—
Total Diatomales	4,200	—	4,200	55,800	9,000	2,812,800	4,920,000	7,324,000
Total Dinoflagellata	165,600	41,400	87,600	118,200	54,200	9,600	48,000	16,000
Total Protozoa	—	—	6,600	12,300	17,800	19,200	60,000	22,000

Table VIII. *Analyses of samples collected on a line of stations eastwards from Cape Vakop, South Georgia. Survey of Jan.–Feb.* 1930. *The positions of the stations are charted in Fig.* 4.

Station	350	351	352	353	354	355	356
Date	9. ii. 30	9. ii. 30	9. ii. 30	9. ii. 30	9. ii. 30	9. ii. 30	10. ii. 30
Temp. °C. (mean of 0–20 m.)	3·86	3·69	2·94	2·39	2·34	2·01	2·01
Salinity ‰ (mean of 0–20 m.)	33·65	33·71	33·87	33·87	33·87	33·86	33·87
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	70	86	88	94	78	53	57
O_2 cc. per l. (mean of 0–20 m.)	7·01	—	6·77	—	6·79	—	7·15
*p*H (mean of 0–20 m.)	8·12	8·13	8·10	8·10	8·10	8·12	8·12
Volume of sample cc.	4	1	0·5	2	2	10	45
Fraction examined	1 : 200	1 : 100	1 : 100	1 : 200	1 : 100	1 : 3,000	1 : 3,000
Diatomales:							
Coscinodiscus spp.	—	—	—	4,600	10,000	165,000	297,000
Corethron valdiviae	—	—	—	—	10,000	3,285,000	16,224,000
Rhizosolenia alata	—	—	—	—	—	75,000	495,000
R. styliformis	—	—	—	—	5,000	—	—
Thalassiothrix antarctica	—	—	—	13,800	—	2,115,000	13,248,000
Dinoflagellata:							
Peridinium antarcticum	26,000	7,500	2,000	—	40,000	300	—
Ceratium pentagonum f. *grandis*	36,400	2,500	2,000	—	15,000	—	—
Protozoa:							
Radiolaria	5,200	—	—	4,600	5,000	15,000	—
Tintinnidae	—	—	2,000	4,800	—	45,000	—
Copepoda	20,800	3,800	3,000	36,800	10,000	300	—
Nauplii	57,200	6,300	5,000	9,200	30,000	15,000	99,000
Pteropoda: *Limacina* juv.	5,200	—	—	—	—	—	—
Total Diatomales	—	—	—	18,400	25,000	5,640,000	30,264,000
Total Dinoflagellata	62,400	10,000	4,000	—	55,000	300	—
Total Protozoa	5,200	—	2,000	9,400	5,000	60,000	—

Table IX. *Analyses of samples collected on a line of stations north-eastwards from Cape Larsen, South Georgia. Survey of Nov.* 1930. *The positions of the stations are charted in Fig.* 4.

Station	498	499	500	496	495	494	493	492
Date	20. xi. 30	21. xi. 30	21. xi. 30	19. xi. 30	19. xi. 30	19. xi. 30	18. xi. 30	18. xi. 30
Temp. °C. (mean of 0–20 m.)	−0·62	−0·62	−0·78	−1·10	−0·95	−0·86	0·33	−0·42
Salinity ‰ (mean of 0–20 m.)	33·91	33·91	33·92	33·91	33·91	33·96	33·95	33·96
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	80	75	80	90	87	89	83	74
O_2 cc. per l. (mean of 0–20 m.)	—	7·92	7·84	—	—	7·81	—	—
*p*H	8·02	8·02	8·01	7·98	7·99	8·00	8·06	8·05
Volume of sample cc.	920	600	1040	560	900	260	60	880
Fraction examined	1 : 96,000	1 : 72,000	1 : 115,200	1 : 57,600	1 : 72,000	1 : 24,000	1 : 9,000	1 : 96,000
Diatomales:								
Coscinodiscus spp.	384,000	—	—	288,000	288,000	96,000	7,800	288,000
Asteromphalus hookerii	—	—	—	—	7,200	—	—	—
A. regularis	—	72,000	—	57,600	14,400	—	2,400	—
Thalassiosira antarctica	6,624,000	1,224,000	3,456,000	7,603,200	18,144,000	2,640,000	12,600,000+*	7,968,000
Dactyliosolen laevis	288,000	144,000	460,800	172,800	720,000	—	100,200	—
Corethron valdiviae	21,792,000	20,448,000	3,686,400	633,600	1,296,000	552,000	540,000	47,424,000
Rhizosolenia alata	—	144,000	230,400	633,600	144,000	120,000	—	192,000
R. chunii	—	144,000	115,200	—	—	—	720,000	—
R. simplex	—	—	—	57,600	—	—	1,200	—
R. styliformis	1,920,000	864,000	1,382,400	3,916,800	7,056,000	1,752,000	270,000	864,000
Chaetoceros atlanticus	—	1,368,000	230,400	—	—	—	270,000	—
Ch. criophilum	38,976,000	13,176,000	56,217,600	21,024,000	31,536,000	8,160,000	7,200	14,784,000
Ch. dichaeta	672,000	—	576,000	115,200	—	—	—	—
Ch. neglectus	3,936,000	1,584,000	3,110,400	—	—	120,000	360,000	1,344,000
Ch. tortissimus	—	—	—	—	—	408,000	—	—
Biddulphia striata	96,000	216,000	115,200	—	576,000	48,000	36,000	192,000
Eucampia antarctica	—	—	—	172,800	—	—	270,000	—
Fragilaria antarctica	1,440,000	—	2,304,000	3,916,800	3,456,000	—	10,800,000	1,920,000
Fragilaria antarctica f. *bouvet*	2,496,000	—	—	1,618,800	864,000	—	—	—
Thalassiothrix antarctica	864,000	1,152,000	1,497,600	1,152,000	1,440,000	480,000	180,000	384,000
Navicula oceanica	—	—	—	—	—	—	90,000	—
N. pellucida	—	—	—	57,600	14,400	—	—	—
Navicula spp.	—	—	—	—	—	48,000	—	—
Nitzschia seriata	864,000	504,000	576,000	115,200	432,000	744,000	13,386,000	1,824,000
Dinoflagellata:								
Dinophysis sp.	—	—	—	—	—	—	600	—
Peridinium antarcticum	—	—	—	—	—	—	—	4,800
Peridinium sp.	—	—	—	—	14,400	—	—	—
Ceratium pentagonum f. *grandis*	—	—	—	—	—	—	600	—
Silicoflagellata	288,000	72,000	345,600	57,600	—	24,000	—	384,000
Protozoa:								
Radiolaria	—	—	—	4,800	36,000	24,000	12,000	96,000
Tintinnidae	96,000	144,000	—	87,600	14,400	48,000	4,200	96,000
Copepoda	14,400	7,200	—	4,800	14,400	1,200	5,400	4,800
Nauplii	24,000	10,800	—	7,200	14,400	24,000	90,000	4,800
Pteropoda	—	—	—	—	14,400	—	600	—
Total Diatomales	80,352,000	41,040,000	73,958,400	41,535,600	65,980,800	15,168,000	40,114,800*	77,568,000
Total Dinoflagellata	—	—	—	—	14,400	—	1,200	4,800
Total Protozoa	96,000	144,000	—	92,400	50,400	72,000	16,200	192,000

* Excluding uncountable gelatinous colonies.

Table X. *Analyses of samples collected on a line of stations NNW from Prince Olaf Harbour, South Georgia. Survey of Nov. 1930. The positions of the stations are charted in Fig. 4.*

Station ...	484	485	486	487	488	489	490	491
Date ...	16. xi. 30	16. xi. 30	16. xi. 30	16. xi. 30	17. xi. 30	17. xi. 30	17. xi. 30	17. xi. 30
Temp. ° C. (mean of 0–20 m.)	−0·57	−0·64	0·42	−0·41	−0·49	−0·79	−0·65	−0·56
Salinity ‰ (mean of 0–20 m.)	33·96	33·94	33·97	33·93	33·96	33·91	33·89	33·96
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	80	70	77	79	80	88	88	86
O_2 cc. per l. (mean of 0–20 m.)	—	8·20	—	7·85	—	7·86	—	8·20
*p*H (mean of 0–20 m.)	8·00	8·05	8·06	8·05	8·05	8·04	8·05	8·03
Volume of sample cc.	150	780	90	130	110	380	720	720
Fraction examined ...	1 : 13,800	1 : 90,000	1 : 15,000	1 : 15,000	1 : 16,800 (1 : 600)	1 : 57,600 (1 : 600)	1 : 75,000	1 : 72,000
Diatomales:								
Melosira sphaerica	—	—	—	—	33,600	—	—	—
Hyalodiscus chromatoaster	—	—	—	45,000	—	—	—	—
Coscinodiscus centralis	—	90,000	—	75,000	—	—	—	—
Coscinodiscus spp.	27,600	180,000	15,000	—	151,200	4,800	—	—
Asteromphalus hookerii	—	—	15,000	—	—	—	—	—
A. regularis	—	—	—	—	33,600	—	—	—
Thalassiosira antarctica	—	7,470,000	870,000	1,545,000	1,209,600	172,800	151,200	812,000
Corethron valdiviae	9,494,400	39,240,000	390,000	390,000	1,696,800	7,372,800	18,068,400	24,480,000
Corethron valdiviae (auxosporenbildung)	220,800	1,620,000	—	—	25,200	806,400	—	—
Rhizosolenia alata	—	—	60,000	30,000	33,600	115,200	—	216,000
R. chunnii	—	—	90,000	15,000	67,200	—	—	—
R. styliformis	13,800	270,000	135,000	405,000	184,800	230,400	680,400	648,000
Chaetoceros criophilum	331,200	2,700,000	2,665,000	3,450,000	3,410,000	15,667,200	19,807,200	10,080,000
Ch. dichaeta	—	—	105,000	—	—	115,200	—	—
Ch. neglectus	—	1,260,000	—	—	352,800	633,600	2,646,000	3,600,000
Ch. schimperianus	—	—	—	—	—	—	—	72,000
Biddulphia striata	—	—	45,000	15,000	—	—	75,600	72,000
Eucampia antarctica f. *balaustium*	—	360,000	—	—	67,200*	—	—	—
Eucampia antarctica f. *möelleria*	—	—	75,000	315,000	67,200*	—	—	—
Fragilaria antarctica	—	1,440,000	315,000	840,000	201,600	—	—	648,000
Fragilaria antarctica f. *bouvet*	—	—	420,000	—	—	—	—	—
Thalassiothrix antarctica	—	270,000	45,000	150,000	201,600	64,800	982,800	144,000
Navicula oceanica	—	90,000	45,000	—	—	2,400	—	—
Nitzschia seriata	—	270,000	45,000	30,000	117,600	—	907,200	432,000
? Diatom spores	—	—	—	—	168,000	—	—	288,000
Dinoflagellata:								
Ceratium pentagonum f. *grandis*	—	—	—	—	600	—	—	—
Silicoflagellata	—	180,000	15,000	30,000	—	—	—	144,000
Protozoa:								
Radiolaria	—	—	—	15,000	33,600	7,200	—	—
Tintinnidae	—	180,000	—	60,000	16,800	2,400	—	—
Copepoda	—	—	—	15,000	600	4,800	—	—
Nauplii	27,600	—	—	30,000	16,800	7,200	—	—
Total Diatomales	10,087,800	55,260,000	5,400,000	7,305,000	8,047,200	25,185,600	43,318,800	41,492,000
Total Dinoflagellata	—	—	—	—	600	—	—	—
Total Protozoa	—	180,000	—	75,000	50,400	9,600	—	—

* Intermediates, both forms present in same chains.

Table XI. *Analyses of samples collected on a line of stations W × N from Bird Island, South Georgia. Survey of Nov. 1930. The positions of the stations are charted in Fig. 4.*

Station ...	483	482	481	480	479	478	477	475
Date ...	14. xi. 30	14. xi. 30	13. xi. 30	13. xi. 30	13. xi. 30	13. xi. 30	13. xi. 30	12. xi. 30
Temp. ° C. (mean of 0–20 m.)	−0·48	−0·58	−0·55	−0·65	−0·65	0·20	−0·02	0·00
Salinity °/₀₀ (mean of 0–20 m.)	34·03	33·96	33·95	33·89	33·91	33·93	34·02	34·03
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	80	95	90	102	90	101	106	110
O_2 cc. per l. (mean of 0–20 m.)	—	8·02	—	8·00	—	7·57	—	7·61
*p*H (mean of 0–20 m.)	8·00	8·02	8·03	8·03	8·00	8·01	7·98	7·98
Volume of sample cc....	20	65	70	210	35	15	20	18
Fraction examined ...	1 : 300	1 : 12,000 (1 : 600)	1 : 15,000	1 : 72,000	1 : 7,500	1 : 900	1 : 9,500	1 : 7,800
Diatomales:								
Hyalodiscus kerguelensis	6,300	108,000	—	—	—	—	—	—
Coscinodiscus spp.	6,300	216,000	180,000	216,000	232,500	72,900	66,500	187,200
Asteromphalus challengerensis	—	—	—	—	—	—	—	15,600
A. hookerii	—	600	—	—	—	16,200	9,500	15,600
A. parvulus	—	—	—	—	52,500	16,200	—	—
A. regularis	—	—	—	—	22,500	—	—	39,000
Actinocyclus sp.	—	—	—	—	—	—	—	7,800
Thalassiosira antarctica	18,900	3,456,000	2,580,000	4,248,000	577,500	16,200	28,500	85,800
Dactyliosolen antarcticus	—	—	—	—	—	—	—	7,800
D. laevis	—	108,000	—	144,000	247,500	64,800	38,000	93,600
Leptocylindrus sp.	—	—	—	—	22,500	8,100	—	—
Corethron valdiviae	951,300	3,420,000	3,120,000	7,184,000	90,000	48,600	152,000	85,800
Corethron valdiviae (spineless chains)	—	—	—	—	82,500	—	—	—
Rhizosolenia alata	—	108,000	60,000	216,000	30,000	24,300	28,500	39,000
R. antarctica	—	—	—	—	82,500	—	—	23,400
R. chunnii	12,600	4,200	210,000	1,728,000	22,500	—	—	—
R. crassa	—	—	30,000	—	—	—	—	—
R. simplex	—	—	30,000	—	—	8,100	—	—
R. styliformis	—	504,000	360,000	720,000	—	24,300	57,000	23,400
Chaetoceros criophilum	6,300	3,312,000	2,820,000	7,344,000	127,500	105,300	617,500	109,200
Small Chaetocerids (mainly *neglectus*)	—	252,000	630,000	3,168,000	1,072,500	437,400	247,000	702,000
Biddulphia striata	—	72,000	—	504,000	45,000	32,400	—	—
Eucampia antarctica	—	10,200	810,000	504,000	210,000	129,600	38,000	23,400
Fragilaria antarctica	—	792,000	1,470,000	3,168,000	2,535,000	413,100	313,500	1,341,600
Fragilaria antarctica f. *bouvet*	—	—	—	2,304,000	2,925,000	413,100	76,000	460,200
Thalassiothrix antarctica	—	216,000	—	864,000	352,500	72,900	38,000	85,800
Navicula pellucida	—	—	—	—	22,500	—	—	—
Navicula sp.	—	—	—	—	—	—	—	31,200
Gyrosigma directum	—	—	—	72,000	—	8,100	—	23,400
Tropodoneis antarctica	—	—	—	72,000	—	—	—	—
Nitzschia delicatissima	—	—	—	—	—	—	—	171,600
N. seriata	—	252,000	720,000	3,456,000	2,205,000	275,400	—	922,400
Dinoflagellata:								
Dinophysis sp.	—	—	—	—	7,500	24,300	—	23,400
Peridinium antarcticum	—	—	—	—	7,500	—	—	—
Peridinium sp. (small)	—	—	—	—	—	8,100	—	23,400
Ceratium pentagonum f. *grandis*	—	1,800	—	—	—	—	—	—
Silicoflagellata	—	—	—	216,000	75,000	40,500	—	85,800
Protozoa:								
Radiolaria	—	3,000	—	72,000	15,000	8,100	—	7,800
Foraminifera	—	—	—	144,000	15,000	—	—	—
Tintinnidae	6,300	1,800	—	72,000	37,500	16,200	9,500	23,400
Metazoa	31,500	6,000	—	72,000	15,000	24,300	28,500	15,600
Total Diatomales	1,001,700	12,831,000	13,020,000	35,912,000	10,957,000	2,397,600	1,710,000	4,494,800
Total Dinoflagellata	—	1,800	—	—	15,000	32,400	—	46,800
Total Protozoa	6,300	4,800	—	288,000	67,500	24,300	9,500	31,200

Table XII. *Analyses of samples collected on a line of stations SW × S from Annenkov Island, South Georgia. Survey of Nov.* 1930. *The positions of the stations are charted in Fig.* 4.

Station ...	525	524	523	522	521	520
Date ...	29. xi. 30	29. xi. 30	29. xi. 30	28. xi. 30	28. xi. 30	28. xi. 30
Temp. °C. (mean of 0–20 m.)	0·29	−0·06	−0·30	−0·21	−0·71	−0·48
Salinity ‰ (mean of 0–20 m.)	33·82	33·87	33·88	33·89	33·86	33·88
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	69	75	82	79	76	79
O_2 cc. per l. (mean of 0–20 m.)	—	8·49	—	7·90	—	7·88
*p*H (mean of 0–20 m.)	8·20	8·13	8·07	8·08	8·04	8·07
Volume of sample cc. ...	240	560	900	480	1,650	720
Fraction examined ...	1 : 43,200	1 : 72,000	1 : 86,400	1 : 60,000	1 : 189,000	1 : 82,800
Diatomales:						
Chaetoceros socialis	∞	∞	—	—	—	—
Thalassiosira antarctica (colonial)	+	+	A few	A few	A few	—
Chaetoceros neglectus (small)*	+	Present	—	—	—	—
Chaetoceros spp.*	Present	Present	—	—	—	—
Melosira sphaerica	86,400	—	—	—	—	—
Coscinodiscus spp.	43,200	72,000	345,600	240,000	—	248,400
Asteromphalus challengerensis	—	—	—	—	189,000	—
A. hookerii	—	—	—	—	189,000	—
A. parvulus	—	—	—	120,000	—	82,800
A. regularis	43,200	—	172,800	120,000	378,000	248,400
Thalassiosira antarctica†	22,075,200‡§	32,040,000‡§	19,180,800‡	8,280,000‡	19,278,000‡	28,648,800
Dactyliosolen laevis	734,400	432,000	2,246,600	1,560,000	1,701,000	579,600
Corethron valdiviae	172,000	144,000	1,382,400	840,000	1,890,000	910,800
Corethron valdiviae (spineless chains)	518,400	216,000	1,036,800	600,000	756,000	1,076,400
Rhizosolenia alata	43,200	—	691,200	120,000	756,000	910,800
R. chunnii	—	—	518,400	120,000	189,000	—
R. styliformis	—	144,000	1,209,600	840,000	8,694,000	1,573,200
R. truncata	216,000	—	—	—	—	—
Chaetoceros atlanticus	—	—	1,036,800	—	1,323,000	496,800
Ch. criophilum	648,000	2,592,000	21,081,600	11,280,000	35,910,000	17,636,400
Ch. curvatus	—	—	—	720,000	—	—
Ch. dichaeta	—	—	691,200	360,000	1,323,000	993,600
Ch. neglectus†	—	—	11,923,200	4,200,000	6,615,000	1,987,200
Ch. schimperianus	—	—	—	—	1,890,000	579,600
Biddulphia striata	604,800	1,872,000	1,555,200	1,200,000	756,000	745,200
Eucampia antarctica	5,659,200	8,568,000	691,200	1,080,000	2,268,000	1,159,200
Fragilaria antarctica	2,505,600	6,480,000	12,960,000	2,520,000	9,639,000	9,139,600
Fragilaria antarctica f. *bouvet*	—	1,152,000	11,232,000	10,800,000	22,302,000	21,196,800
Thalassiothrix antarctica	1,036,800	2,376,000	10,195,000	4,080,000	3,780,000	3,394,800
Navicula oceanica	—	—	—	120,000	—	—
N. pellucida	—	—	—	—	756,000	165,600
Navicula spp.	—	—	—	240,000	189,000	82,800
Nitzschia seriata	734,400	1,728,000	5,011,200	7,920,000	8,694,000	7,617,600
Nitzschia sp. "A."	43,200	144,000	518,400	—	189,000	—
Dinoflagellata:						
Peridinium sp.	43,200	—	—	120,000	—	—
Silicoflagellata	43,200	432,000	1,555,200	360,000	1,890,000	662,400
Protozoa:						
Tintinnidae	129,600	288,000	172,800	120,000	189,000	248,400
Nauplii	43,200	—	—	120,000	18,000	82,800
Total Diatomales†	35,164,800	57,960,000	105,926,800	57,360,000	130,410,000	107,474,400

* Uncountable owing to presence of above. † Excluding uncountable colonies. ‡ Excluding gelatinous colonies.

§ A few *Coscinosira antarctica* counted as *Thalassiosira*.

Table XIII. *Analyses of samples collected on a line of stations SSE from Undine South Harbour, South Georgia. Survey of Nov.* 1930. *The positions of the stations are charted in Fig.* 4.

Station ...	517	518	519	516	515	514
Date ...	26. xi. 30	27. xi. 30	27. xi. 30	26. xi. 30	26. xi. 30	26. xi. 30
Temp. °C. (mean of 0–20 m.)	0·17	−0·13	−0·21	−0·50	−0·33	−0·41
Salinity ‰ (mean of 0–20 m.)	33·87	33·90	33·91	33·90	33·88	33·88
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	66	75	79	83	75	81
O_2 cc. per l. (mean of 0–20 m.)	—	8·15	—	7·97	—	7·93
*p*H	8·17	8·10	8·08	8·06	8·06	8·06
Volume of sample cc. ...	920	480	320	440	230	270
Fraction examined ...	1 : 96,000 (1 : 9,600)	1 : 115,200	1 : 96,000	1 : 96,000	1 : 32,400	1 : 37,800
Diatomales:						
*Chaetoceros socialis**	∞²	∞	+	Present	+	∞
*Thalassiosira antarctica**	∞	+	—	—	∞	∞
*Chaetoceros neglectus**	∞	+	—	—	—	—
Coscinodiscus spp.	192,000	230,400	—	—	32,400	113,400
Asteromphalus challengerensis	—	115,200	—	—	—	—
A. parvulus	—	—	—	—	64,800	—
A. regularis	—	115,200	—	384,000	—	113,400
Thalassiosira antarctica†	38,016,000	38,707,000	25,536,000	68,352,000	7,192,800	6,917,400
Coscinosira antarctica	—	230,400	—	—	—	—
Dactyliosolen flexuosus	—	—	—	96,000	64,800	—
D. laevis	960,000	2,073,600	672,000	864,000	939,600	340,200
Corethron valdiviae	1,152,000	1,728,000	864,000	576,000	680,400	340,200
Corethron valdiviae (spineless chains)	1,344,000	345,600	480,000	—	—	—
Rhizosolenia alata	576,000	576,000	192,000	384,000	162,000	226,800
R. bidens	192,000	—	—	—	—	—
R. chunnii	—	345,600	96,000	—	97,200	75,600
R. styliformis	576,000	230,400	96,000	1,056,000	162,000	264,600
R. torpedo	—	—	—	96,000	32,400	—
Chaetoceros atlanticus	2,496,000	345,600	576,000	384,000	518,400	—
Ch. criophilum	11,328,000	6,336,000	3,360,000	9,888,000	1,717,200	3,628,800
Ch. dichaeta	—	—	3,744,000	576,000	810,000	1,134,000
Ch. neglectus	—	—	7,488,000	6,816,000	4,082,400	3,780,000
Ch. schimperianus	—	345,600	480,000	576,000	291,600	189,000
Eucampia antarctica	13,056,000	3,686,400	2,304,000	1,920,000	810,000	264,600
Fragilaria antarctica	9,216,000	8,409,600	1,920,000	8,832,000	2,268,000	4,951,800
Fragilaria antarctica f. *bouvet*	—	15,206,400	17,472,000	2,784,000	8,067,600	—
Thalassiothrix antarctica	2,880,000	3,801,600	4,128,000	1,824,000	2,203,200	2,381,400
Navicula oceanica	—	—	96,000	—	32,400	—
N. pellucida	—	—	—	—	—	75,600
Nitzschia closterium	—	—	—	—	32,400	—
N. seriata	3,072,000	1,267,200	5,760,000	2,016,000	2,106,000	1,398,600
Nitzschia sp. "A."	—	115,200	96,000	288,000	32,400	75,600
Dinoflagellata:						
Dinophysis sp.	—	115,200	—	—	—	—
Peridinium antarcticum	—	—	96,000	—	—	37,800
Silicoflagellata	192,000	—	192,000	576,000	129,600	—
Protozoa:						
Radiolaria	—	115,200	—	192,000	32,400	—
Tintinnidae	384,000	345,600	192,000	—	32,400	37,800
Metazoa	28,800	9,600	96,000	100,800	36,000	—
Total Diatomales†	87,360,000	85,708,600	76,128,000	108,864,000	32,400,000	26,762,400
Total Dinoflagellata	—	115,200	96,000	—	—	37,800
Total Protozoa	384,000	460,800	192,000	192,000	64,800	37,800

* Uncountable. † Excluding uncountable colonies.

Table XIV. *Analyses of samples collected on a line of stations eastwards from Cooper Island, South Georgia. Survey of Nov. 1930. The positions of the stations are charted in Fig. 4.*

Station	513	512	511	510	509	508
Date	25. xi. 30	25. xi. 30	25. xi. 30	25. xi. 30	24. xi. 30	24. xi. 30
Temp. ° C. (mean of 0–20 m.)	−0·43	−0·61	−0·89	−0·88	−0·82	−0·96
Salinity ‰ (mean of 0–20 m.)	33·87	33·87	33·87	33·86	33·80	33·75
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	81	79	84	81	75	74
O_2 cc. per l. (mean of 0–20 m.)	—	8·05	—	7·89	—	8·07
*p*H	8·07	8·07	8·05	8·06	8·06	8·03
Volume of sample cc.	250	950	690	480	380	720
Fraction examined	1 : 39,600	1 : 120,000	1 : 72,000	1 : 81,000	1 : 45,000	1 : 72,000
Diatomales:						
Chaetoceros socialis	∞	∞	—	∞	+	∞
Coscinodiscus spp.	79,200	—	288,000	162,000	90,000	—
Asteromphalus parvulus	—	—	—	—	90,000	—
A. regularis	—	—	144,000	162,000	90,000	144,000
*Thalassiosira antarctica**	12,513,600	37,200,000†	10,800,000	33,696,000†	26,370,000	24,624,000†
Dactyliosolen laevis	39,600	960,000	576,000	810,000	180,000	1,152,000
Corethron valdiviae	118,800	480,000	1,296,000	1,458,000	1,260,000	576,000
Rhizosolenia alata	39,600	240,000	—	486,000	45,000	576,000
R. chunnii	—	—	—	—	135,000	—
R. styliformis	79,200	1,680,000	1,152,000	2,430,000	1,350,000	1,008,000
Chaetoceros atlanticus	—	—	432,000	—	180,000	—
Ch. criophilum	6,613,200	11,522,000	33,126,000	22,518,000	7,920,000	16,416,000
Ch. curvatus	—	—	—	—	45,000	—
Ch. neglectus	—	24,960,000‡	432,000	20,726,000	4,725,000	—
Ch. schimperianus	—	—	—	—	450,000	864,000
Biddulphia striata	—	1,440,000	144,000	1,134,000	675,000	1,440,000
Eucampia antarctica	435,600	18,240,000	864,000	8,100,000	1,935,000	4,608,000
Fragilaria antarctica	2,772,000	8,640,000	6,336,000	24,948,000	2,385,000	2,016,000
Fragilaria antarctica f. *bouvet*	—	12,480,000	1,152,000	4,860,000	3,960,000	20,736,000
Synedra spathulata	—	—	—	—	45,000	—
Thalassiothrix antarctica	1,900,800	4,080,000	2,160,000	2,592,000	1,620,000	2,304,000
Th. ? longissima	—	—	—	162,500	—	—
Navicula oceanica	—	—	—	—	—	144,000
N. pellucida	—	—	—	324,000	45,000	—
Nitzschia seriata	—	2,160,000	576,000	2,106,000	1,035,000	—
Nitzschia sp. "A."	39,600	—	—	—	45,000	—
Dinoflagellata:						
Peridinium antarcticum	—	—	—	—	1,800	—
Peridinium sp. (small)	—	—	—	81,000	—	—
Silicoflagellata	—	—	—	81,000	180,000	144,000
Protozoa:						
Tintinnidae	—	240,000	432,000	648,000	90,000	—
Metazoa	—	—	144,000	7,200	46,800	72,000
Total Diatomales*	24,631,200	124,082,000	59,478,000	126,674,000	54,675,000	76,608,000
Total Dinoflagellata	—	—	—	81,000	1,800	—

* Excluding uncountable colonies. † Excluding gelatinous colonies. ‡ Estimated from number of chains.

Table XV. *Analyses of samples collected on a line of stations ENE from Cape Vakop, South Georgia. Survey of Nov. 1930. The positions of the stations are charted in Fig. 4.*

Station	507	506	505	504	503	502	501
Date	23. xi. 30	23. xi. 30	23. xi. 30	23. xi. 30	23. xi. 30	22. xi. 30	22. xi. 30
Temp. ° C.	−0·71	−0·58	−0·70	−1·34	−1·15	−0·80	−0·98
Salinity ‰	33·91	33·92	33·90	33·90	33·89	33·82	33·87
P_2O_5 mg./m.^{3} } mean of 0–20 m.	87	81	82	93	89	95	101
O_2 cc. per l.	—	7·80	—	7·62	—	7·83+	—
*p*H	8·02	8·06	8·05	7·99	8·00	8·00	7·98
Volume of sample cc. ...	130	660	340	640	620	580	400
Fraction examined ...	1 : 27,600	1 : 96,000 (1 : 600)	1 : 75,600	1 : 72,000	1 : 90,000 (1 : 300)	1 : 72,000 (1 : 300)	1 : 48,000 (1 : 300)
Diatomales:							
Chaetoceros socialis	∞	—	—	—	—	—	—
Coscinodiscus bouvet	110,400	192,000	151,200	—	—	—	—
Coscinodiscus spp.	—	—	151,200	—	90,000	72,000	—
Asteromphalus regularis	—	—	453,600	—	—	72,000	—
Thalassiosira antarctica	9,936,000	17,664,000*	26,460,000*	2,736,000	9,720,000	2,448,000	720,000
Dactyliosolen antarcticus	—	—	—	—	—	72,000	—
D. laevis	55,200	480,000	2,116,800	—	—	—	48,000
Corethron valdiviae	1,300,000	2,496,000	1,058,400	1,440,000	630,000	864,000	336,000
Rhizosolenia alata	27,600	96,000	529,000	720,000	540,000	288,000	384,000
R. chunnii	—	—	151,200	—	—	—	—
R. styliformis	55,200	576,000	1,134,000	4,320,000	5,040,000	9,576,000	6,464,000
Chaetoceros criophilum	3,091,200	14,112,000	2,721,000	14,904,000	15,210,000	14,328,000	9,744,000
Ch. dichaeta	—	1,344,000	1,058,400	—	—	360,000	144,000
Ch. neglectus	—	8,544,000	7,030,800	2,664,000	270,000	—	—
Ch. schimperianus	220,800	3,744,000	907,200	—	—	—	—
Biddulphia striata	82,800	768,000	1,360,800	—	—	72,000	48,000
Eucampia antarctica	1,849,200	192,000	2,570,400	288,000	—	—	—
Fragilaria antarctica	1,876,800	6,720,000	13,980,000	720,000	720,000	432,000	192,000
Thalassiothrix antarctica	193,200	3,840,000	3,553,200	1,080,000	540,000	576,000	432,000
Th. ? longissima	—	—	—	144,000	—	—	—
Achnanthes sp.	—	—	1,209,600	—	—	—	—
Nitschia seriata	—	1,920,000	2,419,200	3,240,000	1,530,000	1,944,000	1,344,000
Nitschia sp. "A."	—	—	—	144,000	—	—	—
Spores (? of *Chaetoceros criophilum*)	—	—	—	—	—	288,000	—
Dinoflagellata:							
Peridinium sp.	—	96,000	—	—	—	—	—
Silicoflagellata	27,600	384,000	—	72,000	—	—	—
Protozoa:							
Protocystis swirei	—	192,000	—	—	—	—	12,000
Other Radiolaria	—	—	—	72,000	—	—	12,000
Tintinnidae	—	480,000	—	—	—	—	96,000
Metazoa	27,600	4,800	—	75,600	18,000	18,000	48,000
Total Diatomales†	18,878,400	62,690,000	69,016,800	32,400,000	34,290,000	31,392,000	19,856,000
Total Protozoa	—	672,000	—	72,000	—	—	120,000

* Free chains and individuals only, gelatinous colonies not estimated. † Excluding uncountable colonies.

Table XVI. *Analyses of samples collected on a line of stations northwards from Prince Olaf Harbour, South Georgia, in March* 1931.

Station	WS 567	WS 568	WS 569	WS 572	WS 573	WS 574	WS 575	WS 570
Date	6. iii. 31	6. iii. 31	6. iii. 31	24. iii. 31	25. iii. 31	26. iii. 31	26. iii. 31	8. iii. 31
Temp. ° C. } mean of	1·99	2·04	2·49	2·04	2·11	2·18	2·81	2·28
Salinity ‰ } 0–20 m.	33·73	33·85	33·77	33·91	33·83	33·83	33·82	33·83
Volume of sample cc....	6	70	90	480	142	180	170	170
Fraction examined ...	1 : 300	1 : 3,150	1 : 4,800	1 : 19,200	1 : 10,500	1 : 12,000	1 : 13,500	1 : 12,000
Diatomales:								
Coscinodiscus spp.	300	9,450	—	—	—	24,000	13,500	—
Thalassiosira antarctica	—	—	—	—	—	120,000	67,500	48,000
Dactyliosolen antarcticus	—	—	—	—	21,000	216,000	459,000	132,000
Corethron valdiviae	14,100	664,650	2,078,400	4,627,200	210,000	576,000	135,000	156,000
Rhizosolenia alata	—	3,150	—	—	21,000	72,000	94,500	24,000
R. styliformis	—	50,400	—	19,200	105,000	192,000	94,500	396,000
Chaetoceros atlanticus	—	50,400	—	57,600	—	240,000	688,500	—
Ch. criophilum	3,300	828,450	542,400	8,659,200	2,436,000*	3,456,000	5,062,500	6,696,000
Ch. curvatus	—	3,150	—	—	—	72,000	108,000	—
Ch. dichaeta	300	15,750	—	—	—	384,000	270,000	204,000
Ch. neglectus	—	25,200	—	—	—	72,000	607,500	156,000
Synedra spathulata	—	—	—	—	—	—	13,500	—
Thalassiothrix antarctica	—	40,950	—	—	31,500	120,000	283,500	288,000
Navicula pellucida	—	3,150	—	—	—	—	40,500	—
Nitzschia seriata	—	72,450	—	—	1,417,500	7,776,000	6,007,500	4,224,000
Dinoflagellata:								
Peridinium antarcticum	300	3,150	9,200	19,200	—	—	27,000	—
Silicoflagellata	—	—	—	38,400	31,500	120,000	27,000	—
Protozoa:								
Foraminifera	—	—	—	—	—	—	13,500	—
Tintinnid (inshore sp.)	7,800	—	4,800	—	—	—	—	—
Tintinnidae (others)	—	18,900	28,800	57,600	52,500	96,000	67,500	72,000
Copepoda	6,000	6,300	—	—	—	24,000	13,500	—
Nauplii	11,400	28,350	9,200	19,200	—	—	40,500	—
Pteropoda	900	—	—	—	—	—	—	—
Total Diatomales	18,000	1,767,150	2,620,800	13,363,200	4,242,000†	13,320,000†	13,945,500	12,324,000
Total Protozoa	7,800	18,900	33,600	57,600	52,500	96,000	81,000	72,000

* Mainly dying frustules, chloroplasts few if any.

† Sample contained large numbers of spines and fragments from dying *Chaetoceros criophilum*.

Table XVII. *Analyses of samples collected on a line of stations from the Antarctic convergence in 55° 52′ S : 56° 53′ W to the neighbourhood of Elephant Island, November 1929. The positions of the stations are charted in Fig. 32.*

Station	**WS 468**	**WS 469**	**WS 470**	**WS 471**	**WS 472**	**WS 473**	**WS 474**
Lat. S	55° 52′	56° 42′	57° 50′	58° 53′	59° 42½′	60° 32½′	61° 03′
Long. W...	56° 53′	57° 00′	57° 27′	57° 54′	58° 01′	58° 21′	56° 42′
Date	9/10. xi. 29	10. xi. 29	11. xi. 29	12. xi. 29	12. xi. 29	13. xi. 29	13. xi. 29
Temp. ° C. } mean of	5·09	3·44	1·59	−0·14	−0·19	−0·49	−0·56
Salinity ‰ } 0–20 m.	34·12	34·10	33·95	33·94	33·99	34·00	34·01
Volume of sample cc.	5	6	41	32	260	80	7
Fraction examined	1 : 300	1 : 2,400	1 : 16,800	1 : 21,600	1 : 90,000	1 : 38,400	1 : 1,200
Diatomales:							
Asteromphalus challengerensis	—	—	16,800	—	180,000	—	—
A. hookerii	—	—	—	—	180,000	—	—
A. parvulus	—	—	—	—	—	76,800	—
A. regularis	—	—	33,600	—	—	153,600	—
Coscinodiscus spp.	29,400	—	—	43,200	180,000	115,200	—
Thalassiosira antarctica	—	16,800	554,400	280,800	66,420,000	1,612,800	32,400
Dactyliosolen antarcticus	600	21,600	218,400	345,600	5,040,000	422,400	7,200
Leptocylindrus sp.	—	—	33,600	—	—	—	—
Corethron valdiviae	—	180,000	302,400	259,200	900,000	499,200	10,800
Corethron valdiviae (spineless chains)	—	62,400	—	151,200	1,260,000	460,800	—
Rhizosolenia alata	300	12,000	67,200	172,800	1,080,000	614,400	195,600*
R. polydactyla	—	14,400	—	—	—	—	—
R. rhombus	—	—	—	—	360,000	—	—
R. styliformis	—	9,600	33,600	43,200	3,960,000	192,000	9,600
R. torpedo	—	—	—	21,600	—	76,800	—
R. truncata	—	—	67,200	—	—	—	—
Chaetoceros atlanticus	—	—	2,738,400	—	7,200,000	768,000	—
Ch. castracanei	—	—	1,075,200	64,800	—	—	—
Ch. criophilum	—	—	117,600	151,200	1,440,000	345,600	20,400
Ch. ? decipiens	6,900	—	—	—	—	—	—
Ch. dichaeta	—	24,000	588,000	1,965,600	—	1,728,000	—
Ch. flexuosus	—	—	285,600	—	—	—	—
Ch. neglectus	—	43,200	+ +	1,339,200	5,400,000	14,284,000	—
Ch. radiculum	—	—	50,400	—	—	—	—
Ch. schimperianus	—	—	100,800	—	5,400,000	499,200	—
Biddulphia striata	—	—	50,400	151,200	7,920,000	384,000	8,400
Eucampia antarctica	—	—	134,400	64,800	6,300,000	844,800	2,400
Fragilaria antarctica	92,400	57,600	235,200	172,800	31,680,000	2,457,600	—
Synedra spathulata	—	48,000	67,200	453,600	4,320,000	652,800	19,200
Thalassiothrix antarctica	—	55,200	705,600	—	540,000	—	—
Navicula oceanica	—	—	—	43,200	—	115,200	—
N. pellucida	—	—	—	—	—	76,800	—
Nitzschia seriata	—	127,200	9,307,200	6,199,200	14,580,000	28,876,800	129,600
Dinoflagellata:							
Dinophysis sp.	300	—	—	21,600	—	38,400	26,400
Ceratium fusus	300	—	—	—	—	—	—
C. pentagonum f. *grandis*	10,800	—	84,000	—	—	—	—
Peridinium antarcticum	300	—	33,600	—	—	—	—
Peridinium spp.	300	—	16,800	—	—	—	—
Silicoflagellata	—	—	168,000	—	—	76,800	—
Protozoa:							
Radiolaria	—	—	16,800	—	—	—	—
Foraminifera	900	2,400	16,800	—	—	—	—
Tintinnidae	1,200	4,800	100,800	21,600	180,000	153,600	26,400
Metazoa	73,500	19,200	151,200	—	180,000	38,400	10,800
Total Diatomales	129,600	672,000	16,783,200†	11,923,200	164,340,000	55,142,400	435,600
Total Dinoflagellata	12,000	—	134,400	21,600	—	38,400	26,400
Total Protozoa	2,100	7,200	134,400	21,600	180,000	38,400	26,400

* Mainly f. *gracillima*. † Excluding uncountable colonies of *Chaetoceros neglectus*.

Table XVIII. *Analyses of samples collected on a line of stations between the Falkland Islands and South Georgia, Feb.–Mar.* 1930. *The positions of the stations are charted in Fig.* 32.

Station ...	WS 518	WS 519	WS 520	WS 521	WS 522	WS 523	WS 524	WS 525	WS 526
Lat. S ...	51° 55½′	52° 09½′	52° 25′	52° 41′	52° 56′	53° 07′	53° 36′	53° 38½′	53° 51′
Long. W ...	55° 35′	53° 21½′	51° 20′	49° 14′	47° 14′	45° 00′	43° 00′	41° 09′	39° 45′
Date ...	26. ii. 30	26. ii. 30	27. ii. 30	28. ii. 30	28. ii. 30	1. iii. 30	2. iii. 30	2. iii. 30	3. iii. 30
Temp. °C. } mean of	7·16	5·75	6·34	4·61	4·34	4·01	3·40	3·20	2·89
Salinity ‰ } 0–20 m.	34·09	33·95	34·11	34·00	33·92	33·94	33·93	33·93	33·88
Volume of sample cc....	35	43	29	14	11	26	12	14	7
Fraction examined ...	1 : 3,000	1 : 3,000	1 : 3,000	1 : 3,000	1 : 300	1 : 3,000	1 : 1,000	1 : 300	1 : 300
Diatomales:									
Dactyliosolen antarcticus	—	—	—	45,000	12,000	—	—	—	—
Corethron valdiviae	—	—	—	—	15,000	9,000	45,000	—	12,000
Corethron valdiviae (spineless chains)	90,000	1,152,000	704,000	252,000	—	252,000	—	—	—
Rhizosolenia alata	—	108,000	30,000	81,000	—	18,000	15,000	—	—
R. curva	54,000	126,000	24,000	18,000	—	27,000	—	—	—
R. polydactyla	3,078,000	4,806,000	3,000,000	594,000	—	711,000	60,000	9,000	—
R. styliformis	1,512,000	1,494,000	2,856,000	423,000	30,000	513,000	135,000	18,000	—
Thalassiothrix antarctica	—	—	—	—	—	18,000	45,000	—	24,000
Dinoflagellata:									
Peridinium elegans	18,000	—	—	—	—	—	—	—	—
Peridinium spp.	—	180,000	42,000	9,000	—	3,000	30,000	—	24,000
Ceratium pentagonum	90,000	144,000	48,000	63,000	—	—	—	—	—
Ceratium spp.	—	—	—	—	—	—	9,000	9,000	—
Protozoa:									
Foraminifera	—	—	600	—	—	—	—	—	—
Copepoda	—	18,000	24,000	27,000	30,000	9,000	60,000	54,000	36,000
Nauplii	18,000	18,000	—	45,000	33,000	27,000	90,000	45,000	60,000
Pteropoda: *Limacina* juv.	—	—	—	3,000	12,000	—	—	—	—
Total Diatomales	4,734,000	7,686,000	7,114,000	1,413,000	57,000	1,548,000	300,000	27,000	36,000
Total Dinoflagellata	108,000	324,000	90,000	72,000	—	3,000	39,000	9,000	24,000

Table XIX. *Analyses of samples collected on a line of stations between the South Sandwich Islands and the Burdwood Bank, Mar.–Apr.* 1930. *The positions of the stations are charted in Fig.* 32.

Station	372	373	374	375	WS 527	WS 528	WS 529	WS 530	WS 531
Lat. S	57° 57′	58° 00′	57° 55′	57° 47′	57° 30′	56° 53′	56° 05′	55° 22′	54° 25½′
Long. W	29° 53′	33° 44′	37° 30′	40° 49′	45° 35′	49° 46′	53° 45′	57° 46′	61° 25½′
Date	18/19. iii. 30	19. iii. 30	20. iii. 30	21. iii. 30	30. iii. 30	31. iii. 30	2. iv. 30	3/4. iv. 30	5. iv. 30
Temp. ° C. } mean of 0–20 m.	0·42	1·40	1·19	2·00	1·62	2·90	2·37	5·78	6·26
Salinity ‰ } mean of 0–20 m.	33·82	33·92	34·04	33·95	33·95	33·92	33·89	34·12	34·22
Volume of sample cc.	4	2	15	2	—	—	—	—	—
Fraction examined	1 : 200	1 : 200	1 : 700	1 : 200	1 : 300	1 : 300	1 : 9,000	1 : 3,000	1 : 7,800
Diatomales:									
Hyalodiscus kerguelensis	—	—	—	—	—	—	—	—	156,000
Coscinodiscus bouvet	31,000	5,400	35,000	5,000	—	—	—	—	—
Coscinodiscus spp.	—	—	—	—	300	5,400	30,000	21,000	694,000
Asteromphalus challengerensis	—	—	—	—	—	—	300	—	—
A. hookerii	—	—	—	—	—	—	—	300	—
A. regularis	—	—	—	—	—	900	—	—	—
Dactyliosolen antarcticus	—	—	7,000	—	—	12,000	45,000	42,000	—
Corethron valdiviae	—	—	—	—	2,100	27,600	30,000	54,000	—
Corethron valdiviae (spineless chains)	—	—	21,000	—	—	—	—	—	—
Rhizosolenia alata	—	—	28,000	—	—	18,300	15,000	54,000	—
R. polydactyla	—	—	—	—	300	—	—	145,000	93,600
R. styliformis	—	—	77,000	—	300	10,500	45,000	96,000	—
Small Chaetocerids (mainly *atlanticus*)	—	—	35,000	—	1,200	80,100	3,375,000	21,000	234,000
Chaetoceros criophilum	12,400	—	—	—	—	3,000	60,000	—	56,600
Fragilaria antarctica	—	—	—	—	—	56,700	360,000	—	—
Fragilaria antarctica f. *bouvet*	—	—	—	—	—	—	—	—	374,400
Thalassiothrix antarctica	18,600	6,600	—	—	—	900	60,000	—	—
Nitzschia seriata	—	—	—	—	—	80,700	252,000	—	—
Dinoflagellata:									
Peridinium antarcticum	—	—	—	—	—	6,300	—	—	—
Peridinium sp.	—	—	—	—	300	5,400	—	—	—
Ceratium pentagonum	—	—	—	—	—	—	45,000	87,000	—
Ceratium sp.	—	—	—	—	—	59,700	—	—	31,200
Silicoflagellata	—	—	—	—	—	300	—	—	—
Protozoa:									
Radiolaria: *Protocystis swirei*	—	—	—	—	1,200	8,700	60,000	—	—
Foraminifera	—	—	7,000	—	—	4,200	12,000	—	15,600
Tintinnidae	—	—	—	—	—	3,600	45,000	—	7,800
Copepoda	18,600	18,000	14,000	50,000	24,000	37,500	9,000	54,000	15,600
Nauplii	6,200	5,800	14,000	40,000	33,300	96,000	16,500	21,000	7,800
Pteropoda: *Limacina* juv.	6,200	—	—	—	—	—	—	—	—
Total Diatomales	62,000	12,000	203,000	5,000	4,200	296,100	4,272,000	428,300	1,518,800
Total Dinoflagellata	—	—	—	—	300	71,400	45,000	87,000	31,200
Total Protozoa	—	—	7,000	—	1,200	16,500	117,000	—	23,400

Table XX. *Analyses of samples from Station 376 in Bransfield Strait, and on a line of stations from Livingston I., South Shetland Islands, northwards across Drake Passage to Cape Horn, April 1930. The positions of the stations are charted in Fig. 32.*

Station	376	378	379	380	381	382	383	384	385	386	387	388
Lat. S	62° 33′	62° 21½′	62° 14¼′	62° 05½′	61° 56¾′	61° 27½′	60° 32′	59° 36½′	58° 41′	57° 45½′	56° 50′	56° 19½′
Long. W	59° 19½′	60° 36′	60° 43¼′	60° 53½′	61° 03¾′	61° 38½′	62° 42′	63° 43½′	64° 43½′	65° 42′	66° 39′	67° 09¾′
Date	11. iv. 30	13. iv. 30	13. iv. 30	13. iv. 30	13. iv. 30	13/14. iv. 30	14. iv. 30	14. iv. 30	15. iv. 30	15. iv. 30	16. iv. 30	16. iv. 30
Temp. ° C. (mean of 0–20 m.)	0·27	0·40	0·10*	0·30*	0·00*	0·32	0·46	2·04	4·89	5·00	5·40	7·59
Salinity ‰ (mean of 0–20 m.)	34·04	34·05	34·04*	33·93*	33·89*	33·78	33·85	33·86	34·16	34·15	34·12	33·58
P_2O_5 mg./m.³ (mean of 0–20 m.)	101	112	83*	98*	100*	117	107	115	91	87	91	71
*p*H (mean of 0–20 m.)	8·00	8·06	7·95*	7·97*	8·00*	8·10	8·05	8·06	8·10	8·08	8·10	8·11
Volume of sample cc.	12	68	178	29	17	80	31	14	5	3	8	2
Fraction examined	1 : 3,000	1 : 30,000 (1 : 3,000)	1 : 12,000 (1 : 300)	1 : 1,500	1 : 3,000 (1 : 200)	1 : 30,000 (1 : 3,000)	1 : 30,000	1 : 3,000	1 : 200	1 : 200	1 : 300	1 : 200
Diatomales:												
Coscinodiscus spp.	30,000	90,000	300,000	41,500	72,000	123,000	90,000	—	—	1,200	1,200	—
Asteromphalus hookerii	—	—	—	13,500	—	—	—	—	—	—	—	—
A. parvulus	3,000	3,000	—	12,000	—	—	—	—	—	—	—	—
Actinocyclus sp.	—	—	—	—	—	120,000	30,000	—	—	—	—	—
Dactyliosolen antarcticus	—	120,000	120,000	—	180,000	780,000	210,000	30,000	10,400	3,200	3,300	—
D. flexuosus	—	—	—	—	—	—	—	—	10,000	—	—	—
Corethron valdiviae	60,000	33,000	60,000	27,000	54,000	1,260,000	180,000	510,000	60,600	23,200	—	—
Rhizosolenia alata	120,000	60,000	—	27,000	17,200	129,000	—	—	90,000	800	36,900	1,200
R. chunii	—	—	—	27,000	—	—	—	—	—	—	—	—
R. polydactyla	—	—	—	—	—	—	—	—	150,000	—	26,400	—
R. simplex	3,000	—	—	—	17,200	60,000	—	—	60,000	1,600	10,200	3,200
R. styliformis	60,000	—	—	12,000	—	360,000	33,000	—	—	9,200	149,000	2,800
R. torpedo	—	—	60,000	—	—	—	27,000	—	20,400	—	—	—
R. truncata	—	—	—	—	—	—	—	—	—	1,800	—	4,000
Small Chaetocerids (mainly *atlanticus*)	1,950,000	50,190,000	150,000,000†	16,240,000	6,570,000	84,540,000	21,930,000	990,000	100,000	65,200	16,000	21,200
Chaetoceros castracanei	—	—	—	—	19,800	—	—	—	—	—	—	—
Ch. criophilum	570,000	750,000	1,620,000	28,500	144,000	363,000	540,000	60,000	—	—	—	—
Ch. cruciatum	—	90,000	—	—	—	—	—	—	—	—	—	—
Ch. radiculum	90,000	—	180,000	—	54,000	—	—	—	—	—	—	—
Eucampia antarctica	—	30,000	840,000	135,000	864,000	40,000	—	—	—	—	18,900	—
Fragilaria antarctica	1,320,000	3,630,000	4,500,000	990,000	2,484,000	2,820,000	1,080,000	690,000	—	9,600	—	—
Fragilaria antarctica f. *bouvet*	—	900,000	—	—	720,000	—	—	—	—	—	—	—
Thalassiothrix antarctica	420,000	600,000	720,000	—	27,000	1,140,000	—	—	—	—	2,100	—
Nitzschia seriata	4,170,000	18,510,000	28,920,000	3,088,000	864,000	19,500,000	810,000	4,650,000	80,000	—	—	9,600
Dinoflagellata:												
Dinophysis sp.	—	—	—	—	—	120,000	—	—	—	—	—	—
Peridinium spp.	30,000	—	—	41,500	90,000	—	—	—	19,800	800	900	—
Ceratium pentagonum	—	—	—	—	—	—	—	—	10,000	4,000	4,200	3,600
Ceratium sp.	—	—	—	—	—	—	—	60,000	—	—	—	—
Silicoflagellata	—	—	—	—	—	300,000	120,000	—	30,000	—	—	—
Protozoa:												
Radiolaria	—	3,000	60,000	—	—	—	150,000	90,000	—	—	—	—
Foraminifera	—	—	—	—	—	—	—	30,000	—	—	900	—
Tintinnidae	—	30,000	—	—	—	60,000	—	—	—	—	—	—
Metazoa	—	—	9,000	27,000	54,000	—	90,000	—	20,200	4,800	16,200	15,200
Total Diatomales	8,796,000	75,006,000	187,320,000†	20,625,500	12,687,200	111,235,000	24,920,000	6,930,000	581,400	115,800	264,000	40,000
Total Dinoflagellata	30,000	—	—	41,500	90,000	120,000	—	60,000	29,800	4,800	5,100	3,600
Total Protozoa	—	33,000	60,000	—	—	60,000	150,000	120,000	—	—	900	—

* Surface samples only. † Estimated from number of chains.

Table XXI. *Analyses of samples collected on a line of stations from the Antarctic convergence southwards across the Scotia Sea, March* 1931. *The positions of the stations are shown in Fig.* 32.

Station ...	633	634	635	636	637	638	639
Lat. S ...	54° 58¼′	56° 14½′	57° 42¾′	59° 01¾′	60° 00¼′	61° 00½′	61° 57¾′
Long. W...	52° 16½′	51° 06¾′	50° 06¼′	49° 18½′	49° 28¼′	49° 48½′	51° 59′
Date ...	5. iii. 31	6. iii. 31	7. iii. 31	8. iii. 31	8. iii. 31	9. iii. 31	9. iii. 31
Temp. ° C. (mean of 0–20 m.)	5·13	4·46	2·82	1·20	0·53	−0·14	−0·77
Salinity ‰ (mean of 0–20 m.)	33·94	33·93	33·88	34·11	34·36	33·43	33·85
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	91	88	108	102	125	107	114
O_2 cc. per l. (mean of 0–20 m.)	7·22	7·38	7·79	7·67	7·32	8·18	7·43
*p*H (mean of 0–20 m.)	8·02	8·00	7·97	7·97	7·88	7·94	7·92
Volume of sample cc. ...	12	24	10	18	3	7	10
Fraction examined ...	1 : 9,000 (1 : 300)	1 : 8,100	1 : 1,200	1 : 7,500	1 : 300	1 : 300	1 : 300
Diatomales:							
Coscinodiscus bouvet	—	—	—	—	—	—	300
Coscinodiscus spp.	18,000	113,400	8,400	30,000	2,400	—	1,800
Asteromphalus challengerensis	300	8,100	1,200	—	900	—	—
A. hookerii	18,000	16,200	2,400	15,000	—	—	300
A. regularis	—	—	—	—	—	—	300
Actinocyclus bifrons	9,000	—	2,400	—	300	—	—
Dactyliosolen antarcticus	369,000	251,100	14,400	75,000	—	—	—
Leptocylindrus sp.	—	—	—	165,000	—	—	—
Corethron valdiviae	18,000	32,400	2,400	135,000	4,200	105,300	94,200
Corethron valdiviae (spineless chains)	909,000	2,219,400	10,800	—	—	—	—
Rhizosolenia alata	153,000	186,300	3,600	—	600	—	—
R. antarctica	—	81,000	—	—	—	—	—
R. curva	1,200	16,200	—	—	—	—	—
R. polydactyla	9,000	40,500	—	—	—	—	—
R. styliformis	9,000	56,700	2,400	15,000	1,200	—	—
R. torpedo	—	—	2,400	—	—	—	—
R. truncata	—	—	—	—	300	—	—
Chaetoceros atlanticus	189,000	89,100	814,800	3,030,000	28,200	—	900
Ch. criophilum	9,000	—	6,000	135,000	3,900	7,800	22,200
Ch. dichaeta	63,000	32,400	3,600	1,065,000	8,400	—	2,400
Ch. neglectus	—	—	—	5,100,000	19,200	—	—
Ch. schimperianus	—	—	—	105,000	—	—	—
Biddulphia striata	—	—	—	—	—	—	2,400
Eucampia antarctica	—	—	—	—	—	—	6,600
Fragilaria antarctica	72,000	874,800	38,400	—	20,400	—	6,000
Fragilaria antarctica f. *bouvet*	—	—	—	720,000	—	—	—
Thalassiothrix antarctica	18,000	170,100	7,200	15,000	6,900	4,500	1,500
Navicula spp.	9,000	16,200	2,400	15,000	—	—	—
Nitzschia seriata	12,267,000	36,450,000	170,400	5,160,000	14,700	—	1,500
Dinoflagellata:							
Dinophysis sp.	3,900	24,300	6,000	—	—	—	—
Peridinium antarcticum	300	—	—	—	—	—	—
Peridinium sp.	—	—	—	—	—	—	300
Ceratium pentagonum	33,600	194,400	1,200	—	—	—	—
Silicoflagellata	300	8,100	1,200	150,000	600	—	—
Protozoa:							
Radiolaria: Challengeridae	3,900	56,700	6,000	7,500	600	—	—
Foraminifera	—	—	1,200	—	—	—	—
Tintinnidae	9,000	32,400	3,600	45,000	4,500	—	1,800
Metazoa	18,600	153,900	14,400	15,000	5,700	600	1,200
Total Diatomales	14,140,500	40,653,900	1,093,200	15,765,000	111,600	117,600	140,400
Total Dinoflagellata	37,800	218,700	7,200	—	—	—	300
Total Protozoa	12,900	89,100	10,800	52,500	5,100	—	1,800

Table XXII. *Analyses of samples collected on a line of stations between Elephant Island and Staten Island, March* 1931. *The positions of the stations are charted in Fig.* 32.

Station	644	645	646	647	648	649	650	651
Lat. S	61° 20½′	60° 51½′	60° 22½′	59° 29¼′	58° 30¾′	57° 43½′	56° 19¼′	55° 08′
Long. W	56° 40′	57° 12¾′	57° 43′	58° 39¾′	59° 41¼′	60° 22¼′	62° 12¼′	63° 31′
Date	11. iii. 31	11. iii. 31	11. iii. 31	12. iii. 31	12. iii. 31	12/13. iii. 31	13. iii. 31	14. iii. 31
Temp. ° C. (mean of 0–20 m.)	1·45	1·85*	2·31	2·72	3·75	6·68	7·16	7·23
Salinity ‰ (mean of 0–20 m.)	34·04	33·80*	33·82	33·87	33·84	34·04	34·08	34·05
N_2 mg./m.^{3} (mean of 0–20 m.)	460	—	—	480	—	435	—	360
O_2 cc. per l. (mean of 0–20 m.)	7·11	—	7·14	7·21	6·98	6·55	6·55	6·38
*p*H (mean of 0–20 m.)	7·94	—	7·94	7·96	7·97	7·98	7·99	8·01
Volume of sample cc. ...	4	12	22	150	14	3	4	4
Fraction exmained	1 : 300	1 : 1,200	1 : 1,200	1 : 19,200	1 : 1,140	1 : 300	1 : 300	1 : 300
Diatomales:								
Coscinodiscus spp.	—	—	—	—	78,660	13,800	2,100	900
Asteromphalus challengerensis	—	—	—	—	1,140	—	—	—
A. hookerii	—	—	1,200	38,400	1,140	—	—	—
A. parvulus	—	1,200	1,200	—	2,280	600	300	—
A. regularis	300	—	1,200	38,400	5,700	1,800	1,200	—
Actinocyclus bifrons	—	—	—	38,400	—	—	—	—
Thalassiosira antarctica	—	3,600	14,400	268,800	—	—	—	—
Dactyliosolen antarcticus	—	—	—	153,600	90,060	31,200	9,300	3,300
D. flexuosus	—	—	—	38,400	—	—	—	—
D. laevis	—	4,800	—	—	—	—	—	—
Leptocylindrus sp.	—	—	9,600	460,800	—	—	1,500	—
Corethron valdiviae	7,200	36,000	33,600	422,400	11,400	6,000	5,100	1,800
Corethron valdiviae (spineless chains)	—	—	—	—	339,720	55,800	16,500	3,000
Rhizosolenia alata	—	12,000	8,400	38,400	62,700	10,800	8,700	5,100
R. bidens	—	—	—	38,400	—	—	—	—
R. chunnii	—	—	4,800	—	—	—	—	—
R. curva	—	—	—	—	3,420	1,200	300	—
R. polydactyla	—	—	—	—	11,400	—	600	—
R. simplex	—	—	—	—	12,540	1,200	1,200	300
R. styliformis	600	4,800	2,400	614,400	13,680	1,800	600	300
R. truncata	300	—	—	76,800	—	—	—	—
Chaetoceros atlanticus	—	91,200	21,600	1,920,000	92,340	12,000	6,900	7,200
Ch. criophilum	1,200	19,200	28,800	537,600	6,840	—	600	—
Ch. curvatus	—	—	—	76,800	—	—	—	—
Ch. dichaeta	1,800	46,800	12,000	1,728,000	18,240	—	—	—
Ch. neglectus	2,100	210,000	356,400	22,656,000	—	—	—	—
Ch. schimperianus	—	7,200	—	268,800	—	—	—	—
Biddulphia striata	300	—	—	—	—	—	—	—
Fragilaria antarctica	—	—	19,200	2,534,400	294,120	4,800	—	—
Synedra spathulata	—	4,800	4,800	38,400	—	—	—	—
Thalassiothrix antarctica	—	3,600	8,400	384,000	6,840	—	1,500	—
Navicula spp.	—	—	1,200	—	2,280	—	1,500	—
Nitzschia seriata	—	124,800	349,200	5,068,800	9,726,480	32,400	81,600	5,700
Dinoflagellata:								
Dinophysis sp.	—	—	—	—	1,140	600	—	—
Peridinium antarcticum	—	—	—	—	3,420	—	—	—
Ceratium pentagonum	—	—	—	—	30,780	18,000	10,200	5,400
Silicoflagellata	—	—	2,400	307,200	—	—	—	—
Protozoa:								
Radiolaria: Challengeridae	—	—	—	—	5,700	1,800	900	1,200
Tintinnidae	1,500	6,000	8,400	115,200	14,820	1,200	600	—
Sticholonche sp.	—	1,200	—	—	—	—	—	—
Metazoa	300	3,900	8,400	19,800	67,440	33,000	25,500	17,700
Total Diatomales	13,800	570,000	881,400	37,440,000	10,780,980	159,600	139,500	27,600
Total Dinoflagellata	—	—	—	—	35,340	18,600	10,200	5,400
Total Protozoa	1,500	7,200	8,400	115,200	20,520	3,000	1,500	1,200

Table XXIII. *Analyses of samples collected on a line of stations between Staten Island and South Georgia, March* 1931. *The positions of the stations are charted in Fig.* 32.

Station ...	651	653	655	656	657	658
Lat. S ...	55° 08′	54° 04′	53° 30½′	53° 19¼′	53° 31½′	53° 38¼′
Long. W ...	63° 31′	54° 11¾′	50° 40¾′	47° 53′	44° 23¾′	40° 27¼′
Date ...	14. iii. 31	21. iii. 31	23. iii. 31	24. iii. 31	25. iii. 31	26. iii. 31
Temp. ° C. (mean of 0–20 m.)	7·23	6·18	5·99	4·78	2·18	2·64
Salinity ‰ (mean of 0–20 m.)	34·05	34·08	34·11	34·01	33·84	33·88
*p*H (mean of 0–20 m.)	8·01	7·98	7·98	7·98	7·98	7·97
Volume of sample cc....	4	4	3	6	5	10
Fraction examined ...	1 : 300	1 : 300	1 : 300	1 : 300	1 : 300	1 : 300
Diatomales:						
Coscinodiscus spp.	900	1,200	300	1,200	2,100	—
Asteromphalus regularis	—	—	—	300	—	—
Thalassiosira antarctica	—	—	—	—	—	900
Dactyliosolen antarcticus	3,300	1,200	—	25,200	1,200	1,200
Corethron valdiviae	1,800	17,100	13,500	11,400	6,600	19,200
Corethron valdiviae (spineless chains)	3,000	2,700	—	68,100	3,900	—
Rhizosolenia alata	5,100	6,300	1,500	10,500	2,700	7,200
R. curva	—	4,500	—	900	1,500	300
R. polydactyla	—	—	—	—	—	300
R. styliformis	300	900	300	900	900	7,800
Chaetoceros atlanticus	7,200	900	—	4,800	12,000	2,700
Ch. criophilum	—	1,500	—	4,800	11,700	61,200
Ch. curvatus	—	—	600	1,200	—	—
Ch. dichaeta	—	900	—	900	—	—
Chaetoceros sp.	4,200	—	—	—	—	—
Fragilaria antarctica	—	—	—	22,800	—	—
Synedra spathulata	—	—	—	—	300	600
Thalassiothrix antarctica	—	—	—	2,100	—	1,500
Navicula pellucida	—	—	—	—	300	—
Nitzschia seriata	5,700	5,400	—	167,100	19,200	—
Dinoflagellata:						
Peridinium sp.	—	600	—	1,200	—	1,800
Ceratium pentagonum	5,400	5,400	—	6,000	600	—
Protozoa:						
Radiolaria: Challengeridae	1,200	—	—	2,700	300	600
Radiolaria: Others	—	—	—	300	—	—
Foraminifera	—	600	1,800	600	1,200	—
Tintinnidae	—	—	—	—	—	900
Polychaete larvae	300	—	—	—	—	—
Copepoda	3,900	12,900	3,300	2,100	600	900
Nauplii	13,200	16,200	7,500	9,600	6,300	3,900
Pteropoda: *Limacina* juv.	300	—	—	2,100	300	—
Total Diatomales	31,800	42,600	18,300	322,200	59,700	102,900
Total Dinoflagellata	5,400	6,000	—	7,200	600	1,800
Total Protozoa	1,200	600	1,800	3,600	1,500	1,500

Table XXIV. *Analyses of samples collected between South Georgia and Zavodovski Island, South Sandwich Islands, Feb.* 1930. *The positions of the stations are charted in Fig.* 32.

Station	**359**	**342**	**360**	**361**	**362**
Lat. S	55° 07′	55° 47′	55° 53′	55° 53½′	56° 04′
Long. W	32° 12′	34° 11′	32° 33′	30° 46′	29° 15′
Temp. °C.	24. ii. 30	7. ii. 30	24/25. ii. 30	25. ii. 30	25. ii. 30
Salinity ‰ mean of	1·43	2·24	1·32	1·10	0·98
P_2O_5 mg./m.³ 0–20 m.	33·83	33·82	33·87	33·87	33·80
*p*H	104	85	107	101	102
Volume of sample cc.	50	17	28	8	9
Fraction examined	1 : 12,000	1 : 2,000	1 : 3,000 (1 : 300)	1 : 200	1 : 200
Diatomales:					
Coscinodiscus spp.	60,000	40,000	117,600	15,600	16,800
Corethron valdiviae	—	—	—	—	4,200
Corethron valdiviae (spineless chains)	26,400,000	4,080,000	11,856,000	33,600	—
Rhizosolenia alata	120,000	12,000	—	—	4,400
Biddulphia striata	120,000	—	—	—	—
Eucampia antarctica	60,000	—	—	—	—
Fragilaria antarctica	2,880,000	—	—	—	—
Thalassiothrix antarctica	2,040,000	3,192,000	1,710,000	2,400	—
Gyrosigma directum	60,000	—	—	—	—
Nitzschia seriata	1,200,000	—	—	2,400	—
Dinoflagellata:					
Peridinium antarcticum	—	—	39,000	—	—
Ceratium pentagonum f. *grandis*	—	16,000	20,100	—	—
Silicoflagellata	60,000	—	—	—	—
Protozoa: Radiolaria	—	6,000	—	—	8,400
Foraminifera	—	—	19,800	—	—
Tintinnidae	—	16,000	—	—	—
Copepoda	60,000	8,000	19,500	4,800	21,000
Nauplii	—	24,000	—	2,400	29,400
Pteropoda	—	—	—	—	4,200
Total Diatomales	32,940,000	7,324,000	13,683,000	56,000	25,400
Total Dinoflagellata	—	16,000	59,100	—	—
Total Protozoa	—	22,000	19,800	—	8,400

Table XXV. *Analyses of samples collected among the South Sandwich Islands, March 1930. The positions of the stations are charted in Fig. 32.*

Station	**365**	**369**	**368**
Lat. S	56° 55′	59° 17¼′	—
Long. W	27° 02′	26° 57′	—
	Between Visokoi Island and Candlemas Island	Between Bristol Island and Southern Thule	One mile north of Twitcher Rock, Southern Thule
Date	2. iii. 30	9. iii. 30	8. iii. 30
Temp. °C. (mean of 0–20 m.)	0·43	0·23	0·10
Salinity ‰ (mean of 0–20 m.)	33·80	34·01	34·04
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	91	91	—
O_2 cc. per l. (mean of 0–20 m.)	5·91	—	—
*p*H (mean of 0–20 m.)	8·01	8·06	8·05
Volume of sample cc.	10	65	35
Fraction examined	1 : 5,400	1 : 9,000	1 : 8,700 (1 : 200)
Diatomales:			
Melosira sol	237,600	—	—
Coscinodiscus bouvet	745,200	450,000	549,000
Coscinodiscus spp.	32,400	—	—
Asteromphalus regularis	—	—	17,400
Dactyliosolen antarcticus	21,600	36,000	69,600
Corethron valdiviae	10,800	18,000	—
Corethron valdiviae (spineless chains)	—	54,000	—
Rhizosolenia alata	—	18,000	52,200
R. styliformis	—	756,000	626,400
Chaetoceros spp., mainly *dichaeta*	1,814,000	1,458,000	556,800
Ch. castracanei	—	126,000	—
Ch. criophilum	—	288,000	330,000
Eucampia antarctica	21,600	—	34,800
Fragilaria antarctica	—	—	139,200
Navicula pellucida	—	—	17,400
Protozoa: Tintinnidae	10,800	—	—
Sticholonche sp.	—	18,000	—
Copepoda	10,800	—	17,400
Nauplii	54,000	27,000	17,400
Total Diatomales	2,883,200	3,204,000	2,392,800
Total Protozoa	10,800	18,000	—

Table XXVI. *Analyses of samples collected west of Bouvet Island along the ice-edge, including the 24 hour station 461, October 1930. The positions of the stations are charted in Discovery Reports,* IV, *Plate I.*

Station	**453**	**460**	**461 A**	**461 B**	**461 C**	**461 D**	**461 E**	**461 F**	**461 G**
Lat. S	54° 05½′	56° 46′	56° 44′	56° 44′	56° 44′	56° 41′	56° 41′	56° 44′	56° 44¾′
Long.	03° 57¼′ E	00° 41¾′ W	02° 23¾′ W	02° 23′ W	02° 22′ W	02° 24′ W	02° 24′ W	02° 22′ W	02° 21½′ W
Date	16/17. x. 30	20/21. x. 30	21. x. 30	21. x. 30	21/22. x. 30	22. x. 30	22. x. 30	22. x. 30	22. x. 30
Time	2040	2146	1603	1956	2344	0355	0725	1130	1540
Temp. ° C.	−1·60	−1·40	−1·72	−1·83	−1·80	−1·72	−1·80	−1·76	−1·75
Salinity ‰ (mean of 0–20 m.)	34·08	34·07	34·15	34·12	34·17	34·16	34·17	34·16	34·17
P_2O_5 mg./m.^{3}	96	104	104	—	—	—	—	—	105
O_2 cc. per l.	7·02	7·40	—	—	—	—	—	—	6·81
*p*H	7·97	7·95	—	—	—	—	—	—	7·94
Volume of sample cc.	3	2	12	12	8	12	6	5	10
Fraction examined	1 : 300	1 : 300	1 : 900	1 : 1,080	1 : 1,020	1 : 1,260	1 : 1,020	1 : 900	1 : 900
Diatomales:									
Coscinodiscus bouvet	300	300	900	2,160	1,020	—	2,040	1,800	1,800
Asteromphalus hookerii	—	—	—	—	1,020	—	—	—	—
A. regularis	—	—	900	—	2,040	—	—	—	900
Thalassiosira antarctica	1,200	900	9,900	28,080	15,300	71,820	23,460	10,800	12,600
Leptocylindrus sp.	1,200	2,100	—	—	—	—	2,040	—	3,600
Corethron valdiviae	38,100	7,500	11,700	73,440	25,500	73,080	28,560	31,500	36,000
Rhizosolenia alata	—	—	12,600	14,040	10,200	20,160	19,380	10,800	7,200
R. polydactyla	—	—	900	—	—	—	—	—	—
R. styliformis	300	300	12,600	10,800	10,200	17,640	4,080	3,600	1,800
Chaetoceros atlanticus	1,200	—	—	3,240	—	—	—	—	—
Ch. criophilum	3,000	600	16,200	25,920	10,200	6,300	6,120	4,500	6,300
Ch. cruciatum	—	—	37,800	—	—	—	—	—	—
Ch. curvatus	—	—	—	4,320	—	—	—	—	—
Ch. dichaeta	2,100	3,000	27,900	66,960	38,760	66,780	13,260	18,900	31,500
Ch. neglectus	—	2,400	—	334,800	41,820	259,560	71,400	63,900	91,800
Ch. radiculum/schimperianus	—	—	—	5,400	18,360	26,460	6,120	4,500	6,300
Biddulphia striata	—	900	—	—	—	3,780	1,020	900	900
Eucampia antarctica	—	300	—	3,240	—	2,520	—	1,800	—
Fragilaria antarctica	7,200	8,400	7,200	58,320	8,160	136,080	48,960	10,800	39,600
Fragilaria antarctica f. *bouvet*	—	—	36,000	164,160	—	231,840	89,760	36,000	50,400
Synedra spathulata	—	4,800	14,400	82,080	17,340	54,180	23,460	21,600	20,700
Thalassiothrix antarctica	—	—	900	—	—	—	—	—	—
Navicula pellucida	300	—	—	—	—	—	—	—	1,800
Navicula sp.	—	—	—	1,080	—	—	—	—	—
Nitzschia seriata	—	9,000	151,200	213,840	61,200	177,660	103,020	110,700	96,300
Dinoflagellata:									
Dinophysis rotundata	—	—	900	—	—	—	—	—	—
Peridinium elegans	—	—	1,800	1,080	1,020	—	—	—	—
Peridinium sp.	—	—	—	—	—	—	—	2,700	—
Silicoflagellata	—	—	900	—	—	—	—	—	900
Protozoa:									
Radiolaria: Challengeridae	—	—	3,600	2,160	1,020	—	1,020	1,800	1,800
Foraminifera	300	—	900	1,080	2,040	1,260	—	1,800	900
Tintinnidae	—	600	3,600	6,480	2,040	2,520	2,040	900	900
Metazoa	—	600	34,200	15,120	22,440	5,040	18,360	11,700	3,900
Total Diatomales	54,900	40,500	341,100	1,092,960	261,120	1,147,860	442,680	334,800	417,600
Total Dinoflagellata	—	—	2,700	1,080	1,020	—	—	2,700	—
Total Protozoa	300	600	8,100	9,720	6,000	3,780	3,060	4,500	3,600

Table XXVII. *Analyses of samples collected at a series of stations across the north of the Weddell Sea area, December* 1930. *The positions of the stations are charted in Fig.* 32.

Station	529	528	531	532	533	534	536
Lat. S	55° 11½′	55° 33′	57° 27′	58° 29′	59° 36′	60° 08′	60° 43′
Long. W	31° 39′	30° 15′	34° 25′	37° 44′	42° 34′	47° 53′	52° 29½′
Date	13. xii. 30	12. xii. 30	14. xii. 30	15. xii. 30	16. xii. 30	17. xii. 30	18. xii. 30
Temp. ° C. } surface samples	−0·65	−1·46	−0·90	−1·20	0·15	0·15	−0·30
Salinity ‰ } only	33·69	33·79	33·69	33·71	33·98	34·09	34·42
Volume of sample cc.... ...	170	32	1,200	120	154	35	60
Fraction examined	1 : 33,600	1 : 9,600	1 : 96,000	1 : 14,400	1 : 12,600	1 : 9,000	1 : 7,500 (1 : 300)
Diatomales:							
Coscinodiscus spp.	—	—	96,000	14,400	50,400	—	—
Asteromphalus hookerii	—	—	96,000	—	—	—	—
A. parvulus	—	—	96,000	—	—	—	—
A. regularis	—	—	—	14,400	—	—	—
Actinocyclus sp.	—	—	—	—	12,600	—	—
Thalassiosira antarctica	268,800	124,800	3,936,000	720,000	1,285,200	72,000	150,000
Dactyliosolen laevis	—	—	480,000	—	—	9,000	—
Leptocylindrus sp.	67,200	—	—	—	—	—	7,500
Corethron valdiviae	2,822,400	67,200	1,536,000	403,200	3,049,200	189,000	3,412,500
Corethron valdiviae (auxosporenbildung)	—	—	—	—	—	—	82,500
Rhizosolenia alata	470,400	57,600	1,056,000	288,000	226,800	90,000	105,000
R. chunnii	—	—	288,000	—	63,000	—	—
R. simplex	—	—	—	—	12,600	—	—
R. styliformis	4,233,600	4,052,700	9,120,000	2,260,800	1,260,000	693,000	—
R. torpedo	—	—	—	—	12,600	—	—
R. truncata	—	9,600	—	—	—	—	82,500
Chaetoceros atlanticus	403,200	—	288,000	—	50,400	—	—
Ch. criophilum	11,961,600	—	64,992,000	1,324,800	1,045,800	486,000	45,000
Ch. curvatus	67,200	9,600	96,000	—	—	—	15,000
Ch. dichaeta	1,008,000	345,600	2,304,000	201,600	138,600	90,000	210,000
Ch. neglectus	3,427,200	—	3,648,000	2,577,600	3,591,000	135,000	262,500
Ch. schimperianus	67,200	19,200	—	100,800	—	—	—
Biddulphia striata	134,400	—	960,000	432,000	567,000	9,000	52,500
Eucampia antarctica	—	38,400	384,000	216,000	705,600	9,000	67,500
Fragilaria antarctica	806,400	172,800	13,728,000	1,267,200	680,400	90,000	105,000
Fragilaria antarctica f. *bouvet*	—	—	—	—	75,600	216,000	—
Thalassiothrix antarctica	67,200	—	768,000	216,000	176,400	18,000	7,500
Navicula pellucida	67,200	—	96,000	—	—	—	—
Navicula sp.	—	19,200	96,000	—	—	—	—
Nitzschia closterium	134,400	19,200	96,000	—	—	—	—
N. seriata	1,276,800	2,572,800	2,112,000	1,656,000	2,318,400	216,000	—
Dinoflagellata:							
Dinophysis sp.	67,200	—	—	—	—	—	—
Peridinium antarcticum	67,200	—	—	—	—	—	—
Peridinium sp.	67,200	—	—	—	—	—	—
Silicoflagellata	470,400	48,000	576,000	—	—	—	—
Protozoa:							
Foraminifera	—	—	—	—	—	—	7,500
Tintinnidae	—	—	96,000	—	12,600	—	15,000
Metazoa	—	19,200	—	—	1,500	9,900	1,200
Total Diatomales	27,283,200	7,508,200	106,272,000	11,692,800	15,145,200	2,322,000	4,605,000
Total Dinoflagellata	201,600	—	—	—	—	—	—
Total Protozoa	—	—	96,000	—	12,600	—	22,500

Table XXVIII. *Analyses of samples collected between* 53° *and* 57° *S* : 25° *and* 36° *W, Jan.–Feb.* 1931. *The positions of the stations are charted in Fig.* 46.

Station	WS 534	WS 535	WS 561	WS 536	WS 537	WS 560
Lat. S	54° 17½′	55° 12′	55° 22′	56° 28′	56° 10′	56° 27′
Long. W	35° 39′	31° 51′	33° 04′	27° 21′	25° 35′	28° 59′
Date	22/23. i. 31	23. i. 31	10. ii. 31	24. i. 31	25/26. i. 31	9. ii. 31
Temp. ° C. } mean of 0–20 m.	1·56	1·20*	1·28*	−0·11*	0·59	0·70*
Salinity ‰ } or surface	33·87	33·46*	33·61*	33·68*	33·76	33·37*
Volume of sample cc.	10	1,440	720	70	380	1,056
Fraction examined	1 : 300	1 : 162,000	1 : 28,800	1 : 3,000	1 : 21,600	1 : 33,600
Diatomales:						
Coscinodiscus bouvet	—	—	—	3,000	—	—
Coscinodiscus spp.	300	162,000	—	9,000	—	—
Asteromphalus challengerensis	—	—	—	3,000	—	—
A. regularis	—	162,000	—	—	—	—
Thalassiosira antarctica	—	1,944,000	230,400	6,000	—	33,600
Dactyliosolen antarcticus	—	1,944,000	—	—	43,200	—
Corethron valdiviae	5,100	2,916,000	1,123,200	2,913,000	1,490,400	8,232,000
Corethron valdiviae (spineless chains)	—	3,078,000	—	—	—	—
Rhizosolenia alata	—	3,078,000	86,400	—	—	168,000
R. styliformis	—	23,814,000	4,896,000	117,000	5,788,800	9,945,600
R. torpedo	—	—	28,800	—	—	—
R. truncata	—	—	—	12,000	—	—
Chaetoceros atlanticus	—	1,296,000	259,200	—	—	537,600
Ch. criophilum	16,500	108,702,000	20,044,800	612,000	6,393,600	28,123,200
Ch. dichaeta	—	6,642,000	144,000	21,000	—	—
Ch. ?didymum	—	810,000	—	—	—	—
Ch. neglectus	—	1,944,000	230,400	372,000	—	3,460,800
Ch. schimperianus	—	810,000	—	—	—	—
Eucampia antarctica	—	—	—	6,000	—	—
Fragilaria antarctica	—	16,848,000	—	144,000	—	403,200
Thalassiothrix antarctica	—	5,670,000	288,000	72,000	21,600	33,600
Navicula oceanica	—	324,000	—	—	—	—
Nitzschia seriata	—	44,388,000	—	51,000	—	—
Dinoflagellata:						
Peridinium antarcticum	—	162,000	57,600	—	—	—
Peridinium sp.	—	—	28,800	—	—	67,200
Silicoflagellata	—	162,000	—	3,000	21,600	—
Protozoa:						
Tintinnidae	—	1,296,000	—	21,000	—	67,200
Copepoda	4,200	—	—	3,000	—	—
Euphausiidae juv.	300	—	—	—	—	—
Nauplii	900	162,000	57,600	—	—	—
Total Diatomales	21,900	224,532,000	27,331,200	4,341,000	13,737,600	50,937,600
Total Dinoflagellata	—	162,000	86,400	—	—	67,200

* Surface samples only.

Table XXIX. *Analyses of samples collected between 57° and 60° S : 18° and 25° W, Jan–Feb. 1931. The positions of the stations are charted in Fig. 46.*

Station ...	WS 538	WS 559	WS 539	WS 540	WS 541	WS 542
Lat. S ...	57° 03½′	57° 19′	57° 41½′	57° 55′	57° 51½′	58° 39′
Long. W ...	24° 32′	24° 50′	23° 12′	21° 21′	19° 51½′	18° 13′
Date ...	26. i. 31	8. ii. 31	26. i. 31	27/28. i. 31	28. i. 31	28. i. 31
Temp. ° C. } mean of 0–20 m.	0·35*	0·40*	−0·30*	−0·29	0·68*	−0·09*
Salinity ‰ } or surface	33·34*	33·43*	33·18*	33·19	33·35*	33·40*
Volume of sample cc. ...	100	68	340	168	80	300
Fraction examined ...	1 : 7,200	1 : 4,200	1 : 12,000	1 : 7,200	1 : 11,200	1 : 26,400
Diatomales:						
Coscinodiscus sp.	—	—	—	7,200	—	—
Thalassiosira antarctica	—	—	12,000	7,200	—	5,649,600†
Dactyliosolen antarcticus	—	—	—	—	—	369,600
Corethron valdiviae	2,260,800	3,574,200	672,000	360,000	403,200	105,600
Rhizosolenia alata	14,400	8,400	—	—	11,200	—
R. bidens	—	—	—	—	—	1,267,200
R. crassa	—	—	—	—	—	52,800
R. styliformis	432,000	21,000	936,000	561,600	5,465,600	50,371,200
Chaetoceros criophilum	676,800	37,800	14,004,000	6,796,800‡	940,800	—
Ch. dichaeta	36,000	—	—	—	67,200	264,000
Ch. neglectus	525,600	—	—	—	246,400	—
Eucampia antarctica	—	—	—	—	—	52,800
Fragilaria antarctica	—	—	48,000	57,600	89,600	211,200
Synedra spathulata	—	—	—	—	—	1,267,200
Thalassiothrix antarctica	—	12,600	24,000	—	—	—
Nitzschia seriata	158,400	—	—	—	190,400	—
Dinoflagellata:						
Peridinium turbinatum	—	—	—	7,200	—	—
Peridinium sp.	—	4,200	—	—	—	—
Silicoflagellata	—	—	24,000	7,200	11,200	—
Protozoa:						
Tintinnidae	—	12,600	48,000	21,600	11,200	52,800
Copepoda	—	—	—	7,200	—	105,600
Nauplii	14,400	12,600	12,000	7,200	—	52,800
Total Diatomales	4,104,000	3,654,000	15,696,000	7,790,400	7,414,400	59,611,200
Total Dinoflagellata	—	4,200	—	7,200	—	—

* Surface samples only. † Minute colonial form. ‡ Mostly dead and dying frustules.

Table XXX. *Analyses of samples collected between* 60° *and* 65° *S* : 15° *and* 20° *W*, *Jan.–Feb.* 1931. *The positions of the stations are charted in Fig.* 46.

Station	WS 543	WS 545	WS 547	WS 554	WS 548
Lat. S	60° 10½′	61° 51′	62° 40′	63° 20′	64° 07′
Long. W	18° 00′	17° 15′	17° 02′	17° 23′	15° 38′
Date	29. i. 31	30. i. 31	30. i. 31	5. ii. 31	31. i. 31
Temp. °C. } mean of 0–20 m.	−0·45*	−0·92*	−0·85*	−0·28	−0·58
Salinity ‰ } or surface	33·45*	34·07*	33·96*	33·96	34·06
Volume of sample cc.	420	85	25	12	20
Fraction examined	1 : 86,400	1 : 7,200	1 : 2,000	1 : 1,350	1 : 4,200
Diatomales:					
Coscinodiscus spp.	—	14,400	—	—	71,400
Asteromphalus hookerii	—	—	4,000	—	8,400
A. parvulus	—	—	—	5,400	—
Thalassiosira antarctica	3,369,600†	—	24,000	18,900	—
Dactyliosolen antarcticus	950,400	—	—	10,800	37,800
D. flexuosus	—	—	—	1,350	—
Leptocylindrus sp.	—	36,000	32,000	13,500	4,200
Corethron valdiviae	6,912,000	72,000‡	22,000	8,100	33,600
Corethron valdiviae (spineless chains)	—	—	—	—	8,400
Rhizosolenia alata	259,200	50,400	32,000	16,200	—
R. rhombus	172,800	—	—	—	—
R. styliformis	92,534,400	1,605,600	66,000	13,500	42,000
R. torpedo	—	—	2,000?	—	4,200
R. truncata	172,800	50,400	—	13,500	58,800
Chaetoceros criophilum	259,200	352,800	30,000	24,300	29,400
Ch. dichaeta	1,209,600	28,800	10,000	17,550	12,600
Ch. neglectus	2,332,800	108,000	8,000	195,750	667,800
Ch. schimperianus	345,600	—	2,000	2,700	33,600
Eucampia antarctica	—	—	—	2,700	—
Fragilaria antarctica	3,456,000	864,000	240,000	324,000	268,800
Synedra spathulata	1,296,000	360,000	64,000	9,450	37,800
Navicula pellucida	—	—	—	1,350	21,000
Nitzschia closterium	1,296,000	—	—	4,050	—
N. seriata	14,342,400	1,008,000	3,702,000	3,029,400	12,839,400
N. ?sigmoidea (Nitzsch) Wm. Sm.	86,400	—	—	—	—
Dinoflagellata:					
Dinophysis sp.	—	—	2,000	4,050	8,400
Peridinium sp.	—	—	2,000	1,350	4,200
Silicoflagellata	172,800	21,600	—	14,850	29,400
Protozoa:					
Radiolaria: Challengeridae	—	—	—	—	8,400
Others	—	—	—	5,400	4,200
Foraminifera	—	7,200	—	1,350	—
Tintinnidae	259,200	—	—	5,400	—
Sticholonche sp.	—	7,200	—	—	—
Metazoa	—	7,200	34,000	29,300	16,800
Total Diatomales	128,995,200	4,550,400	4,238,000	3,715,200	14,179,200
Total Dinoflagellata	—	—	4,000	5,400	12,600
Total Protozoa	259,200	14,400	—	12,150	12,600

* Surface samples only. † Minute colonial form. ‡ Large individuals, result of recent auxospore formation.

Table XXXI. *Analyses of samples collected between 65° and 69° S : 16° and 13° W, Jan.–Feb. 1931. The positions of the stations are charted in Fig. 46.*

Station ...	WS 549	WS 550	WS 551	WS 552 A	WS 552 B	WS 552 C	WS 552 D
Lat. S ...	65° 17′	66° 51½′	68° 17½′	68° 53′	—	—	—
Long. W...	15° 33′	15° 24′	14° 26½′	13° 03′	—	—	—
Date ...	31. i. 31	1. ii. 31	1. ii. 31	2. ii. 31	—	—	—
Temp. ° C. } mean of 0–20 m.	−0·50*	−0·23*	1·27*	−1·30	—	—	—
Salinity ‰ } or surface	34·14*	34·06*	33·91*	33·91	—	—	—
Volume of sample cc. ...	34	112	150	30	44	29	40
Fraction examined ...	1 : 15,000	1 : 14,400	1 : 18,000	1 : 1,050	1 : 2,250	1 : 4,800	1 : 2,700
Diatomales:							
Coscinodiscus bouvet	15,000	—	—	—	—	—	—
Coscinodiscus spp.	15,000	14,400	36,000	—	—	—	—
Asteromphalus challengerensis	—	—	—	—	2,250	—	—
A. hookerii	15,000	—	—	—	—	—	—
A. regularis	—	28,800	18,000	1,050	—	4,800	5,400
Actinocyclus bifrons	—	—	—	2,100	—	—	—
Thalassiosira antarctica	75,000	172,800	216,000	24,150	33,750	24,000	21,600
Dactyliosolen antarcticus	210,000	590,400	432,000	25,200	31,500	48,000	21,600
D. flexuosus	—	—	18,000	—	—	—	—
Leptocylindrus sp.	15,000	—	72,000	7,350	11,250	—	—
Corethron valdiviae	300,000	374,400	3,348,000	105,000	173,250	360,000	270,000
Corethron valdiviae (spineless chains)	60,000	86,400	—	—	—	—	—
Rhizosolenia alata	75,000	57,600	414,000	19,950	33,750	33,600	27,000
R. antarctica	—	100,800	—	—	—	—	—
R. crassa	15,000	14,400	—	—	—	—	—
R. styliformis	60,000	115,200	162,000	3,150	4,500	4,800	21,600
R. truncata	—	43,200	90,000	21,000	9,000	19,200	16,200
Chaetoceros criophilum	120,000	475,200	216,000	19,950	24,750	19,200	27,000
Ch. dichaeta	330,000	273,000	450,000	46,200	81,000	134,400	70,200
Ch. neglectus	1,050,000	∞	∞	+	+	+	++
Ch. schimperianus	—	—	126,000	7,350	4,500	67,200	10,800
Ch. socialis	—	—	—	+	+	+	+
Eucampia antarctica	—	144,000	18,000	6,300	4,500	4,800	—
Fragilaria antarctica	—	921,600	2,520,000	254,100	378,000	460,800	151,200
Synedra spathulata	90,000	374,000	414,000	31,500	40,500	33,600	37,800
Navicula sp.	30,000	—	90,000	—	—	—	—
Amphora sp.	—	—	36,000	—	—	—	—
Cymbella sp.	—	—	18,000	—	—	—	—
Nitzschia closterium	—	1,080,000	3,312,000	1,568,700	900,000	753,600	999,000
N. seriata	10,440,000	3,153,600	12,528,000	1,575,000	1,887,750	1,430,400	1,107,000
Dinoflagellata:							
Dinophysis ellipsoidea	15,000	—	—	—	—	—	—
Dinophysis spp.	15,000	—	36,000	3,150	9,000	14,400	5,400
Peridinium antarcticum	15,000	—	—	—	—	—	—
Peridinium spp.	—	—	18,000	1,050	—	4,800	5,400
Silicoflagellata	150,000	129,600	270,000	13,650	13,000	19,200	21,600
Protozoa:							
Radiolaria	45,000	—	—	1,050	6,750	—	—
Tintinnidae	—	14,400	—	2,100	4,500	4,800	5,400
Metazoa	30,000	14,400	72,000	9,450	13,450	14,400	16,200
Total Diatomales	12,915,000	8,020,800†	24,534,000†	3,718,050†	3,620,250†	3,398,400†	2,786,400†
Total Dinoflagellata	45,000	—	54,000	4,200	9,000	19,200	10,800
Total Protozoa	45,000	14,400	—	3,150	11,250	4,800	5,400

* Surface samples only. † Excluding inestimable small Chaetocerids.

Table XXXII. *Analyses of samples collected on a line of stations between Elephant Island and the South Sandwich Islands, February 1931. The positions of the stations are charted in Fig. 32.*

Station	613	614	615	617	618	619	620	621	622	623	624	625	626
Lat. S ...	60° 59¾′	60° 07¾′	60° 55½′	60° 22′	59° 42¾′	59° 33′	59° 12′	58° 50¼′	59° 05½′	59° 00¾′	58° 34¾′	58° 02′	57° 22′
Long. W ...	50° 42½′	48° 20¼′	47° 58¾′	45° 40′	43° 57¾′	43° 07¼′	40° 23½′	38° 53′	36° 25′	34° 11′	31° 21½′	29° 11½′	26° 29¾′
Date ...	12. ii. 31	12. ii. 31	13. ii. 31	18. ii. 31	18/19. ii. 31	19. ii. 31	19/20. ii. 31	20. ii. 31	20/21. ii. 31	21. ii. 31	21/22. ii. 31	22. ii. 31	22. ii. 31
Temp. ° C. } mean of 0–20 m.	0·21*	0·72*	−0·68*	−0·92*	1·29	−0·52*	−0·50	0·25*	−0·89	−0·40*	0·23	0·18*	−0·09*
Salinity ‰ } or surface	34·45*	34·30*	32·73*	33·44*	34·13	32·79*	32·74	33·18*	33·00	33·11*	33·31	33·40*	33·62*
Volume of sample cc. ...	5	5	30	12	6	11	40	176	164	146	656	166	170
Fraction examined ...	1 : 600	1 : 300	1 : 1,200	1 : 1,140	1 : 300	1 : 600	1 : 1,200	1 : 9,000	1 : 7,200	1 : 6,600	1 : 45,600	1 : 6,300	1 : 8,400
Diatomales:													
Coscinodiscus bouvet	—	—	—	—	—	—	—	—	7,200	—	—	—	8,400
Coscinodiscus spp.	10,800	1,800	—	2,280	300	1,200	2,400	54,000	—	—	—	—	—
Asteromphalus hookerii	—	—	—	—	600	—	—	—	—	—	—	—	—
A. parvulus	—	—	—	—	300	1,800	—	—	—	—	—	—	—
A. regularis	—	—	—	—	900	—	—	—	—	—	—	6,300	—
Actinocyclus corona	—	—	—	—	—	—	—	—	—	—	—	6,300	—
Thalassiosira antarctica	6,000	—	6,000	23,940	8,100	3,000	6,000	—	14,400	46,200	45,600	6,300	—
Dactyliosolen laevis	—	—	—	—	—	600	—	18,000	—	—	45,600	—	—
Leptocylindrus sp.	—	—	—	—	—	—	—	—	—	—	—	6,300	—
Corethron valdiviae	174,000	43,500	524,400	183,540	29,700	72,600	628,800	3,618,000	367,200	415,800	3,100,800	2,041,200	10,029,600
Rhizosolenia alata	1,200	600	3,600	1,140	1,200	1,800	3,600	—	7,200	85,800	136,800	—	8,400
R. styliformis	—	300	8,400	—	6,600	9,000	10,800	1,134,000	720,000	864,600	3,556,800	1,115,100	109,200
R. truncata	600	—	—	9,120	300	1,200	1,200	—	—	—	—	—	—
Chaetoceros atlanticus	—	—	—	21,660	5,100	—	7,200	90,000	43,200	39,600	—	—	—
Ch. criophilum	4,800	5,400	27,600	34,200	31,500	102,600	261,600	4,428,000	5,718,800	2,052,600	29,366,400	3,074,400	277,200
Ch. dichaeta	—	—	8,400	14,820	600	4,200	14,400	126,000	115,200	52,800	45,600	63,000	50,400
Ch. neglectus	—	—	9,600	—	—	17,400	39,600	—	—	343,200	592,800	252,000	67,200
Ch. schimperianus	—	—	—	3,420	900	—	—	—	—	—	—	—	—
Ch. tortissimus	—	—	—	—	—	—	26,400	—	—	—	—	—	—
Biddulphia striata	—	—	—	25,080	900	3,000	—	—	—	13,200	—	—	—
Eucampia antarctica	—	—	—	13,680	—	—	—	—	—	—	—	6,300	—
Fragilaria antarctica	62,400	—	16,800	176,700	39,000	9,600	—	216,000	—	66,000	—	100,800	67,200
Synedra spathulata	4,200	—	—	—	300	—	1,200	—	—	—	—	—	—
Thalassiothrix antarctica	—	14,700	114,000	—	900	—	—	162,000	—	13,200	319,200	18,900	16,800
Navicula pellucida	—	—	—	—	—	600	—	—	—	—	—	—	—
Nitzschia seriata	—	—	—	—	4,500	3,000	—	—	259,200	—	364,800	18,900	75,600
Dinoflagellata:													
Peridinium antarcticum	—	—	—	—	300	600	—	18,000	14,400	—	—	6,300	8,400
Silicoflagellata	—	—	—	—	—	—	1,200	18,000	—	—	45,600	25,200	58,800
Protozoa:													
Radiolaria	2,400	—	—	—	—	600	—	27,000	7,200	6,600	—	—	—
Foraminifera	600	300	—	—	—	—	—	—	—	—	—	—	—
Tintinnidae	15,600	1,500	4,800	14,820	22,800	7,800	21,600	126,000	—	19,800	182,400	31,500	16,800
Metazoa	16,200	1,500	3,600	5,700	35,400	38,400	37,200	54,000	15,000	23,400	—	6,300	8,400
Total Diatomales	264,000	66,300	718,800	509,580	131,700	231,600	1,003,200	9,846,000	7,250,400	3,993,000	37,574,400	6,715,800	10,710,000
Total Protozoa	18,600	1,800	4,800	14,820	22,800	8,400	21,600	153,000	7,200	26,400	182,400	31,500	16,800

* Surface samples only.

Table XXXIII. *Analyses of samples collected on a line of stations from Admiralty Bay southwards across Bransfield Strait, February* 1929. *The positions of the stations are charted in Fig.* 49.

Station ...	WS 382	WS 383	WS 384	WS 385	WS 386	WS 387	WS 388
Lat. S ...	62° 15½′	62° 20¾′	62° 25¾′	62° 32′	62° 41′	62° 49′	62° 55½′
Long. W ...	58° 18½′	58° 13′	58° 06¼′	57° 55′	57° 44′	57° 40′	57° 40′
Date ...	15. ii. 29	15. ii. 29	15. ii. 29	16. ii. 29	16. ii. 29	16. ii. 29	16. ii. 29
Temp. ° C. (mean of 0–20 m.)	1·54	1·92	2·09	1·25	1·02	0·91	0·66
Salinity ‰ (mean of 0–20 m.)	33·94	34·01	34·05	33·75	33·62	34·11	34·14
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	142	135	134	134	133	147	173
*p*H (mean of 0–20 m.)	7·96	7·89	7·95	7·93	7·91	7·92	7·93
Volume of sample cc. ...	4	70	28	17	16	24	15
Fraction examined ...	1 : 500	1 : 6,000	1 : 4,200	1 : 2,400	1 : 2,100	1 : 3,600	1 : 2,100
Diatomales:							
Coscinodiscus spp.	3,000	—	—	—	—	—	—
Thalassiosira antarctica	174,000	12,000	12,600	21,600	27,300	18,000	2,100
Corethron valdiviae	450,000	7,026,000	2,906,400	2,008,800	1,887,900	2,145,600	1,081,500
Rhizosolenia alata f. *gracillima*	10,500	6,000	—	—	—	—	—
R. styliformis	—	—	—	—	—	—	6,300
Chaetoceros criophilum	1,500	—	—	—	4,200	28,800	16,800
Biddulphia striata	—	—	—	2,400	—	3,600	—
Eucampia antarctica	—	—	—	—	—	3,600	—
Fragilaria antarctica	—	—	—	14,400	12,600	—	—
Synedra sp.?	—	—	—	—	—	—	8,400
Thalassiothrix antarctica	—	—	—	—	—	3,600	—
Nitzschia seriata	4,500	—	—	—	—	—	6,300
Protozoa:							
Foraminifera	—	—	—	—	2,100	—	—
Tintinnidae, small sp.*	21,000	—	—	—	—	10,800	—
Others	15,000	6,000	16,800	21,600	6,300	54,000	21,000
Polychaete larvae	1,500	—	—	—	—	—	—
Copepoda	1,500	—	—	—	—	—	—
Nauplii	6,000	6,000	12,600	12,000	2,100	—	—
Total Diatomales	643,500	7,044,000	2,919,000	2,047,200	1,932,000	2,203,200	1,121,400
Total Protozoa	36,000	6,000	16,800	21,600	8,400	64,800	21,000

* Similar to the small sp. found round South Georgia in inshore waters.

Table XXXIV. *Analyses of samples collected on a line of stations across Bransfield Strait, between Macfarlane Strait and Astrolabe Island, February* 1929. *The positions of the stations are charted in Fig.* 49.

Station ...	WS 393	WS 392	WS 391	WS 390	WS 389
Lat. S ...	62° 42′	62° 52′	63° 02′	63° 10½′	63° 17′
Long. W ...	59° 41′	59° 26′	59° 12′	59° 01′	58° 51′
Temp. °C. (mean of 0–20 m.)	1·56	1·36	1·87	2·07	0·90
Salinity ‰ (mean of 0–20 m.)	33·86	34·03	34·02	34·00	34·13
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	113	116	127	122	134
*p*H (mean of 0–20 m.)	7·95	7·95	8·00	7·93	7·90
Volume of sample cc. ...	8	90	240	180	25
Fraction examined ...	1 : 1,350	1 : 9,600	1 : 48,000 (1 : 3,000)	1 : 9,600	1 : 2,400
Diatomales:					
Thalassiosira antarctica	—	9,600	—	—	2,400
Corethron valdiviae	1,561,950	10,329,600	37,152,000	10,569,600	2,359,200
Rhizosolenia alata f. *gracillima*	14,850	19,200	—	9,600	—
R. styliformis	1,350	—	—	—	—
Chaetoceros criophilum	12,150	—	18,000	—	—
Fragilaria antarctica	—	—	96,000	—	38,400
Synedra spathulata	2,700	—	—	—	—
Nitzschia seriata	2,700	—	—	—	—
Dinoflagellata:					
Peridinium antarcticum	—	—	3,000	—	—
Protozoa:					
Tintinnidae	16,200	—	12,000	—	7,200
Copepoda	—	—	6,000	—	—
Nauplii	9,450	—	15,000	—	—
Total Diatomales	1,595,700	10,358,400	37,266,000	10,579,200	2,400,000

Table XXXV. *Analyses of samples collected at a series of stations across the western end of Bransfield Strait, February* 1929. *The positions of the stations are charted in Fig.* 49.

Station	WS 394 Between Deception Island and Livingston Island	WS 399 Between Smith Island and Snow Island	WS 398 Between Smith Island and Low Island	WS 397	WS 396	WS 395
Lat. S	62° 51′	62° 50′	63° 09′	63° 29½′	63° 38½′	63° 48½′
Long. W...	60° 40′	61° 58½′	62° 27′	62° 37′	62° 28½′	62° 26′
Date	18. ii. 29	20. ii. 29	20. ii. 29	19. ii. 29	19. ii. 29	19. ii. 29
Temp. ° C.	1·89	2·62	1·49	1·84	2·03	2·25
Salinity $^\circ/_{\circ\circ}$ mean of	33·99	33·69	33·85	33·73	33·47	33·44
P_2O_5 mg./m.^{3} 0–20 m.	128	115	132	115	127	121
*p*H	7·96	8·01	7·96	7·95	8·00	8·00
Volume of sample cc.	2	20	3	16	9	6
Fraction examined	1 : 300	1 : 4,200	1 : 300	1 : 1,800	1 : 2,100	1 : 1,050
Diatomales:						
Thalassiosira antarctica	106,800	—	—	—	—	1,050
Dactyliosolen antarcticus	600	—	—	—	—	—
D. laevis	—	8,400	—	—	—	—
Leptocylindrus sp.	—	16,800	—	—	—	—
Corethron valdiviae	138,600	386,400	121,800	1,796,400	984,900	586,950
Corethron valdiviae (spineless chains)	300	—	—	—	—	—
Rhizosolenia alata f. *gracillima*	600	130,200	3,900	14,400	2,100	1,050
R. styliformis	—	8,400	300	—	—	—
Chaetoceros atlanticus	—	71,400	300	—	—	—
Ch. criophilum	3,000	264,600	2,700	9,000	2,100	1,050
Ch. dichaeta	—	25,200	—	—	—	—
Ch. neglectus	—	58,800	—	—	—	—
Ch. schimperianus	—	29,400	—	—	—	—
Eucampia antarctica	—	—	600	—	—	—
Synedra spathulata	600	8,400	4,800	—	—	—
Thalassiothrix antarctica	—	4,200	—	—	—	—
Lycmophora sp.	—	—	300	—	—	—
Nitzschia seriata	—	142,800	2,100	3,600	10,500	10,500
Silicoflagellata	—	12,600	—	—	—	—
Protozoa:						
Tintinnidae	2,400	8,400	2,100	14,400	2,100	5,250
Copepoda	300	4,200	300	—	—	—
Nauplii	600	21,000	1,200	—	—	—
Total Diatomales	250,500	1,155,000	136,800	1,823,400	999,600	600,600

Table XXXVI. *Analyses of samples collected at Station WS 475 to the north-west of Bridgeman Island and on a line from Admiralty Bay southwards across the Bransfield Strait, November 1929. The positions of the stations are charted in Fig. 56.*

Station ...	WS 475	WS 476	WS 477	WS 478	WS 479	WS 480	WS 481
Lat. S ...	61° 48′	62° 16′	62° 20½′	62° 24½′	62° 32½′	62° 51½′	62° 59′
Long. W ...	55° 51′	58° 18′	58° 14′	58° 06½′	57° 55′	57° 47½′	57° 28′
Date ...	14. xi. 29	14. xi. 29	14/15. xi. 29	15. xi. 29	15/16. xi. 29	16. xi. 29	16. xi. 29
Temp. ° C. (mean of 0–20 m.)	−0·82	−0·68	−0·80	−0·89	−0·90	−0·79	−1·24
Salinity ‰ (mean of 0–20 m.)	34·03	34·05	33·97	34·02	33·97	34·23	34·49
Volume of sample cc. ...	260	55	170	52	180	210	39
Fraction examined ...	1 : 24,000	1 : 4,800	1 : 18,000	1 : 7,200	1 : 18,000	1 : 18,000 (1 : 6,000)	1 : 4,200 (1 : 1,200)
Diatomales:							
Melosira sol	—	—	—	—	—	—	42,000
Coscinodiscus bouvet	24,000	—	108,000	—	—	6,000	46,200
Coscinodiscus spp.	—	33,600	—	14,400	—	—	12,600
Thalassiosira antarctica	504,000	1,200,000	1,728,000	64,800	540,000	72,000	730,800
Corethron valdiviae	23,976,000	3,268,800	13,608,000	4,874,400	12,132,000	11,808,000	2,767,800
Rhizosolenia alata	—	—	—	—	—	—	21,000
Rhizosolenia alata f. *gracillima*	120,000	43,200	306,000	—	288,000	108,000	—
R. truncata	48,000	—	—	—	—	—	37,800
Chaetoceros atlanticus	—	—	—	—	—	—	16,800
Ch. criophilum	—	—	—	—	90,000	36,000	46,200
Ch. dichaeta	—	—	—	—	—	—	12,600
Ch. neglectus	—	—	—	—	54,000	—	50,400
Biddulphia (Triceratium) arctica	—	—	—	—	—	—	1,200
B. striata	96,000	24,000	216,000	—	144,000	12,000	96,600
Eucampia antarctica	96,000	72,000	—	—	162,000	54,000	441,000
Fragilaria antarctica	768,000	168,000	3,636,000	—	864,000	—	256,200
Thalassiothrix antarctica	24,000	—	18,000	—	—	—	—
Lycmophora lyngbyei	—	4,800	—	—	—	—	—
Cocconeis ?costatum	—	4,800	—	—	—	—	—
Nitzschia seriata	—	28,800	—	—	90,000	—	25,200
Dinoflagellata:							
Peridinium antarcticum	—	—	18,000	—	—	—	—
Peridinium sp.	—	—	—	—	—	—	12,600
Protozoa:							
Tintinnidae, small sp.*	—	14,400	—	14,400	—	—	—
Others	240,000	72,000	234,000	36,000	252,000	18,000	29,400
Polychaete larvae	24,000	4,800	—	—	—	—	—
Copepoda	—	4,800	—	14,400	—	6,000	4,200
Nauplii	—	9,600	18,000	7,200	36,000	—	1,200
Appendicularia	—	—	—	—	—	—	1,200
Total Diatomales	25,656,000	4,848,000	19,620,000	4,953,600	14,364,000	12,096,000	4,604,400
Total Protozoa	240,000	86,400	234,000	50,400	252,000	18,000	29,400

* Similar to that observed in inshore waters off South Georgia.

Table XXXVII. *Analyses of samples collected on a line of stations across Bransfield Strait, between Macfarlane Strait and Astrolabe Island. The positions of the stations are charted in Fig.* 56.

Station	WS 483	WS 484	WS 485	WS 486	WS 487
Lat. S	62° 46¾′	62° 54′	63° 02½′	63° 11½′	63° 17′
Long. W	59° 37½′	59° 28′	59° 17′	59° 13′	59° 20′
Date	21. xi. 29	21. xi. 29	21. xi. 29	21. xi. 29	22. xi. 29
Temp. ° C. mean of 0–20 m.	−0·78	−0·71	−0·70	−0·70	−0·88
Salinity ‰ mean of 0–20 m.	34·03	34·03	34·05	34·10	34·28
Volume of sample cc.	34	70	210	240	86
Fraction examined	1 : 6,000	1 : 4,800	1 : 12,000	1 : 21,000	1 : 8,400
Diatomales:					
Coscinodiscus spp.	—	4,800	—	—	—
Thalassiosira antarctica	—	24,000	24,000	—	42,000
Corethron valdiviae	2,928,000	4,665,600	10,956,000	19,488,000	5,233,200
Rhizosolenia alata f. *gracillima*	6,000	—	—	168,000	—
Chaetoceros criophilum	6,000	—	—	84,000	—
Biddulphia striata	6,000	—	—	—	—
Thalassiothrix antarctica	—	—	—	21,000	—
Nitzschia seriata	42,000	—	—	—	—
Dinoflagellata: *Peridinium* sp.	—	—	—	21,000	—
Protozoa:					
Tintinnidae, small sp.*	18,000	—	—	—	—
Others	48,000	4,800	—	—	67,200
Nauplii	6,000	—	—	—	—
Total Diatomales	2,988,000	4,694,400	10,980,000	19,761,000	5,275,200

* Similar to that found in inshore waters round South Georgia.

Table XXXVIII. *Analyses of samples collected at a series of stations across the western end of Bransfield Strait, November* 1929. *The positions of the stations are charted in Fig.* 56.

Station	WS 493 Between Deception & Livingston Islands	WS 492 Between Smith and Snow Islands	WS 491	WS 490	WS 489	WS 488
Lat. S	62° 51′	62° 50½′	63° 12′	63° 24½′	63° 38′	63° 51½′
Long. W	60° 34′	61° 53′	62° 26′	62° 35½′	62° 32′	62° 30′
Date	23. xi. 29	23. xi. 29	23. xi. 29	22/23. xi. 29	22. xi. 29	22. xi. 29
Temp. ° C. mean of 0–20 m.	−0·51	−0·69	−0·67	−0·57	−0·85	−1·07
Salinity ‰ mean of 0–20 m.	34·07	33·95	34·06	34·06	33·97	33·86
Volume of sample cc.	18	17	14	21	44	2
Fraction examined	1 : 2,400	1 : 1,800	1 : 1,200	1 : 2,400	1 : 8,400	1 : 600
Diatomales:						
Thalassiosira antarctica	55,200	—	26,400	16,800	—	4,200
Corethron valdiviae	2,294,400	1,632,600	1,045,200	1,766,400	2,284,800	258,000
Rhizosolenia alata f. *gracillima*	38,400	43,200	16,800	40,800	67,200	2,400
R. styliformis	—	—	—	—	—	600
Chaetoceros criophilum	2,400	5,400	—	2,400	—	—
Ch. ? *didymus*	—	7,200	—	—	—	—
Ch. neglectus	—	25,200	—	—	—	—
Ch. schimperianus	—	—	3,600	—	—	—
Biddulphia striata	7,200	1,800	4,800	2,400	8,400	600
Eucampia antarctica	—	—	8,400	19,200	—	—
Fragilaria antarctica	—	—	—	—	—	9,600
Fragilaria antarctica f. *bouvet*	—	—	—	81,600	—	—
Thalassiothrix antarctica	2,400	3,600	—	2,400	—	—
Nitzschia seriata	21,600	36,000	2,400	—	327,600	7,800
Protozoa:						
Tintinnidae, small sp.*	14,400	10,800	—	—	16,800	—
Others	81,600	43,200	102,000	100,800	117,600	7,800
Copepoda	4,800	—	6,000	4,800	—	2,400
Nauplii	2,400	—	2,400	—	16,800	—
Total Diatomales	2,421,600	1,755,000	1,107,600	1,932,000	2,688,000	283,200
Total Protozoa	96,000	54,000	102,000	100,800	134,400	7,800

* Similar to that found round South Georgia in inshore waters.

Table XXXIX. *Analyses of samples collected on a line of stations to the east of Bransfield Strait, from Elephant and Clarence Islands towards Joinville Island, December* 1930. *The positions of the stations are charted in Fig.* 56.

Station	537	538	539	540	541
Lat. S	61° 07½′	61° 29′	61° 48′	62° 06¼′	62° 22′
Long. W	54° 26′	54° 44¼′	54° 51½′	55° 08½′	55° 23′
Date	19. xii. 30	19. xii. 30	19. xii. 30	19. xii. 30	19/20. xii. 30
Temp. ° C. (mean of 0–20 m.)	−0·02	−0·27	−0·31	−0·51	−0·85
Salinity ‰ (mean of 0–20 m.)	34·32	34·24	34·32	34·37	34·54
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	136	115	123	120	111
O_2 cc. per l. (mean of 0–20 m.)	—	7·63	—	7·10	—
*p*H (mean of 0–20 m.)	7·96	8·00	7·96	8·00	8·00
Volume of sample cc.	64	192	116	44	24
Fraction examined	1 : 9,600	1 : 40,800	1 : 19,200	1 : 10,200 (1 : 300)	1 : 12,000
Diatomales:					
Coscinodiscus spp.	9,600	81,600	38,400	—	—
Thalassiosira antarctica	96,000	—	172,800	20,400	2,088,000
Corethron valdiviae	5,424,000	20,930,400	13,651,200	3,967,800	588,000
Corethron valdiviae (auxosporenbildung)	115,200	775,200	249,200	71,400	—
Rhizosolenia alata	—	—	—	—	48,000
Rhizosolenia alata f. *gracillima*	19,200	244,800	134,400	10,200	—
R. truncata	—	—	—	—	36,000
Chaetoceros criophilum	—	122,400	—	20,400	48,000
Ch. dichaeta	—	—	—	—	48,000
Ch. flexuosus	—	—	—	—	156,000
Ch. neglectus	—	—	—	316,200	432,000
Ch. socialis	—	—	—	—	++
Ch. tortissimus	—	—	—	—	684,000
Biddulphia striata	—	—	38,400	10,200	420,000
Eucampia antarctica	—	—	—	71,400	396,000
Fragilaria antarctica	—	—	345,600	—	144,000
Synedra spathulata	—	—	—	—	12,000
Thalassiothrix antarctica	—	40,800	—	—	—
Navicula pellucida	—	—	—	—	12,000
Nitzschia seriata	—	—	—	20,400	96,000
Dinoflagellata: *Peridinium* sp.	—	—	—	—	12,000
Silicoflagellata	—	—	38,400	—	12,000
Protozoa:					
Radiolaria: *Protocystis swirei*	—	—	—	10,200	—
Others	—	—	—	20,400	—
Tintinnidae	19,200	—	—	30,600	—
Copepoda	—	—	—	600	—
Nauplii	—	—	—	10,200	—
Total Diatomales	5,664,000	22,195,200	14,630,400	4,508,400	5,208,000*
Total Protozoa	19,200	—	—	61,200	—

* Excluding uncountable colonies of *Chaetoceros socialis* which also rendered the count of *Ch. neglectus* doubtful. Note: large numbers of Euphausian faecal pellets in the sample, consisting of diatom remains, suggest that the feeding was good.

Table XL. *Analyses of samples collected on a line of stations from Cape Melville, King George Island, southwards across the eastern end of Bransfield Strait, December 1930. The positions of the stations are charted in Fig. 56.*

Station	542	543	544	545	546	547
Lat. S	62° 08′	62° 16′	62° 26¼′	62° 37′	62° 46¼′	62° 59¼′
Long. W.	57° 28½′	57° 20′	57° 15½′	57° 12¼′	57° 11¼′	57° 03′
Date	20. xii. 30	20. xii. 30	20. xii. 30	20. xii. 30	20. xii. 30	20. xii. 30
Temp. °C. (mean of 0–20 m.)	−0·16	0·24	−0·14	−0·10	−0·72	−1·01
Salinity ‰ (mean of 0–20 m.)	34·15	34·21	34·28	34·27	34·51	33·53
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	133	117	104	117	114	119
O_2 cc. per l. (mean of 0–20 m.)	—	7·63	—	7·73	—	6·90
*p*H (mean of 0–20 m.)	8·01	8·02	8·00	8·02	7·97	7·96
Volume of sample cc.	6	6	60	38	26	24
Fraction examined	1 : 200	1 : 300	1 : 8,100	1 : 4,800	1 : 9,600	1 : 9,000
Diatomales:						
Coscinodiscus bouvet	—	—	—	—	9,600	18,000
Thalassiosira antarctica	81,600	5,700	—	9,600	374,400	990,000
Corethron valdiviae	11,400	154,500	5,718,600	2,256,000	1,612,800	774,000
Rhizosolenia alata	—	—	—	—	249,600	63,000
Rhizosolenia alata f. *gracillima*	6,000	4,200	—	9,600	—	—
R. styliformis	—	—	16,200	—	19,200	9,000
R. truncata	4,200	—	—	—	134,400	162,000
Chaetoceros criophilum	—	—	—	19,200	—	9,000
Ch. dichaeta	—	—	—	—	96,000	63,000
Ch. flexuosus	—	—	—	—	—	90,000
Ch. neglectus	—	—	—	—	3,504,000*	++
Ch. socialis	—	—	—	—	++	++
Ch. tortissimus	—	—	—	—	1,056,000	2,133,000
Biddulphia striata	600	—	—	—	297,600	414,000
Eucampia antarctica	2,400	—	—	—	316,800	261,000
Fragilaria antarctica	28,800	—	—	—	806,400	675,000
Synedra spathulata	—	—	—	9,600	—	—
Thalassiothrix antarctica	—	900	—	—	9,600	—
Lycmophora sp.	1,800	300	—	—	—	—
Navicula sp.	600	—	—	—	—	—
Nitzschia seriata	—	—	—	—	19,200	162,000
Protozoa:						
Tintinnidae	30,000	8,700	48,600	9,600	—	—
Copepoda	3,000	300	—	—	—	—
Nauplii	2,000	600	—	—	—	—
Fish larvae	200	—	—	—	—	—
Total Diatomales	137,400	165,600	5,734,800	2,304,000	8,505,600†	5,814,000†

* Counting impaired by *Ch. socialis*. † Excluding uncountable colonies.

Table XLI. *Analyses of samples collected on a series of stations across the western end of Bransfield Strait, December* 1930. *The positions of the stations are charted in Fig.* 56.

Station	549	550	551	555	552	553
Lat. S	63° 00¾′	63° 08¾′	63° 17½′	63° 17¾′	63° 26¼′	63° 33¾′
Long. W	61° 16½′	61° 05¾′	60° 55¾′	61° 19¾′	60° 45′	60° 33½′
Date	21/22. xii. 30	22. xii. 30	22. xii. 30	28. xii. 30	22. xii. 30	22. xii. 30
Temp. °C. (mean of 0–20 m.)	0·18	0·31	0·82	0·88*	0·72	0·86
Salinity ‰ (mean of 0–20 m.)	34·10	34·04	34·12	34·02*	34·14	34·18
P_2O_5 mg./m.^{3} (mean of 0–20 m.)	107	103	100	—	107	109
O_2 cc. per l. (mean of 0–20 m.)	7·49	—	7·48	—	—	7·56
*p*H (mean of 0–20 m.)	8·01	8·02	8·02	—	8·02	8·02
Volume of sample cc.	7	4	5	48	3	3
Fraction examined	1 : 800	1 : 300	1 : 300	1 : 6,750	1 : 300	1 : 300
Diatomales:						
Coscinodiscus spp.	800	—	—	—	—	300
Thalassiosira antarctica	24,000	12,600	2,700	—	600	4,200
Corethron valdiviae	500,000	150,600	177,600	2,524,500	67,500	72,900
Rhizosolenia alata f. *gracillima*	4,800	2,100	—	20,250	3,300	3,000
R. styliformis	4,000	2,100	—	—	—	—
R. truncata	1,600	—	—	—	—	300
Chaetoceros neglectus	11,200	10,200	—	40,500	9,600	5,400
Biddulphia striata	2,400	300	—	—	—	900
Eucampia antarctica	3,200	—	—	—	—	—
Fragilaria antarctica	—	6,000	6,300	81,000	2,400	—
Thalassiothrix antarctica	1,600	300	—	—	—	—
Thalassiothrix sp.	—	—	—	—	—	1,200
Navicula sp.	1,600	300	—	—	—	300
Nitzschia seriata	—	1,800	—	—	—	600
Dinoflagellata:						
Peridinium sp.	800	—	—	—	—	—
Protozoa:						
Radiolaria	4,000	—	300	—	—	—
Tintinnidae	8,000	1,200	6,300	33,750	11,400	11,400
Copepoda	800	300	300	—	—	—
Nauplii	3,200	300	3,000	—	600	300
Appendicularia	—	—	—	300	—	—
Total Diatomales	564,800	186,300	186,600	2,666,250	83,400	89,100
Total Protozoa	12,000	1,200	6,600	33,750	11,400	11,400

* Surface samples only.

Table XLII. *Analyses of samples collected at a series of stations west of the Bransfield Strait, Jan.–Feb.* 1931. *The positions of the stations are charted in Fig.* 56.

Station	**610** Outside Strait NW of Snow Island	**609** Outside the Strait, to the NW of Snow Island	**608** Inside Snow Island	**607** Inside Snow Island	**606** Mouth of de Gerlache Strait	**605** 1·4 miles N 18° E of Waif Island, Palmer Archipelago
Lat. S	62° 17¼′	62° 08¾′	62° 52½′	62° 56½′	64° 13½′	—
Long. W	62° 28¼′	62° 57¼′	61° 32½′	61° 16′	61° 38′	—
Date	8. ii. 31	8. ii. 31	7. ii. 31	27. i. 31	26. i. 31	26. i. 31
Temp. °C. mean of 0–20 m. or surface	3·12*	1·91	1·20*	0·97*	2·05	1·50
Salinity °/₀₀ mean of 0–20 m. or surface	—	33·83	34·24*	34·17*	33·90	33·86*
Volume of sample cc. ...	15	14	3	2	20	105
Fraction examined	1 : 1,900	1 : 300	1 : 300	1 : 300	1 : 4,800	1 : 25,800
Diatomales:						
Coscinodiscus bouvet	—	—	—	—	28,800	—
Coscinodiscus spp.	—	300	900	2,100	—	77,400
Asteromphalus regularis	—	600	—	—	—	—
Thalassiosira antarctica	3,800	102,600	310,800	16,200	619,200	3,302,400
Corethron valdiviae	435,100	216,600	5,700	44,400	52,800	541,800
Rhizosolenia alata	—	—	14,400	—	38,400	77,400
Rhizosolenia alata f. *gracillima*	290,700	433,200	—	21,900	—	—
R. styliformis	—	34,200	600	—	—	—
R. truncata	—	—	—	—	43,200	309,600
Chaetoceros criophilum	22,800	45,600	—	900	—	25,800
Ch. dichaeta	19,000	92,200	—	—	—	—
Ch. neglectus	250,800	57,000	—	—	+	++
Ch. schimperianus	—	34,200	—	—	—	—
Ch. socialis	—	—	—	—	++	∞
Ch. tortissimus	—	—	—	—	+	++
Biddulphia striata	—	300	—	2,400	364,800	464,400
Eucampia antarctica	—	—	—	3,600	326,400	1,625,400
Fragilaria antarctica	—	4,800	5,400	36,600	470,400	4,334,400
Fragilaria antarctica f. *bouvet*	—	—	—	—	—	825,600
Lycmophora sp.	—	—	—	—	4,800	51,600
Nitzschia closterium	—	—	—	30,300	1,372,800	283,800
N. seriata	—	45,600	—	14,100	96,000	928,800
Silicoflagellata	—	11,400	—	—	4,800	—
Protozoa:						
Radiolaria: *Protocystis swirei*	—	11,400	—	—	—	—
Others	—	—	—	300	—	—
Tintinnidae	19,000	45,600	32,100	29,400	91,200	206,400
Copepoda	—	1,500	—	—	—	—
Nauplii	17,100	6,000	—	4,200	9,600	—
Total Diatomales	1,022,200	1,067,200	337,800	172,500	3,417,600†	12,848,400†
Total Protozoa	19,000	57,000	32,100	29,700	91,200	206,400

* Surface samples only. † Excluding uncountable small Chaetocerids.

Table XLIII. *Analyses of samples collected between 67° and 71° S : 72° and 88° W, in the Bellingshausen Sea, December 1929 and February 1930. The positions of the stations are charted in Fig. 71.*

Station	WS 495	WS 508	WS 506	WS 505
Lat. S	67° 47′	69° 04′	70° 31′	70° 10½′
Long. W	73° 51′	77° 40′	81° 36′	87° 46′
Date	22. xii. 29	10. ii. 30	7. ii. 30	4. ii. 30
Temp. °C. (mean of 0–20 m.)	−1·33	−0·10	−1·74	−1·45
Salinity ‰ (mean of 0–20 m.)	33·65	33·49	33·53	33·31
Volume of sample cc.	7	75	5	11
Fraction examined	1 : 2,100	1 : 12,000	1 : 2,400	1 : 1,200
Diatomales:				
Asteromphalus parvulus	—	12,000	2,400	—
Thalassiosira antarctica	27,300	24,000	43,200	7,200
Dactyliosolen laevis	—	—	—	8,400
Corethron valdiviae	130,200	13,260,000	60,000	363,600
Corethron valdiviae (spineless chains)	—	—	—	7,200
Rhizosolenia alata f. *gracillima*	84,000	180,000	—	12,000
R. polydactyla	—	—	—	8,400
R. styliformis	—	—	—	4,800
R. truncata	14,700	—	67,200	9,600
Chaetoceros atlanticus	—	—	—	6,000
Ch. criophilum	—	120,000	52,800	7,200
Ch. dichaeta	42,000	—	33,600	—
Ch. flexuosus	25,200	—	—	—
Ch. neglectus	84,000	—	55,200	—
Ch. schimperianus	—	—	4,800	—
Biddulphia striata	14,700	—	62,400	7,200
Eucampia antarctica	4,200	—	12,000	—
Fragilaria antarctica	50,400	—	19,200	—
Synedra spathulata	—	—	14,400	—
Thalassiothrix antarctica	—	—	—	6,000
Achnanthes sp.	8,400	—	—	—
Amphiprora sp.	6,300	—	—	—
Nitzschia closterium	254,100	—	55,200	—
N. seriata	14,700	—	156,000	75,600
Dinoflagellata:				
Peridinium antarcticum	—	—	—	1,200
Peridinium sp.	4,200	—	—	—
Silicoflagellata	—	12,000	14,400	1,200
Protozoa:				
Radiolaria	—	—	12,000	—
Tintinnidae	—	—	2,400	3,600
Copepoda	—	—	2,400	—
Nauplii	4,200	24,000	9,600	2,400
Total Diatomales	760,200	13,596,000	638,400	523,200
Total Protozoa	—	—	14,400	3,600

Table XLIV. *Analyses of samples collected at a series of stations from Adelaide Island to Anvers Island, outside the Biscoe Islands, Dec. 1929–Jan. 1930. The positions of the stations are charted in Fig. 71.*

Station	WS 496	WS 498	WS 499	WS 500	WS 501
Lat. S	67° 14′	66° 21′	65° 45′	65° 11¾′	64° 52′
Long. W	70° 12′	69° 01′	67° 18′	65° 49′	63° 58′
Date	30. xii. 29	2/3. i. 30	3. i. 30	3. i. 30	3. i. 30
Temp. °C. (mean of 0–20 m.)	0·04	0·98	0·74	1·13	0·85
Salinity ‰ (mean of 0–20 m.)	33·60	33·47	33·82	33·68	33·43
Volume of sample cc.	40	54	30	35	39
Fraction examined	1 : 4,800	1 : 9,600	1 : 2,400	1 : 4,800	1 : 19,200
Diatomales:					
Coscinodiscus bouvet	—	—	—	—	268,800
Coscinodiscus spp.	4,800	—	4,800	—	—
Thalassiosira antarctica	120,000	9,600	86,400	28,800	6,566,400
Corethron valdiviae	1,896,000	3,388,800	1,665,600	2,726,400	345,600
Rhizosolenia alata f. *gracillima*	43,200	1,516,800	14,400	57,600	249,600
R. styliformis	—	—	—	—	19,200
R. truncata	9,600	—	—	—	1,824,000
Chaetoceros criophilum	—	57,600	—	—	—
Ch. flexuosus	24,000	—	—	—	364,800
Ch. neglectus	—	38,400	—	—	27,648,000*
Ch. schimperianus	—	28,800	—	—	—
Ch. tortissimus	—	—	—	—	16,896,000*
Biddulphia striata	67,200	9,600	2,400	—	2,592,000
Eucampia antarctica	38,400	—	2,400	—	3,264,000
Fragilaria antarctica	28,800	—	67,200	—	460,800
Synedra spathulata	4,800	9,600	—	—	—
Achnanthes sp.	9,600	—	—	—	172,800
Nitzschia closterium	—	—	—	—	2,112,000
N. seriata	120,000	134,400	16,800	38,400	1,267,200
Protozoa:					
Foraminifera	—	9,600	2,400	—	—
Tintinnidae	129,600	9,600	74,400	67,200	38,400
Appendicularia	4,800	—	—	—	—
Total Diatomales	2,366,400	5,193,600	1,860,000	2,851,200	64,051,200
Total Protozoa	129,600	19,200	76,800	67,200	38,400

* Estimated from the number of chains.

Table XLV. *Analyses of samples collected between* 69° *and* 70° *S* : 90° *and* 100° *W, in the Bellingshausen Sea, Jan.–Feb.* 1930. *The positions of the stations are charted in Fig.* 71.

Station	**WS 502**	**WS 504**
Lat. S	69° 43′	69° 36′
Long. W	99° 38′	94° 14′
Date	30. i. 30	2. ii. 30
Temp. °C. } mean of	−0·36	−0·72
Salinity ‰ } 20 m.	33·38	33·24
Volume of sample cc.	17	69
Fraction examined	1 : 4,800	1 : 28,800
Diatomales:		
Asteromphalus hookerii	—	28,800
Coscinodiscus sp.	4,800	—
Thalassiosira antarctica	48,000	—
Dactyliosolen laevis	24,000	—
Leptocylindrus sp.	14,400	—
Corethron valdiviae	105,600	10,368,000
Corethron valdiviae (spineless chains)	14,400	—
Rhizosolenia alata f. *gracillima*	4,800	—
R. styliformis	19,200	28,800
R. truncata	9,600	259,200
Chaetoceros castracanei	—	86,400
Ch. criophilum	19,200	86,400
Ch. dichaeta	33,600	489,600
Ch. neglectus	++	12,268,800
Ch. schimperianus	—	57,600
Ch. socialis	++	—
Biddulphia striata	14,400	—
Eucampia antarctica	67,200	—
Fragilaria antarctica	153,600	230,400
Synedra spathulata	9,600	—
Thalassiothrix antarctica	115,400	172,800
Nitzschia closterium	964,800	5,328,000
N. seriata	1,358,400	2,419,200
Dinoflagellata:		
Peridinium antarcticum	4,800	—
Silicoflagellata	9,600	144,000
Protozoa:		
Tintinnidae	4,800	28,800
Polychaete larvae	—	28,800
Nauplii	4,800	28,800
Total Diatomales	2,980,800*	31,724,000

* Excluding uncountable small Chaetocerids.

Table XLVI. *Analyses of samples collected on a line of stations from Adelaide Island to 66° 17½′ S : 71° 57′ W, February 1930. The positions of the stations are charted in Fig. 71.*

Station ...	WS 509	WS 510	WS 511	WS 512	WS 513	WS 514	WS 515	WS 516	WS 517
Lat. S ...	67° 18′	67° 11′	67° 04′	66° 57′	66° 49½′	66° 40½′	66° 32½′	66° 25½′	66° 17½′
Long. W ...	69° 28′	69° 46′	70° 04′	70° 22′	70° 40½′	71° 01′	71° 20½′	71° 38½′	71° 57′
Date ...	11. ii. 30	11. ii. 30	11. ii. 30	11. ii. 30	11. ii. 30	11. ii. 30	11/12. ii. 30	12. ii. 30	12. ii. 30
Temp. °C. } mean of ...	0·72	0·93	0·74	0·92	0·90	0·80	1·55	1·70	1·92
Salinity ‰ } 0–20 m. ...	33·59	33·06	33·02	33·69	33·71	33·69	33·68	33·69	33·59
Volume of sample cc. ...	75	80	55	90	105	110	39	25	55
Fraction examined ...	1 : 12,000	1 : 9,600	1 : 6,000	1 : 9,600	9,600	1 : 24,000	1 : 7,200	1 : 19,200	1 : 16,800
Diatomales:									
Coscinodiscus stellaris	—	—	36,000	—	—	—	—	—	—
Thalassiosira antarctica	132,000	38,400	396,000	—	48,000	—	—	38,400	—
Dactyliosolen laevis	—	—	—	—	—	—	—	96,000	33,600
Corethron valdiviae	6,192,000	7,708,800	6,468,000	4,444,800	8,592,000	13,848,000	2,102,400	960,000	3,897,600
Rhizosolenia alata f. *gracillima*	4,800,000	1,536,000	912,000	3,984,000	4,876,800	1,608,000	2,671,200	8,524,800	3,662,400
R. polydactyla	—	—	—	—	—	24,000	—	19,200	—
R. styliformis	60,000	19,200	42,000	19,200	9,600	48,000	—	—	—
R. truncata	—	—	—	—	9,600	—	—	—	—
Chaetoceros castracanei	—	—	—	—	—	—	—	—	50,400
Ch. criophilum	120,000	134,400	150,000	76,800	489,600	552,000	100,800	153,600	100,800
Ch. dichaeta	—	—	—	—	—	—	57,600	134,400	134,400
Ch. neglectus	—	—	156,000	—	—	—	—	—	—
Ch. tortissimus	—	—	180,000	—	—	—	—	—	—
Biddulphia striata	60,000	9,600	30,000	—	—	—	—	—	—
Eucampia antarctica	24,000	—	258,000	—	—	—	—	—	—
Fragilaria antarctica	288,000	537,600	192,000	—	—	—	—	—	—
Synedra spathulata	—	—	—	—	—	—	—	115,200	67,200
Thalassiothrix antarctica	—	—	—	—	—	—	7,200	19,200	16,800
Nitzschia seriata	792,000	364,800	906,000	57,600	182,400	—	—	172,800	—
Dinoflagellata:									
Peridinium antarcticum	—	—	6,000	—	—	—	—	—	—
Peridinium spp.	—	—	—	—	9,600	—	—	—	—
Silicoflagellata	—	—	—	9,600	9,600	—	—	—	84,000
Protozoa:									
Radiolaria	—	—	6,000	—	—	—	—	—	16,800
Foraminifera	—	9,600	—	—	—	—	—	—	—
Tintinnidae	—	48,000	84,000	19,200	67,200	—	86,400	—	50,400
Copepoda	—	—	—	—	9,600	—	—	—	—
Nauplii	—	28,800	12,000	—	28,800	—	7,200	—	—
Total Diatomales	12,468,000	10,348,800	9,726,000	8,582,400	14,208,000	16,080,000	4,939,200	10,233,600	7,963,200
Total Protozoa	—	57,600	90,000	19,200	67,200	—	86,400	—	57,200

Table XLVII. *Analyses of samples collected on a line of stations from Adelaide Island north-westwards to 64° 17′ S: 75° 35′ W, January 1931. The positions of the stations are charted in Fig. 74.*

Station	584	583	585	586	587	588	589	590	591	592
Lat S.	67° 26¾′	67° 18¼′	67° 08½′	66° 49′	66° 28½′	66° 11½′	65° 54′	65° 20½′	64° 51½′	64° 17′
Long. W	69° 35½′	69° 53′	70° 15½′	70° 50′	71° 16¼′	71° 50¼′	72° 24¼′	73° 30½′	74° 22½′	75° 35′
Date	13. i. 31	12. i. 31	13. i. 31	13. i. 31	13. i. 31	13. i. 31	13/14. i. 31	14. i. 31	14. i. 31	15. i. 31
Temp. °C. (mean of 0–20 m.)	−0·73	−0·19*	−1·08	−1·47	−0·32	0·98	0·92	1·23	1·49*	1·60*
Salinity ‰ (mean of 0–20 m.)	33·18	33·10*	33·33	33·14	32·92	33·76	33·57	33·77	33·73*	33·89*
P_2O_5 mg./m.³ (mean of 0–20 m.)	83	—	97	99	87	96	103	105	—	—
O_2 cc. per l. (mean of 0–20 m.)	8·10	—	7·88	7·89	7·99	7·60	7·62	7·56	—	—
*p*H (mean of 0–20 m.)	8·14	—	8·11	8·07	8·05	7·99	8·03	8·03	—	—
Volume of sample cc.	10	8	4	2	2	16	29	32	13	36
Fraction examined	1 : 4,500	1 : 300	1 : 300	1 : 300	1 300	1 : 1,350	1 : 5,400	1 : 8,100	1 : 2,000	1 : 8,100
Diatomales:										
Asteromphalus hookerii	—	—	—	—	—	—	—	—	—	24,300
A. parvulus	—	—	—	—	—	—	—	24,300	6,000	24,300
Thalassiosira antarctica	22,500	14,400	3,900	3,300	2,100	—	—	16,200	42,000	145,800
Dactyliosolen laevis	—	—	300	—	—	—	—	—	—	—
Corethron valdiviae	108,000	206,400	50,100	20,700	15,900	319,950	1,625,400	2,308,500	102,000	332,100
Rhizosolenia alata	67,500	16,800	5,700	600	1,200	—	—	—	—	64,800
Rhizosolenia alata f. *gracillima*	—	—	—	—	—	203,850	264,600	234,900	90,000	—
R. chunnii	—	—	—	—	—	—	—	—	—	48,600
R. styliformis	—	—	—	—	—	—	5,400	8,100	6,000	24,300
R. truncata	27,000	—	—	2,400	2,400	6,750	—	—	—	—
Chaetoceros atlanticus	—	—	—	—	1,800	—	—	—	—	24,300
Ch. criophilum	—	4,800	3,300	—	—	4,050	16,200	32,400	18,000	16,200
Ch. dichaeta	—	—	—	3,000	—	—	32,400	—	30,000	226,800
Ch. flexuosus	—	—	—	—	—	—	48,600	—	—	—
Ch. neglectus	13,355,000	76,800	8,700	—	—	89,100	199,800	769,500	84,000	234,900
Ch. schimperianus	—	—	—	—	—	4,050	—	—	—	56,700
Ch. tortissimus	2,520,000	—	5,400	—	—	—	205,200	—	—	—
Biddulphia striata	—	—	1,200	—	—	—	—	—	—	16,200
Eucampia antarctica	13,500	—	—	—	—	—	—	—	—	121,500
Fragilaria antarctica	—	38,400	26,400	1,800	—	—	—	—	48,000	518,400
Synedra spathulata	—	—	—	—	—	—	—	—	48,000	—
Thalassiothrix antarctica	—	9,600	—	—	1,200	—	—	—	—	121,500
Navicula pellucida	4,500	—	—	—	—	—	—	—	—	16,200
Amphora sp.	4,500	—	—	—	—	—	—	—	—	—
Nitzschia seriata	31,500	—	—	—	—	—	—	—	348,000	3,709,800
Dinoflagellata:										
Peridinium antarcticum	—	2,400	—	—	300	1,350	—	—	—	16,200
Peridinium sp.	—	—	—	—	—	—	—	—	—	16,200
Silicoflagellata	—	—	—	—	—	—	—	—	6,000	16,200
Protozoa:										
Tintinnidae	—	—	300	—	900	1,350	—	32,400	12,000	72,900
Metazoa	—	4,800	1,200	900	600	1,350	10,800	8,400	30,000	49,800
Total Diatomales	17,154,000	367,200	105,000	31,800	26,000	627,750	2,397,600	3,393,900	822,000	5,726,700
Total Dinoflagellata	—	2,400	—	—	300	1,350	—	—	—	32,400

* Surface samples only.

Table XLVIII. *Analyses of samples collected on a line of stations south-eastwards from the outer end of the preceding line, towards the northernmost of the Biscoe Islands, January 1931. The positions of the stations are charted in Fig. 74.*

Station	593	594	595	596
Lat. S	64° 42′	64° 56¼′	65° 14¾′	65° 31′
Long. W.	73° 33½′	72° 11′	70° 26½′	68° 55½′
Date	15. i. 31	15. i. 31	16. i. 31	16. i. 31
Temp. °C.	1·22*	1·49*	1·30*	1·51*
Salinity °/₀₀	33·82*	33·78*	33·80*	33·73*
Volume of sample cc.	42	37	24	148
Fraction examined	1 : 6,600	1 : 8,100	1 : 5,100	1 : 19,200
Diatomales:				
Coscinodiscus sp.	13,200	24,300	—	—
Asteromphalus challengerensis	6,600	—	—	—
A. hookerii	—	8,100	—	—
A. regularis	6,600	—	—	—
Thalassiosira antarctica	—	—	20,400	—
Dactyliosolen laevis	6,600	—	—	—
Leptocylindrus sp.	33,000	24,300	—	—
Corethron valdiviae	138,600	267,300	1,887,000	13,344,000
Rhizosolenia alata f. *gracillima*	290,400	413,100	316,200	2,899,200
R. chunnii	6,600	—	—	—
R. styliformis	59,400	48,600	30,600	134,400
Chaetoceros atlanticus	435,600	121,500	—	—
Ch. criophilum	118,800	121,500	20,400	249,600
Ch. curvatus	—	—	20,400	—
Ch. dichaeta	52,800	315,900	—	403,200
Ch. neglectus	693,000	639,900	1,244,400	—
Ch. schimperianus	59,400	81,000	—	249,600
Biddulphia striata	13,200	—	—	—
Eucampia antarctica	72,600	—	30,600	—
Fragilaria antarctica	158,400	97,200	367,200	—
Synedra spathulata	72,600	186,300	40,800	—
Thalassiothrix antarctica	92,400	—	—	19,200
Navicula pellucida	—	8,100	—	—
Nitzschia seriata	5,379,000	3,377,700	1,907,400	—
Silicoflagellata	19,800	8,100	20,400	—
Protozoa:				
Radiolaria: *Protocystis ?swirei*	—	8,100	—	—
Foraminifera	6,600	8,100	—	—
Tintinnidae	39,600	137,700	51,000	—
Copepoda	—	16,200	—	—
Nauplii	33,000	145,800	30,600	19,200
Appendicularia: *Fritillaria* sp.	300	600	—	—
Total Diatomales	7,708,800	5,734,800	5,885,400	17,299,200
Total Protozoa	33,300	162,600	51,000	—

* Surface samples only.

Table XLIX. *Analyses of samples collected between Anvers Island and 70° W, excluding stations on the two lines dealt with in the preceding tables, Dec. 1930–Jan. 1931. The positions of the stations are charted in Fig. 74.*

Station ...	556	604	557	603	558	602	597	559	601	560	598	599
Lat. S ...	64° 16½′	Mouth of	64° 26¾′	65° 04½′	65° 31′	66° 03½′	65° 51¼′	66° 21¾′	66° 41′	66° 47¼′	66° 59½′	67° 08′
Long. W ...	63° 58½′	Schoellaert	65° 40′	67° 51½′	67° 07¾′	66° 25′	69° 58½′	68° 55½′	66° 56′	69° 19′	69° 41′	69° 06½′
Date ...	28. xii. 30	Channel	29. xii. 30	20. i. 31	29. xii. 30	19. i. 31	16. i. 31	30. xii. 30	18. i. 31	30. xii. 30	16. i. 31	17. i. 31
Temp. °C. } mean of 0–20 m.	1·42*	0·18*	−1·20	1·08*	−1·07	−0·02*	1·85*	—	−0·68*	−1·00	0·22*	−0·79
Salinity ‰ } or surface	33·84*	33·27*	32·61	33·19	33·02	32·97*	33·74*	—	32·96*	33·25	33·09*	33·20
Volume of sample cc.	48	14	6	100	132	39	220	50	17	2	21	26
Fraction examined ...	1 : 8,700	1 : 5,400	1 : 8,100	1 : 18,000	1 : 15,000	1 : 3,900	1 : 15,000	1 : 7,200	1 : 7,200	1 : 300	1 : 8,400	1 : 8,100
Diatomales:												
Melosira sol	—	—	—	—	—	—	—	—	—	300	—	—
Coscinodiscus bouvet	—	—	—	—	—	—	—	—	—	—	8,400	—
Coscinodiscus spp.	—	10,800	24,300	—	15,000	3,900	—	7,200	21,600	—	—	24,300
Actinocyclus sp.	—	10,800	—	—	—	—	—	—	—	—	—	—
Thalassiosira antarctica	—	432,000	170,100	72,000	240,000	39,000	—	28,800	511,200	11,700	92,400	81,000
Corethron valdiviae	2,966,700	324,000	72,900	8,532,000	6,675,000	3,861,000	14,400,000	3,938,400	1,202,400	58,200	1,436,400	1,077,300
Rhizosolenia alata f. *gracillima*	43,500	43,200	24,300	990,000	30,000	46,800	1,425,000	424,800	—	1,800	109,200	542,700
R. styliformis	—	—	—	54,000	—	—	15,000	14,400	—	—	8,400	—
R. truncata	—	194,400	40,500	—	45,000	—	—	—	151,200	4,200	16,800	16,200
Chaetoceros atlanticus	—	—	24,300	—	—	—	—	—	—	—	—	—
Ch. criophilum	8,700	—	8,100	36,000	—	11,700	90,000	7,200	—	2,100	—	24,300
Ch. dichaeta	—	10,800	—	—	—	—	—	21,600	—	—	—	81,000
Ch. flexuosus	—	—	56,700	—	—	—	—	57,600	—	—	—	32,400
Ch. neglectus	234,900	3,898,800	372,600	—	120,000	27,300	585,000	244,800	1,008,000	2,700	1,915,200	1,085,400
Ch. tortissimus	—	—	—	—	—	—	—	—	57,600	—	2,024,400	2,940,300
Biddulphia polymorpha	—	—	—	—	—	11,700	—	—	7,200	—	—	—
B. striata	—	21,600	32,400	18,000	—	—	—	14,400	50,400	1,500	25,200	72,900
Eucampia antarctica	—	43,200	16,200	—	75,000	—	—	—	36,000	600	—	113,400
Fragilaria antarctica	—	1,479,600	477,900	576,000	570,000	62,400	—	374,400	316,800	52,500	260,400	129,600
Synedra spathulata	—	21,600	24,300	—	—	—	—	—	7,200	—	—	16,200
Thalassiothrix antarctica	—	—	16,200	—	30,000	—	—	—	—	300	—	—
Lycmophora sp.	—	54,000	—	—	—	—	—	—	7,200	—	—	—
Navicula ?grunowi	—	—	—	—	—	—	—	—	14,400	—	—	—
Nitzschia closterium	—	86,400	—	—	—	—	—	—	—	—	—	—
N. seriata	—	216,000	89,100	—	—	42,900	30,000	—	100,800	—	—	81,000
Nitzschia sp. "A."	—	—	145,800	—	—	—	—	—	165,600	—	—	—
Dinoflagellata:												
Dinophysis sp.	—	—	—	—	—	—	15,000	—	—	—	—	—
Peridinium antarcticum	—	—	—	—	—	—	—	—	—	300	—	—
Peridinium sp.	—	—	—	—	—	—	—	—	7,200	—	—	—
Silicoflagellata	—	—	—	—	—	—	15,000	—	—	—	—	—
Protozoa: Tintinnidae	43,500	270,000	16,200	36,000	—	46,800	60,000	—	14,400	600	25,200	8,100
Copepoda	—	—	600	—	—	—	—	900	—	—	—	—
Nauplii	—	10,800	300	—	1,500	—	15,000	1,500	43,200	3,300	8,400	—
Total Diatomales	3,253,800	6,847,200	1,628,100	10,278,000	7,800,000	4,106,700	16,545,000	5,133,600	3,657,600	135,900	5,896,800	6,318,000

* Surface samples only.

Table L. *Analyses of samples collected between 66° and 68° S : 70° and 80° W, in the Bellingshausen Sea, Dec. 1930–Jan. 1931. The positions of the stations are charted in Fig. 74.*

Station ...	561	582	562	581	580	579
Lat. S ...	66° 47¼′	66° 58¼′	67° 15½′	67° 46′	67° 41½′	66° 41¾′
Long. W...	72° 09¼′	72° 24′	75° 27′	74° 50′	75° 56½′	79° 10′
Date ...	31. xii. 30	12. i. 31	31. xii. 30	11. i. 31	10. i. 31	10. i. 31
Temp. °C. surface	−1·35	−0·15	−0·62	−1·32	−0·10	−0·25
Salinity °/₀₀ surface	33·57	33·37	33·26	33·08	33·24	33·12
Volume of sample cc. ...	12	6	6	26	16	14
Fraction examined ...	1 : 7,500	1 : 300	1 : 1,200	1 : 4,500	1 : 5,100	1 : 4,800
Diatomales:						
Coscinodiscus spp.	—	—	—	4,500	—	—
Thalassiosira antarctica	52,500	4,200	4,800	40,500	20,400	163,200
Dactyliosolen laevis	7,500	1,500	—	—	—	—
Leptocylindrus sp.	—	—	—	—	10,200	—
Corethron valdiviae	810,000	200,100	194,400	1,296,000	479,400	316,800
Rhizosolenia alata	75,000	10,200	10,800	—	—	—
Rhizosolenia alata f. *gracillima*	—	—	—	31,500	96,900	28,800
R. styliformis	—	—	—	13,500	—	—
R. truncata	60,000	7,800	7,200	18,000	5,100	19,200
Chaetoceros criophilum	7,500	3,300	—	—	—	33,600
Ch. dichaeta	90,000	2,400	3,600	22,500	10,200	43,200
Ch. neglectus	315,000	149,400	140,400	405,000	617,100	422,400
Ch. schimperianus	—	—	1,200	—	—	14,400
Ch. tortissimus	—	—	48,000	—	—	—
Biddulphia striata	15,000	2,400	—	—	—	—
Eucampia antarctica	15,000	1,200	1,200	—	10,200	24,000
Fragilaria antarctica	120,000	16,500	28,800	18,000	61,200	—
Fragilaria antarctica f. *bouvet*	—	6,000	—	36,000	—	153,600
Synedra spathulata	—	300	—	13,500	—	—
Thalassiothrix antarctica	—	900	—	—	—	—
Lycmophora sp.	—	—	—	—	5,100	—
Navicula sp.	—	—	—	9,000	—	—
Nitzschia closterium	—	—	—	4,500	—	—
N. seriata	67,500	6,900	—	31,500	107,100	264,000
Dinoflagellata: *Peridinium* sp.	—	—	—	4,500	—	—
Silicoflagellata	—	—	—	—	—	4,800
Protozoa:						
Radiolaria	7,500	2,400	—	—	5,100	—
Foraminifera	—	300	—	—	—	—
Tintinnidae	—	—	—	—	—	4,800
Copepoda	—	600	—	—	5,100	2,400
Nauplii	1,200	3,000	1,200	—	10,200	4,800
Total Diatomales	1,635,000	413,100	440,400	1,944,000	1,422,900	1,483,200
Total Protozoa	7,500	2,700	—	—	5,100	4,800

Table LI. *Analyses of samples collected between* 66° *and* 68° 15′ *S* : 80° *and* 90° *W in the Bellingshausen Sea, January* 1931. *The positions of the stations are charted in Fig.* 74.

Station	564	578	565	566	577	567	576
Lat. S	67° 10½′	67° 54′	67° 20′	66° 23′	68° 06½′	66° 45′	67° 50′
Long. W	80° 53′	81° 26¾′	82° 10′	85° 28½′	85° 10′	89° 24′	89° 12¾′
Date	1. i. 31	9. i. 31	2. i. 31	2. i. 31	9. i. 31	3. i. 31	8. i. 31
Temp. °C. surface	−0·82	−1·20	0·20	0·95	−0·20	0·40	−1·15
Salinity ‰ surface	33·29	33·21	33·91	33·90	33·30	33·91	33·35
Volume of sample cc.	24	18	8	28	32	40	18
Fraction examined	1 : 4,800	1 : 4,800	1 : 300	1 : 7,000	1 : 5,100	1 : 9,000	1 : 4,800
Diatomales:							
Coscinodiscus sp.	—	—	1,500	—	5,100	18,000	—
Asteromphalus hookerii	—	—	—	—	10,200	18,000	—
A. parvulus	—	—	—	—	5,100	—	9,600
Actinocyclus bifrons	—	—	—	—	—	18,000	—
Thalassiosira antarctica	48,000	76,800	7,500	266,000	183,600	216,000	216,000
Dactyliosolen laevis	—	4,800	—	—	—	—	—
Leptocylindrus sp.	—	9,600	—	—	—	72,000	9,600
Corethron valdiviae	1,276,800	220,800	22,500	70,000	61,200	—	427,200
Corethron valdiviae (spineless chains)	—	—	3,000	—	—	54,000	38,400
Rhizosolenia alata	—	24,000	—	—	35,700	—	28,800
Rhizosolenia alata f. *gracillima*	182,400	—	13,500	42,000	—	36,000	—
R. chunnii	—	—	13,500	14,000	15,300	72,000	—
R. simplex	—	—	—	—	—	36,000	—
R. styliformis	—	9,600	—	14,000	10,200	—	—
R. truncata	—	48,000	—	49,000	56,100	216,000	4,800
Chaetoceros atlanticus	—	48,000	—	154,000	61,200	—	105,600
Ch. criophilum	38,400	—	10,500	49,000	35,700	36,000	24,000
Ch. dichaeta	—	86,400	4,500	532,000	346,800	198,000	153,600
Ch. neglectus	537,600	2,798,400	—	1,890,000	1,458,600	—	2,270,400
Ch. schimperianus	—	4,800	6,000	105,000	20,400	—	—
Biddulphia striata	19,200	19,200	—	—	25,500	—	28,800
Eucampia antarctica	—	9,600	—	49,000	66,300	—	—
Fragilaria antarctica	460,800	115,200	36,000	896,000	204,000	684,000	—
Fragilaria antarctica f. *bouvet*	370,200	230,400	—	2,898,000	897,600	6,678,000	76,800
Synedra spathulata	—	52,800	—	—	66,300	—	—
Thalassiothrix antarctica	86,400	—	19,500	700,000	147,900	810,000	62,400
Navicula pellucida	—	—	—	—	—	36,000	—
Navicula sp.	9,600	—	—	14,000	—	18,000	—
Nitzschia seriata	86,400	240,000	49,500	5,803,000	1,637,100	8,946,000	264,000
Dinoflagellata:							
Dinophysis rotundata	—	4,800	—	—	—	—	4,800
Dinophysis sp.	—	—	3,000	—	—	—	—
Peridinium sp.	—	—	—	35,000	—	—	—
Ceratium pentagonum f. *grandis*	—	—	—	—	—	18,000	—
Silicoflagellata	—	—	—	14,000	10,200	54,000	—
Protozoa: Tintinnidae	—	4,800	—	—	10,200	—	9,600
Copepoda	—	—	6,000	7,000	—	—	2,400
Nauplii	4,800	—	7,500	21,000	5,100	—	9,600
Total Diatomales	3,052,800	3,998,400	187,500	13,545,000	5,349,900	18,162,000	3,720,000

Table LII. *Analyses of samples collected between* 67° 45′ *and* 69° 15′ *S* : 90° *and* 102° *W, in the Bellingshausen Sea, January* 1931. *The positions of the stations are charted in Fig.* 74.

Station	575	568	574	569	573	570	571	572
Lat. S	67° 53¼′	67° 48½′	67° 43′	68° 40½′	68° 05¾′	69° 07½′	69° 12½′	69° 16′
Long. W	91° 23′	92° 42¼′	94° 18¼′	96° 21′	98° 13½′	99° 49¾′	100° 39¼′	101° 07¾′
Date	8. i. 31	3. i. 31	7. i. 31	4. i. 31	7. i. 31	4. i. 31	5. i. 31	6. i. 31
Temp. °C. surface	−1·47	0·25	−0·68	−1·50	0·02	−0·68	−1·20	−1·10
Salinity ‰ surface	33·37	33·68	33·71	32·94	33·48	33·10	32·95	32·94
Volume of sample cc.	43	63	24	27	138	27	93	55
Fraction examined	1 : 5,100	1 : 7,200	1 : 4,500	1 : 5,100	1 : 9,000	1 : 4,000	1 : 9,000	1 : 10,200
Diatomales:								
Coscinodiscus spp.	10,200	—	—	—	—	—	—	—
Asteromphalus hookerii	—	14,400	—	—	18,000	—	—	—
A. parvulus	—	14,400	—	—	18,000	—	—	—
Thalassiosira antarctica	775,200	93,600	18,000	214,200	72,000	324,000	126,000	326,400
Dactyliosolen antarcticus	—	7,200	—	—	—	—	—	—
D. laevis	—	—	18,000	10,200	54,000	—	18,000	40,800
Leptocylindrus sp.	—	—	4,500	—	—	—	—	—
Corethron valdiviae	311,100	136,800	27,000	61,200	54,000	24,000	36,000	40,800
Corethron valdiviae (spineless chains)	—	—	9,000	—	72,000	96,000	—	81,600
Rhizosolenia alata f. *gracillima*	10,200	129,600	22,500	—	18,000	—	36,000	40,800
R. chunnii	—	172,800	—	—	—	—	36,000	—
R. styliformis	5,100	144,000	13,500	—	36,000	24,000	18,000	—
R. truncata	61,200	14,400	13,500	295,800	36,000	72,000	90,000	183,600
Chaetoceros atlanticus	25,500	280,800	58,500	193,800	54,000	—	324,000	326,400
Ch. castracanei	—	57,600	—	71,400	—	—	—	61,200
Ch. criophilum	15,300	86,400	63,000	81,600	36,000	84,000	54,000	20,400
Ch. curvatus	—	57,600	9,000	—	—	—	72,000	—
Ch. dichaeta	612,000	1,692,000	85,500	285,600	90,000	360,000	432,000	489,600
Ch. neglectus	∞	1,260,000	175,500	377,400	—	240,000	360,000	408,000
Ch. schimperianus	30,600	936,000	18,000	—	—	—	—	—
Ch. tortissimus	+	—	—	—	—	—	—	—
Biddulphia striata	15,300	—	—	—	—	—	—	—
Eucampia antarctica	40,800	122,400	—	—	—	36,000	144,000	122,400
Fragilaria antarctica	285,600	1,555,200	36,000	1,142,400	342,000	408,000	792,000	1,795,200
Fragilaria antarctica f. *bouvet*	132,600	—	144,000	3,549,600	864,000	2,136,000	1,008,000	3,508,800
Thalassiothrix antarctica	188,700	3,751,200	1,489,500	1,672,800	10,098,000	2,244,000	7,056,000	5,344,800
Navicula pellucida	—	—	—	—	—	—	—	20,400
Navicula sp.	—	36,000	—	—	—	—	18,000	—
Nitzschia seriata	1,157,700	3,520,800	652,500	3,233,400	1,854,000	2,208,000	2,250,000	4,916,400
Dinoflagellata:								
Dinophysis ovatum	—	—	—	—	—	—	—	20,400
D. rotundata	—	—	4,500	—	36,000	—	—	61,200
Dinophysis sp.	—	—	—	10,200	—	—	—	—
Peridinium spp.	—	—	—	—	38,400	—	54,000	102,000
Silicoflagellata	25,500	122,400	9,000	40,800	54,000	—	72,000	81,800
Protozoa:								
Radiolaria	—	—	—	—	1,200	—	—	20,400
Foraminifera	—	—	—	10,200	1,200	—	36,000	—
Tintinnidae	—	—	4,500	20,400	90,000	—	18,000	40,800
Metazoa	—	28,800	33,900	20,400	13,200	24,000	3,600	20,400
Total Diatomales	3,677,100*	14,083,200	2,857,500	11,189,400	13,716,000	8,256,000	12,870,000	17,727,600
Total Dinoflagellata	—	—	4,500	10,200	74,400	—	54,000	183,600
Total Protozoa	—	—	4,500	30,600	92,400	—	54,000	61,200

* Excluding uncountable small Chaetocerids.

Table LIII. *Analyses of Phytoplankton catches at the routine stations in East Cumberland Bay.*

Station No.	Neritic Forms						Immigrants							
	Fragilaria sp.		*Coscinodiscus stellaris*		*Lycmophora lyngbyei*		*Corethron valdiviae*		*Rhizosolenia styliformis*		*Chaetoceros criophilum*		*Thalassiosira antarctica*	
	25–0 m.	50–0 m.	25–0 m.	50–0 m.	25–0 m.	50–0 m.	25–0 m.	50–0 m.	25–0 m.	50–0 m.	25–0 m.	50–0 m.	25–0 m.	50–0 m.
MS 84	179,200	—	2,800	—	2,000	—	2,800	—	200	—	—	—	—	—
MS 85	165,600	—	—	—	3,600	—	141,400	—	7,200	—	75,600	—	—	—
MS 86	248,000	245,200	24,000	7,200	—	7,200	136,000	129,600	6,000	—	552,000	546,800	—	28,800
MS 87	50,400	—	900	—	900	—	300	—	300	—	1,800	—	—	—
MS 88	2,700	3,000	—	300	—	—	—	—	—	—	600	—	—	—
MS 89	363,900	381,500	1,200	2,700	—	900	—	—	—	—	900	—	—	—
MS 90	343,200	340,700	1,800	1,500	—	600	—	—	—	—	—	—	—	—
MS 91	77,700	—	15,000	—	—	—	—	—	—	—	—	—	—	—
MS 92	21,800	25,400	8,400	14,000	—	—	—	200	—	—	1,000	—	—	—
MS 95	70,400	72,300	693,760	645,500	640	900	—	—	—	—	—	—	—	—
MS 97	19,400	43,200	10,800	29,400	—	—	800	1,200	—	—	4,000	4,400	—	—
MS 98	8,000	6,600	6,400	7,400	—	—	—	—	—	—	—	—	—	—
MS 99	21,400	22,000	3,800	4,800	—	—	—	—	—	—	—	—	—	—
MS 100	18,800	18,600	3,200	5,400	200	200	200	600	—	—	—	—	—	—
MS 101	12,300	14,400	2,640	4,200	—	—	—	1,000	—	200	—	—	—	1,200
MS 102	6,720	26,880	3,570	3,570	—	210	210	420	—	—	—	—	—	—
MS 103	5,200	4,800	6,600	7,600	—	—	800	800	—	—	—	400	—	—
MS 104	13,440	10,800	7,980	12,180	—	—	840	1,050	—	—	—	—	—	—
MS 105	—	—	21,200	21,200	1,200	—	—	—	—	—	—	—	—	—
MS 106	26,000	29,600	10,900	11,800	—	—	300	—	—	—	—	—	—	—

Station No.	Stragglers								Total diatoms	
	Biddulphia striata		*Biddulphia polymorpha*		*Asteromphalus parvulus*		*Actinocyclus corona*			
	25–0 m.	50–0 m.	25–0 m.	50–0 m.	25–0 m.	50–0 m.	25–0 m.	50–0 m.	25–0 m.	50–0 m.
MS 84	—	—	—	—	—	—	—	—	187,000	—
MS 85	—	—	—	—	300	—	—	—	393,700	—
MS 86	—	—	—	—	—	—	—	—	965,000	964,800
MS 87	—	—	300	—	—	—	—	—	54,900	—
MS 88	—	—	—	—	—	—	—	—	3,300	3,300
MS 89	900	—	—	—	—	—	—	—	366,900	385,100
MS 90	—	—	—	—	—	—	—	—	345,000	342,800
MS 91	—	—	—	—	—	—	—	—	94,000	—
MS 92	—	—	—	—	—	—	—	—	31,200	39,600
MS 95	—	—	—	—	—	—	—	—	764,700	738,700
MS 97	—	—	—	—	—	—	—	—	35,000	78,200
MS 98	—	—	—	—	—	—	—	—	14,400	14,000
MS 99	—	—	—	200	—	—	—	—	25,200	27,000
MS 100	—	—	—	—	—	—	—	—	22,400	24,800
MS 101	—	—	—	—	—	—	—	—	15,000	21,000
MS 102	—	—	—	—	—	—	—	—	10,500	31,080
MS 103	—	—	—	—	—	—	—	—	12,600	13,600
MS 104	—	—	—	—	—	—	—	210	22,260	23,520
MS 105	—	—	—	—	—	—	—	—	22,400	23,600
MS 106	—	—	—	—	—	—	—	—	37,200	41,400

Table LIV. *Main features of hydrological, meteorological, and plankton observations at the routine stations in East Cumberland Bay.*

Station No.	Mean temp. °C.		Mean salinity ‰		Mean O_2 cc./litre		Mean P_2O_5 mg./m.³		Precipitation in mm. for interval between stations	Sunshine in hrs. for interval between stations	N (+) and S (−) wind components on day of station	N 50 V 25–0 m.					
	20–0 m.	75–0 m.	20–0 m.	75–0 m.	20–0 m.	75–0 m.	20–0 m.	75–0 m.				Total diatoms	*Fragilaria* sp.	*Coscinodiscus stellaris*	Copepoda	Nauplii	Protozoa: Tintinnidae
MS 84	+0·38	−0·43	32·93	33·22	—	—	94	99	26·3	33	−1·1	187,000	179,200	2,800	5,600	16,800	605,600
MS 85	+0·48	−0·29	33·24	33·31	8·14	7·99	88	96	0·6	50	+2·0	393,700	165,600	—	7,200	18,000	201,600
MS 86	+0·50	−0·23	33·36	33·52	7·86	7·66	89	102	3·3	34	+6·5	965,000	245,000	24,000	27,000	294,000	118,000
MS 87	+0·41	+0·24	33·40	33·57	7·80	7·69	85	88	46·8	29	+9·0	54,900	50,400	900	6,600	12,000	1,200
MS 88	+0·74	+0·11	33·13	33·50	7·89	7·83	84	90	13·2	78	—	3,300	2,700	—	3,300	21,900	—
MS 89	+0·92	+0·26	33·04	33·65	7·74	7·49	77	80	1·9	70	—	366,900	363,900	1,200	2,700	8,400	300
MS 90	+0·86	+0·52	33·06	33·38	—	—	74	80	3·6	5	−15·7	345,000	343,200	1,800	—	2,400	—
MS 91	+0·96	+0·64	33·31	33·55	7·62	7·56	71	75	17·9	47	+18·7	94,000	77,700	15,000	5,400	7,200	300
MS 92	+1·30	+0·67	33·49	33·71	7·46	7·38	78	85	26·2	25	+5·4	31,200	21,800	8,400	1,800	400	—
MS 95	+1·07	+0·74	33·66	33·84	7·51	7·33	86	90	4·0	18	+14·2	764,700	70,400	693,760	8,960	14,720	640
MS 97	+1·76	+1·29	33·24	33·71	7·67	7·26	67	85	11·5	11	+7·6	35,000	19,400	10,800	1,000	1,000	200
MS 98	+1·79	+1·19	33·51	33·76	7·56	7·44	86	90	19·7	26	+11·7	14,400	8,000	6,400	1,000	1,200	1,400
MS 99	+2·20	+1·66	33·31	33·56	7·50	7·34	88	93	27·3	16	+6·8	25,200	21,400	3,800	200	200	200
MS 100	+2·15	+1·57	33·09	33·53	7·44	7·39	78	87	13·7	40	−13·6	22,400	18,800	3,200	—	200	2,000
MS 101	+1·74	+1·71	33·60	33·81	7·50	7·43	83	91	17·5	30	—	15,000	12,300	2,640	1,540	5,500	2,860
MS 102	+1·82	+1·41	32·56	32·81	7·39	7·28	81	85	84·9	12	—	10,500	6,720	3,570	630	3,150	3,150
MS 103	+1·96	+1·69	32·79	33·03	7·32	7·26	82	90	19·0	42	−3·2	12,600	5,200	6,600	2,200	5,000	7,400
MS 104	+1·94	+1·77	32·75	33·00	7·40	7·31	85	90	25·7	15	−6·2	22,260	13,440	7,980	1,890	15,330	8,400
MS 105	+1·74	+1·77	32·88	33·41	7·31	7·19	88	91	45·4	19	+10·4	22,400	—	21,200	3,000	23,100	1,200
MS 106	+1·83	+1·56	33·09	33·46	7·18	7·09	88	90	99·4	38	+18·9	37,200	26,000	10,900	7,500	29,000	8,700

Table LV. *Observations in Moränen Fjord.*

Station	Depth	Temp. °C.	Salinity ‰	σ_t	*p*H	P_2O_5 mg./m.³	O_2 cc. per l.	Plankton	35–0 m.	50–0 m.
MS 93	0	2·40	32·01	25·57						
	0	3·05	31·94	25·47						
MS 94	0	1·70	30·88	24·72	8·22	54	8·07	*Coscinodiscus stellaris*	303,900	734,400
	5	1·25	31·98	25·63	8·17	54	—	*Fragilaria* sp.	43,500	61,200
	10	0·95	32·38	25·95	8·12	56	—	*Chaetoceros criophilum*	—	27,900
	20	1·10	32·77	26·27	8·12	65	7·47	*Corethron valdiviae*	—	13,000
	30	1·00	33·12	26·55	8·12	86	—	*Thalassiosira antarctica*	—	2,700
	40	0·30	33·12	26·59	8·02	96	7·26			
	50	0·00	33·39	26·83	7·97	99	—	Total	347,400	839,200
	75	−0·45	33·48	26·92	7·97	100	6·45	Other forms	3,300	18,000
MS 96	0	1·95	31·65	25·32	8·32	58	8·05			
	100	−0·65	33·68	27·09	7·92	129	6·05			

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THE SOUTHERN SEA LION, *OTARIA BYRONIA* (DE BLAINVILLE)

By

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CONTENTS

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(Plates I–XIII; text-figs. 1–7)

INTRODUCTION

The southern sea lion, *Otaria byronia*, has for long been well known to zoologists so far as its structure and taxonomic position are concerned, but our knowledge of its natural history has hitherto been of the scantiest. Since this seal is likely to prove of some economic importance in the Falkland Islands, the Discovery Committee decided to undertake an investigation of the species, and the present paper is based on observations and collections which I have made during the period from December 1929 to March 1932.

Before it can be considered that our knowledge of *Otaria byronia* is complete, so far as the Falkland Islands are concerned, further information is still required on the following heads:

(1) Length of life of both sexes.
(2) Rates of birth, death and increase.
(3) Oestrous cycle and extreme limits of breeding season.
(4) Habits of migration, if any.
(5) Census of the herd in the Falklands.

It would be invidious to name in particular any of the numerous friends in the Falklands without whose help this work could never have been conducted: I wish therefore to express my gratitude to them collectively. The Staff of the British Museum (Natural History) has been most helpful on many occasions, and I would also express my thanks to Mr R. H. Burne, F.R.S., the Curator of the Museum of the Royal College of Surgeons, and to Dr A. S. Parkes, F.R.S., for valuable assistance.

Reference is frequently made in the course of this report to Cape Dolphin. Cape Dolphin forms the north-west point of East Falkland Island. It is the site of an extensive sea-lion colony, and a considerable part of the work here described was done there.

HISTORICAL

The southern sea lion is an Otariid of the largest size, and like all its congeners it is gregarious and polygamous, and resorts to recognized breeding places at the appropriate season of the year. It inhabits the coasts of South America from the Rio de la Plata of the east side to about 4 degrees south latitude on the west, including the Galapagos and Falkland Islands. In the latter it breeds in very large numbers.

The sea lion is known to most of the inhabitants of the Falklands as the "seal", or perhaps "hair seal" in order to distinguish it from the fur seal, which is also well known, at any rate by repute. The adult male *Otaria* is generally termed a "lion" and the female a "clapmatch", a name derived from the Scandinavian "klapmyss" (*Cristophora cristata*). In the first place "clapmatch" was applied to the elephant seal, a proceeding more logical than might be expected, but by carelessness or ignorance the name has become transferred to the female sea lion in the Falklands and Australia and has even been used for the female fur seal in the latter place. In the Falklands people may be found who are quite prepared to argue that "sea lion" is the name of the adult male only and not of the whole species.

The species has been known since the beginning of the sixteenth century. In Pigafetta's account of Magellan's voyage (1520) mention is made of "sea-wolves of many colours" being seen on the coast of South America to the south of Cabo Santa Maria, which is on the north side of the entrance to the Rio de la Plata; great variation in colour is a distinctive character of *Otaria byronia*. The name used here, "sea-wolf", is merely a translation of the Spanish name for a seal—"lobo marino"—which is still in use for the sea lion in South America, while the word "lobo" (wolf) is also embodied in the name for the fur seal—"lobo fino", or "lobo de dos pelos", that is with two kinds of pelt.

In the narrative of Loaysa's voyage (1526) a seal was stated to have been killed at the Santa Cruz River in Patagonia having "several large stones in the stomach, as big as a fist and very smooth", again pointing to *Otaria*.

The sea lions were regarded as an important source of "refreshment" on the Patagonian coast: for example, from two to three hundred were killed on the "Islas de los Lobos", probably those in 45° 03′ S, for the expedition of Simon de Alcazaba (1535). Then Drake's people "kylled some seyles for owr provysyon" and later took "two hundred in the space of one hour", at Port Desire (Patagonia) on the same Penguin Island where John Davis salted twenty hogsheads of seal meat in 1592. Similarly Cavendish laid in a stock of salted seal meat in 1587 from another Penguin Island, apparently in the Magellan Straits.

Perhaps the best early description of *Otaria byronia* is that in the narrative of the voyage of the brothers Nodal (1619). They came to a place where the number of sea lions was so great that they did not venture to attack them or even to land; of the seals it was said that the males were of the size of bullocks and brown or black, while the females were bigger than large hounds and rather white. "The hands are like those of a turtle and the feet like a duck's with bones like fingers. The tail is short."

Other writers have at least indicated some of the external characters—"The former part like unto a lyons, with shagge hair and mostache" (Hawkins, 1593) and "their hands and feet were like wings but with nails showing". Hawkins took rather an anthropomorphic view of his sea lions. Writing of some they had tried to kill, he says that there was "a great company of seals" and "after they had recovered the water, they did, as it were, scorne us, defie us, and daunced before us". The sea lions were, of course, bobbing up and down in the water to inspect the creatures which had made the disturbance.

In Loaysa's voyage and again in that of Alcazaba it is stated that the liver is more or less poisonous. "Most of us who ate it suffered from the head to the feet", and "the livers of these seals is so poisonous that they give fevers and headache to every one who eat them, and presently all the hair on their bodies falls off and some die". It is difficult to explain these statements; I have eaten a great deal of sea-lion liver and experienced none of the effects mentioned. The liver of the polar bear is also said to be poisonous. One inclines to think that the bad effect might be due to sudden surfeits of a fresh delicacy after a long spell of preserved food.

Among later voyagers (Pernety and Hawkesworth) the name "sea lion" appears to have been applied indiscriminately to elephant seals and sea lions, although Pernety does differentiate between them in his illustrations, strange as they are.

NOMENCLATURE

The southern sea lion was not known to Linnaeus at the time of the publication of the tenth edition of the *Systema Naturae*, and until the time of Péron was always confused with Steller's sea lion, of which an account had been written by the discoverer.

J. A. Allen (1905) has published such a detailed account of the synonymy of this species that it is not necessary to give more than an outline here. It may, however, be mentioned that Schreber (1776), for example, describes *Phoca jubata* mainly from Steller's account of "Leo marinus" but uses Pernety's figure. In 1816 Péron gave the name *Otaria* to the eared seals and distinguished between *Otaria jubata* (Steller's sea lion) and *Otaria leonina* (the southern sea lion); the latter specific name was, however, preoccupied for the elephant seal. The next specific name is *flavescens* (Shaw, 1800), but the reference is to a specimen not clearly identifiable; finally de Blainville in 1820 gave the name *byronia* to a skull brought home by Byron in 1766 and now in the Museum of the Royal College of Surgeons (No. 974). This skull is said to have come from Tinian in the Caroline Islands, far beyond the range of *Otaria byronia*, but it is nevertheless the skull of an adult male of the species. Byron had of course been in the Falklands and other places in the region inhabited by this sea lion, and there can be no doubt that the locality given for the skull is simply the result of an error.

Th. Gill (1866) separated the Steller's and the southern sea lion into different genera, retaining the latter in *Otaria* as *O. jubata*, but creating the new genus *Eumetopias* for Steller's species, with the specific name of *stelleri*. As J. A. Allen has pointed out, this must give way to *jubata* (Péron), leaving the southern sea lion as *Otaria byronia* (de Blainville).

A considerable number of ephemeral species were erected during the nineteenth century, apparently whenever the skull of some stage not previously seen turned up, so that Allen was able to list twenty-four Latin names for this species. The source of error lay in the lack of information on the species, which resulted in the failure to appreciate that even in the adult there is considerable individual variation, that the species takes several years to become adult, and that there is a very marked difference in size between the sexes.

PHYSICAL CHARACTERS

In his monograph of the North American Pinnipedes J. A. Allen (1880) remarks on the great range of individual and age variation in the order, and *Otaria* furnishes no exception.

There are six stages in the life of this species, the first five each corresponding to a year of the animal's life. Even after breeding it is possible that growth and development continue, although the degree to which they do so is subject to the individual idiosyncrasy of the particular animal.

In deciding the age of one of these seals the principal characters which have to be considered are the following:

(1) Length of the animal from tip of snout to tip of tail, and, associated with this, bodily development.

(2) Coat colour.

(3) Length of skull in a straight line from the front of the premaxillae to the back of the occipital condyles—the condylo-basal length.

(4) Proportion of the skull length to the total length of the body.

(5) Proportions of various skull measurements to the length of the skull.

(6) Osteological development.

(7) Dental development.

(8) Condition of the reproductive glands, when they can be examined.

It is unnecessary to give a description of the external form of the sea lion, which is sufficiently familiar (Figs. 1, 2; Plates II, III, VII), although it may not be appreciated how great is the contrast in development in the adult male between the enormous fore-part of the body and the comparatively feeble hind-quarters. There is a great difference in size between the sexes; the average length of nine specimens of the adult male was 234 cm., and of eleven adult females 179 cm. The weight of an adult male collected by the 'Scotia' was over 1500 lb., that of the female is of course very much less.

Murie (1872 and 1874) has given a detailed account of the anatomy based on a young male from the collection of the Zoological Society.

BODY MEASUREMENTS

Length of the animal and body development (*Table II*)

Newly born. There is only one specimen of this stage in the collection, that of a very young male, which if not exactly newly born could not have been more than a few days old; the total length was 83·8 cm. This pup presented the usual characters of the very young mammal, namely a slightly made body and a large head. There appears to be no external difference between the sexes at this age.

First year (about six months old). Males 120·3 cm., 10 specimens; females 112·7 cm., 5 specimens. The males soon out-distance the females in the rapid period of growth which is comprised in the first six months; during this time the males increase by about 43 per cent and the females by 34 per cent (approximately). The single "newly

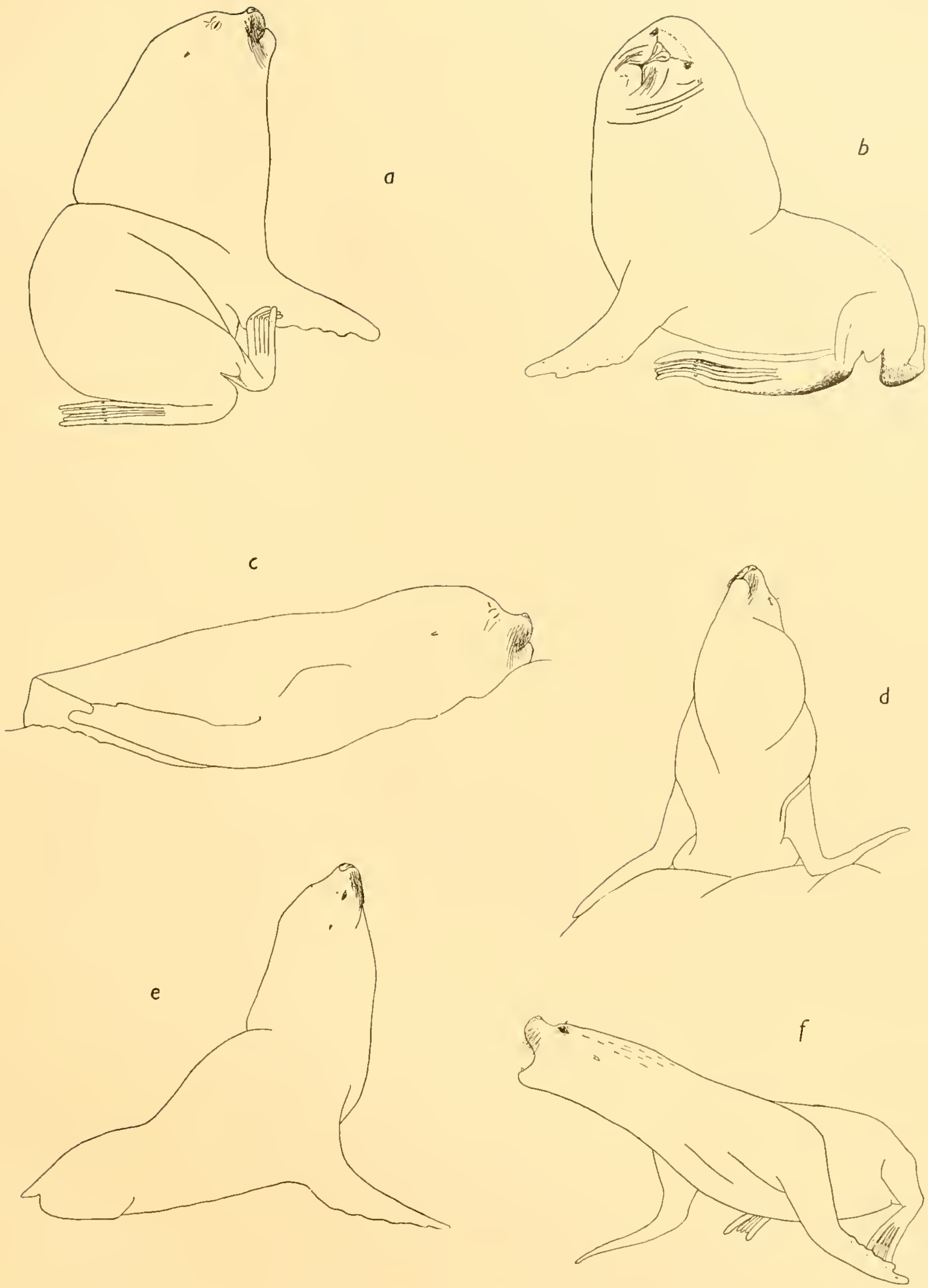

Fig. 1. Drawings of sea lions from life.

a, adult male, at ease.

b, adult male, attentive.

c, adult male asleep with the hind flippers turned forward.

d, adult female resting with the head thrown back.

e, adult female at ease.

f, adult male enraged.

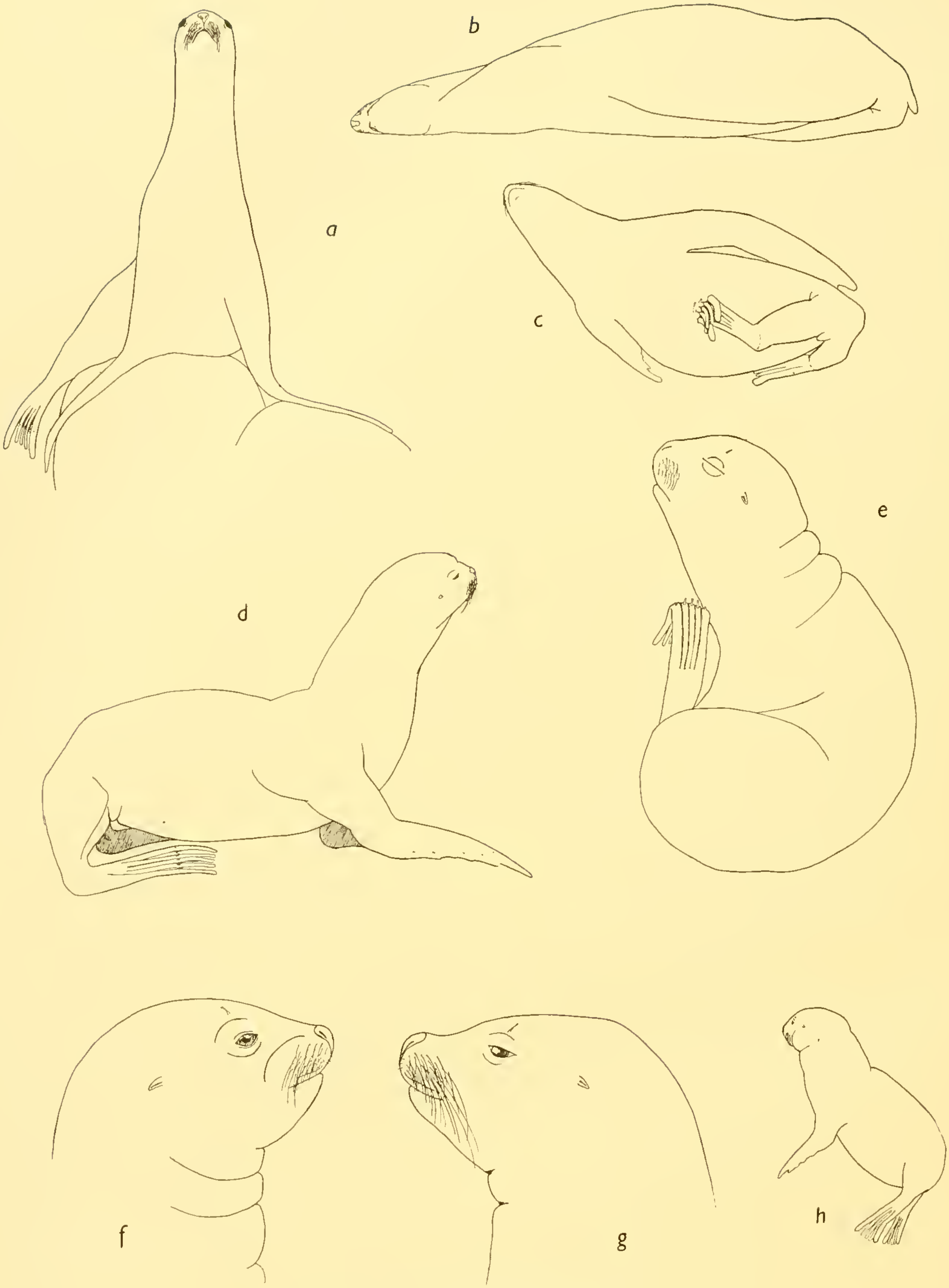

Fig. 2. Drawings of sea lions from life.

a, adult female attentive, neck fully extended.
b, adult female asleep.
c, adult female scratching the belly with the three long claws of the hind flipper.
d, adult female showing quadrupedal action.
e, pup a few weeks old, scratching.
f, head of pup a few weeks old.
g, head of adult female.
h, pup a few weeks old.

Table I

List of sea lions collected arranged in numerical order of a large series of bone labels used in the course of the work. The lack of consecutiveness does not indicate that specimens are missing: the labels attached to the skulls have invariably been used for the identification numbers and these only are included. The last number, DE 47, is from an earlier series.

Reference No.	Sex	Total length cm.	Date of collection	Reference No.	Sex	Total length cm.	Date of collection
1001	f.	157·4	29. vii. '31	1111	m.	134·6	26. vi. '30
1008	f.	129·5	8. viii. '31	1112	m.	134·6	26. vi. '30
1012	m.	126·9	29. vii. '31	1114	f.	190·4	8. vi. '30
1016	f.	151·0	8. viii. '31	1115	m.	147·3	26. vi. '30
1021	m.	138·4	29. vii. '31	1116	m.	137·1	11. vi. '30
1023	f.	142·2	8. viii. '31	1117	m.	121·9	9. vi. '30
1026	f.	124·5	29. vii. '31	1119	m.	119·3	8. vi. '30
1027	m.	253·9	25. iii. '30	1120	m.	195·5	26. vi. '30
1030	f.	153·6	29. vii. '31	1122	f.	177·7	10. vi. '30
1033	m.	137·1	29. vii. '31	1123	m.	129·5	11. vi. '30
1036	m.	139·6	29. vii. '31	1124	f.	119·3	10. vi. '30
1037	m.	241·2	25. iii. '30	1125	m.	139·6	11. vi. '30
1043	f.	121·9	10. viii. '31	1126	m.	157·4	26. vi. '30
1050	m.	144·7	29. vii. '31	1127	m.	152·3	26. vi. '30
1051	f.	96·5	22. iv. '31	1128	m.	139·6	11. vi. '30
1056	f.	137·1	19. vi. '30	1129	f.	170·1	8. vi. '30
1058	m.	256·4	30. vi. '30	1131	f.	177·7	8. vi. '30
1061	f.	126·9	15. vi. '31	1132	f.	182·3	8. vi. '30
1062	m.	162·5	30. vi. '30	1133	m.	182·8	26. vi. '30
1065	f.	160·0	19. vii. '30	1135	m.	210·7	26. vi. '30
1075	f.	116·8	19. vii. '31	1136	m.	132·0	26. vi. '30
1078	f.	121·9	10. viii. '30	1137	f.	182·8	8. vi. '30
1079	m.	236·1	v. '30*	1138	m.	213·3	26. vi. '30
1081	f.	114·3	20. vii. '31	1141	m.	228·5	26. vi. '30
1086	m.	116·8	30. vi. '30	1142	f.	109·2	11. vi. '30
1087	m.	83·8	4. i. '32	1143	m.	213·4	11. vi. '30
1088	m.	226·0	26. vi. '30	1144	m.	210·7	26. vi. '30
1089	m.	215·8	17. i. '32	1145	m.	106·6	11. vi. '30
1090	m.	114·3	30. vi. '31	1146	m.	119·3	8. vi. '30
1097	m.	121·9	26. vi. '30	1149	f.	180·3	9. vi. '30
1098	f.	142·2	20. vii. '31	1150	m.	134·6	26. vi. '30
1100	f.	157·4	19. vi. '31	1151	?f.	?78·5	11. vi. '30†
1101	m.	137·0	11. vi. '30	1152	m.	226·0	26. vi. '30
1102	f.	111·7	26. vi. '30	1153	m.	No data	i. '23
1103	m.	116·8	8. vi. '30	1161	f.	187·9	xi. '31
1104	f.	190·4	10. vi. '30	1167	f.	157·4	2. iii. '32
1106	m.	160·0	26. vi. '30	1168	f.	172·7	17. i. '32
1107	m.	205·7	26. vi. '30	1170	m.	231·0	17. i. '32
1108	m.	172·7	26. vi. '30	1175	f.	165·0	2. iii. '32
1109	m.	149·8	26. vi. '30	1179	f.	142·2	2. iii. '32
1110	f.	111·7	8. vi. '30	DE 47	f.	111·7	vii. '31

* Killed in January. † Skeleton found.

Table II

Average measurements

Year of age	Total length cm.	Skull length mm.	Skull length as % of body length	Zygomatic width mm.	Zygomatic width as % of skull length	Hamulo-premaxillar length mm.	Hamulo-premaxillar length as % of skull length	Rate of growth as % of previous year's average: Body	Rate of growth as % of previous year's average: Skull	No. of specimens	Approximate age months
					Males						
Newly born	83·8	148·0	17·7	92·0	62·2	89·0	60·1	—	—	1	—
								43·0	32·2		
I	120·3	195·6	16·3	108·3	55·4	123·5	63·1	—	—	10	6
								12·8	16·3		
II	135·7	227·4	16·7	119·3	52·3	145·0	63·5	—	—	9–10	18
								12·3	5·1		
III	152·4	239·0	15·7	129·1	54·0	156·4	65·4	—	—	5	30
								13·3	13·2		
IV	172·7	270·6	15·7	143·2	52·9	181·4	67·0	—	—	5	42
								22·0	14·0		
V	210·7	308·5	14·6	175·5	56·9	214·5	69·5	—	—	4	54
								11·2	—		
VI and over	234·3	327·2	14·0	—	—	—	—	—	—	9	66 or over
								—	11·5		
	—	344·9	—	215·9	62·6	241·2	69·9	—	—	31	
					Females						
Newly born (♂)	83·8	148·0	—	—	—	—	—	—	—	1	—
								34·5	25·9		
I	112·7	186·4	16·5	101·6	54·5	114·0	61·2	—	—	4–5	6
								5·1	7·8		
II	118·5	201·0	17·0	110·0	54·7	125·3	62·3	—	—	3	18
								5·5	5·7		
III	125·0	212·5	17·0	113·5	53·4	132·2	62·2	—	—	4	30
								14·5	5·7		
IV	143·1	224·7	15·7	117·5	52·3	141·0	62·7	—	—	4	42
								9·2	2·8		
V	156·2	231·0	14·8	128·3	55·5	152·3	65·9	—	—	3	54
								14·9	10·3		
VI and over	179·5	254·9	14·2	140·7	55·2	173·2	67·9	—	—	10–11	66 or over

Note. The male of 83·8 cm. is the only very young animal in the collection, it had therefore to be used as representing the newly born for *both* sexes; the figures for females in which this measurement is involved must be accepted with a certain reserve.

born" pup had to be taken as a standard for the growth of the females as well as the males, and since it was a male the figure given here for the females must be accepted with reserve. The growth in length during the first year is accompanied by a great increase in bulk, the healthy pup of six months being a very fat and thick-set animal.

Second year (about eighteen months). Males 135·7 cm., 9 specimens; females 118·5 cm., 3 specimens. The rate of growth has slowed to 13 per cent in the males and 5 per cent in the females. Both sexes are much more slender compared with their body length than in the previous year; they seem to lose condition a good deal when they cease sucking.

Third year (about thirty months). Males 152·4 cm., 5 specimens; females 125 cm., 4 specimens. The rate of growth in each sex is about the same as in the previous year.

Fourth year (about forty-two months). Males 173 cm., 5 specimens; females 143 cm., 4 specimens. The rate of growth is 13 per cent for males and 14 per cent for females.

Fifth year (about fifty-four months). Males 211 cm., 4 specimens; females 156 cm., 3 specimens. The rate of growth in the males shows a further increase, to 22 per cent, some of this stage reaching the size of the small adult males. In the females the rate of growth appears to drop to 9 per cent, a decrease which, if it really occurs, is perhaps associated with the onset of sexual activity.

Sixth year and upwards. Adult males, 234 cm., 9 specimens; adult females, 179 cm., 11 specimens. The rates of growth are 11 and 15 per cent respectively for males and females (Figs. 3, 4).

COLOUR

At first sight a herd of sea lions appears to be uniformly brown in colour, but on closer inspection the colour is seen to be very variable.

In the adult males the darker colours predominate; the following list is arranged in order of frequency:

(1) Dark brown all over, mane sometimes paler.
(2) Very dark brown, almost black, mane dull yellow.
(3) Grey, often with a slight greenish cast, mane pale.
(4) Very pale gold all over.

Except in phase 4 the belly is always dark yellow and the hair of the flippers reddish. Phase 1 is the commonest, as is indicated, and 2 and 3 are frequent. Phase 4 is extremely rare: I have seen only one specimen, but no doubt others exist since a corresponding colour in cows has been seen on a number of occasions.

The "mane" covers the top of the head and the neck, and is thickest at the back and thinnest at the front.

The adult cows may be divided into five groups:

(1) Dark brown, with the back of the head and neck dull yellow, face dark.
(2) Dark brown with the whole head and neck yellow, muzzle dark.
(3) Very dark brown, usually with a paler colour at the muzzle.
(4) Dull yellow all over, face dark.
(5) Pale cream all over, face dark.

All these phases are quite common except the last. Except in phase 5 the belly of the female is of much the same dark yellow as that of the male.

These adult colour variations are constant in the individual which shows them; when the animal is moulting the new coat is a replica of its predecessor with a change to a distinctly colder tone. The colour of the new coat gradually becomes warmer as time passes.

The variations in colour described above do not become noticeable until the animals are adult, but there are slight variations in colour among the sub-adult females.

The newly born pups are practically black, but this fades somewhat and a chocolate tinge appears, while the colour is often paler on the breast. After the first moult, which happens when the animal is a few months old, the colour is a very dark grizzled grey with a slight greenish cast. This coat becomes much paler and reddish during the first year; in the second and third years the young of both sexes are a tolerably bright reddish brown, but the females tend to have a paler region on the back of the neck.

After the third year the males become darker and more definitely brown, while the females become colder, more grey, in colour.

The annual moult begins in the autumn and continues for a considerable time: as a rule the pups and cows shed before the bulls do so. All the sea lions do not moult simultaneously, and specimens may be found in the moulting condition from April to August. The coat is shed first on the face, then in the following order: neck, flanks, rump and finally on the back.

As has been indicated the colour of the new coat is the same as that of its predecessor (in the adult), but it has a definitely colder tone which gives an almost bluish cast; this gradually disappears until by the time summer has returned the coat has regained its warm tone. The contrast in tone between the two coats is so marked that on the paler seal, when they are partly shed, the old coat shows in rusty patches.

The vibrissae are long, strong and mobile, reaching a length of a foot in the adult male; but the fine tip is often broken off. The number on each side is about thirty and the colour usually dull straw, so that they form a pale moustache which is a noticeable character of the species. There is, however, some variation in the actual colour of the bristles. The musculature of the vibrissae is well developed and they are easily erected. When the mouth is opened they rotate downwards and forwards so as to screen the open sides of the gape, a screening which must be of use when the sea lion is pursuing small prey such as *Munida*. When at rest the "moustache" lies flat against the sides of the upper jaw, drooping slightly towards the ends of the bristles. The bare parts of the skin are all almost black.

It is difficult but not impossible to distinguish between the younger immature males and the females of corresponding size. The female is slighter in build and has a rather more pup-like head and she is often paler about the head and neck. In the fourth year the males begin noticeably to develop the massive head and lower jaw characters of their sex, while the female retains throughout life much of her youthful appearance. The mane is not developed until the animal is becoming adult.

The voice of the adult male is deep, powerful and slightly husky. It is produced in a mixture of roars and coughs and the breath is expelled with great force, as I have observed from a position close enough to feel the breath on my face. The cloud of steam emitted in cold weather is remarkable for size and volume. The pitch of the voice is about that of the lowest D on the piano. The bulls grunt and groan a good deal besides roaring. The female has a strong voice, rather resembling that of a large domestic calf and about the same pitch, while the pup has a high-pitched, sheep-like bleat. All stages emit snarling noises when fighting.

DEVELOPMENTAL STAGES OF THE SKULL

During these investigations 82 skulls were collected (Table I). Most of them were from animals specially killed, but a few were from seal found dead, but fresh, on the beach and one was taken from an adult male which had been dead for a considerable time but of which the skeleton was still intact. One skull was secured in Stanley from a bull which had been killed some years before, so that place and date were available but no record of the total length. All the skulls were prepared by being boiled as soon as possible, a proceeding which was necessitated by the extreme difficulty of drying meat in the Falklands and by the need to make preliminary examinations as a guide to future researches.

The development of the skull is rather different in the two sexes, which will therefore be considered separately; but in both there is an increase in zygomatic width relative to the length of the skull, from the fourth year onwards. Since skulls which are completely ossified are of different sizes it follows that the size at which growth ceases varies with the individual.

Male skull

The number of male skulls collected was 46 (Table IV) and in addition 21 skulls of adult males in the British Museum (Natural History) and the Museum of the Royal College of Surgeons have been examined (Table III). Of the skulls which I myself collected the majority were obtained between June 8 and July 29; among the others are an adult and a sub-adult male, killed on January 17, another adult killed in 1923, and an almost new-born pup found dead on January 4. Unless specifically mentioned the sub-adult male and the pup are left out of account.

An examination of the series of skulls shows that each of the six stages has its own osteological characters, a statement which applies to both sexes. The measurements in Table II and in Figs. 3, 4 are the *averages* for the groups of skulls in each stage.

In the FIRST YEAR the average length of the skull is 195·6 mm., 16·3 per cent of the body length; the zygomatic width is 108·3 mm., being 55·4 per cent of the skull length; and the distance from the tip of one of the hamular processes to the end of the pre-maxillae is 123·5 mm., 63·1 per cent of the length of the skull. The skull is in general smooth all over and obviously juvenile in character. There are still traces of the sutures of the occipital segment; the suture between the basi-occipital and the basisphenoid is open and all the sutures are simple. There is a depression in the middle line just behind the orbital processes of the frontals, and the temporal line is about level with these processes.

The permanent canines are absent and only two of my ten skulls retain milk canines; the incisors are all about the same length and the second cheek teeth are just erupting (Plates VIII, IX, X, figs. 2).

In the SECOND YEAR the length of the skull is 227·4 mm., 16·7 per cent of the body length; the zygomatic width is 119·3 mm., 52·5 per cent of the length of the skull;

Table III

List and measurements of skulls in the collections of the British Museum (Natural History) and the Museum of the Royal College of Surgeons. The former are marked "B" and the latter "S"

Reference No.		Length of skull mm.	Zygomatic width mm.	Hamulo-pre-maxillar length mm.
969	S	338	226	248
335^l	B	340	206	Damaged
335^m	B	342	215	247
964	S	342	222	240
335^c	B	343	222	246
87.6.18.2	B	344	229	Damaged
974	S*	344	208	221
25.12.17.1	B	346	233	Damaged
1904.7	B	349	234	243
335^p	B	350	223	Damaged
138.3	S†	351	208	244
966	S	352	Damaged	249
335^n	B	354	218	Damaged
335^j	B	355	227	257
335^x	B	357	242	244
335^o	B	359	239	261
970	S	360	237	251
335^d	B	365	239	260
1914.7	B	365	221	250
971	S	366	230	257
972	S	382	234	270

* Type. † In the dental collection.

and the hamulo-premaxillar measurement is 145 mm., 63·5 per cent of the skull length. The skull is still smooth, but on the whole much better ossified; the occipital segment is completely fused, the interparietal part of the sagittal suture is becoming complex and the suture between the basi-occipital and the basisphenoid is sometimes closed. The depression behind the interorbital processes of the frontals is still visible, but the temporal line is higher up, nearer the middle line. The permanent canines are now present but are only a little longer than the cheek teeth, which are all well developed. The third upper incisors are now the longest teeth in the skull, being about twice the length of the first and second incisors (Plates VIII, IX, X, figs. 3).

Table IV

Measurements of skulls of male sea lions arranged in age groups

Reference No.	Length of animal cm.	Length of skull mm.	Zygomatic width mm.	Hamulo-premaxillar length mm.	Date of collection
			First year		
1087	83·8	148	92	89	January 4
1145	106·6	188	99	116	June 8
1090	114·3	197	107	123·5	June 30
1086	116·8	186	106	116	,,
1103	116·8	199	110	125	June 8
1146	119·3	188	104	121	,,
1119	119·3	201	112	130	,,
1117	121·9	194	104	123	,,
1097	121·9	202	111	121·5	June 26
1123	129·5	198	114	125	June 8
1116	137·1	203	116	134	,,
			Second year		
1012	126·9	220	116	Damaged	July 29
1136	132·0	230	114	147	June 26
1111	134·6	227	123	145	,,
1150	134·6	230	120	145	,,
1112	134·6	230	120	151	,,
1033	137·1	224	119	143	July 29
1021	138·4	226	118	144	,,
1125	139·6	215	117	131	June 11
1128	139·6	234	123	150	,,
1036	139·6	238	123	149	July 29
			Third year		
1050	144·7	238	130	151	July 29
1115	147·3	233	126	152	June 26
1109	149·8	237	129	158	,,
1126	157·4	247	124·5	160	,,
1062	162·6	240	136	161	June 30
			Fourth year		
1127	152·3	262	140	181	June 26
1106	160·0	261	137	170	,,
1108	172·7	265	135	178	,,
1133	182·8	277	149	179	,,
1120	195·5	288	155	199	,,
			Fifth year		
1107	205·7	304	184	219	June 26
1135	210·7	308	167	208	,,
1138	213·3	301	174	208	,,
1143	213·3	321	173	223	June 11
1089	215·8	311	178	217	January 17
			Sixth year and over		
1144	210·7	332	199	225	June 26
1152	226·0	324	191	222	,,
1088	226·0	342	191	232	,,
1141	228·5	320	198	222	,,
1170	231·0	322	191	220	January 17
1079	236·1	332	204	225	May
1037	241·2	325	201	Damaged	March 25
1027	253·9	325	185	227	,,
1058	256·4	323	204	229	June 30
1153	No data	(342)	201	240	January

The skull of the THIRD YEAR is 239 mm. long, 15·7 per cent of the body length; zygomatic width 129·1 mm., 54 per cent of the skull length; and hamulo-premaxillar length 156·4 mm., or 65·4 per cent of the skull length.

This stage has a more massive skull and the profile of the cranium is beginning to be flattened. The first sign of a ridge appears at the posterior edge of the temporal line, which is more strongly marked and still nearer the vertex than in the preceding stage; the supra-occipital begins to fuse with the parietal bones. The canines are now the longest of the teeth (Plates VIII, IX, X, figs. 4).

By the FOURTH YEAR the length is 270·6 mm., being 15·7 per cent of the body length; the zygomatic width is 143·2 mm., 52·9 per cent of the skull length; and the hamulo-premaxillar measurement is 181·4 mm., 67·0 per cent of the skull length.

The juvenile appearance has been lost and indications of the eventual form of the skull begin to appear. The supra-occipital and the parietals are completely fused and the temporal lines almost meet in the middle line; they are separated only by a slight bony ridge on each frontal, the beginning of the sagittal crest. The canines are naturally still larger and the incisors show signs of wear (Plates VIII, IX, X, figs. 5). In this stage and in all those which precede it the nasal part of the skull has a curved profile and the dorsal surface of the nasal bones is easily seen from in front.

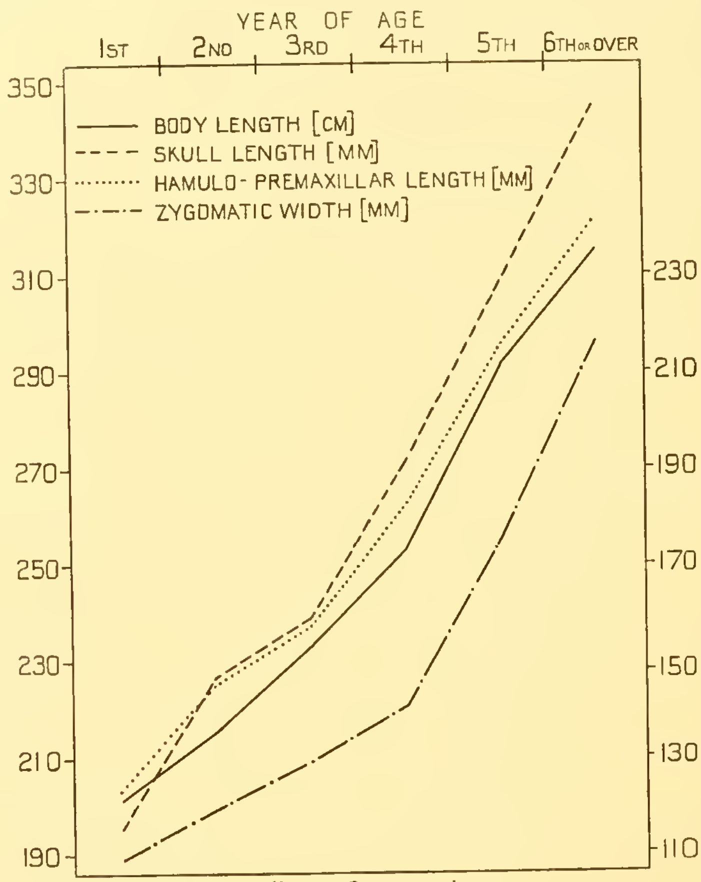

Fig. 3. Male sea lions. Increase in measurements during growth.

In the FIFTH, SUB-ADULT, YEAR the skull has a length of 308·5 mm., 14·6 per cent of the body length; with a zygomatic width of 175·5 mm., and hamulo-premaxillar length of 214·5 mm., 69·5 per cent of the skull length.

Although it is much less massive than in the adult the skull of this stage is definitely suggestive of the ultimate form; the dorsum is nearly straight, and instead of being curved down towards the front, the nasals are now nearly in a straight line with the dorsum, with the result that the front edges and *not* the upper surfaces of the nasals are presented towards the front. There are distinct but not largely developed occipital and sagittal crests and only the latter separate the temporal lines, so that the jaw muscles now cover the whole of the sides and top of the cranium. The pterygoids and palatines project much farther below the level of the bony palate and the squamosals are fused to the supra-occipitals. The canines much exceed the outer incisors in length (Plates VIII, IX, X, figs. 6).

The ADULT skull, that from an animal in its sixth year at the youngest, has an average length of 344·9 mm. (31 specimens); the proportion to body length is 14 per cent (9 specimens), the zygomatic width is 215·9 mm. and the hamulo-premaxillar length is 241·2 mm., the two last being 62·6 and 69·9 per cent of the total length of the skull.

In this stage the nasals are almost quite flat, and in profile are in the same straight line as the median anterior prolongations of the frontals, which are now below the level of the post-orbital processes. In profile the line of the nasals and the anterior parts of the frontals forms an angle of 160 degrees or less with the dorsum of the cranium proper, the point at which the change of direction takes place being situated approximately at the level of the posterior end of the jugal. The profile of the upper surface of the skull as a whole is thus once more bent, instead of being straight as it was in the fifth year. This change of direction of the profile increases with age, being 150 degrees in the skull No. 335*x* of the National Collection; it tends to be obscured, however, by the development of the sagittal crest.

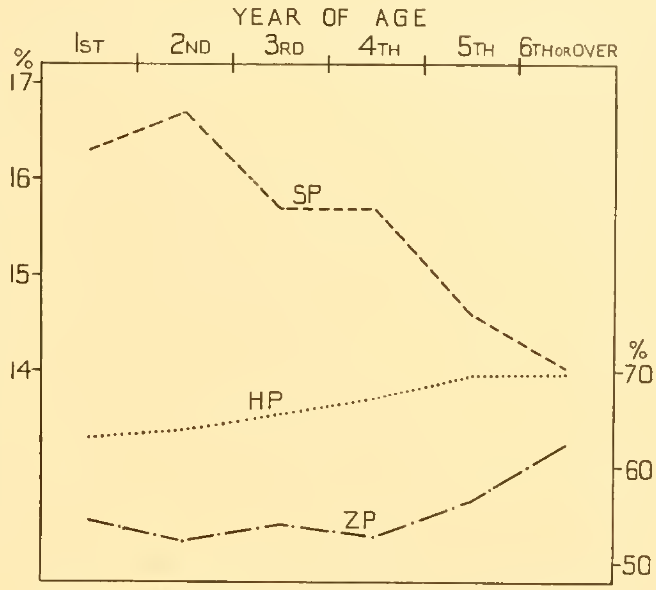

Fig. 4. Male sea lions. Variations in proportions during growth.

SP: Skull length as percentage of body length.
HP: Hamulo-premaxillar length as percentage of skull length.
ZP: Zygomatic width as percentage of skull length.

Other osteological characters of the adult are these: the frontal and parietal segments are fused together, the alisphenoid is united to the palatine and the latter to the pterygoid, which is in turn fused with the parietal, while the squamosal is fused to the surrounding bones. It follows that no further growth of the cranium is possible.

The supra-occipital crest develops greatly, sometimes to an enormous size, as in the skull No. 335*x*, where it is 6 cm. in height. The sagittal crest also develops markedly in its posterior part, but in the anterior the development is irregular. Tubercles of irregular shape are nearly always developed at the junction of the parietal and frontal on either side, and less often on the parietal just in front of the occipital crest. Everywhere the ridges and rugosities of the skull are strongly developed and the whole structure impresses one with the idea of extreme strength.

The premaxillae nearly always unite in front and later fuse with the maxillae, and eventually the palatine plates of the maxillae and of the palatines themselves fuse in the middle line and the transverse suture between them closes. The pterygoids become deeper and tend to approach one another below the level of the palate and the external plates extend beyond the hamular processes. In the younger adults the jugal begins to unite with the maxilla; but it is only in the most completely ossified skulls that it unites with the squamosal.

In the adult the pre-orbital part of the skull becomes broad and massive in accordance with the great development of the canine teeth and the upper third incisors. With advancing age the bone surrounding the teeth, particularly the more anterior, and forming their sockets, becomes thickened and rather cancellous, and some—frequently front teeth—become broken or displaced, no doubt in fighting (Plates VIII, IX, X, figs. 7).

In the completely ossified state every suture is fused and almost all are obliterated, so that the skull becomes a single mass of bone; but only three of the thirty-one adult male skulls available have reached this state. Of these skulls two are in the National Collection and are 346 and 357 mm. in length respectively (the average length for the entire series of thirty-one being 345 mm.), and the third which is in the Museum of the Royal College of Surgeons is the largest skull I have seen—382 mm. long. It is 27 mm. longer than the next largest, but in its proportions adheres closely to the averages for the whole series of adult male skulls. Of these three skulls the difference between the smallest and the next in size is 11 mm. or 3·2 per cent of the smaller, the difference between the second and the largest is 25 mm., 7·0 per cent of the second, and between the smallest and the largest 36 mm. or 10·4 per cent of the smallest.

It is quite clear from this series of skulls that full growth is not synonymous with sexual maturity and that the size which may be attained is subject to considerable variation.

The most remarkable skull of an adult male is that in the British Museum (Natural History), No. 335*x*, which came from the Falkland Islands. Although it is exceeded in size by six others it is excelled by none in the development of the crests and tubercles. Both of the upper canines and one of the third incisors are broken off; it is the skull of an aged animal.

Female skull

The series of female skulls numbers 34; of these 27 were collected between June 10 and August 10, and only those taken between these dates have been considered in determining the annual stages. Two skulls of adult cows of unknown age collected in November and January have also been retained for consideration.

The female skull presents a series of changes which are analogous to but less pronounced than those of the male, as might indeed be expected since the ultimate form is much less specialized. The skull naturally retains at all times much of the juvenile character, and this, combined with individual variability, renders less obvious the differences between the age groups, which as in the male are six in number.

FIRST YEAR. Total length 186·4 mm., 16·5 per cent of the body length; zygomatic

Table V

Measurements of female sea lions arranged in age groups

Reference No.	Length of animal cm.	Length of skull mm.	Zygomatic width mm.	Hamulo-premaxillar length mm.	Date of collection
			First year		
1051	96·5	166	98	102	April 27
1142	109·2	187	101·5	115	June 11
1110	111·7	182	Damaged	Damaged	June 8
DE 47	111·7	186	101	113	July —
1102	111·7	188	99·5	114	June 26
1124	119·7	189	104·5	114	June 10
			Second year		
1081	114·3	199	109	123	July 20
1075	116·8	199	111·5	123	July 19
1026	124·4	205	109·5	131	July 29
			Third year		
1043	121·9	212	112	132·5	August 10
1078	121·9	213	116	133	,,
1061	126·9	212	112	135	June 15
1008	129·5	213	114	128·5	August 8
			Fourth year		
1056	137·1	224	115	139	June 19
1098	142·2	220	117	137	August 8
1023	142·2	223	117	136	July 20
1179	142·2	223	120	147	March 2
1016	151·0	232	121	152	August 8
			Fifth year		
1030	153·6	231	128	150	July 29
1001	157·4	228	126	155	,,
1100	157·4	235	131	152	June 19
1167	157·4	242	130	157	March 2
1175	165·0	237	127	157	,,
			Sixth year and over		
1065	160·0	247	132	164	July 19
1129	170·1	247	135	168	June 8
1168	172·7	247	135	169	January 17
1122	177·7	248	138	177	June 10
1131	177·7	255	146	175	June 8
1149	180·3	264	142	178	June 9
1132	182·3	254	139	172	June 8
1137	182·8	253	144	165	,,
1161	187·9	262	—	—	November
1104	190·4	260	145	179	June 10
1114	190·4	267	151	180	June 8

width 101·6 mm., 54·5 per cent of the skull length; hamulo-premaxillar length 114 mm., 61·2 of the total length. There is very little difference from the male skull of the same age except for smaller size and more insignificant development of the pre-orbital region. The temporal line is about level with the post-orbital processes, and the whole cranium is smooth and rounded. All the permanent teeth are present, but the permanent canines scarcely show above the gum and, as in the male, milk canines may be present. All the sutures may be traced, but the components of the occipital segment have begun to fuse. The suture between the basi-occipital and the basisphenoid is open (Plates XI, XII, XIII, figs. 1).

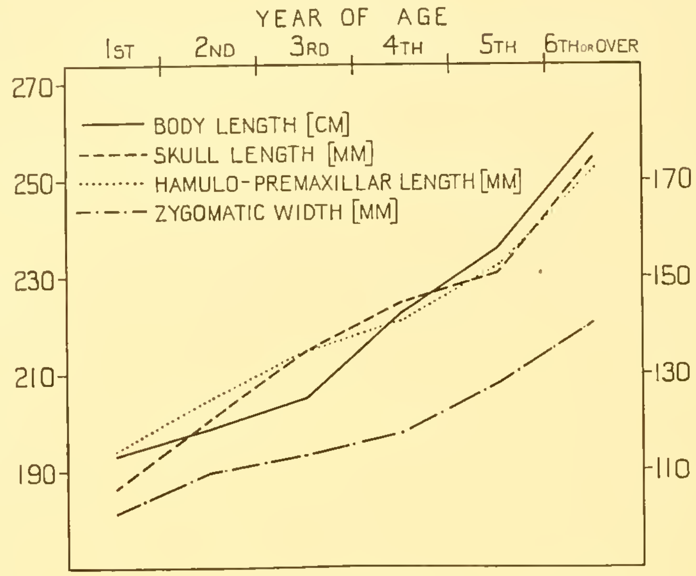

Fig. 5. Female sea lions. Increase in measurements during growth.

SECOND YEAR. Total length 201 mm., 17·0 per cent of the body length; zygomatic width 110 mm., 54·7 per cent of the length; and hamulo-premaxillar length 125·3 mm., 62·3 per cent. The cranium is slightly flattened and the facial region slightly better developed in proportion to the skull as a whole, while the temporal line has moved up towards the middle line as the jaw muscles have developed. On the whole the teeth have increased in size and the permanent canines are now present and the longest teeth in the jaws. There is increased fusion of the occipital region but all the other sutures are patent (Plates XI, XII, XIII, figs. 2).

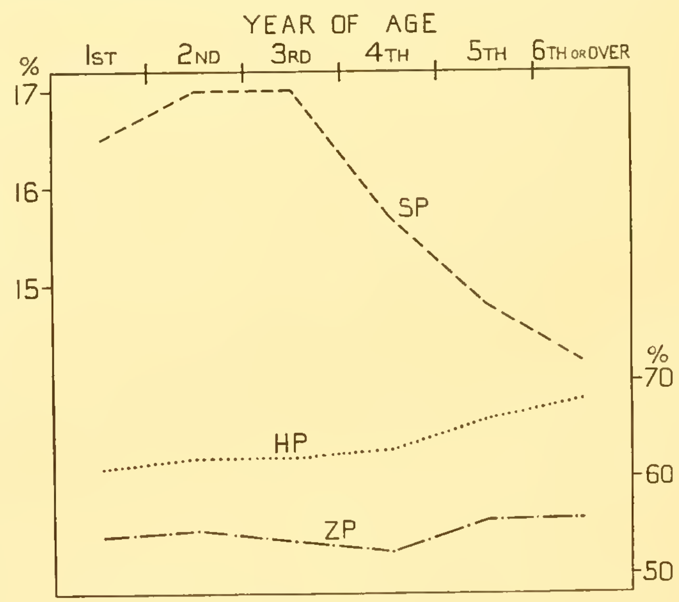

Fig. 6. Female sea lions. Variation in proportions during growth.

SP: Skull length as percentage of body length.
HP: Hamulo-premaxillar length as percentage of skull length.
ZP: Zygomatic width as percentage of skull length.

THIRD YEAR. Total length 212·5 mm., 17·0 per cent of the body length; zygomatic width 113·5 mm., 53·4 per cent of the total length; hamulo-premaxillar length 132·2 mm., or 62·2 per cent of the length. The flattening of the cranium is more pronounced, while the occipital segment is completely fused and the suture between the basi-occipital and the basisphenoid disappears: this change has usually occurred in the male by the second year, but in the female is a ready means of distinguishing between the third year stage and its predecessor (Fig. 7*a*; Plates XI, XII, XIII, figs. 3).

FOURTH YEAR. Total length 224·7 mm., 15·7 per cent of the body length; zygomatic width 117·5 mm., 52·3 per cent of the total length; hamulo-premaxillar length 141 mm., 62·7 per cent of the total length. The cranium is still more markedly flattened and the whole skull is definitely more massive. The interparietal and parieto-frontal sutures have increased in complexity, and the temporal line is beginning to approach the sagittal. There is a relative enlargement of the pterygoid, which is associated with a straightening in a vertical line of the suture between the pterygoid and the

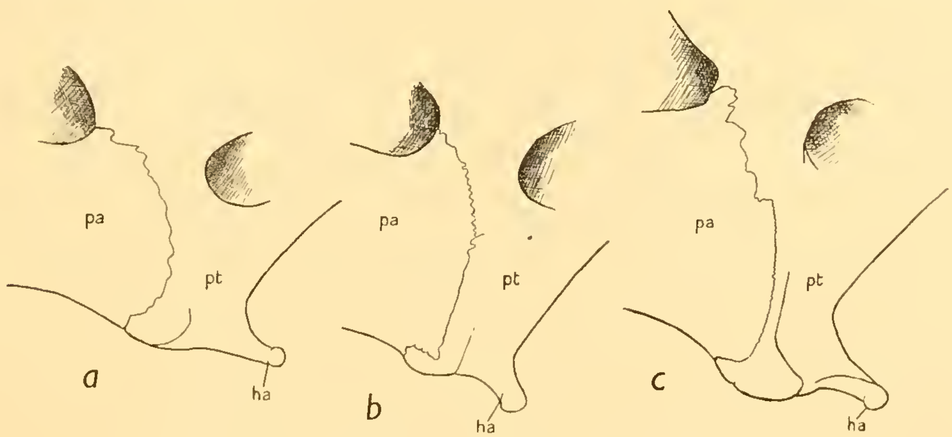

Fig. 7. Pterygoid regions of three skulls of female sea lions.

a. Third year, specimen No. 1061. *b*. Fourth year, specimen No. 1023. *c*. Fifth year, specimen No. 1100. In each figure: *ha* = hamular process; *pa* = palatine bone; *pt* = pterygoid bone.

palatine. The hamular processes are still comparatively slender and the palate begins to assume the laterally contracted form characteristic of the adult (Fig. 7*b*; Plates XI, XII, XIII, figs. 4).

FIFTH YEAR. Total length 231·0 mm., being 14·8 per cent of the body length; zygomatic width 128·3 mm. and hamulo-premaxillar length 152·3 mm. which are respectively 55·5 and 65·9 per cent of the total length of the skull. The skull is now approaching the adult character; in some specimens the occipital and sagittal crests begin to appear and the temporal lines almost meet anteriorly. The zygomatic arch is markedly more massive and the palate displays the narrow, concave and elongated form of the adult. There is an increase in the relative length of the facial part of the skull, and the downwardly directed plates of the pterygoids show a still further increase in size, while their junction with the palatines is almost quite straight. The hamular processes are more oblique, and in their increased length approach the fully adult condition (Fig. 7*c*; Plates XI, XII, XIII, figs. 5).

SIXTH YEAR, AND OLDER. Total length 254·9 mm., 14·2 per cent of body length;

zygomatic width 140·7 mm., being 55·2 per cent of the total skull length; and hamulo-premaxillar length 173·2 mm., 67·9 per cent. It is now no longer possible to determine age by the skulls. In these skulls the cranial sutures disappear and the muscular crests usually become emphasized, while in the oldest, or at any rate the most completely ossified specimens, the jugal fuses to the maxilla as it does in the adult male. The palate deepens very much and the pterygoids lengthen until they project far below the palate and eventually the pterygoids fuse with the palatine bones (Plates XI, XII, XIII, figs. 6).

There are four skulls which are better ossified than any of the others; the cranium is completely fused, the jugal is united to the maxilla and the development of the ridges and rugosities for the attachment of muscles, considered with the other characters, shows that these are skulls of aged animals. The lengths are 255, 264, 254 and 267 mm., the order being that of body length. It will be noticed that the first and third hardly depart from the average for the series, but the fourth is not only the largest skull but is from one of the two largest animals. All these animals were pregnant when killed. Since these crania are incapable of further growth it is clear that they have attained their full size.

The rate of growth of the skull, like that of the body, is highest during the first six months in both sexes, when it is 32 per cent for males and about 26 per cent for females. The rate of growth for male skulls falls to 16 per cent between the first and second years and 5 per cent between the second and third years, rising again in the short series of measurements available to 13 per cent between the third and fourth years, and finally to 14 per cent between the fourth and fifth years: thereafter it declines to 11·5 per cent. The rate of growth of the female skull falls to 7·8 per cent between the first and second years and continues to decline until it reaches 2·8 per cent between the fourth and fifth years, showing an abrupt rise after that to 10·3 per cent between the fifth and sixth years (Table II).

It will be observed that, in the female, between the fourth and fifth year, there is a fall in the rates of growth, and that this is succeeded by a rise between the fifth and the succeeding stage. It is possible that this indicates the onset of sexual activity which begins towards the end of the fourth year in the female. Otherwise it is difficult to offer an explanation, unless the apparent fall is the result of accident resulting from the limited number of specimens available for measurement. It may, however, be remarked that the fall appears in the rates of growth of both body and skull.

DENTITION

Of the adult

According to Reynolds (1913) the dentition of *Otaria* is $\frac{3}{2}\frac{1}{1}\frac{4}{4}\frac{1 \text{ or } 2}{1} = 34$ or 36. In *O. byronia* the *normal* state is $\frac{3}{2}\frac{1}{1}\frac{4}{4}\frac{2}{1} = 36$, but the last upper cheek tooth is not infrequently lost, as for example in the males 1089 and 1127 and the female 1129. In two other males, Nos. 1138 and 1135 (Plate X, fig. 6), there is a full dentition on the right side, while the left of each is $\frac{3}{2}\frac{1}{1}\frac{4}{4}\frac{1}{1}$. The last upper cheek tooth is often set at some distance behind the others, and it is always small and lightly rooted; it appears as if the species were in the process of losing this tooth.

In the adult male one or both of the lower incisors of each side may be lost, and if the animal lives long enough the socket is obliterated. Skull No. 335*x* in the National Collection is very fully developed from the osteological point of view and has no trace at all of sockets for the incisors in the mandible: the rami are fused—an unusual condition. It is likely that these teeth are lost in fighting; damaged teeth are not uncommon in the adult males and one can often hear the fangs of the opponents clash together during their combats. The females lose these incisors also at times; but less frequently than do the males.

In some animals the teeth are much worn; but this alone must be accepted with caution as evidence of age, since animals from sandy places tend to have their teeth more worn than do those from other places, and this difference is observable among the male skulls of my collection (Colyer, 1931).

Of the young

The dentition of the very young pup, No. 1087, may be briefly described. *Upper jaw:* the four central permanent incisors have erupted and the tips of the fifth and sixth cheek teeth on each side are visible. *Lower jaw:* the central incisors and the first cheek teeth are visible, but the second incisors barely show. Of the milk teeth the upper and lower canines and the upper second cheek tooth, while in the lower jaw the canine and first cheek tooth and perhaps a trace of the second are visible on the right: on the left side the canines and the second, third and fourth cheek teeth remain. Most of the unerupted permanent teeth may be seen in the dried gum. The milk cheek teeth are simple little knobs like the heads of very large pins (Plates IX, X, figs. 1).

At the age of six months the canines are the only milk teeth left, if indeed they are still present, and they are replaced by the permanent canines before the animal is eighteen months old.

The male pup No. 1119 is remarkable for having a number of supernumerary teeth. The incisors and milk canines are normal, but in the upper jaws there are on the left side seven and on the right side no less than nine permanent cheek teeth, while each side of the lower jaw contains six cheek teeth. This animal has therefore a total of $\frac{11}{9} + \frac{13}{9} = 42$ teeth, six in excess of the normal number.

BIONOMICS

HABITS AND BEHAVIOUR (GENERAL)

Movement on the land is arduous and the sea lions quickly lose their wind and sink down to rest, often going to sleep when they do so. They may eventually cover what must be for them considerable distances on the land: I have found them about half a mile inland from the place where they must have climbed the cliffs, and quite out of sight of the sea. I have seen a cow walking along a beach parallel with the water, and followed by her pup; her journey could not have been much less than half a mile and it was accomplished in lengths of about a hundred yards with rests between. Reports of sea lions being met miles inland and far above sea-level are not uncommon. The animals are usually described as emaciated, but this condition might result from starvation ensuing on the journey and is not necessarily a proof that some of the sea lions "go inland to die". The rivers of the Falklands are all small and swift and sea lions are not reported from them. The Australian species goes up rivers and has been found far from the sea, and this may have given rise to the myth of the "bunyip": the tale of the "yaquaru", a mysterious carnivore occasionally seen in the Paraguay River (Falkner, 1774), might well be based on a wandering *Otaria*.

The actual action of the legs is of course the same as in ordinary mammals, but the soft tissues and tail extend so far towards the ankle joints that in walking the whole hind quarters are swung forward with every step. The resulting gait is extremely clumsy; but if the animal is excited the pace is surprising—on a rough beach I should expect an adult male to run, or rather gallop, as fast as a man can run. The adult males, however, find movement on the land much more arduous than do any of the other stages (Plate VI, fig. 2; Plate VII, fig. 1).

In the water *Otaria byronia* shows itself to be an expert swimmer and diver: it will throw itself into the water from a considerable height and can fight its way offshore against heavy surf. In swimming at slow speeds the large front flippers are used in a rowing manner; the hind-quarters and flippers are only brought into play when speed is required; they are then used with a twisting or sculling movement and the acceleration produced is remarkable. When travelling at high speeds, and sometimes in pure sport, *Otaria* will leap almost or completely from the water at each breath; but in such evolutions it does not exhibit the beautiful clean action of the fur seal. The sea lions spend a good deal of their time playing together in the water, when they go through the most complicated motions with ease and grace: they are particularly fond of swimming on their backs.

In breathing while swimming the head is thrust well above the surface and the animal makes an expiration which can be heard at some distance in calm weather; inspiration may be accompanied by a rasping, whistling sound as in the Cetacea. When a sea lion is swimming quietly about in the one place a large bubble of air will sometimes be expelled a perceptible time before the animal comes up to breathe: every breath even may be expelled in this way.

Although the sea lions return to the same rookery every year the precise sense of direction in the water is not infallible. I have seen a party of cows come ashore on a rookery and begin bellowing for their pups; but when they received no answer they returned to the water and swam along the shore peering at the land as they did so. After they had gone several hundred yards they came to the next rookery and there they went ashore and remained, having obviously made a mistake in the first place. It is suggested below, in writing of dead pups, that cows may lose altogether the places where their pups have been left.

Otaria shows little fear of surf and is frequently seen swimming and playing in heavy breakers close to some cliff-foot or off a favourite beach; the movement of the water perhaps stirs up the food animals. The species is able, however, to recognize the impossibility of landing in breakers if they are too heavy; I have seen a sea lion come up to a rock in bad weather and after inspection decide that landing was not feasible and go off to an easier place.

The four principal features of the character of *Otaria byronia* are gregariousness, pugnacity, curiosity and timidity. The first two of these, and indeed the last also, appear rather contradictory, but they are all present nevertheless.

Otaria is very seldom found singly, generally in little groups of two or three if there are few animals present; but if there are many most of them will be seen lying in heaps and a few odd individuals by themselves. When a sea lion comes up from the water it will always make for any others which can be found and settle itself beside them. The cows, pups and immature animals lie in any position on top of one another; but the adult males, probably on account of their large size, usually lie side by side and sometimes use one another as pillows. Outside the breeding season a good deal of time is spent in sleeping in this social fashion, the animals waking only to change their positions or to scratch themselves with the three long claws of the hind flippers, a proceeding in which they take pleasure. Several days may be spent in this manner and parties of seal may often be found asleep half a mile from the sea.

The adult males are not ferociously quarrelsome except in the breeding season, when they display great animosity to one another. Towards man their attitude varies. Some become uneasy when approached; but others not only stand their ground resolutely, but even become definitely aggressive, making short charges and emitting loud coughs of rage. These animals can generally be avoided by running away, since the harem bulls will not abandon their stations; but bulls which have no cows will sometimes pursue farther than one expects.

The actual fights between the bulls are usually short and accompanied by a great deal of noise and clashing of teeth; the movement is very fast and the general effect is that of a dog fight on a grand scale. At times one or both of the combatants secures a hold in his adversary's neck and then each seal pushes against the other's neck and breast until strength and weight tell. The defeated animal flees as fast as he can, pursued by the victor, who endeavours to inflict further damage, particularly on the axilla where the skin is thin—wounds on the back and flanks are fairly common.

Many of the fights do not result in a decision: I have seen bulls fight almost to a standstill without either giving in. In the breeding season the harem bulls are much gashed about the face and neck, and the hair on those parts is usually matted with blood (Plate III, fig. 1). It would seem that the bulls are almost insensitive to pain, for there is no flinching when an opponent takes hold, only an increase of rage. The animals are amazingly quick in avoiding a bite. The combative aspect of the sexual instinct would appear to be the strongest part of it—I have seen a male abandon coitus in order to engage in a fight.

The cows quarrel and snap among themselves a good deal when they are in the harems, but this behaviour is suppressed as soon as possible by the harem bull. The cows also show irritation towards strange pups. Pups do not very readily recognize their own mothers, and if a cow receives too much attention from a strange pup she may even grip it in her mouth and throw it from her.

The pups themselves learn to snarl and bite at an early age, apart from their play which, like that of the older sea lions, commonly takes the form of mock combats. The immature animals are the most peaceable; it is common to find them without a scar on the skin, a condition practically non-existent among adults of either sex.

Sea lions are definitely curious with regard to objects which are strange but do not frighten them; to make a general statement, unmoving objects about their own eye-level are much less frightening than those above. I have been more than once embarrassed by the approach of sea lions when I have been sitting on the beach near them.

As to their timidity, on very little provocation, such as a sudden movement or the appearance of a person above them, a herd of hundreds will fall into blind panic and rush towards the sea—one animal takes fright and the others follow it and they do not stop until they have gone some distance, usually pausing, however, when they reach the water's edge. It is remarkable how quickly a stretch of beach will be denuded of seal by a wave of fright passing along it (Plate III, fig. 4). This kind of panic is not nearly so effective among the breeding animals at the height of the season as it is at other times. It is a little difficult to explain this timidity, since the animals have no natural enemies and have probably never seen a human being; one can understand it well enough where the sea lions have been constantly visited and chased by visitors "in order to see them run". The sea lion, when surprised, always jumps up with a bellow of fright; the effect on an unprepared horse is remarkable and is one of the reasons for the sea lion's unpopularity in the Falklands.

Very slow movement on the part of a human being, although observed, does not cause immediate alarm, only uneasiness, but this readily turns to panic. Timidity is an obstacle to enumerations, for it necessitates long periods of stillness on the part of the observer in order to permit the animals to settle down.

It has sometimes occurred to me that the timidity may be due in part to inadequate sight; *Otaria* always seems to peer at objects. The eyes are undoubtedly very sensitive.

When in repose the upper eyelids are always drooping as if to protect the eyes, and when the animal is ashore there is such a continual stream of tears that there is usually a large wet patch behind and below each eye. This flow has in the past excited the compassion of observers who attribute to the seal emotions which it very doubtfully possesses. The function of the tears is to avert the desiccation and irritation to which the eyes of the animal are liable when they are exposed for long to the air and dust. This sensitivity is so marked that many sea lions became blind in the course of a drive which was made for commercial purposes—an operation which was not repeated.

As might be expected from the uproar on the rookeries very little attention is paid to strange noises, nor does *Otaria* seem to have any liking for musical sounds; this is a taste for which *Phoca* is well known, and I believe it is found in *Hydrurga* also. When addressed in low tones the sea lion pays no heed, but shouting will often help to move an obstinate animal. Nevertheless the adult is sensitive to quite minute differences in tone, since a cow will pick out her pup's voice from among those of fifty other sea lions of all ages and she is never at fault. The pups on the other hand will answer almost any cow they hear.

Although it is inevitable that all hunting is done by sight, the sense of smell is well developed; the scent of man is at times sufficient to induce panic in sea lions at a distance of 200 yards.

The sea lion is sensitive to touch, but when consideration is given to the severe and numerous superficial wounds which they give and receive during the breeding season, it appears that they have no acute sense of pain in the skin. Scars and wounds are the rule and not the exception; they are particularly numerous on breeding cows who receive most of their injuries from the bulls.

FOOD

The diet of *Otaria* is varied; squid is perhaps the commonest food, then *Munida* and finally fish. It is obvious that squids are abundant round the Falklands. I have no recognizable specimen from a sea-lion's stomach, but examples from a large shoal of these invertebrates which entered Stanley Harbour have been identified as a species of *Loligo* by Mr G. C. Robson. By the action of the gastric juice the ink becomes a bright yellow in the stomach of the sea lion, and this colour is maintained even in the faeces. Similarly with *Munida* the faeces are brick red and skeletal parts of the crustacean are abundant in them, while the faeces derived from fish are grey and contain bones. Once these identifications had been made it was very easy to see even from a distance what had been the recently prevalent food of the sea lions.

It seems likely that the pups begin to eat solid food as a result of their habit of playing with and biting everything which takes their fancy. They may, for example, be seen gnawing the mixed growths on rocks exposed by the ebb or chewing pieces of the seaweed *Durvillea* found on the beach, and they doubtless learn by experience that some flavours are preferable to others. The stomachs of twelve pups examined in June gave the following results:

No. of specimen	Stomach contents	No. of specimen	Stomach contents
1036	Milk, stones	1119	*Munida*, sedentary ascidian
1090	,, ,,	1123	*Munida*, seaweed, stones
1103	*Munida*, spider crab	1124	Milk
1110	Empty	1128	No food, stones
1116	Milk	1142	,, ,,
1117	Seaweed	1146	Milk

These pups were in part at least subsisting on milk; but they were evidently experimenting without much discrimination on other forms of food and were taking stuff from the bottom. They were as a rule playing in shallow water only a few inches deep. I have never found ascidians or spider crabs in the stomachs of older animals. Occasionally the species eats large Medusae.

The sea lion will at times kill and eat birds. At one time I was stationed on Bird Island, West Falkland, where there is a very large rookery of the rockhopper penguin. As is usual at such places the birds could be seen coming ashore in herds, and it was common for such companies to be pursued by parties of sea lions, which were sometimes able to surround the birds and catch what suited themselves. The surviving penguins finally made for the shore at a headlong pace, and indeed all the penguins seemed to come to the island at top speed. On two occasions I found penguins badly torn and dying from wounds received from the sea lions, both birds being injured about the neck. I have also had reports of *Otaria* eating the logger or steamer duck (*Tachyeres*), which is abundant in the Falklands, and it is certain that on the appearance of a sea lion these birds will at once rush for the shore in a state of excitement.

The sea lions are very fond of cruising about in the *Macrocystis* beds, where small Nototheniid fish are plentiful, and they can often be seen plunging about far off shore where a flock of sea birds has collected. The attraction for birds and seals alike is almost certainly a shoal of *Munida* of the sort which is so often seen off the Falklands.

Many stomachs of adults contain no food nor remains of it. Of nineteen examined nine were in this state and every one of the others contained squid remains; *Munida* was present in one and fish possibly had been present in another.

In the stomach of practically every sea lion there may be found a quantity of stones, varying in size, roughly but not invariably, with the size of the animal. The details of stones taken from four stomachs follow:

No. and sex	Length of animal cm.	No. of stones	Weight of stones gm.	Size of largest stone mm.	Condition of stones
1170♂	231	6	1460	94 × 74 × 44	Beach-worn pebbles
1100♀	157	17	709	39 × 23 × 6	Angles rounded, many beach-worn
1061♀	129	22	57	23 × 19 × 9	One pebble, all others beach-worn
1051♀	96	3	174	73 × 39 × 25	All angles rounded, not pebbles

It will be observed that the number of the stones varies, and the condition. The stones are not necessarily beach-worn pebbles; they may be comparatively sharp fragments of cliff talus, although they show some signs of the grinding to which they have been subjected. Three hypotheses have been advanced to explain the presence of the stones: it may be that all are correct, and there is at least no doubt that the stones will have some of the effects suggested in (*a*) and (*b*), if only incidentally.

(*a*) They perform the same function in the remarkably muscular stomach of *Otaria* as does grit in the gizzard of a fowl, namely, to assist in pulping the food.

(*b*) The stones are ballast, taken in to trim the sea lion in the water. It is a fact that the hind-quarters are very light in proportion to the fore-part of the animal and that the pup, when learning to swim, seems to be "by the head" in nautical phraseology, that is to say too heavy forward.

(*c*) The stones serve to grind up and destroy the Nematodes with which the stomach is invariably infested (Hahn, 1884).

The stones either wear away or are thrown up, for, as has been stated, the largest stones are usually from the largest sea lions; but I have never myself seen the act of regurgitation. Nevertheless the animal is quite capable of it, since I have seen a female vomit after a fit of coughing and the stomach contents were thrown several feet. It may be remarked that the fur seal of the Falkland Islands does not normally ingest stones.

SEXUAL MATURITY

Neither sex shows the facies of the fully adult until the sixth year. The males of the fifth year are large animals; they may attain a total length equal to that of the smaller adults, but the head and neck, although well developed, fall short of the massive structure of the bull (Plate VII, fig. 1). Sections of the testis of a fifth year male shot in January show spermatozoa, but not in the same quantity as the testis of an adult male shot at the same time, and in the latter the tubules are larger.

The fifth year male may be described as sub-adult, but even if he is capable of service he would have no chance in a contest with an adult, and indeed these sub-adults are visibly afraid of the bulls. In the skull the onset of adolescence is marked by a rather rapid increase in the proportion of the zygomatic width to the length of the skull as well as by the osteological characters described on p. 284.

The female becomes sexually active about the end of the fourth year. During that year the colour of the coat and the form of the pterygoid region of the skull give indications of the approaching change, but the ovaries are only very slightly enlarged. The important change takes place between the fourth and the fifth years.

There is an alteration in the form of the skull, as is shown by the relatively increased length of the palate and the greater zygomatic width, and the ovaries become active. Three females of this stage were killed in July, Nos. 1001, 1030 and 1100, and of them, one had every appearance of having aborted, one was pregnant and the third had ovulated. They were all sexually mature.

The time and place of the fertilization of the virgin cows are obscure; I have never recognized one *in coitu*, and from the results of the counts of site No. II set out on p. 308 it appears that they do not join the harems, which are only used by the cows about to give birth.

In two of these counts the number of cows varied from 212 to 223 with an average of 217, and the number of pups, counted a little later, gave an average of 255. There were counted, in fact, more pups than cows, so that, since no cow ever produces more than one pup at a time, there could hardly have been any virgins in this rookery. It seems likely that the virgins are covered by idle bulls as opportunity offers, and it may even be suggested that abortion may be the result of excessive attention, since idle bulls are so numerous. Failure to conceive might also result from the excess of bulls, for the virgin cows could escape, as solitary cows often do, while the males were engaged in fighting.

From an examination of the available ovarian material it appears that the potential breeding season is very much longer than that which is so obvious: the true nature of things is concealed by the rapidity with which the cows come on heat after parturition and in normal circumstances the immediate availability of a bull. That there are other possibilities is shown by the condition of No. 1065 which contained an almost ripe follicle and would thus shortly have been available for impregnation, although the animal was killed on July 19, about six months distant from the "breeding season". Moreover, seven cows killed on June 8, 9 and 10 were all pregnant, with foetuses of comparable size, from 83 to 127 mm. in length; but No. 1030, which was killed on July 29 had a foetus with the great length of 269 mm. which could not possibly have been begotten at the same time as the others, even if allowance is made for the additional seven weeks.

The data are not sufficient to permit of any statement as to the oestrous cycle in this species.

BREEDING HABITS

Outside the breeding season all stages of the sea lion are more or less mixed together. As summer approaches the breeding and non-breeding animals separate, but many of the previous season's pups remain with their mothers until the next are born. The two sections of the community have their own separate parts of the beaches; but odd members of either section may occur on beaches which properly belong to the other, and on their own resorts the numbers of the non-breeding animals vary from day to day—the sea lions are constantly coming and going and shifting about.

The non-breeding herd contains all the immature seal, some of the previous season's pups and many of the idle bulls—bulls which have not been able to secure cows (Plates V, VI, VII).

The breeding herd consists of the harem bulls, the pregnant cows about to give birth, the newly born pups and the virgin cows. There is also a fringe of idle bulls, many of them the newly adult, while well-grown immature males appear from time to time but are always on the move.

It cannot be definitely stated when the breeding season begins or ends; it is at its height in the first half of January, but some pups are born in December and pairing goes on until near the end of January. The break up of the harems is gradual and its effects are visible early in February, that is to say as soon as all the cows have been covered or at any rate all except stray individuals; but at the time named, early February, the bulls still display their masculine ferocity. The season may be taken as being approximately December to February, but since *Otaria* is more or less resident on its rookeries the breeding season is not nearly so well defined as that of *Callorhinus alascanus*, which is possibly the only completely migratory Otariid (see also p. 305).

The actual breeding sites are always above ordinary high-water mark; although I have seen sites flooded by exceptionally high tides. They are always protected in some way from the full force of the sea. The rookery may be situated on a beach which is itself not exposed, such as some of those on the islands in Falkland Sound, or the beach may be so wide that this is in itself an adequate protection; failing these, off-lying rocks, reefs or kelp-beds will supply the deficiency. On some beaches the defences are only effective in summer; when the autumn gales begin such sites are abandoned, whole crowds of sea lions moving simultaneously to more sheltered places (see p. 302).

The breeding herd is not found in a continuous mass, but is broken up into separate rookeries by unsuitable stretches of coast; the actual nature of the coast is a matter of indifference, as breeding takes place on shingle, cliff talus or flat shelves.

Each rookery consists of one or more harems, and when more than one is present the rookery appears to be a continuous mass of cows with the bulls dotted about among them. The harem formation is the result of the bulls taking up their stations and, as the cows collect, of each bull keeping control of as many cows as he can (Plate II; Plate III, figs. 3, 4; Plate IV, fig. 1). Owing to the large excess of adult males the average number of cows in a harem is less than the bulls can look after, quite a large proportion of them having only one cow.

The bulls take an interest in the young cows as early as August and no doubt do their best to retain them until they come on heat. About the time mentioned I shot two young cows and on both occasions had great difficulty in driving off the bulls. One of them could hardly have been more infuriated if it had been the height of the breeding season.

There is no attempt to keep the harems separated by space; they are often so close as to be absolutely indistinguishable to the observer (Plate III, figs. 3, 4), but the bulls have always certain knowledge of the limits of their own territory and violently resist any offer of encroachment. Besides the neighbouring harem bulls the idle bulls which haunt the edges of the rookeries are a source of constant irritation to the harem bulls, who expend a good deal of energy in driving off these possible rivals: fights take place among the idle bulls also, but are not of any importance nor do they last long.

The harem bulls keep their stations with the utmost pertinacity; even if an exceptionally high tide drives cows and pups up the beach, the bulls may be seen partly submerged and even lifting with each wave, as they sit patiently at their posts waiting for the ebb.

When a new cow arrives at a harem she advances in a rather hesitating manner until she is noticed by the bull. The bull evinces definite signs of interest, one may even say of satisfaction, and after this the new cow settles down at once. Once a cow is received into a harem she is not allowed to return to the water until she has been covered by the bull, and no violence is spared to achieve this object. I have seen a cow, alarmed at my appearance, make desperate efforts to reach the water; but the bull, after striving by mere pressure against her and finding this of no avail, seized her by the flank, and in spite of her bites and struggles, lifted her back on to the rock which she had left: it may be estimated that the cow weighed three hundred pounds.

Cows from neighbouring harems will often be chased away by bulls, having presumably been covered by their own bulls, and the harem bulls will not permit their cows to fight among themselves, but roar and threaten until the cows quieten down.

The pups, of which each cow produces one, never more, are born at night or early in the morning and parturition seems to be rather exhausting to the cows. The placenta and membranes are quickly cleared away by the skuas and Scoresby's gulls which haunt the rookeries (Plate IV, fig. 2; Plate VI, fig. 2), the latter birds acting as general scavengers and consuming as much as they can find of the faeces of the sea lions. Parturition begins in December and the latest birth of which I have a record was on January 15. On the 31st of that month, however, I have seen a pup dead, but so recently born that the membranes were still covering it. I consider that this had been a still-birth. Pairing takes place soon after the birth of the pup; the latest observed coitus was on January 23, although a male was observed to make an unsuccessful attempt on the 31st. There is therefore a space of eight days between the latest live birth and the latest impregnation, so that the period of gestation must be a few days under a year.

There is a good deal of love-making among the sea lions; the male and female sit facing one another and with snaky movements twist their necks from side to side, thus caressing one another on the front and sides of the neck and occasionally rubbing their mouths together, while the cow at times grips the neck of the male in her teeth but does not bite. After doing this for some time the animals sit back with their noses in the air in the characteristic Otarian attitude: coitus seldom follows. At times the cow will endeavour to excite the bull by presenting her hind quarters and bending her head backwards until she can take hold of the male's neck with her teeth and pull at it in a playful manner; for some reason this behaviour is seldom effective.

When the male does attempt coitus the female will often try to escape, so that there is usually a good deal of growling and biting and pursuit before the bull catches the cow and holds her down by grasping her between his front flippers and resting his great weight on her, he also presses on the cow's neck and shoulders with his head and even uses his teeth if necessary; such pressure is exerted that the cow is visibly flattened out (Plate III, fig. 2). The attempts at copulation are often clumsy enough to begin with, and after an entrance has been effected the bull spends about five minutes in the movements which lead to an orgasm, grunting at times and sometimes finding it necessary to rest. The orgasm of the female is frequently well marked and accompanied by writhing movements of the head and neck, the only free parts, while she often seizes the neck of the male firmly in her teeth. It may be opportune to remark that the female does *not* "lie on her back to receive the caresses of the male" (Gray, 1844). The female definitely refuses to take the male unless she is in suitable condition.

After service the cows are permitted by the bull to resort to the sea, whence they return at intervals to suckle the pups. There is some means by which the bull can distinguish between impregnated and unimpregnated cows, probably by the sense of smell; at any rate they retain the unimpregnated in the harems and the others are allowed to come and go as they please.

When all the available cows have been covered the disintegration of the harems begins; wandering immature seal begin to mix with the cows, while the bulls spend most of their time in sleep. They have lost much of their ferocity, although they still adhere to their chosen stations on the beach and act as a sort of guard for the pups: it may well be that they are completely indifferent to the pups and protest against invasion of their sections of the rookery from habit only. During the breeding season the harem bulls have no chance of eating and very little of sleeping; they cover as many cows as possible and live in a state of almost continual warfare. As the result they are exhausted by February and often so emaciated that the vertebral spines, shoulder-blades and larynx are all easily seen, the animals presenting a striking contrast to their fat and glossy appearance two or three months previously.

In the absence of the cows for feeding the pups wander about a good deal, as soon as they are strong enough, and play with and mouth each other and all sorts of miscellaneous objects which they find on the beach. The cows suckle the pups for a period of variable length, sometimes until the next pup is born; but I have even seen young animals which appeared to be two years old sucking from cows in the breeding season. When the suckling of a pup has been carried over a breeding season it seems probable that the cow has not been impregnated, has miscarried, or has had a still-born pup. A possible cause of some of these troubles may be found in the great excess of breeding males in present conditions. Young sea lions of the previous season may sometimes be seen lying about among the cows with their newly born pups. But more usually the pups become separated from their mothers before a year is out, and in any case they have mostly begun to eat solid food by the time they are six months old (see p. 296).

When a cow returns to the rookery to suckle her pup she comes slowly out of the water, bellowing loudly until she hears the voice of her own pup among the numerous responses, and when she does so she rushes across the intervening animals without regard to the bites she receives and almost at once begins to suckle the pup. Attempts to secure milk by any strange pup are repelled with vigour. It is possible that pressure of milk rather than maternal affection is the cause of the cow's behaviour; I have seen a female seated on a rock, and beside her a restless pup which she pushed and lifted towards the teats over and over again in spite of the little creature's efforts to go away, the mother bellowing at intervals in the same way as do cows when they come ashore; finally the pup began to suck and the cow appeared satisfied.

As more and more of the cows are served and take to the water the pups begin to herd together in "pods" and spend their time playing together and sleeping (Plate IV, fig. 2). They begin to play at the edge of the water or in pools left by the tide and may be very much scattered at low water; but they return before the rising tide and seldom venture into deep water before the cows lead them out to it. The sea lion pup is a clumsy and excitable swimmer and cannot dive effectively: the efforts of the cow appear to be specially directed towards teaching the pup to dive, that is, to swim downwards. The pup is gradually coaxed from the beach by the cow calling and then swimming away, but she will come back again and again even to the water's edge, if the pup persists in returning to the shore. When the two are finally in deep water the mother begins to play about, diving and swimming idly round while the pup endeavours to follow her. It is a belief in the Falklands that the cow takes the pup on her back and thus teaches it to dive. What happens is the reverse, the pup tries to climb out of the water on to the mother's back and she is intent on diving away from under it so as to force it to swim by itself and eventually to follow her downwards.

By March there is a complete coalescence of the herd and a general restlessness sets in. Individual cows may be seen wandering along the beach accompanied by their pups, and I have seen a well-defined group of about five hundred sea lions move itself bodily along the beach for a distance of half a mile or so, for no apparent reason unless it were to find more shelter from the sea: the new site, having been empty for some time, must have been a good deal more sanitary than the previous one. Apart from these purely local movements the animals leave their rookeries and the diminution, although gradual, is steady, as is shown by the counts on Cape Dolphin rookery.

SEXUAL CAPACITY OF BULLS

From the economic standpoint the sexual capacity of the bulls is a matter of great importance, since on it depends the proportion of bulls which may be killed: an attempt has therefore been made to arrive at a reasonable figure. For a variety of reasons it was not always possible to distinguish between the classes of sea lion in the count of the whole herd, but a count of animals was made in which distinctions were recorded. Care was taken to distinguish between bulls which had one cow and those which had more than one.

The total number counted was 2298, comprising 1984 cows and 314 bulls, an average of 6·3 cows per bull. Of the 314 bulls 69 had one cow each, and after deducting them and their cows from the totals, we have 1915 cows and 245 bulls, with the increased average of 7·8 cows per bull. In the following calculations on the sexual capacity of the bulls those with but one cow are omitted, since they cannot properly be regarded as harem bulls, but rather as idle bulls which have succeeded in securing single stray cows; they are generally found on the outskirts of the rookeries or even apart from them altogether and, as is stated on p. 307, the menage is often broken up and the bull reverts to his status of idle bull.

If Table VI be examined it will be found that the number of cows in a harem varies from 2 to 12, with the average, as stated of 7·8; and that of the 245 bulls 87, or 27·7 per cent, have harems below the average, having 470 cows among them with an average

Table VI

Harems. Condensed extract from field note-book showing bulls and cows in groups as they were counted, bulls with one cow and their cows being omitted

Total animals	Bulls	Cows	Average no. of cows per bull
50	9	41	4·6
39	5	34	6·8
106	15	91	6·1
265	23	242	10·5
92	10	82	8·2
350	35	315	9·0
22	2	20	10·0
85	11	74	6·7
16	3	13	4·3
13	1	12	12·0
121	11	110	10·0
31	5	26	5·2
8	1	7	7·0
3	1	2	2·0
15	2	13	6·5
3	1	2	2·0
104	9	95	10·6
121	13	108	8·3
31	6	25	4·2
11	1	10	10·0
8	1	7	7·0
14	2	12	6·0
37	7	30	4·3
35	4	31	7·7
29	3	26	8·7
17	3	14	4·7
43	4	39	9·7
11	1	10	10·0
12	3	9	3·0
62	6	56	9·3
97	14	83	5·9
215	23	192	8·3
94	10	84	8·4
2160	245	1915	7·82

of 5·4 cows per bull. Turning now to the remaining 158 bulls, which have harems above the general average, it will be found that they constitute 72·3 per cent of all the bulls, that they have altogether 1445 cows and that their average harem is 9·15 cows per bull. Of the total bulls 58, that is 23·7 per cent, have harems over 9 in number, possessing as they do 594 cows in all—an average harem of 10·2.

Having regard to these figures I consider that 9 cows as the average harem can safely be adopted as a working basis, particularly since it is below the average harem of 23·7 per cent of these bulls. There is of course in this herd, untouched like most of those in the Falklands, a very large excess of males and this is the reason for the large percentage of small harems. It might be found that the figure of 9 is too low to work to, in order to take full advantage of the economic value of the herd. I have seen a bull with 17 cows, but am unable to say if he was able to keep them all.

Reverting to the total cows in the count of 2298 sea lions, their number was 1984, and on the basis of 9 cows to each bull they would require only 230 bulls, which gives an immediate surplus of 84 of them not required for breeding.

IDLE BULLS

Besides the harem bulls there is always a considerable but varying number of adult males, "idle" bulls, hanging about the borders of the breeding rookeries. These animals cannot be accurately counted, since, having no attachment to one part of the beach, they are always moving about and at times retire to their own particular beaches, which are not used by the breeding herd, in order to sleep: there is always a chance that some of them may acquire a cow and thus cease to be idle bulls in the strict sense of the term. Their numbers are usually tolerably high compared with the harem bulls, on a stretch of beach containing 150 bulls, 88 of them had harems of more than one cow, 27 had one only and 35, or 23·3 per cent, were idle bulls.

If, as there is every reason to suppose, the sexes are born in equal numbers, and if there is no selective death-rate (of which there is no indication), the number of adult bulls should equal the number of breeding cows since they are of the same ages; but if this is so it is clear from the work on Cape Dolphin that all the bulls are not ashore there at one time. There were indeed some hundreds usually to be found at two particular places, as is indicated on p. 298, but there were not bulls equal in number to the estimated number of breeding cows—4500. An explanation of such apparent deficiencies may be found in the accumulations of bulls which are found sometimes at places where there is no breeding herd at all, or next to none. Thus, in the neighbourhood of Macbride Head in East Falkland there were at the end of December two places where small breeding rookeries were established. At one there were 40 breeding cows and 69 bulls and at the other there were about 250 cows and only 10 bulls: the nature of the ground, however, made an accurate count impossible. Between these two places and at least a mile distant from each are two bays, and in one of these there were 364 and in the other 631 bulls of *Otaria* (Plate V, fig. 2); and farther to the east there was another company of 30 bulls in a small valley. At Macbride Head there were five cows and in the valley one. There were thus 296 cows and 1104 bulls in this locality, a surplus of bulls so great that it could not possibly have originated from the little breeding rookeries in the neighbourhood. It is an interesting speculation whether Cape Dolphin may not have been the origin of the majority of these surplus males, since it is the only large breeding rookery within a reasonable distance.

Again, at Cape Meredith on West Falkland 271 cows were found in January on the breeding rookery, attended by 68 harem and idle bulls; but at a distance of about two miles there is a well-known hauling ground for bulls where there were 140 of them.

On this part of the coast the numbers of the sexes were more nearly equal than they were at Cape Dolphin, since here there were 208 bulls to 271 cows. Other examples of herds consisting almost entirely of males could be given, but enough has been written to show that many of the idle bulls have their own beaches and hauling grounds and that they may be found on them even in the breeding season. A few stray cows may be found on the outskirts of such places and they have as a rule been taken charge of by bulls (Plates V, VI, VII).

MIGRATION

Whether or not any of the animals engage in a partial migration from the Falklands is doubtful, since they may merely be spread about the very extensive coasts. They certainly leave some places altogether for the winter, but not all, nor is every rookery completely abandoned. There seems to be no certain rule; thus High Island and Green Island in Salvador Waters, East Falkland, are only two miles apart; but the former is altogether forsaken in winter, whereas the sea lions remain on the latter all the year round. So far as I know both islands are breeding places and they are completely sheltered, being many miles from open water.

Devincenzi (1925) says that from Lobos Island, Uruguay, there is a migration *to the south* in early winter, but that the sea lions return after a short absence, and he further states that only the sick and aged are left behind. This is not so in the Falklands: *Otaria byronia* is present in the islands in reasonable numbers throughout the year and seldom abandons completely the recognized rookeries.

Sea lions may be met with, as late as December, in an area of water roughly 120 miles north of the Falklands—not on passage, but playing and feeding in a region which must be a rich feeding place, since birds are numerous and one usually expects to see whales there. Early in November, I have seen parties of sea lions apparently on a passage south, when I have been approaching the Falklands from Monte Video. *Otaria* may possibly be partly migratory so far as the Falklands are concerned, and it at least goes a long way off shore to feed.

LENGTH OF LIFE

Accurate information as to the length of life of *Otaria byronia* is sparse. Flower (1931) mentions two females which lived in the collection of the Zoological Society for $16\frac{1}{2}$ and $17\frac{1}{2}$ years respectively. The second animal was believed to be 2 years old when it was brought to London, and this would bring her age to $19\frac{1}{2}$ years when she died. He records the following ages for other Otariids in captivity: *Eumetopias*, 17 years (one specimen); *Zalophus*, $12\frac{1}{2}$–19 years (6 specimens); and *Arctocephalus pusillus* $12\frac{1}{2}$ and 20 years. Males of the northern fur seal, *Callorhinus alascanus*, are known to live to 12 or 14 years, but branded cows which were 17 years old have been seen. The whole family is obviously tolerably long lived.

Mr R. Greenshields, who is a resident in the Falklands, informed me that he was at one time well acquainted with a large male sea lion which came up annually in the same place and superintended a particularly large harem. I asked if this animal came up for 5 or 6 years and was told that it was more than that.

I suggest that 7 years would be a reasonable estimate for the length of adult life. On this basis the life of the male, with 5 years of immaturity, would be 12 years and the life of the female would be 11 years including 4 years of immaturity. This may be, and probably is, too low; but if the figures are to be used in calculations for the management of the herd it is best that they should be conservative.

PARASITES

No external parasites were found. For the identification of the internal parasites, with the exception of the *Halarachne*, I am indebted to Dr H. A. Baylis of the British Museum.

NEMATODA. *Contracaecum rectangulum* (v. Linstow, 1907) has been identified from specimens taken from the stomachs and intestines of six individuals. It is almost invariably present in the stomach and occurs sometimes in tangled masses partly embedded in the mucosa. A new species of *Uncinaria* was found in several dead pups. It has been described by Dr Baylis under the name of *Uncinaria hamiltoni* (Baylis, 1933).

ACANTHOCEPHALA. In a single sea lion a few specimens of a greenish parasite were found in the intestine. These are a species of *Corynosoma* which resembles *C. hamani* in appearance, but is apparently different from that species and also from *C. bullosum*; it may be an undescribed form.

CESTODA. This group is represented by two species. Of the one, two specimens, all that were seen, were taken from the intestine of a young female and are probably *Diphyllobothrium scoticum* (Rennie and Reid, 1912). The second species is represented by cysticercoids from the blubber of *Otaria* and belongs to a species of *Phyllobothrium*. The cysticercoids are identical with specimens which I collected from the blubber of a leopard seal (*Hydrurga*) in the Falklands and are perhaps the same as the form recorded by Rennie and Reid from the blubber of the Weddell seal (*Leptonychotes*). I have also found somewhat similar cysticercoids in the blubber of the fur seal and of a dolphin in the Falklands and in the blubber of the Sperm whale elsewhere.

ARACHNIDA. In the posterior part of the nasal passages of many animals a number of thin whitish objects were found adhering to the dorsal wall. These have been identified as mites of the genus *Halarachne* belonging to a new species, and are the subject of a separate paper (*infra* p. 321) by Dr S. Finnegan of the British Museum. After I had begun to observe the presence of these parasites I found them in every sea lion I examined and became convinced of their constant occurrence.

OTHER DISEASES. No other diseased conditions were noticed except very frequent nasal catarrh and coughs: both of these are probably due to the dust which is present in considerable amount in dry weather at such places as Cape Dolphin where the beach is partly clay. The fits of coughing are sometimes so severe as to induce vomiting.

CAUSES OF DEATH

A considerable number of pups are always found dead on the rookeries and many more must escape observation. Towards the end of the breeding season I went over the site of a rookery where the average number of pups had been 255. Fifteen dead pups were found in various stages of decomposition and these alone indicate a death-rate of 5·6 per cent before the break up of the harems and before the onset of winter conditions. The true death-rate is higher, since the young pups are frail and dead ones will soon be stamped out of sight and out of all recognition by the crowd of living seal.

After the breeding season pups are often met with in a state of extreme emaciation, either very sick or dead, and post-mortem examination shows an *Uncinaria* infection and a blood-stained condition of the mucus which fills the intestines. The parasite is probably the cause of the sickly condition and eventually of death.

Some loss may be attributed to isolation due to the possession of a single cow by a bull. These groups are often found detached and sometimes remote from the rookeries, and the two adults seem particularly liable to wander, with the frequent result that they do not come back and the pup is left to die. The solitary cow goes away to feed, and is probably drawn towards a crowded part of the beach on her return journey and is thereafter unable to find her former position on the shore (see p. 293). The bull which had been her master would return to some place where his sexual impulse had more opportunity of being satisfied. Even on the rookeries pups die of starvation through wandering away at an early age or through the cows failing to return to their own places.

The violence of their own species is the cause of some deaths: cows will handle strange pups very roughly. One young pup, only a few days old, was found dead with deep wounds in the liver where the fangs of an older seal had crushed into it and there had been extensive bleeding into the coelom. I have seen a large immature male chase a pup and throw it about when caught, apparently for amusement.

Young immature sea lions are often found dead in winter; their frequency shows that the death-rate is higher then than it is when they become older, for the more advanced immature animals are practically never found dead. Of these young animals five skulls were collected from specimens which could be dealt with. I was not able to find any cause of death; most of the animals were tolerably fat and some at any rate had died where they lay, above high-water mark; but others were found below on the tidal beach, sometimes wrapped in masses of kelp thrown up by heavy seas. Some of these animals were probably drowned, as is almost inevitable in a species which has at times to swim off shore against a heavy sea; but this would only explain part of these deaths. Birds of prey, probably giant petrels, often completely eviscerate dead seals which they find on the beach, either through the natural openings or through quite a small hole torn in the axilla where the skin is thin (cf. Matthews, 1929, p. 573).

Of older sea lions one harem bull died in the middle of a rookery in the height of the season; he had no wounds visible from a distance, nor had he seemed to be sick when I saw him, which was almost every day: some time afterwards I was able to examine the carcase at close quarters, when it was considerably decomposed, but no marks were found on it. It may be suggested that this animal had simply reached the end of his natural term of life and that the great strain of the breeding season had been too much for him. Similarly a very large cow was found dead without marks of external violence; she was the second largest cow which I handled: she had unfortunately been eviscerated by the birds.

The leopard seal is responsible for a certain number of deaths. I have had a report of two leopard seals attacking a large sea lion and killing it, and the stomach of one killed in October, when the previous season's pups are quite large animals, was full of lumps of skin and blubber of such pups, as well as other fragments. The leopard seal is so uncommon in the Falklands that it can be of no importance as a menace to the sea lions.

In the Galapagos sharks are stated to eat the pups of *Otaria byronia*; but there are no sharks in the Falklands. Killer whales appear to be extremely rare: I have never seen them and have found only one skull on many miles of beach. Land carnivores are absent, nor are there any birds of prey sufficiently powerful to attack even a pup of *Otaria*: the species has in fact practically no natural enemies at all in the islands.

ESTIMATION OF NUMBERS

Although the sea lion is to be found at all times in the Falklands it varies considerably in concentration. At the height of the breeding season the number of adults on the rookeries is at its maximum, but after the breeding season the animals begin to disperse and continue to do so during the winter. It is only a short time before the following breeding season that the sea lions begin to concentrate on the breeding rookeries, the bulls taking up their stations before the cows assemble. As late as December 17 a count on Cape Dolphin yielded the following result, which includes at least as many bulls as a count in the height of the season: bulls 1650; cows 207; pups 32; other stages 337; total 2226.

On the Cape Dolphin rookery the maximum number is present about the middle of January: at this time an actual count of the sea lions present came to 6282, of which 5346 were breeding animals. Pups are excluded from the total, but immature sea lions and idle bulls are included. This count does not represent the entire herd pertaining to Cape Dolphin, since the immature seal are on the move the whole time and many of the idle bulls take to the water also. The idle bulls may indeed haul up elsewhere, as is suggested on p. 304: they amount to some hundreds.

In order to determine the day to day variability of the population a stretch of shore containing an assembly with clearly defined limits was chosen for counting at short intervals. The result is as follows, the numbers referring to breeding adults, bulls which were stationary, and cows:

Date	No. of sea lions on site II
January 11	250
,, 12	265
,, 12	259
,, 21	253

The average is 257, while the variation in either direction is comparatively small. Although just at this season any one count of adults does not very seriously depart from an average, as more and more cows are covered by the bulls the counts quickly become much less reliable, since the cows then resort to the sea in ever increasing numbers and return to suckle the pups at irregular times. As soon after the date of the last count as January 23 only 190 adults were found on this stretch of beach.

Counts of two groups of pups were made in the same way. This class is certainly all ashore at the same time, but their small size and restlessness makes counting difficult; at times it is indeed impossible, such as at low water on a wide beach, when they are spread all over the beach and into the shallow water and are most energetic. In spite of the difficulties a count of pups is preferable to all others, although a count of breeding cows in the earlier part of the season is, as has been shown, tolerably reliable and it is certainly easier to carry out.

The counts of pups made on two sites are as follows:

Date	No. on site I	No. on site II
January 31	457	232
February 4	479	269
„ 5	474	244
„ 6	488	286
„ 7	454	246

By the date of the next count, February 13, the breeding organization was much broken up and many of the pups had moved away; the numbers seen were: site I, 336 and site II, 217. Counts of pups therefore should if possible be carried out between January 21 (the date of the last observed birth) and the end of the first week in February.

To sum up, counts of cows may be made up to the end of the third week in January, but thereafter pups only should be counted.

RATE OF INCREASE

The rate of increase is a matter of importance with reference to the future of the herd. It depends on two factors, birth-rate and death-rate. As to the first, this is dependent on the length of life of the cows and on the age at which they first give birth. The evidence points to the occurrence of the birth of the first pup when the cow is five years old, and it is suggested that seven years would be a reasonable length of breeding life to allow; therefore each cow, apart from accident, would bear seven pups during her life. There is no means of arriving at the death-rate at present; that it is heavy during the first year is shown by the finding of so many dead pups, and judging from the increased rarity of dead seals in subsequent stages, it declines after the first year. Man does not molest the species to any serious extent, except as regards the activities, of late years, of a small commercial sealing company.

The northern fur seal is the only Otariid of which there is information as to the length of life and the death-rate in the natural state. The death-rate of the males is enormous, over 80 per cent for the years of life until the animals are adult and about 30 per cent per annum after that. The rates for the cows are: 35 per cent in the first, 15 per cent in the second and 10 per cent in the third year, that is 73 per cent for the first three years.

This fur seal suffers considerably from the attacks of the killer whale and, as is well known, spends a large part of each year exposed to the hazards of an extensive migration. On the other hand this species produces the first pup at the age of three years, and branded cows have been seen with pups at the age of 16 or 17 years. The average annual rate of increase at the Pribilof Islands is 5 per cent, but it has been known to fall as low as 3 per cent and to rise to over 11. It is suggested in the section on the economic aspect of *Otaria* that a rate of increase of 8 per cent per annum may be assumed for the present.

DAMAGE DONE BY SEA LIONS

To fish. Complaints have been made from time to time that the sea lions, particularly those from the islands in the approaches to Stanley Harbour, prevent "mullet" (*Eleginus*) and "smelt" (*Basilichthys*) from coming in to places where they may be caught with a seine net or hand line, or destroy quantities of them. It may be mentioned that the harbour mouth at the place where the islands are situated is three miles wide, and there is no sign at any time of a barrage of sea lions across it. The food of *Otaria*, as has been said, includes fish, but it feeds very largely on squids and *Munida*.

Although it is no doubt true that the actual presence of a seal of any sort at a place where there is a shoal of fish will disperse them, it seems much more likely that the variations in numbers of the fish are due to factors which have nothing whatever to do with the sea lions. No complaints of the activities of the seals are made when the fish do come in, as they continue to do. Similar complaints have been made with regard to the sea lions of the Pacific coast of North America, referring to the "salmon"; but investigation has shown that these allegations are almost without foundation and that the diminution has been due rather to methods of fishing. There is not in any sense of the words a fishing industry in the Falklands.

To penguins. The sea lion has been blamed for the diminution of the gentoo penguin, a species which is much valued for the sake of its eggs and for the real improvement in pasture land which it brings about. There is no proof of the culpability of *Otaria*; so far as I have seen birds are not usually eaten; if they were, neither logger (steamer) ducks nor penguins could maintain their numbers against the onslaughts of the sea-lion herds in the Falklands.

The diminution of the gentoo penguin may rather be due to the continuous and merciless robbing of the eggs to which the bird has been subjected for many years. Another factor in the reduction of the numbers of this bird may be found in the epidemics which occur from time to time.

To tussac grass. Besides the actual beaches *Otaria* favours the land near them, particularly where tussac grass (*Poa flabellata*) grows. The animals are fond of going in among the high tussocks (tussac bogs, in local speech) in order to sleep in shelter, and they often climb on top of the plants for the purpose.

Tussac grass grows mostly on the smaller islands where the ground is soft and peaty; but where the sea lions travel through and lie about on it, the ground becomes much hardened and is often worn so smooth that it is slippery in wet weather. The plants on which the animals rest are flattened out, while the vegetation is almost completely killed off if the sea lions are sufficiently numerous (Plate VI, fig. 2; Plate VII, fig. 1).

In the Falklands tussac grass is much used as food for horses and cattle, either as green forage or as pasture; it is commonly stated that domestic animals will not eat tussac with which sea lions have been in contact on account of the smell of them and their excrement, and there is no reason at all to doubt that this is so. On the other hand the sea lions definitely improve the ground on which the tussac grows by hardening it in the manner described above, by keeping down the dense tangle of dead leaves between the "bogs" and by fertilizing the ground.

The evidence points to this, that the presence of a small or even a moderate number of sea lions is beneficial to tussac, but the presence of a large number is detrimental, because the grass will be destroyed.

On the main islands the sea lion comes inland at a few places where there is no tussac, but the amount of pasture destroyed is absolutely negligible. In some localities the effect is definitely beneficial, through the destruction of the uneatable flora and the fertilization of the soil, which eventually results in the growth of grass in place of the other plants.

The damage done to the tussac is insignificant compared with the total area on which the plant grows luxuriously, and much of this area is almost or quite inaccessible for pastoral purposes. The complaints which have been made are based on the presence of more or less numerous sea lions on islands which are convenient for grazing or cutting, or on land which has been artificially planted. Some of these complaints were justified and have resulted in the granting of official permits to kill or drive off sea lions from specified places on various farms; but the killing of sea lions under these limited permits has in no way injured the herd up to the present time. The system requires, however, rigorous supervision, since there are people who would like to see the sea lions very seriously reduced or completely exterminated because they dislike the animals.

There is a general prejudice against the sea lion in the Falklands, partly because many of the people who work on the tussac islands are rather frightened of them and the misdeeds of the animals are therefore exaggerated. In the Falklands horses are a vital means of transport, and one reason for the prejudice against the sea lions is the dislike which most horses seem to have for them. It may be that the horses dislike the smell of a carnivore, but it is open to question whether much of the dislike is not taught to the horses through bad handling; a horse taking fright on its first acquaintance with a strange animal, such as a sea lion, is promptly beaten by the rider, with the inevitable consequence that fear is fixed in the horse's mind—fear not so much of the sea lion as of being beaten again for having seen the strange animal. I found that horses are very readily accustomed to the smell, sight and sound of sea lions; it was indeed easy enough to persuade them to tow dead seals back to my camp on the end of a rope, an act which one would suppose was sufficiently alarming. Sheep and cattle pay practically no attention to sea lions.

In concluding this section it is desirable to lay stress on the value of the sea lion as an asset to the colony and to emphasize the necessity of keeping permits for its destruction to the lowest possible figure and of granting them only after the most careful consideration.

COMMERCIAL UTILIZATION

It has been mentioned on p. 272 that sea lions were valued by the earlier voyagers as a source of supply of fresh meat; but they were known to have other uses. Hawkins (1593) says: "They are beneficial to man in their skinnes for many purposes; in the mostaches to make pick-tooths, and in their fatt to make train-oyle". In his account of Anson's voyage in 1740 Walter details the uses to which seal oil was put; he is writing it is true of elephant seal oil prepared at Juan Fernandez, but it is obvious that other seafaring people must have had the same requirements as Anson. Walter says: "The oil made served for several purposes, as burning in lamps, or mixing with pitch to pay the ship's side, or when worked up with wood ashes to supply the use of tallow (of which we had none left) to give the ship boot-hose tops" (that is, to apply between wind and water). Byron replenished his oil supply from sea lions in the Falklands (Callander, 1768), and Cook did the same at New Year Island in 1775, when he found a sea-lion rookery there (Forster, 1777).

As whalers and sealers ventured more and more into the Southern Ocean the seals of the Falklands attracted their attention. The history of this period is not well known, but seals of all species evidently were far more plentiful then than now. "Sea lion" is used for both *Otaria* and *Mirounga* and both species were hunted, the latter almost to total extinction in the colony at a date which may be placed about 1870. Some of the older sealers combined fur sealing and oil cooking, but the two businesses eventually came to be rather separated, in the Falklands at any rate. Even now there may be found the remains of the stone hearths and sometimes the large cast-iron cauldrons used by these sealers, who also prepared a good deal of penguin oil, to the great and permanent detriment of some of the rookeries of those birds. Lance heads surviving from the seal-hunting times are occasionally met with; they are about 30 in. long in the shaft, which is about $\frac{1}{2}$ in. thick and terminates in an oval blade about 4 by $2\frac{1}{2}$ in. Skulls and other bones of sea lions and elephant seals are to be found at the boiling down places. This commercial sealing persisted in the Falklands until within living memory but eventually it died out.

Besides the oil and hides, other parts of sea lions have been, and perhaps still are, used in trade. A few years ago, when there were in Stanley two Chinese seamen detained there by some legal matter, one of them approached me with a polite request for a few sea-lion whiskers, for which it was difficult to imagine that he had any use.

I have since learned that in North America there was and may still be a regular business for the supply of "sea-lion trimmings" to China, a set of trimmings consisting of the vibrissae and dried genitalia of an adult male sea lion. The vibrissae are used as prickers for opium pipes and the genitalia in the preparation of rejuvenating draughts for aged mandarins.

In recent years an attempt has been made to utilize the sea lions in the Falklands commercially, the principal product being the oil; hides also were exported but only experimentally. The oil business has not met with success, partly because it was started at a time when oil prices were falling and they have remained low ever since.

The official returns made by the company include the number of seals killed and the amount of oil produced; but during part of the time for which returns are available elephant seals were being taken as well as sea lions, and at two places special permission was given to kill all stages of the sea lion in order to reduce the damage they were reported to be doing to pasture. Apart from such exceptions only adult male sea lions could be killed.

For the purposes of this paper selections have been made from the returns and they comprise adult male sea lions only, these being the animals on which any commercial operations must be based. The following figures are from the report for the year 1930:

Month	Number of sea lions	Oil produced gallons	Average amount of oil per sea lion: gallons
May	368	3012·40	8·19
June	273	2479·90	9·08
July	589	5869·06	9·96
August	846	10969·20	12·97
September	2033	29020·44	14·27
October	454	4830·63	10·64
Totals	4563	56181·63	12·31

It will be observed that there is a steady rise in oil production per animal, that is of fatness, through the winter up to October, when there is a sudden falling off. Five catches for October are recorded and among themselves they show a downward tendency, they are the following:

Number of sea lions	Number of gallons per sea lion
71	11·27
187	11·50
100	9·60
44	10·00
52*	9·23

* This catch of 52 animals includes three leopard seals.

With the exception of the last catch all the animals were killed at one of two places which had been industriously worked all winter; I incline to believe that the October catch included a proportion of not quite mature animals, since it is hardly reasonable to suppose that the adult bulls begin to fall off in condition shortly before the breeding season, and their physical appearance at that time does not justify the idea.

The total number of seal in the table is 4563, which produced 56,182 gallons of oil, equal to 1404·54 barrels of 40 gallons each or 234·09 tons. During a working period of seven months the average production of oil was 12·31 gallons per animal, varying from about 8 to about 14 gallons according to the season. From 2·8 to 5 sea lions are therefore the equivalent of a standard barrel of oil and from 17 to 30 the equivalent of a ton. The mean of 2·8 and 5 is 3·6 which gives a value of 11·0 gallons per animal, 21·6 (say 22) sea lions to the ton of oil, and 45 tons per 1000 animals. The present price of seal oil is in the neighbourhood of £15 per ton, and if 22 sea lions produce a ton of oil, this gives a value of 13*s.* 7*d.* to each animal, exclusive of the value of the hide, if any.

The sea-lion herd in the Falklands is very large: it is not outside the bounds of possibility that it may exceed 100,000 head. It must therefore be regarded as an asset to the colony, containing as it does potentialities for the supply of oil and hides for an indefinite period, if properly managed. It cannot therefore be too strongly urged that every effort should be made to encourage this animal and to maintain the breeding herd in its highest state of efficiency.

Having regard to the great excess of adult males the herd would benefit by selective killing and might achieve a more rapid rate of increase. The continual fighting and trampling about in the rookeries and the single cow harems represent definite waste, for each bull can look after a number of cows.

In using the sea lions as a source of supply for oil *the killing must be restricted to adult males*, since they are the only class which can be reduced without risk of damage to the herd. There is an excess of bulls much beyond the breeding requirements, and the bulls are also the most remunerative to work. A reservation must be made for breeding purposes, and the proportion of the bulls to be reserved depends on two factors: (i) the sexual capacity of the bulls, and (ii) the rate of increase of the sexually mature cows.

The sexual capacity of the bulls has been discussed, and on p. 304 it is suggested that a proportion of one bull to every nine cows is desirable, to start with at any rate. As for (ii) it is clear that the annual increase cannot be very great owing to the substantial death-rate in the first, and although to a less degree, in the subsequent immature years also. The northern fur seal cows increase by 8 per cent per annum and the Falkland Islands fur seal as a whole had increased by 50 per cent in the seven years preceding 1930; on calculation this represents an average increase of about 6·0 per cent per annum. The sea lion is tolerably closely related to the fur seal, and is a good deal larger and therefore the less liable to the attacks of other animals. In the entire absence of any other guide it seems not unreasonable to adopt 8 per cent per annum as a provisional figure for the rate of increase of breeding sea-lion cows, and since there is no indication of a selective death-rate at present, it may be adopted as the figure for the rate of increase of the bulls. The bulls become adult at the same age as that of the females when they produce their first pup, and it will be remembered that it is on the counts of the breeding cows or the pups that a census must be based.

As an illustration of the way in which this assumed rate of increase may be used the Cape Dolphin rookery may be considered. There are here, in round numbers, 4500 breeding cows; these will require 500 bulls, and the increase of 8 per cent (360) will require a further 40 bulls at the allowance of nine cows to one bull. An allowance must be made for stray cows and for virgin seal coming up for service for the first time; 10 per cent should be sufficient for this, and a further 10 per cent should be allowed for unforeseen factors, bringing the total reservation to 648 bulls. Since there are as many bulls as there are breeding cows there will be 4500 of them, and this, less, let us say, 650, gives the figure of 3850 as the number of surplus bulls. If, for the sake of convenience, the killable surplus is taken at 3500, seven bulls may be killed for every nine breeding cows and on this basis 77 per cent of the catch analysed on p. 313 could have been taken from the herd based on Cape Dolphin.

To sum up, with an increase of 8 per cent bulls in the untouched herd may be killed until the catch represents 77 per cent of the counted breeding cows and thereafter a number of bulls equal to the difference between the increase of the bulls (8 per cent per annum) and the number of additional bulls required to serve the additional 8 per cent of cows. Thus of the increase of 360 bulls mentioned above, 40 would be required for the 360 additional cows, leaving 320 as surplus—almost exactly 7 per cent of 4500, the total number of cows. As a precaution the lower figure of 6·5 per cent of the counted cows should be used to calculate the number of bulls which might be killed annually.

There is good reason to suppose that the sea lions of the Falklands can be exploited profitably, and that if due precautions are taken a sealing industry can be established on a permanent basis. Hitherto only a few of the existing rookeries have been worked, and even on these many more bulls can be taken before the accumulated surplus of this sex has been removed. In a revival of the industry it is important that operations should be spread over all the herds and not limited to a few of the more convenient sites, and efficient supervision of all sealing will be indispensable. Even if all the rookeries are exploited some years must elapse before the surplus bulls are removed, and by this action, as already noted, definite improvement in the herds will be effected. Thereafter, when the surplus of adult males is exhausted, the extent of the industry must be regulated on the lines set forth in this report, each herd yielding annually 6·5 per cent of its total number of bulls. Regulation can only be based on an adequate census of the herds, and to take such a census is obviously a matter of considerable difficulty. Few of the rookeries are easy of access, bad weather will hinder operations, and as explained on p. 309, there are only two short and consecutive periods durin the season when the work can be undertaken.

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PLATE I

Breeding Places

Fig. 1. On cliff talus, Cape Meredith, West Falkland.

Fig. 2. On open beach, Cape Dolphin, East Falkland.

Fig. 3. On rocky shore, Cape Meredith, West Falkland.

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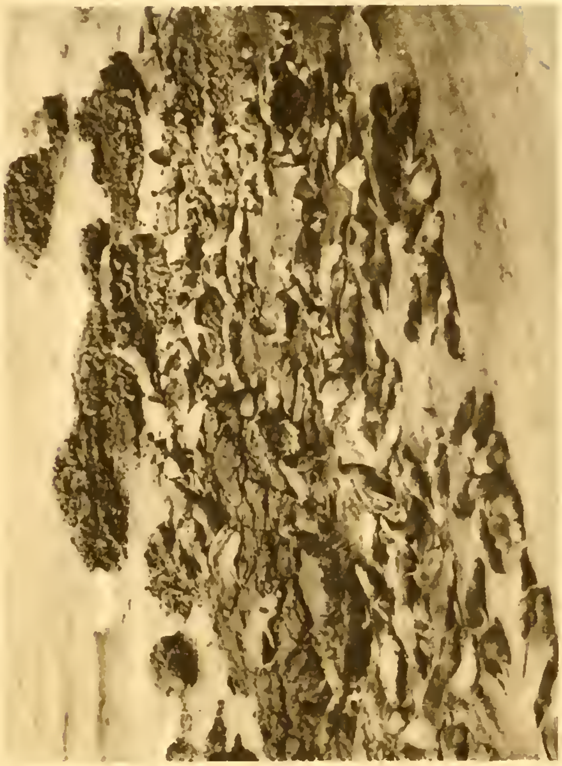

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THE SOUTHERN SEA LION

PLATE II

Breeding Animals

Fig. 1. Cow and bull at the beginning of the season, before birth of pup.

Fig. 2. At the beginning of the season, but some cows have already given birth.

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PLATE III

Breeding Animals

Fig. 1. Bull with small harem of two cows.

Fig. 2. Bull and cow *in coitu*.

Fig. 3. Several moderate-sized harems, animals at ease.

Fig. 4. A larger congregation than in Fig. 3, animals alarmed.

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PLATE IV

Breeding Animals

Fig. 1. Towards end of season, pups crowded together after an alarm, bulls keeping station.

Fig. 2. Pups playing in rock pool, several adults are also to be seen. Scoresby's gulls in attendance.

Fig. 3. End of season, animals spread over the beach.

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PLATE V

Non-breeding Animals

Fig. 1. General view of a hauling ground at Cape Dolphin, East Falkland. Many idle bulls are present.

Fig. 2. One of the two hauling grounds at Macbride Head, East Falkland.

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PLATE VI

Non-breeding Animals

Fig. 1. Sea lions, almost all idle bulls, at the water's edge, sleeping, playing and fighting.

Fig. 2. Idle bulls on ground planted with tussac but denuded, largely by the sea lions. The animal on the right shows the action in walking. The attitude of the bull in the foreground is typical of the whole family when resting.

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PLATE VII

Non-breeding Animals

Fig. 1. Idle bulls on ground planted with tussac but denuded. The animal on the left shows the action in walking. Fifth year male.

Fig. 2. Idle bulls asleep on hauling ground at Cape Dolphin, East Falkland.

Fig. 3. Idle bulls on the beach at about high-water mark.

Fig. 4. Immature seal asleep on their hauling ground at Cape Dolphin. There are one or two idle bulls present.

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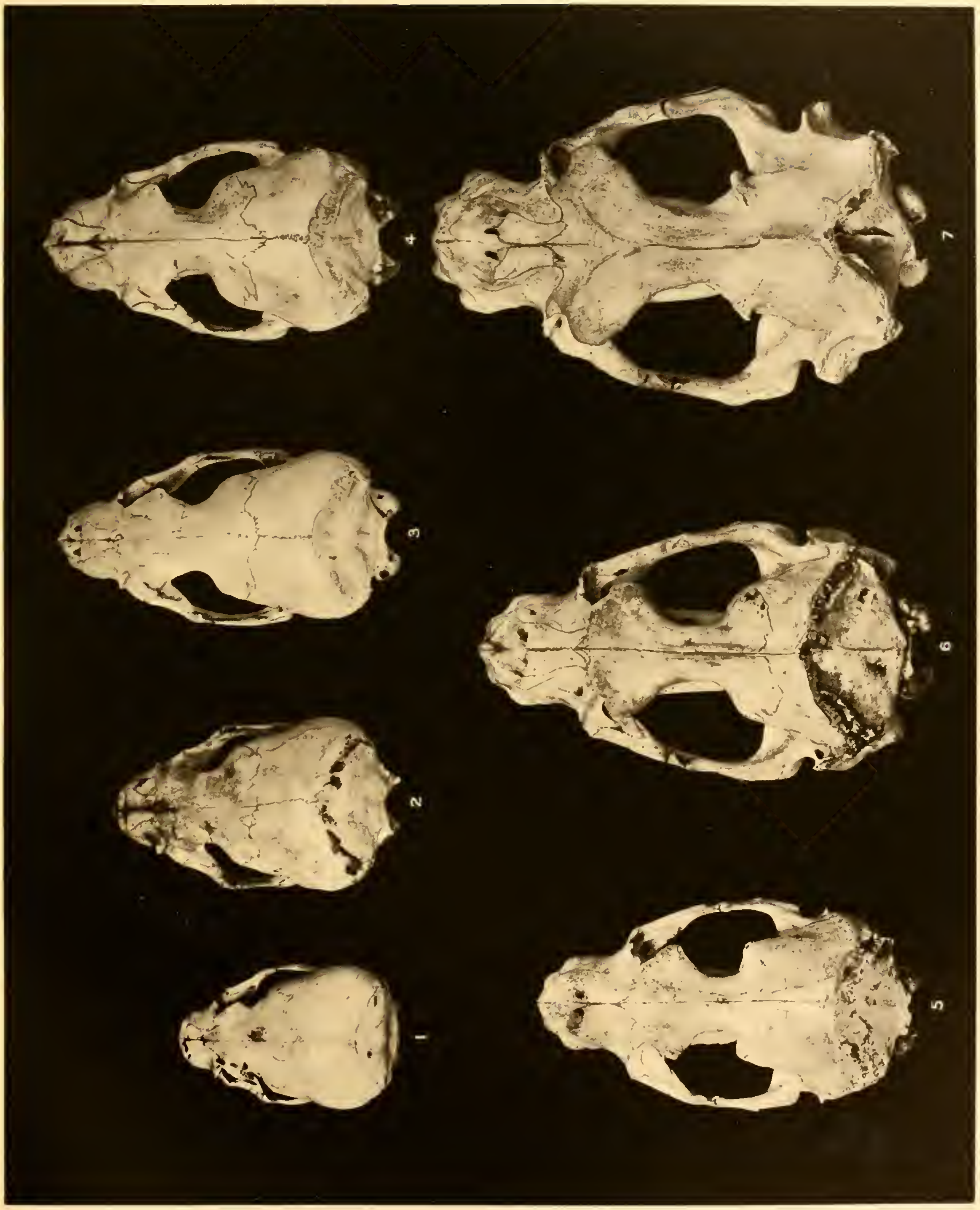
THE SOUTHERN SEA LION

PLATE VIII

Skulls of Southern Sea Lions, males. Dorsal aspects.

Fig. 1. Newly born, No. 1087.
Fig. 2. First year, No. 1090.
Fig. 3. Second year, No. 1136.
Fig. 4. Third year, No. 1109.
Fig. 5. Fourth year, No. 1106.
Fig. 6. Fifth year, No. 1135.
Fig. 7. Sixth year or over, No. 1079.



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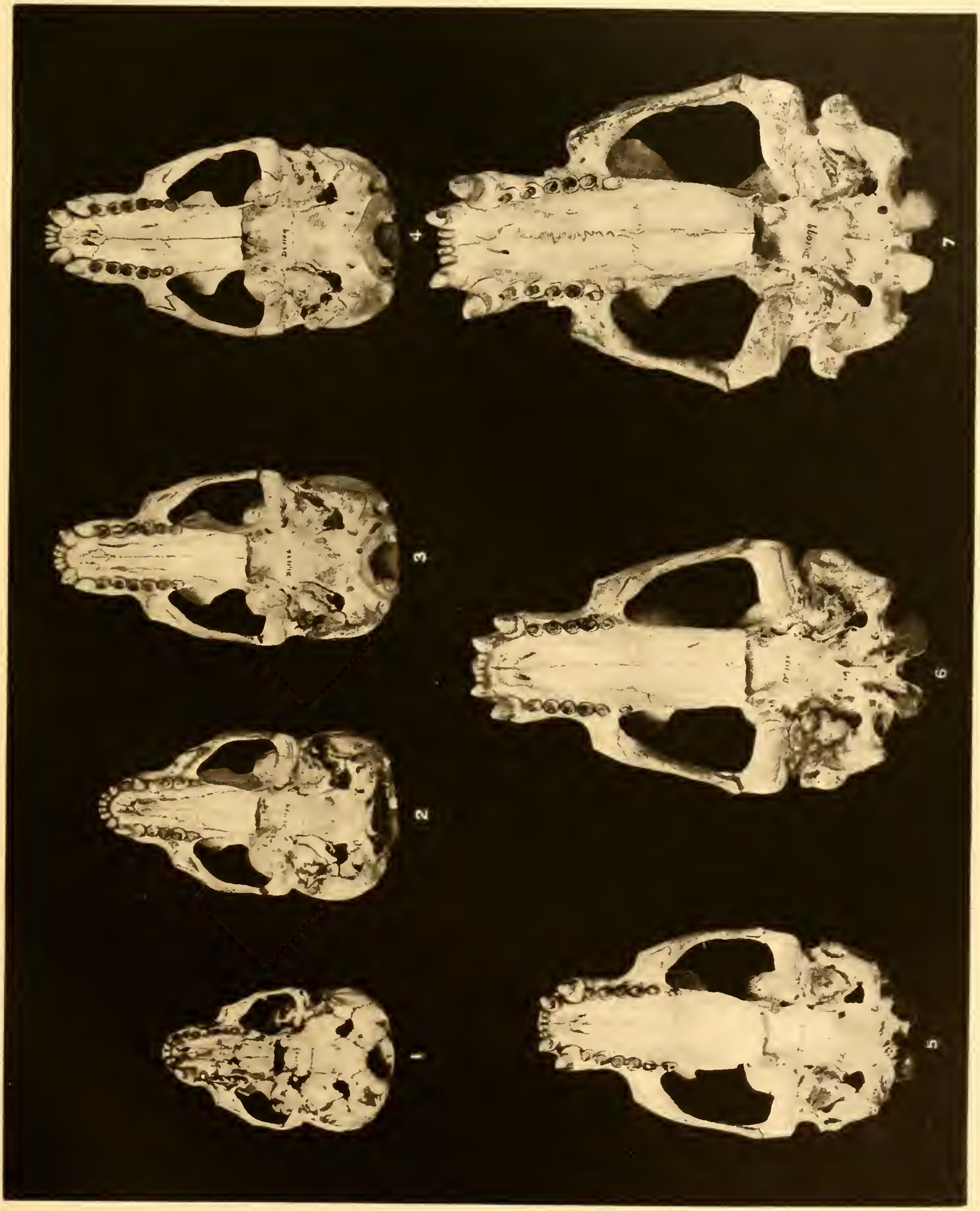
THE SOUTHERN SEA LION

PLATE IX

Skulls of Southern Sea Lions, males. Ventral aspects.

Fig. 1. Newly born, No. 1087.
Fig. 2. First year, No. 1090.
Fig. 3. Second year, No. 1136.
Fig. 4. Third year, No. 1109.
Fig. 5. Fourth year, No. 1106.
Fig. 6. Fifth year, No. 1135.
Fig. 7. Sixth year or over, No. 1079.

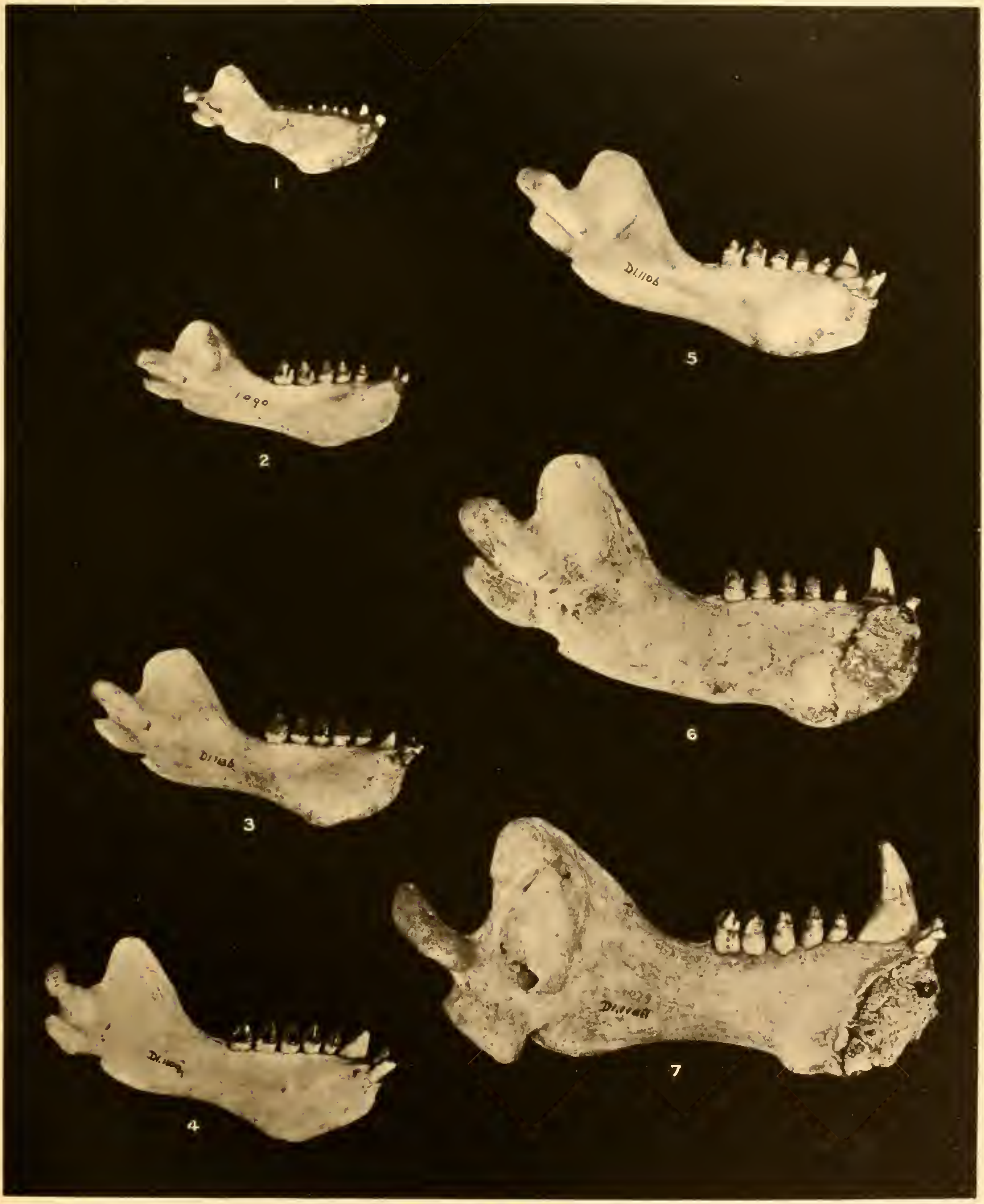


THE SOUTHERN SEA LION

PLATE X

Lower jaws of Southern Sea Lions, males. Internal aspects.

Fig. 1. Newly born, No. 1087.
Fig. 2. First year, No. 1090.
Fig. 3. Second year, No. 1136.
Fig. 4. Third year, No. 1109.
Fig. 5. Fourth year, No. 1106.
Fig. 6. Fifth year, No. 1135.
Fig. 7. Sixth year or over, No. 1079.



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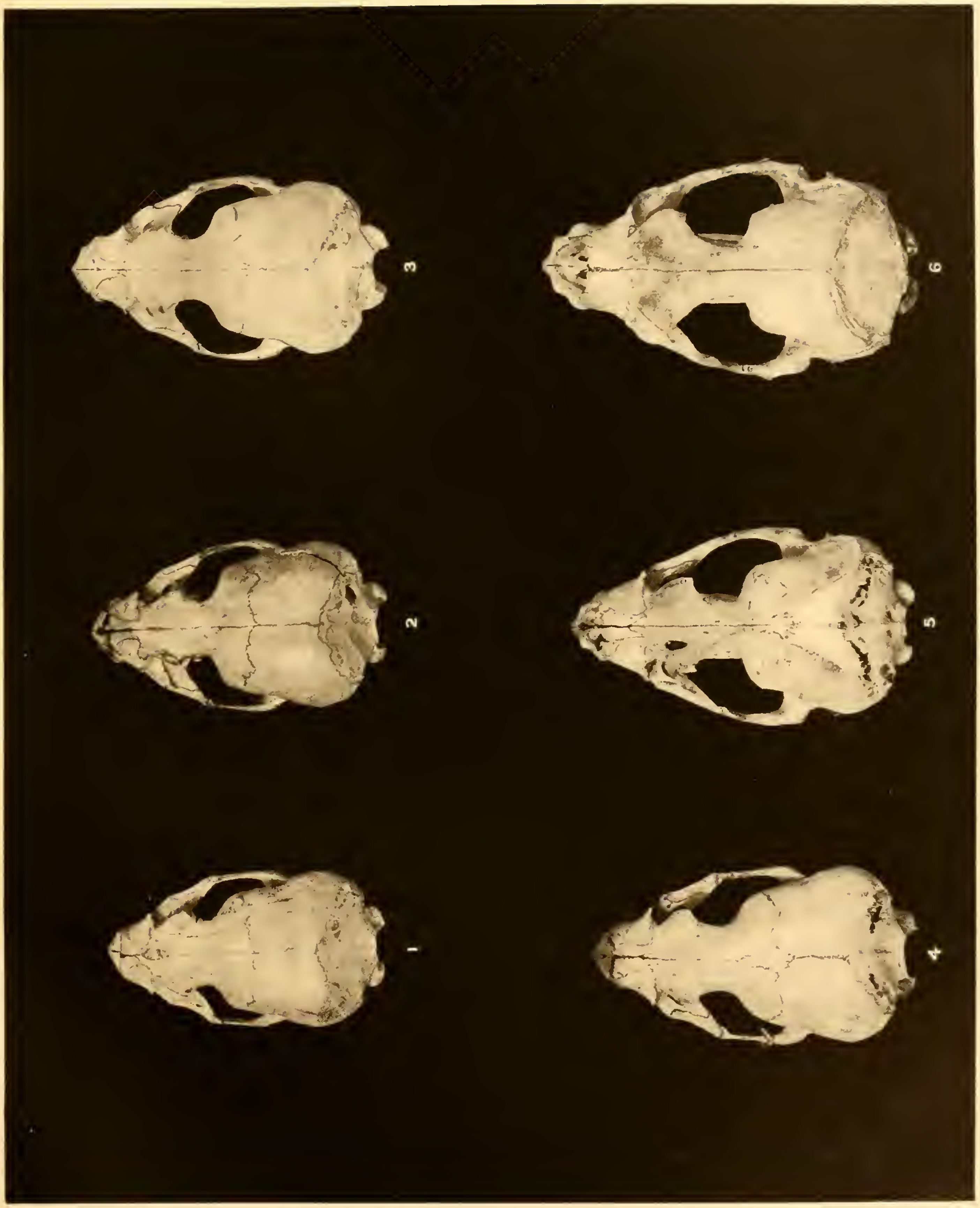
THE SOUTHERN SEA LION

PLATE XI

Skulls of Southern Sea Lions, females. Dorsal aspects.

Fig. 1. First year, No. 1102.
Fig. 2. Second year, No. 1075.
Fig. 3. Third year, No. 1078.
Fig. 4. Fourth year, No. 1023.
Fig. 5. Fifth year, No. 1100.
Fig. 6. Sixth year or over, No. 1132.

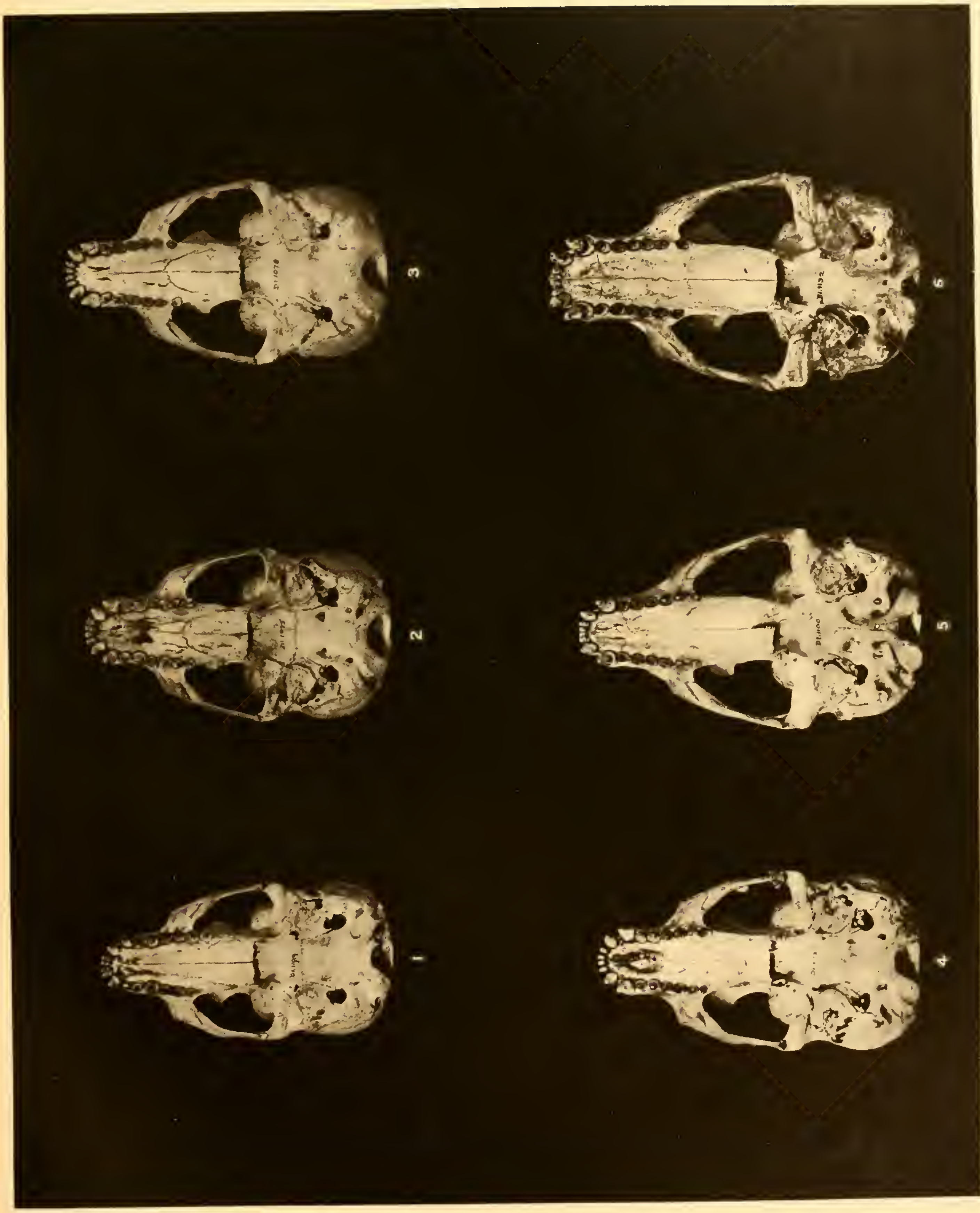


THE SOUTHERN SEA LION

PLATE XII

Skulls of Southern Sea Lions, females. Ventral aspects.

Fig. 1. First year, No. 1102.
Fig. 2. Second year, No. 1075.
Fig. 3. Third year, No. 1078.
Fig. 4. Fourth year, No. 1023.
Fig. 5. Fifth year, No. 1100.
Fig. 6. Sixth year or over, No. 1132.



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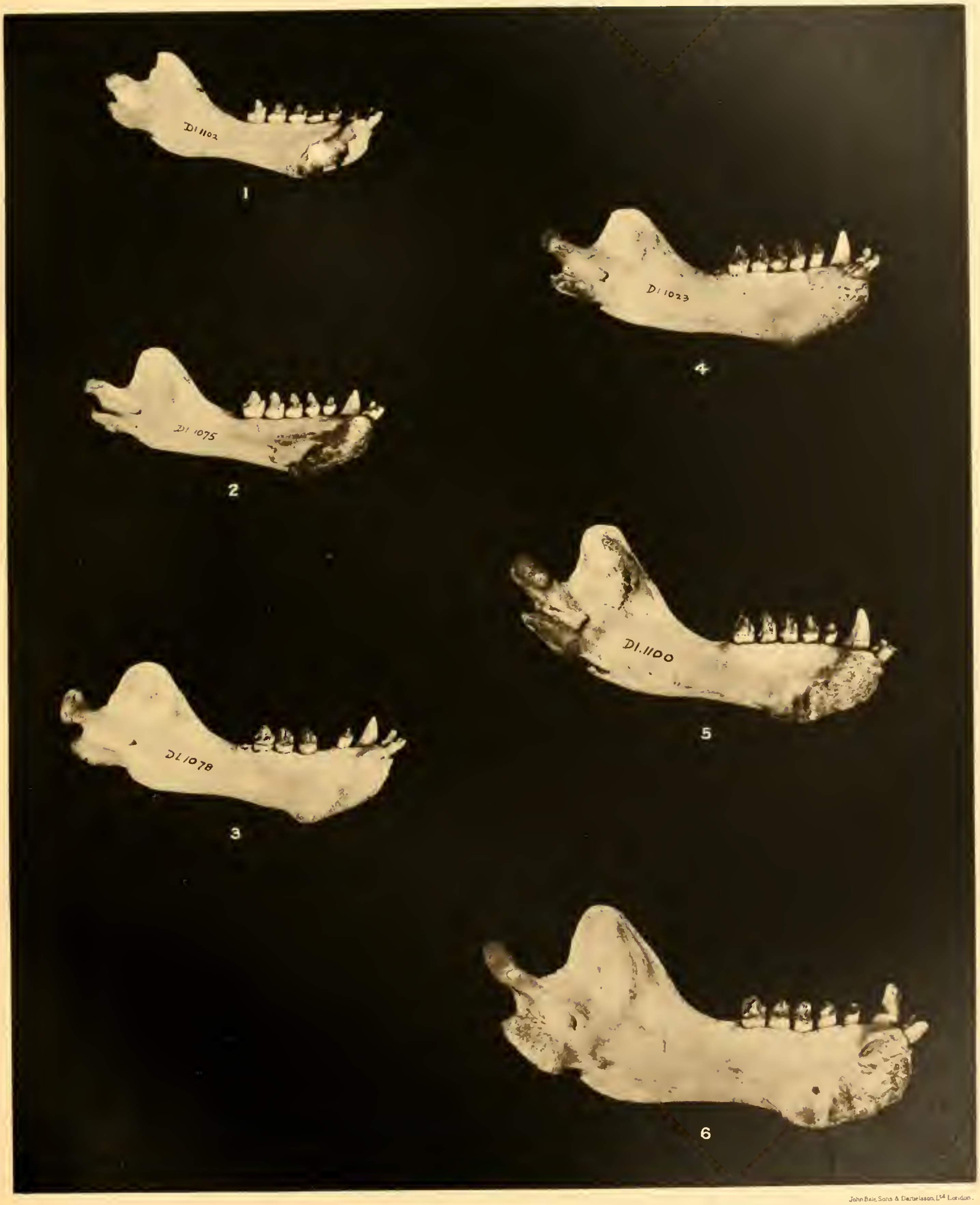
THE SOUTHERN SEA LION

PLATE XIII

Lower jaws of Southern Sea Lions, females. Internal aspects.

Fig. 1. First year, No. 1102.
Fig. 2. Second year, No. 1075.
Fig. 3. Third year, No. 1078.
Fig. 4. Fourth year, No. 1023.
Fig. 5. Fifth year, No. 1100.
Fig. 6. Sixth year or over, No. 1132.



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THE SOUTHERN SEA LION.

[*Discovery Reports. Vol. VIII, pp.* 319-328, *January*, 1934.]

ON A NEW SPECIES OF MITE OF THE FAMILY HALARACHNIDAE FROM THE SOUTHERN SEA LION

By

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Department of Zoology, British Museum (Natural History)

ON A NEW SPECIES OF MITE OF THE FAMILY HALARACHNIDAE FROM THE SOUTHERN SEA LION

By Susan Finnegan, B.Sc., Ph.D.

Department of Zoology, British Museum (Natural History)

(Text-figs. 1–12)

A number of mites of the genus *Halarachne* were collected by Mr J. E. Hamilton from the posterior nares of the sea lion, *Otaria byronia*, at Cape Dolphin, Falkland Islands, while working for the Discovery Committee in 1931.

The genus *Halarachne* has a wide geographical distribution, being recorded from the Arctic, the Irish Sea, the North Atlantic, the Californian Coast and the Antarctic. The recorded hosts are seals, sea lions and walrus.

There are seven known species, three of which were carefully redescribed by Dr A. C. Oudemans in his monograph of the genus (1926). Descriptions of two species not mentioned in the monograph may be found in papers by Steding (1923) and Ferris (1925).

The Falkland Islands specimens, although bearing a close resemblance to *Halarachne rosmari*, Oudemans, represent a new species.

Halarachne magellanica, sp.n.

Diagnosis. Lateral plates extend from legs I to III. Anal plate pear-shaped. Genital plate oval. Female chelicera with well-developed digitus fixus. Male chelicera with rudimentary sperm-carrier.

Description. Female (Fig. 1). Body long and attenuated. Podosoma with slightly undulating outline, rather pointed anteriorly, convexities over legs II and III. Opisthosoma of mature ♀ usually enlarged in anterior third to about the same width as podosoma at broadest, narrowed in posterior two-thirds into cylindrical form and broadened slightly at tip.

Colour of specimens in formalin a dirty brownish white; chitinized portions—legs, shield and tracheae—dark yellowish brown to red-brown.

Dorsal shield (Fig. 2) one and two-third times as long as broad, very much narrower anteriorly than posteriorly, greatest breadth over legs III. Markings very much as in *H. rosmari*, with six pairs of hairs on shield and one large pair just external to it anteriorly. Lateral shields extending from legs I to III, and, as in the case of all other plates on the body, margins weakly defined. Anal plate (Fig. 3) pear-shaped, situated with apex dorsally and anal aperture posteriorly. Peritrematal plate scarcely visible from dorsal view.

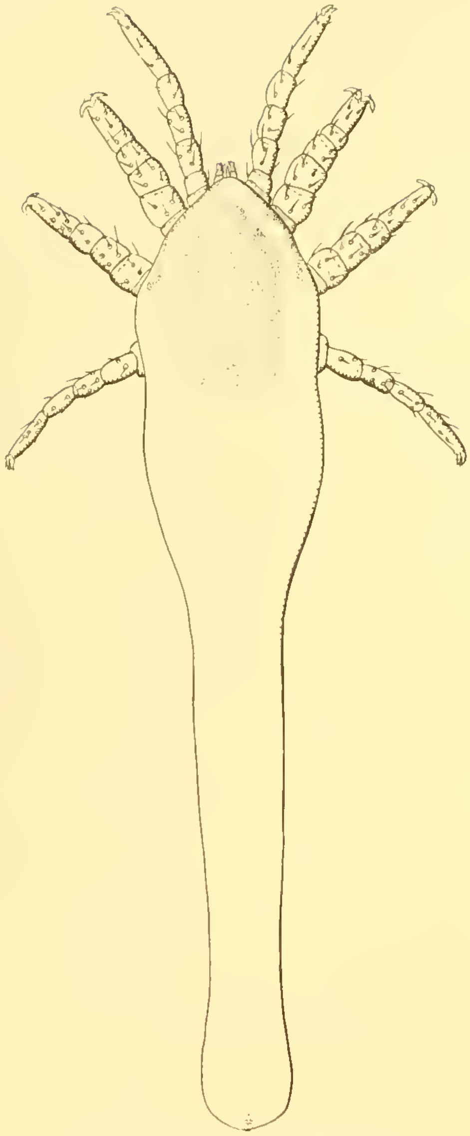

Fig. 1. *Halarachne magellanica*, sp.n. Dorsal view of female: × 25.

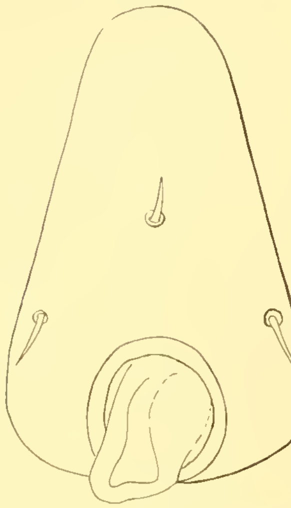

Fig. 3. Anal plate of female.

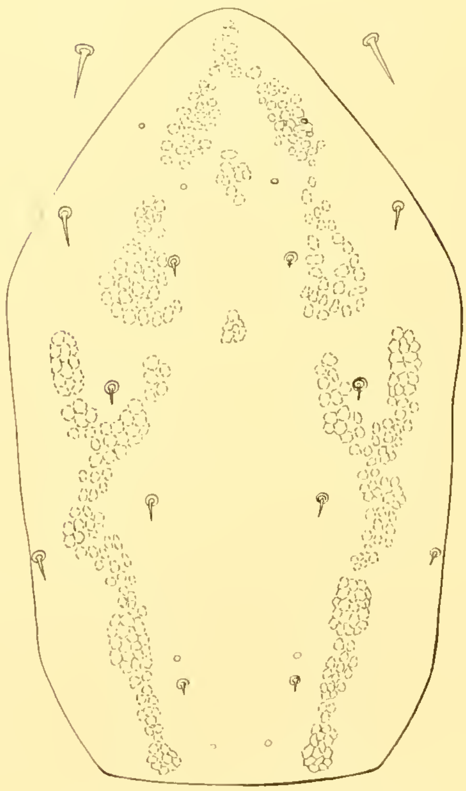

Fig. 2. Dorsal shield of female.

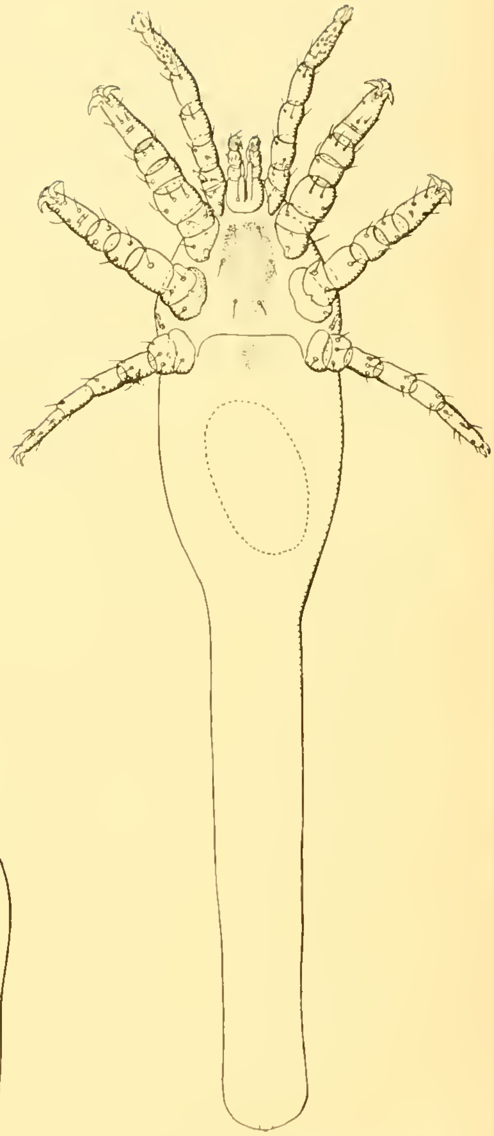

Fig. 4. *Halarachne magellanica*, sp.n. Ventral view of female: × 25.

No tritosternum present. Sternal plate (Fig. 4) trapezoid in anterior half, triangular, with slightly rounded apex posteriorly. Three pairs of hairs: one pair on shield a little distance behind anterior margin, the other two pairs situated on the periphery of the shield, one pair at the middle and one pair at a distance approximately its own length from the posterior limit. Genital plate oval, larger than in other species of *Halarachne*. Genital slit practically straight across, showing slight concavity at centre. Chitin of opisthosoma striated as in *H. rosmari*, also one or two minute hairs scattered on the surface as in the latter species.

Epistome triangular, asymmetric, showing a certain amount of variation in individual specimens (Figs. 5*a*, *b*). Hypostome with 10–12 rows of teeth.

Chelicerae (Fig. 6): first article nearly as long as broad, second two and a half times as long as broad, as in *H. rosmari* (in general, this appendage bears more resemblance to *H. rosmari* than to any of the other species of *Halarachne*). In addition to the tibial

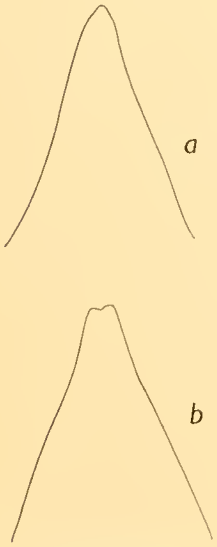

Fig. 5. Epistome of female.

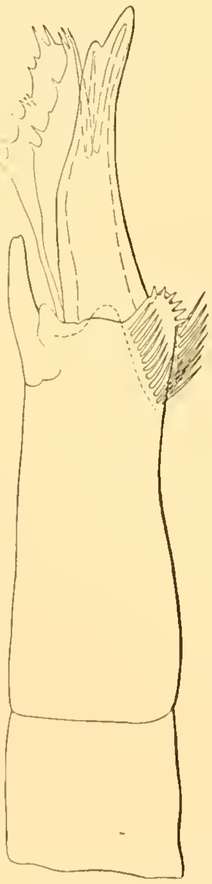

Fig. 6. Chelicera of female.

Fig. 7. Maxillipalp of female.

fringe there are five short, stout teeth. Even under oil immersion it is difficult to decide whether these teeth are in line with the tibial fringe or distinct, but they appear to be distinct. The digitus fixus barely reaches one-third the length of the digitus mobilis; it is slender and slightly bifid at the extremity; proximally a small membranous flap projects over the base. Digitus mobilis pointed, with small accessory projection at a short distance from the tip and bearing a broad leaf-shaped membrane drawn out at irregular intervals into long, sharp spikes. This membrane is strengthened by thickenings in the nature of a mid-rib.

Malae externae large. Third and fourth articles of maxillipalps (Fig. 7) each with four hairs; terminal article with the usual forked hair and numerous short hairs.

First pair of legs longest, then fourth, second and third pairs. First and fourth pairs slender, second and third pairs stout, fourth pair the most slender and second pair the stoutest of the legs. Claws and general arrangement of hairs much the same as in other species of the genus. Arrangement of hairs and spines in the sensory area of leg I specifically distinct (Fig. 8).

Stigmata lying between legs III and IV scarcely visible from dorsal view. Peritrematal plate very slightly chitinized and difficult to distinguish, elongate and slender, resembling that of *H. zalophi* rather than *H. rosmari* (Fig. 9). The position of the stigma

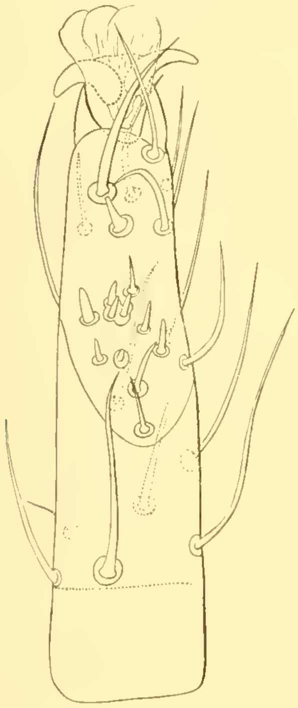

Fig. 8. Sensory area of leg I of female.

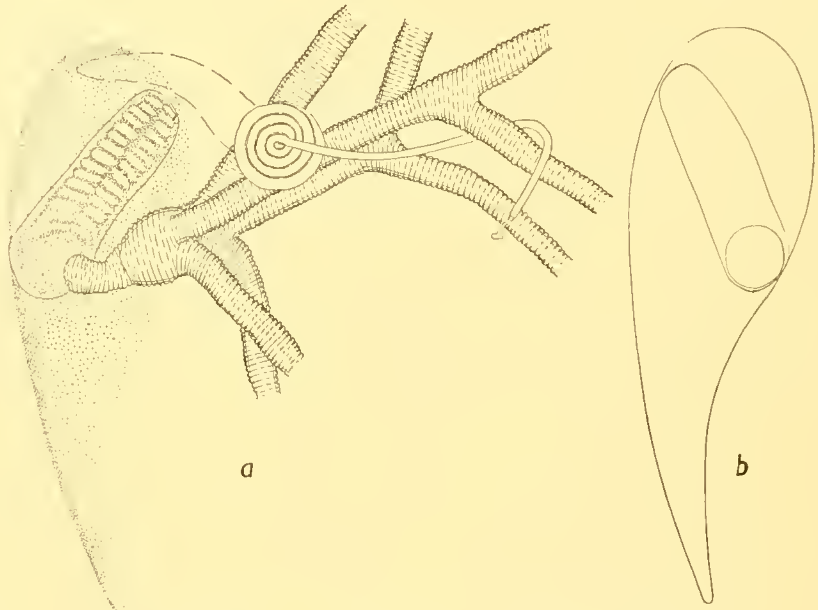

Fig. 9. Peritrematal plate, stigma and tracheae of female.

in relation to the peritrematal plate is seen in Fig. 9*b*; Fig. 9*a* was drawn from a preparation in which, as frequently happens, the stigma has been twisted out of position. Tracheae dividing into seven branches, three curving round anteriorly and four posteriorly. Lying a little distance in from the peritrematal plate is a duct, the proximal portion closely coiled, the distal portion free. In some preparations the free portion of the duct runs straight back to the region of the fourth coxae, in others the duct stretches across towards the genital lip, and in the preparation figured the duct curves back over two of the tracheal trunks. What the function of this duct is I do not know.

Male (Fig. 10). Smaller than the female, podosoma more rounded, opisthosoma more slender. Dorsal, lateral and anal plates as in female. Tritosternum absent. Sternal plate extending from the anterior border of coxae II to middle of coxae IV. General form somewhat elongate heart-shaped, anterior margin bilobate. Genital aperture in middle of anterior margin. Penis highly chitinized. Chelicera (Fig. 12) a strong, stout appendage; first article broader than long, second article one and a quarter times longer than broad; these are broader than the corresponding articles in the female. Digitus fixus not distinguishable unless represented by the slight prolongation at point *A*. Digitus mobilis as in *H. rosmari*, a long, curved and slender hooked shaft with membranous leaf-like process and rudimentary sperm-carrier forked distally. Articulation heavily chitinized.

Maxillipalps (Fig. 11) as in female, except article II which bears a stout conical process on inner border.

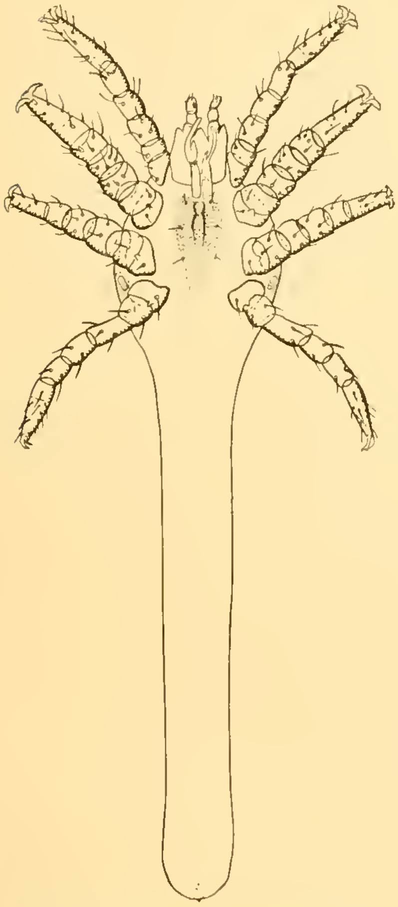

Fig. 10. *Halarachne magellanica*, sp.n. Ventral view of male: × 25

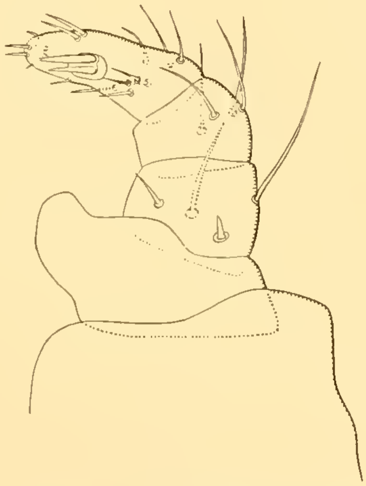

Fig. 11. Maxillipalp of male.

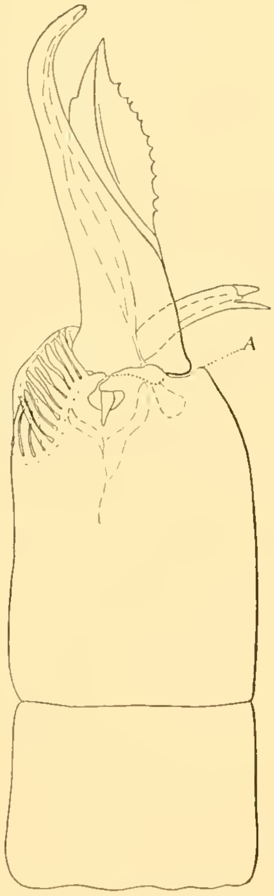

Fig. 12. Chelicera of male.

Material examined. Numerous females and three males from the nasopharynx of *Otaria byronia* (cow 4 ft. 8 in. in length), Beach, Cape Dolphin, Falkland Islands, 20. vi. 31.

Collector. J. E. Hamilton.

Holotype ♀: British Museum (Natural History).

Reg. No. 1933. 11. 6. 1.

Measurements. Female: length 5·0 mm.; breadth between legs III and IV 1·0 mm.; length of opisthosoma 3·75 mm. Male: length 4·2 mm.; breadth between legs III and IV 0·9 mm.; length of opisthosoma 3·2 mm.

Affinities. Although *Halarachne magellanica* resembles *H. rosmari* closely in many respects, and in particular in the form of the highly specialized chelicerae, it may be distinguished from *H. rosmari*, as well as from all other species in which the character has been described, by the oval form of the genital shield and its comparatively large size. From *H. rosmari* it may further be separated by the form of the anal plate, the sternal plate, the genital slit and the sensory area of the first pair of legs in both male and female.

Habitat. This is the first record of a species of *Halarachne* from *Otaria byronia*. Two species, *H. zalophi*, Oudemans, and *H. otariae*, Steding (possibly a synonym of *H. zalophi*), are recorded from the nares of *Otaria californica*.

The records of the hosts and hence of the probable distribution of some of the species are of doubtful value. *H. attenuata* was described by Banks (1910) "from a seal pup, St Paul Island". Dr Oudemans takes this to be the St Paul Island of the Southern Indian Ocean, but there are two other St Paul Islands—one off the coast of Nova Scotia and one in the Pribilov Islands, Bering Sea—and it seems more probable that Banks was referring to one of the latter, most likely the Pribilov Islands, where there is a large fur seal herd. The species *H. americana*, described by Banks in 1899, was taken in Zoological Gardens from the branchial passages of *Monachus tropicalis*; but in such a case accidental infection is always possible and it is doubtful whether one is justified in regarding the distribution of the host (West Indies, Coast of Yucatan to Florida and Bahamas) as established for the parasite. This difficulty is further illustrated in the case of *H. rosmari*, which was taken from the nares of a walrus sent from Franz-Josef Land to Hagenbeck's Zoological Gardens in Hamburg; but in a letter to Mr J. E. Hamilton Dr Hagenbeck states: "...the whole time before the war our Walrusses and Sea Lions have always lived together in the same basin. There is consequently every possibility of the Sea Lions' parasites having gone from those to the Walrus". One ought to add, however, that Dr Oudemans, who described the species, is of opinion that since the walrus and sea lions were only together for a few months "it is scarcely admissible that in such a short time the Halarachnids of *Zalophus* should go over and propagate in the nasal cavities of *Odobaenus*." Until we know more of the life-history and habits of the mite this question must remain doubtful.

I wish to thank Dr Kai L. Henriksen of the Zoologiske Museum, Copenhagen, for allowing me to examine specimens of *Halarachne halichoeri*, and Dr E. Titschack of the Zoologisches Staatsinstitut und Zoologisches Museum, Hamburg, for a similar kindness in lending me specimens of *Halarachne rosmari*.

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[*Discovery Reports. Vol. VIII, pp.* 329–396, *Plates XIV, XV, February*, 1934]

SCYPHOMEDUSAE

By

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Conservator of the Rijks Museum van Natuurlijke Historie and
privaat-docent at the University, Leiden, Netherlands

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SCYPHOMEDUSAE

By G. Stiasny, D.Sc., Leiden

(Plates XIV, XV; text-figs. 1–12)

INTRODUCTION

The present paper is a report on Scyphomedusae, based on collections made by the R.R.S. 'Discovery' and R.R.S. 'Discovery II' and to a smaller extent by the R.R.S. 'William Scoresby'. The cruises of these ships took place in the years 1925 to 1931, and followed a route along the West African coast, but chiefly in the Southern Atlantic and Antarctic Oceans, fishing at depths ranging from the surface down to about 2500 m. The study of the present collections produced no surprising results. They are not rich with regard to the number of different species, and contain no new forms. The present catches are, however, important for other reasons. They are made especially in a region of the South Atlantic between 30 and 55° S Lat., hardly explored with regard to Scyphomedusae. The previous expeditions (those of the 'Challenger', 'Valdivia', 'Scotia' and 'Gauss') paid occasional visits only to this area; the hauls made were very few and dispersed, and mostly single specimens of Scyphomedusae were caught.

The 'Discovery' and 'Discovery II', however, obtained large series of some forms (*Periphylla* and *Atolla*), the study of which made it possible to settle certain systematic problems, to fill up a gap in our knowledge of the geographical and bathymetrical distribution, and to add in this way not inconsiderably to our knowledge of the Scyphomedusan fauna of the South Atlantic. A rich collection of the rare *Atolla chuni*, Vanhoeffen, has been gathered, only three specimens of this form having hitherto been known. The importance of the Discovery collection is augmented by the fact that it enables us to compare the results of the studies of these catches with those made by the 'Michael Sars' in the North Atlantic. In many respects the Michael Sars collections form a counterpart to those of the 'Discovery'. Just as the 'Michael Sars' explored a boreal region between 20 and 60° N Lat., the 'Discovery' examined the sub-tropical and sub-Antarctic waters of the southern part of the Atlantic in a belt of the same breadth. In both cases the bulk of the collected specimens is made up of a large number of *Periphylla* and *Atolla*. The 'Discovery', however, obtained a much smaller number of *Pelagia* than did the 'Michael Sars' (Broch, 1913).

The results and conclusions reached by Broch on the relation between the increase of quantity of pigment, size and number of individuals and the increase of depth, could be checked and controlled with the rich series of *Periphylla* and *Atolla*. It was found that Broch's conclusions could be confirmed in some respects, but that in others they must be regarded as going too far. One of the most important results of Broch's studies was that the material brought home by the 'Michael Sars' demonstrates that the intensity of pigmentation corresponds with the bathymetrical distribution of some forms. As Hjort has shown with fishes the differently coloured individuals are distributed according to certain rules within the different layers of water. According to Broch this should also be the case with the Scyphomedusae, and he tried, corroborating the studies of Bigelow, to show that among deep-sea medusae the variation in colour is correlated with bathymetrical distribution—that the more hyaline individuals occur in shallower water, and conversely that those from deeper water have denser pigmentation.

The Discovery hauls of *Periphylla* (in a less degree those of *Atolla*) show, however, that Broch has gone too far in framing a general rule on these lines. As may be seen from the lists of the present series, hyaline and densely pigmented specimens of *Periphylla* often occur in different layers; but they are also found in the same hauls near each other, and the various stages of pigmentation are to be found together in the same layers. This is easily understood, as the intensity of pigmentation depends not so much upon the stratum in which the animals live as on the stage of development. Young stages from the surface are generally less darkly pigmented than the older ones living in greater depths. It is in general no doubt true that in *Periphylla* the size increases with the depth; because during the development the medusa sinks from shallow into deeper layers, so that the youngest and smallest stages are found near the surface and the adults in the depths; but we find also different developmental stages living in the same strata.

I cannot, however, agree with Broch that the number of individuals increases with the depth. Broch's own tables are not sufficient and the numbers too scanty for establishing this observation as a rule or dogma and the present series does not afford any confirmation to his conclusions.

With regard to the study of pigmentation and bathymetrical distribution it is very much to be regretted that relatively so few hauls were made with closing nets. Whenever such an expression as (–0) or (–50) follows the figure for depth, it is implied that the net (70 cm., 2 m., $4\frac{1}{2}$ m. tow-net, young fish trawl), though fishing for the time indicated at the major depths, was hauled open to the surface or to a higher level.[1] The great majority of the catches have been made in this way; but the remarkable *Phacellophora ornata* and one specimen of *Pelagia noctiluca* were caught by the Kelvin tube, having no doubt become entangled with the instrument during its passage to the surface. Thus there is no certainty that all the organisms were really taken at the indicated depth, because some individuals will have been caught during the upward passage of the net, as noted by Bigelow (1909, p. 231). This eminent medusologist has pointed out that such catches are no doubt of great value in obtaining much material, but they are of little use in locating the level from which the specimens were taken unless such records are checked by some other class of observation. One must, however, not fail to recognize the great technical difficulties of closing large towed nets (of 2 m. or $4\frac{1}{2}$ m. diameter), which are the only instruments suitable for collecting Scyphomedusae. Moreover, more specimens with precise indications of depth have been collected by the 'Discovery'

[1] *Discovery Reports. Station-List*, 1925–7, p. 5. Cambridge, 1929.

than by all previous expeditions to the South Atlantic and Antarctic ocean together (compare the lists on pp. 334–5). Dr Kemp informs me that in a great number of hauls, whether open or closed, depth gauges were used, and thus better indications of the depth which the net reached were obtained than in previous expeditions. The method of capture must not be overlooked in a discussion of the range of the bathypelagic fauna as has so often been done before.

Although the important reports of the last 30 years, mostly based on collections from the great marine expeditions (those of the 'Challenger', 'Plankton', 'Valdivia', 'Scotia', 'Gauss', 'Belgica', 'Discovery' and 'Southern Cross', 'Albatross', 'Pourquoi Pas?', 'Michael Sars' and 'Arcturus') have resulted in a revision of the classification of the Scyphomedusae, many systematic questions have remained unsettled. In this respect the Discovery material proved suitable, for instance in the case of the different stages of development of *Periphylla hyacinthina*, hitherto described as different species, or with regard to the various forms of *Atolla wyvillei*. Here we have to do with some of those puzzling instances (not uncommon among medusae, as already pointed out by Mayer, 1910, p. 517, and Bigelow, 1928, p. 517) where the Linnean system of classification proves to be inadequate to express the true relationship of the different closely related forms; for "as the intermediate or transitional stages prove to outnumber greatly the so-called bonae species, the classification breaks down".

A study of the recent literature on Scyphomedusae clearly shows the tendency to simplify the system as much as possible and to adopt, instead of the many local varieties, races or forms, only a few well-founded species with great variability and large distribution. Previously (as in Haeckel) the indication of a new exotic locality sufficed for establishing a new species. Recent authors (Mayer, Bigelow, and the author himself) take the conception of species in a wider sense. In this way the system is greatly simplified, although this procedure, if driven too far, undoubtedly involves the possibility of error. Bigelow, especially, in working out the Arcturus material (1928), has gone very far in this respect in revising the genera *Periphylla*, *Linuche*, *Nausithoë*, *Atolla*, *Pelagia* and *Aurelia*—in my own opinion rather too radically. He appears to have fallen from one extreme into the other. From a similar point of view, but perhaps less drastically, the author of the present report has tried to carry out the study of the Discovery material.

The material, especially that of the large series of *Periphylla* and *Atolla*, is mainly in a very good state of preservation. The brilliant colours, however, have mostly more or less faded or wholly vanished. Some specimens only of *Periphylla hyacinthina*, *Atolla wyvillei* and most of the individuals of *A. chuni* show fresh unfaded colours. Vanhoeffen (1903), who took part in the cruise of the 'Valdivia', and Broch (1913), who examined the rich freshly preserved material of the 'Michael Sars', were in this respect in a much more favourable position than the author (see, however, p. 393).

As regards measurements I wish to point out why I have given as few as possible in contrast with the long tables of most previous authors: in the first place because I attribute but little value to measurements in general, and secondly because I have in hand material already several years old. Measurements of animals so strongly contractile as jelly-fishes long preserved in formalin can never be exact. Moreover, they are subject to inevitable personal error on account of the practical difficulties in taking measurements of small or very large specimens. Thus I rather doubt whether, even when a sufficient number of observations are regarded collectively, the most important faults can be eliminated (Kramp, 1924, p. 44). Moreover, the figures in the tables hitherto published are often not mutually comparable. The height of the bell, for instance has been indicated by various authors in different ways, including or excluding the lappet zone, the breadth measured above the central furrow or at the level of the lappets, and so on. Moreover, contraction is not limited to a single organ but involves various parts of the body in very different degrees (central disc, ring muscle).

The 'Discovery' and 'Discovery II' have collected over a very wide area. The material of Scyphomedusae comprises specimens from Cape Verde to the coast of the Antarctic Continent. Along the whole route medusae were found both in the neighbourhood of the African coast and in the open ocean between South Africa and South America. It is in these regions that the work of the ships has mainly taken place, and in which the bulk of the material has consequently been collected. A short trip was made from the South Orkneys to the South Shetland Islands and the Bellingshausen Sea; but it is obvious that only a few specimens have been gathered in these waters. From the 'William Scoresby' there are very few catches of medusae, made between the Falkland Islands, South Georgia and Coats Land.

It will be remembered that the 'Discovery', when under the command of Captain Scott (1901–3), worked in the Pacific quadrant of the Antarctic. The collections made by this expedition and examined by Browne (1910) were thus caught in localities far distant from those obtained by the same vessel in 1925–7 and recorded in this paper.

Scyphomedusae have been collected by several recent expeditions in the South Atlantic.

The Challenger Expedition (Haeckel, 1882) brought home:

Two *Charybdea murrayana*, Haeckel. St. 348, West coast of Africa, not far from Sierra Leone, 30° 10′ N, 14° 51′ W. Depth 200 fathoms.

Two *Atolla wyvillei*, Haeckel. St. 318, South Atlantic Ocean, St Mathias Bay, not far from the coast of Patagonia, 42° 32′ S, 56° 27′ W. Depth 2040 fathoms.

Two *Nauphanta challengeri*, Haeckel. St. 335, South Atlantic Ocean, not far from Tristan d'Acunha, 32° 24′ S, 13° 5′ W. Depth 1425 fathoms.

The Deutsche Tiefsee (Valdivia) Expedition (Vanhoeffen, 1903) collected only along the West African coast and in the waters from the Cape to Bouvet Island. The depths of the hauls are not indicated.

Eleven *Atolla bairdi*, Fewkes. In different localities in the tropical Guinea stream.

Four *Atolla verrilli*, Fewkes. In West African waters north of the Equator and between the mouth of the Congo and the Cape.

Two *Atolla chuni*, Vanhoeffen. Between the Cape and Bouvet Island.

One *Atolla wyvillei*, Haeckel. South-east of Bouvet Island.

Two *Periphylla hyacinthina*, Steenstrup. One in the Guinea stream, the other in the Benguela stream.

Three *Periphylla dodecabostrycha*, Brandt. One in the Guinea stream, two in the Benguela stream.

Two *Periphylla regina*, Vanhoeffen. One in the West Wind Drift, St. 120, 42° 17′ S, 14° 1′ E, near Bouvet Island. Closing net, 1000–1500 m. depth. One in the "Antarktische Trift", St. 136, 55° 57′ S, 16° 14′ E, south-east of Bouvet Island. Vertical net, 2000 m.

One *Nausithoë punctata*, Kölliker. In the Gulf of Guinea.

One *Nausithoë rubra*, Vanhoeffen. St. 73, south of the Congo mouth.

Many *Pelagia phosphora*, Haeckel. Between 50° N and 40° S.

The Expedition antarctique française ('Pourquoi Pas?') (Maas, 1908) fished along the Antarctic archipelago and in the Bellingshausen Sea where medusae were collected in two hauls only:

One *Couthouyia gaudichaudi*, Lesson (= *Desmonema gaudichaudi*, Maas). About 65° S, 66° W (Paris), off Wandel Island.

Two *Diplulmaris antarctica*, Maas. About 65° S, 66° W (Paris), off Anvers Island.

The Scottish Antarctic Expedition ('Scotia') (Browne, 1909) fished along the coast of the Atlantic quadrant of the Antarctic Continent, in the waters of the Falkland Islands and of the South American coast:

One *Atolla chuni*, Vanhoeffen. St. 450, 48° S, 9° 30′ W, between South Georgia and Bouvet Island. 1332 fathoms.

One *Atolla wyvillei*, Haeckel. St. 413, 72° 02′ S, 23° 40′ W, north-west of Coats Land. 0–1000 fathoms.

Fourteen *Pelagia perla* (Slabber). Fayal Harbour, and north and west of the Azores.

Three *Desmonema chierchiana*, Vanhoeffen. Stanley Harbour, Falkland Islands.

One *Phacellophora ornata* (Verrill). St. 98, 34° 2′ S, 49° 7′ W, 15° E of Montevideo. Surface.

The Deutsche Südpolar Expedition ('Gauss') (Vanhoeffen, 1908) did not examine the same part of the South Atlantic as the 'Discovery'. The 'Gauss' worked in the middle of the Atlantic on both sides of the Atlantic threshold and farther north between the Equator and 40° S. The large number of *Pelagia* is striking, but in other respects the collection is very poor. *Periphylla* and *Atolla* were collected by the 'Gauss' only in the same places as the 'Discovery', in the waters off Cape Verde and west of the Cape of Good Hope.

One *Periphylla dodecabostrycha*, Brandt. At the Equator. 3000 m.

One *Periphylla dodecabostrycha*, Brandt. West of Cape Verde. 3000 m.

One *Periphylla regina* (Haeckel). West of Cape Town. (Lost.)[1]

One *Atolla verrilli*, Fewkes. Between Tristan d'Acunha and Cape Town. 3000 m.

One *Atolla verrilli*, Fewkes. West of Cape Verde. 3000 m.

One *Atolla verrilli*, Fewkes. At the Equator. 3000 m.

Three *Nausithoë punctata*, Kölliker. St Vincent, Cape Verde. Surface.

One *Palephyra* sp. At the Equator. 400 m.

One hundred and six *Pelagia noctiluca*. Along the whole route in the Atlantic.

All these expeditions that worked in the South Atlantic collected but few specimens (not more than eleven) of each species. *Pelagia* only is an exception, as the 'Valdivia'

[1] The specimen taken west of Cape Town was lost, and of two others taken in the 'Eisberggebiet' between 58°–63° S and 90°–97° E at 2000 m. one was badly damaged: only one well preserved specimen thus exists from the Indian Ocean quadrant.

and 'Gauss' record many, or more than 100 specimens. These small numbers may be due firstly to the small numbers of stations, secondly to a certain scarceness of animal life in general in these regions, and thirdly to the predominance of surface collections, large Scyphomedusae being relatively rare in superficial layers far from the coast.

I restrict myself here to mentioning only the collections of expeditions to the South Atlantic and the Atlantic quadrant of the Antarctic Ocean, as Maas (1906) and Browne (1910) have given a complete list of Scyphomedusae recorded from the whole Antarctic region, and Vanhoeffen (1909) has published a chart of their geographical distribution. Few additional specimens have been obtained from the Indian Ocean and Pacific sectors, and the lists and charts hardly need any alteration.

From the above records it is evident that the Antarctic and sub-Antarctic parts of the South Atlantic[1] are extremely poorly explored, and that these regions have become better known with regard to Scyphomedusae by the results of the 'Discovery', our knowledge of the geographical distribution of some forms especially having become much enlarged. The 'Discovery', the 'Discovery II' and the 'William Scoresby' collected the following material:

CHARYBDEIDEA.
Tamoya haplonema, F. Müller. 6 specimens.

CORONATAE.
Periphylla hyacinthina, Steenstrup. 103 specimens.
Nausithoë punctata, Kölliker. 5 specimens.
Atolla wyvillei, Haeckel. 185 specimens.
Atolla chuni, Vanhoeffen. 43 specimens.

SEMAEOSTOMEAE.
Pelagia noctiluca, Forskål. 26 specimens.
Chrysaora fulgida, Reynaud. 3 specimens.
Desmonema gaudichaudi, Lesson. 1 specimen.
Desmonema chierchiana, Vanhoeffen. 1 specimen.
Phacellophora ornata (Verrill). 1 specimen.
374 specimens in all.

The number of species is not large (10); they belong to eight different genera and there are 374 specimens in all. All these species are holoplanktonic and not a single specimen of the neritic Lucernaridae (Stauromedusae) has been collected. This is the more striking, because in the waters round South Georgia many hauls were made. There was during the cruise of the 'Discovery' a biological station established at South Georgia, and previously *Haliclystus antarcticus*, Pfeffer, was collected there by van der Steinen.[2] The absence of littoral species in the present material is no doubt due to the

[1] In order to avoid misunderstanding regarding the position of the northern boundary line of the Antarctic Ocean, I consider, following Browne (1910, p. 324), that the Falkland Islands (± 52° S) lie outside the boundary line of Antarctic waters.

[2] See Pfeffer, G., 1889, Zur Fauna von Süd Georgien, *Mitt. Naturhist. Mus. Hamburg*, Jahrg. 6; Thiel, Max E., 1928, Die Scyphomedusen des Zoologischen Staatsinstituts und Zoologischen Museums in Hamburg. I, Cubomedusae, Stauromedusae und Coronatae, *Mitt. Zool. Staatsinst. und Zool. Mus. Hamburg*, Bd. XLIII.

collecting having been done almost exclusively far from shore. The only pelagic form found by previous expeditions in the Antarctic Ocean and not collected by the 'Discovery' is *Diplulmaris antarctica*, Maas, known from Cape Adare, Kaiser Wilhelm II Land, and Anvers Island in the Palmer Archipelago.

The occurrence of *Tamoya haplonema* in the waters off Cape Lopez, French Congo, is interesting, the known distribution of this medusa having previously been restricted to the Atlantic coasts of North and South America and the West Indies.

Periphylla hyacinthina. All the 103 specimens have been referred to one single species. It appears in three different main types, formerly believed to be three different species, but actually nothing more than different stages of growth of a single species. I restrict the name forma *dodecabostrycha* to small, flat specimens of 35 mm. maximum diameter, mostly with gonads distinctly visible from without and with a "Stielcanal". I unite all large plump dome-shaped specimens, previously for the most part called *dodecabostrycha*, with those determined as *regina* under the name forma *regina*. I reserve the name forma *hyacinthina* (typica) for medium-sized slender specimens with pointed bell and stomach. The small and feebly pigmented *dodecabostrycha* stages live generally in more superficial layers; they most probably have their origin on the continental slope, and, slowly sinking into greater depths, are transformed into the *hyacinthina* and *regina* stages. The larger darkly pigmented forms of *hyacinthina* (typica) and *regina* are true bathypelagic forms and as a rule are caught far from the coast.

Thus there exists a certain relation between the amount of pigmentation and the depth in which the medusa lives, but there are also layers in which all stages of pigmentation and development occur together.

There is an increase of size towards deep water, but not an increase of numbers with depth as Broch states.

Periphylla hyacinthina in the *dodecabostrycha* stage has not until now been found in the tropics in superficial layers. In the present series there are several catches from Ascension and the Gulf of Guinea, from 250–0 and 175–125–0 m. respectively. Their occurrence is most probably due to cold upwelling currents. Some specimens of the *dodecabostrycha* stage have been found in the Bellingshausen Sea and south of the South Shetlands. This is very remarkable for similar young stages have never been found before so far south in true Antarctic waters. The *dodecabostrycha* stage is preceded by a rare young developmental stage, first described by Bigelow (1909), which I have called the "Bigelow stage" in honour of the leading authority in medusology. This stage, of which several specimens are present, is characterized by restriction of the dark endodermic pigment to the central stomach and the rhopalia, the peripheral zone being entirely hyaline.

Atolla. I distinguish only two species of *Atolla*: *wyvillei* with smooth lappets, and *chuni* with lappets studded with tubercles. I divided the 185 specimens of *A. wyvillei* in the present series into three groups or forms: *wyvillei* (typica), *bairdi* and *verrilli*, based on the characters of the furrows on the central disc. In the present series there is not a single specimen with radial furrows running all over the disc. The gastro-vascular system of the Discovery material of *Atolla* differs in some respects (very large amount of pigmentation, length of the lappet canals) from the descriptions given hitherto. In accordance with the results of Broch an increase of pigmentation should be found with increase in depth. *A. bairdi* and *verrilli* are typical of the North Atlantic region and do not occur south of 55° S. *A. wyvillei* has its most northern limit in the Gulf of Guinea and occurs only in a layer of water of low salinity (34·5–34·75 ‰). It is the only form in Antarctic waters or in waters of Antarctic origin.

Very probably *wyvillei* on the one hand, and *bairdi* and *verrilli* on the other hand, are distinct geographical forms confined to special currents or regions. *A. wyvillei* (typical form) sinks slowly into deeper layers proceeding from the Antarctic to the Cape.

The rich material of *A. chuni* (43 specimens), in different stages of development, made it possible to complete the short description of this "rare" medusa given by Vanhoeffen, with respect to the gastro-vascular system, subumbrellar papillae, pigmentation and warts on the lappets. The distribution of this form is exclusively restricted to the sub-Antarctic part of the Atlantic; the species has not been found in Antarctic water south of the latitude of Cape Horn, nor north of 30° S. Most individuals have been caught in the neighbourhood of continents or groups of islands. *A. chuni* belongs to the "intermediate fauna" of Bigelow, and prefers deeper layers than *wyvillei* with a maximum occurrence in about 1200–1300 m. No specimen has been caught between the surface and 900 m. depth. With regard to salinity the occurrence of *A. chuni* is confined to strata of 34·35–34·75 ‰.

Pelagia noctiluca. A catch of eight specimens at St. 168 in the waters between the South Orkneys and Clarence Island, in 60° 58′ S, is very interesting, for Vanhoeffen points out in the Valdivia Report (1903, p. 37) that 42° S is the southern limit of geographical distribution of this medusa. It is the first time that a *Pelagia* has been found in these cold Antarctic waters.

I believe *Desmonema gaudichaudi*, Lesson, and *Desmonema chierchiana*, Vanhoeffen, to be two different species.

Phacellophora ornata (Verrill). A young developmental stage of this large medusa has been found in Elephant Bay, West Africa, an important locality since this form has hitherto been found exclusively at Eastport, Maine, in Fundy Bay, and only once in the South Atlantic near the coast of Montevideo.

In the first place I wish to thank my wife, Dr G. Stiasny-Wijnhoff, for her invaluable assistance in many difficult cases, her indefatigable patience and the opportunity to discuss with her the interesting problems relating to the development and distribution of the deep-sea medusae.

The manuscript has profited very much from a revision of the text kindly undertaken by Dr Stanley Kemp and Dr N. A. Mackintosh; moreover I am obliged to Dr Kemp for much valuable information and advice. The Discovery results on hydrography were not published when this report was written and I am indebted to Mr G. E. R. Deacon of the hydrographical staff of the expedition for suggestions and

information regarding the currents, salinity and temperature of the area in question. These could be checked with the recent statements of Wüst[1] from the same regions.

I take the opportunity of thanking Captain A. K. Totton of the British Museum, London, Dr C. J. van der Klaauw, lecturer at the University in Leiden and MM. R. van Eecke and J. Zaneveld for the help rendered to me in many respects in preparing this report.

THE MATERIAL

Order CHARYBDEIDEA, Poche

Family CHARYBDEIDAE, Haeckel

Tamoya haplonema, F. Müller

Order CORONATAE, Vanhoeffen

Family PERIPHYLLIDAE, Haeckel

Periphylla hyacinthina, Steenstrup

Family NAUSITHOIDAE, Bigelow

Nausithoë punctata, Kölliker

Family ATOLLIDAE, Bigelow

Atolla wyvillei, Haeckel — *Atolla chuni*, Vanhoeffen

Order SEMAEOSTOMEAE, Agassiz

Family PELAGIDAE, Gegenbaur

Pelagia noctiluca, Forskål — *Chrysaora fulgida*, Reynaud

Family CYANEIDAE, Agassiz

Desmonema chierchiana, Vanhoeffen — *Desmonema gaudichaudi*, Lesson

Family ULMARIDAE, Haeckel

Sub-family *STHENONIDAE*, Agassiz

Phacellophora ornata (Verrill)

Order CHARYBDEIDEA, Poche, 1914

= CHARYBDEIDAE, Gegenbaur, 1856 = CUBOMEDUSAE, Haeckel, 1879

Family CHARYBDEIDAE, Haeckel, 1879

Genus Tamoya, F. Müller, 1859

Tamoya haplonema, F. Müller (Fig. 1)

Six fair specimens. St. 279. 10. viii. 27. Off Cape Lopez, French Congo, from 8·5 miles N 71° E to 15 miles N 24° E of Cape Lopez. Large otter trawl, 58–67 m.

The present six specimens agree so accurately with my diagnosis of the genus *Tamoya* (1930, p. 10) that they could be determined with complete certainty as be-

[1] Wüst, G., Der Ursprung der atlantischen Tiefenwässer, *Zeitschr. Ges. Erdkunde, Berlin*, Jubiläumsband, 1928.

Id., Schichtung und Zirkulation des atlantischen Oceans. 1 Lief. Das Bodenwasser und die Gliederung der atlantischen Tiefsee. *Wiss. Ergebn. der Deutschen atlant. Exp. auf dem 'Meteor'*. Leipzig, 1933.

Id., Bodenwasser und Bodenconfiguration der atlantischen Tiefsee. *Zeitschr. Ges. Erdkunde, Berlin*, 1933.

longing to this genus. In spite of the relatively small size and feeble development of the gonads in most of the specimens, which certainly are not yet fully developed, the principal characteristics are distinctly to be seen: the more or less cylindrical form, the mesogloea not thickened at the apex, the feebly formed pillars, the large wide stomach, the transparent, well-developed, crescent-shaped mesenteries, and the gastric filament arranged in vertical interradial rows along the sides of the stomach. The gonads, however, which are absent in four specimens, are developed in two specimens as broad, unfolded, plainly bordered leaves, running almost from the apex to the velarium, and have more the shape usually described in *Charybdea*. As previously mentioned, however (1930, p. 9), I believe that the grade of folding of the border of the gonads depends very much on the age of the specimens. The description given by Mayer (1910, p. 513) is better than his figures (pl. 57, figs. 2, 2′). I therefore give in Figs. 1 *a–c* somewhat schematic sketches of the whole medusa, of the velarium and the sensory pit, and believe it convenient to add some details concerning the present specimens.

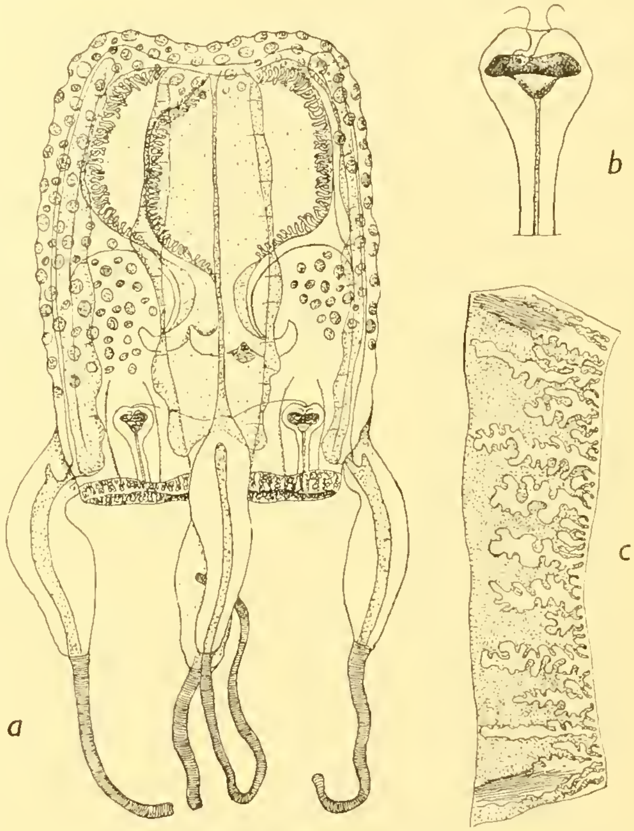

Fig. 1. *Tamoya haplonema*, F. Müller.
a, side view, × 2/3. *b*, sensory pit, × 3. *c*, part of the velarium with dendritic velar canals, × 4.

The FORM OF THE BELL is cylindrical with a widening in the middle part (Fig. 1 *a*).

The EXUMBRELLA of the medusa is, in the upper parts, thickly covered with small or larger, oval or round, wart-like, colourless clusters of nematocysts. Towards the proximal part of the umbrella they diminish in size. The velarium and the pedalia are absolutely free from nematocysts; Mayer writes that both are covered with large white wart-like clusters.

The CORNER PILLARS are very feebly protruding.

The PEDALIA are very variable both in length and breadth (see Table I). The upwardly directed diverticulum of the canal in the pedalia on the outer side of the base, described by Uchida in *Tamoya alata* from Japan (1929), is present in our species.

The VELARIUM (Fig. 1 *c*) is broad and stout. The number of velar canals is about 10; they are strongly branched dendritically and terminate in numerous non-anastomosing branches. Müller's (1859) fig. 12, pl. i, agrees much better than the figure of Mayer, pl. lvii, fig. 2′.

The STOMACH is large and broad. The many filiform unbranched GASTRIC CIRRI run in long vertical rows along the interradial sides of the stomach.

The MESENTERIES are very distinct. They are completely transparent, crescent-shaped and strongly protruding.

The SENSORY PIT, which lies in a broad flask-shaped thickening of the exumbrella, is a broad deep groove and opens with a single large orifice (Fig. 1 *b*). The upper and under squamae rhopalares here run parallel and do not form two round orifices as has been described by Uchida in *T. alata* (1929, fig. 87 B).

The SENSORY ORGAN bears six eyes, two larger medians and two pairs of smaller ones of a feeble brownish yellow colour.

Table I

Showing measurements (*in mm.*) *of the six specimens of* Tamoya haplonema, *F. Müller*

Height	Diameter		Pedalia		Tentacles		Distance of sensory pit from margin	Velarium	
	At the apex	In the middle	Length	Breadth	Length	Thick-ness		Breadth	Number of canals
55	35	45	25	10	12	2	10	8	10
70	40	60	28	12	25	3	12	12	10
60	40	50	30	12	10	4	12	10	10
87	50	65	35	13	20–40	5	13	15	10
80	40	60	35	14	15	5	12	10	10
85	35	50	20	10	30	6	10	8	10

The COLOUR is greyish white, tentacles light rose, gonads and stomach yellowish. The clusters of nematocysts on the exumbrella are nearly transparent, without pigment.

Tamoya alata, Reynaud, described recently by Uchida from Japanese waters (1929), is very similar to our specimens of *T. haplonema*, but the differences between the two forms are still so large that I do not believe them to be identical. The differences consist in:

The arrangement of the gastric filaments. In the Discovery specimens they run vertically. In Uchida's specimen of *alata* they are arranged horizontally in a row of interradial crescentic areas. I am inclined now to agree with Uchida that the direction of the gastric filaments may be regarded as of specific rather than of generic importance.

The different form of the velar canals: here large and broad, strongly branched and with fine dendritically branched ends. In *alata* (see Uchida's fig. 85, p. 176) they are much smaller, less branched and finer.

The different form of the opening of the sensory pit: in *haplonema* a single one, very large and broad, in *alata* biscuit-shaped and opening outwards by two round orifices.

St. 279 in the Gulf of Guinea in the vicinity of St Lopez is a very interesting locality. In the eastern part of the tropical Atlantic only the cubomedusa *Charybdea murrayana*, Haeckel, has been found and this species is certainly not identical either with *Tamoya haplonema* or with *alata*. It is a typical *Charybdea* which fully agrees with my diagnosis of that genus. *Tamoya haplonema* was hitherto known in the Atlantic only from the coasts of North and South America and the West Indies.[1] *T. alata*, however, is distributed in the Pacific and Indian Oceans and probably in the West Indies too. Whether the specimens mentioned by Bigelow (1918, p. 400) from Florida and the Bahamas are true *alata* cannot be made out with certainty from his too brief description. Thus, the locality St Lopez is wholly isolated. The temperature at the station at a depth of 58–67 m.—remarkable for a cubomedusa—was about 24·6° C.

Order CORONATAE, Vanhoeffen, 1892

Family PERIPHYLLIDAE, Haeckel, 1879

Genus **Periphylla**, Steenstrup, 1837

Maas (1897) and Vanhoeffen (1903) recognize but three of the many *Periphylla* species of Haeckel: *dodecabostrycha* (Brandt), *hyacinthina*, Steenstrup, and *regina* (Haeckel). Mayer (1910) and Bigelow (1909, 1913) think it probable that there is but a single bathypelagic cosmopolitan species, *hyacinthina*, and that *dodecabostrycha* and *regina* are merely developmental stages, varieties or local races of this species. Further studies by Bigelow (1928) and especially by Broch (1913), who examined the large series collected by the Michael Sars expedition in the North Atlantic, revealed that *Periphylla dodecabostrycha* and *hyacinthina* ought to be definitely united. In this respect both authors agree, but not with regard to the species *regina*. Broch retained Haeckel's name (with the exception of two doubtful specimens) for a few individuals of a type different from *hyacinthina*. Bigelow, who found transitional forms between both species in the Arcturus material from the tropical Pacific, arrives at the conclusion that further studies on large series are necessary to decide whether *regina* is in fact separable from *hyacinthina* or not.

Among the material in the Discovery collection there are 103 specimens of *Periphylla* which belong, I believe, to all three forms and the study of these may help to settle the question finally. The situation at present with regard to the limits of these species is indeed that what one might call *dodecabostrycha* another might consider to be *hyacinthina*; on the other hand the large *dodecabostrycha* and *regina* are not well distinguished either.[2] This is especially striking in the case of the species *dodecabostrycha*, in which very

[1] See also the short description of two specimens of *Tamoya haplonema*, F. Müller, from Swan Island (south of Cuba) by Lee Boone, *Coelenterata from tropical East American Seas*, Bull. Bingham Oceanogr. Collect., 1, Art. 5, 1928.

[2] The difficulties in these determinations are considerably augmented by the fact that there are some contradictions in the diagnoses or descriptions of the species. For instance both Maas (1904) and Vanhoeffen (1892) agree that in *P. hyacinthina* the bell is relatively high and the pigmentation so dense that the gonads cannot be seen by looking through the walls of the bell; in *dodecabostrycha* the bell is flatter, its apex blunter and the pigmentation lighter, so that the gonads may be seen more or less clearly by looking through the bell walls from outside. However, Vanhoeffen (1892, Taf. 1, fig. 1) gives a figure of *P. hyacinthina* from life showing the gonads clearly visible through the hyaline walls of the pedal zone; similarly in *Periphylla regina* Maas (1897, Taf. x) shows the bell only faintly pigmented, whereas Vanhoeffen (1903) in his Valdivia report shows it quite densely pigmented (Pl. II, fig. 6). (See Mayer, 1906.)

small specimens with a low flat cup-shaped umbrella (Vanhoeffen, 1892, pl. ii, fig. 1) are put together with very large specimens of ± 200 mm. diameter with broad dome-shaped umbrella (Brandt, 1838, pl. xxix; Mayer, 1906, pl. ii, fig. 6). Only *P. hyacinthina* is distinctly described with slender and high umbrella. The discrimination of large *dodecabostrycha* and *regina* appears to be very arbitrary.

I believe that we here have to do only with a single species (to be called by the oldest name *hyacinthina*) *which appears in three different main types*: forma *dodecabostrycha*, forma *hyacinthina typica* and forma *regina*—a distinction similar to that given by Mayer (1910) but in another sense. The main types are connected by transitory stages, and the characteristics overlap so that it is often very difficult to say to which form a given species belongs.[1] In the present series I distinguish besides the three principal types a young developmental stage, preceding the *dodecabostrycha* stage, which I call the "Bigelow" stage (here included in the *dodecabostrycha* group), transitional stages between forma *dodecabostrycha* and *hyacinthina* and intermediate stages between forma *hyacinthina* and *regina*. The distinction of these five stages seems to be supported by the geographical and bathymetrical distribution. Whether they are biological or geographical races will be discussed later on (p. 362).

I recognize the following five stages:

(1) Forma *DODECABOSTRYCHA*.

(*a*) *Bigelow stage*, as figured by Bigelow, 1909, pl. ix, fig. 2, described on p. 27 and called by him "*dodecabostrycha*-stage of *P. hyacinthina*", 5–17 mm. diameter. The figure shows the restriction of endodermic pigment to the central stomach and the rhopalia. The peripheral system is entirely hyaline; the rhopalia as a rule are pigmented. The ring muscle is already well developed, as are the pedalia, and the ring furrow is deeply marked; there is no apical projection of the stomach into the mesogloea (no "Stielcanal").

(*b*) *Dodecabostrycha typica*. Small, up to 30–35 mm. diam., broader than high, flat, cone-shaped, mostly with "Stielcanal" (apical projection of the stomach into the mesogloea); gonads if present distinctly visible from the outside, pigment on the stomach and ring sinus, peripheral zone transparent. See for instance Vanhoeffen, 1892, pl. ii, fig. 1, and pl. i, fig. 1, *non hyacinthina*!; further, Maas, 1904, pl. v, fig. 36; but not Brandt's (1838) type specimen of *Chrysaora* (*Dodecabostrycha*) *dubia*, pls. xxix, xxx (see below under *regina*).

(2) Transitional stages between forma *DODECABOSTRYCHA* and forma *HYACINTHINA*.

Slender, as broad as high or a little higher than broad, from 35 mm. diam. upwards; pedalia and lappets slender, furrows between the pedalia reaching as far as the coronal furrow and forming here a wavy line on its under border; stomach highly vaulted, often pointed, mostly without "Stielcanal", mostly without or only

[1] The difficulties in discriminating the specimens evidently prove, I believe, that we really have to do with only one large species.

with feebly developed gonads; stomach darkly pigmented, lappet zone transparent or the lappet muscle feebly brownish.

In these stages the highly vaulted bell and pointed stomach of the *hyacinthina* type is combined with the transparent lappet zone of the *dodecabostrycha* type.

(3) FORMA *HYACINTHINA TYPICA*.

High, narrow, pointed bell, from 35 to 80 mm. in diameter, rather higher than broad, mostly with "Stielcanal"; lappets and pedalia slender, wavy line on the under border of the coronal furrow; stomach high, vaulted. Entire entodermal system (stomach and peripheral zone) deeply pigmented, gonads not visible from outside. See for instance Haeckel, 1879, pl. xxiv; Vanhoeffen, 1892, pl. i, fig. 2, and 1903, pl. ii, fig. 9; Maas, 1904, pl. v, fig. 35; Mayer, 1906, pl. ii, fig. 5, *non dodecabostrycha*!

(4) TRANSITIONAL STAGES BETWEEN FORMA *HYACINTHINA* AND *REGINA*.

Similar to the so-called developmental stage of *regina* figured by Vanhoeffen, 1903, pl. ii, fig. 8, described on pp. 23, 24; 8–36 mm. diameter. Flat, central disc broad, pedalia feebly developed, without "Stielcanal", with or without poorly developed gonads, many gastric cirri. Stomach and peripheral zone evenly chocolate brown, tentacles whitish.

These specimens are obvious on account of their flat form, relatively broad central disc, and even chocolate-brown colour.

(5) FORMA *REGINA*.

The largest form, from 80 up to 200 mm. diameter, much broader than high, blunt, dome-shaped, all organs broad, umbrella flat, tentacle bulbs and pedalia broad, not globular, clefts between pedalia not reaching to the under border of the coronal furrow, no wavy line there. Stomach mostly highly vaulted, rarely rounded, mostly without "Stielcanal". Stomach very deeply pigmented, covering of the subumbrella very dark, peripheral zone less dark, reddish brown, mostly with a pattern on the lappets.

The main characteristic is here the whole blunt form of the medusa having all the organs broadly and massively developed, the dome-shaped rounded bell being broader than high.[1] Cf. Brandt (1838), *Chrysaora* (*Dodecabostrycha*) *dubia*, pls. xxix, xxx; Haeckel, 1881, pl. xxiv; Maas, 1897, pl. x; Vanhoeffen, 1903, pl. ii, fig. 6; Mayer, 1906, pl. ii, fig. 6 (*non dodecabostrycha*!); Browne, 1910, pl. vii, fig. 1 (*non dodecabostrycha*), Broch, 1913, fig. 1, type vi.

[1] I fully agree with Maas (1897, p. 67), who writes: "Ein wirkliches Merkmal, das auch von der Conservierung sehr wenig betroffen wird, finde ich nicht in den Proportionen, sondern *in der Gesammtform des Schirmes*, die an lebendem wie an abgetötetem Material gleich charakteristisch hervortritt. Die einen Formen zeigen einen spitz zugehenden hochgewölbten Schirm, der noch einen Aufsatz mit Stielcanal trägt, alle Teile, Lappen, Pedalien sind schlank; *die anderen Formen zeichnen sich durch Breitenentwicklung und massige Entfaltung aller ihrer Teile aus, der Schirm ist viel flacher, die Tentakelbulben, Pedalien, etc., im Verhältnis breiter wie bei den ersterwähnten*. Die ersten entsprechen *dodecabostrycha* (*mirabilis*), die anderen *regina*. Dazu kommt noch ein sehr charakteristischer Farbenunterschied...auch die Gesammtgrösse bietet dazu etwas Anhalt, *regina* ist i. A. etwa $1\frac{1}{2}$–2 mal so gross wie *dodecabostrycha*".

I here include all large, broad, blunt specimens which mostly have been determined previously as *dodecabostrycha*, uniting them in one group with those properly determined as *regina*.

Periphylla hyacinthina, Steenstrup

(Plate XIV, figs. 1–2; Plate XV, figs. 1–3; Fig. 2)

Forma **dodecabostrycha** (including the "Bigelow" stage)

28. x. 25. 13° 25′ N, 18° 22′ W, off Cape Verde.[1] 4½ m. tow-net, 0–900 m.

Six specimens, distorted, 15–22 mm. diam., with and without "Stielcanal", without gonads, stomach poorly pigmented, lappet zone quite transparent. Together with five dark *Periphylla hyacinthina* typica.

St. 288. 21. viii. 27. 00° 56′ S, 14° 08′ 30″ W, north of Ascension Island. Young fish trawl, 250 (–0) m.

One specimen, 26 mm. diam., 22 mm. high, broad, with "Stielcanal", with gonads.

St. 285. 16. viii. 27. 2° 43′ 30″ S, 00° 56′ 30″ W, Gulf of Guinea. 4½ m. tow-net, 125–175 (–0) m.

Two specimens, 16 and 20 mm. diam., badly preserved, with "Stielcanal", one with gonads. Together with two dark *P. hyacinthina typica*.

St. 276. 5. vii. 27. 5° 54′ S, 11° 19′ E, Gulf of Guinea. Young fish trawl, 150–0 m.

One specimen, 12 mm. diam., 7 mm. high, stomach only pigmented dark brown, peripheral system wholly transparent, rhopalia without pigment: "Bigelow" stage.

St. 81. 18. vi. 26. 32° 45′ S, 8° 47′ W, north of Tristan d'Acunha. 4½ m. tow-net, 650–0 m.

One specimen, badly preserved, 12 mm. diam., flat, with "Stielcanal", stomach only with pigment: "Bigelow" stage.

St. 86. 24. vi. 26. 33° 25′ S, 6° 31′ E, between Tristan d'Acunha and the Cape of Good Hope. 4½ m. tow-net, 1000 (–0) m.

One specimen, 22 mm. diam., deformed, very flat, pigment faded, without gonads, without "Stielcanal".

St. 405. 4. vi. 30. 33° 50½′ to 34° 16′ S, 15° 46′ to 15° 02′ E, west of the Cape of Good Hope. Young fish trawl, 1200–0 m.

Two specimens, typical, in fair condition, 22 mm. diam., 18 mm. high, with long "Stielcanal", stomach very dark, gonads well developed.

St. 101. 15. x. 26. 33° 50′ to 34° 13′ S, 16° 54′ to 15° 49′ E, west of the Cape of Good Hope. 4½ m. tow-net, 350–400 (–0) m.

One specimen typical, 22 mm. diam., 20 mm. high, with "Stielcanal", gonads well developed, stomach very dark.

St. 87. 25. vi. 26. 33° 53′ 45″ S, 9° 26′ 30″ E, west of Cape of Good Hope. Young fish trawl, 1000 (–0) m.

Five specimens, only one well preserved, others deformed; three "Bigelow" stages, 5, 7, 12 mm. diam., pigment on stomach only; two *dodecabostrycha* typica, 22 and 24 mm. diam., 16 and 18 mm. high, one with, the other without "Stielcanal", both with greenish gonads.

St. 257. 29. vi. 27. 35° 01′ S, 10° 18′ E, west of Cape of Good Hope. Young fish trawl, 250 (–0) m.

One specimen, 25 mm. diam., 18 mm. high, very dark pigment on the stomach, with gonads, irregular warts on central disc and lappets.

[1] Throughout this paper the records of occurrence are arranged according to latitude, from north to south.

St. 407. 12. vi. 30. 35° 13′ to 34° 57′ S, 17° 50½′ to 17° 48′ E, south-west of Cape of Good Hope. 4½ m. tow-net, 800–900 m.

Eleven specimens, well preserved, 17–22 mm. diam.; nine typical, two "Bigelow" stages. The typical are all broader than high, with "Stielcanal", well-developed gonads visible from outside, pigment very dark, lappet zone fully transparent, largest specimen 18 mm. high. Caught together with many specimens of *Atolla chuni* and *wyvillei*.

St. 256. 23. vi. 27. 35° 14′ S, 6° 49′ E, west of Cape of Good Hope. Young fish trawl, 850–1100 (–0) m.

Five specimens well preserved, typical, 17–22 mm. in diam., all broader than high; two with, three without "Stielcanal"; one without, others with gonads. Together with one *Periphylla hyacinthina*, transitional stage.

St. 256. 23. vi. 27. 35° 14′ S, 6° 49′ E, west of Cape of Good Hope. Young fish trawl, 850–1100 (–0) m.

One specimen in fair condition, highly vaulted, 21 mm. diam., 19 mm. high, with "Stielcanal", gonads greenish with large eggs.

St. 151. 16. i. 27. 53° 25′ S, 35° 15′ W, north of South Georgia. 1 m. tow-net, 500–625 m.

One specimen, 11 mm. diam., flat, "Bigelow" stage, rhopalia without pigment.

St. 592. 15. i. 31. 64° 17′ S, 75° 31′ W, south of South Shetlands. 1 m. tow-net, 350–124 m.

One specimen, 27 mm. diam., 16 mm. high, badly preserved, flatly vaulted, short "Stielcanal", *reddish* not dark brown pigment on stomach, lappet zone fully transparent, tentacles brownish.

St. 590. 14. i. 31. 65° 20½′ S, 73° 30½′ W, between South Shetlands and Bellingshausen Sea. Young fish trawl, 1150–1400 m.

One specimen, typical, preserved in spirit, 22 mm. diam., 18 mm. high, with "Stielcanal", no gonads.

Transitional stages to **hyacinthina typica**[1]

2. xi. 25. 6° 55′ N, 15° 54′ W, south of Cape Verde Islands. 2 m. tow-net, 0–800 m.

One specimen, fixed chromo-formalin, 23 mm. diam., flat, depressed, no "Stielcanal", no gonads, stomach dark brown, lappet zone hyaline, with pigment on lappet muscles.

St. 286. 17. viii. 27. 3° 06′ 30″ S, 3° 53′ W, Gulf of Guinea. Young fish trawl, 125 (–0) m.

One specimen in fair condition, peculiarly formed, 21 mm. diam., 26 mm. high, much higher than broad, with long broad "Stielcanal", gonads distinctly to be seen from outside, stomach dark brown, lappet zone hyaline, lappet muscles only faintly brownish: *a typical transitional stage.*

St. 270. 27. vii. 27. 13° 58′ 30″ S, 11° 43′ 30″ E, Elephant Bay, Angola. 70 cm. tow-net, 126–0 m.

One beautiful specimen, 29 mm. diam., 26 mm. high, stomach highly vaulted, no "Stielcanal", no gonads, stomach dark brown, lappets transparent with brownish muscles, brownish tentacles.

St. 100 c. 4. x. 26. 33° 20′ to 33° 46′ S, 15° 18′ to 15° 8′ E, west of Cape of Good Hope. Young fish trawl, 2000–2500 m.

One specimen in fair condition, 25 mm. broad and high, with "Stielcanal", gonads clearly visible from outside, stomach very deeply pigmented, lappets hyaline with pigment on lappet muscles.

St. 256. 23. vi. 27. 35° 14′ S, 6° 49′ E, west of Cape of Good Hope. Young fish trawl, 850–1100 (–0) m.

One specimen, 32 mm. diam., 27 mm. high, with "Stielcanal", with gonads, stomach dark brown, *lappet zone brownish*, tentacles white, gonads visible from outside: transitional stage on account of colour of lappets.

[1] In this group the size of the specimen is very variable. Here the colour of the lappet zone is regarded as the more important character.

St. 76. 5. vi. 26. 39° 50′ 30″ S, 36° 23′ W, north of South Georgia. $4\frac{1}{2}$ m. tow-net, 1500–0 m.

One specimen in fair condition, 28 mm. diam., 30 mm. high, stomach highly vaulted, no "Stielcanal", no gonads, stomach dark brown, lappet zone transparent, rhopalia with pigment.

St. 668. 19. iv. 31. 46° 42′ S, 30° 22′ W, north of South Georgia. Young fish trawl, 375–0 m.

One fair specimen, 52 mm. diam., 55 mm. high, stomach highly vaulted, no "Stielcanal", no gonads, stomach very deeply pigmented, lappet zone transparent, muscles brownish.

St. 395. 18. v. 30. 48° $26\frac{3}{4}$′ S, 22° 08′ W, north-east of South Georgia. $4\frac{1}{2}$ m. tow-net, 1500–1600 m.

One specimen, 80 mm. diam., 75 mm. high, stomach highly vaulted, with "Stielcanal", no gonads, stomach dark brown, lappet zone transparent with brown pigment on muscles only.

St. WS 410. 13. iii. 29. 51° 56′ S, 55° 07′ W, east of Falkland Islands. 1 m. tow-net, 78–0 m.

One beautiful specimen, 72 mm. broad, 68 mm. high, stomach highly vaulted, short "Stielcanal", no gonads, stomach dark brown, lappet muscles faintly pigmented.

St. WS 283. 17. ix. 28. 54° 22′ S, 34° 25′ W, east of South Georgia, 70 cm. tow-net, 78–0 m.

One specimen in fair condition, 78 mm. broad, 72 mm. high, stomach pointed, no "Stielcanal", no gonads, stomach dark brown, lappet muscles light brown or hyaline, tentacles brownish on inside, white on outside.

St. 344. 7. ii. 30. 55° 30′ S, 34° 33′ W, south of South Georgia. 70 cm. tow-net, 500–250 m.

One beautiful specimen, 35 mm. broad and high, stomach pointed, no "Stielcanal", no gonads, stomach dark brown, lappet zone transparent, tentacles brownish.

St. WS 552B. 2. ii. 31. 68° 53′ to 68° 50′ S, 13° 03′ W, north of Coats Land. 1 m. tow-net, 560–450 m.

Two very beautiful specimens: (i) 85 mm. broad, 83 mm. high, without "Stielcanal"; (ii) 52 mm. broad, 61 mm. high, with short "Stielcanal". Stomach highly vaulted, no gonads, stomach *reddish* brown, rather light, not dark brown, subgenital space without pigment, lappet zone transparent white, tentacle muscles, tentacles and rhopalia with brown pigment, coronal furrow whitish. This specimen is very peculiar in coloration.

Forma hyacinthina typica[1]

10. x. 25. 41° 37′ 15″ N, 12° 30′ 20″ W, off Portugal. 2 m. tow-net, 0–900 m.

One specimen, preserved in spirit, broad, 29 mm. diam., 18 mm. high, with "Stielcanal", no gonads, stomach deeply, lappets more diffusely, pigmented, jelly yellowish.

28. x. 25. 13° 25′ N, 18° 32′ W, off Cape Verde, $4\frac{1}{2}$ m. tow-net, 0–900 m.

Five specimens more or less damaged: (*a*) 80 mm. diam., 55 mm. high, with "Stielcanal", gonads feebly developed; (*b*) 60 mm. diam., 76 mm. high, with "Stielcanal", without gonads; (*c*) three specimens, 25, 32, 35 mm. diam., flatly depressed, without "Stielcanal" and gonads. All deeply pigmented on stomach and lappet zone. Found together with six specimens of forma *dodecabostrycha*.

St. 298. 29. viii. 27. 12° 08′ N, 20° 53′ 30″ W, off Cape Verde. Young fish trawl, 900–1200 (–0) m.

One specimen, 47 mm. diam., 40 mm. high, stomach highly vaulted, with "Stielcanal", no gonads, stomach dark brown, lappet zone diffusely pigmented.

[1] The specimens determined here as *P. h. typica* do not correspond, it is true, exactly to the diagnosis (p. 344), particularly with regard to the proportionate dimensions; but the rather slender lappets and pedalia, the highly vaulted stomach with "Stielcanal", and last but not least *the dark colour of the lappet zone*, were decisive characters for the determination. Perhaps they might be regarded by another as belonging to transitional stages between forma *dodecabostrycha* and forma *regina*.

St. 296. 26. viii. 27. 8° 12′ N, 18° 49′ W, south of Cape Verde. Young fish trawl, 450–500 (–0) m.

One specimen badly preserved, 52 mm. diam., 46 mm. high, with long "Stielcanal", no gonads, pigment mostly vanished, lappet zone rather dark.

St. 285. 16. viii. 27. 2° 43′ 30″ S, 00° 56′ 30″ W, Gulf of Guinea. 4½ m. tow-net, 125–175 (–0) m.

Two specimens: one 39 mm. diam., 22 mm. high, deformed; one 46 mm. diam., 25 mm. high, deformed. Both with short "Stielcanal", without gonads, very deeply pigmented on stomach and lappet zone, tentacles white.

St. 276. 5. vii. 27. 5° 54′ S, 11° 19′ E, Gulf of Guinea. Young fish trawl, 150–0 m.

One specimen in fair condition, 31 mm. diam., 26 mm. high, with long "Stielcanal", without gonads, stomach very deeply pigmented, lappet zone reddish brown.

St. 440. 21. ix. 30. 30° 13½′ to 30° 25½′ S, 32° 48½′ to 32° 48′ E, east of Cape Agulhas. Young fish trawl, 1000–0 m.

Two specimens in fair condition: (*a*) 33 mm. diam., 28 mm. high; (*b*) 26 mm. diam., 24 mm. high. With long "Stielcanal", one with opening at the apex, no gonads, stomach very dark brown, lappet zone more reddish. Found together with seven *Atolla wyvillei*.

St. 86. 24. vi. 26. 33° 25′ S, 6° 31′ E, west of Cape of Good Hope. 4½ m. tow-net, 1000 (–0) m.

Two specimens in fair condition, 70 mm. diam., 65 mm. high, and 46 mm. diam., 52 mm. high, stomach pointed, with very long "Stielcanal" (8 mm. long), with opening at the apex, gonads feebly developed, stomach very dark brown, lappet zone with diffuse dark brown pigment, tentacles white, with peculiar radial structure on the exumbrella.

Transitional stages between hyacinthina typica and regina

St. 72. 1. vi. 26. 41° 43′ 20″ S, 42° 20′ 40″ W, far north-east of Falkland Islands. 4½ m. tow-net, 2000 (–0) m.

One specimen, badly preserved, 27 mm. diam., 12 mm. high, central disc 13 mm. broad, pigment on stomach faded, lappet zone diffusely pigmented.

St. 151. 16. i. 27. 53° 25′ S, 35° 15′ W, north-east of South Georgia. 4½ m. tow-net, 1025–1275 m.

One specimen badly preserved, 26 mm. diam., 12 mm. high, central disc 14 mm. diam., faded, without gonads.

St. WS 361. 14. i. 29. 55° 24′ S, 34° 42′ W, south of South Georgia. 70 cm. tow-net, 1000–750 m.

One specimen in fair condition, vasiform, 31 mm. diam., 12 mm. high, central disc 16 mm. broad, lappet zone turned upwards, no gonads, without "Stielcanal", stomach dark red, pedalia and lappets diffusely reddish brown, tentacles white.

St. 391. 18. iv. 30. 55° 48½′ S, 52° 35′ W, between Falklands and South Orkneys. 4½ m. tow-net, 1200–1300 (–0) m.

Two specimens, deformed, flat, without gonads: one 36 mm. diam., 8 mm. high, central disc 18 mm. diam.; the other 27 mm. diam., flat, central disc 13 mm. diam. Together with five specimens of *regina*.

Forma regina[1]

St. 85. 23. vi. 26. 33° 07′ 10″ S, 4° 30′ 20″ E, west of Cape of Good Hope. 4½ m. tow-net, 2000 (–0) m.

One specimen low, plump, damaged on stomach, stomach highly vaulted with cicatrice on the apex, no "Stielcanal", with feebly developed gonads, dark purple pigment on stomach mostly vanished, peripheral zone poorly pigmented.

[1] For measurements see Table II, p. 354.

St. 76. 5. vi. 26. 39° 50′ 30″ S, 36° 23′ E, north of South Georgia. 4½ m. tow-net, 1500–0 m.

Two specimens much damaged, flat, low dome-shaped, stomach highly vaulted, without "Stielcanal", gonads well developed, many gastric cirri, stomach very dark purple-brown, peripheral zone diffusely *dark reddish brown* with pattern.

St. 414. 28. viii. 30. 40° 28′ S, 16° 54′ E, west of Gough Island. 1 m. tow-net, 1700–1000 m.

One specimen well preserved, with a 6 mm. broad round opening at the apex, stomach highly vaulted, tent-shaped, with eight pockets, gonads feebly developed, many gastric cirri visible from outside, stomach very dark purple, peripheral zone diffusely reddish brown, pigmented with broad dark brown pattern on lappets, tentacles 230 mm. long (Plate XIV, figs. 1, 2).

St. 72. 1. vi. 26. 41° 43′ 20″ S, 42° 20′ 40″ W, far north-east of Falkland Islands. 4½ m. tow-net, 2000 (–0) m.

Two specimens, stomach highly vaulted, with pouches, forming an eight-rayed star, clearly visible from outside, no "Stielcanal", one with large opening at the apex, 8 mm. broad, the other with cicatrice. Many long gastric cirri. Gonads poorly developed. The larger specimen with dark purple stomach, the smaller less dark, both with hyaline peripheral zone with brown pattern.

St. 8. 8. xi. 26. 42° 36′ 30″ S, 18° 9′ 30″ W, south-west of Tristan d'Acunha. 2 m. tow-net, 1500–1700 m.

One specimen, badly preserved, damaged, without gonads, traces only of pigment on stomach and lappets, central disc and lappets with irregularly formed large warts, small opening at apex.

St. 71. 30. v. 26. 43° 20′ S, 46° 02′ W, north of Falkland Islands. Young fish trawl, 2000–0 m.

One specimen, stomach trumpet-shaped, with very broad short apical part, no "Stielcanal", no gonads, many white cirri, stomach dark brown, faint brown pattern on lappets.

St. 239. 2. vi. 27. 46° 56′ S, 46° 03′ W, north of Falkland Islands. 4½ m. tow-net, 1050–1350 (–0) m.

One specimen badly preserved, peripheral zone partly torn away, bell low, dome-shaped, stomach highly vaulted, with short thin "Stielcanal" and small opening at the apex, many gastric cirri, gonads whitish, well developed (♀), pigment on stomach dark brown, lappets transparent, lappet muscles light brown, tentacles 150 mm. long, silvery white.

St. 395. 13. v. 30. 48° 26′ S, 22° 8′ W, north-east of South Georgia. 4½ m. tow-net, 1500–1600 m.

Three specimens in fair condition, one with 4 mm. broad round opening at the apex, others with deep cicatrice, stomach tent-shaped, highly vaulted, with eight pouches, no "Stielcanal", many gastric cirri, gonads well developed, in one specimen visible from outside, stomach dark purple-brown, *peripheral zone dark reddish brown with pattern on lappets* (may be regarded as transitional to *hyacinthina* typica).

St. 12. 18. xi. 26. 51° 55′ S, 32° 27′ 30″ W, north of South Georgia. 4½ m. tow-net, 1200–1500 m.

One specimen, badly preserved, distorted, gonads developed.

St. 114. 12. xi. 26. 52° 25′ S, 9° 50′ W, west of Bouvet Island. 4½ m. tow-net, 650–700 m.

Three specimens, beautiful, very dark reddish brown pigment on stomach and peripheral zone, stomach rounded, with eight pockets, no "Stielcanal", no opening at the apex, gonads feebly developed (may be regarded as transitional to *hyacinthina* typica).

St. 151. 16. i. 27. 53° 25′ S, 35° 15′ W, north-east of South Georgia. 4½ m. tow-net, 1025–1075 m.

Four specimens with highly vaulted stomach, no "Stielcanal", on two specimens cicatrice on apex, gonads on two largest well developed, many gastric cirri, stomach dark purple, peripheral zone more transparent, with pattern, the smallest with diffuse dark pigment on lappets.

St. 391. 18. iv. 30. 55° 48½′ S, 52° 35′ W, between Falkland Islands and South Orkneys. 4½ m. tow-net, 1200–1300 (–0) m.

Five specimens: one specimen with large (10 mm. wide) round opening at the apex, another with 6 mm. wide opening, one with closed cicatrice, stomach trumpet-shaped or of a broad pyramidal form, with eight pockets, all with well-developed gonads. Stomach in all very dark purple-brown. One specimen with hyaline lappet zone without design, one specimen with faintly pigmented lappet zone and distinct pattern, three specimens *with dark reddish brown diffusely pigmented pedalia and lappets.*

St. 461 E. 22. x. 30. 56° 41′ S, 20° 24′ W, west of Bouvet Island. 1 m. tow-net, no depth indicated.

One specimen very large, badly preserved, stomach highly vaulted, no "Stielcanal", many long white gastric cirri, gonads well developed, tentacles very thick, 250 mm. long, white or mother-of-pearl-coloured, with traces of brown pigment, stomach very dark purple, *peripheral zone with reddish brown pigment,* lappets with pattern. Type of the so-called large "*dodecabostrycha*", *sensu* Brandt.

St. 461. 21. x. 30. 56° 44′ S, 2° 22′ W, west of Bouvet Island. 1 m. tow-net, 525–420 m.

One specimen, very plump, broad, stomach pyramid-shaped, no "Stielcanal", gonads feebly developed, stomach dark purple, peripheral zone diffusely light brown, with faint pattern on lappets, preserved in spirit.

St. 366. 6. iii. 30. Four cables south of Cook Island, South Sandwich Islands. Large dredge, 155–322 m.

One specimen not well preserved, stomach highly vaulted, with small "Stielcanal", gonads feebly, gastric cirri well developed, stomach dark purple, peripheral zone hyaline, without pattern, traces of pigment on lappet muscles. A large "*dodecabostrycha*" in the old sense.

St. 383. 14. iv. 30. 60° 32′ S, 62° 42′ W. South Shetlands. 70 cm. tow-net, 1500–1000 m.

One specimen in fair condition, damaged on the peripheral zone, central part with polygonal furrows, stomach trumpet-shaped with eight pockets, no "Stielcanal", stomach very dark, purple brown, lappet zone and pedalia diffusely pigmented with dark reddish brown, with pattern on lappets, tentacles white.

The question whether the species *hyacinthina* and *dodecabostrycha* must be united or kept separate is, I believe, definitely settled (Bigelow, Mayer, Broch). I shall consider here, therefore, only the relation between the species *regina* and *dodecabostrycha*.

In point of fact the distinction between a large *dodecabostrycha* and a full-grown *regina* seems impossible to me. Broch and Bigelow (1928) found specimens precisely intermediate. The large size and the low dome-like bell are common to both. I therefore cannot agree with Vanhoeffen (1903, p. 22; 1908, p. 36) who attributes these characters to *regina* alone. The form of the stomach is very variable, and its shape—whether evenly rounded or dome-like, or highly vaulted, with or without an apical projection into the mesogloea ("Stielcanal")—may be dependent on the physiological condition of the medusa. An evenly rounded floor of the subumbrella is occasionally to be seen in *dodecabostrycha* too (Mayer, 1906, pl. ii, fig. 6). In many cases the pointed stomach is so highly vaulted that there is no space left for a "Stielcanal". *There remains, therefore, as a principal character for* regina *the form of the pedalia only*, whether globular and thick or slender and rectangular. I cannot, however, attribute to this character such decisive importance as has been done by previous authors, because in the type specimen the pedalia are not globular, but feebly developed and rather rectangular; because the pedalia in the other descriptions and figures of *regina* are described and figured in a very different and mostly insufficient way; and because the various descriptions do not agree with each other.

Among the series of *Periphylla* in the present material I found twenty-nine specimens, all of which I at first identified as large *dodecabostrycha*, but later on I found that there are intermediate forms between them and the large blunt specimens described hitherto as *regina*. Thus it became impossible for me to keep both forms separate and I identified the specimens as *regina*. I must confess, however, that I did not find a single specimen uniting all the four characters enumerated by Broch (1913, p. 8) for *regina*. It is therefore possible that another medusologist may consider that the present series of twenty-nine specimens consists exclusively of large *dodecabostrycha* without a single *regina*. This is the more likely as the specimens differ in some morphological respects from the descriptions hitherto given by the various authors.

The reasons for the instability of the species *regina* lie in the facts that only relatively few well-preserved specimens of this so-called species have been captured and studied, that there is no good figure of it in the literature, and that Haeckel's description of *Periphema regina* is in many respects insufficient because the type specimen was badly damaged. Furthermore, the various authors differ in their appreciation of the characters for systematic purposes. One takes the shape of the bell or of the stomach and lack or presence of a "Stielcanal", another the more or less globular shape of the pedalia.

Let us examine the literature on this point:

The CHALLENGER EXPEDITION (Haeckel, 1881) captured a specimen in broken fragments in the sub-Antarctic, south-west of Kerguelen, 62° 26′ S, 95° 44′ E, St. 156, from a depth of 1975 fathoms. Haeckel gives a poor description of this type specimen under the name *Periphema regina*. No figure of the external shape of the medusa could be given, but only of a fragment of the border of the umbrella, with pedalia, lappets and tentacles (pl. xxiv, fig. 2). The bell is said to be nearly as high as broad; the pedalia are not figured as globular or semiglobular, but are described (p. 85) as being slightly vaulted and comparatively small, the rhopalar being figured longer and narrower than the tentacular ones. Mayer (1910, p. 547) believes them, according to Haeckel's figure, to be rectangular and longer than wide. Browne (1910), who saw the type specimen of *regina* in the British Museum, found it to consist "only of a few fragments of little scientific value" (p. 43).

The VALDIVIA EXPEDITION (Vanhoeffen, 1903) brought home two specimens only of *P. regina* from the Antarctic (St. 120, 42° 17′ S, 14° 1′ E, in the West Wind Drift, closing net, 1000–1500 m. depth and St. 136, 55° 57′ S, 16° 14′ E, in the Antarctic Drift, vertical net, 2000 m.). The other stations, 264 and 271, where *P. regina* has been collected, are in the Indian North Equatorial current and in the Gulf of Aden, from 1079 and 1200 m. depth. The very beautiful figure given by Vanhoeffen (1903, pl. ii, fig. 6) is not accurate. It shows very well the external shape, with low dome, rounded floor of the stomach and lack of "Stielcanal", but there is no trace of a coronal furrow and the pedalia cannot be distinctly seen. The principal characters mentioned by Vanhoeffen—dome-like vaulted bell, brighter reddish brown colour, and late development of gonads—do not suffice, I believe, to separate the specimens from large *dodecabostrycha*.

Maas (1897), studying the ALBATROSS material, found *regina* in the Gulf of California and in the neighbourhood of Central America in the Pacific (p. 65). The figure on pl. x, partly after a sketch from life by Agassiz, gives a vague impression of the habitus with the thick gelatinous substance, low dome, deep coronal furrow and rounded stomach without apical projection, but is certainly not correct with regard to the pedalia, lappet zone and colour. The pedalia, to begin with, are very large blunt balls of equal size and form, lying between the lappets. They are separated by a deep cleft not only from each other but also from the tentacles and lappets. In fact, the pedalia pass gradually into the lappets. Here they are figured as perfectly isolated from them. I believe that in this figure we find the origin of the statement that the pedalia of *regina* ought to be globular or at least semiglobular. The colour of the stomach in this figure is certainly not correct (see below). The lappets show traces of a horseshoe-shaped, rose pigment pattern similar to that which I found in the Discovery specimens. Maas finds (p. 64) the remarkable characteristics less in proportions or details than in the general shape and in the broad plump form not only of the bell but also of the pedalia, bulbs and tentacles (see footnote, p. 344).

The DEUTSCHE SÜDPOLAR EXPEDITION (Vanhoeffen, 1908) captured one specimen in the waters near Cape Town at a depth of 3000 m. and two others in the 'Eisberggebiet' south of Kerguelen on the route to Gaussberg. No description is given, but in a few lines reference is made to a "large form with dome-like bell" (the same characters as in large *dodecabostrycha*). One specimen was lost before it had been studied (p. 36).

The 'SOUTHERN CROSS' (Browne, 1910, pp. 42–6) secured five specimens of a *Periphylla*, mostly broken into pieces or in a very bad state of preservation, in the waters near Cape Adare on the surface or in less than six fathoms (Browne, *Southern Cross Collections*, 1902, p. 214; 1910, pp. 42–6), and the 'Discovery' obtained a single specimen (captured by hand) in McMurdo Sound. The occurrence of a *Periphylla* at or near the surface in the Antarctic region is very remarkable. The description given by Browne is very unsatisfactory and it is impossible to identify the much damaged specimens with any certainty. Browne himself felt uncertain about his identification of them as *dodecabostrycha*. He writes that the rounded shape of the top of the umbrella is in favour of the specimens being *regina*; but after comparing Dr Wilson's sketch (pl. viii, fig. 1) with that of *regina* by Agassiz he came to the conclusion that the specimens did not belong to that species. His determination is based not so much on the shape of the umbrella as on the shape of the pedalia, the rhopalar being longer and narrower than the tentacular ones as in Haeckel's figure (in the figure by Agassiz they are represented as of equal size) and having quite a different form. They look as if they were constricted in the middle, having a globular part next the coronal furrow and a flatter part nearer to the lappets. It is a pity that Browne's figure is so unsatisfactory in this respect, the pedalia being figured in such a different and strange manner. I rather doubt whether the figure in question is very accurate, not only regarding the pedalia but also in other respects (e.g. lack of coronal furrow).

The large broad *Periphylla* from the Hawaiian Islands, identified by Mayer (1906) as *dodecabostrycha* and figured in pl. ii, fig. 6, with low dome, rounded stomach, no "Stielcanal", deep coronal furrow and rather broad pedalia, next to fig. 5 of a young specimen with sharply pointed bell, high vaulted stomach and "Stielcanal", might equally have been identified as *regina*. Mayer thinks (p. 1137) that the shape of the umbrella changes with age, becoming flatter and relatively wider as the medusa grows larger. The principal reason for his identification may be that the pedalia are more rectangular, not globular as they ought to be in *regina*.

The same may be the case with the *Periphylla* figured by Vanhoeffen (1911, fig. 1) and identified as *hyacinthina*.

Broch (1913) studied nine specimens which he believed to be *regina* on account of the rounded bell, the apex of the stomach being evenly rounded, with no trace of the so-called "Stielcanal", and the pedalia more globular and less oblong than is usual in *hyacinthina*. With regard to pigmentation he found no difference between this species and *hyacinthina*. It is to be regretted that he did not give a figure of his so-called *regina*, having had freshly preserved specimens in fair condition, and that he writes nothing about the two doubtful specimens from St. 49 (500 m. depth) and from St. 81 (1500 m.).

Bigelow (1928) in his Arcturus Report (pp. 495–6) mentions two specimens, also from the tropical Pacific, which were precisely intermediate between *hyacinthina* and *regina* because they had no "Stielcanal" and the pedalia showed the usual *hyacinthina* form—thus combining the characters used by Broch for separating both forms. Bigelow gives no figure.

Resuming, *I come to the conclusion that it is impossible to distinguish a large, so-called,* "dodecabostrycha" *from* regina. *I therefore restrict the name* dodecabostrycha *to small flat specimens of 35 mm. maximum diameter, with transparent peripheral zone; the name* hyacinthina *to medium-sized specimens with pointed bell and stomach with more or less pigmented peripheral zone; and the name* regina *to the large plump dome-like specimens.*

With regard to the few transitional stages between forma *hyacinthina* and *regina* I must observe that I at first thought them to be developmental stages of *regina*. There is, however, no necessity to do so. It is true they resemble the young larva figured by Vanhoeffen (1908, pl. ii, fig. 8); but they are much larger; the flat form of the bell and the broad central disc are also found in *dodecabostrycha*; there is no "Stielcanal", though this occurs also in *hyacinthina*, and the pedalia are always small and not relatively large as they should be if we were in fact dealing with developmental stages of *regina*. Besides, they are caught in strata more superficial than the habitat of *regina*. I therefore believe these stages to be particularly low and deeply pigmented transitional stages between *hyacinthina* and *regina*.

To this discussion I wish to add some details, especially with regard to the large specimens of the *regina* type in the present series. Short remarks have been given already in the list above. Measurements of the bell, central disc and pedalia are given in Table II.

Table II

Showing measurements in mm. of the twenty-nine specimens of Periphylla hyacinthina *forma* regina

Station	Diameter of the lappet zone	Diameter of central disc above the furrow	Height of the bell	Height of the central disc	Breadth of pedalia		Breadth of the smooth zone	Relation between height and diameter
					Rhopalar	Tentacular		
239	150	125	—	93	—	—	—	—
71	85	65	75	38	9	12	7	1·13
12	100	—	60	—	—	—	—	1·66
76	125	107	112	65	10	15	15	1·16
	112	85	82	52	8	13	12	1·36
151	130	86	83	35	15	20	15	1·57
	110	75	72	36	11	17	13	1·53
	82	56	58	35	10	14	7	1·46
	105	75	88	35	13	18	12	1·19
85	122	78	82	42	12	15	12	1·49
72	140	90	95	52	15	20	17	1·48
	110	83	72	42	8	12	13	1·53
114	98	62	65	35	8	10	6	1·52
	110	66	63	32	10	15	8	1·74
	85	54	57	29	6	10	5	1·49
8	85	60	33	38	—	—	—	1·58
383	90	68	84	52	7	13	9	1·09
461	45	36	30	18	4	5	4	1·5
	136	86	78	45	19	24	18	1·75
395	125	96	98	62	17	22	15	1·28
	120	88	92	52	15	20	14	1·30
414	150	96	110	65	16	19	15	1·36
461 E	200	130	160	60	18	25	30	1·25
366	140	120	130	75	17	22	12	1·07
391	130	83	80	40	15	20	16	1·63
	110	90	90	35	16	18	15	1·22
	102	78	76	40	14	16	10	1·34
	80	63	65	32	8	12	6	1·22
	95	58	45	27	6	8	8	2·11

SIZE. Most specimens are from 100 up to 150 mm. in diameter. A single specimen from St. 461 E has a diameter of 200 mm. The central disc is relatively broad; the relation between height and diameter is very variable, but most specimens are rather flatter than high.

FORM. Mayer called attention to the fact that the form of the bell apparently changes with age, becoming flatter and relatively wider as the medusa grows larger (1906, p. 1137). I agree with this so far as the older stages are concerned, but not with respect to the small "Bigelow" stages and stages of *dodecabostrycha* typica, which are generally much flatter than the older transitional and *hyacinthina* stages.

The SURFACE OF THE EXUMBRELLA is mostly perfectly smooth, though some specimens show a radial structure of nettle-warts (St. 86) or a network of wide meshes (St. 383), or irregular large warts on the central disc and the lappets (St. 8). In most cases the apex of the umbrella is evenly rounded, but some specimens show at the spot on the apex where the opening of the so-called "Stielcanal" might be expected, a more or less deep crater-like groove, which seems to be a healed cicatrice (Sts. 72, 85, 151). In others there is a deep hole at the apex (Sts. 72, 391, 395, 414: Plate XIV, figs. 1 and 2) (see p. 356).

The LAPPETS (Plate XIV, figs. 1, 2) are oval, broad and spade-shaped, the tentacular ones being a little longer and broader than the rhopalar ones. The latter often include a broader angle and their outline is a little more curved inwards. The strongly developed white or reddish lappet muscles are often visible through the more or less transparent lappets, so that the latter are no longer entirely transparent.

The TENTACLES are thick, especially thickened on the base, often broad and ribbon like, in the largest specimen 250 mm. long.

The PEDALIA (Plate XIV, figs. 1, 2; XV, fig. 3) in the present large specimens of the *regina* type are broad and blunt, only a little vaulted, rather oblong or rectangular, and never globular or semiglobular. Rhopalar and tentacular pedalia are of a different form. The clefts on both sides of the tentacular pedalia run straight, but those on both sides of the rhopalar ones run more irregularly, proximally curved outwards, distally more inwards, S-shaped, and forming an angle on both sides of the rhopalium (see Plate XIV, fig. 2, middle), so that the rhopalar pedalia seem to be constricted and pointed, the tentacular ones being rectangular and transversely cut off. The clefts in the large specimens never originate from the lower border of the annular furrow, but begin at a distance of about 10–12 mm. from it. Between the coronal furrow and the origin of the clefts there is a broad, even, flat zone which separates the pedalia from the furrow. This is very typical for all specimens of the present series and the shape of the pedalia is thus quite different from all figures in the literature of large *dodecabostrycha* or *regina*. In *hyacinthina* the clefts between the pedalia extend from the lower border of the coronal furrow and divide the latter into numerous small flexures which together form a wavy line. In the present specimens it runs straight and is not wavy at all. The rhopalar pedalia are always a little narrower than the tentacular ones but the difference in size of both is never as large as in a Discovery specimen mentioned by Browne (1910, p. 46), for it is 10 mm. in this specimen.

The STOMACH of the specimens of the *regina* type is very thick-walled and much stronger than in the specimens of forma *hyacinthina*. In not a single specimen was the apex evenly rounded, and in one or two cases only (Sts. 239, 366) a thin apical projection into the mesogloea was to be seen (the so-called "Stielcanal"). In most specimens the stomach is highly vaulted, rising to the apex in the form of a sort of tent, which is suspended on the four septa. On both sides of these there are often to be seen four pairs of pouches, which give to the stomach, if seen from above, the outline of an eight-rayed star—a very obvious feature (Plate XIV, fig. 1; XV, fig. 3). In several specimens a round deep gap in the mesogloea at the apex is to be seen (e.g. Sts. 72 and 395), which leads directly into the stomach. I do not think that this large opening could have been produced artificially in catching or preserving the animal. There is a broad communication between the interior of the stomach and the surrounding medium at the apex in the intact animal. I cannot, however, imagine how the animals may have fed and how they could have remained alive even during a short time with such a wound and a large opening of the stomach on the apex in form of an anus. In specimens of *Cassiopea* from the coast, which frequently lie on the bottom with the exumbrella turned towards the ground, a similar opening at the apex is often visible, but only in the jelly of the exumbrella on the surface, never so deep as to reach the stomach. In other specimens (Sts. 151, 85, 72) a round healed cicatrice is visible lying in a deep crater-like groove at the apex of the umbrella (see above p. 355). All this is very strange.

With regard to the "Stielcanal" Broch in the Michael Sars Report (1913, p. 7) says that "this apical projection of the stomach into the mesogloea is mostly confined to larger animals and that there is no such canal in the very smallest specimens". In the present series most individuals of the forma *dodecabostrycha*, some *hyacinthina* and a few of forma *regina* have a "Stielcanal", but the specimens in the youngest stage, the 'Bigelow' stage, have none. This is very striking indeed, because in this young stage the presence of a "Stielcanal" is to be expected if the animal in fact is derived from a sessile form (*Scyphistoma*). This is an important and puzzling problem.

The GASTRIC CIRRI in the large specimens are very long (20–30 mm.) and very numerous (in some medusae certainly many hundreds).

The GONADS are mostly poorly developed in most *hyacinthina* and even in many of the large specimens of *regina*, but well developed in most of the *dodecabostrycha* individuals. They are easily overlooked from outside, not so much on account of the very dark pigment of the stomach and the ring sinus, but much more on account of the dark chocolate-brown or velvety pigment covering the walls of the subumbrella and of the subgenital porticus. Vanhoeffen writes (1903, p. 23) that in a specimen of *regina* 72 mm. in diameter the gonads were not yet developed. The same is the case too with many of the *regina* stage in the present series. It is strange that the small *dodecabostrycha* stages generally show the gonads much better developed than the large ones of the *regina* type. If developed they are greenish or yellowish in colour (see the discussion below on geographical distribution).

PIGMENTATION. Maas (1897, p. 64), who regards the colour as a good specific character for *regina*, speaks about a "leicht rötlicher Ton, der bei entodermalen Teilen in rot oder rotviolett übergehen kann", but his opinion is based on a sketch from Agassiz (pl. x) which shows the stomach coloured in a very strange and unusual manner, "differing interestingly from most other deep-sea medusae" (Broch, 1913, p. 9). It is pinkish on the whole with a dark purple cross and with tracks of pinkish pigment both on lappets and pedalia. In this respect too (see above under pedalia) the figure is certainly not accurate. Vanhoeffen's figure of *regina* in the Valdivia Report (1903, pl. ii, fig. 6) shows only a small difference in colouring of the somewhat lighter lappet zone in comparison with the lappets in *hyacinthina* (*ibid.*, fig. 9). The lappets as figured here are not pigmented with a uniform dark brown as in *hyacinthina*, but are darker on the sides and in the middle, and more transparent on both sides of the middle rib. In the text he speaks about a "hellere mehr rotbraune Farbe von *regina*" (p. 23). Broch (1913, p. 9) could observe in fresh specimens no difference whatever in the colouring of *regina* and *hyacinthina*.

The Discovery material is very interesting in this respect (Plate XV, figs. 1, 2). Most large specimens of the *regina* type show a purple or dark brown stomach and ring sinus, a dark brown, velvety covering of the subumbrella and a more or less transparent lappet zone. Specimens from Sts. 114, 383, 391, 395 show in the peripheral zone a diffusely reddish or rusty brown pigmentation which is much less transparent. In all specimens, however, with transparent or pigmented lappet zone on each lappet a characteristic pigmentation is visible. As will be seen from the photographs (Plate XV, figs. 1, 2) at a small distance from the border a continuous wavy line of dark brown pigment can be distinguished along the whole periphery, forming all over the border a lobed band in the shape of an elegant festoon. In other cases this line is interrupted at the insertion of the tentacles, forming an isolated horseshoe-like pattern or design in each lappet. In some other cases the horseshoe is interrupted at the top of the lappet, the pigment forming two arches near the border of them. On the pedalia I have never seen such stripes (see the figure by Maas). In the middle of each lappet there is on the subumbrellar side a very dark brown stripe, which runs along the septum down the middle line of each lappet. In a few cases (St. 114), three specimens from 650–700 m. depth, and (St. WS 361) one specimen from 750–1000 m. depth, the colour of the pedalia was diffuse dark brown.

With regard to the pigmentation of the *dodecabostrycha* and *hyacinthina* stages the transparency of the lappet zone or its darker pigmentation is said by all previous authors to be a good criterion for distinguishing both forms. In the present series, however, it was in many cases very difficult to reach a decision. The pigmented subumbrellar muscles of the lappets are often so distinctly visible through the almost transparent gelatinous substance of the lappets, that the lappet zone cannot be said to be entirely transparent. It is the same with the pigmentation of the stomach and the distal parts of the gastro-vascular system. It was not at all easy in many cases to say whether the gonads were visible from without or not, or whether they surpass the coronal furrow or not. Such distinctions may be possible in fresh material such as Vanhoeffen or Broch possessed, but not in the collections of the Discovery which are several years old. The classification of the present series according to the pigmentation is therefore more or less arbitrary and only possible in conjunction with other characters.

The specimens from St. WS 552B, transitional stages between *dodecabostrycha* and *hyacinthina*, must be mentioned here separately on account of the strange coloration of the stomach. It is not dark brown as is normal, but reddish brown with a faint tint of blue. The lappet zone of both specimens is a transparent white with brown pigment on the tentacle muscles only.

Table III

Showing the bathymetrical distribution of the different forms of Periphylla hyacinthina, *Steenstrup. Figures denote numbers of specimens*

Depth (m.)	Forma *dodeca-bostrycha*	Transitional stages to *hyacinthina*	Forma *hyacinthina* typica	Transitional stages to *regina*	Forma *regina*
0–250	5	4	3	—	—
250–500	2	2	1	—	1
500–750	2	2	—	—	4
750–1000	23	1	10	1	—
±1000–1250	8	1	1	1	—
±1250–1500	1	1	—	2	14
±1500–1750	—	1	—	1	5
1750–2000	—	—	—	—	4
2000–2500	—	1	—	—	—
Total	41	13	15	5	28*

* The depth of the specimen from St. 461 E is not indicated.

Bigelow (1909, 1928) and Broch (1913) have stated already that there is a relation between the amount of pigmentation and the depth at which the medusa lives. From his table 2, p. 6, Broch deduces the rule that the darker the specimens the deeper they generally occur. This is right to a certain extent, but in my opinion it is no exact rule and may not be generalized. The lighter *dodecabostrycha* stage lives in more superficial strata than the darker *hyacinthina* and the darkest *regina*. All three stages of development, however, occur also in the same layers (see Table III): for instance, from 750 to 1000 m., 23 *dodecabostrycha*, 10 *hyacinthina* typica, 1 *regina*; in the layer of 1250–1500 m. 1 *dodecabostrycha*, 1 *hyacinthina*, 14 *regina*. The different degrees of pigmentation occur in one and the same stratum.

Broch's own table, No. 2, p. 6, reveals the same fact as ours. His figures are not at all so convincing as he believes. For instance, between 500 and 600 m. 8 *dodecabostrycha*, 23 intermediates, 6 *hyacinthina*. In 700–800 m. and 1000–1100 m. there are much more intermediates than *hyacinthina* typica, and the hauls from 1250–1500 m. only show higher numbers in favour of the *hyacinthina* type. It is, however, a mistake to take the actual numbers of collected specimens instead of percentages. If regarded in this way *then in fact the pigmentation increases with the depth* as seen in Table IV modified after Broch. In the table *regina* is not included because the species is treated by Broch separately. He could find no difference whatever in colour between *hyacinthina* and *regina*.

Similarly Broch traces an increase in size towards deep water (p. 7). I believe, however, that his table 3 on *hyacinthina* gives him no right to draw this conclusion. According to Broch all large specimens ought to be found in the greatest depth. This, however, is not the case. In his haul from 1500 m. there are more small specimens than large ones.

In the layer of 500–600 m. there are as many or more specimens of the same size than in the stratum of 1500 m.; moreover, his largest specimens are not caught at the greatest depths (600 and 1100 m.).

Table IV

Showing the bathymetrical distribution of the three stages in pigmentation represented in the specimens obtained by the 'Michael Sars' in the North Atlantic (see Broch's fig. 2, p. 6)

Depth (m.)	Stages of pigmentation		
	dodecabostrycha %	Intermediate %	*hyacinthina* typica %
0	—	—	—
50	85	15	—
100	100	—	—
150–250	62½	12½	25
500–600	21	62	17
700–800	27	64	12
1000–1100	11	61	28
1250	—	34	66
1500	15	—	85

Broch's table on *Periphylla regina* on p. 9 is more convincing. The specimens of 10 and 14 mm. diameter live at a depth of 900 m., those at 1250 m. are 15½ and 37 mm. in diameter, at 1500 m. 34, 35, 40 and 43 mm. and one specimen at 4500 m. measured 55 mm. in diameter. Broch's material, however, is too scanty for any conclusions to be drawn in this respect.

With regard to the rich material recorded by Broch from the Sognefjord (p. 8) his list has not been worked out sufficiently to be of any use. The few data given in that table are not at all in favour of his statements, because large and small individuals occur side by side in several layers (75, 500 and 750 m.).

Our Table III shows, as does table 2 of Broch, that the small *dodecabostrycha* and *hyacinthina* are absent from the deeper strata, that the larger *regina* is absent from the upper layers and that in intermediate strata forms of all sizes are represented. As the small *dodecabostrycha* lives in the upper layers and the large *regina* is found in the deeper horizons it is true that the size increases with the depth, but in a sense different to that stated by Broch, who took our three developmental stages as three different species. This has been discussed at length under bathymetrical range. As shown there the *regina* stages during their growth sink slowly into deeper layers.

Broch asserts further that there is an increase of the number of individuals according to increase in depth. I cannot agree with him in this respect. It is a pity that the abundant Sognefjord material of about 1000 individuals has not been worked out as carefully as the Atlantic specimens.

Let us examine Broch's table 3. According to his assertion the largest number ought to be found at the greatest depth. This is, however, by no means the case. At his greatest depth (1500 m.) Broch found twelve individuals of *hyacinthina*, in 500–600 m., however, thirty-six. The maximum occurrence is in this layer. In 700–800 m. there are nineteen, in 1000–1100 m. eighteen specimens, in 1250 m. only seven and in 1500 m. twelve specimens. The number diminishes rather from the stratum of 500–600 m. to greater depths and the occurrence is not at all a regular one.

Broch's table on p. 8, illustrating the vertical distribution of *P. hyacinthina* in the "secondary centre" of the Sognefjord, is not in accordance with his statements either. Here two maxima are present, one at 500 m. with 426 specimens, another in 750 m.

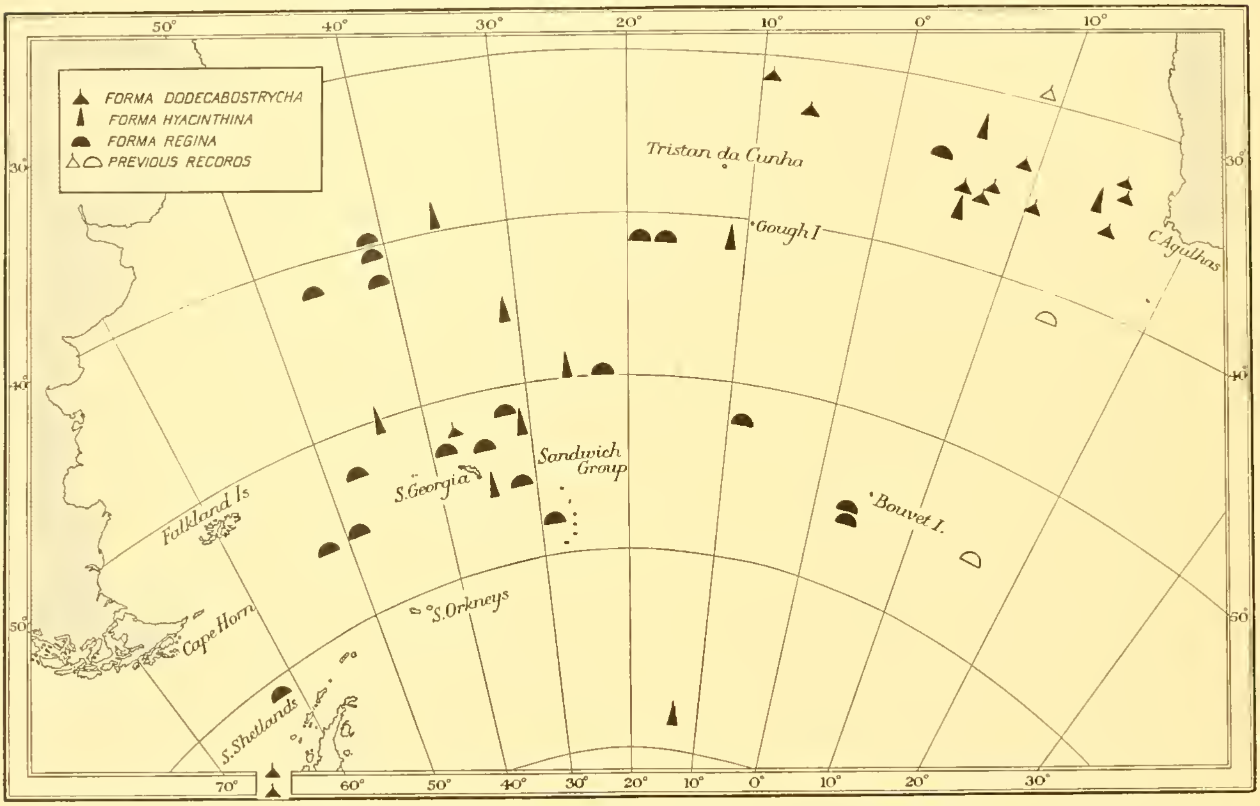

Fig. 2. Chart showing the distribution of *Periphylla hyacinthina*, Steenstrup, in the South Atlantic and Southern oceans.

with 400 individuals, separated by the stratum of 650 m. with 72 specimens only. The upper strata show no increase in the numbers of specimens either. Broch's table on p. 9 on *regina* demonstrates nothing in this respect, the figures being too scanty.

My Table III also shows that an increase in number with depth does not exist. The numbers show a maximum occurrence for each stage, which lies for *dodecabostrycha* and *hyacinthina* at 750–1000 m. and for *regina* at 1250–1500 m. It is possible that an increase takes place towards these optima from the surface, in deeper layers a decrease of numbers may take place (see forma *regina*). An interesting difference between Broch's and my material is, that the maximum occurrence of the Michael Sars specimens of *hyacinthina* is found in 500–600 m., but that of the Discovery specimens in 750–1000 m. As to *regina* my results agree in general with those of Broch.

Geographical distribution (Fig. 2). Our knowledge of the distribution of the genus *Periphylla* in the Atlantic Ocean has been augmented rather extensively by the Michael Sars and the Discovery Expeditions. The former explored the Atlantic from Baffin Bay to Cape Verde, the latter from Cape Verde to the Antarctic; thus both expeditions together explored the whole Atlantic from the far north to the far south. A gap still exists in the Western Atlantic between 30° N and 30° S, because both expeditions worked in these regions mainly in the eastern part along the African coast; but this gap has at least partially been filled recently by Bigelow's Arcturus explorations (1928). The tropical waters above the South Atlantic ridge are still poorly explored.

Periphylla has been found by the 'Discovery' on its entire course from the tropics to the Antarctic Continent (Fig. 2 represents mainly the hauls between 30 and 70° S). It is very abundant in the neighbourhood of the West African coast (Cape Verde, Gulf of Guinea, South Africa), and has been collected quite often in a region between 30 and 60° S. A few specimens only have been taken in Antarctic waters (St. 590, Bellingshausen Sea, and St. 592, South Shetlands).

This agrees with the records of previous expeditions, which found *Periphylla* in the Pacific from the Sandwich Islands and California to Cape Adare and in the Indian Ocean from Aden and east of Sumatra to the border of the Antarctic Continent.

Our three forms, however, are not equally distributed over the Atlantic. An inspection of Broch's chart (fig. 4) and mine reveals the fact *that the largest specimens of the* hyacinthina *and* regina *types have never been taken in the neighbourhood of the coast. Our small* dodecabostrycha, *however, have with a few exceptions only been found in the neighbourhood of the coast.* As to *hyacinthina* and *dodecabostrycha* both charts are not directly comparable, because the "*hyacinthina*" of Broch contains our small *dodecabostrycha* and pointed *hyacinthina* and our *regina* embraces all large *dodecabostrycha* and *regina*. According to the present hauls the forms *hyacinthina* and *regina* are pelagic forms of the open sea ("Hochsee formen") and are caught as a rule far from the coast. This agrees with the results of the Michael Sars Expedition (chart 4) with the exception of the one specimen from the Straits of Gibraltar. It seems rather strange that between 30° N and 30° S no *regina* is known in the Atlantic Ocean. This fact can, I believe, only be explained by the circumstance that in this region the open sea is practically unexplored. In the other oceans forma *regina* has been found in the tropics (Maas, 1897; Bigelow, 1909, 1928) near the Galapagos and in the Gulf of Aden. All other occurrences are from sub-Antarctic waters. How Broch can presume (p. 9) that *P. regina* has only been found in the tropical and sub-tropical parts of the ocean I cannot understand, but it seems very probable that later expeditions will find it in these regions.

Another fact of interest is that small *dodecabostrycha* do not occur in deep-sea hauls except in the neighbourhood of the Continental slope: for instance the Valdivia hauls from Sts. 55, 74 *b*, 85, etc. (see Vanhoeffen, 1903, p. 23), and the Discovery Sts. 87, 256, 590. This makes it probable that *the small stages of* Periphylla *have their origin on the continental slope or near the coast* (for instance, in the vicinity of South Georgia) *and that they are driven into the open sea and sink slowly to greater depths.*

The small *dodecabostrycha* found in the Bellingshausen Sea and south of the South Shetlands are remarkable. Never before has a small *dodecabostrycha* been found in waters neighbouring the Antarctic continent.

The geographical distribution gives no grounds for the opinion that the forms *dodecabostrycha*, *hyacinthina* and *regina* are geographical races. They all three live in the same regions, which cannot be separated, and they have often been collected in the same localities and even in the same hauls (see Maas, 1897). I have come to the conclusion *that they are different stages of growth of the same species*, dodecabostrycha *being the youngest*, hyacinthina *forming the middle stage, and* regina *being the oldest stage of development*. The fact that the gonads of *hyacinthina* are always feebly developed, while in the small *dodecabostrycha* and the large *regina* they are well developed, seems to be unfavourable to this view. Previous authors (Vanhoeffen, Bigelow) took these characters as a strong argument against the union of *regina* and *dodecabostrycha*. I believe that in the young *dodecabostrycha* the gonads become mature, in the *hyacinthina* stage they become reduced and in the *regina* stage they become mature again. In this way a rather satisfactory explanation would be found for the fact that *regina* becomes mature so late, for it is its second maturity. It would be similar to the case of ctenophores (dissogony).

Bathymetrical distribution. (See Tables III and V.) *Periphylla* is represented in the catches of the 'Discovery' and 'William Scoresby' at every depth from 0 to 2500 m. If we observe the bathymetrical distribution of the different forms of *Periphylla* we find that forma *dodecabostrycha* and *hyacinthina* are found more superficially than *regina*. *Dodecabostrycha* is represented in these series by forty-one specimens, of which twenty-three occur in depths of 750–1000 m., eight individuals have been found at depths of 1000–1500 m., and nine specimens in the upper strata. Forma *hyacinthina* (fifteen specimens) has its maximum with ten specimens at the same depth as *dodecabostrycha*, viz. in 750–1000 m. The transitional stages between these two, with thirteen individuals, were caught mostly in more superficial layers from 1000 m. upwards. The forma *regina*, represented by twenty-nine specimens, has its maximum (fourteen specimens) in 1250–1500 m.; it occurs also in deeper strata (1500–1750 m. with five; in 1750–2000 m. with four specimens). This agrees perfectly with Broch's statements (p. 9) on *regina*. In these deeper layers *dodecabostrycha* and *hyacinthina* are almost entirely absent. The intermediate stages between *hyacinthina* and *regina* (five specimens) live at a depth of 750–1750 m., and therefore in somewhat higher layers than *regina*.

Periphylla has not yet been found in the tropics in superficial layers; in the Arctic and sub-Antarctic regions on the contrary it is often at the surface (Bigelow, 1928). Kramp (1924) found *Periphylla* in surface hauls in the Mediterranean and off the coasts of Spain and Portugal in depths of 150 m. In the present material there are many hauls from the tropics from a depth of 250–0 m.: viz. from Ascension (St. 288, 250–0 m.), from the Gulf of Guinea (Sts. 285 and 276, from 125–175–0 and 150–0 m.) with forma *dodecabostrycha*, with transitional stages to *hyacinthina* from St. 286, Gulf of Guinea, and St. 270 Elephant Bay, both from 125–0 m., and *hyacinthina* typica from Sts. 276 and

285 (Gulf of Guinea, from 150–0 and 125–175–0 m.). Since *P. dodecabostrycha* as a rule lives in greater depths of 500–1250 m., and has been found by the 'Valdivia' (Vanhoeffen, 1903) in the Guinea stream at depths of 2000 and 1200 m., it seems probable that the individuals caught by the 'Discovery' in the Gulf of Guinea have been transported to the surface by the cold vertical upwelling stream ("Auftriebwasser").

On the whole the results of our studies on the bathymetrical distribution of *Periphylla* agree with those of most previous authors (Vanhoeffen, Maas, Mayer, Bigelow), but *not with those of Kramp and Broch.* Kramp (1913) found in the waters of Greenland, that specimens of every size may be found at every depth, but that small individuals are more abundant in deeper strata, and that large specimens may occasionally ascend towards the surface. This view does not agree with our facts. His results on the vertical distribution of the Mediterranean *P. hyacinthina* (1924, p. 42) correspond better. According to Broch (1913)[1] *P. hyacinthina* in the North Atlantic has a bathymetrical range from 50 to about 1500 m. with a somewhat prominent maximum at about 500 m. In our series the limits are still wider, from the upper layers to 2500 m. According to Broch the faintly pigmented *dodecabostrycha* prefer the shallower waters down to 500 m., while in the Discovery series the maximum of *dodecabostrycha* occurs in a stratum of 750–1000 m. According to Broch the deeply coloured typical *hyacinthina* predominate below 1000 m. In the present series they have their maximum at 750–1000 m. According to Broch the intermediate group is mostly found in the intermediate waters. In our series the few specimens of this type occur in the more superficial layers from 750 m. upwards.

In Antarctic seas forma *regina* has been found mostly *in deep waters* by this expedition, as will be seen from Table V. Browne (1910), however, records a few specimens from Cape Adare and McMurdo Sound from the surface. That deep-water forms in the cold regions are found at the surface is a well-known fact, and it agrees with the statements about *P. hyacinthina* in the Davis Strait by Kramp (1924, p. 72).

Periphylla hyacinthina *proves to be a true bathypelagic medusa which during its development sinks slowly into deeper layers.* The occasional occurrence of the *dodecabostrycha* specimens in superficial layers in the tropical regions is perhaps to be explained by cold vertical upwelling currents which carry deep-sea animals to the surface.

[1] Besides the 128 specimens of *Periphylla* brought home from the Atlantic the 'Michael Sars' made a haul in the Sognefjord which contained no less than 1075 specimens of *P. hyacinthina*! Nobody else besides Broch has possessed such an enormous quantity of fresh material of this jelly-fish. It is very much to be regretted that Broch omitted the opportunity of making a thorough study of this unique material. If the number of the Atlantic specimens was too small to allow him to draw final conclusions with regard to the bathymetric range (p. 7), this most probably would not have occurred with the rich Sognefjord material. In his report he only makes a few remarks on the strange "secondary centre" in the Sognefjord, and gives a rather superficial table.

Table V

Showing the bathymetrical distribution of Periphylla hyacinthina, *Steenstrup*

Station	Locality	Depth in metres	Number of specimens	Total
	Forma *dodecabostrycha*			
285	Gulf of Guinea	125–175 (–0)	2	
276	Gulf of Guinea	150–0	1	
257	West of Cape of Good Hope	250 (–0)	1	
288	North of Ascension	250 (–0)	1	
592	South of South Shetlands	350–124	1	
101	West of Cape of Good Hope	350–400 (–0)	1	
151	North of South Georgia	500–625	1	
81	Tristan d'Acunha	650–0	1	
407	South-west of Cape of Good Hope	800–900	11	
13° 25′ N, 18° 22′ W	Off Cape Verde	0–900	6	
86	West of Cape of Good Hope	1000 (–0)	1	
256	West of Cape of Good Hope	850–1100 (–0)	1	
256	West of Cape of Good Hope	850–1100 (–0)	5	
87	Cape of Good Hope	1000 (–0)	5	
590	Bellingshausen Sea	1150–1400	1	
405	West of Cape of Good Hope	1200–0	2	41
	Transitional stages to *hyacinthina*			
WS 283	East of South Georgia	78–0	1	
WS 410	East of Falkland Islands	78–0	1	
286	Gulf of Guinea	125–0	1	
270	Elephant Bay	126–0	1	
668	North of South Georgia	375–0	1	
344	South of South Georgia	500–250	1	
WS 552	South of South Sandwich Islands	560–0	2	
6° 55′ N, 15° 54′ W	South of Cape Verde	0–800	1	
256	West of Cape of Good Hope	850–1100 (–0)	1	
76	North of South Georgia	1500–0	1	
395	North-east of South Georgia	1500–1600	1	
100 C	West of Cape of Good Hope	2000–2500	1	13
	Forma *hyacinthina* typica			
285	Gulf of Guinea	125–175 (–0)	2	
276	Gulf of Guinea	150–0	1	
296	South of Cape Verde	400–500 (–0)	1	
41° 37′ 15″ S, 12° 30′ 20″ W	South-west of Gough Island	0–900	1	
13° 25′ N, 18° 32′ W	Off Cape Verde	0–900	5	
86	West of Cape of Good Hope	1000 (–0)	2	
298	Cape Verde	900–1200 (–0)	1	
440	East of Cape Agulhas	1000–0	2	15
	Transitional stages to *regina*			
WS 361	South of South Georgia	1000–750	1	
151	Off South Georgia	1025–1275	1	
391	Between Falkland Islands and South Orkneys	1200–1300 (–0)	2	
72	South of Tristan d'Acunha	2000 (–0)	1	5
				74

Table V (*contd.*)

Station	Locality	Depth in metres	Number of specimens	Total
			Carried forward	74
	Forma *regina*			
366	South Sandwich Islands	155–322	1	
461 E	West of Bouvet Island	525–420	1	
114	West of Bouvet Island	650–700	3	
151	North-east of South Georgia	1025–1275	4	
239	North of Falkland Islands	1050–1350 (–0)	1	
391	Between Falkland Islands and South Orkneys	1200–1300 (–0)	5	
12	North of South Georgia	1200–1500	1	
383	North-west of South Shetland Islands	1500–1000	1	
76	North of South Georgia	1500–0	2	
395	North-east of South Georgia	1500–1600	3	
414	West of Gough Island	1700–1000	1	
8	South-west of Tristan d'Acunha	1500–1700	1	
71	North of Falkland Islands	2000–0	1	
85	West of Cape of Good Hope	2000 (–0)	1	
72	North of Falkland Islands	2000 (–0)	2	
461 E	West of Bouvet Island	—	1	29
				103

Family NAUSITHOIDAE, Claus, 1878

Genus Nausithoë, Kölliker, 1853

Nausithoë punctata, Kölliker

St. 276. 5. viii. 27. 5° 54′ S, 11° 19′ E, Gulf of Guinea. Young fish trawl, 150–0 m. Four specimens, 4–7 mm. diam.

St. 86. 24. vi. 26. 33° 25′ S, 6° 31′ E, west of Cape of Good Hope. 4½ m. tow-net, 1000 (–0) m. One specimen, 7 mm. diam.

All specimens show the main characters of this very common species: finely punctate surface, broad oviform lappets, central disc without radial furrows, globular equidistant gonads, gastric cirri of each bundle arising in a straight row, no pigment. Umbrella transparent milky, gonads yellowish. Ocelli very faintly pigmented.

This medusa is a surface form limited to coastal waters, and its range includes the tropical belts of all three great oceans. The Plankton Expedition found it on the north-east coast of South America (Vanhoeffen, 1892) and the Valdivia Expedition (Vanhoeffen, 1903) captured one specimen in the Gulf of Guinea (St. 58) at 200 m. depth.

Family ATOLLIDAE, Bigelow, 1913

(= COLLASPIDAE, Haeckel)

Genus Atolla, Haeckel, 1879

In corroboration of the results of Haeckel (1879, 1881), Vanhoeffen (1903), Maas (1904), Mayer (1906, 1910), Bigelow (1909, 1913) and Broch (1913), Browne in 1916 came to the conclusion from his own investigations that most probably all the different species of *Atolla* hitherto described are variants or contraction phases of two species only. The nine species previously supposed to be distinct have thus successively been reduced to two only: *A. wyvillei* with smooth lappets and *A. chuni* with lappets studded with small papillae ("glass-beads" of Vanhoeffen) (cf. Bigelow, 1928, p. 505).

The study of the rich Discovery material has confirmed Browne's opinion. In the present material I have distinguished two species only: *wyvillei* and *chuni*. All the characters, apart from the presence or absence of papillae on the lappets, which have hitherto been used for separating the different species (i.e. presence or absence of radial furrows on the central disc, form and number of the same, breadth of septal notches, diameter of central disc in relation to the diameter of the bell, number of tentacles, absence or presence of a smooth annular zone between the ring furrow and the pedalia and of septal areas subdividing the tentacular canals near their base) have been proved to be so highly variable that they are of little or no systematic value.

Of all these variable characters of *Atolla* the sculpturing of the central lens, with or without radial furrows at the margin, has been found the most useful. Although the present series shows intermediate forms between the *bairdi* type with smooth central lens, the *verrilli* type with the central lens scored with narrow furrows, and the *wyvillei* type indented with broad radial furrows, I have, following the excellent studies of Bigelow, divided the comprehensive species *wyvillei* into three types or forms: *wyvillei* (typica), *bairdi* and *verrilli*. The Discovery Expeditions brought home altogether 228 *Atolla*, of which 185 belong to *A. wyvillei* and 43 to *A. chuni*.

Atolla wyvillei, Haeckel

(Plate XV, fig. 4; Figs. 3–6)

2. xi. 25. 6° 55′ N, 15° 54′ W, south of Cape Verde. 2 m. tow-net, 0–800 m.

Three specimens of *bairdi*, 11, 13, 15 mm. diam., faded, Broch's pigment group I.

St. 298. 29. viii. 27. 13° 01′ 45″ N, 21° 34′ 45″ W, south of Cape Verde. Young fish trawl, 900–1200 (–0) m.

Four specimens of *bairdi*, 21–62 mm. in diam.; one specimen of *wyvillei* (perhaps transition-stage to *verrilli*), 17 mm. diam. All pale, the last the darkest, traces of pigment on coronal furrow, ring muscle greenish yellow, gonads free of pigment, group III of Broch ?.

28. x. 25. 13° 25′ N, 18° 22′ W, south of Cape Verde. 4½ m. tow-net, 0–900 m.

Twenty-four specimens, all *bairdi*, 30–65 mm. diam., with smooth disc, very feeble notches at the margin of central disc, gonads well developed, stomach deeply pigmented, traces of pigment on and between pedalia and in central furrow, ring muscle without pigment, Broch's groups III and IV.

St. 700. 18. v. 31. 20° 21½′ N, 22° 33½′ W, south of Cape Verde. Young fish trawl, 2025–0 m.

One specimen of *bairdi*, 48 mm. diam., central disc 34 mm. diam., very beautiful, with feeble notches on the margin of central disc reddish brown, circular muscle greenish, not pigmented, gonads well developed. Broch's pigment group IV.

St. 281. 12. viii. 27. 00° 46′ S, 5° 49′ 15″ E, Gulf of Guinea. Young fish trawl, 850–950 (–0) m.

Three specimens of *wyvillei* (*verrilli*), 25–27 mm. diam., pale, stomach with gonads without pigment, traces of it on exumbrella, ring muscle without pigment, Broch's group III.

St. 282. 12. viii. 27. 1° 11′ S, 5° 38′ E, Annobon Island, Gulf of Guinea. Young fish trawl, 300 (–0) m.

Two specimens: one *wyvillei*, 21 mm. diam.; one *bairdi*, 13 mm. diam. Faded?, only stomach and tentacle muscles pigmented, gonads whitish, Broch's pigment group I.

St. 287. 12. viii. 27. 2° 49′ 30″ S, 9° 25′ 30″ W, north-east of Ascension. Young fish trawl, 800–1000 (–0) m.

One specimen of *wyvillei* (–*verrilli*), 22 mm. diam., no gonads, Broch's group III.

St. 270. 27. vii. 27. 13° 58′ 30″ S, 11° 43′ 30″ E, off Elephant Bay. Young fish trawl, 200 (–0) m.

Three specimens of *bairdi*, 7, 15, 18 mm. diam., very beautiful, the largest with net structure on central disc, without gonads, very deeply pigmented, Broch's group IV.

St. 267. 23. vii. 27. 24° 31′ S, 12° 15′ 30″ E, Cape of Good Hope. Young fish trawl, 450–550 (–0) m.

Three specimens: one *wyvillei*, 18 mm. diam.; one *verrilli*, 16 mm. diam.; one *bairdi*, 6 mm. diam. The larger ones with well-developed gonads, deeply pigmented, Broch's group III.

St. 440. 21. ix. 30. 30° 13½′ to 30° 25′ S, 32° 48½′ to 32° 48′ E, east of Cape Agulhas. Young fish trawl, 1000–0 m.

Seven specimens: three *wyvillei*, 25–27 mm. diam.; three *verrilli*, 25–29 mm. diam.; one *bairdi*, 18 mm. diam. Most specimens with excretory organs marked by pigment spots, stomach blackish purple, gonads dark brown, tentacle muscles brownish, Broch's pigment group I.

St. 81. 18. vi. 26. 32° 45′ S, 8° 47′ W, east of Tristan d'Acunha. 4½ m. tow-net, 650 (–0) m.

Two specimens of *bairdi*, 10, 12 mm. diam., distorted, faded.

St. 85. 23. vi. 26. 33° 07′ 40″ S, 4° 30′ 20″ E, west of Cape of Good Hope. 4½ m. tow-net, 2000 (–0) m.

Two specimens: one *wyvillei*, 43 mm. diam.; one *verrilli*, 31 mm. diam. Pale, Broch's group III, ring muscle not pigmented.

St. 85. 23. vi. 26. 33° 07′ 40″ S, 4° 20′ 40″ W, west of Cape of Good Hope. 4½ m. tow-net, 2000 (–0) m.

One specimen of *bairdi* (?), 16 mm. diam., distorted, faded.

St. 100c. 4. x. 27. 33° 20′ 10″ to 33° 46′ S, 15° 18′ to 15° 08′ E, Cape of Good Hope. Young fish trawl, 2000–2500 m.

One specimen of *wyvillei*, 27 mm. diam., gonads well developed, brownish, Broch's stage III.

St. 86. 24. vi. 26. 33° 25′ S, 6° 31′ E, Cape of Good Hope. 4½ m. tow-net, 1000 (–0) m.

Six specimens: two *wyvillei*, 21, 42 mm. diam.; two *verrilli*, 15, 17 mm. diam.; two *bairdi*, 12, 28 mm. diam. The *wyvillei* specimens the darkest of Broch's pigment stage III, others faded (?), Broch's group I.

St. 86. 24. vi. 26. 33° 25′ S, 6° 31′ E, Cape of Good Hope. 4½ m. tow-net, 1000 (–0) m.

Ten specimens: two *wyvillei*, 23, 62 mm. diam., no furrows on pedalia; four *bairdi*, 36, 42, 48, 50 mm. diam., with fine or rough network on the central disc, only slightly notched at the margin of the central disc; four *bairdi*, 15–20 mm. in diam., with smooth central disc; all with annular zone. All a little faded, Broch's pigment stage III, with traces of pigment in the central furrow, gonads dark brown.

St. 405. 4. x. 30. 33° 50′ to 34° 16′ S, 15° 46′ to 15° 02′ E, Cape of Good Hope. Young fish trawl, 1200–0 m.

Four specimens: three *wyvillei*, 16, 21, 36 mm., the largest with yellow gonads, very dark, Broch's stage IV; one *verrilli*, 12 mm. diam., faded, Broch's group I with Vanhoeffen's excretory pigment spots.

St. 101. 15. x. 26. 33° 50′ to 37° 13′ S, 16° 04′ to 15° 49′ E, Cape of Good Hope. 4½ m. tow-net, 300–400 (–0) m.

Seven specimens: one *wyvillei*, six *verrilli* (*–bairdi*), 17–22 mm. in diam. Several specimens with irregular furrows on central disc, faded, Broch's group III.

St. 87. 25. vi. 26. 33° 53′ 45″ S, 9° 26′ 30″ E, Cape of Good Hope. Young fish trawl, 1000 (–0) m.

Three specimens of *wyvillei*, 12, 17, 32 mm. diam., the two smaller ones pale, Broch's stage I, the largest very dark, group IV of Broch.

St. 407. 12. vi. 30. 35° 13′ to 34° 57′ S, 17° 50½′ to 17° 48′ E, Cape of Good Hope. 4½ m. tow-net, 800–900 m.

Eighteen specimens: six *wyvillei*, 17–28 mm. diam.; twelve *bairdi*, 16–22 mm. diam. With traces of radial notches at the margin of central disc, many with pigment spots and excretory organs pigmented.

Pigmentation:

Two *wyvillei*, Broch's group IV.	Four *bairdi*, Broch's group IV.
Two *wyvillei*, Broch's group III, with brown gonads.	Four *bairdi*, Broch's group III.
Two *wyvillei*, Broch's group I.	Four *bairdi*, Broch's group I.

St. 256. 23. vi. 27. 35° 14′ S, 6° 49′ E, Cape of Good Hope. Young fish trawl, 850–1100 (–0) m.

Two specimens of *wyvillei*, 21, 23 mm. diam., very beautiful, gonads well developed, Broch's stage III.

St. 78. 12. vii. 26. 35° 18′ S, 19° 01′ 10″ W, west of Tristan d'Acunha. Young fish trawl, 1000 (–0) m.

Two specimens of *verrilli* (?), 6, 11 mm. diam., distorted, faded, Broch's pigment stage III ?.

St. 401. 22. v. 30. 37° 31½′ S, 4° 33′ E to 37° 29′ S, 4° 39′ E, between Cape of Good Hope and Gough Island. Young fish trawl, 1250–1300 m.

One specimen of *wyvillei*, 34 mm. diam., faded, damaged, without stomach, no furrows on pedalia, Broch's stage I.

St. 76. 5. vi. 26. 39° 50′ 30″ S, 36° 23′ W, far north of South Georgia. 4½ m. tow-net, 1500–0 m.

Two specimens: one *wyvillei*, 28 mm. diam.; one *bairdi*, 17 mm. diam. Ring muscle without pigment, Broch's stage III.

St. 72. 1. vi. 26. 41° 43′ 20″ S, 42° 20′ 40″ W, between Falkland Islands and Tristan d'Acunha. 4½ m. tow-net, 2000 (–0) m.

Seven specimens: four *wyvillei*, 50 mm. diam.; three *bairdi*, 42 mm. diam. One specimen of *wyvillei* very high, 32 mm., with broad annular zone, with narrow and broad pedalia, with furrows and without; others without furrows on pedalia. All *wyvillei* darkly pigmented, Broch's stage III or IV; the *bairdi* paler (III), ring muscle not pigmented.

St. 8. 8. xi. 26. 42° 36′ 30″ S, 18° 19′ 30″ W, between Tristan d'Acunha and South Georgia. 4½ m. tow-net, 600–700 m.

Two specimens of *wyvillei*, 18, 32 mm. diam., faded, larger specimen with dark stomach, pigment on pedalia, gonads whitish, Broch's pigment group III.

St. 71. 20. i. 26. 43° 20′ S, 47° 58′ W, north of Falkland Islands. Young fish trawl, 2000 (–0) m.

One specimen of *wyvillei*, 17 mm. diam., faded, Broch's group I.

St. 71. 30. i. 26. 43° 20′ S, 47° 58′ N, north of Falkland Islands. Young fish trawl, 2000 (–0) m.

Four specimens of *wyvillei*: one of 17 mm. diam., faded, Broch's group I; three of 25, 46, 65 mm. diam. The specimen of 46 mm. very high, 28 mm., with broad furrows on central disc, the other of 65 mm. flat, 22 mm. high, with narrow furrows, ring muscle not pigmented, Broch's stage III, with gonads visible, traces of pigment in central furrow and furrows on pedalia.

St. 107. 4. xi. 26. 45° 03′ S, 17° 03′ E, between Cape of Good Hope and Bouvet Island. $4\frac{1}{2}$ m. tow-net, 850–950 m.

Five specimens of *wyvillei*, 25–33 mm. diam., much faded, central furrow with ring muscle without pigment, Broch's group III.

St. 9. 11. xi. 26. 46° 11′ 30″ S, 22° 27′ 30″ W, between Tristan d'Acunha and South Georgia. 2 m. tow-net, 0–1250 m.

Two specimens: one *verrilli*, 17 mm., distorted; one *bairdi*, 17 mm., faded, Broch's group III?.

St. 395. 18. v. 30. 48° $26\frac{3}{4}$′ to 48° $26\frac{1}{2}$′ S, 22° 10′ to 22° $06\frac{1}{2}$′ W, north of South Georgia. $4\frac{1}{2}$ m. tow-net, 1500–1600 m.

Four specimens: two *wyvillei*, 56, 58 mm. diam.; two *verrilli*, 32, 82 mm. diam. Largest specimen of *verrilli* flat, no annular zone visible, central disc 48 mm. diam., with 28 tentacles; smaller specimen faded, without stomach. One specimen of *wyvillei* with broad and narrow notches on the margin of the central disc, all very dark, Broch's group IV, but ring muscle yellowish, not pigmented. Gonads mostly developed.

St. 666. 17. iv. 31. 49° $58\frac{3}{4}$′ to 49° $58\frac{3}{4}$′ S, 29° $52\frac{1}{2}$′ to 30° 13′ W, north-east of South Georgia. Young fish trawl, 1500–1000 m.

One specimen of *wyvillei*, 67 mm. diam., central disc 52 mm., central furrow, notches on central disc, pigmented, no furrows on pedalia, ring muscle not pigmented, Broch's group IV, gonads well developed and not visible from outside.

St. 12. 18. xi. 26. 51° 55′ S, 32° 27′ 30″ W, north-east of South Georgia. $4\frac{1}{2}$ m. tow-net, 1200–1500 m.

Nine specimens of *wyvillei*, 42–51 mm. diam., mostly with furrows on pedalia; two specimens relatively high with broad coronal furrow; three specimens very deeply pigmented, Broch's stage IV, ring muscle with traces of pigment; the others much paler, stage III, ring muscle greenish yellow without pigment; mostly 22 pedalia, 21 notches on central disc.

St. 114. 12. xi. 26. 52° 25′ S, 9° 50′ E, east of Bouvet Island. 2 m. tow-net, 650–750 m.

Two specimens of *wyvillei*, 52, 65 mm. diam., in spirit, fixed in picric acid, discoloured, gonads well developed.

St. 114. 12. xi. 26. 52° 25′ S, 9° 50′ E, east of Bouvet Island. $4\frac{1}{2}$ m. tow-net, 650–750 m.

Eight specimens of *wyvillei*, 48–52 mm. in diam., with and without furrows on pedalia, ring muscle not pigmented, greenish yellow; six specimens of Broch's stage III, two of stage IV, with pigment spots on and between pedalia, in the furrows of the disc and in the coronal furrow.

St. WS 263. 28. viii. 28. 53° 20′ S, 35° 04′ W, north-east of South Georgia. 70 cm. tow-net, 1000–750 m.

One specimen of *wyvillei*, in fair condition, 68 mm. in diam., central disc 45 mm., furrows on central disc broad and long, dark brown in colour, deep furrows on pedalia and lappets, annular zone covered by overhanging central disc, Broch's group IV, ring muscle partially blotched with pigment, subumbrella covered with reddish brown pigment.

St. 151. 16. i. 27. 53° 25′ S, 35° 15′ W, north of South Georgia. $4\frac{1}{2}$ m. tow-net, 1025–1075 m.

Nineteen specimens: fifteen *wyvillei*, one *verrilli*, three *bairdi*. The *wyvillei* well preserved, 17–65 mm. diam.; one specimen 65 mm. broad, central disc 45 mm. in diam., 45 mm. high; another specimen of same type 55 mm. in diam., central disc 42 mm., height 36 mm.: both with broad deep central furrow and broad annular zone. All others much flatter with overhanging central lens. All very deeply pigmented, mostly of Broch's stage III; four *wyvillei* of stage IV, with faintly visible gonads.

St. 391. 18. iv. 30. 55° 48½′ S, 52° 35′ W south of Falkland Islands. 4½ m. tow-net, 1200–1300 (–0) m.

Three specimens: one *wyvillei*, 96 mm. diam., central disc 56 mm., no furrows on pedalia, annular zone very small, slightly notched on margin of central disc, no gonads, Broch's group IV, very dark, but somewhat faded, transitional stage to *verrilli*; one *verrilli*, 18 mm. diam., Broch's group III; one *bairdi*, 12 mm. diam., Broch's group III.

St. 592. 15. i. 31. 64° 17′ S, 75° 31′ W, south of South Shetlands. 1 m. tow-net, 350–124 m.

One specimen of *wyvillei*, in fair condition, 62 mm. diam., central disc 38 mm., furrows on central disc and pedalia, coronal furrow deeply pigmented, Broch's group IV, gonads well developed but hardly visible from outside, flat, central lens overhanging, no annular zone visible.

St. 595. 16. i. 31. 65° 13¾′ S, 70° 26½′ W, south of South Shetlands. 1 m. tow-net, 380–133 m.

One specimen of *wyvillei*, in fair condition, 82 mm. diam., central disc 51 mm., annular zone very narrow, furrows on central disc 4 mm. broad, 8 mm. long, ring muscle with traces of reddish brown pigment, greenish yellow, furrows on pedalia, coronal furrow and subumbrella with dark purple pigment, Broch's stage IV, gonads whitish, well developed.

St. 563. 1. i. 31. 66° 58½′ S, 79° 32½′ W, Bellingshausen Sea. 1 m. tow-net, 450–180 m.

One specimen of *wyvillei*, very beautiful, 78 mm. diam., central disc 51 mm., height 25 mm., Broch's stage IV, traces of pigment on the greenish circular muscle, notches on central disc very broad (4½ mm.), 6 mm. long, deeply pigmented.

St. WS 552F. 3. xi. 31. 68° 53′ to 68° 50′ S, 13° 03′ to 13° 03′ W, north-west of Coats Land. 1 m. tow-net, 460–360 m.

One specimen of *wyvillei*, 72 mm. diam., central disc 42 mm., in fair condition, Broch's pigment group IV, furrows on central disc very conspicuous, 4 mm. broad, 5 mm. long, the whole subumbrella covered with a layer of reddish brown pigment, coronal furrow, ring muscle, all furrows on pedalia and between them and on the lappets pigmented, no annular zone, gonads well developed, whitish.

The three different types of this species have been treated so often in the literature that I can restrict myself here to a few observations.

Furrows. Plate XV, fig. 4, shows distinctly that if twenty-four pedalia are present there are as a rule twenty-three furrows on the central disc. There is no furrow on the latter in the radius of the septal notch above a very broad pedalion which has no furrow either. This is a trace of bilateral symmetry. As will be seen from the list above I recognize ninety-one specimens as *wyvillei* (typica), seventy-two as the *bairdi* form and twenty-one as the *verrilli* form—on the basis of the furrows on the central disc. The discrimination of these three types is not difficult with the extremes—*wyvillei* on one side, *bairdi* on the other—but in many cases it was not at all easy to say whether a given specimen belongs to the *verrilli* or *wyvillei* type. In those cases judgment is often very arbitrary. Deep broad radial furrows are only to be seen on large specimens. On small specimens it is almost impossible to say, with any certainty, whether they belong to one or other form, because there is considerable variation in the breadth of the furrows, not only in different specimens of the same form, but also in a single specimen. According to Broch (1913), who recognizes the species *wyvillei* next to *bairdi* as a good species, there is a great resemblance between *bairdi* and *verrilli*. I found more transitional stages, however, between the narrow flat furrows of the *verrilli* type and the broad deep ones of the *wyvillei* type.

Broch, who studied the rich and fresh material of the Michael Sars Expedition (± 200 specimens) separates the specimens of *bairdi* into three groups according to the radial furrows: one group provided with distinct radial furrows all over the central disc, a second with incomplete furrows visible only at the margin of the disc, and a third with a perfectly smooth disc without any traces of radial furrow. (The only specimen caught by the 'Michael Sars' with deep broad notches and furrows on the pedalia was identified by Broch as *A. wyvillei*.) Broch's first group of *bairdi* comprises no less than one-third of his material. In the present series, on the other hand, there is not a single specimen with radial furrows running all over the disc. The central portion is always smooth; the furrows are restricted to the marginal region of the central disc, with the exception only of a few specimens showing a structure similar to a network with large regular or irregular polygonal meshes (Sts. 86, 405; Fig. 3). One may think that during the haul the net has left an impression of the meshes on the soft surface of the central disc. In those cases the indentation of the margin was never radial, as is usual, but irregular, with a variable number of notches. In other cases there were on the surface of the disc four furrows which formed a cross, with a depression at the apex, by which the surface was divided into four parts. Broch, with his fresh material, succeeded in producing the furrows running over the disc by a slight pressure with the point of the forceps in the middle of the disc, and believes that the radial furrows of the *bairdi* type may be due to contractions of the central disc. I repeatedly tried to produce radial furrows by a similar procedure, but in vain, perhaps because my material is mostly several years old. With regard to the other groups Broch mentions less than one-third of all *Atolla* as being of the *verrilli* type (fifty-seven) and a little more than one-half (103) of the *bairdi* type. I found nearly as many specimens of the *bairdi* as of the *wyvillei* type (seventy-two and ninety-one respectively) and relatively few (twenty-one specimens) of the *verrilli* type.

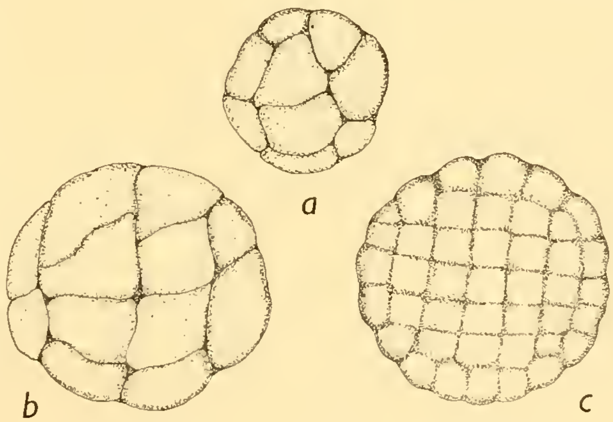

Fig. 3. *Atolla wyvillei*, Haeckel, forma *bairdi*, mihi. Central disc with rough (*a*, *b*) or finer (*c*) network. Three specimens from St. 86, × ½.

Certainly the radial furrows on the central disc do not attain their typical broad shape before the specimen has reached a considerable size, being broad in large, and narrow in small specimens. In the large Antarctic specimens from Sts. 41, 42, 44, 45 the furrows are very conspicuous: large, long, deep and, moreover, darkly pigmented. In some specimens a part of the furrow is broad and another part much narrower, and the same applies to the pedalia.

Annular zone. In most specimens the annular zone between the circular furrow and the pedalia was distinctly visible; in a few, particularly flat ones, the annular zone was covered by the overhanging lens and therefore apparently invisible, but it was always present. In all high specimens with broad and deep coronal furrows, the annular zone is very broad. Its presence or absence, as recently shown by Bigelow (1928), is of no systematic importance, because it depends only on the degree of contraction of the whole medusa. If covered by the central disc in flat specimens, it is easily made visible by lifting the central disc. In several specimens I found fine radial furrows on the annular zone corresponding to the furrows on the pedalia and the notches of the central disc.

Furrows on pedalia. In most specimens of the *wyvillei* type the furrows on the pedalia are very distinctly visible, in a few the pedalia were smooth (e.g. St. 86). This characteristic is thus not necessarily correlated with the deep notches of the central disc.

Gastro-vascular system (Figs. 4, 5). The present series of *Atolla wyvillei* differs in respect of the gastro-vascular system from the descriptions given by previous authors (Vanhoeffen, 1903, for *A. valdiviae*; Maas, 1904, for *A. bairdi*; and Bigelow, 1909, for *wyvillei*) by a much larger amount of pigment in the canals and pockets: the canals in the lappets reach much farther distally than figured by these authors, in whose figures they reach only a little beyond the base of the lappets. The tentacular pockets are very much broader than the narrow rhopalar canals; the pigment in the tentacular pockets reaches right up to the border of the lappets. The base of the tentacles lies deeply enclosed in a sinus within the tentacular pockets. The figures of Maas (1903, pl. iii, fig. 23 and 1904, pl. iv, fig. 34), which both show broad cathammal regions on the base of the tentacles, agree less well than Vanhoeffen's figure of the gastro-vascular system of *A. alexandri* (1903, pl. vii, fig. 41), where the tentacular pockets surround the base of the tentacles in a broad arch. Here, however, the tentacular pockets are represented as being much less narrow than in the present specimens. It is very strange that in the figures of these authors the canals entering the lappets are represented as being very short. In the Discovery specimens they are always much longer and reach far into the lappets, nearly to the end of the lappet pockets (*cf.* Vanhoeffen, 1903, pl. vi, fig. 41; Maas, 1897, pl. xi, fig. 2; 1904, pl. iv, figs. 33, 34; Bigelow, 1909, pl. viii). One receives thus quite a different impression of the whole gastro-vascular system.

Fig. 4. *Atolla wyvillei*, Haeckel, forma *typica*, mihi. Part of the gastro-vascular system of a young specimen. From St. 86, × 5.

Septal regions ("false septa") subdividing the tentacular canals near their bases are seen in all three forms. They are present in most specimens of the *wyvillei* type too, where their absence would be expected according to Bigelow (1909, p. 40). As may be seen from Figs. 4 and 5 they are of great variability both in size and form, very broad and long in large, small and narrow in small individuals, leaf-, egg-, or spoon-shaped. These false septa become very clearly visible when the subumbrellar pigment has fallen off or been taken away. I therefore do not believe that they are a specific character of great importance.

Excretory organs. The system of probable excretory organs (discovered by Vanhoeffen in 1903), consisting of eight pores in each principal radius near the perradial corners of the stomach, whose position is marked by eight dark brown oval spots upon the floor of the subumbrella (figured by Maas, 1904, pl. v, fig. 38), has been observed by me in several specimens, mostly young ones, from Sts. 405 and 440.

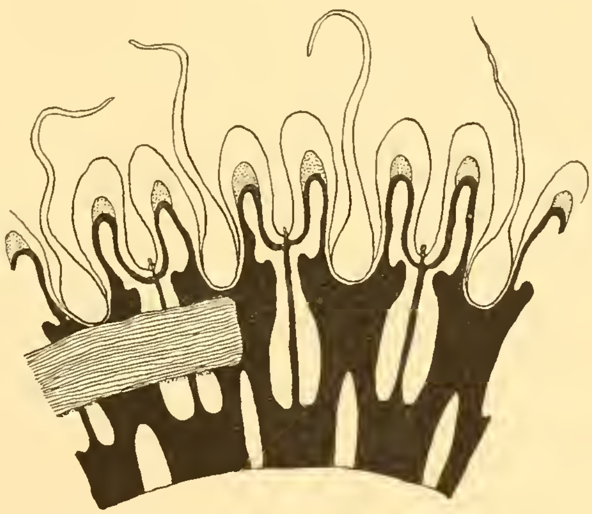

Fig. 5. *Atolla wyvillei*, Haeckel, forma *typica*, mihi. Part of the gastro-vascular system of an adult specimen. From St. 86, × 3.

Pigmentation. Broch makes out that his own results, corroborating those of Bigelow, indicate that the pigmentation increases with deeper water. He possessed the freshly preserved material from the Michael Sars Expedition, all with vivid and fresh colours. Although he found the pigmentation of the individuals subject to great variation, and found every transition stage between hyaline and very dark specimens, he kept four groups of a different colouring separate, limiting the stages as follows: I, only the stomach and occasionally the gonads containing pigment; II, the ring muscle also pigmented; III, pigment covering other parts of the subumbrella too, the gonads being always visible from the exumbrellar side of the medusa; IV, the pigmentation so dense that the gonads are quite invisible from the upper side. His table 9 shows the bathymetrical distribution of 180 specimens of *Atolla bairdi*: one specimen from 250 m. is almost hyaline. Of the twenty-nine specimens from 500 m., twenty-three belong to stage I, six to stage II. From 750 m. there are forty-eight specimens, five of which belong to stage I, twenty to stage II, sixteen to stage III and seven to stage IV, which means that three-quarters of all the specimens belong to stages II and III. Down to a depth of 750 m. there is indeed an increase in pigment, but not at depths of 1000–1500 m. At 1000 m. more than half the specimens belong to stage II and one-third to stage III; at 1250 m. one-third belongs to stage II, one-fifth to stage III and one-quarter to stage IV; at 1500 m. one-half to stage II, one-third to stage III and one-fifth to stage IV, which means that three-quarters of all specimens belong to stages II and III. One cannot of course speak of an increase of pigmentation towards the depth down to 750 m. Of Broch's 180 specimens thirty-eight are of type I, seventy-seven of type II, forty-seven of type III, and eighteen of type IV.

The Discovery material is mostly several years old and the pigment-bearing epithelium often more or less broken away and the specimens faded. It was therefore in many cases very difficult to place the specimens in respect of their pigmentation in one of Broch's four groups. Strictly speaking, Broch's groups I and II are not represented in the present series. Specimens with pigment on the stomach only, and occasionally on

Table VI

Showing the bathymetrical distribution of the Discovery specimens of Atolla wyvillei *arranged in the four colour groups (I–IV) of Broch. The figures denote numbers of individuals. Closing net hauls only, with the exception of Sts.* 270 *and* 282

Station	Depth in metres	I	II	III	IV	Total
270	200–0	—	—	—	3	3
282	300–0	2	—	—	—	2
101	300–400	—	—	7?	—	7
592	350–124	—	—	—	1	1
595	380–133	—	—	—	1	1
563	450–180	—	—	—	1	1
WS 552F	460–360	—	—	—	1	1
8	600–700	—	—	2	—	2
114	650–700	—	—	6	2	8
407	800–900	6	—	6	6	18
107	850–950	—	—	5	—	5
WS 263	1000–750	—	—	—	1	1
151	1025–1275	—	—	15	4	19
12	1200–1500	—	—	6	3	9
401	1250–1300	1	—	—	—	1
666	1500–1000	—	—	—	1	1
395	1500–1600	—	—	—	4	4
100C	2000–2500	—	—	1	—	1
		9	—	48	28	85

the gonads too, but otherwise transparent, are not present. Pigment is always to be found besides on the stomach, on the peripheral zone, especially on the tentacle muscles and in the subtentacular pockets. No specimens are found with pigment on stomach and ring muscle only. The pigment on the ring muscle is very labile, and falls off very easily in the form of dark, irregularly formed large or small pieces of subumbrellar epithelium. Even in the relatively few large dark specimens which I place in Broch's group III or IV the ring muscle is only partially pigmented, and never fully covered with pigment. It was difficult not only to place the faintly pigmented or faded specimens in Broch's groups I or II, but also to place the dark specimens belonging to groups III or IV. In many cases the gonads of the large specimens were not developed. It was therefore often impossible to say with any certainty whether a specimen belonged to Broch's groups III or IV. Most probably the greater part of the exumbrella and subumbrella in dark specimens is covered with pigment, with the exception only of the apical part of the central disc. Everywhere there are spots, traces of pigment in the furrows of the central disc, in the coronal furrow, between the pedalia and in their furrows, in the tentacle muscles, and in the subtentacular pockets. The stomach and the peripheral parts of the gastro-vascular system and the subtentacular pockets are mostly very deeply pigmented. In the darker specimens the largest part of the subumbrella is covered with a dark reddish brown epithelium hanging down here and there in small pieces from the surface.

In the present series of eighty-five specimens the bathymetrical distribution of which could be established by closing net hauls (see Table VII), nine belong to stage I, none to stage II, forty-eight to stage III and twenty-eight to stage IV.

According to Broch's statements the very dark specimens of stages III and IV are never found above the 750 m. In the Discovery material the Antarctic specimens from Sts. 592, 595, 563, WS 552F, caught between 450 and 124 m., are very dark, and all belong to stage IV. Off the African coast very dark specimens of the *bairdi* and *wyvillei* type were found at the surface (St. 270, Elephant Bay, and St. 101, west of Cape of Good Hope). There were also found here dark and lighter specimens of three different stages of pigmentation in one and the same haul, e.g. at St. 407, and in many other catches with open nets dark and light specimens are picked up together. On the other hand a very light specimen was caught at a great depth (St. 401, 1250–1300 m.). As seen from Table VI the bulk of the dark specimens were caught in an intermediate layer between 650 and 1500 m. Only occasionally have some been found in more superficial layers or in still deeper water. This is not in accordance with Broch's table 9. Here the lighter stages live in more superficial layers and have their maximum at 500–750 m. The deeply pigmented specimens live only in water deeper than 750 m. The single specimen of *Atolla wyvillei* caught by the 'Michael Sars' was taken at a depth of 1500 m. The maximum of Broch's specimens of *bairdi* lay at 1000 m. Still I agree with Broch that the pigmentation generally increases with the depth. That Table VII does not show this rule is due to the fact that the hauls from Antarctic waters and Elephant Bay are here included. We know that in polar regions the distribution of deep-water organisms is universal, and that on the West African coast upwelling cold-water currents drive abyssal forms upwards to higher strata.

The RING MUSCLE in most cases, particularly in deeply pigmented specimens, where the pigment is partly fallen off, is of a strange greenish yellow colour, with a tint of opal or mother-of-pearl, or is of a vivid yellowish colour. On a specimen from St. WS 263 I found dark brown radial stripes on the greenish ring muscle.

GEOGRAPHICAL DISTRIBUTION (see Fig. 6). *Atolla* is found along the whole route of the 'Discovery' from the Cape Verde Islands and the Gulf of Guinea, along the coast of West Africa to the Antarctic regions. Most specimens were caught in a broad zone between the southern part of America and Africa, between 30 and 60° S. A few specimens have previously been recorded from the same regions by the Challenger Expedition (far north of the Falkland Islands), the Plankton and Valdivia Expeditions (in the Guinea Stream), by the latter also between the mouth of the Congo and the Cape of Good Hope, and south of Bouvet Island, by the Deutsche Südpolar (Gauss) Expedition between Tristan d'Acunha and the Cape of Good Hope and Cape Verde, and by the 'Scotia' near Coats Land. What the 'Michael Sars' has done in the North Atlantic, the 'Discovery' has done in the south. No other expedition brought home such a number of *Atolla* from these regions. In correspondence with the results of the 'Michael Sars'

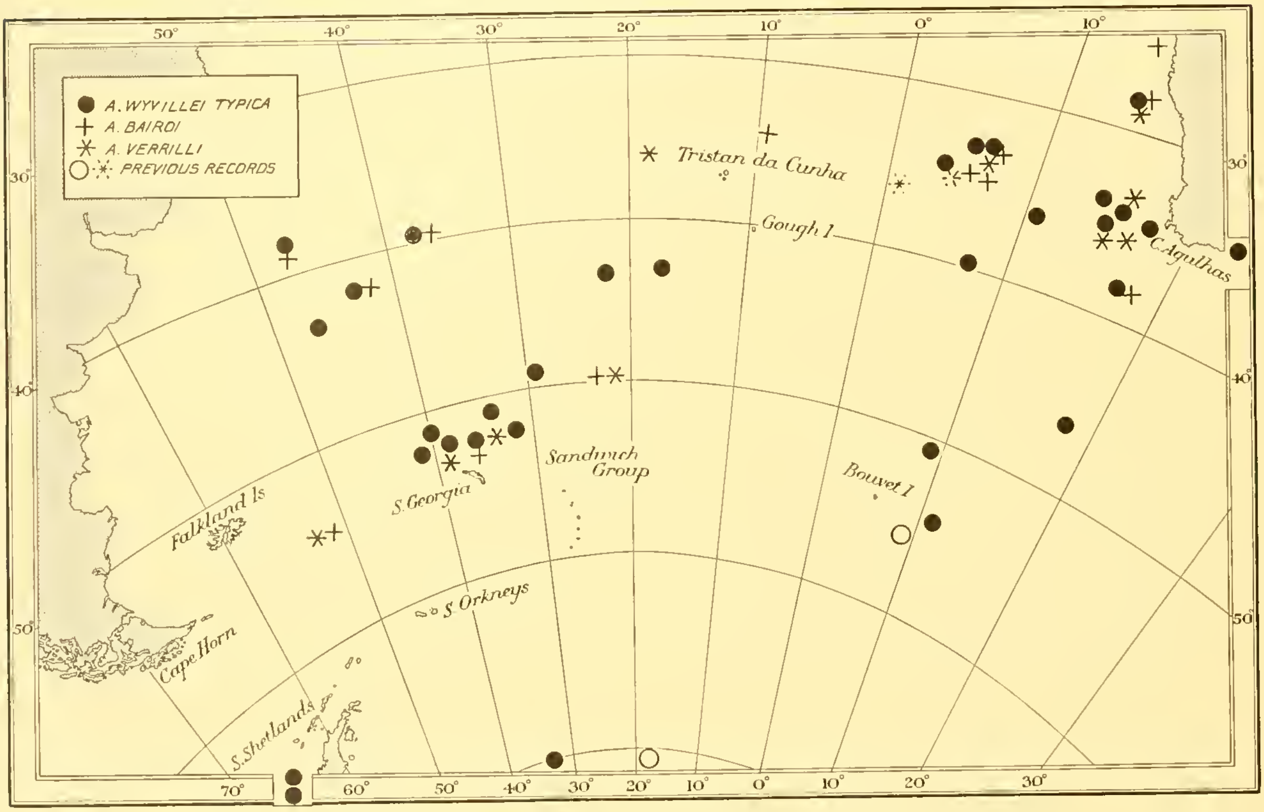

Fig. 6. Chart showing the distribution of *Atolla wyvillei*, Haeckel, in the South Atlantic and Southern oceans.

only *Atolla* forma *bairdi* and *verrilli* have been taken in the neighbourhood of Cape Verde from a depth of 800–200 m. *Atolla wyvillei* typica, which previously has been recorded as the only species in Antarctic waters, has been found by the 'Discovery' in the same regions (south of South Shetlands, Bellingshausen Sea, South Georgia, Bouvet Island).

Between the tropical region on the one side and the Antarctic on the other, we find a large region in which all three kinds are found near each other. In several hauls specimens of all three forms were found together. A glance at Fig. 6 shows also that the material is not distributed equally along the route. There seem to exist several centres of distribution: south of Cape Verde, north of South Georgia, the waters near the Cape of Good Hope and west of the Cape. It is, however, not impossible that this must be partially ascribed to more thorough collecting at these places. The southernmost station at which *A.* forma *bairdi* and *verrilli* have been found is St. 391 in 55° S, 52° W. The northernmost localities of *A.* forma *wyvillei* are in the Gulf of Guinea in 8° N at a depth of 850–900 m. It is obvious that *A.* forma *wyvillei* only occurs in a layer of water of low salinity which in the eastern basin of the Atlantic does not reach farther than 10° N. In the Guinea basin this water layer of 34·5–34·7 ‰ salinity is found at a depth of 500–1000 m. As *A.* forma *wyvillei* is the only form from Antarctic waters, and occurs in more southern regions, especially in water of Antarctic origin, and as forma *bairdi* and forma *verrilli* are typical of the northern Atlantic regions and do not occur farther south than 55° S, it seems very probable that *wyvillei* and *bairdi* (the latter including *verrilli*) *are two distinct geographical forms which are confined to special currents or regions* (cf. however, Broch, 1913, p. 16).

Vertical distribution. As may be seen from Tables VI and VII *Atolla* was found from the surface (200–0 m.) down to 2000–2500 m. Most specimens occur between 700 and 1500 m., and *Atolla* belongs therefore to the "intermediate fauna" of Bigelow (1909, 1913). The largest number was caught at 13° 25′ N, 18° 22′ W (south of Cape Verde) with twenty-four specimens from 900 m. upwards, the next at St. 151 in 1025–1275 m. in depth with nineteen specimens and the third on St. 407 with eighteen specimens from 800–900 m. depth. We will now consider each form separately.

Atolla wyvillei forma *verrilli* has been found at a depth of 1000 m. or more with the exception of two stations, 267 and 101, where it was caught in 450–550 and 300–400 m. The occurrence in more superficial layers here is perhaps due to cold upwelling currents. The Valdivia Expedition (1903, p. 10) found this form at several stations on the west coast of Africa from the Equator to the Cape (depth not indicated). The Deutsche Südpolar Expedition found it between Tristan d'Acunha and Cape Town, and west of Cape Verde to the south of the Equator at a depth of 3000 m. (1909, p. 36).

Atolla wyvillei forma *bairdi* occurs below 900 m. with the exception of the hauls at Sts. 270 (Elephant Bay), 282 (Annobon Island) from 200 to 400 m. and St. 267 (Cape) from 450–500 m. in regions where cold upwelling currents are present, and in a catch from 650 m. at St. 81 (Tristan d'Acunha) in a layer of low salinity of 34·5 ‰. More than half the specimens come from a depth of 800–1000 m. This form was found previously by the Plankton Expedition (1892, p. 16) south of Cape Verde in 4000 m., and by the Valdivia Expedition in the Guinea stream (1903, p. 10, depth not indicated).

Atolla wyvillei forma typica is found in the upper layers in the far south, Sts. 592 and 595 (South Shetlands) and WS 552F (Coats Land), off the west coast of Africa at Annobon Island (St. 282) in the Gulf of Guinea, north of the Cape (St. 267), and north-west of the Cape (St. 407), at all of which places (besides the Antarctic localities) deep water from the depths rises towards the surface. Elsewhere it occurs only in great depths between 800 and 1600 m. (maxima at 1000 and 1500 m.) with the exception of St. 114 near Bouvet Island, where it occurs at about 700 m. The 'Challenger' found

Table VII

Showing the bathymetrical distribution of Atolla wyvillei, *Haeckel. Figures denote numbers of specimens*

Station	Locality	Depth in metres	*wyvillei* typica	*bairdi*	*verrilli*	Total
270	Elephant Bay	200–0	—	3	—	3
282	Annobon Island	300 (–0)	1	1	—	2
592	South of South Shetlands	350–124	1	—	—	1
595	South of South Shetlands	380–133	1	—	—	1
101	Cape of Good Hope	300–400 (–0)	1	—	6	7
563	South of South Shetlands	450–180	1	—	—	1
WS 552F	Coats Land	460–360	1	—	—	1
267	Cape of Good Hope	450–550	1	1	1	3
81	Tristan d'Acunha	650 (–0)	—	2	—	2
8	Tristan d'Acunha	600–700	2	—	—	2
114	Bouvet Island	650–700	8	—	—	8
114	Bouvet Island	650–700	2	—	—	2
6° 55′ N, 15° 5′ W	Cape Verde	0–800	—	3	—	3
407	Cape of Good Hope	800–900	6	12	—	18
13° 25′ N, 18° 22′ W	Cape Verde	0–900	—	24	—	24
107	Bouvet Island	850–950	5	—	—	5
281	Gulf of Guinea	850–950	3	—	—	3
86	Cape of Good Hope	1000 (–0)	2	8	—	10
WS 263	South Georgia	1000–750	1	—	—	1
87	Cape of Good Hope	1000 (–0)	3	—	—	3
86	Cape of Good Hope	1000 (–0)	2	2	2	6
287	Ascension Island	800–1000 (–0)	1	—	—	1
78	Tristan d'Acunha	1000 (–0)	—	—	2	2
440	Cape Agulhas	1000 (–0)	3	1	3	7
256	Cape of Good Hope	850–1100	2	—	—	2
298	Cape Verde	900–1200	1	4	—	5
405	Cape of Good Hope	1200–0	3	—	1	4
9	Tristan d'Acunha	0–1250	—	1	1	2
151	South Georgia	1025–1275	15	3	1	19
401	Between the Cape and Gough Island	1250–1300	1	—	—	1
391	South of Falkland Island	1200–1300 (–0)	1	1	1	3
12	South Georgia	1200–1500	9	—	—	9
76	South Georgia	1500–0	1	1	—	2
666	North-east of South Georgia	1500–1000	1	—	—	1
395	South Georgia	1500–1600	2	—	2	4
71	Falkland Islands	2000–0	4	—	—	4
72	Between Falkland Islands and Tristan d'Acunha	2000 (–0)	4	3	—	7
85	Cape of Good Hope	2000–0	1	—	1	2
71	Falkland Islands	2000 (–0)	1	—	—	1
85	Cape of Good Hope	2000–0	—	1	—	1
700	Cape Verde	2025–0	—	1	—	1
100C	Cape of Good Hope	2000–2500	1	—	—	1
			92	72	21	185

wyvillei in St Mathias Bay not far from the coast of Patagonia in 42° 32′ S, 57° 27′ W in 2040 fms. The 'Valdivia' secured a specimen south-east of Bouvet Island in 56° 30′ S, 14° 29′ E in a vertical haul from 1500 m. (821 fms.). The 'Scotia' caught a specimen in 72° 02′ S, 23° 40′ W, vertical net, 0–1000 fms. (Browne, 1908, p. 241).

From south to north this form sinks slowly into the deeper layers. It is found from the surface to 400 m. off the coast of Antarctica, it lives near Bouvet Island in 650 and 700 m. depth, between Bouvet Island and the Cape at 850–950 m. and at Cape Agulhas and the Cape of Good Hope at ± 1000 m. (see Table VII).

With regard to temperature it seems that forma *wyvillei* occurs mostly in waters of 2–3° C.; the highest temperature is 4° C. near Ascension Island and the Gulf of Guinea and the Cape Verde Islands, and the lowest temperature observed is at South Georgia (Sts. 151 and 12) where it was found in about 1·25 to 1·5° C. It is evident that the upward movement of warm deep water in the far south affords a valid explanation of the occurrence of *A. wyvillei* in the upper layers in these latitudes.

The vertical distribution of *Atolla* thus agrees perfectly with Browne's description (1910, p. 10).

Atolla chuni, Vanhoeffen

(Plate XIV, figs. 3, 4; Plate XV, fig. 5; Figs. 7–9)

St. 85. 23. vi. 26. 33° 07′ 40″ S, 4° 30′ 20″ E, west of Cape of Good Hope. $4\frac{1}{2}$ m. tow-net, 2000 (–0) m.

One specimen faded, nine or eleven warts on lappets, seldom united into a crista, gonads well developed, yellowish.

St. 256. 23. vi. 27. 35° 14′ S, 6° 49′ E, west of Cape of Good Hope. Young fish trawl, 850–1100 (–0) m.

One specimen, in fair condition, flat, very deeply pigmented, seven or nine warts on lappets, furrows on disc very feeble, no gonads.

St. 76. 5. vi. 26. 39° 50′ 30″ S, 36° 23′ W, far north of South Georgia. $4\frac{1}{2}$ m. tow-net, 1500–0 m.

Two specimens, flat, the larger with very feeble radial furrows on margin of central disc, large warts on lappets, the smaller without radial furrows, very small warts, no gonads, both very deeply pigmented.

St. 407. 12. vi. 30. 35° 13′ to 34° 57′ S, 17° $50\frac{1}{2}$′ to 17° 48′ E, south-west of Cape of Good Hope. $4\frac{1}{2}$ m. tow-net, 800–900 m.

Four specimens, flat, feebly pigmented, only stomach and lappet zone with pigment; together with many *Atolla wyvillei* and *Periphylla hyacinthina* forma *dodecabostrycha*.

St. 72. 1. vi. 26. 41° 43′ 20″ S, 42° 20′ 40″ W, between Falkland Islands and Tristan d'Acunha. $4\frac{1}{2}$ m. tow-net, 2000 (–0) m.

One specimen, faded, gonads feebly developed, together with many *Atolla wyvillei*.

St. 107. 4. xi. 26. 45° 03′ S, 17° 03′ E, between the Cape of Good Hope and Bouvet Island. $4\frac{1}{2}$ m. tow-net, 850–950 m.

Three specimens; two with irregular sculpture on central disc, seven and nine warts on lappets, only stomach and lappet zone pigmented, faded, the largest the darkest, with smooth central disc, with gonads.

St. 668. 19. iv. 31. 46° 42½′ S, 30° 32′ W to 46° 43½′ S, 30° 22′ W, north of South Georgia. 4½ m. tow-net. 1500–1000 m.

One specimen, very beautiful, warts feebly developed, flat, very deeply pigmented, gonads (♂) strongly folded, well developed, covered with reddish brown pigment.

St. 395. 13. v. 30. 48° 26¾′ S, 22° 10′ W to 48° 26½′ S, 22° 06½′ W, north-east of South Georgia. 4½ m. tow-net, 1500–1600 m.

Six specimens: three small developmental stages of 10 mm., deformed, only stomach and tentacle muscle pigmented; three larger specimens, one of 45 mm. diam., 18 mm. high, others flat, very dark, with gonads.

St. 151. 16. i. 27. 53° 25′ S, 35° 15′ W, north of South Georgia. 4½ m. tow-net, 1025–1075 m.

Three specimens, very deeply pigmented, two flat ones, one high, gonads feebly developed, 7–9 warts on lappets.

St. 391. 18. iv. 30. 55° 48½′ S, 52° 35′ W, south-east of Falkland Islands. 4½ m. tow-net, 1200–1300 (–0) m.

One specimen, flat, warts very small, very deeply pigmented, no gonads.

St. 391. 18. iv. 30. 55° 48½′ S, 52° 35′ W, south-east of Falkland Islands. 4½ m. tow-net, 1200–1300 (–0) m.

Twenty specimens, in fair condition, some with fine polygonal furrows on central disc, notches often deep, warts on lappets 7, 9, 11, often flat, forming a crista. Most larger specimens with strongly developed folded gonads forming a continuous ring. In the smaller ones the gonads are separated in a varying degree from one another.

Of this species only very few specimens are known. The Valdivia Expedition (Vanhoeffen, 1903, p. 12) caught two beautiful individuals at St. 120 between the Cape of Good Hope and Bouvet Island in 42° 18′ S, 14° 1′ E in a vertical haul at 1500 m. (821 fms.); the 'Scotia' (Browne, 1909, pp. 240–1) took one damaged specimen between South Georgia and Bouvet Island at St. 450, 48° S, 9° 50′ W in 1332 fms. Vanhoeffen (1903) gives two large coloured figures (general shape) of this species in pl. i, figs. 1 and 2, and a small one representing the lappets with the warts in pl. v, fig. 26. He gives no description and confines himself to mentioning a few characteristics: the highly vaulted bell, twenty-three radial furrows on the central disc, twenty-four pedalia and last but not least the lappets adorned with warts or small papilla-like protuberances. Mayer (1910, p. 562) mentions as a character an annular ridge hidden within the ring furrow, but this ridge is not to be seen in Vanhoeffen's figures, and it is not mentioned in his description.

In the Discovery material no less than forty-three specimens are present, on most of which the warts ("glass beads") on the lappets are distinctly visible. In some developmental stages of about 10 mm. diameter and in a few large specimens the warts are very feebly developed. There is a remarkable constancy in respect of the number of tentacles (24), pedalia (23) and radial furrows (23) on the central disc.

Size of the bell (Plate XIV, figs. 3, 4; Plate XV, fig. 5). The diameter of the largest specimen with mature gonads is 65 mm. The specimens caught by the 'Valdivia' had a diameter of 27 and 50 mm. and those taken by the 'Scotia' may have had a diameter of about 50 mm. *Atolla chuni* does not attain the size of *A. wyvillei*, but is considerably smaller.

Table VIII

Showing measurements in mm. of twenty-six specimens of
Atolla chuni, *Vanhoeffen*

Station	Diameter of the bell	Diameter of the central disc	Height of the bell*	Diameter of the ring muscle	Diameter of the stomach	Breadth of the lappet zone
85	55	32	24	45	22	15
256	25	15	Flat	20	16	7
76	29	15	15	23	12	6
76	15	17	7	13	7	3
407	32	16	17	27	16	7
407	18	10	5	16	7	4
407	23	12	Flat	20	9	6
407	16	7	Flat	14	6	3
107	30	17	7	26	12	6
107	25	15	5	22	8	5
107	21	21	15	30	15	7
395	45	27	18	38	18	15
395	32	15	17	27	12	9
395	30	16	12	26	12	10
668	65	35	22	47	26	10
391	65	33	25	42	25	15
391	45	25	21	35	16	11
391	52	30	23	42	22	12
391	42	27	22	30	16	9
391	32	15	12	35	12	7
391	27	14	Flat	22	10	6
391	25	12	6	21	11	7
391	17	8	9	15	10	4
391	15	9	Flat	15	6	$3\frac{1}{2}$
391	10	6	Flat	$7\frac{1}{2}$	4	$1\frac{1}{2}$
391	8	5	Flat	7	4	$1\frac{1}{2}$

* Lappets included.

The CENTRAL DISC is relatively broad, exceeding half the diameter of the bell. Its surface as a rule is smooth, but sometimes there is to be seen a more or less fine or irregular network of larger or smaller polygonal meshes. The radial furrows on the central disc are mostly very faint and feebly developed according to the *verrilli* type, or the border of the central disc is plain as in *bairdi*. In a few specimens only, from St. 391, the furrows are deeper and a little broader, resembling more the *wyvillei* type.

The HEIGHT OF THE BELL (Plate XIV, fig. 3) is very variable, very flat individuals being found together with relatively high ones. Often the central lenticular disc resembles a highly vaulted watch-glass. On the whole this species seems to be a little higher than *wyvillei*, and the central disc more vaulted.

The PEDALIA are all as long as broad or a little longer than broad (Figs. 7 *a*, *b*), very regular, more or less circular in outline, mostly ball-shaped, forming together a row of regular large round beads, seldom flattening each other, and not so uniformly or so strongly compressed as in the different forms of *wyvillei*. They are always smooth, without furrows.

The MARGINAL LAPPETS are not pointed and vaulted as somewhat schematically figured by Vanhoeffen (1903, pl. v, fig. 26). In young specimens (fig. 7 *a*) they are broad and spoon-shaped, and lie side by side. In older individuals they are relatively longer, elongated, and have grown together at their bases so as to form pairs and lie slightly one above the other, like scales (Fig. 7 *b*).

The WARTS ON THE LAPPETS show as a rule the number and arrangement described by Vanhoeffen, but they are larger, much stouter, and do not so much resemble round pearls ("Glasperlen"), being more like elongated drops. They lose their pigmentation more easily than the deeper lying parts of the lappets and are therefore conspicuous as white transparent spots between the surrounding dark brown pigment. In many cases I could only distinguish seven warts in the way described by Browne (*loc. cit.*), three on each side, and one in the middle; in these the innermost warts were missing. In other cases there were five on each side, and one in the middle. Sometimes the warts on each side of the rhopalium coalesce to a more or less continuous longitudinal irregular ridge or crista (see Fig. 7 *a* on the left). Sometimes a few irregularly dispersed "pearls" are found between the regularly arranged ones, e.g. two median ones. Sometimes a small longitudinal thickening of the exumbrellar jelly is found above the rhopalium itself. A few specimens have eleven warts, four on each side, two in the middle and one above the rhopalium. In several cases the most distal warts near the end of the lappet are the largest and have properly the form of a drop.

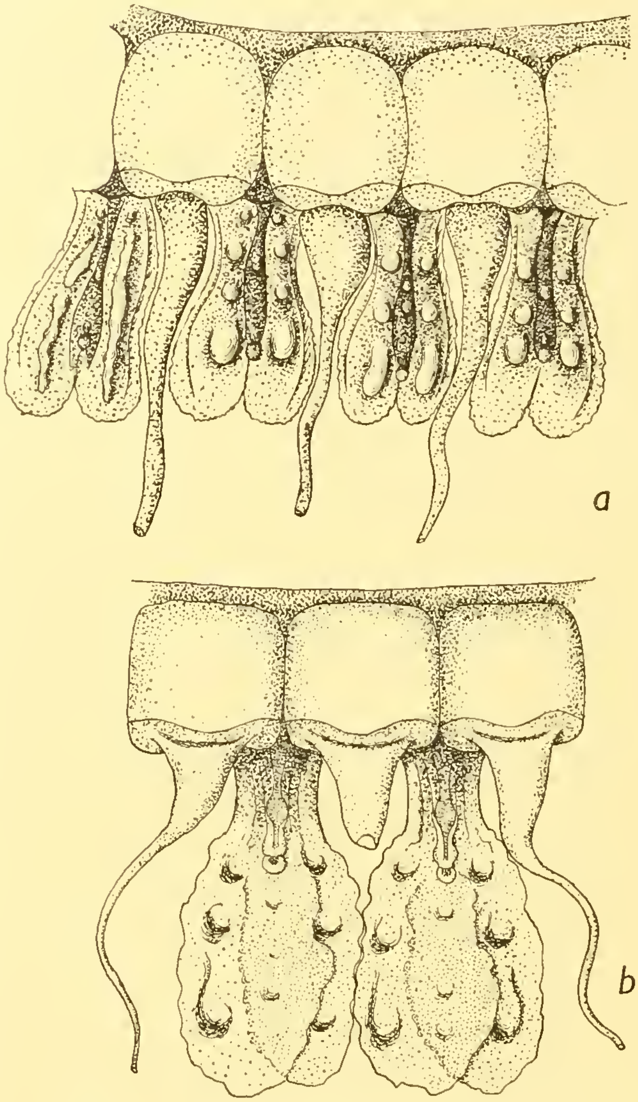

Fig. 7. *Atolla chuni*, Vanhoeffen. Pedalia and marginal lappets with "glass beads." *a*, of a young specimen, × 5. *b*, of an older specimen, × 5.

The RHOPALIA show no peculiarities except that they are surrounded at the base with a thick dark brown mantle of pigment, and in several cases I have seen more or less distinct traces of pigment in the stalk of the rhopalium itself.

The GASTRO-VASCULAR SYSTEM of *Atolla chuni* (Figs. 8 *a*, *b*) agrees on the whole with the descriptions given by Vanhoeffen (1903) for *A. valdiviae*, by Maas (1903, 1904) for *bairdi* and by Bigelow (1909) for *wyvillei*, but there are differences enough to distinguish *A. chuni* from other species of the genus, even with the naked eye. The rhopalar canals and tentacular pockets are here strongly pigmented. The rhopalar canals are thickened locally in their outermost part and become thinner again in the neighbourhood of the rhopalium. Besides this a large subumbrellar papilla lies in the middle above each rhopalar canal. In young specimens (Fig. 8 *a*) this is shaped like a ball or egg, and in older ones (Fig. 8 *b*) distally elongated to form a rounded longitudinal ridge, which diminishes in height towards the margin. Beneath this papilla the otherwise dark rhopalar canals are very poor in pigment and become nearly transparent, so that they are visible only by their outlines. The sudden thickening of the rhopalar canals, combined with the bright transparent oval spot formed by the papilla and the dark purple-brown pigmentation around it, gives its own *cachet* to the gastro-vascular system of *A. chuni*.

In the tentacular pockets the FALSE SEPTA, as already observed by Maas in *A. bairdi* and by Bigelow in *wyvillei*, can almost always be observed. They are very variable in form and size, being long, short, broad, or narrow. There is such great variability of these septal regions subdividing the tentacular canals that they do not prove to be of any systematic value as believed by Maas.

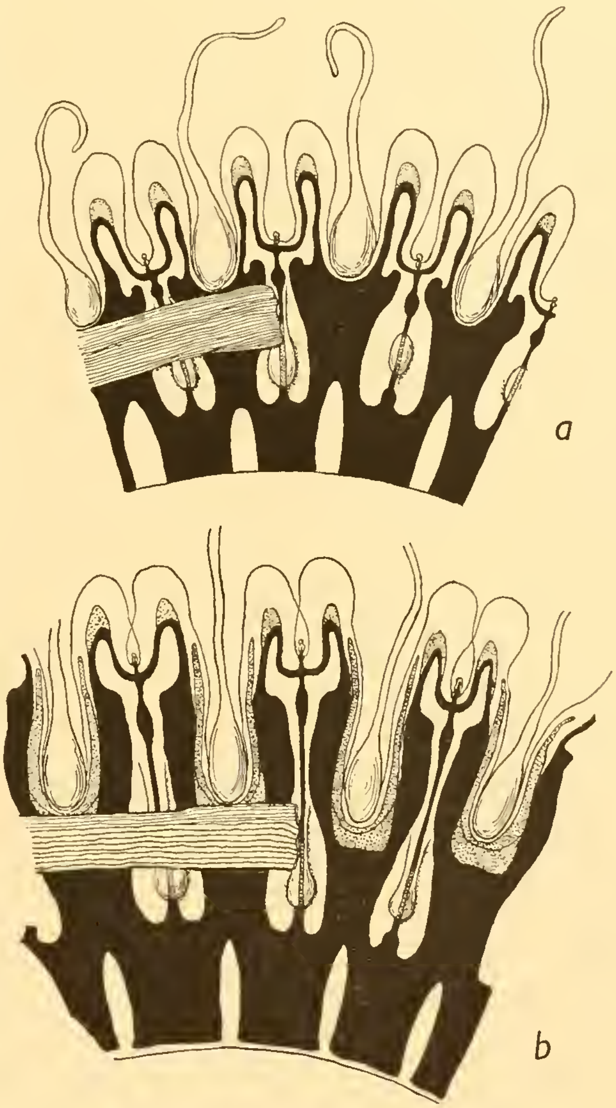

Fig. 8. *Atolla chuni*, Vanhoeffen. Sector of the gastro-vascular system. Ring muscle (on the left) partly cut off.
a, of a young specimen, about 15 mm. in diameter.
b, of an adult specimen, about 50 mm. in diameter.

The small and narrow VESSELS IN THE LAPPET POUCHES reach very far into the lappets so that at their distal ends only a small piece of the endoderm lamella is still visible. For comparison I give here two figures of the gastro-vascular system, the first showing that of a young specimen of about 15 mm. diameter (Fig. 8 *a*) and the second (Fig. 8 *b*) that of an adult animal of about 50 mm. diameter. The differences in the form of the tentacular pouches in both cases are obvious. In the younger specimen the tentacular pouches are distally very broad. Where the long thin lappets arise their outline is curved inward. In the older stages the tentacular pouches are much more elongated, more slender and distally less expanded, and the incurvation at the origins of the lappet canals is less pronounced. In both cases the pigment of the tentacular pouches reaches to the bases of the tentacles surrounding them. In the older specimens the SUBTENTACULAR POUCHES on the subumbrella near the insertion of the tentacles are indicated in Fig. 8 *b* with fine dots. The ends of these pouches reach far into the lappets and are also deeply pigmented. This makes it rather difficult to understand the anatomy of the lappet zone and of the insertion of tentacles. A thorough study of the anatomy of these parts seems to be very necessary, but this is beyond the scope of the present report. In both figures the circular muscle is figured as being partially cut off.

The COLOUR is in all specimens nearly the same, the smaller ones generally a little less dark than the older ones. All are a very dark, deep purple-brown, and much more intensely and brilliantly coloured than in the somewhat faded specimens figured by Vanhoeffen. On the exumbrella all grooves or deeper lying parts are deeply pigmented, especially the coronal furrow, or show at least traces of pigment, as, for instance, the radial furrows on the central disc. In most specimens the subumbrella too is more or less covered with a thick layer of the dark purple brown pigment, which has become partially separated, or hangs here and there in small patches from the surface. Often the ring muscle is wholly covered with pigment, or stained in many places with reddish brown spots, as is the case with the gonads. The gastro-vascular system is very distinctly visible, by its own strong pigmentation, through the more superficial thin pigment stratum. The circular muscle and gonads are, if not covered with pigment, of a yellowish colour, and the muscle sometimes has a greenish yellow hue and is more or less iridescent. The stomach, if not covered by dark pigment, has a greyish blue tint. Generally speaking the pigment in the specimens of *A. chuni* is better preserved than in those of *A. wyvillei*, and it seems to be darker and more resistant.

The GONADS develop rather late. Specimens smaller than 30 mm. diameter have no gonads. In specimens of 50–60 mm. diameter the gonads are strongly folded and form a nearly complete ring, while in smaller ones they are in the form of eight perfect sacs which lie separated from each other at equal distances, or constitute four pairs. Often it was possible to distinguish the eggs in the sacs with the naked eye. If not mature, the gonads are easily overlooked, because they are covered with the thick layer of dark pigment.

GEOGRAPHICAL DISTRIBUTION (see Fig. 9). The catches of the 'Discovery' have greatly enlarged our knowledge of the distribution of *Atolla chuni*. Up till now only three individuals from two localities in the neighbourhood of Bouvet Island were known. In the broad band between 30 and 55° S the 'Discovery' found no less than forty-three specimens. Most individuals have been taken between the west of the Cape of Good

Hope and north of South Georgia, and one haul (St. 391) is from the south-east of the Falkland Islands. The greatest number of individuals has been collected at this station (391) with twenty specimens of different sizes, and at another rich haul at St. 395 (north of South Georgia) there were six specimens. In three localities (Sts. 407, 72, 151) *A. chuni* has been taken together with *A. wyvillei* and *Periphylla hyacinthina*. The distribution of *Atolla chuni* is wholly restricted to the sub-Antarctic part of the Atlantic Ocean; the medusa has not yet been found in Antarctic waters south of the latitude of Cape Horn, nor to the north of 30° S. Comparing the distribution of *A. chuni* with that of *A. wyvillei* in the same regions, we find that in both cases *most individuals are gathered in the neighbourhood of continents or groups of islands.*

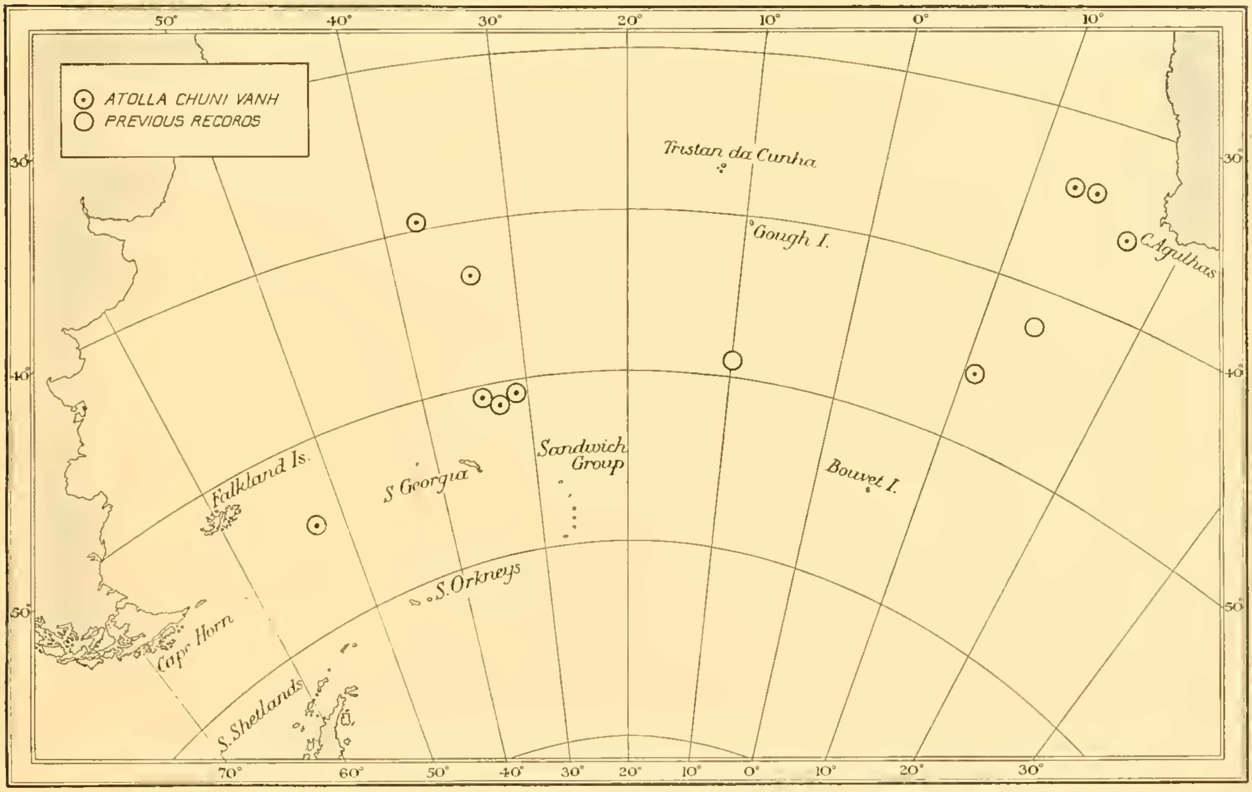

Fig. 9. Chart showing the distribution of *Atolla chuni*, Vanhoeffen.

VERTICAL DISTRIBUTION (see Table IX). *A. chuni* is a true deep-sea medusa with the typical pigmentation of abyssal forms. The 'Valdivia' found it in ± 1500 m. depth, and the 'Scotia' in about 2000 m. The 'Discovery' never collected *A. chuni* in closing net hauls from 800 m. upwards. The most superficial catch was made south-west of the Cape between 800 and 900 m. and between the Cape and Bouvet Island in 850–950 m. In all other closing net hauls the species was present only in depths of 1000–1500 m. The specimens collected with open nets were also found only when nets were used at depths exceeding 1100 m. All these facts prove *A. chuni to be a true component of Bigelow's so-called intermediate fauna*. It prefers deeper layers than *A. wyvillei*. Most striking is the rich catch from St. 391 (south-east of the Falkland Islands) from 1200 to 1300 m. depth, with twenty-one fair individuals, almost the half of the whole. It is a pity that it was not a closing net haul. In the closing net catch from St. 395 (north-east of South Georgia) six specimens were caught at a depth of 1500–1600 m. The maximum occurrence is therefore in a layer between 1200 and 1600 m.

In both basins of the South Atlantic the species lives in the sub-Antarctic or Antarctic intermediate water—in the so-called "Subantarktische Zwischenstrom" of Wüst. The specimens at Sts. 407, 107, 256 and 76 were taken in this water, which has a low salinity: at these stations it was about 34·35–34·45 ‰. South of about 40° S. *A. chuni* was found in different water, with a salinity of 34·65–34·75 ‰, which flows southwards below the north-flowing Antarctic water. (Here I follow the suggestions given by Mr G. E. R. Deacon.) The previous records of *A. chuni* ('Valdivia' and 'Scotia') show a salinity of 34·7 ‰. According to Wüst's temperature section (1928, pl. xxxiv) *A. chuni* occurs in a layer of minus temperatures as well as in water from 0 to 10° C.

Table IX

Showing the bathymetrical distribution of Atolla chuni, *Vanhoeffen*

Station	Locality	Depth in metres	Salinity ‰	Number
407	South-west of Cape of Good Hope	800–900	34·35	4
107	Between the Cape and Bouvet Island	850–950	34·35	3
256	West of Cape of Good Hope	850–1100 (–0)	34·35	1
151	North of South Georgia	1025–1275	34·7	3
391	South-east of Falkland Islands	1200–1300 (–0)	34·65	1
391	South-east of Falkland Islands	1200–1300 (–0)	34·65	20
395	North-east of South Georgia	1500–1600	34·75	6
668	North-east of South Georgia	1500–1000	34·7	1
76	Far north of South Georgia	1500–0	34·43	2
72	Between Falkland Islands and Tristan d'Acunha	2000 (–0)	34·75	1
85	West of Cape of Good Hope	2000 (–0)	34·75	1
			Total	43

Order SEMAEOSTOMEAE, L. Agassiz, 1862

Family PELAGIDAE, Gegenbaur, 1856

Genus Pelagia, Pér. and Les., 1809

Pelagia noctiluca, Forskål

30. x. 26. 9° 55′ N, 18° 34′ W, south of Cape Verde. 2 m. tow-net, 0–200 m.

Two badly preserved specimens of about 20 mm. diam., gonads yellowish.

St. 280.[1] 10. viii. 27. 00° 36′ S, 8° 28′ E, Gulf of Guinea. Young fish trawl, 200–100 (–0) m.

Four specimens, 21, 23, 23, 25 mm. diam, 11, 17, 17, ? mm. high; two vaulted, two vase-like, warts round, gonads yellowish pink.

[1] From this station there exists a coloured sketch from a living specimen with vivid colours, umbrella reddish, tentacles and mouth arms with a bluish or violet hue.

St. 281. 12. viii. 27. 00° 46′ S, 5° 49′ 15″ E, Gulf of Guinea. 70 cm. tow-net, 0 m.

Four specimens, one without mouth arms and manubrium, 19, 20, 27, 31 mm. diam., 14, 11, 7, 18 mm. high; two flat, two vaulted; warts on the flat ones flat, rounded and even, on the highly vaulted specimens high, oval and with ridge; gonads on the largest specimens well developed, dark pinkish.

St. 282. 12. viii. 27. 1° 11′ S, 5° 38′ E, Gulf of Guinea. Young fish trawl, 300 (–0) m.

Two fine specimens of 27 and 30 mm. diam., 16 and 17 mm. high; nettle-warts high, oblong, covering centre and margin (*noctiluca* type), gonads well developed, manubrium relatively long.

St. 285. 16. viii. 27. 2° 43′ 30″ S, 00° 56′ 30″ W, Gulf of Guinea. 4½ m. tow-net, 125–175 (–0) m.

Four specimens, deformed, damaged on mouth arms, 13, 17, 24, 28 mm. diam., height?, warts round to oval, gonads developed on the two largest.

St. 270. 27. vii. 27. 13° 58′ 30″ S, 11° 43′ 30″ E, Elephant Bay. Kelvin tube, 200–0 m.

One specimen, badly damaged, 36 mm. in diam.; flat, umbrella only, without mouth arms; warts small, oblong, with ridge.

29. xi. 26. 25° 47′ S, 17° 48′ W, north of Tristan d'Acunha. Hand-net, 0 m.

One specimen, in fair condition, 35 mm. diam., 17 mm. high, marginal zone smooth ("*cyanella*" type), gonads feebly developed.

St. 168. 25. xi. 27. 60° 58′ S, 48° 05′ W, between South Orkneys and Clarence Island. Young fish trawl, 100–150 (–0) m.

Eight young specimens, well preserved, two damaged on mouth arms; bell flat, transparent; small round oval warts all over the surface of the exumbrella (*noctiluca* type). Gonads relatively well developed, yellowish. Surface temperature – 0·20° C.

Table X

Showing measurements in mm. of eight specimens of Pelagia noctiluca, *Forskål* (*from St.* 168)

Diameter of the bell	Height of the bell	Length of manubrium	Length of mouth arms
31	7	7	12
28	5	6	11
26	5	6	13
22	4	4	12
20	3	3	8
16	—	—	—
15	3	3	10
10	—	—	—

About twenty different species or varieties of the genus *Pelagia* have hitherto been described. All characters, however, to which previous students of the group devoted attention, viz. proportionate dimensions of the bell, length of manubrium and mouth arms, outline of the marginal lappets, shape and arrangement of exumbrellar nettle-warts, etc., proved not to be reliable for discrimination of the species, altering with age or being subject to great variation. According to former statements and the result of extensive studies by Vanhoeffen, Mayer, Broch, Kramp, Bigelow and the author, one comes to the conclusion that there is most probably only a single species of *Pelagia*, with a world-wide distribution over all tropical and sub-tropical parts of the ocean, to which the oldest name (*noctiluca*) ought to be applied. This comprehensive species may be divided, on the base of nettle-warts and geographical distribution, into four groups (cohorts) as proposed by Mayer (1910) and Krumbach (1924). It is one more of the cases where the Linnean system is probably inadequate to express the relationship of all the various closely related forms, united by intermediates (see Introduction, p. 333).

The study of the present material, containing twenty-six mostly small and young specimens, presents no opportunity of reviewing this subject, the characteristics of the different supposed species being still more difficult to observe in small developmental stages than in adult animals. It rather seems once again that no distinction can be based either on the size or shape of the exumbrellar nettle-warts, or on the length of manubrium and mouth arms. The contraction of the bell has a considerable effect on the condition of the nettle-warts, for in specimens with a flat disc-like bell the warts are flat, rounded and smooth, while in others with high dome-like, vaulted bell the warts are high, oblong and mostly provided with a ridge. Generally they are proportionately higher in smaller than in larger specimens. Most individuals are of the *noctiluca* type (whole surface of exumbrella covered with warts), but a few show the marginal zone smooth (*cyanella* type, Bigelow). Moreover, in small specimens it is almost impossible to state exactly the length of the manubrium in comparison with the length of the mouth arms. The figures given in the table above are without any doubt subject to inevitable personal error on account of the practical difficulties of measurement.

Genus **Chrysaora**, Pér. and Les., 1809

Chrysaora fulgida, Reynaud

Syn. *Chrysaora hysoscella*, var. *fulgida*, Mayer

5. x. 26. 33° 1′ S, 17° 58′ E. Hoetjes Bay, Cape Peninsula. Hand-net, 0 m.

One specimen, well preserved but a little damaged; two specimens in pieces.

The well-preserved specimen measures ± 220 mm. in diameter. The thirty-two lappets are short, broad, and nearly semicircular. There is no difference in size and shape between the rhopalar and tentacular ones. The tentacular pouches are in their distal parts one-third broader than the rhopalar ones. The mouth arms are rather poorly folded, $1\frac{1}{2}$ times as long as the diameter, narrow in the middle, with the ends lancet-shaped. There are twenty-four tentacles, broad, band-like and as long as the radius, three per octant. The gonads are well developed, but with unripe eggs, yellowish brown in colour. There is no star on the exumbrella and no pigment on the lappets or mouth arms. The gonads are more pink than the tentacles, some of which are brown.

The two other specimens are so badly damaged that they have fallen into pieces. They were probably larger specimens than the first, with longer richly folded mouth arms; the gonads are more developed.

Although in all three specimens there is nothing to be seen of the star-like design with radial rays on the exumbrella and the vivid colours of the mouth arms and gonads, so typical of this species, the colour being uniformly yellowish brown, I think them to be identical with *Ch. fulgida*, Reynaud, which is very common in the neighbourhood of the Cape of Good Hope. Vanhoeffen (1903, p. 38) found some fragments of a quite similar medusa in Algoa Bay.

Very probably Mayer (1910) is right in believing this form to be identical with *hysoscella*, Eschscholtz.

Family CYANEIDAE, L. Agassiz, 1862

Genus **Desmonema**, L. Agassiz, 1862

The question whether the species *gaudichaudi*, Lesson, and *chierchiana*, Vanhoeffen, can be maintained as separate, or represent only local varieties of one and the same species, is not yet settled. The reason is that too few specimens have been studied. In the Discovery material there are only two specimens which belong to this genus. If I identify them under different names I do so because the two, although more or less damaged on the mouth arms and gonads, show obvious differences.

According to Vanhoeffen (1888, p. 18) *D. chierchiana* differs from *gaudichaudi* by the shorter mouth arms, and the form of the tentacular lappets and gonads. According to Maas (1908) both differ in the form of the tentacular lobes (divided or not) and the number of tentacles. Browne (1908) and Mayer (1910) point out that there are important differences in the shape, number and arrangement of the tentacles. The distribution is different also: *gaudichaudi* is Antarctic and *chierchiana* sub-Antarctic. I may add that the form and size of tentacles, the number and shape of the vessels in the tentacular lappets and the relative width of the lappet zone, are different in both forms.

I am therefore inclined to keep the species separate.

Desmonema gaudichaudi, Lesson (Fig. 10)

St. 150. 16. i. 27. Off South Georgia. 1 m. tow-net, 0–5 m.

One very badly damaged specimen without stomach or mouth arms, and most tentacles torn away; lappet zone only partially preserved. Diameter of the bell 120 mm. with lappets turned outwards.

The jelly of the umbrella is very thin and fragile. The surface of the exumbrella on the lappets is perfectly smooth, and free of warts or clusters of nematocysts. The tentacular lobes are ± 23 mm. in length, 25–27 mm. broad; their distal margin is without any incision or cleft, and almost evenly rounded. The rhopalar lobes are about 20 mm. long and 12 mm. broad. They are separated by deep incisions from the tentacular ones and are much more pointed than those of *chierchiana*. The whole marginal zone is relatively broad in comparison with the length of the broad and short stomach pouches, and much broader than in *chierchiana* (compare fig. 1, pl. i of Maas, 1908, of *D. gaudichaudi*, with Browne's (1910) fig. 2, pl. ii, of *chierchiana*).

The canals in the tentacular lappets (Fig. 10) are few in number, 5–6 only, and very broad and strong. They have a different form of ramification to that figured by Maas (*loc. cit.*). The middle ones run parallel, and are mostly branched centrifugally in the distal parts; the lateral canals are only branched laterally outwards through their whole length. The tentacles always arise between the origins of the canals into the lappets.

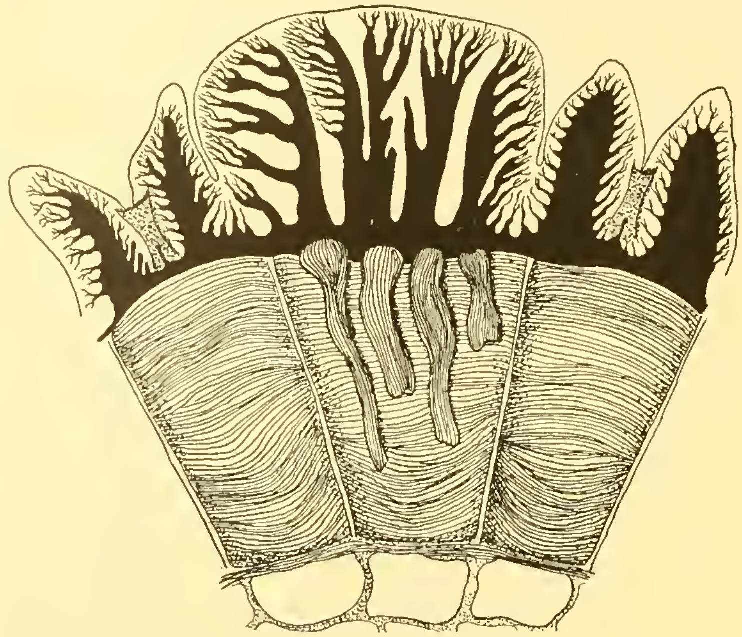

Fig. 10. *Desmonema gaudichaudi*, Lesson.

Sector of the bell with a few canals in the lappets after injection with Delafield's haematoxylin. One row of a few thick tentacles (partially torn away). × 1.

The stomach is 45 mm. in diameter and relatively large, and shows a network ("Täfelung") on the surface of the subumbrella.

The colour of the muscles and tentacles is greenish yellow. The canals in the lappets are whitish and distinctly visible in the completely transparent jelly.

The locality in which this specimen was found is remarkable; for South Georgia is sub-Antarctic, and the species is said to be found only in Antarctic waters.

Desmonema chierchiana, Vanhoeffen (Fig. 11)

St. WS 89. 7. iv. 27. Between the Falkland Islands and Patagonia. Large otter trawl, 28–21 m.

One badly damaged specimen without tentacles or mouth arms; gonads feebly developed; the margin of the bell is well preserved.

The exumbrella is flat and smooth. The jelly is here much harder and more resistant than in the preceding specimen. On the lappets there are many fine longitudinal radial ribs or warts. The medusa, lying on its back in a basin with the margin of the umbrella folded inwards, shows very clearly sixteen radial furrows on the periphery of the exumbrella. The diameter of the bell, with the margin turned outwards, measures ± 180 mm. in diameter, and turned inwards ± 140 mm. The tentacular lobes are 35–40 mm. in breadth and 20–25 mm. in length. The ocular lobes are of the same length or a little shorter, but much narrower, being only ± 15 mm. broad. There is no sharp indentation between the tentacular and the ocular lobes. The tentacular ones are bluntly rounded, and more irregularly bordered, with a round incision in the middle (see Fig. 11). The stomach is circular in outline, about 50 mm. in diameter, and obviously small. The tentacular pouches are ± 35 mm. broad at their distal margin, and the ocular ones 20–25 mm. Both are about 55–60 mm. long. The lappet zone is here relatively narrow in comparison with the length of the radial pouches. The circular muscle bands of the latter are very well developed and separated by sixteen thin septa. There are many fine radial muscles in the distal parts of the pouches, but none in the lappets.

The oral arms are torn away. There is a short manubrium about 15 mm. in length; the subgenital ostia are oval in shape and ± 25 mm. wide, and the arm pillars 7 mm. broad.

There are eight groups of tentacles arranged in 4–5 nearly straight rows adjacent to the outer edge of the circular muscles. All are torn away as if cut off at the base with a knife. The largest are in the innermost row; about 50–60 in all per group, and thread-like.

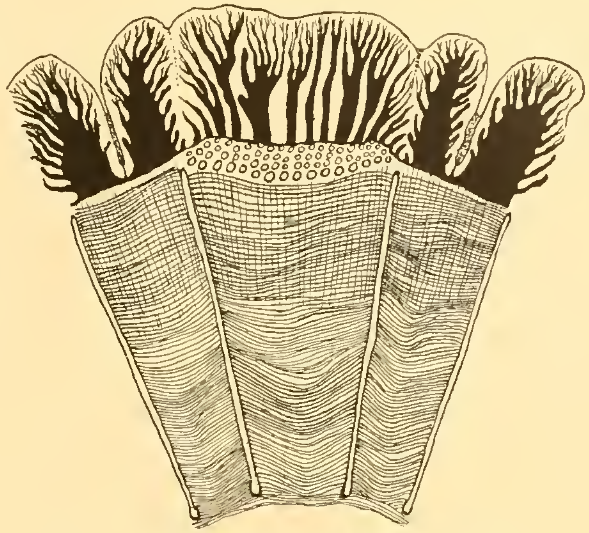

Fig. 11. *Desmonema chierchiana*, Vanhoeffen. Sector of the bell with many canals in the lappets after injection with Delafield's haematoxylin. Many rows of thin tentacles (torn away). × 1.

There are 14–18 branches of radiating vessels in the tentacular lappets, the innermost straight, running parallel, the lateral bent outwards. The branching is much simpler than in the specimen figured by Vanhoeffen (1908, Taf. ii, fig. 2) and restricted mainly to the distal parts of the canals. There are here many more canals, which are, however, much narrower than in *D. gaudichaudi* (compare Fig. 10 with Fig. 11).

The colour of the bell is light yellowish, the subumbrellar muscles pinkish yellow, the vessels in the lappets whitish, the gonads yellowish.

This species is very common in the neighbourhood of the Falkland Islands.

Family ULMARIDAE, Haeckel, 1877

Sub-family *STHENONIDAE*, L. Agassiz, 1862

Genus **Phacellophora**, Brandt, 1838

Phacellophora ornata (Verrill)

(Plate XV, fig. 6; Fig. 12)

St. 270. 27. vii. 27. 13° 58′ 30″ S, 11° 43′ 30″ E, Elephant Bay, Angola. Kelvin tube[1], 200–0 m.

The single specimen is 20 mm. in diameter. The gelatinous substance of the bell is very thin and fragile; the umbrella is vasiform, very irregularly covered with larger or smaller nematocyst warts.

There are sixteen marginal sense organs and thirty-two rhopalar lappets; the latter

[1] It is remarkable that this specimen was caught by the Kelvin tube which is intended only for the collection of bottom samples.

very large and conspicuous, more than three times as long as the flatly rounded ocular ones, and separated from them by deep clefts. Sixteen long tentacles arise from the floor of the subumbrella at a small distance from the bases of the marginal lappets. They are about as long as the radius, 2 mm. broad at the base, hollow, tapering, laterally compressed, and with a wavy thickening along the inner narrow edge covered with nematocysts. Between each pair of rhopalar lappets there is, in the middle, one of these long tentacles, and on each side of the same are the small velar lappets; between these and the rhopalar lappets there are small stunted or pointed buds of tentacles, usually one on each side. The mouth tube is simple, four-cornered, 8 mm. long. The mouth arms are 6 mm. long, with free edges but little folded, and on the border provided very irregularly with clusters of nematocysts (Plate XV, fig. 6).

The central stomach is 15 mm. broad, circular in outline, with about sixty radiating canals; they run from the periphery of the central stomach to the peripheral circular canal, which lies at a small distance from the bell margin. The rhopalar canals show the beginning only of branching, but no anastomoses with the inter-rhopalar canals. The latter are much narrower than the former. The inter-rhopalar canals, always two or three in number, lying between each pair of rhopalar canals, remain simple, unbranched, and are slender and run mostly straight or are rarely a little curved. The ring canal is conspicuous, lying under the bases of the tentacles. Extracircularly the ring canal gives rise to a blind, short, pointed canal into each velar lappet, and a broad rhopalar canal, which immediately forks and sends a thin, curved, blindly ending branch into each rhopalar lappet, and a third thin branch to the sense organ (Fig. 12).

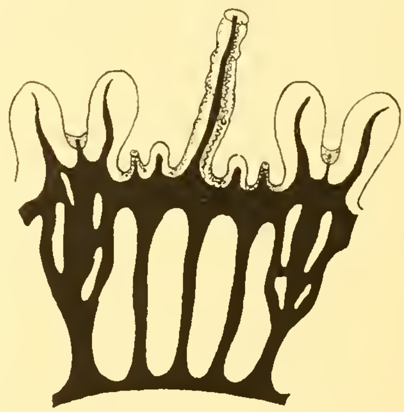

Fig. 12. *Phacellophora ornata*, Verrill. Portion of the border with canals, × 5.

The gastric filaments are very long, and are arranged in four perradial, horseshoe-shaped clusters of about twenty-five each.

The colour of the disc is transparent; uniformly whitish yellow, without any brilliant colours. The tentacles, stomach, vessels and mouth arms are whitish and not transparent.

This very young developmental stage of this relatively rare medusa was found in Elephant Bay, Angola. The locality merits interest because the species has been found hitherto in very few places: Eastport, Maine, and in the Bay of Fundy; one single specimen is mentioned by Browne (1909) from the South Atlantic—'Scotia', St. 98, 34′ 2″ S, 49° 7′ W, 200 miles east of Montevideo, surface.

The differences (outline of the stomach, number of tentacles, simple straight form of the radial canals, which do not anastomose, and the transparent colour) between the present specimen and the much larger ones described by Verrill (1869), Fewkes (1888), Browne (1909) and Mayer (1910) are surely to be attributed to the early stage of development.

ADDITIONAL REMARKS ON THE PIGMENT OF FRESH MATERIAL

Dr Kemp was kind enough to send me some specimens of *Periphylla hyacinthina* and *Atolla wyvillei* collected during the last cruise of the 'Discovery II' in the years 1931–3, and I have thus had the opportunity to study the brilliant colours of fresh material only one or two years old.

One specimen of *Atolla wyvillei* forma *bairdi*, St. WS 612, 750–0 m., is especially interesting. It is 20 mm. in diameter, including the lappet zone, and the height is 55 mm. The whole exumbrellar and subumbrellar surface of the medusa is covered with a thin layer of a vivid reddish-brown pigment. The whole central disc and the lappets (the latter on both sides), the whole subumbrellar surface, the ring muscle and the tentacles are brilliantly coloured; but the epithelium is extremely fragile and falls off at the slightest touch. The stomach is very dark purple brownish-red, of the colour of coagulated blood. Actually the whole surface of the medusa is pigmented and the central disc is not transparent and colourless as believed hitherto. The tint is a bright reddish brown, a little darker in the furrows of the central disc, in the central furrow and between the pedalia.

Four large specimens of *Periphylla hyacinthina* typica, or rather transitional stages to forma *hyacinthina*, from Sts. 539, 716, 1023, 1147, from 0–212 m., show pigmentation similar to the strangely coloured specimen from St. WS 552 B, mentioned above (pp. 347, 357). They have a bluish-red stomach, not so deeply pigmented with purple-brown as usual, the lappet zone transparent white, tentacle muscles, tentacles and rhopalia yellowish brown. The pigment on the tentacles is extremely delicate and falls off very easily, so that the mother-of-pearl underlayer becomes visible. The stomach is dark purple with a bluish tint, darkest in the uppermost parts ("acrogaster") in the neighbourhood of the "Stielcanal", becoming less pigmented, more transparent reddish-blue, in the vicinity of the coronal furrow. The walls of the subgenital porticus are transparent and without any trace of pigment. In three specimens the stomach is somewhat tent-shaped, showing the 8-rayed star formed by the stomach-pockets, but rather less distinct than described by me in the much larger specimens of *regina*.

One specimen of *Atolla wyvillei* forma *verrilli* from St. 1179, 40 mm. in diameter and much faded, is very peculiar; its annular zone is extremely broad, nearly as broad as the height of the central disc.

The localities from which these additional specimens were obtained are as follows:

WS 612	4. vi. 31	27° 08·5′ S,	72° 01·5′ W
539	19. xii. 30	61° 48′ S,	54° 51·5′ W
716	1. xi. 31	42° 08·8′ S,	51° 35′ W
1023	16. xi. 32	50° 48·9′ S,	51° 32·9′ W
1147	7. iii. 33	61° 49·7′ S,	8° 09·9′ W
1179	14. iv. 33	12° 29·8′ S,	3° 41·8′ W

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PLATE XIV

Fig. 1. *Periphylla hyacinthina*, Steenstrup, forma *regina*, mihi. Apical view of a specimen from St. 414. $\times \frac{1}{2}$.

Fig. 2. *Periphylla hyacinthina*, Steenstrup, forma *regina*, mihi. Side view of the same specimen. $\times \frac{1}{2}$.

The figures show the opening at the apex, the form of the pedalia, the stomach pouches forming an 8-rayed star and the characteristic pigmentation of the marginal zone.

Fig. 3. *Atolla chuni*, Vanhoeffen. Side view of a specimen from St. 391. $\times$ 1.

Fig. 4. *Atolla chuni*, Vanhoeffen. Subumbrellar (oral) view of a specimen from St. 391: pigment fully depicted only in one quadrant. $\times$ 1.

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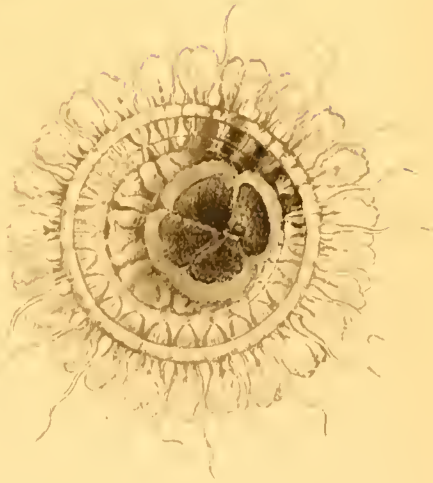

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PLATE XV

Fig. 1. *Periphylla hyacinthina*, Steenstrup, forma *regina*, mihi. Side-view. × 1.

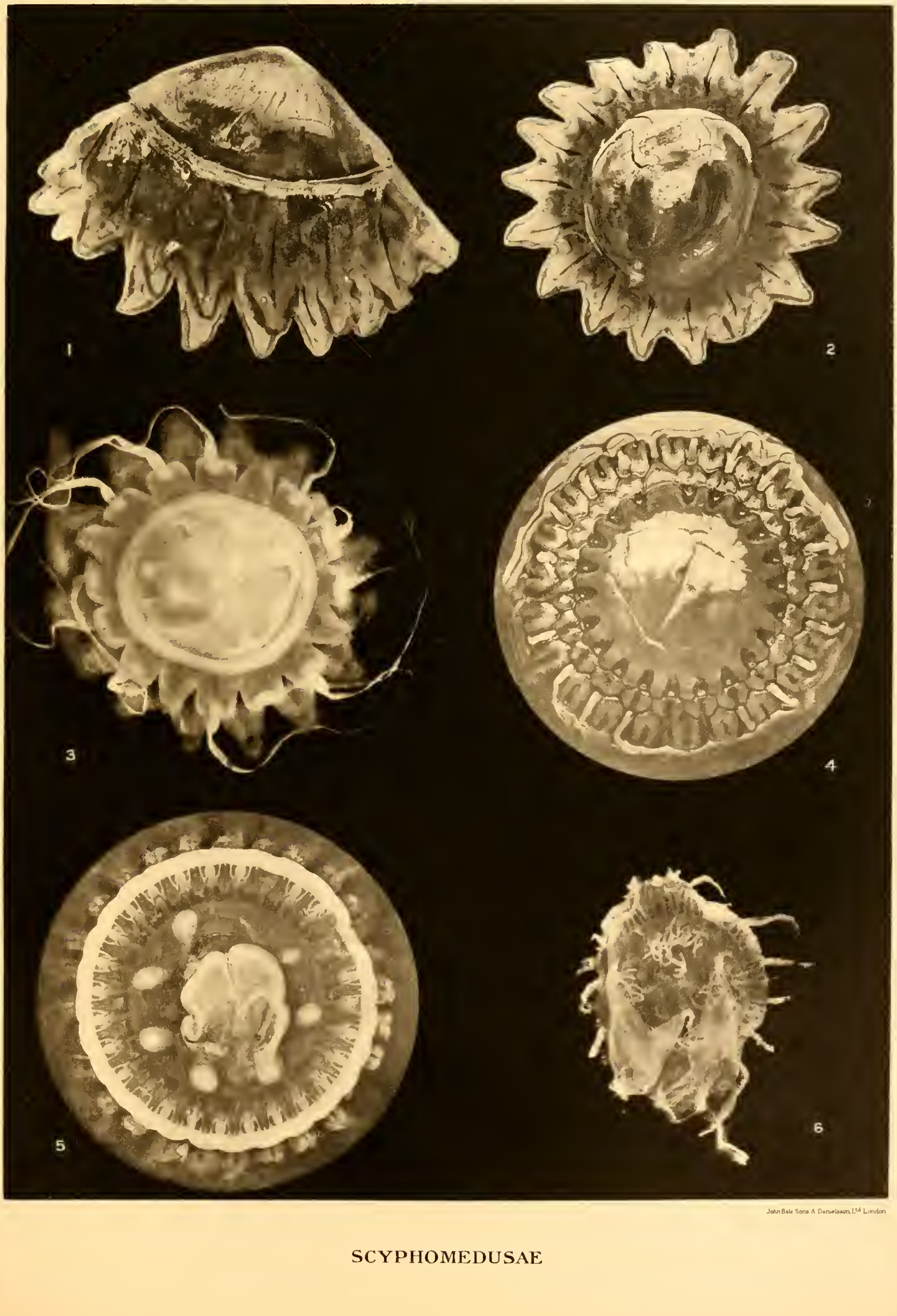
Fig. 2. *Periphylla hyacinthina*, Steenstrup, forma *regina*, mihi. Apical view; with characteristic pigmentation of the lappet zone. From St. 414. × 1.

Fig. 3. *Periphylla hyacinthina*, Steenstrup, forma *regina*, mihi. See form of pedalia and stomach pouches. Photograph by Dr E. H. Marshall of a specimen from St. 151. × ½.

Fig. 4. *Atolla wyvillei*, Haeckel, forma *typica*, mihi. Apical view. × 1.

Fig. 5. *Atolla chuni*, Vanhoeffen. Oral view with dark background. Photograph of an adult specimen from St. 391, by Dr E. H. Marshall. × 1.

Fig. 6. *Phacellophora ornata* (Verrill). Subumbrellar view. × 1.



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