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DISTRIBUTION OF THE MACROPLANKTON IN THE ATLANTIC SECTOR OF THE ANTARCTIC

BY

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INTRODUCTION

In the course of the oceanographical work which the Discovery Committee is conducting in the south, tow-nets of four different kinds have been used systematically for the study of the plankton. These are the 50 cm., 70 cm. and 1 m. nets, and the young-fish trawl. Of the four the 1 m. net, towed obliquely (N 100 B), is the most suitable for investigating the horizontal distribution of the larger plankton organisms. The following report is concerned with the samples taken by this net in the Antarctic surface waters, and its purpose is to find how the Antarctic environment of the whales is reflected in the distribution and variations of the macroplankton.

During the first commission of the R.R.S. 'Discovery' in 1925–7 the 1 m. nets were towed horizontally at routine stations, but it was found that a net towed obliquely from about 100 m. to the surface gives a better representation of the plankton, and the latter method was therefore adopted during the work of the 'William Scoresby' from 1927 to 1931 and of the 'Discovery II' in 1930 and 1931. The catches of the early horizontal nets, many of which have already been examined by Hardy and Gunther (1934), are not strictly comparable with those of the oblique nets; we are thus concerned here with the period 1927–31, and the stations taken into consideration are those in the true Antarctic water, together with a few on the north side of the Antarctic convergence. Of the species taken at these stations only one or two are confined to coastal regions, and we are in fact dealing with the plankton population of the open ocean.

During the period 1927–31 the majority of samples were collected in the neighbourhood of the Falkland Islands Dependencies, but lines of stations also extended from Bouvet Island in the east to a point west of Peter 1st Island in the Bellingshausen Sea. The positions of most of these stations are shown in Fig. 1.

The present report is based on the examination of about 600 samples from the 1 m. nets. From such a large number it is possible to obtain a great deal of information about the plankton, and the material is by no means exhausted by the results put forward in the following pages. It is the purpose of this report, however, not so much to elucidate the individual distribution of the various species as to examine the distribution of the macroplankton as a whole, and to distinguish individual communities whose constitution is dependent on the hydrological and geographical features of their environment.

THE PHYSICAL ENVIRONMENT OF THE ANTARCTIC PLANKTON

A summary account of the hydrology of the Atlantic sector of the Antarctic and the Bellingshausen Sea has been published by Mr G. E. R. Deacon (1933), and I am

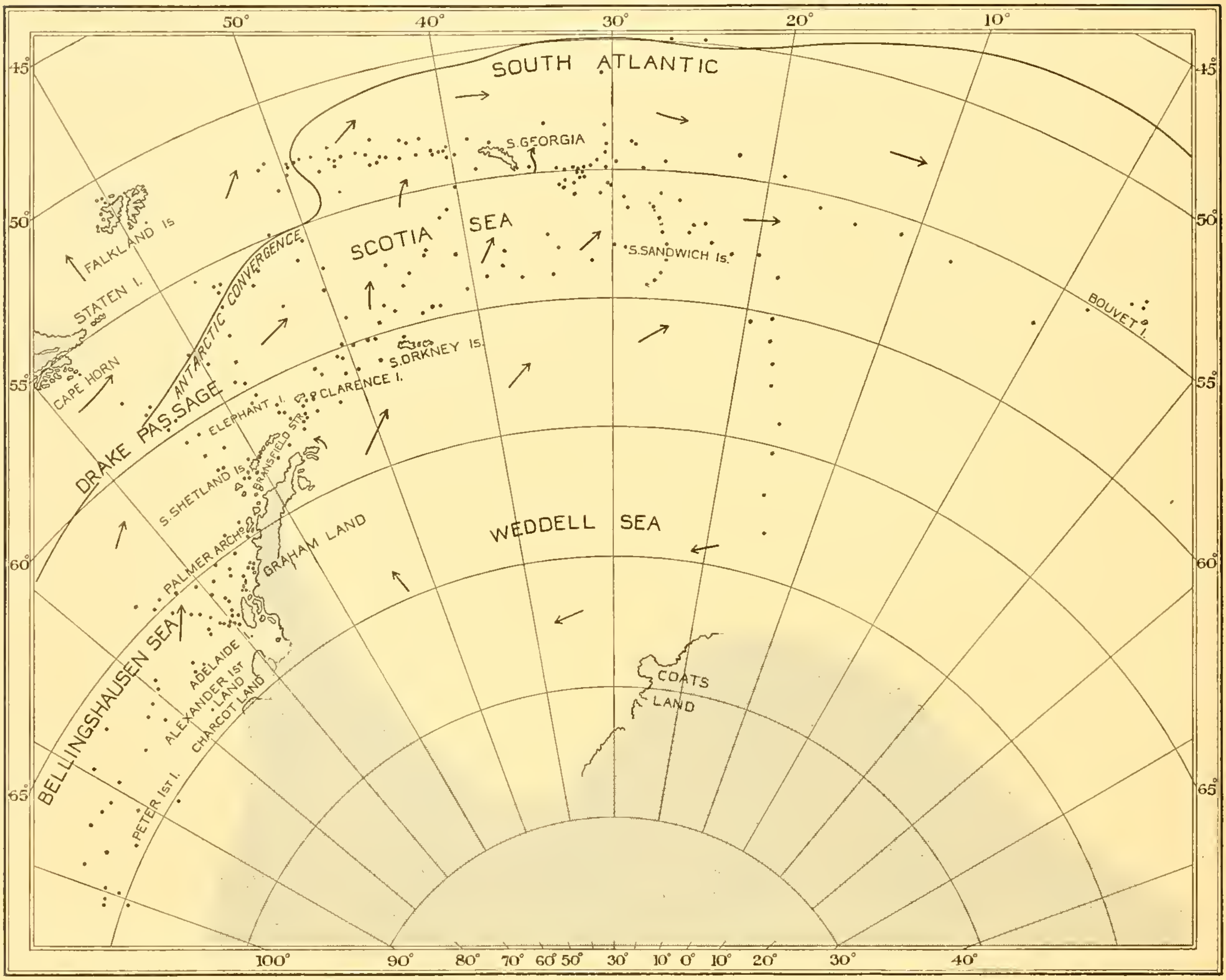

Fig. 1. The Atlantic sector of the Antarctic, showing stations at which N 100 B samples were taken. Stations included in intensive work around South Georgia and in the Bransfield Strait, and a line of close stations off Adelaide Island, are omitted. Surface currents are indicated by arrows.

indebted to him and to Mr A. J. Clowes for much valuable information. There are four primary divisions of the oceans of the southern hemisphere: the Antarctic, sub-Antarctic, sub-Tropical and Tropical Zones. The Antarctic Zone is characterized by a cold, poorly saline surface layer of an average depth of about 200 m. This surface water flows away from the melting pack-ice to which its low temperature and low salinity are due, and gradually works northwards (with a strong easterly component) until it meets the more saline, but warmer and lighter water of the sub-Antarctic Zone, beneath which it sinks. The line along which this sinking takes place is the northern boundary of the Antarctic Zone and is known as the "Antarctic convergence".

Beneath the cold surface water is a much thicker layer of warmer water whose origin is in the North Atlantic or Pacific. There is a southerly component in the direction in which this water drifts, and when it reaches high latitudes it becomes cooled. Part of it rises to the surface to replenish the cold superficial layer, and the rest, which has been cooled but not diluted, sinks to form the Antarctic bottom water. This layer flows in a northerly direction. There is in fact a movement of cold water away from the pole at the surface and bottom, and towards the pole at intermediate depths. The warm intermediate layer is very rich in nutritive salts, and it is the upwelling of these salts into the cold surface layer which enables the richest plankton in the world to flourish in the Antarctic surface water.

In the lower latitudes of the Antarctic Zone the surface waters are drifting in an easterly direction, and Drake Passage may be described as a constriction in this drift. Graham Land and the associated islands and archipelagos, which form the southern promontory of this constriction, separate the Weddell Sea to the east from the Bellingshausen Sea to the west. North of the Weddell Sea lies the Scotia Sea, bounded to the west by Drake Passage and on all other sides by the Scotia Arc. The Scotia Arc is a loop of elevated land projecting eastwards into the Atlantic. It comprises—as existing land masses—Tierra del Fuego, Staten Island, the Shag Rocks, South Georgia, and the South Sandwich, South Orkney and South Shetland Islands. These, as Herdman (1932) has conclusively demonstrated, are connected by well-defined submarine ridges. The Burdwood Bank, to the east of Staten Island, forms part of the arc. Water passing eastwards through Drake Passage is deflected a little to the north-east and flows mainly through a gap in the Scotia Arc between the Burdwood Bank and the Shag Rocks. The Antarctic convergence passes through the middle of Drake Passage, and the water to the south of it is derived mainly from the Bellingshausen Sea.

In the Weddell Sea there is a clockwise circulation. This great bay in the Antarctic Continent receives water drifting westwards in the higher latitudes, and the flow is directed northwards and north-eastwards by the Graham Land Archipelago, and flows out as a very cold current towards the South Sandwich Islands and South Georgia. It joins the drift from the Bellingshausen Sea along a line running from the South Shetlands to South Georgia. The drift from the Weddell Sea carries with it much pack-ice and innumerable icebergs, so that in longitude 20 or 30° W the pack frequently extends far to the north of the South Sandwich Islands, while around 60 or 70° W it is never found very much north of the South Shetland Islands.

We are here dealing only with the larger plankton organisms and their horizontal distribution in the cold surface layer. These are the true Antarctic species. At greater depths we find species which are common to the deep waters of the Antarctic and the tropics, but with these we are not concerned.

METHODS

The construction and method of working the 1 m. oblique net have been fully described by Kemp and Hardy (1929). The essential points are as follows. It is a conical net with an opening 1 m. in diameter and the principal fishing part of the net is of stramin. The filtration of the stramin is roughly equivalent to that of silk bolting cloth having 15 meshes to the inch. "For oblique hauls open N 100 and N 70 were attached to the warp close together and 3 or 4 m. above the lead. With the ship steaming at 2 knots 200 m. was paid away, and as soon as this had been done hauling commenced. The rate of hauling was 10 m. per minute; each haul thus took 20 min. and the distance covered was two-thirds of a mile" (Kemp and Hardy, *loc. cit.*). By this method the net is fished obliquely from a depth of about 100 m. to the surface. The samples are preserved in formalin and stored in screw-top bottles.

The method of analysis of a plankton sample must be adapted to the type of net used. The vertical N 70, for example, is fished at a very uniform speed through an accurately measured column of water, the organisms caught are small and a comparatively refined technique can be used for quantitative estimations. The depth and speed at which the oblique N 100 is fished, however, are greatly affected by the difficulty of adjusting the ship's speed to varying weather conditions, so that precise quantitative comparisons between different samples are of questionable value, and a sufficiently accurate estimate may be obtained by less refined methods.

There is much variation in the richness of the Antarctic plankton, and a single haul may yield anything from a dozen to 200,000 organisms. Different methods must therefore be used for different catches. In small samples, containing up to 200 or 300 organisms, the total number of each species is counted without difficulty. Samples of average size, however, are much bigger than this, and a typical one might contain about 5000 organisms of which perhaps 4000 would be copepods. These have generally been treated as follows. The bulk of the formalin is strained off and the sample is washed into a glass dish with plenty of water. The large animals such as Amphipoda, large Siphonophora, Polychaeta and Salps can generally be quickly picked out. It is then necessary to go very carefully through the whole sample to find any of the species which are both small and present only in small numbers. It is very easy to miss such organisms as *Limacina* or the small siphonophore, *Dimophyes arctica*, whose presence or absence may be of some importance, and it is often advisable to turn over the whole sample several times before dealing with the more numerous organisms. The medium- and large-sized organisms such as Euphausians can all be picked out and counted if there are not more than (say) 60 or 70 of them. For the more numerous organisms subsamples are taken, and it may be necessary to take first a quarter or an eighth and count perhaps the Euphausians and Chaetognatha in that, and then to take anything from 1/16 to 1/256 to count the various species of Copepoda. For the Copepoda it has generally been customary to take a fraction which will contain 100 to 200 specimens. Even then there is a possibility of missing one or two of the rarer species. For taking sub-samples a rough and ready method has been found to be best. The catch is put in a large Petri dish and the water strained off until the sample has the consistency of a loose paste. It is well mixed up and the dish is shaken until the sample lies in a flat, even layer. It is then divided into quarters (or some other fraction), and a quarter is if necessary removed to another dish and further divided. The method is crude, but if carefully done can give surprisingly accurate results. An Einar Lea apparatus can be used, but with large organisms it is not more accurate than the method described above.

In the analysis of these samples no hard and fast line of procedure can be followed. The method must be suited to each sample, and the worker must endeavour to satisfy himself that he has not missed any of the rarer forms, and that he has estimated the approximate numbers of each species present. The analysis of a large sample of perhaps 20,000–30,000 organisms may occupy several hours, especially if there is a great variety of species. The smallest samples can be analysed in about 20 minutes.

The object of plankton work is to determine the nature of the plankton in a given area from the analysis of samples taken at selected points in that area. The inferences thus drawn are liable to certain errors which may arise from the distribution of the plankton itself in the water, from the method of collecting the samples, or from the method of analysing the samples. The subject has been dealt with by Hardy and Gunther (1934), whose remarks apply in a large degree to plankton collected by the N 100 B, and need be discussed only briefly here. The following are some points to be borne in mind: (i) Heterogeneous distribution of the plankton organisms may give a false impression of the fauna of an area. Thus allowances must be made for species which tend to a specially patchy distribution. (ii) Active avoidance of the net must sometimes take place, especially by such species as *Euphausia superba*. I have been able from the ship's side to watch a net being towed a few feet below the surface and passing through a shoal of this species. The Euphausians could clearly be seen to leap backwards out of the way of the approaching net. (iii) Variations in the speed of towing and depth of the net have already been mentioned. (iv) Where a number of species of many groups have to be quickly identified, complete accuracy is not always to be depended on. (v) Big catches of shoaling species such as *E. superba* and *Salpa* may swamp the sample and make an estimation of the other species almost impossible. Such catches must sometimes be disregarded except for the Euphausians or Salps themselves.

It may seem that some of these factors must lead to serious errors in the analyses, but Hardy and Gunther (1934) have shown that fluctuations in the numbers of the smaller plankton organisms are so great that an error of 50 per cent has little significance, and Hart (1934) points out, in connection with the analysis of samples of phytoplankton, that "in practice differences of 100 per cent and over are the smallest that can be regarded as of much significance". The same applies, possibly with even greater force, to the catches of the N 100 B, for although it may be too much to say that the important features of a sample are those which may be recognized at a glance, it is at least probable that the most obvious features will be the important ones, and that a significant difference in the numbers of a species in two samples will be great enough to swamp any minor inaccuracies which might arise from the methods of working the net and analysing the catch. At the same time conclusions must be drawn with caution, and the character of the plankton in a locality must not be judged from a single haul.

ORGANISMS IDENTIFIED

Samples taken by the N 100 B in the Antarctic contain a relatively small number of species, the majority of which are easily recognized. It is therefore possible for a single worker to familiarize himself with the common species and work straight through the samples, avoiding the delay which would be involved if all the catches were sorted and the groups distributed to a number of experts for separate identification. I have, however, received much assistance from Mr F. C. Fraser, formerly of the Discovery staff and now on the staff of the British Museum, and from Dr H. E. Bargmann, Mrs M. E. White and Mr A. H. Laurie, of the Discovery staff, each of whom has undertaken the analysis of a number of the samples. The Copepoda from some of the samples were identified by the late Dr Andrew Scott, who has also furnished a valuable reference set of named specimens. Other named specimens have been provided, of Amphipoda by Dr Barnard of the South African Museum, of Siphonophora by Capt. Totton of the British Museum, of Polychaeta by Mr Monro of the British Museum, and of Pteropoda by the late Miss Massy. Capt. Totton and Mr Monro have also kindly given me personal assistance from time to time. Under the guidance of Dr Kemp I have been able to identify the various species of *Euphausia*.

Even with such assistance it has not been possible throughout to identify by any means all the species which occur, but I have attempted to estimate the number of the following in every sample.

Siphonophora.
- *Diphyes antarctica*, Moser.
- *Dimophyes arctica*, Chun.
- *Pyrostephos vanhöffeni*, Moser.

Medusae.
- *Sibogita borchgrevinki*, E. T. Browne.
- *Solmundella* sp.

Polychaeta.
- *Tomopteris* sp. (large).
- *Tomopteris* sp. (small).
- *Vanadis antarctica* (McIntosh).

Echinodermata.
- *Auricularia antarctica*, MacBride.

Copepoda.
- *Calanus acutus*, Giesbrecht.
- *C. propinquus*, Brady.

Copepoda (*cont.*).
- *C. simillimus*, Giesbrecht.
- *Rhincalanus gigas*, Brady.
- *Pleuromamma robusta* (F. Dahl).
- *Metridia gerlachei*, Giesbrecht.
- *Haloptilus ocellatus*, Wolfenden.
- *Haloptilus* sp.
- *Pareuchaeta* sp.
- *Heterorhabdus* sp.
- *Eucalanus* sp.
- *Euchirella* sp.
- *Candacia* sp.

Amphipoda.
- *Parathemisto gaudichaudi* (Guérin).
- *Primno macropa*, Guérin.
- *Vibilia antarctica*, Stebbing.
- *Eusirus antarcticus* (Thomson).
- *Cyllopus* spp.

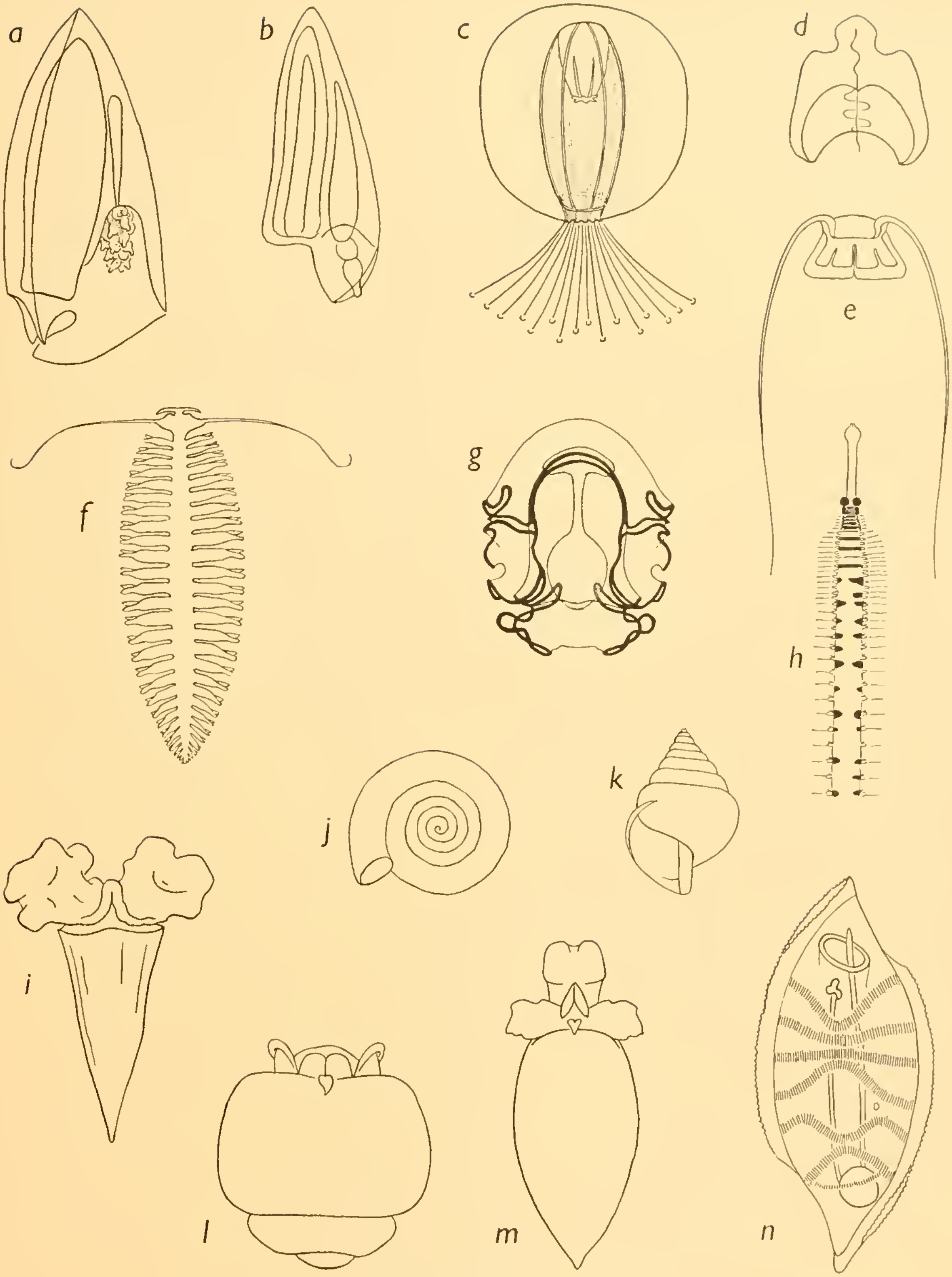

Fig. 2. Species of the Antarctic macroplankton.

a, *Diphyes antarctica*, anterior nectophore, × 2.
b, *Dimophyes arctica*, anterior nectophore (after Moser), × 7.
c, *Sibogita borchgrevinki* (after E. T. Browne), × $1\frac{1}{3}$.
d, *Pyrostephos vanhöffeni*, nectophore, × 5.
e, *Solmundella* sp., × 2.
f, *Tomopteris carpenteri*, × 1.
g, *Auricularia antarctica*, × 8.
h, *Vanadis antarctica*, anterior portion, × 1.
i, *Cleodora sulcata*, × 3.
j, *Limacina helicina*, × 5.
k, *Limacina balea*, × 15.
l, *Spongiobranchaea australis*, × 4.
m, *Clione antarctica*, × 4.
n, *Salpa fusiformis* f. *aspera* (after Ihle), × $1\frac{1}{2}$.

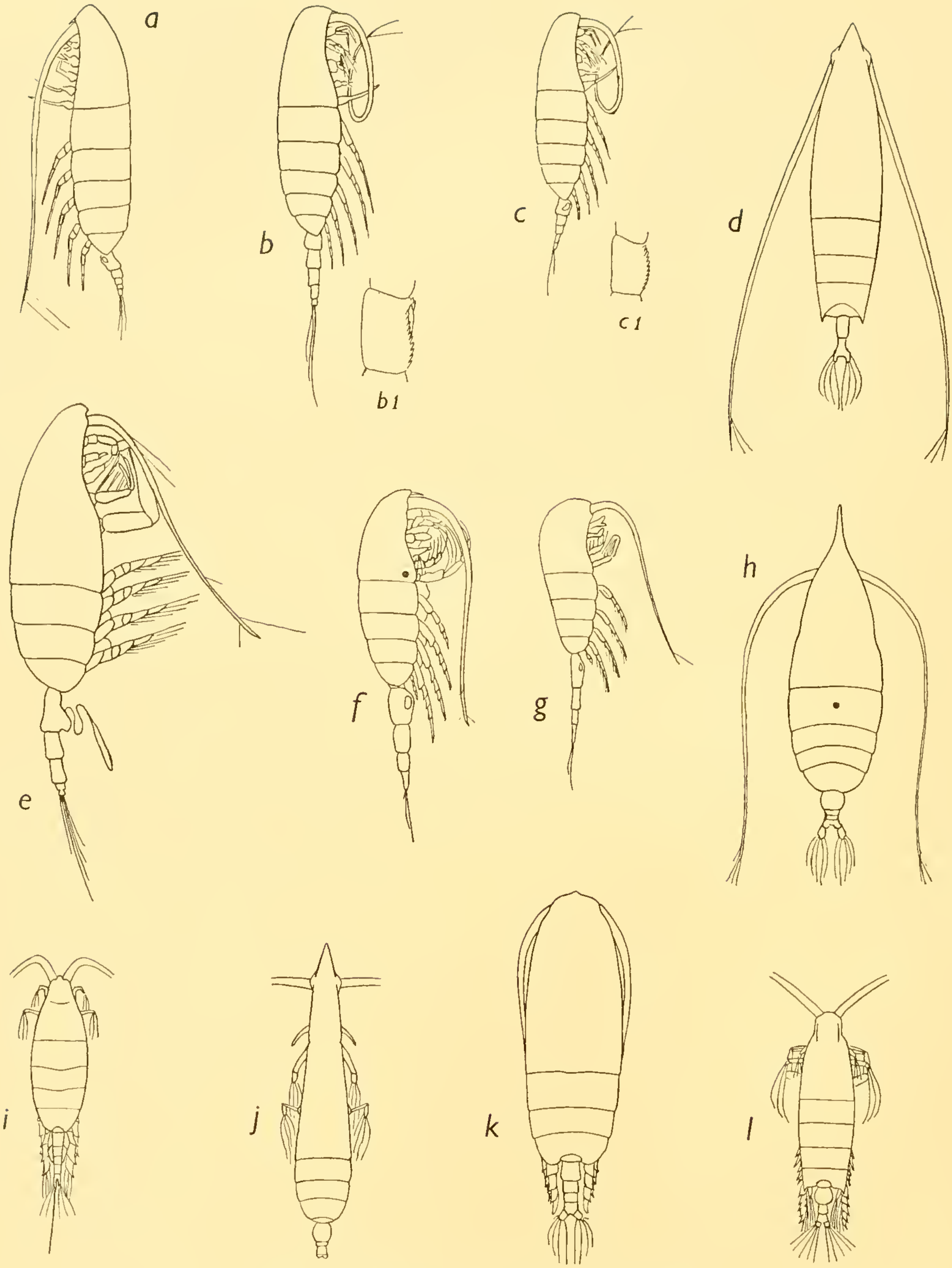

Fig. 3. Species of the Antarctic macroplankton.

a, *Calanus acutus*, × 8.
b, *Calanus propinquus*, × 8.
b 1, *C. propinquus*, basal joint of th. 5.
c, *Calanus simillimus* ♀, × 9.
c 1, *C. simillimus*, basal joint of th. 5.
d, *Rhincalanus gigas*, × 6.
e, *Pareuchaeta antarctica*, × 6.
f, *Pleuromamma robusta* (after Sars), × 10.
g, *Metridia gerlachei*, × 18.
h, *Haloptilus ocellatus* (after Wolfenden), × 6.
i, *Heterorhabdus* sp., × 8.
j, *Eucalanus* sp., × 8.
k, *Euchirella* sp., × 8.
l, *Candacia* sp., × 8.

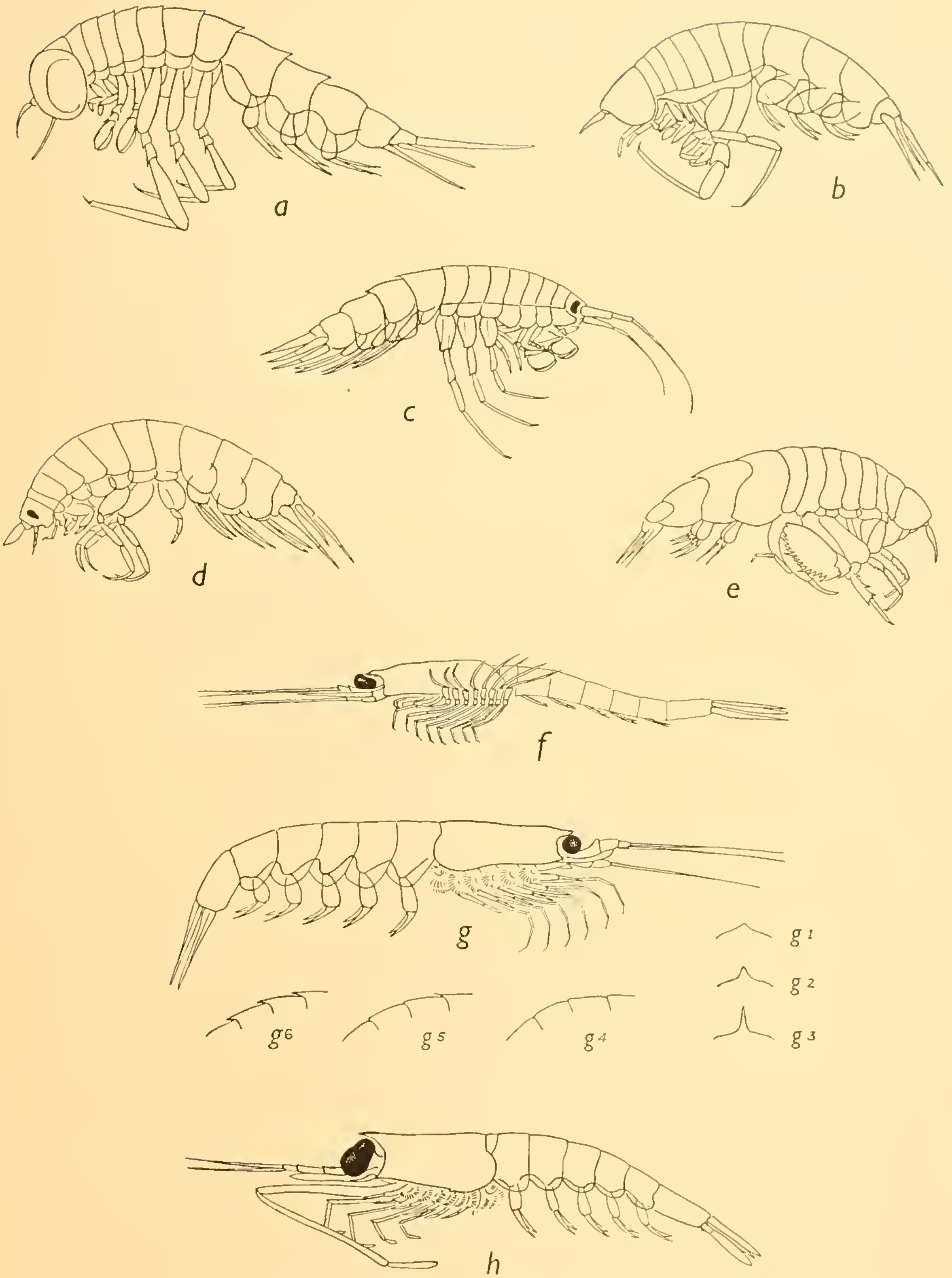

Fig. 4. Species of the Antarctic macroplankton.

a, *Parathemisto gaudichaudi*, × 4.
b, *Cyllopus* sp., × 3.
c, *Eusirus antarcticus*, × 4.
d, *Vibilia antarctica*, × 4.
e, *Primno macropa* (after Stebbing), × 4.
f, *Antarctomysis maxima*, × 2.
g, *Euphausia superba*, × $1\frac{1}{3}$.
g 1, Rostrum of *E. frigida*.
g 2, Rostrum of *E. vallentini*.
g 3, Rostrum of *E. triacantha* and *E. crystallorophias*.
g 4, Abdominal segments 3–5 of *E. frigida* and *E. crystallorophias*.
g 5, Abdominal segments 3–5 of *E. vallentini*.
g 6, Abdominal segments 3–5 of *E. triacantha*.
h, *Thysanoessa macrura*, × 3.

MYSIDACEA.
Antarctomysis sp.

EUPHAUSIACEA.
Euphausia superba, Dana.
E. frigida, Hansen.
E. crystallorophias, Holt and Tattersall.
E. triacantha, Holt and Tattersall.
E. vallentini, Stebbing.
Thysanoessa spp.

MOLLUSCA.
Cleodora sulcata (Pfeffer).
Limacina helicina (Phipps).
L. balea, Möller.
Spongiobranchaea australis, d'Orbigny.
Clione antarctica, E. A. Smith.

LUNICATA.
Salpa fusiformis f. *aspera* (Chamisco).

CHAETOGNATHA.

Each of the above species and genera, and the group Chaetognatha will be treated in this paper as a separate unit. The specimens of *Solmundella* are likely all to be *S. mediterranea*. Specimens of *Haloptilus*, apart from *H. ocellatus*, may include *H. oxycephalus* and possibly others. *Pareuchaeta* sp. is generally *P. antarctica*, but may include *P. biloba*. *Heterorhabdus* sp. probably includes only *H. austrinus*. Some specimens of *Eucalanus* have been identified as *E. acus*, and some of *Euchirella* as *E. rostromagna*. *Candacia* sp. may include more than one species. The identity of *Eusirus antarcticus* has not been determined with absolute certainty. *Cyllopus* spp. includes *C. lucasi* and *C. magellanicus*, and *Thysanoessa* spp. includes *T. macrura*; *Antarctomysis* is probably *A. maxima*. There are two common Antarctic species of *Tomopteris*, *T. carpenteri* and *T. septentrionalis*. When adult the former can always be distinguished from the latter by its greater size, but the identification is otherwise difficult. Those distinguished in this paper as "large *Tomopteris*" are nearly always *T. carpenteri*, and those included under "small *Tomopteris*" are generally *T. septentrionalis*, but may include an unknown proportion of immature *T. carpenteri*. The vast majority of the Chaetognatha are *Eukrohnia hamata*, but *Sagitta gazellae*, *S. maxima*, and *S. planctonis* occur in small numbers. Naturally those units identified only as genera or as a group have little value compared with those identified as species, but nearly all of them occur only in small numbers. Only *Thysanoessa* and the Chaetognatha appear in large numbers, but immature specimens, especially of the former, make up so high a percentage of these two units that complete specific differentiation would have been very difficult, and would have greatly prolonged the period occupied in the analysis of the samples.

For description of the species shown in the above list the following authorities may be consulted.

Moser (1925): *Diphyes antarctica*, *Pyrostephos vanhöffeni*.
Chun (1897): *Dimophyes arctica*.
Browne (1910): *Sibogita borchgrevinki*.
Benham (1921): *Vanadis antarctica*.
MacBride (1912, 1920): *Auricularia antarctica*.
Wolfenden (1908): *Calanus acutus*, *C. propinquus*, *C. simillimus*, *Metridia gerlachei*.
Schmaus and Lehnhofer (1927): *Rhincalanus gigas*.
Sars (1903): *Pleuromamma robusta*.
Wolfenden (1911): *Haloptilus ocellatus*.
Barnard (1932): *Parathemisto gaudichaudi*.

Stebbing (1888): *Primno macropa*, *Vibilia antarctica*.
Stebbing (1906): *Eusirus antarcticus*.
Tattersall (1908): *Euphausia superba*, *E. crystallorophias*, *E. triacantha*, *E. vallentini*.
Hansen (1913): *Euphausia frigida*.
Massy (1920): *Cleodora sulcata*.
Massy (1932): *Limacina helicina*, *Spongiobranchaea australis*.
Bonnevie (1913): *Limacina balea*.
Eliot (1907): *Clione antarctica*.
Ihle (1912): *Salpa fusiformis* f. *aspera*.

Other species which occur from time to time, but which are mostly uncommon and are disregarded here, are certain Medusae, Ctenophora, Polychaeta, Ostracoda and one or two small Amphipoda.

This method of taking only certain units into consideration might be criticized as arbitrary; but the use of any net with a particular aperture and mesh is also arbitrary, and the best we can do is to study certain organisms, and find from them what we can of the general behaviour of the macroplankton.

CRUISES IN THE PERIOD 1927–31

The following notes are not perhaps essential to the purposes of this paper, but since the catches taken in the various cruises will not be dealt with in strict chronological order, I have felt that a brief statement of the order in which the stations were taken might be useful for occasional reference.

During the first commission of the 'Discovery' and the associated work of the 'William Scoresby', the 1 m. nets were towed in horizontal flights of three. On the return of the 'William Scoresby' to South Georgia in February 1928, and in all subsequent work, the oblique 1 m. net (N 100 B) was used at all routine stations. The greater part of the plankton work in the Antarctic has been done during the summer months from October to April, and it will therefore avoid confusion if we speak of summer seasons (which are equivalent to the whaling seasons) rather than of years, and say that the regular work with the N 100 B began in February 1927–8. Full details of all the stations carried out, together with charts, are published in the Station Lists.[1]

Season 1927–8 (Figs. 5 and 10). The work of the 'William Scoresby' began with a line of stations from the Falkland Islands to South Georgia (WS 139–43[2]) and was followed by a survey of the South Georgia whaling grounds (WS 144–93). A line of stations was then worked from South Georgia to the vicinity of the South Shetlands and another line northwards to the Burdwood Bank and the Falkland Islands (WS 196–205).

Season 1928–9 (Figs. 6, 7, 11 and 15). The ship was next engaged in a trawling programme, but plankton work was resumed in August 1928. After a line of stations from the Falkland Islands to South Georgia (WS 253–6), the South Georgia survey was repeated, with the exception of the two southern lines, in incessantly adverse weather conditions, during the end of August and the greater

[1] *Discovery Reports*, III, pp. 1–132, and IV, pp. 1–230.

[2] Where a line of stations crosses the Antarctic convergence, the station numbers given here in brackets include only those taken in Antarctic water together with the first station on the north side of the convergence if it is still quite close to the latter. Stations at which the N 100 B was not used are omitted in the charts shown in Figs. 5–17.

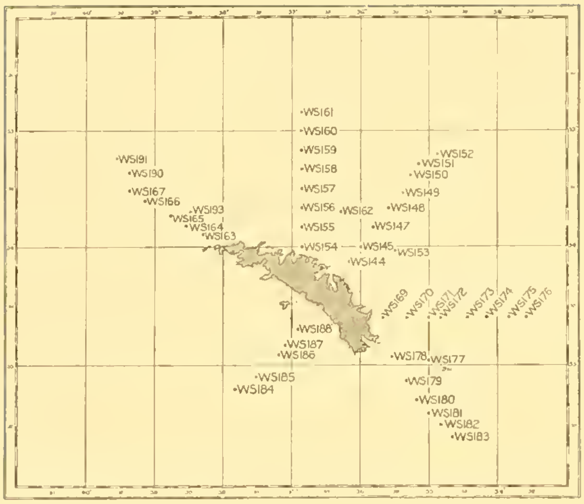

Fig. 5. South Georgia survey, February–March 1927–8.

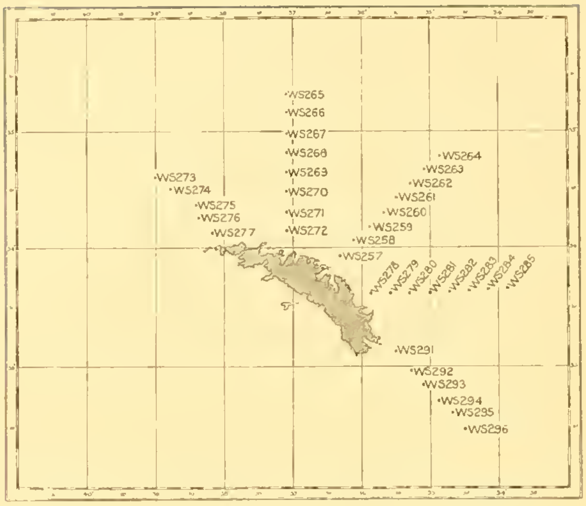

Fig. 6. South Georgia survey, August–October 1928–9.

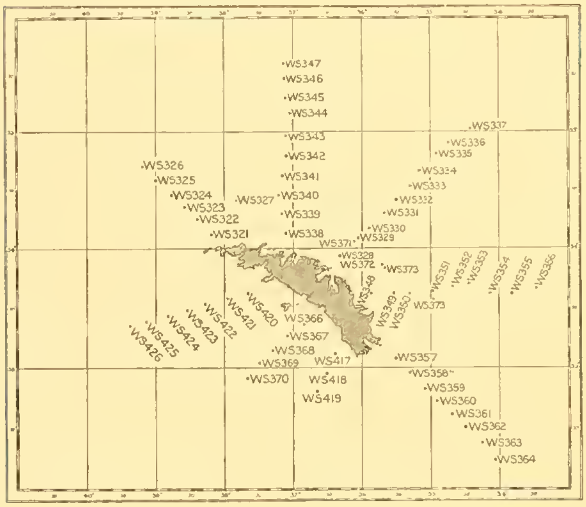

Fig. 7. South Georgia survey, December–January 1928–9.

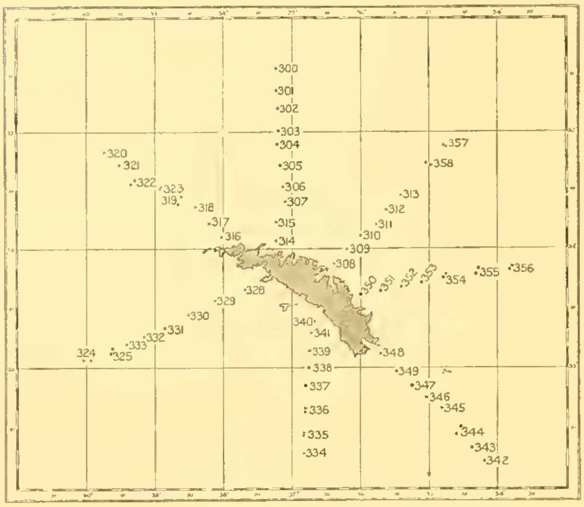

Fig. 8. South Georgia survey, January–February 1929–30.

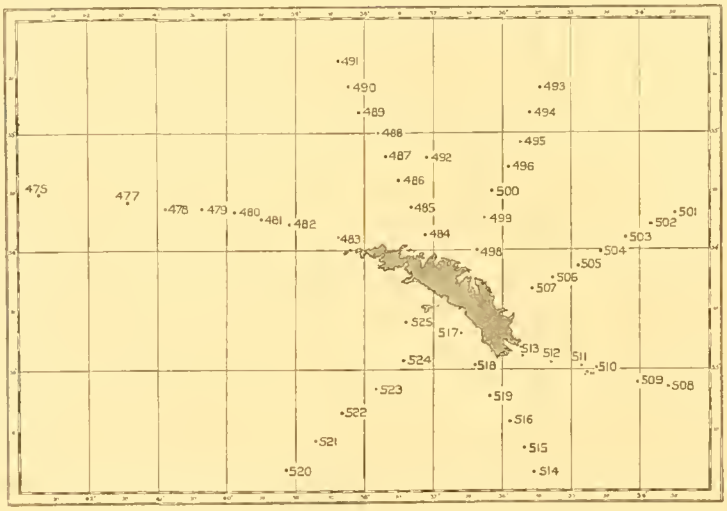

Fig. 9. South Georgia survey, November 1930–31.

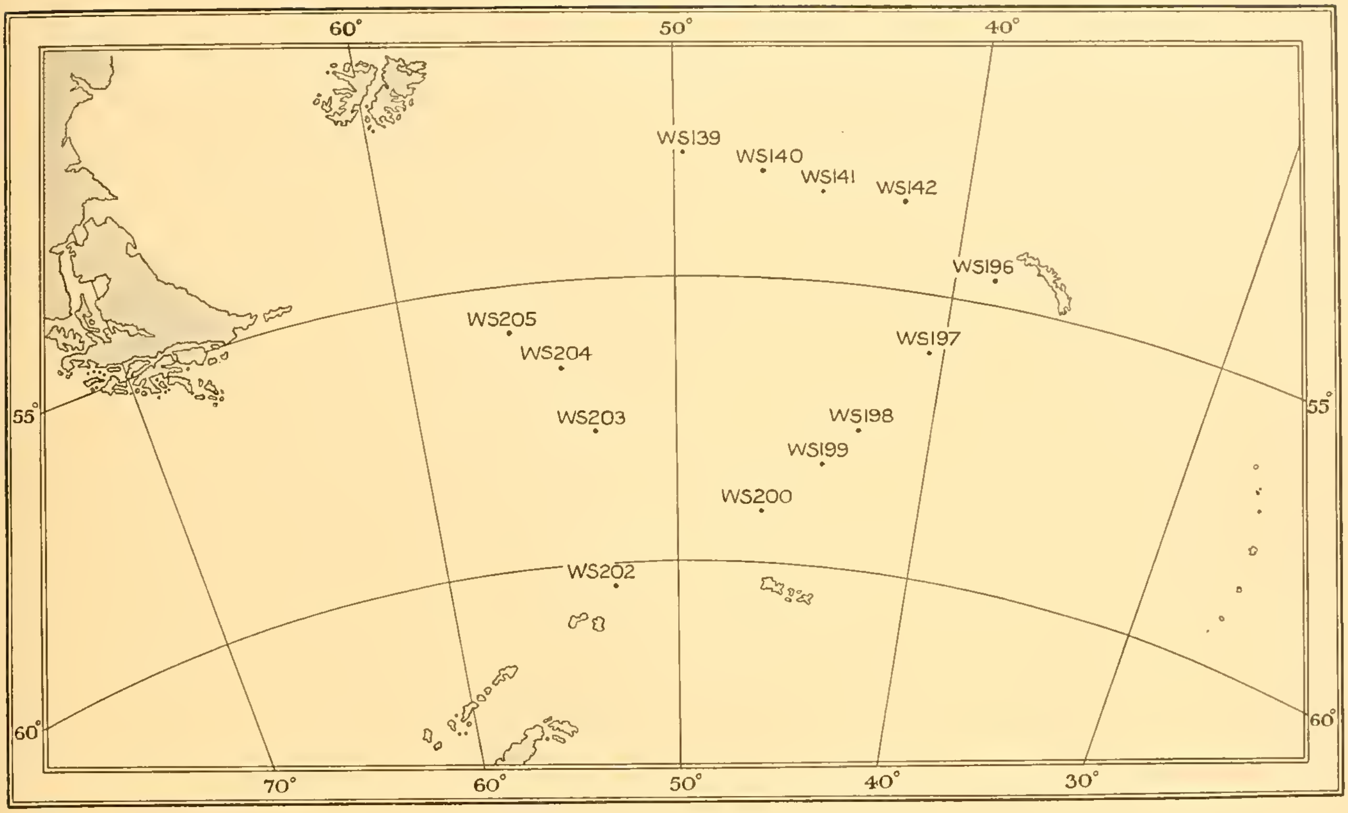

Fig. 10. Stations in the Scotia Sea, 1927–8.

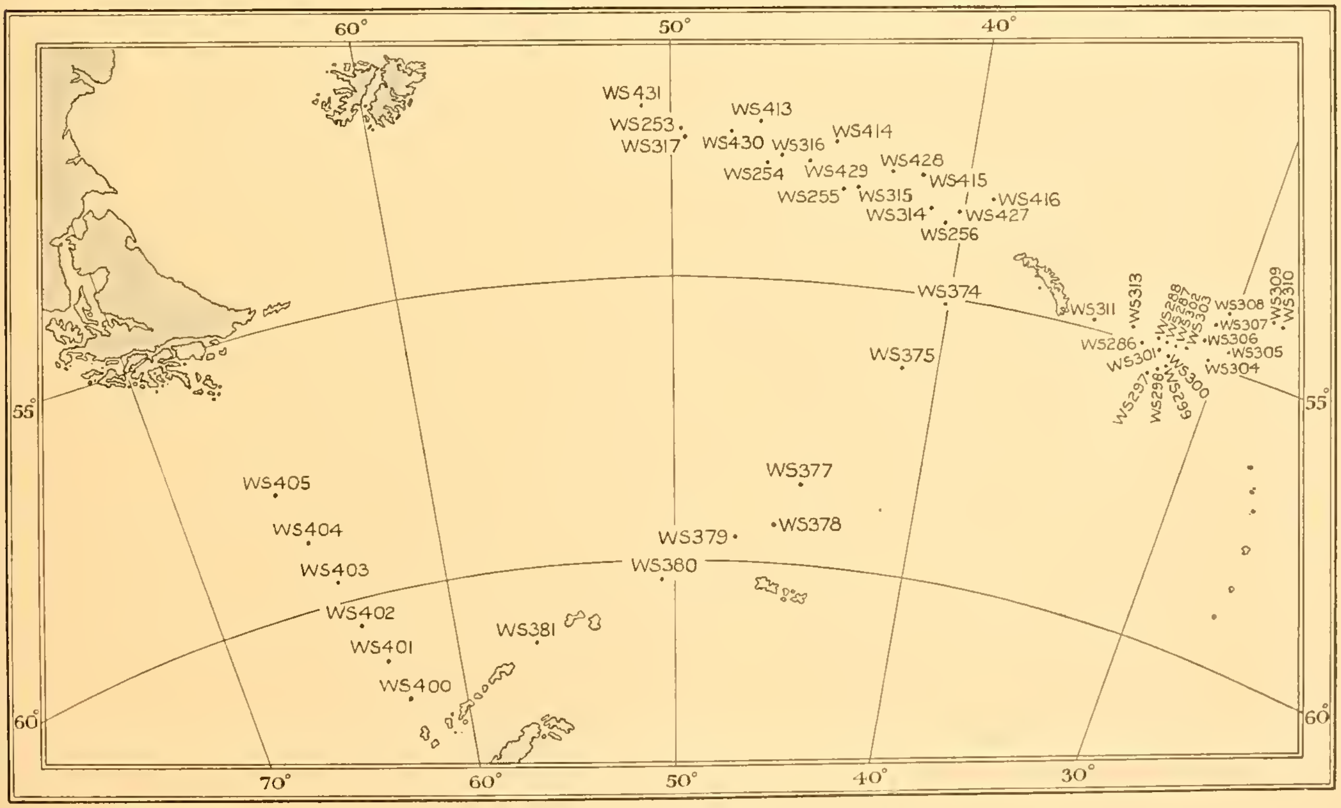

Fig. 11. Stations in the Scotia Sea, etc., 1928–9.

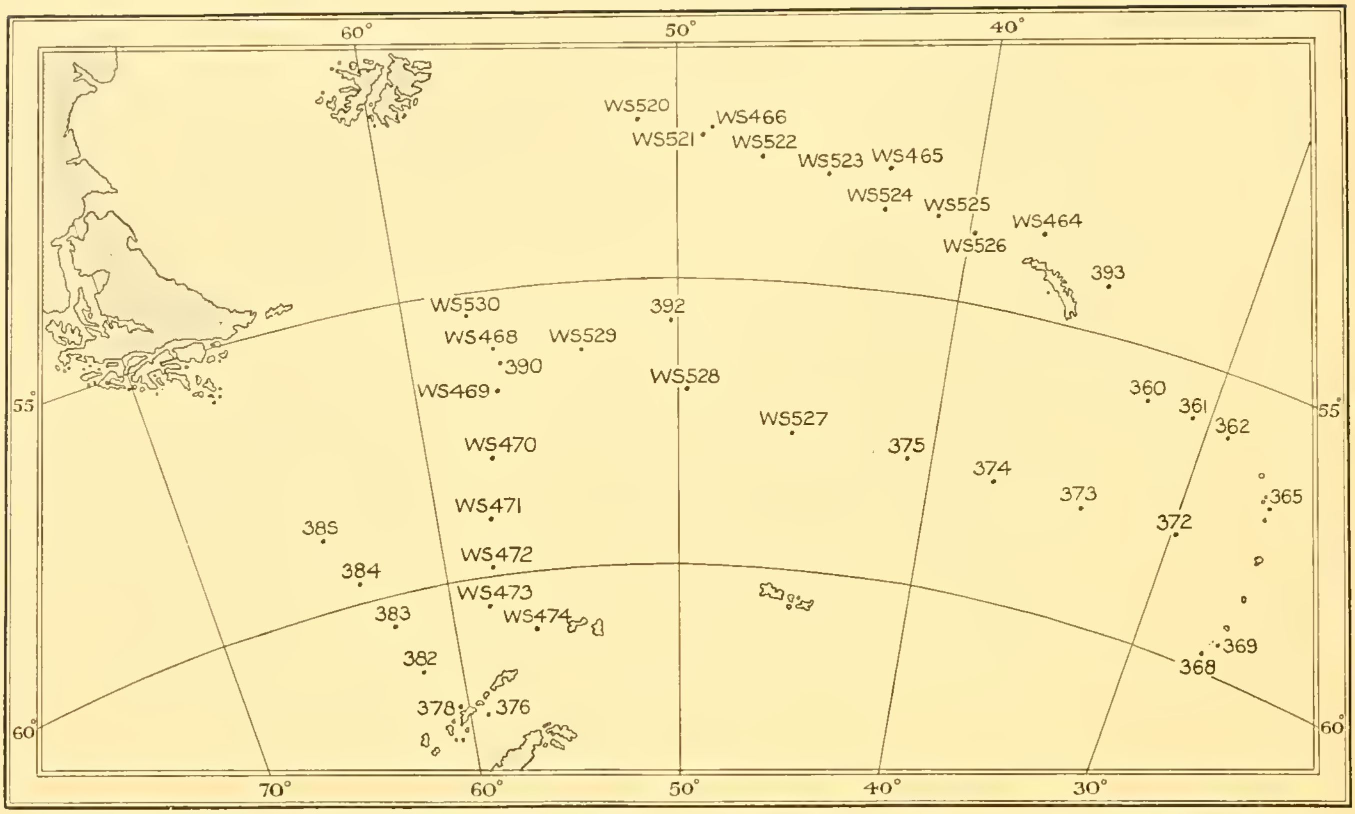

Fig. 12. Stations in Scotia Sea, etc., 1929–30.

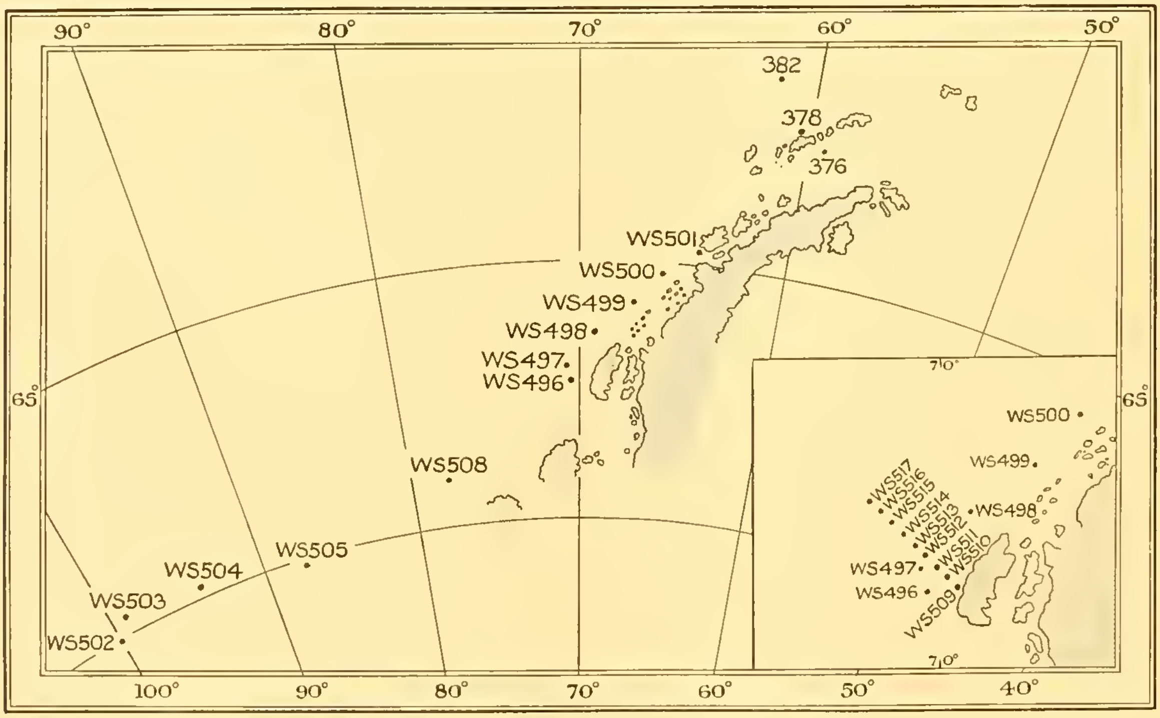

Fig. 13. Stations in Bellingshausen Sea, 1929–30.

part of September (WS 257–96). A series of stations was then worked along the ice-edge to the south-east of the island (WS 287 and 288, and 297–310), and a second line was laid from South Georgia to the Falkland Islands (WS 314–17). After the return of the ship to South Georgia a complete survey was again carried out (WS 321–72 in December–January), and she proceeded to the South Shetland Islands (WS 374–81), where intensive work was done in the Bransfield Strait in February (WS 382–99). A line of stations was then taken across the Drake Passage to Cape Horn (WS 400–5), and then to South Georgia *via* the Falkland Islands (WS 413–16). Here two more lines of stations were taken in April on the south side of the island (WS 417–26) and a fourth line between South Georgia and the Falkland Islands (WS 427–31). The season closed with the ship's departure from South Georgia to Capetown, when two more stations were taken in Antarctic water (WS 434 and 435).

Season 1929–30 (Figs. 8, 12, 13 and 16). The 'William Scoresby' returned to South Georgia in October and proceeded thence to the Falkland Islands (WS 464–6). From November to February she visited the Bellingshausen Sea, and, though primarily engaged in other work, was able to continue some plankton investigations. These included a line of stations from the Falkland Islands to the South Shetlands (WS 468–74), intensive work in the Bransfield Strait (WS 476–93), various stations off the coast of Adelaide Island and the Biscoe Islands (WS 496–501), five stations along the ice-edge in the Bellingshausen Sea as far as 100° W (WS 502–8), and a line of stations at short intervals running north-westward from Adelaide Island (WS 509–17). The ship then returned in February to the Falkland Islands. In the meantime the 'Discovery II' reached South Georgia in January, and proceeded with the usual survey of the whaling grounds (Sts. 300–59). This was followed by a visit to the South Sandwich Islands where six plankton stations were taken (Sts. 360–9), and some time was spent in topographical surveying. In March a line was begun from the Sandwich group to the Burdwood Bank (Sts. 372–5), which was later completed by the 'William Scoresby' (WS 527–30) after the latter ship had worked more stations between the Falkland Islands and South Georgia (WS 520–6). In April the 'Discovery II' visited the South Shetlands, took a station in the Bransfield Strait (St. 376), a line across the Drake Passage (Sts. 378–85), and two more stations on the way back to South Georgia (Sts. 390 and 392). The 'William Scoresby' now left for Europe and the 'Discovery II' for Capetown. At the beginning of the voyage an attempt was made with the latter ship to carry out continuous observations throughout a 24-hour period near South Georgia. Flights of six closing N 100 B were to be taken every four hours (St. 393), but the series was interrupted by bad weather before it could be completed. One more station (St. 394) was taken in Antarctic water on the way to the Cape.

Season 1930–1 (Figs. 9, 14 and 17). The 'Discovery II' sailed from Capetown in October, reached the ice-edge south of Bouvet Island (Sts. 452–60) and followed it westwards to South Georgia (Sts. 462–72). A 24-hour station with closing N 100 B (St. 461) was worked off the ice. The South Georgia survey was repeated in November (Sts. 475–525), and a cruise to higher latitudes begun. The ship followed the ice-edge from a point near the Sandwich group to the Bransfield Strait (Sts. 528–41), taking fourteen stations in the Strait (Sts. 542–55), and continuing the voyage from the South Shetlands to Adelaide Island (Sts. 556–60), and westwards along the ice-edge of the Bellingshausen Sea to about 100° W, 70° S, and back to Adelaide Island (Sts. 561–82). A line of stations was worked north-westwards from Adelaide Island (Sts. 583–92) and a number of other stations off Adelaide Island, the Biscoe Islands, the South Shetlands, and the South Orkneys (Sts. 593–617, January–February)—a period largely occupied also with survey work. The voyage was continued to the South Sandwich Islands (Sts. 618–29), westward towards the Falkland Islands (St. 631), south again to the South Orkneys (Sts. 633–6) and Bransfield Strait (Sts. 637–44), north towards Staten Island (Sts. 646–9), and back to South Georgia at the end of March (Sts. 655–9). In the meantime the 'William Scoresby' returned to South Georgia in January and made a cruise south-eastwards past the South Sandwich Islands, and southwards to the ice-edge in the eastern part of the Weddell Sea, making the return journey on much the same route (WS 534–65, January–

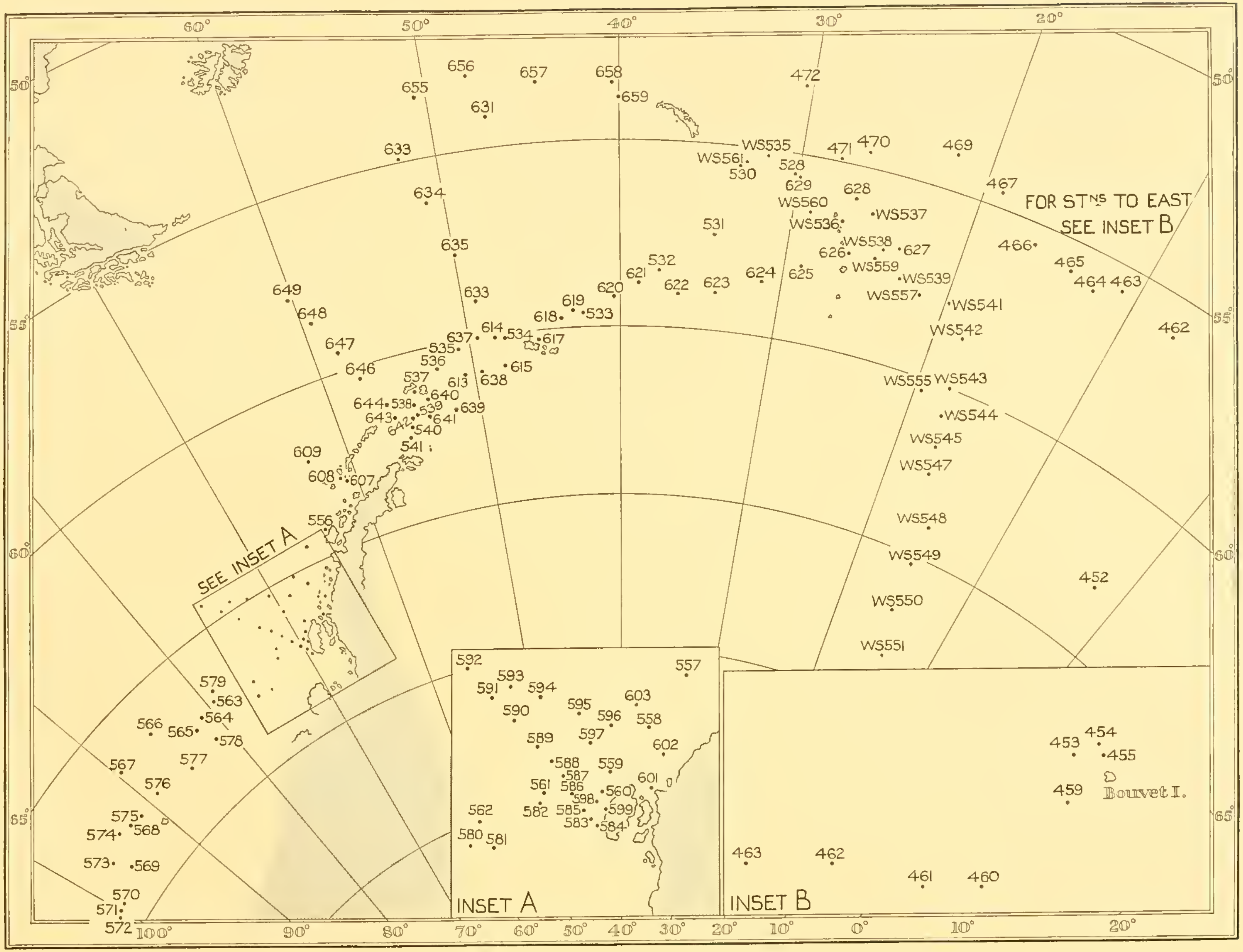

Fig. 14. Stations in the Scotia, Weddell and Bellingshausen Seas, etc., 1930–1.

February). In March she repeated a line of the November survey off South Georgia (WS 567–75) and the season's work was over.

By the time the present paper was ready for publication the 'Discovery II' had returned from a second commission, and a large collection of new N 100 B samples was

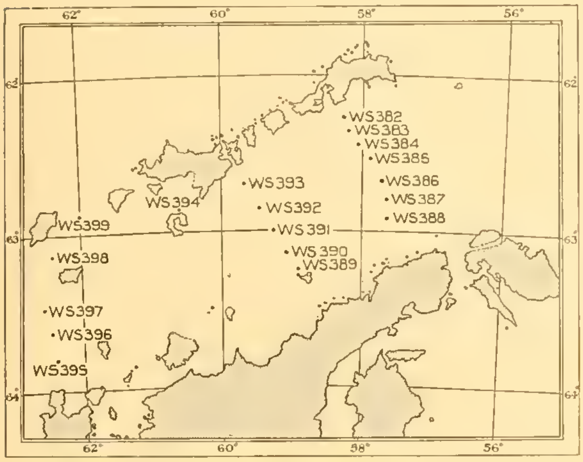

Fig. 15. Stations in Bransfield Strait, 1928–9.

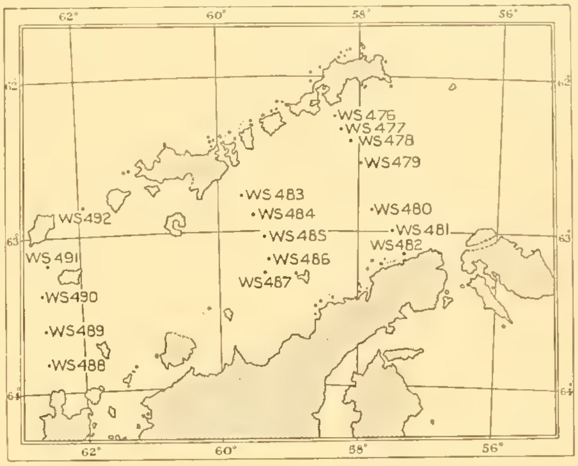

Fig. 16. Stations in Bransfield Strait, 1929–30.

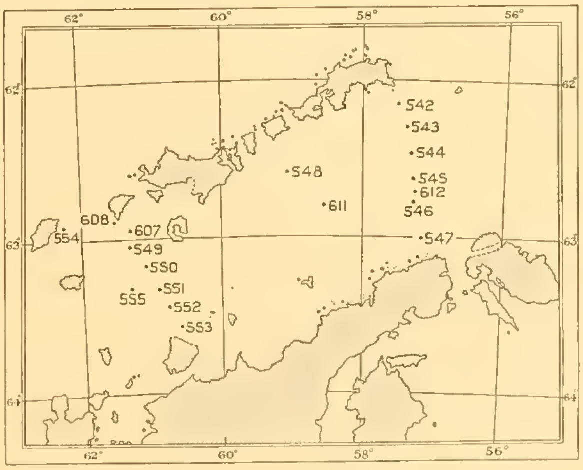

Fig. 17. Stations in Bransfield Strait, 1930–1.

available, but it was thought desirable to publish some results of the four previous seasons' work to avoid the delay which would be entailed if the new material was incorporated with it.

THE ANTARCTIC CONVERGENCE

The Antarctic convergence, which divides the Antarctic from the sub-Antarctic surface waters, is an important faunistic boundary. In the period 1927–31 a number of lines of stations crossed this convergence, and it is necessary first to determine which of these stations lie in Antarctic and which in sub-Antarctic water. The Antarctic convergence can be located by a sudden change in surface temperature and is usually found at the point at which the coldest part of the Antarctic water sinks below the level of 200 m. (see Deacon, 1933, p. 192). Applying these criteria to the data given in the Station Lists (*Discovery Reports*, vols. III and IV) the following can be quoted as the stations nearest the convergence in each line of observations made across it. The position of the convergence is shown by an arrow: sub-Antarctic stations are above the arrows and Antarctic stations below them.

1927–28

WS 139 Cold layer at 750 m.
→
WS 140 Cold layer at 200 m.

WS 205 Cold layer indistinct.
→
WS 204 Cold layer at 200 m.

1928–29

WS 253 Cold layer at 750 m.
→
WS 254 Cold layer at 100 m.

WS 317 Cold layer indistinct.
→
WS 316 Cold layer at 80 m.

WS 405 Cold layer indistinct.
→
WS 404 Cold layer at 150 m.

WS 412 No temperature records.
→WS 413 No temperature records.
WS 414 No temperature records.

WS 431 Faint minimum at 600 m.
→
WS 430 Faint minimum at 400 m.
WS 429 Cold layer at 200 m.

WS 437 Cold layer indistinct.
? →WS 436 No temperature records.
WS 435 Cold layer at 150 m.

1929–30

WS 467 No temperature records.
→WS 466 No temperature records.
WS 465 No temperature records.

WS 468 Cold layer indistinct.
→WS 469 Cold layer at 200–300 m.
WS 470 Cold layer at 150 m.

St. 385 Cold layer indistinct.
→
St. 384 Cold layer at 200 m.

St. 389 Surface temperature 4·35° C.
→St. 390 Surface temperature 4·85° C.
St. 392 Surface temperature 3·90° C.

WS 520 Faint minimum at 600 m.
→
WS 521 Cold layer at 200 m.

WS 530 Cold layer indistinct.
→
WS 529 Cold layer at 150 m.

St. 396 Surface temperature 7·45° C.
→
St. 394 Surface temperature 4·15° C.

1930–1

St. 451 Cold layer indistinct.
St. 452 Cold layer at 100–150 m.

→St. 633 Surface temperature 5·14° C.
St. 632 Surface temperature 4·85° C.
→St. 631 Surface temperature 5·80° C.
St. 630 Surface temperature 3·40° C.

St. 650 Cold layer indistinct.
St. 649 Faint minimum at 400 m.
→
St. 648 Cold layer at 80 m.

St. 655 Faint minimum at 800 m.
St. 656 Cold layer at 300 m.
→
St. 657 Cold layer at 150 m.

Where a pair of stations is shown in the above list the convergence lies between them. Thus at WS 254 the cold layer lies at 100 m., while at WS 253 it lies at 750 m.: WS 253 is therefore in sub-Antarctic and WS 254 in Antarctic water. At WS 404 the cold layer is at 150 m., while at WS 405 it has become obscured through sinking and mixing with deeper water. This indicates that WS 405 is well on the north side of the convergence. At such stations the cold layer can be detected only as an irregularity in a curve showing the rate of decrease of temperature as the depth increases. WS 469 lies just about on the convergence itself. At some stations no temperatures, or only surface temperatures, are given. Thus WS 413, 466 and St. 390 probably lie very near the convergence. Sts. 630–3 lie near an eddy, which is roughly indicated by the bend of the convergence in Fig. 1. From its surface temperature it is evident that St. 630 is in Antarctic water. Sts. 631 and 633 are probably very close to the convergence, and St. 632 in Antarctic water. Sts. 391 and 395, at which the N 100 B was not fished, are omitted from the list.

A full account of the differences and resemblances which exist between the plankton of the surface waters of the Antarctic and sub-Antarctic Zones would be a large subject and will probably be dealt with in subsequent publications. I will give here only a brief indication of the effect of the convergence as a faunistic barrier, and for this purpose have examined the N 100 B analyses for twenty stations lying between 100 and 200 miles north of the convergence. The Copepoda have been identified in only eight of these analyses, but they will serve for a purely qualitative comparison.

Antarctic species occurring north of the convergence can be divided into the following:

Normal inhabitants of sub-Antarctic water

Calanus simillimus. Occurs at five out of eight stations, sometimes in moderate numbers.

Rhincalanus gigas. Occurs at seven out of eight stations, and is generally the most numerous copepod.

Pleuromamma robusta. Appears to occur at four out of eight stations, but its specific identity at these sub-Antarctic stations has not been checked with absolute certainty.

Eucalanus sp. Occurs at four out of eight stations, usually in small numbers.

Parathemisto gaudichaudi. Occurs at seventeen out of twenty stations. Barnard (1932, pp. 6–19) records this species in surface waters at various stations in comparatively low latitudes.

Primno macropa. Occurs at nine out of twenty stations, a high proportion for this species. Occurrence in sub-Antarctic waters confirmed by Barnard.

Vibilia antarctica. Occurs at four out of twenty stations—a sufficiently high proportion. Recorded by Barnard in two sub-Antarctic surface hauls. It is evidently less common than *Primno* in these latitudes.

Euphausia vallentini. Recorded in only eleven out of the twenty stations, but occurs sometimes in large numbers and is actually a typical sub-Antarctic species which only occasionally strays into the Antarctic.

Cleodora sulcata. Recorded at four of the twenty stations. No doubt less common in sub-Antarctic than in Antarctic water.

Limacina balea. Occurs at eleven out of the twenty stations. Massy (1932) gives its distribution as the "temperate zones between Arctic and Antarctic and circumtropical zone".

Spongiobranchaea australis. Occurs at five out of the twenty stations. This is a fairly high proportion.

Dimophyes arctica. This species occurs in large numbers only in the coldest Antarctic water. However, it is recorded at one of our twenty stations, and I am informed by Capt. Totton that it occurs quite commonly at various depths throughout the Atlantic, and there are instances of its occurrence in tropical and sub-tropical surface waters. The latter record can hardly be attributed to accidental straying into warmer waters.

Only juvenile stages apparently common in sub-Antarctic water

Calanus propinquus. At least one of the eight stations has an example of this species and at six of the eight there are varying numbers of young copepods which appear to be *C. propinquus*.

Species probably belonging only to the Antarctic water, but which occasionally stray into sub-Antarctic water

Calanus acutus. Several occurred at one of the eight stations, but it is probably rare everywhere north of the convergence.

Metridia gerlachei. One specimen was recorded at two of the eight stations, but it is really typical of the colder Antarctic water.

Euphausia frigida. Two doubtful records in the twenty stations. This species is not usually taken anywhere to the north of the convergence.

Euphausia triacantha. One example recorded in the twenty stations. Not uncommon in stations only a short distance north of the convergence.

Limacina helicina. Recorded at two of the twenty stations, but like *Metridia* is found mostly in the colder Antarctic water.

Salpa fusiformis f. *aspera*. Occurs at one of the twenty stations. It is said to have a very wide distribution (Ihle, 1912), but it seems commonest in Antarctic water.

Among the organisms of which only the genus is identified, *Tomopteris*, *Pareuchaeta*, *Candacia* and *Thysanoessa* commonly occur in sub-Antarctic water, and *Cyllopus* and *Euchirella* occur once each. The Antarctic species which do not occur at these stations are *Diphyes antarctica*, *Pyrostephos vanhöffeni*, *Vanadis antarctica*, *Auricularia antarctica*, *Haloptilus ocellatus*, *Eusirus antarcticus*, *Euphausia superba*, *E. crystallorophias*, *Clione antarctica*, *Solmundella* sp., *Antarctomysis* sp., and *Haloptilus* sp.

These results may need some revision if a larger body of material is taken into consideration, but they are enough to show that some of the common Antarctic species are also normal inhabitants of sub-Antarctic surface waters, while others are sufficiently rare in the latter zone to be regarded as intruders if they are found there.

DIURNAL VARIATIONS

During the daytime some species sink to a depth which is beyond the reach of the net, while others do not. Therefore, in order to trace the distribution of the macroplankton we must have some idea of the hours between which a haul will be indicative of the presence or absence of each species. The following section of this paper is, however, confined to the study of diurnal variations *as they affect the catches in the N 100 B*, and should not be taken as an attempt to investigate the vertical migrations of the different species. Diurnal variation is, so to speak, an adventitious phenomenon which is caused by vertical migrations, and the proper study of the latter should depend mainly upon hauls taken at different depths with closing nets. Hardy and Gunther (1934) have studied in this way the vertical migrations of certain Antarctic species, and reference to their results is made on p. 96.

The majority of the N 100 B samples from Antarctic water have been collected indiscriminately at all hours of the day and night, so that an estimation of the diurnal variations could be worked out for each species if a comparison were made of the average number per haul for various times of day. The accuracy of the results of this calculation might be disturbed by three factors: (i) the irregularity of distribution of the plankton, (ii) the possible effect of the difference in the period of darkness in different latitudes, and (iii) the varying depths from which the net is fished. These difficulties cannot altogether be disposed of, but the quantity of data is sufficient to swamp any serious error arising from distribution, and we can afford to restrict the estimation almost entirely to samples taken between 52 and 60° S. This will include the great majority of stations without too great a range of latitude. Errors arising from the different depths at which the net begins its oblique passage towards the surface will also be largely discounted through the abundant data. The calculation will of course be rough, but sufficient for our immediate purpose.

It must be remembered that the diurnal variations revealed by this method are those which result only from the more extensive vertical migrations. There may, for instance, be certain species having a well-defined vertical migration within the limits of the Antarctic surface layer, and these might seem here to show little or no diurnal variation.

Of previous work on vertical migrations that of Russell (1925–31) is the most important, but this was done on a much finer scale in the shallow water of the English Channel. It revealed movements of a kind which could not be detected in the N 100 B and took into account various subsidiary factors which must be ignored here.

In working out the variations for each species I have omitted the following stations: (i) All those south of latitude 60° S. (ii) Those in which it was not possible to make a reliable estimate of the numbers of the species in question (such as samples which were

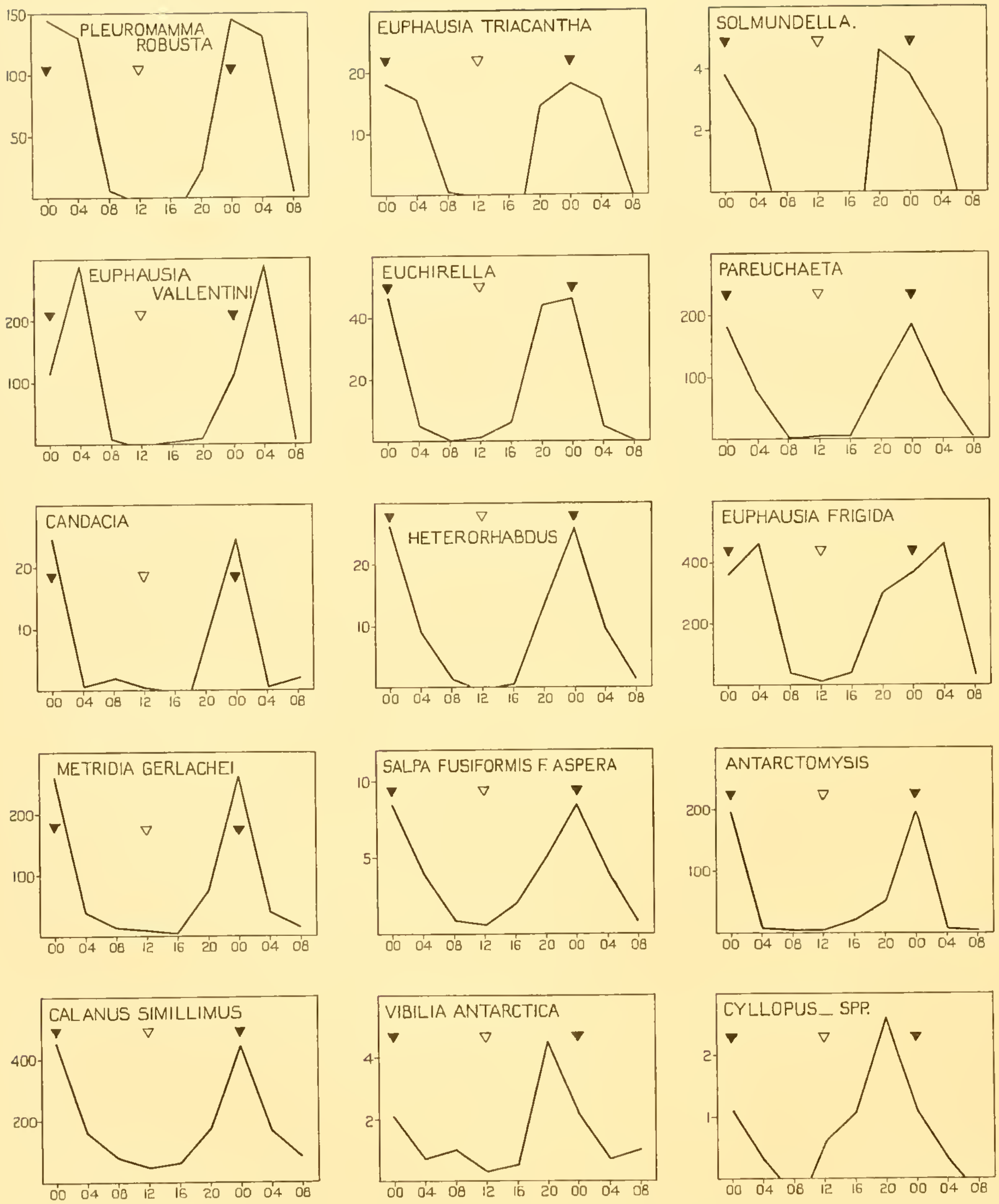

Fig. 18. Diurnal variations of macroplankton species. The curves show the average number per haul at four-hour intervals. Midnight and midday are accentuated by black and white triangles respectively. The species are arranged roughly in order of the magnitude of their diurnal variation (see Table I, p. 95).

swamped with a shoal of *Euphausia superba* or *Salpa*). (iii) Those in an area which was evidently altogether devoid of the species in question. (iv) Those in an area in which the only samples were from a series of daily stations all taken at the same time of day.

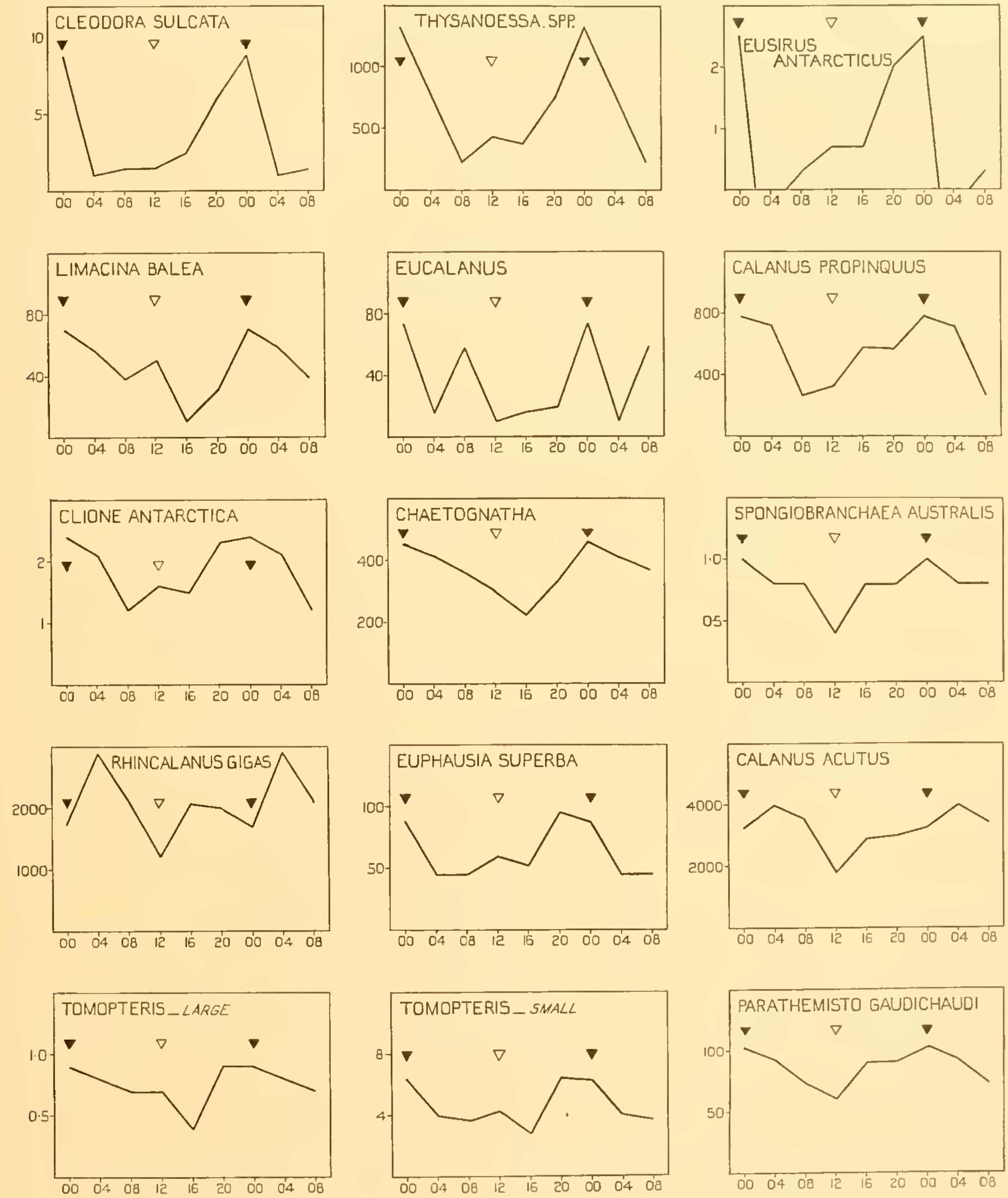

Fig. 19. Diurnal variations of macroplankton species (see legend to Fig. 18).

Figs. 18, 19 and 20 show the variations for each species. With the available data the average per haul for periods of one hour, or even two hours, gives figures which are a little too erratic. Four-hour periods, however, give more regular results, and have therefore been adopted in the construction of the curves. These figures are given in Table I, p. 95.

The following pages contain notes on the variation of individual species. It has already been mentioned that during a cruise of the 'Discovery II' a 24-hour station, 461, was worked south of Bouvet Island. At this station seven flights, each of six oblique closing 1 m. nets, were towed every four hours at a series of depths down to about 700 m., and I have made a preliminary analysis of the samples. Although the present paper is really concerned with the routine N 100 B samples, it will perhaps be permissible to refer here and there to the results of St. 461 in so far as they apply to the results shown in the table on p. 95. There is also a line of stations (618–25) at which the net was hauled twice a day at about 10 a.m. and 10 p.m. through a region of uniform plankton, and these constitute a useful piece of independent evidence.

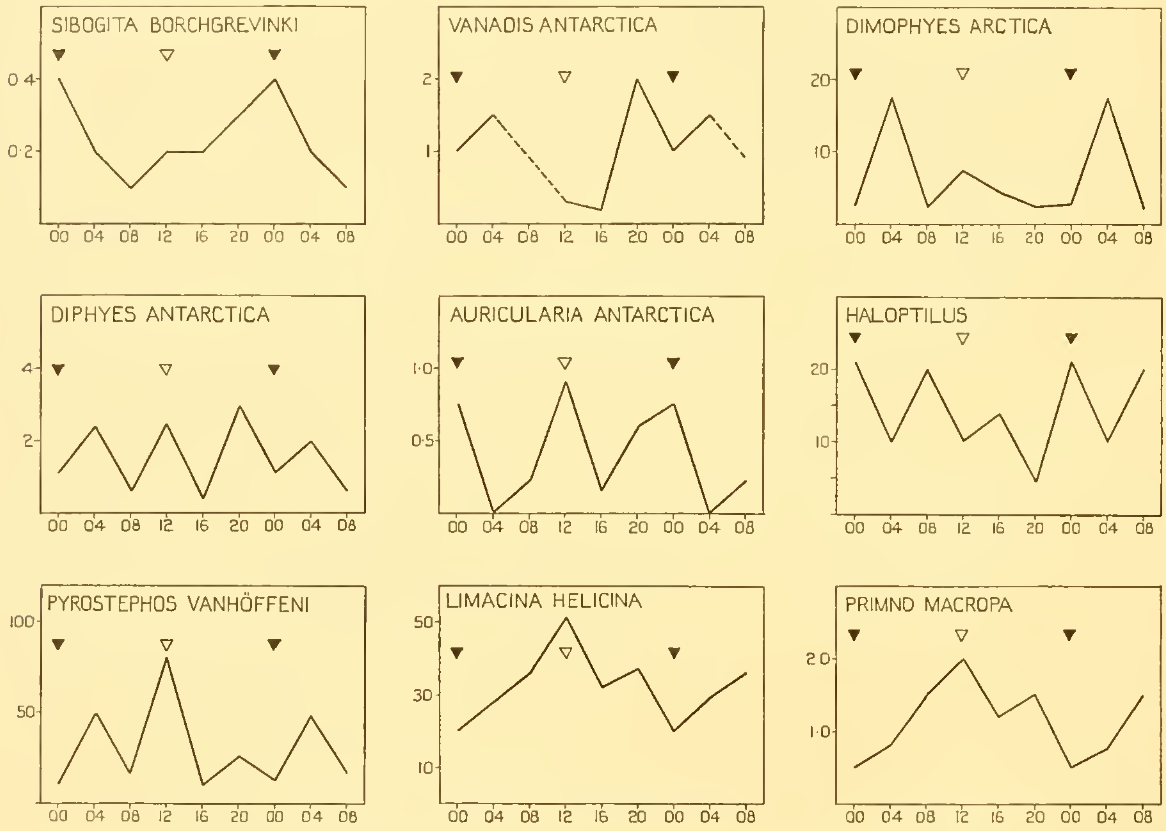

Fig. 20. Diurnal variations of macroplankton species (see legend to Fig. 18).

Diphyes antarctica (Fig. 20). The material is limited, but it is enough to show that there is no significant variation. Specimens taken at St. 461 show no apparent vertical migration.

Dimophyes arctica (Fig. 20). The curve for this species is unreliable, not so much because the species is uncommon north of 60° S as because it occurs in sharply fluctuating numbers. Thus the peak at 0400 is due to only two stations at which the species appeared in larger numbers than usual. The instances of its occurrence are quite evenly distributed throughout the day, and it is very improbable that there is any real variation. The distribution of this species at St. 461 strongly suggests that there is no variation.

Pyrostephos vanhöffeni (Fig. 20). The curve is actually made out for the numbers of nectophores, and not the individual colonies. It is a patchy species and the peak at midday is due to only one station, at which an abnormal number occurred. The actual occurrences are equally distributed through the 24 hours, and the species can be regarded as having no significant diurnal variation.

Sibogita borchgrevinki (Fig. 20). Only fifteen specimens were taken north of 60° S, so that a reliable curve cannot be drawn. The fifteen were spread equally through the day and night, but the stations at which it was counted as absent were mostly day stations. Several specimens occur at St. 461, but there is no sign of any vertical migration.

Solmundella sp. (Fig. 18). This is not a very common form, but in contrast to the four preceding species, it has a very clear diurnal variation, no specimens having been taken in the daytime between 0500 and 1859, except in high latitudes. It is not represented at St. 461.

Tomopteris sp. (large) (Fig. 19). There is a slight suggestion of variation, about equivalent to that of *Calanus acutus*, but it is not of much significance. No conclusive results are to be found in St. 461 or in Sts. 618–25.

Tomopteris sp. (small) (Fig. 19). Similar to the large *Tomopteris*. All these curves which show a slight variation have peaks which might be regarded as accidental, were they not all at or near midnight.

Vanadis antarctica (Fig. 20). As in the case of *Sibogita* we have insufficient material for a trustworthy curve. The genus is recorded at only thirteen stations north of 60° S. They are spread throughout the day, so that there is not likely to be any very significant variation. On the whole slightly more specimens were taken at night.

Auricularia antarctica (Fig. 20). Again there are very few specimens north of 60° S, but these show no sign of any variation; nor do those from farther south. It must perhaps still be regarded as a doubtful species, but any important diurnal variation is very unlikely.

Calanus acutus (Fig. 19). The averages of a large number of hauls and vast numbers of specimens show a slight diurnal variation. The species, however, is taken at all hours, and some of the biggest catches have been in the daytime. There is perhaps a faint suggestion of a tendency towards vertical migration at St. 461, but there is no sign of any variation at Sts. 168–25, and it may for the present be regarded as a species without significant diurnal variation.

Calanus propinquus (Fig. 19). The exact amount of diurnal variation cannot properly be estimated without a very large body of data. There is evidently rather more than in *C. acutus*, but the largest hauls of this species also can be taken in daytime as well as at night. St. 461 gives no definite indication, but Sts. 618–25 confirm the existence of some variation.

Calanus simillimus (Fig. 18). The curve shows a clear variation. The species has been caught at nearly as many day stations as night stations, but the night catches are larger. It is not represented at St. 461.

Rhincalanus gigas (Fig. 19). This species again can be taken in the greatest abundance during the day, but on balance there seems to be some sort of variation. St. 461 and Sts. 618–25, however, do not suggest any definite migration or variation.

Pleuromamma robusta (Fig. 18). Of all species found in the Antarctic surface water, this has on the whole the most pronounced diurnal variation. Examples occurred in only three hauls out of 196 between 0600 and 1959. The vertical migration is shown very clearly at St. 461. It appears to sink below 600 m. during the day, and rises to within reach of the N 100 B only within a few hours of midnight.

Metridia gerlachei (Fig. 18). Here again there is a strongly marked migration, but specimens have occasionally been taken in daytime. At St. 461 there was a wide range of vertical distribution, but the vertical migration was not well defined.

Haloptilus ocellatus. This species occurred only once north of 60° S. Specimens from farther south show no sign of diurnal variation, and St. 461 suggests that there is no vertical migration.

Haloptilus sp. (Fig. 20). Occurrences are spread equally through the 24 hours, and the figures from St. 461 suggest no vertical migration.

Pareuchaeta sp. (Fig. 18). The diurnal variations are very clearly defined, and examples are rarely taken during the hours of daylight. It is evident that this genus lives at a considerable depth and comes within reach of the net only at night. This supposition is confirmed by the catches at St. 461.

Heterorhabdus sp. (Fig. 18). The genus is uncommon, but great variation obviously takes place. St. 461 shows that it lives at a deep level but the series of hauls does not bring out the vertical migration very clearly.

Eucalanus sp. (Fig. 19). The material again is limited and the numbers in which the species occurs are variable. There is evidently a certain amount of variation, but there have been nearly as many occurrences in daytime as at night, and it is difficult to know what would result from a larger body of data. A vigorous vertical migration is improbable.

Euchirella sp. (Fig. 18). There is little material, but there is evidently a marked variation. St. 461 shows a considerable amount of vertical migration.

Candacia sp. (Fig. 18). This is another uncommon organism, but there is no question that it is normally beyond the reach of the net during daytime. The few specimens occurring at St. 461 were taken in the deepest nets.

Parathemisto gaudichaudi (Fig. 19). There is only a slight variation, roughly equivalent to that of *Calanus acutus*. Curiously enough Sts. 618–25 suggest quite a marked diurnal variation. At successive stations the catches were as follows: 21, 4, 260, 7, 19, 8, 68, 1. The alternate large catches were those from the night stations. It was absent from St. 461 except for some doubtful juvenile stages. At all events this species has actually been caught in both large and small numbers almost as often during the day as during the night.

Primno macropa (Fig. 20). The behaviour of this species is most remarkable. From the figures for diurnal variation it seems impossible to avoid the conclusion that it rises to the surface in the daytime and sinks at night, for although the species is of common occurrence in small numbers, none is recorded between 2200 and 0159 except for a single batch of twenty. On the other hand there is a clear maximum about midday. Few were caught at St. 461, but there is no sign of such a reversed migration. Diurnal variation is not of course necessarily proof of a corresponding vertical migration. It is conceivable, for instance, that a species like this might become localized at night into small shoals which are missed by the net.

Vibilia antarctica (Fig. 18). The material is not really adequate and the numbers are patchy. However, there is a most distinct variation. The fact that the peak comes rather before midnight is due to only two or three samples which were abnormally large.

Eusirus antarcticus (Fig. 19). A very doubtful species. Among those occurring south of 60° S there is no evidence of any diurnal variation. Those occurring north of 60° S suggest a sharp variation, but there are so few of them that the apparent maximum around midnight may be quite accidental.

Cyllopus sp. (Fig. 18). There is not very much to go on, but there seems to be a marked variation. As in *Vibilia* the peak comes before midnight, but with the available material we cannot be sure whether this is accidental or whether it represents the actual state of affairs.

Antarctomysis sp. (Fig. 18). There is a pronounced diurnal variation, though the genus has been taken practically as often during the day as at night. This is perhaps connected in some way with the neritic distribution of this genus.

Euphausia superba (Fig. 19). This is a difficult species to deal with owing to its extreme patchiness and tendency to form shoals. Many of the big shoals have been seen at the surface during both the night and the day, but the deeper shoals and the more scattered individuals might undertake vertical migrations. For the estimation of the average per haul at different hours, samples containing over 1000 *E. superba* have been disregarded. This should eliminate the disturbing influence of heavy shoal catches and give some idea of the general behaviour of the species. The resulting curve suggests only a minor degree of diurnal variation. At St. 461 the majority seemed to remain near the surface, while those living at greater depths gave some signs of moving up and down. At Sts. 618–25 there was quite a marked diurnal variation. The explanation would seem to be that while a section of the population of this species undergoes some vertical migration, the greater part remains at the same level, especially perhaps when forming shoals.

Euphausia frigida (Fig. 18). The variation is strongly defined, but fair-sized catches appear now and then during the day and the period of abundance at night is a little more extended than in such organisms as *Pareuchaeta* and *Metridia*. St. 461 suggests a vigorous migration, and the diurnal variations are clearly shown at Sts. 618–25.

Euphausia crystallorophias. This is a neritic species of which few examples have been taken, and none north of 60° S. The few that occur south of 60° S give some suggestion of diurnal variation, and since most of the other species of *Euphausia* undertake vertical migrations, it is probable that *E. crystallorophias* does so too.

Euphausia triacantha (Fig. 18). Here the variation is almost as sharply defined as in *Pleuromamma*. Examples occurred in only three out of 127 hauls between 0600 and 1759.

At St. 461 very few specimens were taken and the vertical migration is not well defined, but it is clear that this species lives at a considerable depth.

Euphausia vallentini (Fig. 18). Since this really belongs to the sub-Antarctic water there is not much material to go on. All that can be said is that there is a very definite variation which seems slightly more marked than that of *E. frigida*.

Thysanoessa spp. (Fig. 19). There is a clear diurnal variation, but it is not nearly so marked as in *Euphausia triacantha* and *E. frigida*. Examples are taken just as often in the middle of the day as at night, but the night hauls are on the average larger. At St. 461 *Thysanoessa* seems much scarcer in daytime, at all depths down to 600 m., than at night. The variations at Sts. 618–25 are of the same order as those shown in the curve.

Cleodora sulcata (Fig. 19). There is evidently a distinct variation. However, the species occurs quite commonly in small or moderate numbers during the day. Three large catches, which were evidently abnormal, have been disregarded in the construction of the curve. There is evidence of vertical migration at St. 461, but no data from Sts. 618–25.

Limacina helicina (Fig. 20). This species seems to be commoner at midday than at midnight, but there is not a great amount of material and it is possible that the peak at midday is accidental. The actual occurrences are distributed through the 24 hours as evenly as could be expected. There is no definite evidence from St. 461 or Sts. 618–25.

Limacina balea (Fig. 19). Like *Euphausia superba*, this species is difficult to place on account of its patchy distribution and tendency to form shoals. The curve is constructed from samples containing less than 1000. This represents the great majority of hauls and shows quite a modest variation, but it is noteworthy that the catches of 1000 to 6000 all took place at night, while two or three catches of 20,000 to 160,000 seemed to bear no particular relation to the time of day. There is no definite evidence from St. 461 or Sts. 618–25.

Spongiobranchaea australis (Fig. 19). Here the rather limited material suggests that there is a slight variation, but the numbers of catches in which the species occurs are fairly equal through the day. There are no examples at Sts. 618–25, and too few at St. 461 to justify any conclusions.

Clione antarctica (Fig. 19). The figures suggest a slight variation of the same order as that of *Calanus propinquus*. There are few specimens but no indication of vertical migration at St. 461.

Salpa fusiformis f. *aspera* (Fig. 18). This is another of those species of which the vast majority of specimens actually caught have been from a limited number of swarms. If shoal catches are included in the calculation of the mean values for the different times of day they produce an unfair distortion of the curve of variation. All samples of 100 or more Salps have therefore been disregarded here, and the resulting curve shows a regular and well-marked variation. If all samples of twenty or more Salps are also disregarded, the shape of the curve is not much affected. There were not enough specimens at St. 461 to provide additional evidence, and none occurred at Sts. 618–25.

Chaetognatha (Fig. 19). The variations of the group as a whole are equivalent to those of *Calanus propinquus*. Large catches are liable to be taken at all times of the day. St. 461 gives inconclusive results, but there is a distinct variation at Sts. 618–25.

Table I. *Mean diurnal variations*

	Average numbers per haul for 4-hour periods						Hours between which hauls are regarded as valid
	0000 (2200–0159)	0400 (0200–0559)	0800 (0600–0959)	1200 (1000–1359)	1600 (1400–1759)	2000 (1800–2159)	
Pleuromamma robusta	145	130	6	0	0	23	2100–0259
Euphausia triacantha	17·9	15·5	0·3	0	0	14·7	2000–0359
Solmundella sp.	3·8	2·0	0	0	0	4·6	2000–0359
Euphausia vallentini	110	290	7·3	0	0·2	11·1	2000–0359
Euchirella sp.	46·5	5·2	0·1	1·2	6·0	44·7	2100–0259
Pareuchaeta sp.	183	75	2	4	5	97	2000–0359
Candacia sp.	24·3	0·4	1·8	0·1	0	8·4	2100–0259
Heterorhabdus sp.	25·9	9·2	1·2	0	0·2	13·3	2000–0359
Euphausia frigida	366	458	33	8	39	302	1800–0559
Metridia gerlachei	258	39	15	11	6	74	2000–0359
Salpa fusiformis f. *aspera*	8·4	4·0	0·9	0·6	1·0	4·9	2000–0359
Antarctomysis sp.	196	6·2	2·4	2·1	19·6	50	2000–0359
Calanus simillimus	446	161	82	53	58	166	1800–0559
Vibilia antarctica	2·1	0·7	1·0	0·3	0·5	4·5	1900–0459
Cyllopus spp.	1·1	0·3	0·0	0·6	1·1	2·6	1900–0459
Cleodora sulcata	8·7	1·0	1·4	1·4	2·4	5·8	1900–0459
Thysanoessa spp.	1318	779	221	435	385	729	1800–0559
Eusirus antarcticus	2·5	0·0	0·3	0·7	0·7	2·0	1800–0559
Euphausia crystallorophias	3·7	1·2	1·2	1·8	4·1	0	All hours
Limacina balea	70	57	38	51	11	30	1700–0659
Eucalanus sp.	73·2	15·7	58·0	10·2	16·4	18·9	1700–0659
Calanus propinquus	779	713	261	331	571	559	1700–0659
Clione antarctica	2·4	2·1	1·2	1·6	1·5	2·3	1700–0659
Chaetognatha	451	408	370	301	220	333	1700–0659
Spongiobranchaea australis	1·0	0·8	0·8	0·4	0·8	0·8	1600–0759
Rhincalanus gigas	1733	2898	2086	1208	2030	2006	1600–0759
Euphausia superba	88	46	46	61	53	96	All hours
Calanus acutus	3250	3969	3453	1849	2890	3021	,,
Tomopteris sp. (large)	0·9	0·8	0·7	0·7	0·4	0·9	,,
Tomopteris sp. (small)	6·3	4·0	3·7	4·2	2·9	6·4	,,
Parathemisto gaudichaudi	103	92	73	61	90	92	,,
Sibogita borchgrevinki	0·4	0·2	0·1	0·2	0·2	0·3	,,
Vanadis antarctica	1·0	1·5	—	0·3	0·2	2·0	,,
Dimophyes arctica	2·6	17·7	2·2	7·5	4·4	2·5	,,
Diphyes antarctica	1·1	2·2	0·6	2·5	0·4	3·0	,,
Auricularia antarctica	1·0	0	0·3	1·2	0·2	0·8	,,
Haloptilus sp.	22·2	10·0	20·0	11·0	14·0	4·4	,,
Haloptilus ocellatus	48	—	—	128	120	164	,,
Pyrostephos vanhöffeni	11·2	48·4	16·1	80·3	10·5	27·1	,,
Limacina helicina	20·5	28·7	36·3	51·3	31·9	37·2	,,
Primno macropa	0·5	0·8	1·5	2·0	1·2	1·5	0400–1959

Throughout this paper hours are expressed according to the 24-hour notation. Bracketed figures at the head of the columns represent the range in time of the observations, while the mean of the 4-hour period, which has been used in the construction of Figs. 18–20, is placed above.

Among the various species there is a complete gradation from those which are plentiful at night and completely vanish from the catches in daytime, to those which show no diurnal variation at all, or which even increase during the day and diminish at night. In Table I on p. 95 the various units are arranged roughly in order of the magnitude of their diurnal variations, and the figures in the first six columns are the average numbers per haul, upon which the curves in Figs. 18–20 are based. Thus *Pleuromamma robusta* averages 145 per haul between the hours of 2200 and 0159, and sinks beyond the reach of the net during the daytime or at least the afternoon. On the other hand such species as *Pyrostephos vanhöffeni* show no clear indication of any diurnal variation and in *Primno macropa* the variation seems actually to be reversed.

It is now clear that observations taken in the middle of the day must be disregarded in any consideration of the distribution of the more migratory species, and it must be decided exactly which hauls can be admitted as an indication of the numbers of each species present. Without a fuller knowledge of the details of vertical migration, as distinct from diurnal variation, the best that can be done is to select, for each variable species, a period of hours before and after midnight which will be appropriate to the diurnal variations of that species. For *Pleuromamma*, for instance, we might allow as valid only the hauls between 9 p.m. and 3 a.m. (2100–0259), while we need not disregard any hauls for such organisms as *Pyrostephos*. Column 7 in Table I shows the periods during which a haul is regarded, for the purposes of the present paper, as an indication of the presence or absence of a species. Those listed in the table below *Rhincalanus* are regarded as having insufficient diurnal variation to merit the exclusion of any of the daytime hauls. It occasionally happens that a species, which on the average is plentiful only at night, is caught in unexpectedly large numbers during the day. If such a catch were comparable to the average haul taken at night about the same time and in the same locality, it may be taken into consideration in the distribution of the species.

Hardy and Gunther (1934) have discussed the vertical migrations of certain species which are included in Table I and conclude that a more or less marked migration is shown by the following species: *Calanus propinquus*, *C. simillimus*, *Metridia gerlachei*, *Pareuchaeta antarctica*, *Parathemisto gaudichaudi*, *Vibilia antarctica*, *Cyllopus* spp., *Euphausia superba*, *E. frigida*, *E. triacantha*, *Thysanoessa* spp., *Limacina helicina*, and *Salpa fusiformis*. Table I shows that all except four of these species also show a clear diurnal variation, and it is therefore mainly in agreement with Hardy and Gunther's results. The exceptions are *Calanus propinquus*, *Parathemisto gaudichaudi*, *Euphausia superba*, and *Limacina helicina*. The explanation of the fact that they show little diurnal variation in the catches of the N 100 B is probably to be explained on the grounds that they inhabit mainly the upper layers, and that their vertical migrations do not take the bulk of them beyond the reach of the net at night. Hardy and Gunther find little or no migration in *Calanus acutus* and *Rhincalanus gigas*, and this also is in agreement with the results expressed in Table I.

RELATIVE ABUNDANCE AND DISTRIBUTION OF INDIVIDUAL SPECIES

In different parts of the Atlantic sector of the Antarctic the plankton varies considerably in both abundance and constitution, and to find the actual relative quantities in which the different species exist would be a very difficult matter, even if it was particularly desirable to do so. However, it is necessary to give some indication as to which species are abundant and which species are uncommon, and the following table shows the average per haul (all hauls with the N 100 B in the Antarctic) and the largest single catch for each species. A disproportionately large number of these hauls have been made in the neighbourhood of South Georgia, but this is a region in which, from time to time, representatives of the plankton typical of both the warmer and colder parts of the Antarctic waters are found.

Table II. *Relative abundance of species (expressed to two significant figures)*

Species	Average number per haul	Largest catch	Species	Average number per haul	Largest catch
		Abundant			
Calanus acutus	1900·00	67,000	*Thysanoessa* spp.	420·00	15,000
Rhincalanus gigas	1200·00	20,000	*Calanus propinquus*	390·00	28,000
*Euphausia superba**	1000·00	190,000	Chaetognatha	260·00	6,300
*Limacina balea**	440·00	160,000			
		Numerous			
Euphausia frigida	140·00	5,800	*Pareuchaeta* sp.	52·00	5,500
Parathemisto gaudichaudi	110·00	3,000	*Pleuromamma robusta*	40·00	6,200
Metridia gerlachei	87·00	6,100	*Salpa fusiformis* f. *aspera**	29·00	6,700
Calanus simillimus	86·00	41,000	*Limacina helicina*	21·00	960
		Moderate			
Antarctomysis sp.	9·80	1,800	*Euchirella* sp.	3·20	510
Pyrostephos vanhöffeni	9·00	1,200	*Cleodora sulcata*	3·10	550
Euphausia vallentini	6·60	1,800	*Haloptilus* sp.	2·40	100
Eucalanus sp.	5·50	590	*Heterorhabdus* sp.	2·20	260
Haloptilus ocellatus	5·40	520	*Dimophyes arctica*	1·90	180
Euphausia triacantha	4·50	230	*Candacia* sp.	1·60	100
Tomopteris sp. (small)	3·60	100	*Clione antarctica*	1·10	40
		Few			
Vibilia antarctica	0·82	66	*Auricularia antarctica*	0·53	100
Primno macropa	0·77	90	*Spongiobranchaea australis*	0·40	27
Cyllopus spp.	0·60	110	*Solmundella* sp.	0·29	32
Euphausia crystallorophias	0·60	200	*Eusirus antarcticus*	0·15	9
Diphyes antarctica	0·59	23	*Vanadis antarctica*	0·08	3
Tomopteris sp. (large)	0·58	39	*Sibogita borchgrevinki*	0·05	2

* Species of which the majority have occurred in shoals or dense patches.

There are large differences in the uniformity of distribution of these species, and some tend to form shoals, or large or small areas of dense concentration. *Euphausia superba* lives mainly in shoals, and *Limacina balea* and *Salpa fusiformis*, though normally found in small numbers, sometimes occur in exceptionally dense masses which may extend over many square miles. Other species such as *Parathemisto gaudichaudi* and *Calanus simillimus* are found only occasionally in abnormally large numbers, the majority of specimens being taken in hauls of normal size. Other species again seem to have no tendency to form any definite aggregations. This point will be dealt with more fully when each species is separately considered in the following pages.

The N 100 B analyses provide a large body of data on the distribution of the various species, but separate species or groups will be dealt with in detail in subsequent publications, and the distribution of individual species will therefore be considered in the briefest possible manner here. For the same reason, little reference will be made to records of the occurrence of each species in the publications of other expeditions, for if this were done the following notes would need to be greatly enlarged. Mention should be made, however, of one or two papers which deal with certain aspects of the distribution of the macroplankton in these waters. For example, Ruud (1932) discusses in detail the general biology and distribution of the Antarctic Euphausiidae and the connection between *Euphausia superba* and the distribution of whales. Further reference will be made to this paper in a later section. Ottestad (1932) has treated the principal species of Copepoda in a similar way. The substance of these papers does not very much overlap that of the present paper, but, so far as their conclusions have any bearing on it, they are mainly in agreement with the following notes. Rustad (1930) has also published a paper on the identification and development of the southern Euphausiidae, but deals only briefly with their distribution.

Except where otherwise stated, the following notes are derived entirely from the samples on which this paper is based.

Diphyes antarctica. This species is confined to the colder parts of the Antarctic waters, and its northern boundary in the area of the Falkland Islands Dependencies is roughly a line running from the South Shetland Islands to South Georgia. It is usually found in the vicinity of the pack-ice, or in water which has recently been covered by the ice. It seems to be scattered very evenly through the regions which it inhabits, appearing at each station in small numbers, and there have been no indications of any tendency to form shoals or even to occur in definitely larger numbers than usual.

Dimophyes arctica. This species is known to occur at least in sub-Antarctic, as well as Antarctic water, but it is only in the colder waters of the Bellingshausen and Weddell Seas that it appears in any quantities. Here it is quite plentiful, but in warmer regions it is rare. Its distribution is more "patchy" than that of *Diphyes antarctica*, but it cannot be said to occur in shoals.

Pyrostephos vanhöffeni. Recorded from time to time everywhere from the Antarctic convergence to the most southerly stations of the Bellingshausen and Weddell Seas, but it is definitely commoner in the colder than in the warmer parts of the Antarctic water. It is curious that it seems to be absent from the coastal regions of the South

Orkneys, South Shetlands, and the eastern Bellingshausen Sea. Of all the stations in this area, including those in Bransfield Strait, it is recorded only at one or two stations off Adelaide Island. The nectophores appear in very variable numbers in the samples, but this is to be expected, as there are said to be about thirty nectophores to each colony.

Sibogita borchgrevinki. Another species which is confined to the higher latitudes, or at least to the colder waters. Its distribution resembles that of *Diphyes antarctica*, but it appears to reach a little farther north. There is rarely more than a single specimen in one sample, and it is probably distributed evenly through the waters to which it belongs.

Solmundella sp. This is a species which seems to have no particular limits. It occurs in small numbers, but has been found everywhere from the convergence to the cold waters of the Bellingshausen and Weddell Seas. Browne (1910) mentions that *S. mediterranea* is found from the tropics to the Antarctic. There are rarely more than ten in one sample, and I have no record of more than thirty-two.

Tomopteris sp. (large). The large *Tomopteris* also is found everywhere from the convergence to the higher latitudes, but it is distinctly commoner in the colder regions. Like *Pyrostephos*, it seems to be absent from the Bransfield Strait, and the whole of the coastal region from the South Orkneys to the eastern part of the Bellingshausen Sea. It is an evenly distributed species and more than two or three in one sample are rarely found. Only once have more than twelve been taken at a time, and that was an extraordinary catch of thirty-nine at a station off South Georgia. There is an interesting colour variety of *Tomopteris carpenteri*. Ordinary specimens are colourless and transparent, but on certain occasions specimens have been taken which were traversed by two broad bands of bright reddish brown which made the animal strikingly conspicuous. These parti-coloured specimens have been found only in cold water in the neighbourhood of the pack-ice of the Weddell and Bellingshausen Seas.

Tomopteris sp. (small). Like the large *Tomopteris* it is found everywhere in the Antarctic water, but is rather commoner in the colder regions. Unlike the other it is found in the coastal region of the South Orkneys, South Shetlands, and eastern Bellingshausen Sea. Its distribution is sometimes quite uniform and sometimes rather patchy, but I have no record of anything which might be called a shoal.

Vanadis antarctica. Occurs in such small numbers that one cannot draw very certain conclusions as to its distribution. It is almost entirely confined to the cold water of the Weddell and Bellingshausen Seas, especially the latter, but it has also been found at one or two stations near the Antarctic convergence in far warmer water than all the others at which it is recorded. There seems to be no doubt about the identity of these specimens, and their occurrence in such an unusual locality is difficult to account for. There is rarely more than one in a single sample.

Auricularia antarctica. Like *Diphyes antarctica*, this species is strictly confined to the colder regions, but since it occurred at WS 198, WS 474 and St. 594 (see Figs. 10, 12 and 14), its northern limit must be placed a little beyond that of *Diphyes*. It is found in the Bellingshausen Sea, the coastal waters of the South Shetlands and South

Orkneys, and the eastern Weddell Sea. It generally occurs in ones and twos, but catches up to 100 were taken in the eastern Weddell area.

Calanus acutus. Numerically this is the most important species of all. It is distributed throughout the Antarctic surface waters, and there have been catches of 1000 or more everywhere from the convergence to the cold waters of the Bellingshausen and Weddell Seas. The very big catches of 5000 and more have been taken only in the South Georgia and South Sandwich areas, the western Bellingshausen and eastern Weddell Seas. The species is on the whole evenly distributed and there is no tendency to form shoals.

Calanus propinquus. This species also is found everywhere in both the warm and cold parts of the Antarctic surface water, but the largest catches have been taken in the neighbourhood of South Georgia and the South Sandwich Islands. It has no tendency to form shoals, but is perhaps a little more localized than *C. acutus.* For instance at Sts. 360–74 in February and March, 1929–30, it was taken in enormous numbers in the eastern part of the Scotia Sea, and it was by far the most prominent copepod at Sts. 453–72 between Bouvet Island and South Georgia in October 1930–1. Specimens taken near the Antarctic convergence are mostly immature.

Calanus simillimus. Normally confined to the warmer waters of the Antarctic. It has not been taken in the Bellingshausen or Weddell Seas and has not often appeared south of a line running from the north side of the South Shetlands to South Georgia, though around South Georgia it is common enough. In March of the warm 1929–30 season, however, it was taken at Sts. 372–5, west of the South Sandwich Islands. This is normally quite an evenly distributed species, and an abnormally large catch has been taken only once, at WS 184, where over 40,000 were taken at a point close to the south coast of South Georgia. The next largest catches were 5000 at WS 466 just on the north side of the convergence, and 2200 at St. 321 off South Georgia.

Rhincalanus gigas. This species has been caught in large numbers at practically every station in the warmer parts of the Antarctic, and there is little doubt that it is abundantly and evenly distributed in these waters at least during the greater part of the summer. It is also taken in large numbers in the Bellingshausen Sea and in the Weddell Sea water, but here it is not by any means always found in abundance. It occurs in small numbers, though at most stations, in the coastal regions of the South Orkneys, South Shetlands and eastern Bellingshausen Sea. It shows no tendency to form shoals, and cannot be regarded as any more patchy than any of the other more numerous species.

Pleuromamma robusta. This is a warm-water species whose proper habitat in Antarctic water appears to be the outer belt immediately south of the convergence. It is of course also found north of the convergence. It is not uncommon in the Weddell Sea water on both the west and east sides of the South Sandwich Islands, but it has occurred at none of the stations in coastal regions of the South Orkneys and South Shetlands, nor in the Bellingshausen or eastern Weddell Sea. As a rule it is as evenly distributed as most of the other copepods, but a very exceptional catch of over 6000 was taken at St. 452, north of Bouvet Island.

Metridia gerlachei. On the whole a cold-water species. A peculiarity of its distribution is that it is found in much the largest quantities between the South Shetlands and South Orkneys, along the Orkney-Sandwich ridge, and around the South Sandwich Islands. It is one of the very few members of the macroplankton which are found in any considerable numbers in this region. Possibly its method of reproduction is in some way associated with the bottom or with the conditions found in shoal waters. However, it is to be found in varying quantities everywhere from the convergence to the highest latitudes. It is a species which is often distributed evenly over large areas but which sometimes appears suddenly in exceptionally large numbers. It thus has some tendency to form shoals, or at least to appear in local concentrations, and it must be regarded as a patchy species.

Haloptilus ocellatus. This species is confined to the coldest water. It has occurred in moderate numbers (100 to 500 per haul) in the Bellingshausen Sea west of Peter 1st Island and in the eastern Weddell Sea. Occasional specimens are recorded from the Orkney-Shetland region and from the ice-edge near Bouvet Island. There is no evidence to show that its distribution is at all patchy.

Haloptilus sp. Found everywhere from the convergence to the Bellingshausen Sea, but it is not recorded from the Sandwich or eastern Weddell regions, and has appeared only once in the Orkney-Shetland coastal region. However, it is among the rarer Copepoda, and there is not enough material to form the basis of any definite conclusions. It is perhaps commonest in the warmer parts of the Antarctic.

Pareuchaeta sp. This genus also has a wide distribution, but it is commonest in the warmer parts of the Antarctic. Like *Rhincalanus* it pervades the whole of the belt lying immediately south of the convergence and is absent only from hauls taken during the daytime. It appears sometimes in the Bellingshausen and Weddell Seas, and is met with in small numbers in Bransfield Strait, in the coastal waters of the South Orkneys and South Shetlands and in the eastern Bellingshausen Sea.

Heterorhabdus sp. Although this is an uncommon genus it clearly belongs to the warmer parts of the Antarctic water; its distribution seems very similar to that of *Calanus simillimus*.

Eucalanus sp. Also clearly typical of the warmer water, but its occurrence is curiously spasmodic. At one time it may be found at every station of a line, say, from South Georgia to the convergence, while at another time none will be caught along a similar line. On the other hand its distribution does not appear to be in any way patchy.

Euchirella sp. This is one of the rarest of the large Antarctic copepod genera. It has occurred here and there in the warmer water, off South Georgia, in the Bellingshausen and Weddell Seas and in the outflowing Weddell water. We cannot say more than that, as a genus, it is not confined either to the warmer or colder Antarctic water.

Candacia sp. This is another scarce genus, but it has not been found in the colder regions and is commonest close to the convergence. It is clearly a warm-water form.

Parathemisto gaudichaudi. The big catches of this species have all been taken in the warmer parts of the Antarctic water, including the South Georgia whaling grounds. Moderate numbers have occurred in the South Sandwich region and small numbers in the coastal region of the South Orkneys and South Sandwich Islands and in the Bellingshausen Sea. In the warmer waters there are practically no night stations at which it was not present, but there is no doubt that it is a patchy species and it sometimes occurs in dense local concentrations. During the 1927–31 period 2000–3000 have been taken on several occasions, and some very big hauls were taken off South Georgia during the first commission of the 'Discovery'. Sometimes, however, it is distributed quite evenly over a large area.

Primno macropa. This species seems to have no particular limits to its distribution in the Antarctic. It is perhaps slightly commoner in the warmer waters, but it is found in small numbers almost everywhere. There is no evidence of any tendency to form shoals or local concentrations.

Vibilia antarctica. Found everywhere from the convergence to the Bellingshausen and Weddell Seas. It seems to be of very regular occurrence around the South Orkneys. It never occurs in very large quantities.

Eusirus antarcticus. Another strictly cold-water species whose northern limit corresponds closely with that of *Diphyes antarctica.* Few specimens have been taken and there is no reason to suppose that its distribution is at all patchy.

Cyllopus spp. Quite evenly distributed from the convergence to the colder regions. As a genus it seems to have no preference for either the warmer or colder parts of the Antarctic, and there appears to be no tendency towards local concentrations.

Antarctomysis sp. This must be classed as a neritic genus. Among the samples upon which the present paper is based it has been found only in the South Georgia and South Sandwich region, but according to Rustad (1930, Mysidacea, p. 20) its distribution is circumpolar. The greatest number have been taken from the shallow water on the south side of South Georgia.

Euphausia superba. In its habits and distribution the "krill", as it is commonly called, stands apart from all other macroplankton species. It will form the subject of separate publications, and it will suffice here to say that it is seldom found north of a line running from the north side of the South Shetland Islands north-eastwards past the western end of South Georgia, and it has not so far been taken in any large numbers in the Bellingshausen and eastern Weddell Seas. It is one of the few species which are found in occasionally large numbers in the coastal region of the South Orkneys and South Shetlands. The average number for all hauls (see Table II, p. 97) shows that numerically it is among the most abundant of macroplankton species, and in mass of living matter it might well be equal to all the rest of the Antarctic macroplankton combined. In its distribution it is the most patchy and irregular of these species, and the great majority of specimens have been taken from actual shoals.

Euphausia frigida. This species occurs mainly in the warm waters of the outer Antarctic Zone and in the outflowing Weddell water in the South Sandwich neighbourhood.

In the coastal region of the South Orkneys and South Shetlands and in the Bellingshausen Sea it occurs sometimes in small numbers. It was not taken at stations in the eastern Weddell Sea. In general it occurs in varying quantities but appears never to form shoals.

Euphausia crystallorophias. Like *Antarctomysis* this must be regarded as a neritic species. It is found, however, only in the colder regions such as the Bransfield Strait and the coastal waters of the eastern part of the Bellingshausen Sea.

Euphausia triacantha. This species occurs in a more strictly limited zone than perhaps any other. To the north it is found only a little way beyond the convergence and to the south it is bounded normally by a line from the South Shetlands running north-eastwards and passing a little to the south of South Georgia. It is thus a typically warm-water species, but it is curious that it does not normally extend far into the sub-Antarctic Zone as do most of the other species typical of the warmer parts of the Antarctic. This fact may perhaps be in some way due to the depth at which it lives. There is no reason for supposing that it forms shoals or local concentrations.

Euphausia vallentini. This is really a sub-Antarctic species, but it sometimes strays south of the convergence and has even been taken off South Georgia on one or two occasions. Zimmer (1914) records a specimen from 58° 29′ S, 89° 58′ E, a very high latitude for this species.

Thysanoessa spp. There have been very few samples which did not contain representatives of this genus. It seems always to be scarce in the Bellingshausen and eastern Weddell Seas, but in the warmer parts of the outer Antarctic, in the outflowing Weddell water and around South Georgia it is often taken in thousands. As a genus it is very variable and patchy, and this characteristic is probably shared by *T. macrura* and *T. vicina.*

Cleodora sulcata. Distributed everywhere from the Bellingshausen Sea to the coldest regions. In most places it is taken normally in ones and twos, but it is more plentiful in the Weddell Sea water in the neighbourhood of the South Sandwich Islands. Here there have been single hauls containing several hundred specimens, and such hauls might be regarded as indicating at least a local concentration. It is distinctly a cold-water species.

Limacina helicina. This is pre-eminently a cold-water species, but at times it is found as far north as the convergence. There are no very definite limits to its distribution, but its occurrence seems to vary according to the time of year. There is no indication that it forms shoals or dense local aggregations such as we find in the case of *L. balea.*

Limacina balea. The distribution of this species is quite different from that of *L. helicina.* The two are sometimes found together, but *L. balea* is more of a warm-water species and seems to reach its greatest development near the convergence. No specimens have been taken in the Bellingshausen Sea or in the eastern Weddell Sea, though it occurs in the outflowing Weddell water. In the warmer parts of the Antarctic water it has occasionally been found in enormous swarms. Some big catches have also been taken off South Georgia and between South Georgia and Bouvet Island.

Spongiobranchaea australis. Found everywhere from the convergence to the coldest regions. It is very evenly distributed, but is possibly a little commoner in the warmer water than elsewhere. There are rarely more than one or two in a sample and there is no evidence of any tendency to form shoals or local concentrations.

Clione antarctica. This species also is widely distributed, but it is rather commoner in cold than in warm water. It is occasionally found as far north as the convergence. On the whole it is very evenly distributed, occurring generally in very small numbers and showing no tendency towards forming local aggregations.

Salpa fusiformis f. *aspera.* Found everywhere from the convergence to the Bellingshausen and Weddell Seas. Its distribution is not unlike that of *Metridia*, for it has been caught in large numbers at all the night stations and at most of the day stations in the vicinity of the South Orkney Islands. It seems that there is nearly everywhere a sprinkling of Salps, and here and there a dense patch. Catches in the South Sandwich region have all been small, but big hauls have been taken off South Georgia and one large aggregation has been met with in the Bellingshausen Sea. The shoaling tendency of the Salps is of a different type from that of the "krill". The former seem occasionally to be concentrated in large areas where the numbers reach a maximum in the centre. A typical example is provided by seven successive stations (564–70), covering some 300 miles in the Bellingshausen Sea. At these the numbers of Salps taken were, respectively, 0, 4, 66, 550, 369, 57, 0. *Euphausia superba* occurs in smaller, denser and more numerous shoals.

Chaetognatha. This group, which is principally made up of *Eukrohnia hamata*, is found in the greatest numbers in the outer, warmer part of the Antarctic water, and the largest catches have, in general, been those closest to the convergence. Large numbers are not likely to be taken south of a line running from the South Shetlands to South Georgia, but some quite large catches have been taken in the western Bellingshausen Sea. The distribution of the Chaetognatha appears on the whole to be very regular, and it would appear that *Eukrohnia hamata*, at any rate, does not tend to form shoals. This species, according to Bigelow and Leslie (1930, p. 564), "ranges from Arctic to the Antarctic in the Atlantic, being confined to the bathyplankton in low and mid-latitudes".

It will be seen from the foregoing notes that the macroplankton can be divided very roughly into three groups: (i) those species which have a definite preference for, or which are actually confined to, the cold water or high latitudes, (ii) those which are definitely typical of the warmer water or lower latitudes, and (iii) those which may be found everywhere and may be taken in maximum numbers in both the warmer and colder regions.

It has been explained that the Antarctic surface water in the greater part of these regions is drifting mainly in an easterly or north-easterly direction, and, as we should expect, the isotherms are roughly parallel to the direction taken by the oceanic currents (see Fig. 22). In Fig. 21 lines are drawn to show the distributional boundaries of those species which show a clear limitation of distribution. For instance, no specimen of *Euphausia vallentini* has been taken at any station on the south side of line No. 4, and none of *Diphyes antarctica* to the north of line No. 1. *Euphausia superba* may be found in large numbers anywhere south of line No. 1, but is very rare to the north of it. It will be seen that the majority of these lines also run roughly parallel to the direction of drift, and indeed it would be surprising if they did not. It is one thing, of course, to say

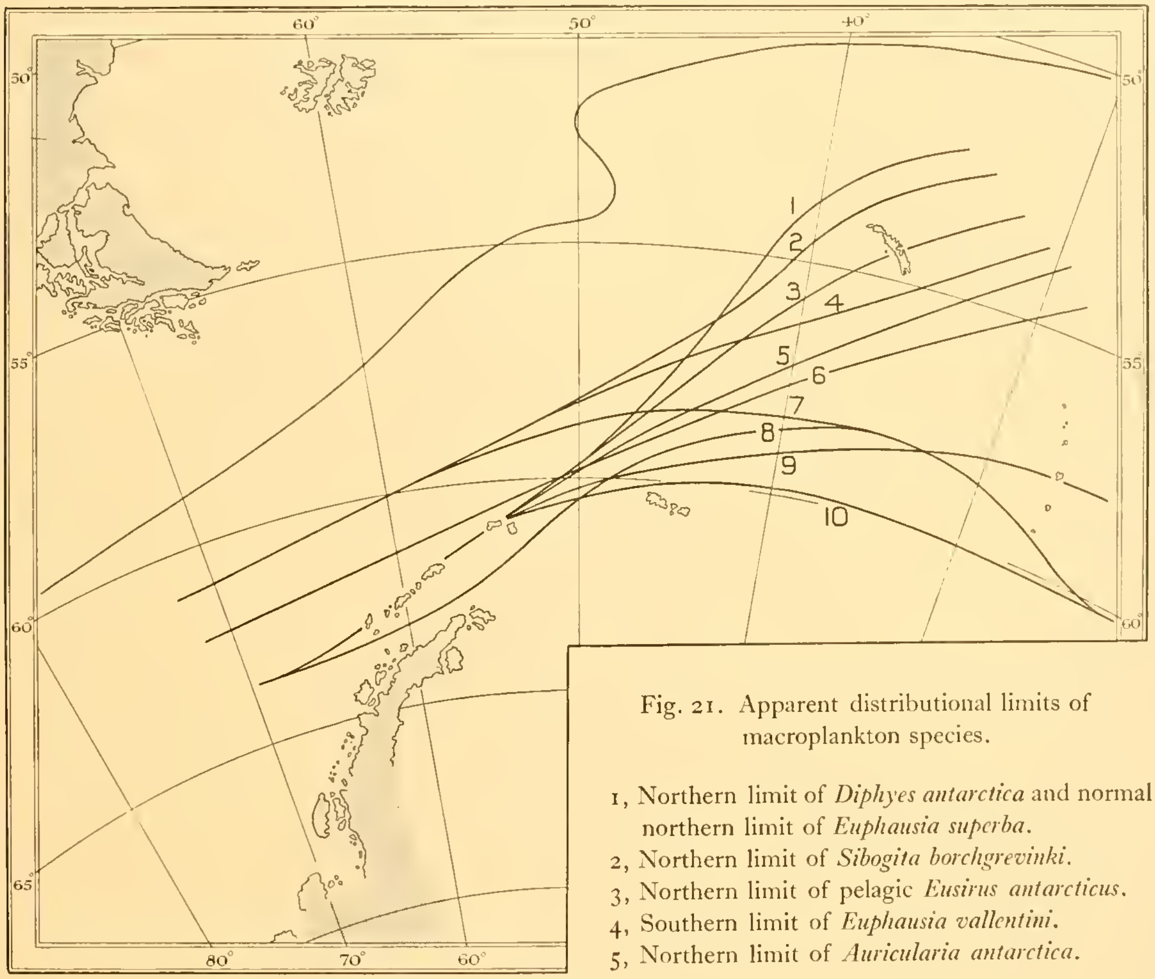

Fig. 21. Apparent distributional limits of macroplankton species.

1, Northern limit of *Diphyes antarctica* and normal northern limit of *Euphausia superba*.
2, Northern limit of *Sibogita borchgrevinki*.
3, Northern limit of pelagic *Eusirus antarcticus*.
4, Southern limit of *Euphausia vallentini*.
5, Northern limit of *Auricularia antarctica*.
6, Southern limit of *Euphausia triacantha*.
7, Southern limit of *Candacia* sp.
8, Southern limit of *Limacina balea*.
9, Southern limit of *Calanus simillimus*.
10, Southern limit of *Pleuromamma robusta* and northern limit of *Haloptilus ocellatus*.

that a species has not been found to the north or to the south of a particular line, and another thing to say that it never occurs there. It must be emphasized therefore that the lines shown on this chart are tentative. The utmost that can be inferred with certainty is that there is a belt of change between South Georgia and the South Shetland Islands. That is to say, an observer moving in a north-easterly direction in this part of the Antarctic water would find few qualitative changes in the plankton, whereas if he travels south-eastwards across the line of the isotherms he will meet with important changes, especially while crossing a belt running approximately from the South Shetland Islands to South Georgia. This zone of rapid qualitative change will be mentioned again in a later section. The point to be emphasized at the moment is that the chart indicates a connection between the distribution of species and the surface temperature of the water within the Antarctic Zone. This temperature ranges from nearly $-2°$ C. to about $+5°$ C., and a quantitative comparison of the different species in respect of their

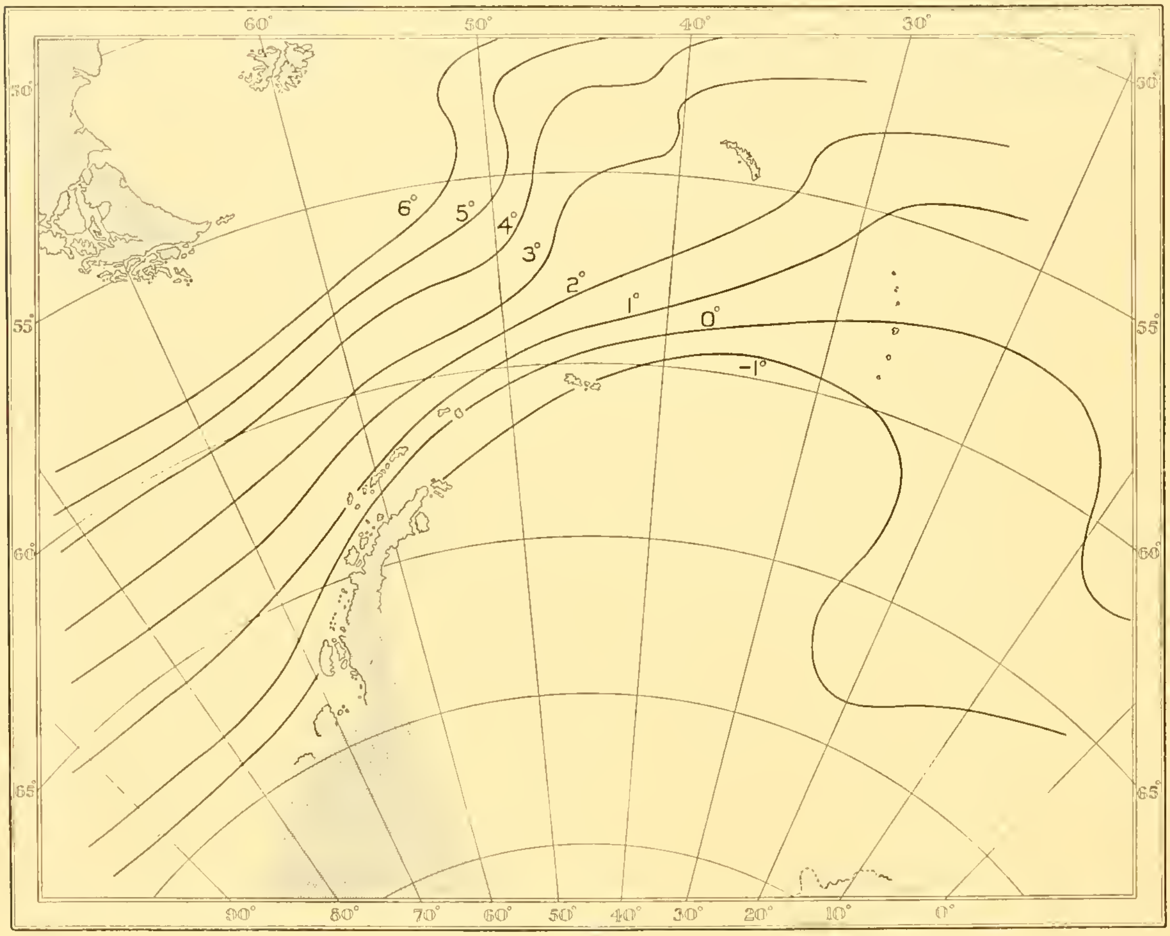

Fig. 22. Approximate positions of the mean summer isotherms.

occurrence in water of different temperatures will provide a clearer distinction between the warm- and cold-water species than is given in the notes on general distribution.

It must be supposed that plankton organisms which have an optimum temperature cannot make active movements to avoid changes in temperature caused by the seasons, the weather, the approach and departure of ice, etc. We should therefore expect more reliable results from the mean temperature of the locality than from the actual temperature of the water in which a species is taken. It would be desirable if possible to compare the distribution of a species with the temperature of the water at the mean depth at which it lives. But at a great many of the stations at which the N 100 B was used the

Table III. *Distribution and temperature.*
Average numbers per haul between the mean summer isotherms

Isotherms: ° C.... ...	− 1·00 to − 1·99	0·00 to − 0·99	0·00 to 0·99	1·00 to 1·99	2·00 to 2·99	3·00 to 3·99	4·00 to 4·99	5·00 to 5·99	6·00 to 6·99
Warm-water species									
(*a*) Practically confined to water above 3° C.									
Euphausia vallentini	—	—	—	—	0·08	4·80	29·1	370	44·1
(*b*) Typical warm-water species.									
Eucalanus sp.	—	—	—	2·80	7·90	17·3	14·4	49·8	96·9
Candacia sp.	—	—	2·30	—	3·80	13·8	5·00	20·8	18·7
Heterorhabdus sp.	—	—	12·1	0·40	3·56	8·80	5·14	11·4	16·3
Euphausia triacantha	—	—	0·88	5·18	21·8	10·2	18·7	32·1	7·00
Calanus simillimus	—	—	5·80	28·3	190	344	82·0	871	293
Pleuromamma robusta	—	5·20	3·40	73·1	201	40·0	146	104	252
(*c*) Warm-water species sometimes found in colder regions.									
Chaetognatha	785	98·2	53·5	129	375	532	763	1550	2320
Limacina balea	—	11·7	813	4·70	97·8	22·6	250	3940	710
Pareuchaeta sp.	72·0	24·8	25·5	140	200	32·5	216	250	63·7
Parathemisto gaudichaudi	0·50	2·90	26·3	23·1	129	182	38·8	148	179
Euphausia frigida	—	7·00	581	150	341	245	205	—	0·20
Widespread species									
(*d*) Species found on all isotherms but with a slight preference for warmer water.									
Primno macropa	2·62	0·46	0·37	1·00	1·50	3·94	9·54	5·50	—
Spongiobranchaea australis	0·20	0·16	0·40	0·63	0·41	2·37	0·36	0·44	1·00
Thysanoessa spp.	48·5	147	513	1100	1120	1160	954	1220	1220
Rhincalanus gigas	2460	1270	393	755	2470	1443	1137	1060	1110
(*e*) Neutral species.									
Haloptilus sp.	51·2	0·02	0·95	0·19	2·68	0·42	4·00	6·15	—
Euchirella sp.	—	4·20	15·2	—	9·60	1·20	—	9·70	2·50
Solmundella sp.	—	0·48	0·96	0·36	0·62	0·22	1·14	1·33	4·57
Cyllopus spp.	0·50	1·04	0·82	1·40	1·10	1·00	0·37	0·33	0·67
(*f*) Species found on all isotherms but with a slight preference for colder water.									
Calanus acutus	8830	1100	1500	1110	1530	492	87·1	189	9·60
Vibilia antarctica	4·16	2·58	1·40	0·67	2·98	0·40	0·25	0·14	—
Calanus propinquus	296	540	1530	2510	811	327	577	265	20·0
Cold-water species									
(*g*) Cold-water species which may occur in large numbers anywhere south of the 3° isotherm.									
Euphausia superba	1·00	336	434	822	1700	95·4	1·80	0·10	0·10
Cleodora sulcata	3·33	2·55	5·75	81·8	0·69	0·10	0·37	0·14	3·00
Salpa fusiformis f. *aspera*	16·6	52·4	79·8	56·4	24·8	11·4	4·60	6·40	40·4
Tomopteris sp. (large)	1·27	0·52	0·60	1·17	0·98	0·21	0·18	—	0·14
Tomopteris sp. (small)	18·0	36·1	5·70	5·00	4·70	2·20	1·00	3·70	9·40
Metridia gerlachei	421	543	289	538	117	68·0	26·7	1·30	—
Clione antarctica	5·89	2·64	1·60	1·37	0·91	1·25	0·56	0·25	—
Limacina helicina	80·2	19·5	25·5	41·6	7·20	7·60	5·50	3·00	—
Pyrostephos vanhöffeni	22·6	32·0	5·30	14·4	8·90	3·30	1·40	3·50	3·30
(*h*) Species typical of the coldest regions, which rarely or never approach the convergence.									
Sibogita borchgrevinki	0·27	0·10	—	0·08	0·12	0·07	—	—	—
Dimophyes arctica	14·4	7·80	0·80	2·20	1·70	—	—	0·20	1·40
Vanadis antarctica	7·27	0·19	0·77	0·03	0·08	—	—	0·42	0·67
Diphyes antarctica	2·09	1·48	0·67	1·61	0·08	—	—	—	—
Eusirus antarcticus	1·57	0·95	0·70	0·07	0·10	—	—	—	—
Auricularia antarctica	4·55	2·50	0·31	0·19	0·02	—	—	—	—
Haloptilus ocellatus	108	24·8	0·40	—	—	—	—	—	—
Neritic species									
Antarctomysis sp.	—	—	—	38·0	48·0	—	—	—	—
Euphausia crystallorophias	—	1·06	0·07	—	—	—	—	—	—

temperature was taken only at the surface. However, the mean surface isotherms bear a sufficiently uniform relation to the mean isotherms at 50 or 100 m. and will serve our purpose here. Since the great majority of stations have been taken in the summer months a much more reliable chart can be constructed of the mean summer isotherms than of the mean annual isotherms. Either would suffice, however, for we are seeking a relative and not an absolute correlation. Fig. 22 shows the mean summer isotherms and is a provisional chart derived from temperatures recorded in the three seasons 1928–31.

In Table III the species are arranged in order of their apparent preference for warm or cold water. The figures in the table represent the average number of each species per haul. Samples have been disregarded where the haul was made at a time of day when the diurnal variations of any particular species precluded the taking of a representative sample. Catches in the Bransfield Strait, where the plankton is disproportionately thin, have usually been omitted, and for all but one or two of the rarer species, only one station has been counted for each line of stations in each South Georgia survey. The end station of the line is taken, or the outermost one permitted by the diurnal variations. The actual figures are much influenced by variations in the general richness of the plankton in different localities, or by patchiness of the plankton, and are therefore individually unreliable. Thus the "$-1°$" column depends almost entirely on a few stations in the Bellingshausen Sea, west of Peter 1st Island, where the plankton was particularly rich, and the figures in this column are consequently deceptively high. The actual figures are therefore used only as the principal basis of a general grouping of the species according to the temperature belt they mainly inhabit.

The table shows the distinction between the warm-water species, the widespread species, and the cold-water species. The neritic species are unimportant and are shown in a separate category. There is of course no very hard and fast distinction between the main groups or the subsidiary groups, and a larger body of data might bring about some modification of the order in which the species are listed.

It is interesting to compare this table with the table of mean diurnal variations, for it will be seen that the warm-water species are mostly those which have the most marked diurnal variations and many of the cold-water species have no significant variations. There are exceptions, for *Parathemisto* shows little diurnal variation, while *Salpa* and *Metridia* vary considerably. Hardy and Gunther (1934), however, find a distinct vertical migration in *Parathemisto*. The phenomenon is no doubt partly connected with the reduction or absence of darkness in summer in the high latitudes inhabited by the cold-water species, but the question will not be pursued any further here, since it can be more properly dealt with when the samples from the 24-hour stations have been finally worked out.

DISTRIBUTION OF RICH AND POOR PLANKTON

It is well known that as a general rule the plankton of the surface waters of the tropics is very thin, that in the temperate regions it is richer, and that in the Arctic and Antarctic it is comparatively abundant. Murray and Hjort (1912) mention that "the closing nets of the 'Michael Sars', when hauled from 200 m. to the surface in the Sargasso Sea, yielded on the average 3 c.c. of plankton, while in the Norwegian Sea from 85 to 225 c.c. were obtained in numerous similar hauls". According to Jespersen (1923) the volume of macroplankton in 50–60° N in the North Atlantic is 10–20 times as great as in 20–30° N. The upwelling in the Antarctic Zone of water rich in nutrient salts results in a luxuriant development of phytoplankton, and this in turn supports an abundant animal plankton. Hart (1934) mentions the richness of the Antarctic phytoplankton, and Hentschel (1928) and Hentschel and Wattenberg (1930) publish charts of the South Atlantic which show the association of areas of rich plankton with the areas of upwelling of cold water.

The richest plankton of all is found in the Antarctic surface water, but it is by no means uniformly abundant over the whole of the Antarctic Zone. The quantity of macroplankton, for instance, varies very much at different times and in different places, and these variations so far as they can be ascertained from the present material will be described in the following pages.

A chart showing the distribution of the total number of organisms per haul is roughly representative of the distribution of the richness of plankton, though it does not necessarily illustrate the distribution of the majority of species. It represents rather the half-dozen commonest species. But the main difficulty in charting the richness of the plankton is, perhaps, that there is no quite satisfactory means of allowing for diurnal variations, since different samples have different proportions of the variable species. However, the few species like *Calanus acutus* and *Rhincalanus gigas*, which make up the bulk of the plankton, do not have a very marked diurnal variation and the time of day has a far smaller effect on the amount of plankton in a sample than the actual distribution of quantity.

GENERAL DISTRIBUTION

Fig. 23 shows the numbers of organisms taken at all stations in January, February and March in all four seasons (1927–31), with the exception of the intensive lines of stations taken in the South Georgia and Bransfield Strait surveys. The figures stand for the number of hundreds of organisms in each sample, but the shoaling species, *Euphausia superba*, *Limacina balea*, and *Salpa fusiformis* are omitted. For instance at WS 551, the last station on the line to the eastern Weddell Sea and marked 56, just over 5600 organisms were taken. Although the diurnal variations have a minor effect on the total contents of a sample, the figures are shown in italics for hauls made in daytime between the hours of 0600 and 1700. The shading is based purely on the figures shown on the chart, and is intended merely to draw attention to the positions at which large, medium or small hauls were taken.

This chart shows that around the coasts of Graham Land, the South Orkneys, the South Shetlands, Adelaide Island, Alexander 1st Land, etc., the summer plankton is very thin. Away from this region in all directions it seems that the richness of the plankton increases, and reaches a maximum in the South Georgia and South Sandwich region, and to the west of Peter 1st Island in the Bellingshausen Sea.

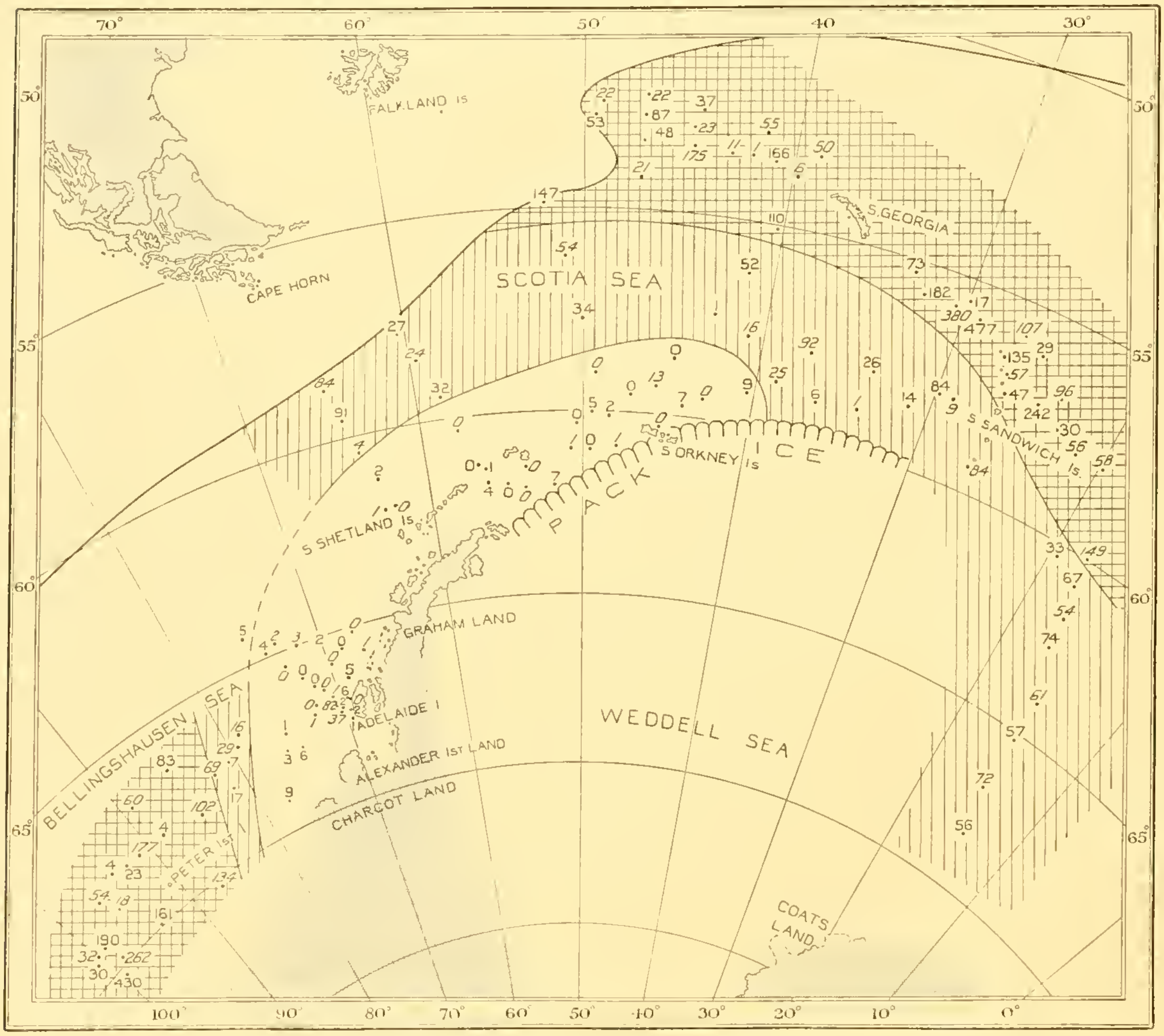

Fig. 23. Distribution of macroplankton quantities in summer. Figures show the number of hundreds of organisms in each sample, shoaling species being omitted. Those in italics are day hauls and others are night hauls.

There can be no doubt of the contrast which normally exists between the South Georgia and Graham Land areas, for these regions have been visited many times in a succession of years. Nor can there be any doubt that the outer parts of the Antarctic water between South Georgia and the Falkland Islands, harbour a quite rich plankton during at least a large part of the summer. Cruises in the Bellingshausen and Weddell Seas have been made on fewer occasions, but it is probable that there is always a rich summer plankton in these regions.

It may be mentioned that Hart (1934) finds that the Bransfield Strait is on the average also poorer in phytoplankton than other areas, but the contrast is not so great as it is with the macroplankton.

The reason for the scarcity of plankton around the South Shetlands and South Orkneys cannot at present be stated with certainty, but this is an area in which there is a considerable upwelling of water from the deeper layers, and these deeper layers are of course comparatively poor in plankton. I am informed by our hydrologists that the region of thin plankton shown in Fig. 23 coincides roughly with an area in which the surface water has been found to have a low oxygen content. This suggests that the water has recently risen from a deeper level where the consumption of oxygen has not been balanced by exposure to air. It is curious that some species, such as *Euphausia superba* and *Salpa fusiformis*, are nevertheless sometimes found in large numbers in parts of this area.

VARIATIONS IN ABUNDANCE

There is evidence to show that in the course of the year certain changes take place in the distribution of the amount of plankton, and although these changes cannot be followed with certainty at the present stage it is worth while to consider the material in some detail. It has not been found practicable to make a series of repeated observations in one place throughout a year or part of a year, and it will be necessary to compare the conditions in, for instance, December in one season with April in another season, and so on. Conclusions drawn in this way must of course be formed with caution.

South Georgia

Figs. 24–30 represent the results of successive surveys of the South Georgia whaling grounds in the four seasons 1927–31, and they are constructed on exactly the same lines as Fig. 23.

The essential facts shown by these charts are as follows.

In the 1927–8 survey (February–March, Fig. 24), the plankton was very thin to the north, east and west, but abundant on the south-west side. The increase here was not due to a special development of one species but to a general increase of all the important species.

In the first 1928–9 survey (August–September, Fig. 25), there was a very thin plankton to the west, north, east and south-east. The south and south-west sides were not examined.

In the second 1928–9 survey (December–January, Fig. 26), the plankton was in most places moderate or rather poor, but there was a patch of rich plankton to the south-east. In general it might be called "patchy". Two extra lines (WS 417–26) worked in April of the same season (Fig. 27) produced fairly heavy catches near the south end of the island, but indicated a rather scarce plankton to the south-west.

In the 1929–30 survey (January–February, Fig. 28), the plankton was patchy in places but in general very abundant. In the same season South Georgia was revisited in May. Although the routine N 100 B was not used again, closing N 100 B's were

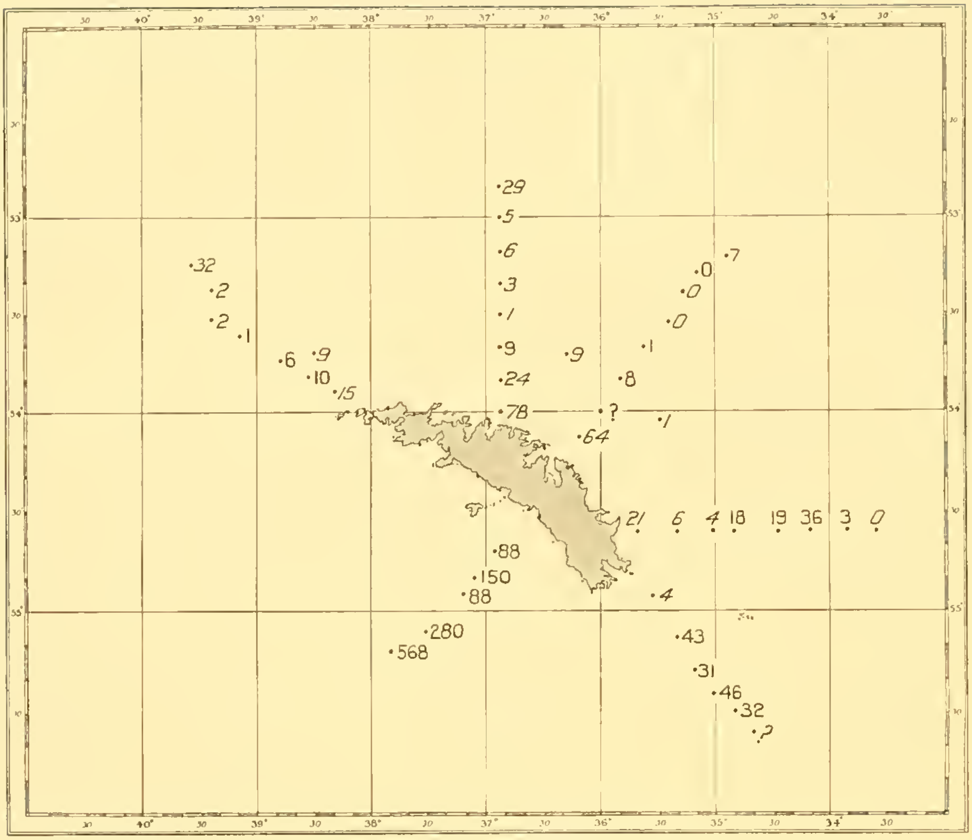

Fig. 24. Distribution of plankton quantities around South Georgia, 1927–8, Sts. WS 144–93.

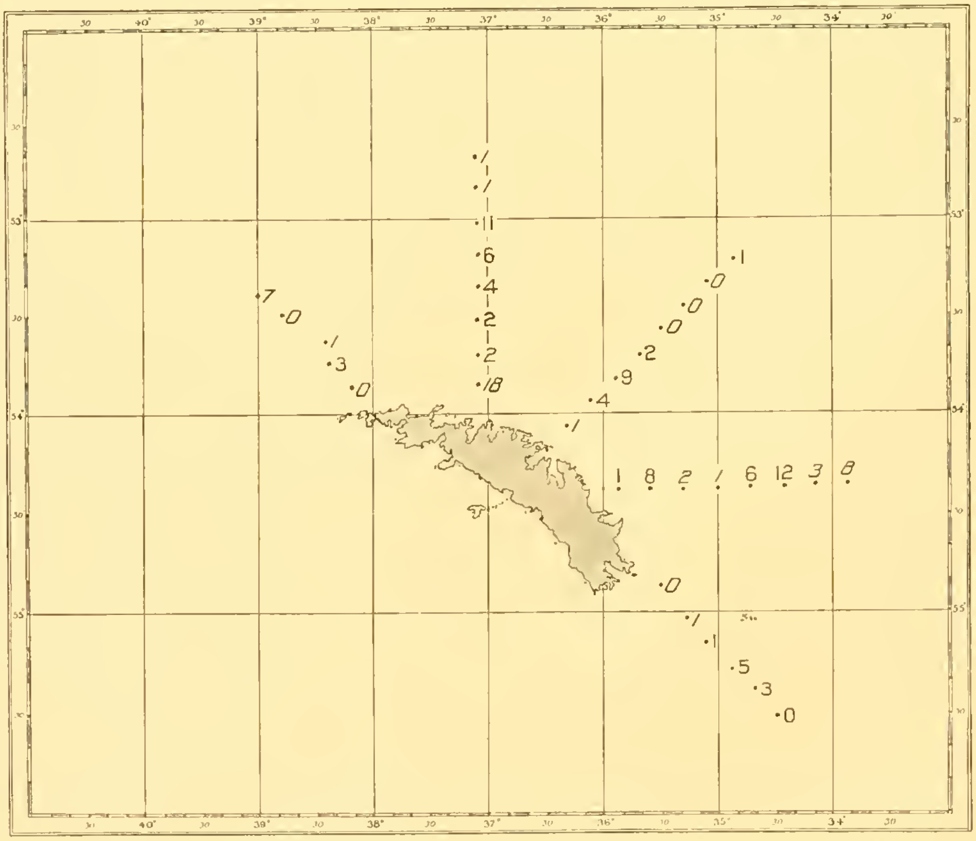

Fig. 25. Distribution of plankton quantities around South Georgia, 1928–9, Sts. WS 257–96.

towed at different levels at an uncompleted 24-hour station (393, see Station List). The catches are not strictly comparable to the routine samples, but they strongly suggest that off the north-east coast in May there was far less plankton than in January.

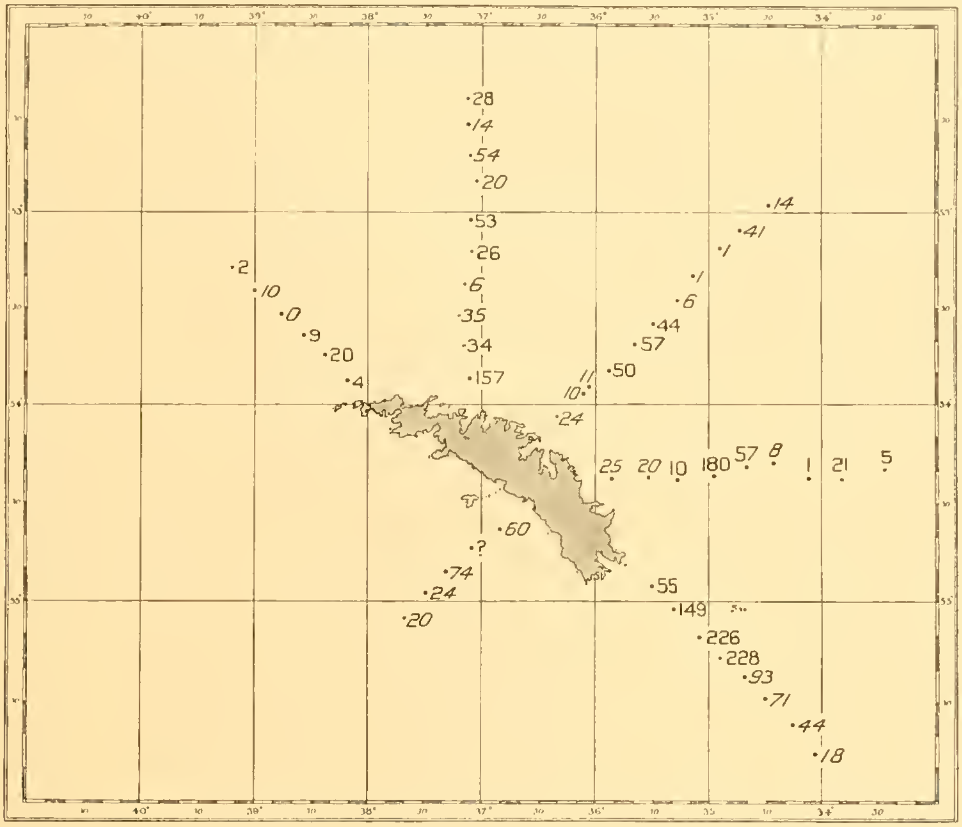

Fig. 26. Distribution of plankton quantities around South Georgia, 1928–9, Sts. WS 321–72.

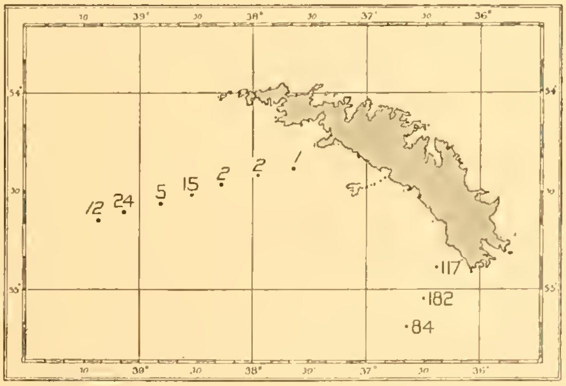

Fig. 27. Distribution of plankton quantities around South Georgia, 1928–9, Sts. WS 417–26.

In the 1930–1 SURVEY (November, Fig. 29), a very rich plankton was again found on the north side of the island, and a slightly less dense population to the south. The line repeated in March in the same season (WS 565–75) showed a considerable reduction in the plankton on the north side of the island (Fig. 30).

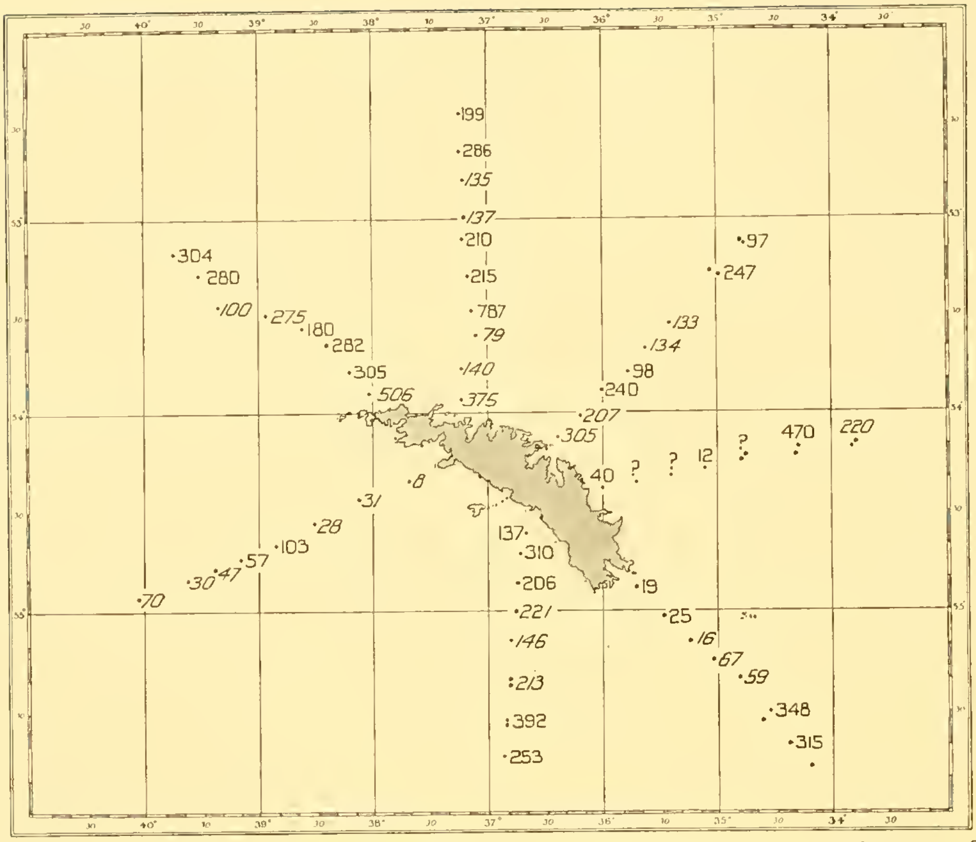

Fig. 28. Distribution of plankton quantities around South Georgia, 1929–30, Sts. 300–58.

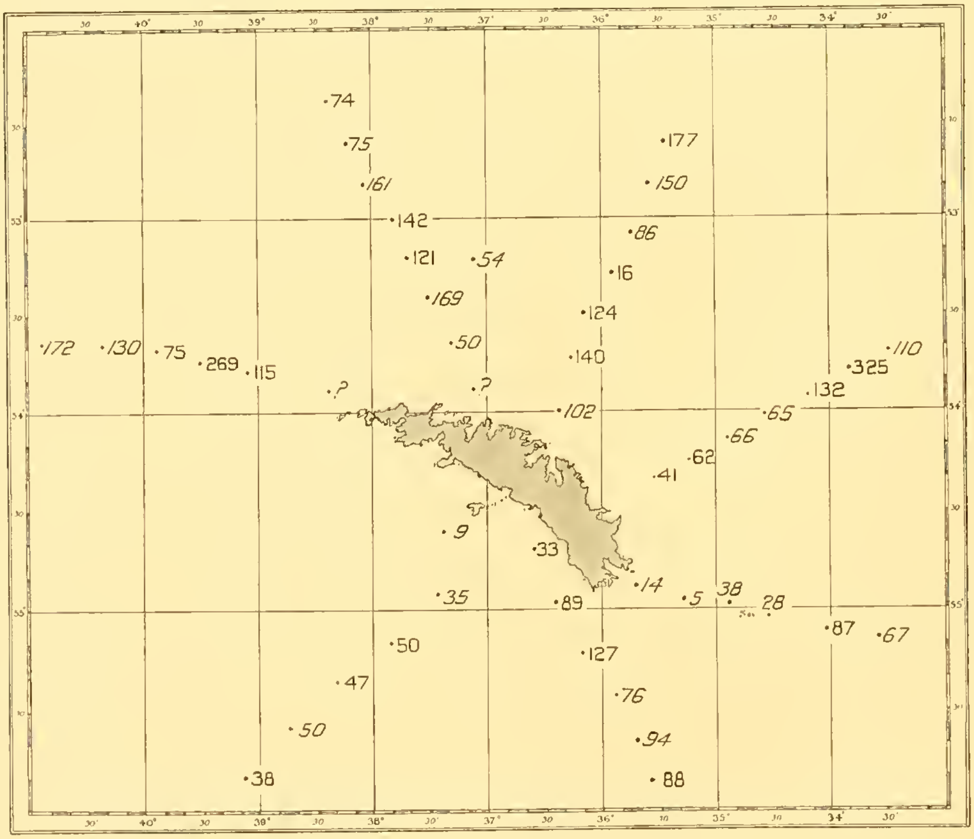

Fig. 29. Distribution of plankton quantities around South Georgia, 1930–1, Sts. 478–525.

The main plankton survey has usually been carried out near the middle of the season, and in those years in which further hauls have been made later in the summer there has been evidence of a reduction in the amount of plankton towards the autumn, at any rate on the north side of the island.

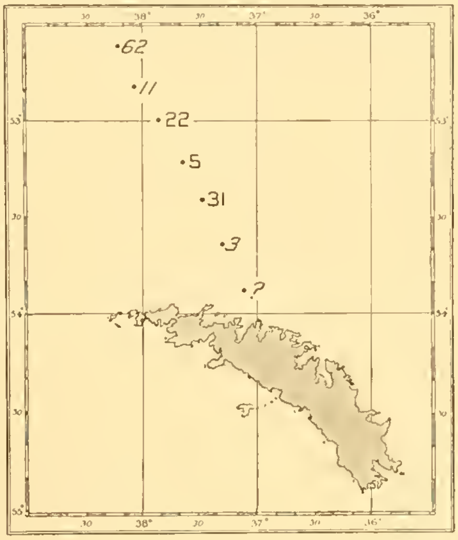

Fig. 30. Distribution of plankton quantities around South Georgia, 1930–1, Sts. WS 565–75.

The following list includes all the N 100 B samples taken in the immediate vicinity of South Georgia during the period 1927–31, and shows the average number of organisms per haul for each group of stations.

Date		Station	Position	Number of hauls	Average number of organisms per haul
1927–8	Feb.–March	WS 144–93	South Georgia survey	44	3,913
	April	WS 196	South-west side of South Georgia	1	2,361
1928–9	Aug.–Sept.	WS 257–96	South Georgia survey	35	468
	October	WS 311	South-east of South Georgia	1	326
	November	WS 313	South-east of South Georgia	1	7,545
	Dec.–Jan.	WS 321–72	South Georgia survey	51	4,674
	April	WS 417–26	South side of South Georgia	10	4,488
1929–30	October	WS 464	North side of South Georgia	1	2,146
	Jan.–Feb.	300–58	South Georgia survey	54	19,224
	May	393	North side of South Georgia	1	(Reduced numbers)
1930–1	November	475–525	South Georgia survey	47	9,485
	March	WS 565–75	North side of South Georgia	7	2,062

In Fig. 31 all four seasons are taken together and the average number of organisms per haul for each group of stations is plotted according to the month or mean date at which the stations were taken. As would be expected the plankton is much richer in the summer than in the winter, but the regularity of the curve is broken by the low figure for the 1928–9 survey (December–January). It is difficult to account for this, but the patchiness of the plankton may be seen from Figs. 24, 26 and 27, and might well result in irregularities in the curve.

Little reliance can be placed on the single stations (WS 311, etc.) for reasons given on p. 71, but it will be seen that they support the suggestion that the plankton increases rapidly about the middle of November. Apart from this no reliance can be placed on the curve, for the reason that the plotted points are derived from different seasons, and the volume of plankton production in these seasons may have been different.

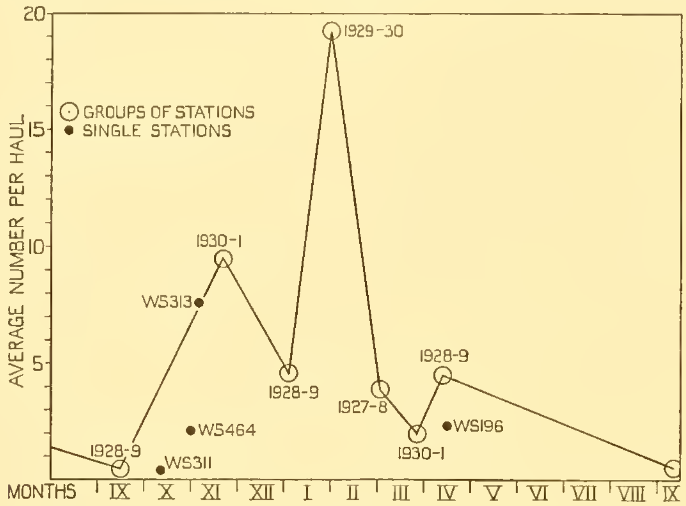

Fig. 31. Quantities of plankton at different times of year around South Georgia. Figures on the vertical scale represent numbers of hundreds of organisms.

If we consider the charts of the four principal surveys in the order of the months in which they were taken, i.e. November 1930–1, December–January 1928–9, January–February 1929–30, and February–March 1927–8, we see that in the earliest (Fig. 29) the richest plankton was mostly grouped to the north of South Georgia, while in the latest (Fig. 24) it was concentrated to the south. In the January–February survey (Fig. 28) it was very rich almost everywhere, but in the December–January survey (Fig. 26) the only rich plankton was a patch to the south-east. It seems possible that there is a tendency for the concentrated plankton to occupy the northern part of the whaling area in the early part of the season, and later to shift down to the south side, and that in 1928–9 the shift for some reason took place unusually early, resulting in the reduction in the average number of organisms per haul in that survey. With the available data we cannot be certain that this shift takes place: it can only be said that there is some evidence for it.

Drake Passage and Scotia Sea

Figs. 32–9 are drawn on exactly the same principle as Fig. 23, but they show the amount of plankton taken at all stations in the Scotia Sea, and each chart shows the stations taken within a single short period. No certain conclusions can at present be drawn from the figures shown, but it will be seen that, while at all times there is a scarce plankton in the vicinity of the South Orkney and South Shetland Islands, the quantity of plankton varies greatly in other places.

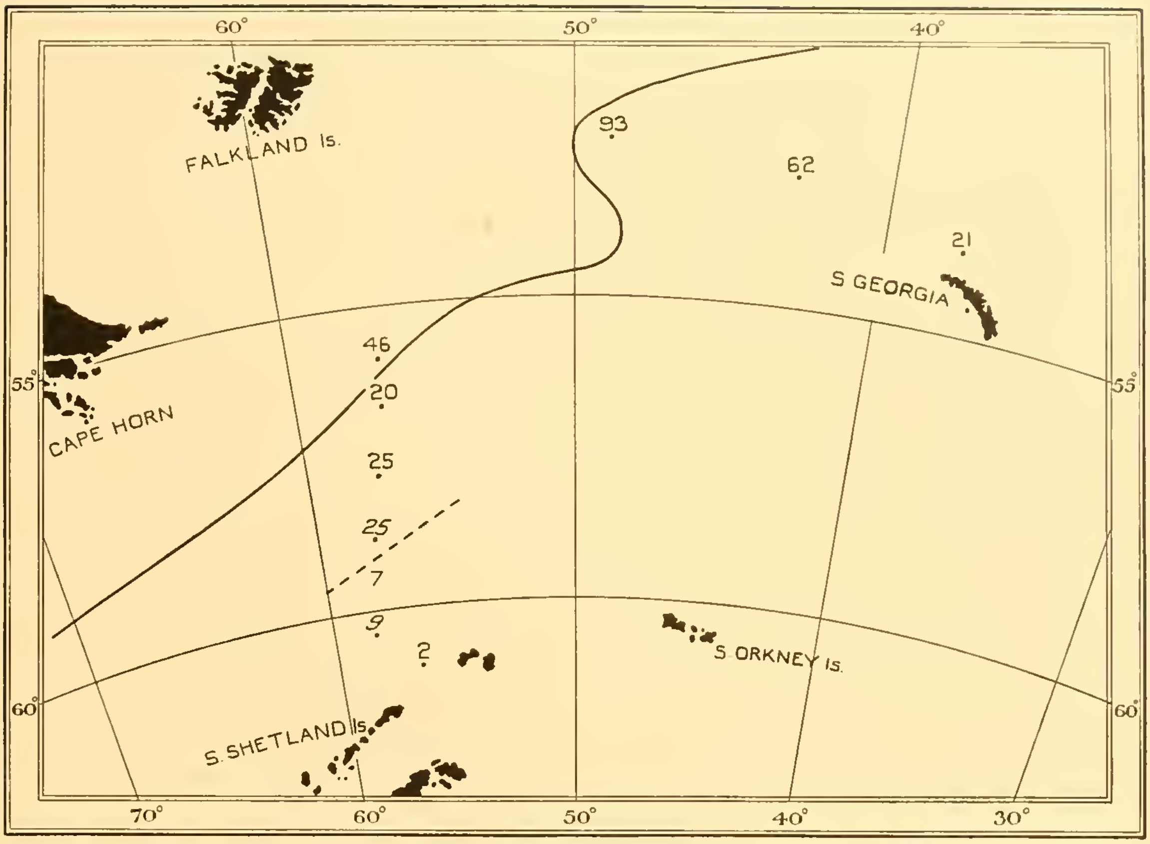

Fig. 32. Distribution of plankton quantities in the Scotia Sea, November 1929–30, Sts. WS 464–74. Figures show the number of hundreds of organisms in each sample, shoaling species being omitted. Those in italics are day hauls and others are night hauls.

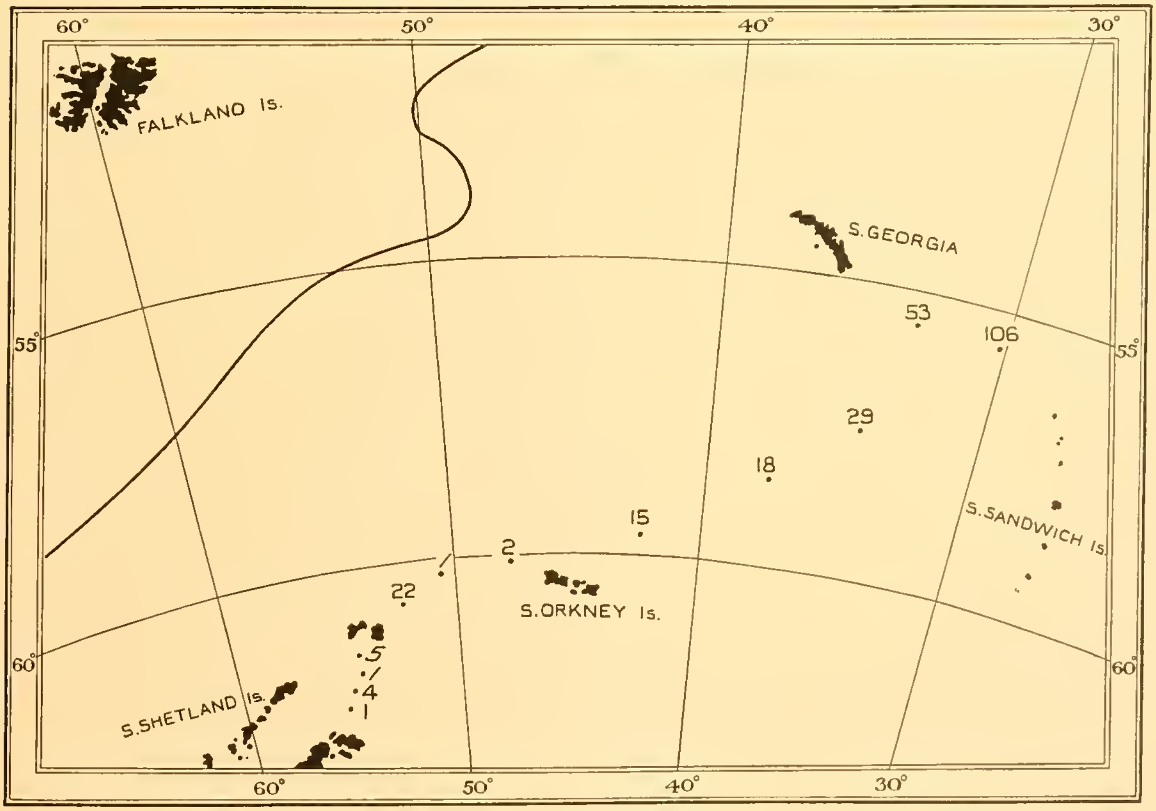

Fig. 33. Distribution of plankton quantities in the Scotia Sea, December 1930–1, Sts. 528–41.

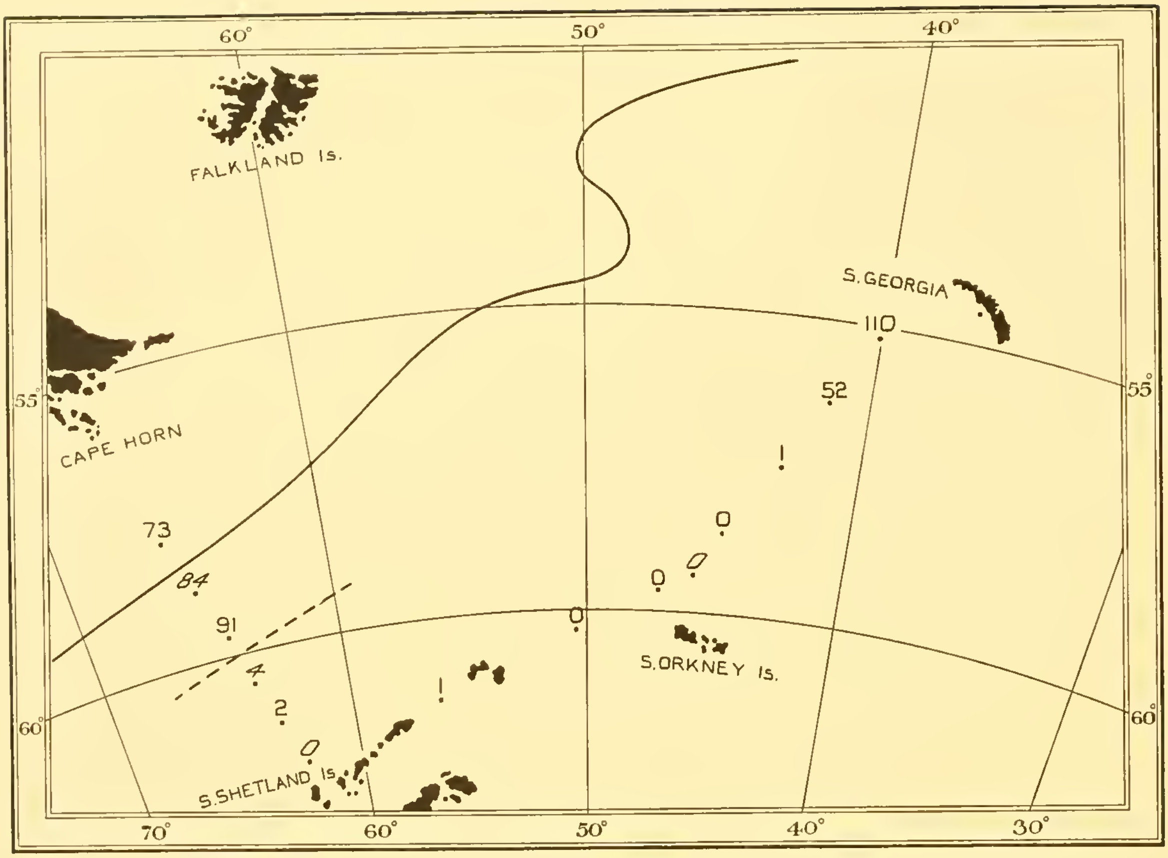

Fig. 34. Distribution of plankton quantities in the Scotia Sea, February 1928–9, Sts. WS 374–405.

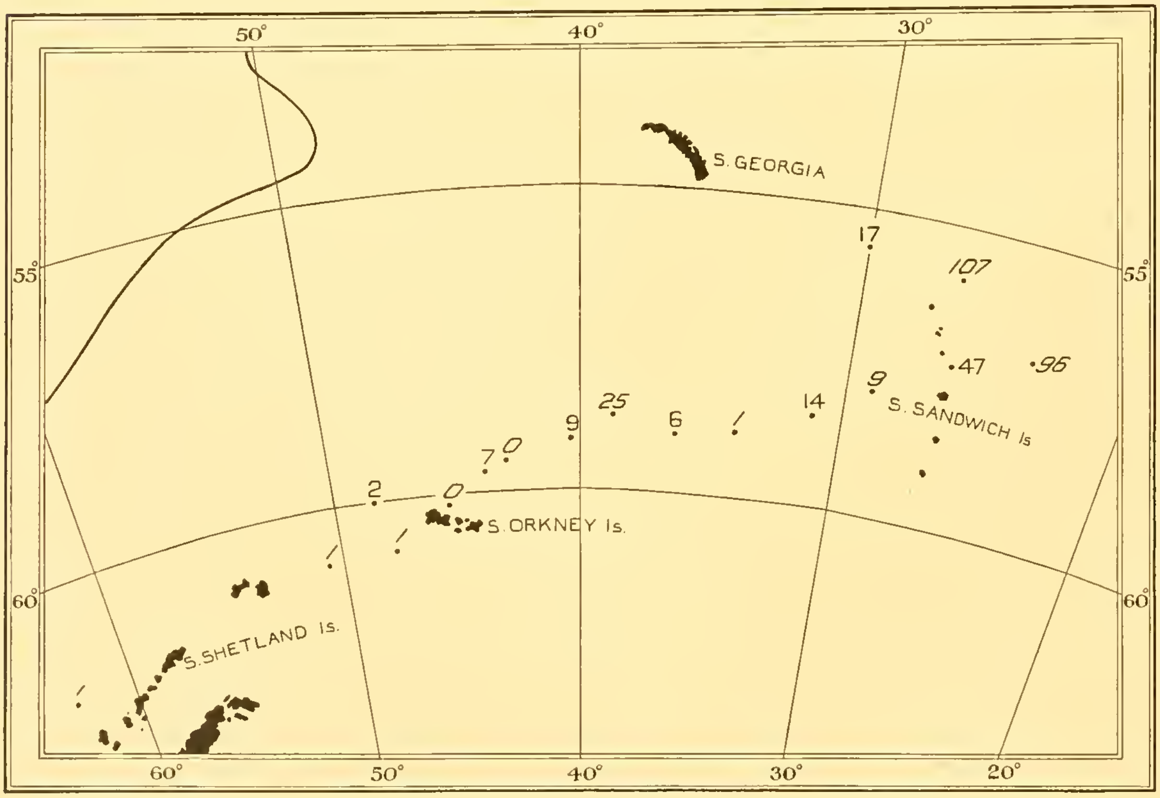

Fig. 35. Distribution of plankton quantities in the Scotia Sea, February 1930–1, Sts. 613–29.

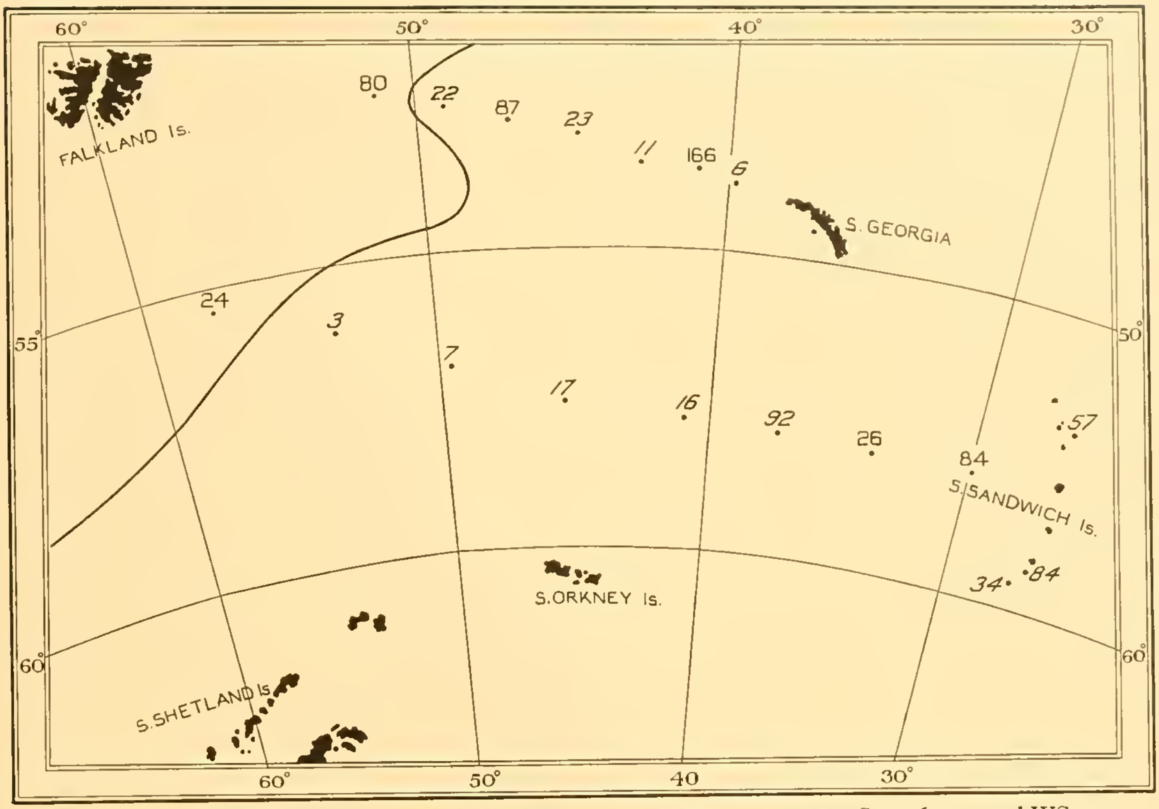

Fig. 36. Distribution of plankton quantities in the Scotia Sea, March 1929–30, Sts. 365–75 and WS 520–30.

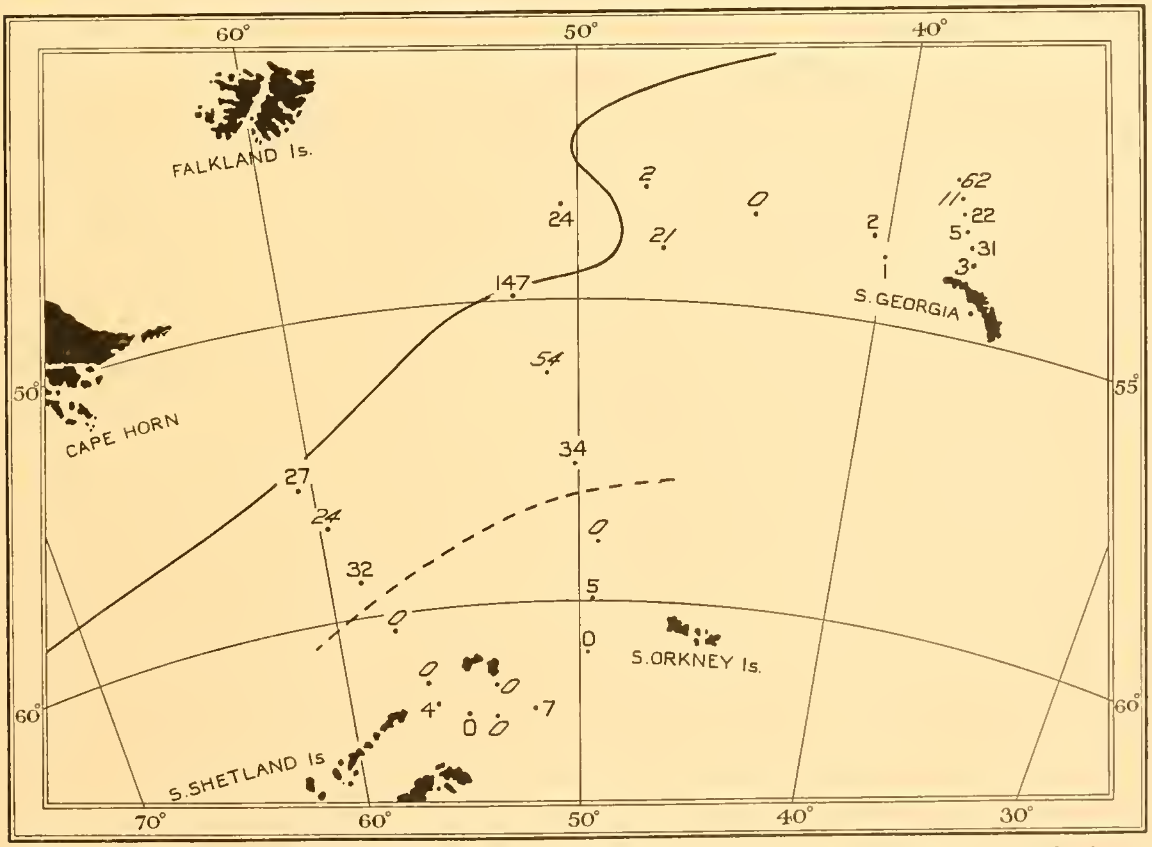

Fig. 37. Distribution of plankton quantities in the Scotia Sea, March 1930–1, Sts. 631–59 and WS 565–75.

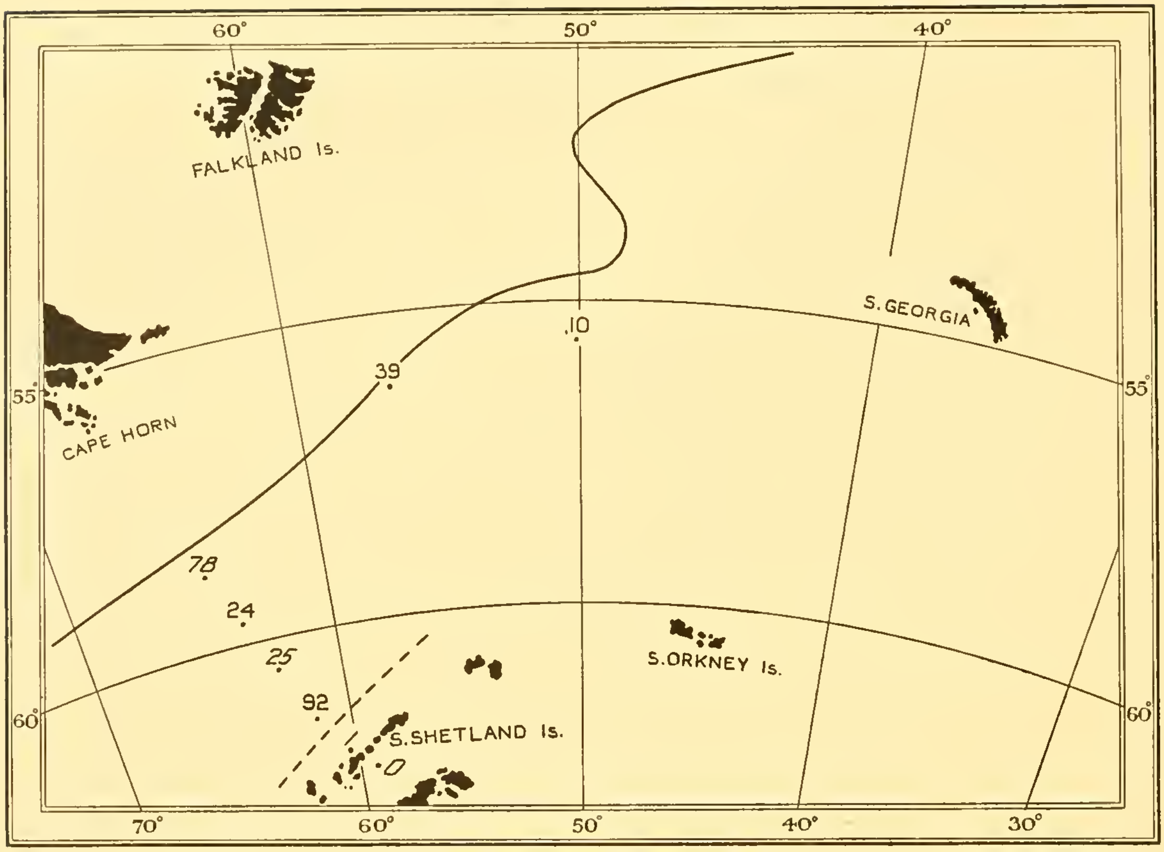

Fig. 38. Distribution of plankton quantities in the Scotia Sea, April 1929–30, Sts. 378–92.

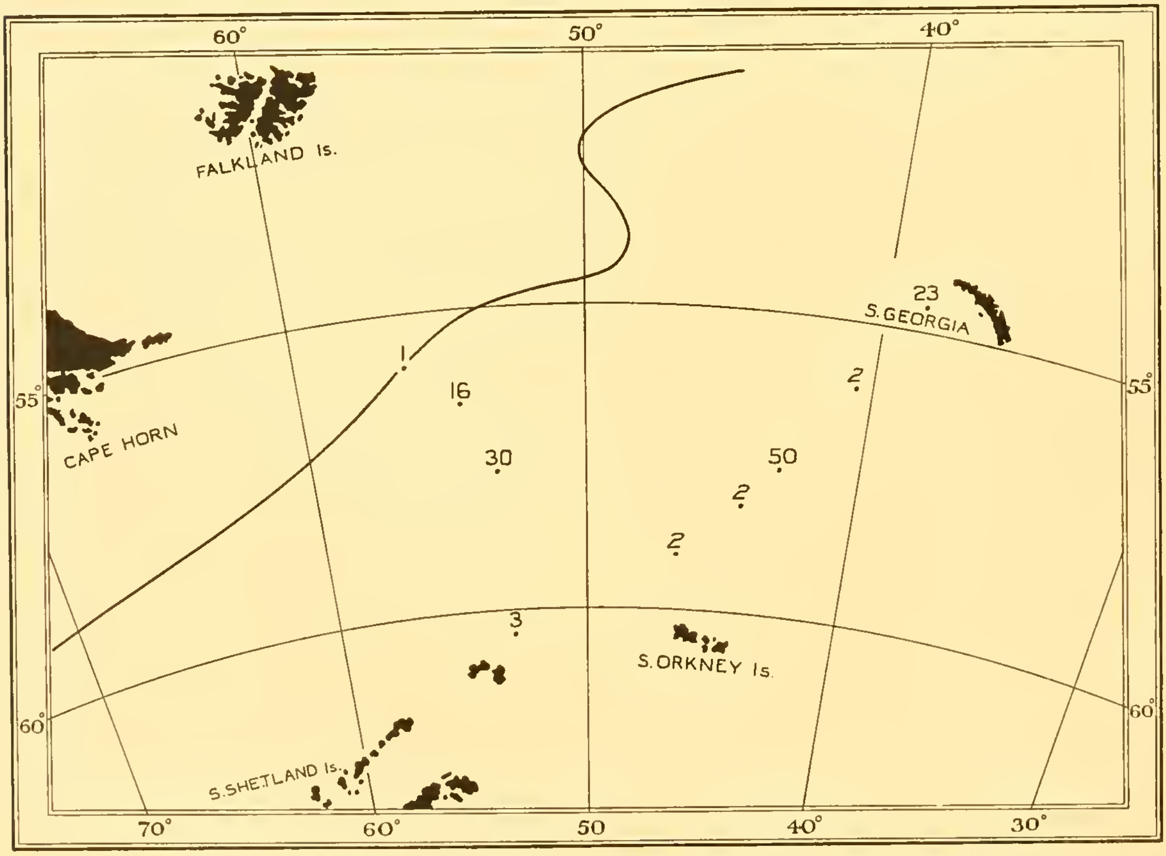

Fig. 39. Distribution of plankton quantities in the Scotia Sea, April 1927–8, Sts. WS 196–205.

These charts are shown primarily as a record for comparison with more recent data or future material, but one interesting point may be mentioned here. In each of the lines of stations between Cape Horn and the South Shetland Islands there is an abrupt change from the rich plankton of the greater part of the Scotia Sea to the thin plankton of the Shetland neighbourhood. The position of the change is indicated by a pecked line in Figs. 32, 34, 37 and 38. If these four figures are compared it will be seen that on the November and February lines (Figs. 32 and 34) the change comes at about 150 miles from the South Shetland Islands, that on the March line (Fig. 37) it is about 100 miles off, and on the April line (Fig. 38) it is only about 30 miles off. From this it seems possible that there is normally a rich plankton in the central part of the Drake Strait which spreads farther south towards the end of the summer. Here comparison is made between different months in different years, so that the apparent shift may possibly be the effect of a coincidence. The results of future work will no doubt settle the question.

If there is in fact such a southward trend of the plankton it would not of course imply an actual transport of plankton towards the south. Such a thing would seem impossible in the present state of our knowledge of the hydrology of these regions. All the evidence goes to show that the Antarctic surface water in these latitudes moves towards the east and north, and there seems no possibility of even a local or periodical deflection towards the south. A more likely explanation might lie in the variation of the amount of upwelling of the "new" water on the south side of the Drake Passage. It has been found that the area occupied by this "new" water extends farthest to the north in midsummer and is most contracted in winter. The boundaries of the "new" water and of the thin plankton do not appear quite to coincide, but there is a similarity in the changes of position of these boundaries. A rich plankton has been found in the Bellingshausen Sea in the neighbourhood of Peter 1st Island, and it is to be supposed that this is carried by the easterly drift towards the Drake Passage. A reduction in the upwelling of water and a shrinkage of the area it occupies in the southern part of the Drake Passage might then make way for the plankton from the Bellingshausen Sea and thus produce the effect of a southerly trend of the rich plankton.

Little can be said of the variations in the quantity of plankton in the more eastern parts of the Scotia Sea. Figs. 32–9 suggest that the plankton may perhaps be a little more patchy in the later than in the earlier part of the summer.

DISTRIBUTION OF WARM- AND COLD-WATER SPECIES

It has been shown that among the Antarctic macroplankton species there are many which prefer, or are confined to, either the warmer or the colder water, but just as there are alterations in the position of the rich and poor plankton, so there are changes in the distribution of the warm- and cold-water species.

SOUTH GEORGIA

Table IV shows, for each species, the average number of specimens per haul for each group of stations off South Georgia. These are the same groups as those listed on p. 115, but the single stations are omitted because they give no reliable indication of the presence or absence of the less common species. The species are listed in order of their preference for warm or cold water, but those which come under the heading of "Wide-spread Species" in Table III, p. 107, are omitted. The groups of stations (vertical columns) are arranged in order of the months in which they were taken.

Table IV. *Warm- and cold-water species near South Georgia*

	South Georgia survey 1930–1	South Georgia survey 1928–9	South Georgia survey 1929–30	South Georgia survey 1927–8	North side of South Georgia 1930–1	South side of South Georgia 1928–9	South Georgia survey 1928–9
	Nov.	Dec.–Jan.	Jan.–Feb.	Feb.–Mar.	March	April	Sept.
Warm-water species							
(*a*) *Euphausia vallentini*	—	—	—	0·02	—	—	1·33
(*b*) *Eucalanus* sp.	51·1	14·4	—	—	—	—	—
Candacia sp.	31·7	—	4·17	4·00	—	—	1·50
Heterorhabdus sp.	5·71	—	—	17·0	—	—	2·56
Euphausia triacantha	2·14	1·08	52·9	17·1	12·0	0·67	3·80
Calanus simillimus	101	188	372	340	—	287	26·7
Pleuromamma robusta	72·7	119	387	106	16·0	21·3	112
(*c*) Chaetognatha	937	160	547	242	135	266	2·61
Limacina balea	3·95	12·4	63·0	1780	—	116	66·1
Pareuchaeta sp.	31·1	549	413	166	213	35·0	2·67
Parathemisto gaudichaudi	18·8	136	597	27·3	91·0	103	3·91
Euphausia frigida	128	208	1200	258	673	233	181
Cold-water species							
(*g*) *Euphausia superba*	3260	29·8	1160	720	1850	7·60	278
Cleodora sulcata	1·57	1·09	0·05	0·24	—	—	0·19
Salpa fusiformis f. *aspera*	7·14	500	0·65	6·53	90·0	0·20	1·11
Tomopteris (large)	1·05	1·67	0·57	0·29	0·60	—	0·14
Tomopteris (small)	7·28	2·85	0·46	0·46	0·40	—	0·51
Metridia gerlachei	372	101	12·5	106	194	81·1	12·3
Clione antarctica	3·41	3·81	0·16	0·04	—	—	2·14
Limacina helicina	77·3	31·5	—	0·09	—	—	1·29
Pyrostephos vanhöffeni	—	0·62	—	0·27	22·4	—	0·29
(*h*) *Sibogita borchgrevinki*	0·14	0·02	—	—	—	—	—
Dimophyes arctica	5·09	0·08	—	—	0·02	—	—
Vanadis antarctica	0·09	0·02	0·02	—	0·60	—	—
Diphyes antarctica	0·37	—	—	—	—	—	—
Eusirus antarcticus	0·45	—	—	—	—	—	—
Auricularia antarctica	—	—	—	—	—	—	—
Haloptilus ocellatus	0·93	—	—	—	—	—	—
Neritic species							
Antarctomysis sp.	54·2	36·1	175	22·7	—	3·75	6·57

It will be seen that the November survey of 1930–1 differs from the others in that it has representatives of all species but one of the very coldest groups (*h*), and it must be remembered that these species never occur except in small numbers, and the mere presence of one of them in a sample is of some significance. The moderately "cold" species also (group (*g*)) are on the whole better represented in this survey than in the others, *Limacina helicina* and *Metridia* being specially numerous. Of the warm-water species *Eucalanus*, *Candacia* and the Chaetognatha are also strongly represented, but *Euphausia triacantha*, *Calanus simillimus*, *Pleuromamma*, *Limacina balea*, *Pareuchaeta*, *Parathemisto*, and *Euphausia frigida* are all in comparatively small numbers. It can be said in fact that in spite of the prominence of one or two warm-water species, this November survey was characterized by a much "colder" plankton than any of the other groups of stations.

During the survey of 1928–9 taken in December and January three of the very coldest group were present and the moderately "cold" species were well represented, notably *Salpa*, *Tomopteris* and *Clione*. Of the warm-water species *Candacia* and *Heterorhabdus* were absent, *Euphausia triacantha* and the Chaetognatha were scarce; but there was an increase in the number of *Calanus simillimus*, *Pleuromamma*, *Limacina balea*, *Parathemisto* and *Euphausia frigida*, and *Pareuchaeta* was more numerous than at any other time.

During the survey of 1929–30 in January and February only one of the coldest group was taken, a single specimen of *Vanadis* at St. 336, and the other "cold" species were very poorly represented. Of the warm-water species *Euphausia triacantha*, *Calanus simillimus*, *Pleuromamma*, *Parathemisto*, and *Euphausia frigida* were more numerous than at any other time (though it must be remembered that the plankton as a whole was very abundant during this survey) and the Chaetognatha, *Limacina balea*, and *Pareuchaeta* were also prominent.

The survey of 1927–8 in February and March was also characterized by a warm-water plankton. None of the "coldest" group was taken, and with the exception of *Metridia* the moderately "cold" species were all scarce. Among the warm-water species the presence of the sub-Antarctic species, *Euphausia vallentini*, is specially significant and although the plankton as a whole was not very rich *Heterorhabdus* and *Limacina balea* here reached their maxima and *Calanus simillimus* and *Euphausia frigida* were both relatively numerous.

At the stations taken in March 1930–1 the plankton population was again of a colder type, in which two of the very cold-water species are present and *Pyrostephos*, *Metridia* and *Salpa* are strongly represented. There is support for the "warm" group, however, in *Pareuchaeta*, *Parathemisto* and *Euphausia frigida*, whose numbers are large in proportion to the total amount of plankton.

At the stations taken in April 1928–9, hardly any colder water species were represented. Of the warm-water species *Eucalanus*, *Candacia* and *Heterorhabdus* were absent, but *Calanus simillimus*, *Limacina balea* and *Parathemisto* were present in quite large numbers.

Finally on the winter survey of September 1928, although the temperature of the water was below 0° C. at all stations and colder than at any other group of stations around South Georgia, none of the "coldest" species was taken and all the warm-water species except *Eucalanus* were present. *Euphausia vallentini* indeed was better represented than during the 1927–8 survey.

The conclusion to be derived from these facts is that, if the stations taken in March 1930–1 are excepted, the order of the groups of stations according to the months in which they were taken is also the order of "coldness" of the plankton population. Thus the November survey had much the "coldest" plankton. Next comes the December–January survey with still a distinct cold-water element, then the January–February survey with a warm-water plankton, and then the February–March survey with a similar plankton but with the sub-Antarctic *E. vallentini* and no *Vanadis*. There is no doubt about the order of "coldness" of these four surveys, and although we are dealing with four successive years it is highly probable that as the summer advances the South Georgia plankton becomes "warmer and warmer". The April stations and the September survey reveal perhaps the "warmest" plankton of all. The cold-water species taken in March 1930–1 can be explained by the fact that that season was an exceptionally cold one in which the pack-ice remained for a long time far north of its usual limits. Whether the November plankton around South Georgia normally has quite such a strong element of cold-water species as it did in 1930–1 is doubtful, but at all events the evidence leaves no reasonable doubt: (i) that in the South Georgia plankton the cold-water species are most strongly represented in the spring, and that as the summer advances they are reduced and the warm-water species gain ground, and that the warm-water plankton continues right through the winter; (ii) that an abnormally cold summer results in a "colder" plankton which however still becomes "warmer" as the summer passes.

There is evidence to show that changes of the same kind take place in other parts of the Antarctic water, and it will be convenient first to take the eastern part of the area covered by stations taken in 1927–31.

THE SOUTH SANDWICH AND WEDDELL SEA REGION

Table V shows, for various groups of stations in this region, the average number per haul of the warm- and cold-water species. The species grouped under (*d*), (*e*), and (*f*) in Table III, p. 107, and the neritic species *Antarctomysis* and *Euphausia crystallorophias*, are omitted.

In the 1927–8 season no cruise was made to the east or south-east of South Georgia, but in September and October 1928–9 the 'William Scoresby' took a number of stations along the edge of the pack-ice which lay about 100 miles to the east of the island (see Fig. 11). Two of the stations (WS 287 and 288) were taken late in September before the winter survey of the South Georgia area had been finished. The ship then returned to South Georgia, completed the survey and then carried out the other ice-edge stations early in October (WS 298–310). We have seen that during this winter survey the plankton was of a clearly warm-water type (see Table IV, September 1928–9, p. 122). The short journey to the ice, however, brought the ship into an entirely different plankton. Column 1 in Table V shows that there was here a typically cold-water plankton in which *Sibogita*, *Dimophyes*, *Diphyes* and *Auricularia* were all present, while the warm-water species were much reduced. The state of affairs is illustrated in Fig. 40.

Table V. *Warm- and cold-water species in the South Sandwich and Weddell regions*

Season	1928–9	1929–30			1930–1				
Month	Sept.–Oct.	Feb.	Mar.	Mar.	Dec.	Jan.–Feb.	Jan.–Feb.	Feb.	Feb.
Station	WS 287–8 and WS 298–310	360–2	365–9	372–3	528–33	WS 536–43 and WS 555–61	WS 544–51	618–23	626–9
Number of samples ...	15	3	2	2	5	10	7	6	4
Column number ...	1	2	3	4	5	6	7	8	9
Warm-water species									
(*a*) *Euphausia vallentini*	—	—	—	—	—	—	—	—	—
(*b*) *Eucalanus* sp.	—	—	—	—	—	—	—	—	—
Candacia sp.	—	—	—	25·0	—	0·71	—	—	—
Heterorhabdus sp.	1·00	200	—	—	—	—	—	—	—
Euphausia triacantha	12·0	0·50	—	—	0·20	—	—	—	—
Calanus simillimus	—	—	—	105	—	0·71	—	—	—
Pleuromamma robusta	—	200	—	—	—	23·9	—	7·00	5·00
(*c*) Chaetognatha	2·17	376	200	15·0	271	160	224	107	58·2
Limacina balea	5·83	25·0	—	—	—	39·3	—	—	3·33
Pareuchaeta sp.	—	800	—	400	24·0	17·1	55·0	29·0	25·0
Parathemisto gaudichaudi	0·46	46·7	—	51·0	9·00	28·3	—	59·6	14·2
Euphausia frigida	30·0	1800	3·33	627	39·8	379	—	34·5	65·5
Cold-water species									
(*g*) *Euphausia superba*	1580	4·33	1770	710	4·80	15,545	17·9	1243	3518
Cleodora sulcata	85·0	1·00	4·50	7·50	9·00	24·6	9·75	5·00	4·00
Salpa fusiformis aspera	0·40	6·00	1·00	4·50	69·0	1·71	8·67	28·0	—
Tomopteris sp. (large)	0·53	0·33	0·67	0·50	2·00	2·00	1·43	1·16	1·25
Tomopteris sp. (small)	6·53	—	0·50	—	6·80	5·10	12·3	0·14	23·3
Metridia gerlachei	—	650	25·0	—	1652	1020	890	348	1155
Clione antarctica	1·33	—	—	—	2·60	6·10	1·00	—	3·50
Limacina helicina	7·60	1·33	10·5	—	40·2	15·1	47·3	—	11·0
Pyrostephos vanhöffeni	—	—	22·0	—	46·8	218	12·0	—	—
(*h*) *Sibogita borchgrevinki*	0·13	—	—	—	0·40	0·10	0·57	—	—
Dimophyes arctica	4·33	—	7·00	—	4·60	28·3	26·3	—	—
Vanadis antarctica	—	0·33	—	—	0·40	0·20	0·57	—	—
Diphyes antarctica	2·93	—	1·00	—	3·60	6·00	10·4	—	7·00
Eusirus antarcticus	—	—	0·50	—	1·60	1·44	—	—	—
Auricularia antarctica	0·33	—	—	—	0·20	1·00	28·3	—	—
Haloptilus ocellatus	—	—	—	—	—	2·00	306	—	—

In the 1929–30 season the 'Discovery II' visited the South Sandwich Islands during the end of February and the beginning of March, just after the South Georgia survey. We have seen that this survey revealed a warm-water plankton, and at the first three stations on the way to the South Sandwich Islands (Sts. 360–2, Fig. 12) the warm-water species were still predominant (see Fig. 41 and column 2 in Table V). At St. 365, however, *Pyrostephos*, *Dimophyes* and *Eusirus* make their appearance, and at St. 369 *Pyrostephos* and *Diphyes antarctica* were taken. At St. 368, the only other N 100 B station taken at this time, the sample could not be properly analysed owing to a large catch of *Euphausia*

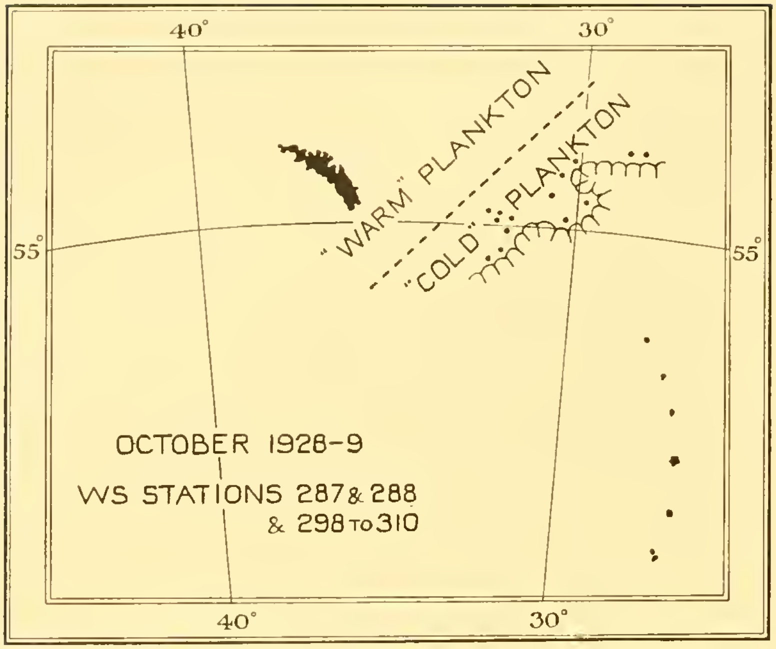

Fig. 40. Distribution of warm- and cold-water plankton between South Georgia and the South Sandwich Islands. The edge of the pack-ice is indicated.

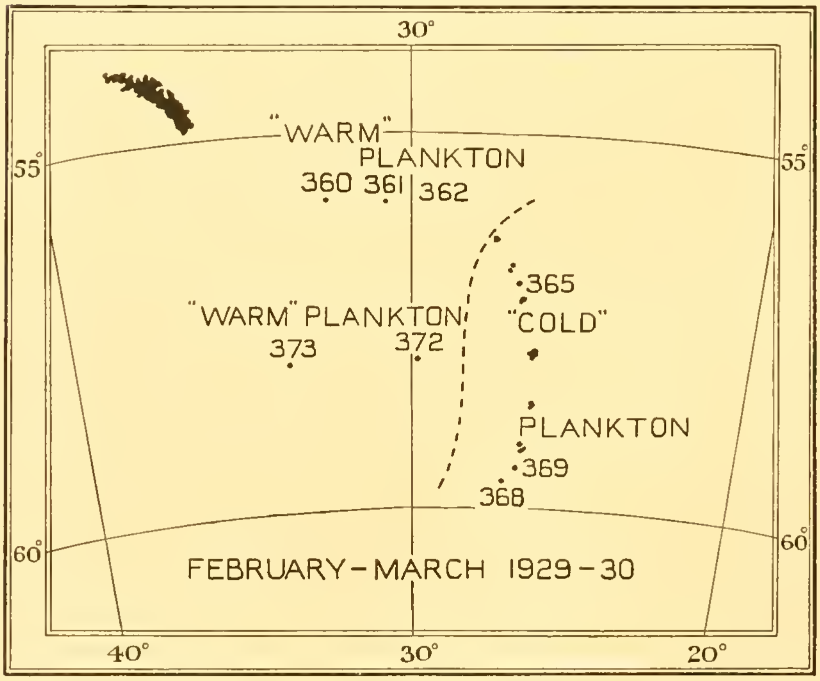

Fig. 41. Distribution of warm- and cold-water plankton between South Georgia and the South Sandwich Islands. No pack-ice was seen.

superba. Column 3 in Table V, however, shows how greatly the warm-water species were reduced at Sts. 365 and 369. On leaving the South Sandwich Islands the ship started a line of stations to the west (Sts. 372, 373, etc.) and here we see the plankton was again of the warm type. Column 4 in the table shows a very striking contrast between Sts. 365 and 369, and Sts. 372 and 373. Fig. 41 shows the relative positions of the "warm" and "cold" plankton.

In the 1930–1 season a number of stations were taken to the east and south-east of South Georgia (see Fig. 14, p. 82). In October the 'Discovery II' sailed from Capetown to South Georgia *via* Bouvet Island and the journey from Bouvet Island to South Georgia was mainly along or through the outskirts of the pack-ice (see Fig. 42). As these stations are in the form of an extended line they are not separated into groups and shown in Table V. The stations at the east end of this line had not perhaps a very "cold" plankton, but *Diphyes antarctica* was present at all of them, *Dimophyes* was taken at St. 453, and *Haloptilus ocellatus* appeared at St. 460. At Sts. 462–9 the plankton was of

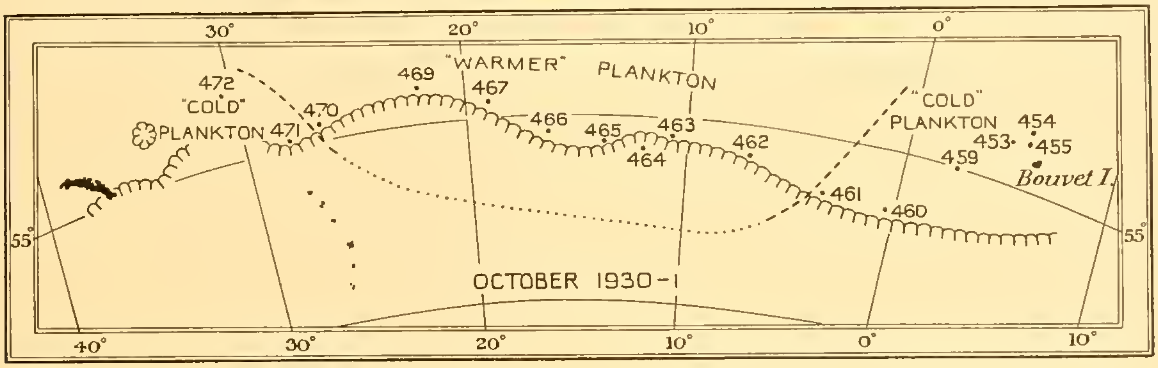

Fig. 42. Distribution of warm- and cold-water plankton between South Georgia and Bouvet Island. The edge of the pack-ice is indicated.

a warmer type. There was a single specimen of *Eusirus* at St. 466 and of *Auricularia* at St. 469, but at all of these stations there were large numbers of *Limacina balea*, reaching a maximum at St. 466, and comparatively abundant *Euphausia frigida* (both warm-water species). At St. 470 there were three specimens of *Eusirus* and at Sts. 471 and 472 *Diphyes antarctica* reappeared and the numbers of *L. balea* and *E. frigida* became suddenly reduced. When the ship reached South Georgia the November survey was begun, and as already noted revealed here a very cold-water plankton. It seems therefore that in the early summer of 1930–1 there was a cold-water plankton in the neighbourhood of Bouvet Island and South Georgia, but between the two a rather "warmer" plankton.

When the ship reached South Georgia the pack-ice was lying close up to the island, but at the end of November, when the survey was finished, the ice-edge had receded some way to the south-east. In December the 'Discovery II' sailed in this direction, and, on meeting the ice, followed its edge in a south-westerly direction, taking Sts. 528–33 in the positions shown in Fig. 43. Here the constitution of the plankton was still very "cold" (see column 5 in Table V, p. 125), even more so than around South Georgia in November. Of the warmest group only *Euphausia triacantha* was represented, and all the coldest species were present except *Haloptilus ocellatus.*

Late in January the 'William Scoresby' also sailed south-eastwards from South Georgia and found that the ice had retreated to the northern end of the Sandwich group. This ice was skirted to the eastward and was found to fall away to the south and disappear. The ship steamed southwards for some 600 miles in open water and finally reached more ice in the eastern part of the Weddell Sea (Fig. 44). At the stations taken off the ice around the South Sandwich Islands the same "cold" plankton was taken, though some warm-water species, particularly *Euphausia frigida*, were well represented (see Table V, column 6). Farther south (WS 544–51) the cold-water species increased

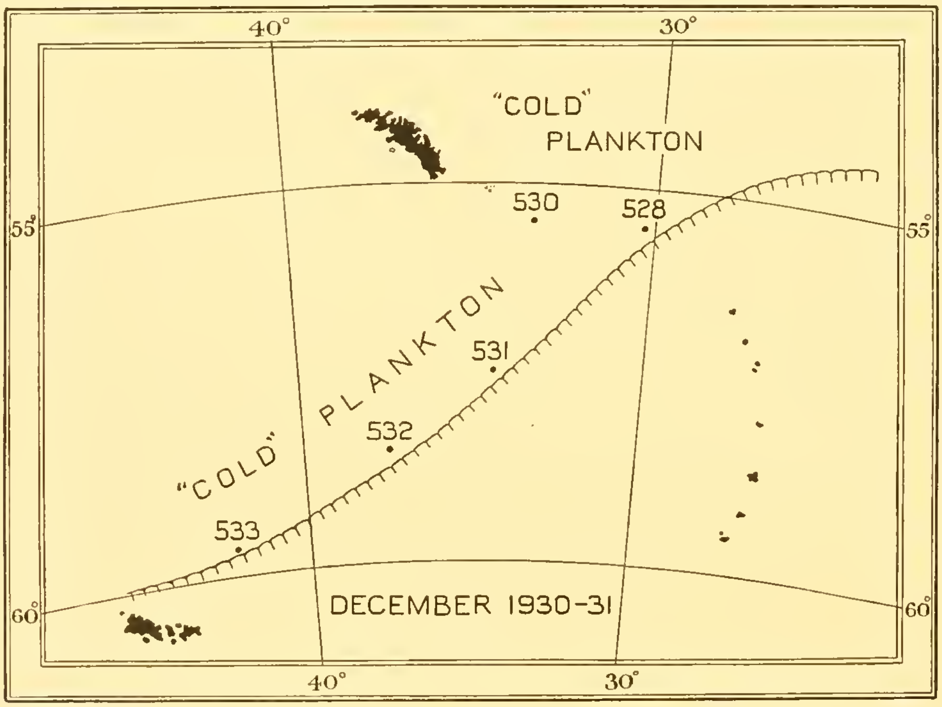

Fig. 43. Distribution of warm- and cold-water plankton in the eastern part of the Scotia Sea. The edge of the pack-ice is indicated.

and the warm-water species almost vanished (see Table V, column 7). *Haloptilus ocellatus* was taken here in exceptional numbers. These last stations were taken in an area which is probably covered with pack-ice during the greater part of the year.

In February the 'Discovery II' returned to the South Sandwich region, working stations along the ice-edge between the South Orkney Islands and the Sandwich group. These stations (618–29) are shown in Fig. 45. The ice here had retreated very little since December (Fig. 43), but the plankton had changed to a much warmer type. None of the very "cold" group was present but such warm-water species as *Pareuchaeta*, *Pleuromamma*, and *Euphausia frigida* were included in the catches. As the ship approached the South Sandwich Islands, however, signs of a "colder" plankton appeared. *Vanadis* occurred at St. 624, and *Diphyes antarctica* at Sts. 625, 626, 628 and 629. At the same time smaller numbers of *Pareuchaeta* and *Pleuromamma* were taken (see Fig. 45 and

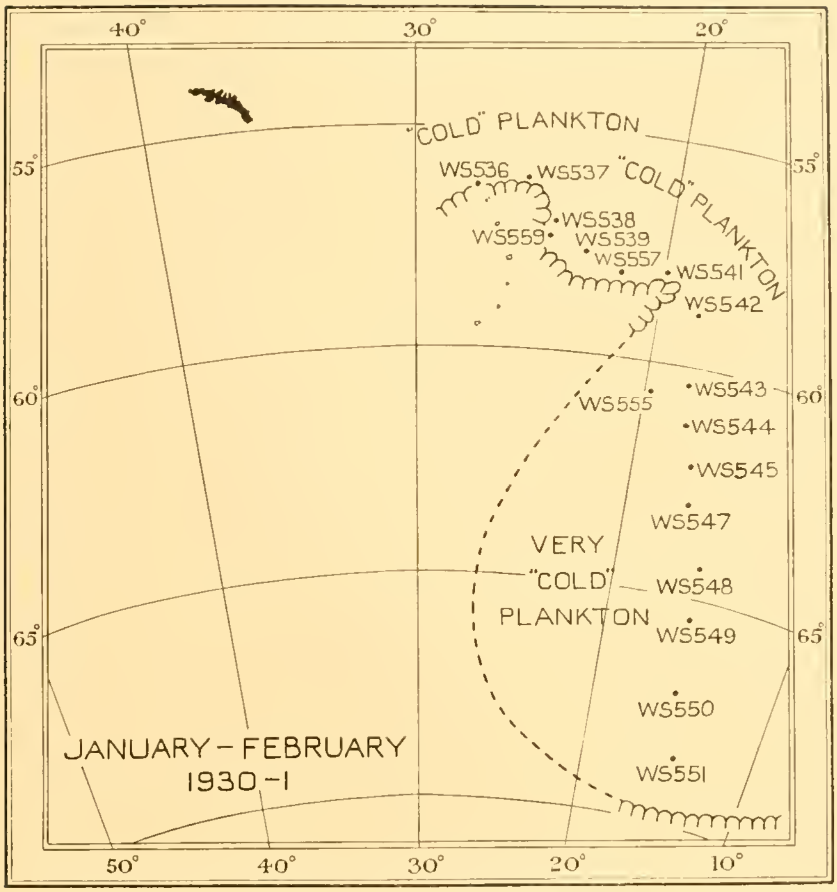

Fig. 44. Distribution of warm- and cold-water plankton near the South Sandwich Islands and in the eastern part of the Weddell Sea. The observed and conjectured positions of the ice edge are indicated.

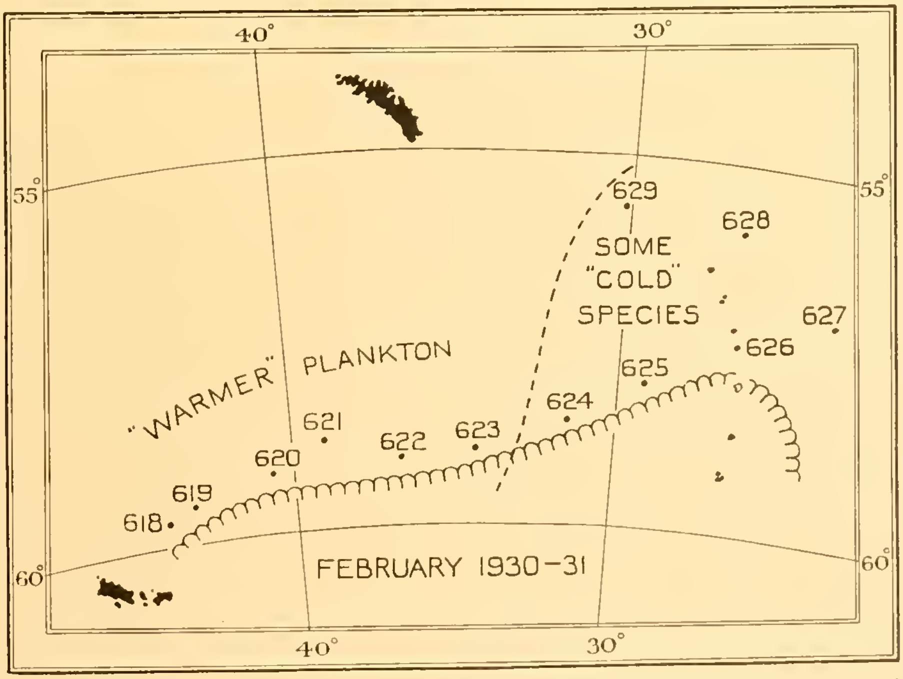

Fig. 45. Distribution of warm- and cold-water plankton in the eastern part of the Scotia Sea. The edge of the pack-ice is indicated.

Table V, column 8). The plankton here, however, although it contained an element of cold-water species, was not nearly so "cold" as it was in the same region earlier in the season. The conditions were in fact very similar to those which obtained about February and March 1929–30 (Fig. 41).

It has been seen that the evidence strongly suggests that around South Georgia the cold-water species are prominent in spring, but become reduced as the summer advances, and we now have clear evidence that in the 1930–1 season, in the area roughly between the South Sandwich and South Orkney Islands, a "cold" plankton in December gave way to a comparatively "warm" plankton in February (compare Figs. 43 and 45). There is every reason to suppose that this is a normal process. 1930–1 is the only single season in which the plankton distribution can be compared in several different months, but the conditions in October 1928–9 and February–March 1929–30 fall into place very well. The 1928–9 season was not so cold as the 1930–1 season, the ice did not reach quite so far north in October, and the area of the South Georgia survey was not invaded by the "cold" plankton, which, however, came very near to it. The 1929–30 season was a mild one and there was no sign of ice round the South Sandwich Islands, but the conditions in February–March were very similar to those in February 1930–1, except that the cold-water species had retreated farther to the south-east.

It is difficult to decide exactly what connection exists between the pack-ice and the presence of the very cold-water species (group (*h*) in Table III, p. 107). They are rarely if ever found except close to the ice or in places in which there has recently been ice. On the other hand the presence of ice does not necessarily entail the presence of cold-water plankton.

Fig. 46 shows the changes in the position of the pack-ice during the 1930–1 season, and its tendency to hang around the South Orkney and South Sandwich Islands while farther to the east the sea becomes clear of pack-ice for hundreds of miles to the southward. In Fig. 47 the boundaries between the warm- and cold-water plankton shown in Figs. 40, 41, 42 and 45 are superimposed on one chart. This shows again how the cold-water plankton retreats to the south-east of South Georgia. It will be seen that westward from the South Sandwich Islands a warmer plankton is always found, and there is evidence of a tendency towards a warmer plankton also to the east of the islands (see Fig. 42). It seems in fact that around the South Sandwich Islands there is a tongue of cold-water plankton reaching up from the south.

The cyclonic circulation in the Weddell Sea, and the cold water which flows out towards the South Orkney and South Sandwich Islands is responsible for the persistent ice and the cold-water plankton in this region, and it is possible that the ridge of the South Sandwich chain temporarily deflects the current towards the north, carrying the cold-water species up in the tongue mentioned above.

The presence of cold-water species near Bouvet Island suggests that there might be another cyclonic system farther to the east, and Wüst (1928) has published a chart of current systems in the Atlantic which does in fact show such a system. Its centre is given as about 60° S, 30° E, and its orbit just embraces the stations near Bouvet Island

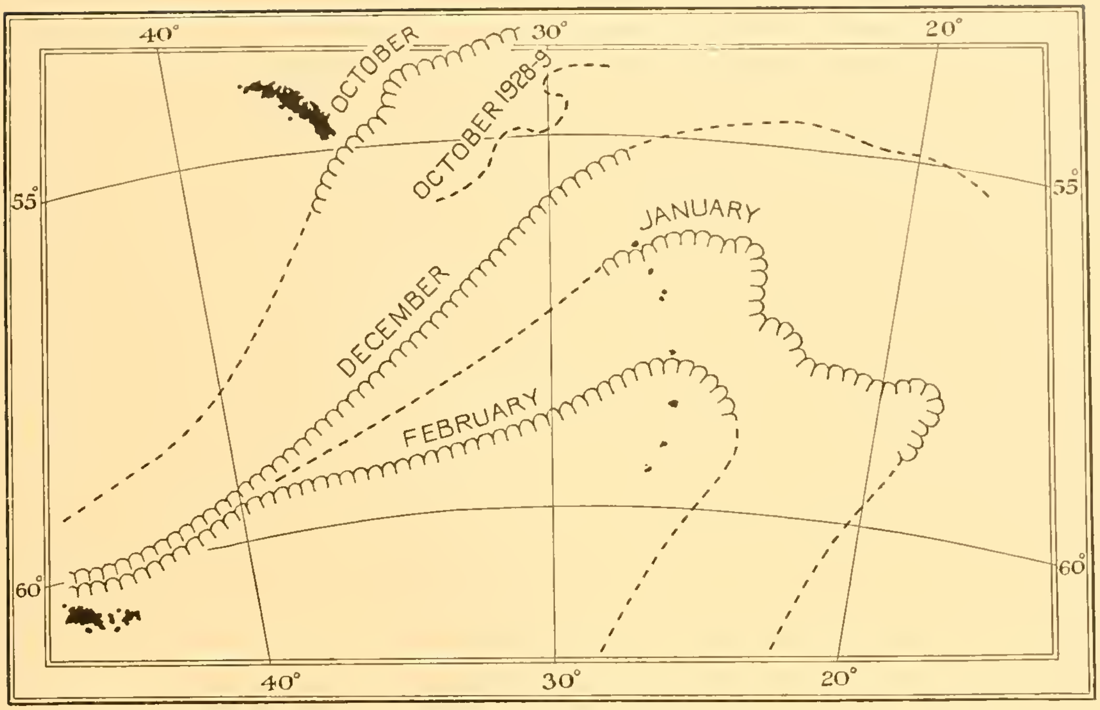

Fig. 46. Changes in the position of the ice edge during the season 1930–1. Note the recession of the ice as the season advances. The position of the ice in October 1928–9 is shown for comparison.

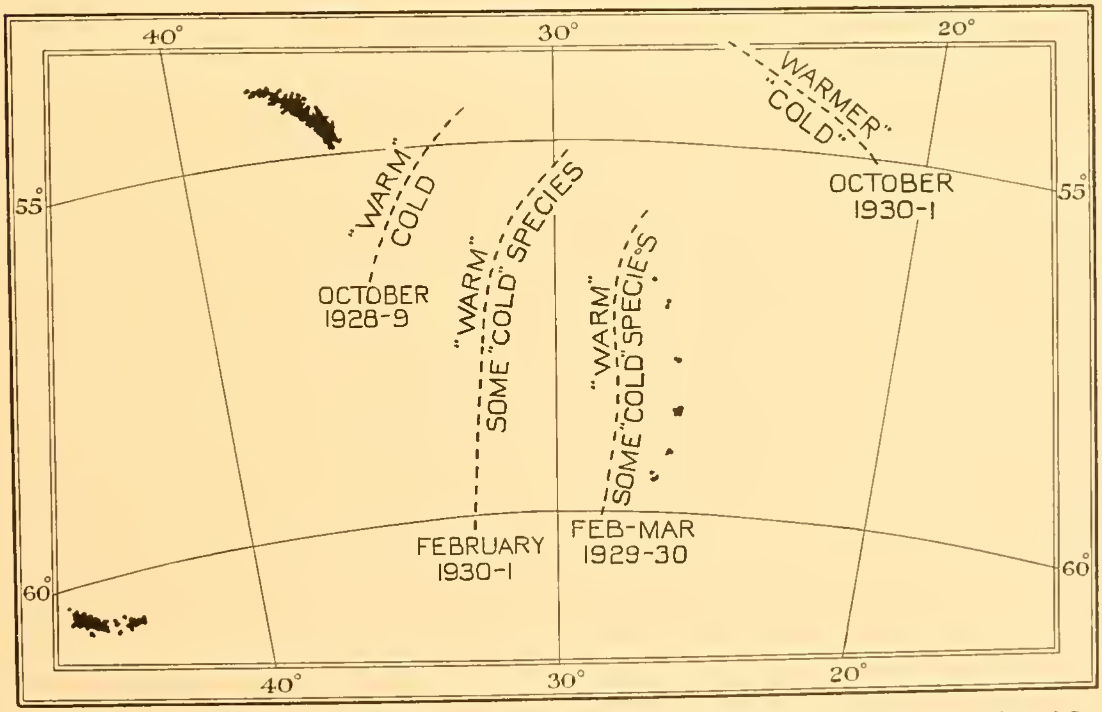

Fig. 47. Relative positions of warm- and cold-water plankton at different times in the vicinity of South Georgia and the South Sandwich Islands.

at which the cold species were found. I understand, however, that in the light of more recent work by the 'Discovery II' it is to be doubted whether there is actually a cyclonic movement here in any way comparable in importance to that of the Weddell Sea.

THE ORKNEY-SHETLAND REGION

Under this heading are included all the stations taken in the area of scarce plankton around the South Orkney and South Shetland Islands and the lines of intensive stations in the Bransfield Strait. In Table VI the separate groups of stations are arranged in order of the months in which they were taken, as in Table IV on p. 122, but the Bransfield Strait stations are dealt with separately. Many of the warm-water species (groups (*a*) and (*b*) in Table III, p. 107) do not occur at all in this region and are therefore omitted from the table.

Table VI. *Warm- and cold-water species in the Orkney-Shetland region*

	Bransfield Strait				South Orkneys to South Shetlands					
Station numbers	WS 476–93	542–55	607–12	WS 382–99	WS 474	534–41	613–15	WS 380, 381	637–44	WS 202
Number of samples ...	18	14	4	18	1	7	3	2	8	1
Year	1929–30	1930–1	1930–1	1928–9	1929–30	1930–1	1930–1	1928–9	1930–1	1927–8
Month	Nov.	Dec.	Feb.	Feb.	Nov.	Dec.	Feb.	Feb.	Mar.	April
Column number	1	2	3	4	5	6	7	8	9	10
Warm-water species										
(*c*) Chaetognatha	7·33	4·86	—	0·33	—	100	21·0	0·50	—	—
Limacina balea	1·10	—	—	—	—	—	—	—	—	—
Pareuchaeta sp.	—	1·20	—	—	—	1·25	2·33	—	56·0	120
Parathemisto gaudichaudi	—	0·07	31·0	15·0	—	0·43	5·67	3·50	11·4	350
Euphausia frigida	—	2·20	32·0	27·7	54·0	14·2	23·0	16·0	14·0	18·0
Cold-water species										
(*g*) *Euphausia superba*	170	12·2	191	429	—	964	2·00	71·0	406	228
Cleodora sulcata	—	0·20	—	—	—	0·50	—	—	—	—
Salpa fusiformis f. *aspera*	—	0·80	1·00	—	—	42·0	191	437	177	3·00
Tomopteris sp. (large)	—	—	—	—	8·00	—	—	—	—	1·00
Tomopteris sp. (small)	0·17	1·07	0·25	—	—	0·43	—	—	0·29	—
Metridia gerlachei	4·71	14·2	—	138	—	50·2	155	11·5	1580	3344
Clione antarctica	0·70	0·57	1·00	—	1·00	0·40	0·33	—	—	—
Limacina helicina	5·78	3·43	—	0·12	6·00	7·29	—	0·50	0·14	—
Pyrostephos vanhöffeni	—	—	—	—	—	—	—	—	—	—
(*h*) *Sibogita borchgrevinki*	—	0·07	—	—	—	0·14	—	—	—	—
Dimophyes arctica	0·78	0·21	—	—	—	1·29	1·33	—	—	—
Vanadis antarctica	—	—	0·25	—	—	—	—	—	0·12	—
Diphyes antarctica	0·28	0·29	—	—	—	0·43	0·67	—	0·12	—
Eusirus antarcticus	—	0·21	—	—	—	0·25	—	—	—	—
Auricularia antarctica	0·17	0·86	0·25	—	1·00	—	0·33	—	0·14	—
Haloptilus ocellatus	—	—	—	—	—	1·43	3·00	—	—	—

The figures here emphasize the relative "coldness" of the 1930–1 plankton rather more clearly than the reduction of cold-water species as the summer goes on. However, if the 1930–1 season is considered separately it will be seen that in the Bransfield Strait the cold-water species were much more strongly represented in December than in February, and that in the latter month, although the Chaetognatha and *Pareuchaeta* were not taken, *Parathemisto* and *Euphausia frigida* had increased very greatly (see columns 2 and 3). The surveys in the Bransfield Strait in 1929–30 and 1928–9 show a marked contrast. At the former, which was in November, plenty of "cold" species were taken, and *Limacina balea* and some Chaetognatha were the only warm-water species. At the latter, which was in February, none of the very "cold" species was present and only one or two of the moderately "cold", while *Parathemisto* and *Euphausia frigida* appeared in quite large numbers for this locality (see columns 1 and 4). It may be mentioned here that the Chaetognatha, as a group, are not to be relied on as a warm element in the plankton, especially in such places as this where *Eukrohnia hamata* is not necessarily the dominant species.

In the region between the South Shetlands and the South Orkneys there was a large element of cold-water species in December 1930–1. In February in the same season there was little, if any, diminution in the very cold-water species, but there were fewer of the moderately "cold" group and more of the warm-water species. In March there were definitely fewer of the "coldest" species, and the warm-water species on the whole were stronger than in February (see columns 6, 7 and 9). Single stations are unreliable, but the one taken in November 1929–30 (column 5) suggests a "colder" plankton than was found in February 1928–9 or April 1927–8.

Table VI provides an interesting example of the unusual coldness of the 1930–1 season. The catches in February of this season can be compared with those of February 1928–9 both in the Bransfield Strait and farther east (columns 3, 4, and 7, 8). It will be seen that a much "colder" plankton was present in 1930–1 than in 1928–9.

THE BELLINGSHAUSEN SEA

The Bellingshausen Sea has been visited only twice, each time in the middle of the summer, so that we have not the material for a comparison of the conditions in different months, but there is some interest in a comparison between the plankton taken by the 'William Scoresby' in 1929–30 and the 'Discovery II' in 1930–1. Table VII shows the average number of warm- and cold-water species taken during these two cruises. It has been seen in a previous section that a much richer plankton was taken in the more westerly part of the Bellingshausen Sea than in the eastern part, and these further stations are therefore treated separately in the table.

The principal conclusion to be drawn from these figures is that, at any rate in the western Bellingshausen Sea, the plankton of 1930–1 was not of a colder type than that of 1929–30, although everywhere to the west of the South Shetlands exceptionally cold conditions were met with in the former season, while in the latter season the conditions were unusually mild. The dates on which the 'William Scoresby' took observations in the western Bellingshausen Sea in 1929–30 were about three weeks later than those of the corresponding stations of the 'Discovery II' in 1930–1, and yet at the former the *very* "cold" species were on the whole more numerous than at the latter. It is true that in the eastern part of the Bellingshausen Sea a slightly "colder" plankton was taken in 1930–1 than in 1929–30, but the difference is not nearly so great here as it was for instance in the region between the South Shetland and South Sandwich Islands. The figures, in fact, seem to suggest that if in any season exceptionally cold or mild conditions are experienced on the east side of the Drake Passage, the same conditions do not necessarily prevail on the west side. More evidence is needed, however, before the point can be definitely settled.

Table VII. *Warm- and cold-water species in the Bellingshausen Sea*

Area	Eastern Bellingshausen		Western Bellingshausen	
Season	1929–30	1930–1	1929–30	1930–1
Month	Jan.–Feb.	Dec.–Jan.	Jan.	Jan.
Station numbers ...	WS 496–501 and WS 508–17	556–62 and 580–603	WS 502–5	563–79
Number of samples ...	14	29	4	17
Warm-water species				
(*c*) Chaetognatha	14·5	4·35	1223	182
Limacina balea	—	—	—	—
Pareuchaeta sp.	18·8	4·54	128	22·2
Parathemisto gaudichaudi	32·8	1·34	0·73	—
Euphausia frigida	—	0·75	—	4·00
Cold-water species				
(*g*) *Euphausia superba*	12·1	3·86	2·50	6·30
Cleodora sulcata	0·17	0·29	5·00	1·12
Salpa fusiformis f. *aspera*	2·00	13·6	—	84·5
Tomopteris sp. (large)	0·07	0·31	4·00	1·00
Tomopteris sp. (small)	0·36	1·83	45·2	16·6
Metridia gerlachei	150	47·7	400	70·5
Clione antarctica	0·14	0·62	10·5	3·87
Limacina helicina	12·1	7·93	51·5	89·9
Pyrostephos vanhöffeni	20·2	2·34	55·2	2·94
(*h*) *Sibogita borchgrevinki*	—	—	0·25	0·12
Dimophyes arctica	—	0·03	4·00	15·2
Vanadis antarctica	—	0·03	1·00	0·41
Diphyes antarctica	—	0·03	1·50	0·94
Eusirus antarcticus	0·33	0·81	0·50	1·00
Auricularia antarctica	0·21	0·34	5·00	0·53
Haloptilus ocellatus	—	0·10	176	2·35

THE NORTHERN ANTARCTIC REGION

This heading refers to the belt of warmer water lying between the Antarctic convergence and South Georgia and the South Shetlands. Most of the lines of stations crossing this zone run between the Falkland Islands and South Georgia, some cross the Drake Passage, and some more stations lie roughly between the South Orkney Islands and the Falkland Islands. There is sufficient material for an independent monthly comparison in two of the seasons, and the four seasons are therefore taken separately in

Table VIII. *Warm- and cold-water species in the outer Antarctic water*

Season	1927–8		1928–9					1929–30					1930–1		
Month	Feb.	Apr.	Aug.	Dec.	Feb.	Mar.	May	Nov.	Nov.	Mar.	Mar.	Apr.	Mar.	Mar.	Mar.
Station numbers	WS 140–2	WS 203, 204	WS 254–6	WS 314–16	WS 400–4	WS 413–16	WS 427–30	WS 464, 465	WS 469–73	WS 521–6	WS 527–9	378–84	633–6	646–9	656–9
Number of samples ...	3	2	3	3	5	4	4	2	5	6	3	4	4	3	4
Position of line	Falklands to South Georgia	South Orkneys to Falklands	Falklands to South Georgia	South Georgia to Falklands	Drake Passage	Falklands to South Georgia	South Georgia to Falklands	South Georgia to Falklands	Falklands to South Shetlands	Falklands to South Georgia	South Sandwich Islands to Burdwood Bank	Drake Passage	Falklands to South Orkneys	Drake Passage	Cape Horn to South Georgia
Column number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Warm-water species															
(*a*) *Euphausia vallentini*	—	10·5	1·50	?	0·50	?	Present	—	—	—	?	—	590	—	?
(*b*) *Eucalanus* sp.	—	—	—	64·0	—	Present	8·00	64·0	10·7	—	?	—	—	—	—
Candacia sp.	—	4·00	8·00	?	—	?	?	—	Present	—	?	—	20·0	—	?
Heterorhabdus sp.	—	4·00	7·00	?	0·50	?	24·0	16·0	—	—	?	50·0	20·0	5·00	?
Euphausia triacantha	7·00	19·5	5·50	?	23·0	Present	Present	0·50	—	6·00	?	29·5	42·0	2·00	?
Calanus simillimus	—	86·0	—	192	80·0	208	252	8·00	6·67	1040	Present	0·67	440	—	Present
Pleuromamma robusta	16·0	28·0	116	?	129	?	Present	64·0	8·00	256	?	40·0	65·0	10·0	?
(*c*) Chaetognatha	803	1148	1·00	256	192	284	784	865	515	262	Present	3601	1055	429	Present
Limacina balea	80,152	2720	13·0	Present	?	288	615	30·0	9·33	3707	Present	—	1400	—	Present
Pareuchaeta sp.	16·0	94·0	2·00	?	218	?	Present	80·0	—	224	?	355	500	40·0	?
Parathemisto gaudichaudi	170	17·5	3·67	932	40·8	93·5	243	97·5	45·8	154	78·3	120	37·7	7·33	12·0
Euphausia frigida	610	87·0	307	24·0	206	417	173	21·0	2·00	713	?	132	31·0	30·0	—
Cold-water species															
(*g*) *Euphausia superba*	—	—	16·0	—	—	2·00	3·00	1·50	—	—	287	2·00	—	2·33	607
Cleodora sulcata	—	—	0·50	—	—	?	—	—	—	1·50	?	—	—	—	—
Salpa fusiformis f. *aspera*	8·00	1·50	—	?	64·5	Present	?	6·50	—	1·00	Present	108	10·0	67·0	?
Tomopteris sp. (large)	—	—	0·33	0·67	—	—	—	0·50	1·00	0·33	1·33	0·25	—	0·33	—
Tomopteris sp. (small)	2·33	—	1·33	1·67	—	—	1·00	—	31·0	—	—	—	—	6·00	—
Metridia gerlachei	96·0	24·0	—	?	46·0	?	?	208	8·00	—	?	—	15·0	130	?
Clione antarctica	1·50	—	1·50	1·00	—	—	—	2·00	4·33	—	?	—	—	—	—
Limacina helicina	Present	—	—	34·7	—	—	—	45·5	21·4	—	—	—	—	—	—
Pyrostephos vanhoffeni	2·00	—	—	12·3	—	—	—	—	18·2	—	—	—	—	—	—
(*h*) *Sibogita borchgrevinki*	—	—	—	—	—	—	—	—	0·20	—	0·33	—	—	0·33	—
Dimophyes arctica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vanadis antarctica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Diphyes antarctica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Eusirus antarcticus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Auricularia antarctica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Haloptilus ocellatus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table VIII. This table shows the average number of warm- and cold-water species per haul for each line of stations. On some of the lines none of the stations was taken in the middle of the night, and consequently the diurnal variations of some species prevent a reliable estimate of their numbers. A query is inserted where a species is absent but might have been taken if there had been a haul between the appropriate hours at night, and "Present" is inserted where a few were actually taken but where a larger number might be expected in a night haul.

In these waters the moderately "cold" species (group (*g*)) play a part corresponding to that of the very "cold" group in the high latitudes. As in other regions, the figures here show a diminution in the proportion of cold-water species as the summer advances. A glance at columns 1 and 2 shows a much "warmer" plankton in April than in February 1927–8. In the 1928–9 season the warm-water species were quite well represented at the August stations, as they were in September off South Georgia, and the "coldest" plankton is found in December, i.e. early in the summer. In February, March and May there is a general reduction of cold-water species and an increase in nearly all the warm-water species. In the 1929–30 season the "coldest" plankton, as we should expect, is taken in November. The cold-water species mostly disappear in March and April, though a specimen of *Sibogita* unaccountably appears in March. Of the warm-water species *Heterorhabdus* sp., *Euphausia triacantha*, *Pleuromamma*, *Pareuchaeta*, *Parathemisto* and *Euphausia frigida* increase towards the end of the season. Others are irregular and *Eucalanus* is more plentiful in November. In the 1930–1 season stations in this area were taken only in March, but it will be seen that the catches include slightly more cold-water species than those of March 1929–30 and 1928–9. We should expect this in view of the fact that the 1930–1 season was a specially cold one.

It is now clear that over the area covered by the investigations, wherever it is possible to compare observations taken at different times of year, the plankton at a given point has a larger element of cold-water species at the beginning of the summer (November and December) than it has later on. It seems also certain that in unusually cold seasons, such as 1930–1, the cold-water species have a tendency to persist in relatively low latitudes for a longer period than they would in a normal season. The stations taken in August and September 1928, suggest that the relatively "warm" plankton, found at the end of the summer, persists throughout the winter. There was at that time a thin plankton composed only of the warm-water species in proportions resembling those of the previous season. It is highly probable that the plankton undergoes little change from March or April or through the winter, remaining as a slowly diminishing population until the spring, when there is an invasion of cold-water species and a development of the rich summer plankton. There seems to be an increase in the proportion of warm-water species as the summer goes on, but this is not quite so clearly defined as the disappearance of the cold-water species.

The gradual change from a cold- towards a warm-water plankton does not of course imply a southerly drift of the Antarctic surface water during the summer. It is quite probable that the cold-water species generally develop earlier in the summer than the warm-water species and become replaced by the latter as time goes on.

It is difficult to say what connection may exist between the plankton population and the movements of the pack-ice. It is generally understood that the ice-edge reaches its most northerly limit at the end of winter or in the spring. This is also the time at which the plankton contains the maximum proportion of cold-water species. The distribution of certain species, also, seems to be limited to regions within the range of the pack-ice, for the northern limit of *Diphyes antarctica*, *Eusirus* and some other species typical of the coldest water coincides, at least approximately, with the northern limit of the pack-ice.

It is worth mentioning, as a matter of separate interest, that a curious red colouring has been noticed in several species taken off the ice-edge in certain places, particularly in the eastern part of the Weddell Sea and to the south-west of Bouvet Island. The catches here included large numbers of *Calanus propinquus* in most of which the antennae were of a bright red colour. The red-banded variety of *Tomopteris carpenteri* mentioned on p. 99 also occurred in some of these samples, and a small red Amphipod, at present unidentified, was not uncommon. The red antennae of the copepods often imparted a striking reddish appearance to the whole sample, especially when combined with other red species.

PLANKTON COMMUNITIES

Certain contrasts between the plankton of different regions have already been established. It has been seen for instance that certain groups of species are typical of the colder and others of the warmer waters. The chart shown in Fig. 21 (p. 105) indicates that the northern limit of some species and the southern limit of others lie in a belt running from the South Shetlands to South Georgia which coincides roughly with the junction of the Bellingshausen and Weddell Sea water. It has further been seen that in the coastal waters of the South Shetlands and South Orkney region the plankton has a characteristic which appears to be constant, namely the persistent scarcity of nearly all the species with which this paper is concerned (see Fig. 23, p. 110). On geographical grounds three main water masses can be distinguished. It will be seen from Fig. 1 that Graham Land and the South Shetlands divide the Weddell Sea from the Bellingshausen Sea in the higher latitudes, and leave a continuous outer belt of Antarctic water in the lower latitudes, which flows from west to east immediately south of the convergence.

In this section the plankton of the Weddell Sea, the Bellingshausen Sea, the outer belt and the area of scarce plankton around the South Orkney and South Shetland Islands are considered separately, but it will be remembered that between the plankton populations of the Weddell Sea and the outer belt there is a comparatively broad transition zone. The populations of these four areas are compared and an attempt is made further to subdivide them according to the nature of the populations. To do this it is necessary to examine separately all the important lines of stations.

THE WEDDELL SEA

A line of stations (WS 535–61) taken in the 1930–1 season gives a useful indication of the plankton conditions in the Weddell Sea water east of the South Sandwich Islands and, farther south, on the eastern side of the Weddell Sea itself (see Fig. 14). Table IX shows, for each station, the numbers of the ten most important species taken on this line, together with the total number of all species excluding those which tend to form shoals. Most of the stations were taken on the outward journey, but some were taken on the return, which was on very much the same course. The latter stations are inserted in the table in their proper positions relative to the others.

Table IX. *South Georgia to eastern Weddell Sea*

Date	January–February 1931									
Station	North WS 561	WS 535	WS 560	WS 536	WS 537	WS 538	WS 559	WS 539	WS 557	WS 541
Hour	21	22	21	22	01	13	21	22	08	12
Calanus acutus	3900	?	>780	7,400	—	?	18,000	35	3600	200
Rhincalanus gigas	1200	?	>260	1,200	—	?	—	250	*420*	*2000*
Euphausia superba	1	190,000	9	21	130	6000	2	9	11	114
Thysanoessa sp.	1200	?	94	200	730	?	600	2100	1200	*139*
Calanus propinquus	40	?	340	1,700	220	?	1,100	50	*180*	*2000*
Euphausia frigida	63	?	75	1,400	800	?	150	160	?	?
Parathemisto gaudichaudi	63	?	4	—	9	?	130	39	5	5
Metridia gerlachei	—	?	160	1,600	1200	?	4,000	160	*80*	?
Pleuromamma robusta	—	?	—	—	10	?	—	37	?	?
Haloptilus ocellatus	—	?	—	—	—	?	—	—	—	—
Total organisms (excluding shoaling species)	7400	?	2000	13,600	3000	?	24,000	3000	*5600*	5800

Date	January–February 1931									
Station	WS 542	WS 543	WS 555	WS 544	WS 545	WS 547	WS 548	WS 549	WS 550	South WS 551
Hour	22	14	23	20	14	22	13	22	10	20
Calanus acutus	?	6,300	1300	2000	1200	5700	3000	3800	4400	2600
Rhincalanus gigas	?	*5,400*	1100	280	?	40	*440*	80	*360*	460
Euphausia superba	5500	270	—	17	1	107	—	—	—	—
Thysanoessa sp.	?	*120*	100	136	*20*	86	*36*	41	*23*	150
Calanus propinquus	?	*960*	120	1600	*440*	1100	*1400*	520	*840*	660
Euphausia frigida	?	*45*	13	—	?	—	?	—	?	—
Parathemisto gaudichaudi	?	—	2	—	—	—	—	—	—	—
Metridia gerlachei	?	*400*	100	2200	*3100*	360	*320*	480	*440*	480
Pleuromamma robusta	?	?	100	?	?	—	?	—	?	—
Haloptilus ocellatus	?	—	20	80	240	—	520	360	480	460
Total organisms (excluding shoaling species)	?	*15,000*	3400	6800	*5500*	7400	*6100*	5700	*7200*	5700

Many of these stations were in high latitudes where there was little darkness at night and where there seems to be little diurnal variation. The total numbers of organisms are, however, shown above in italics where the hauls were made in daytime between the hours of 0600 and 1700, and the figures for species with a marked diurnal variation in lower latitudes are given in italics where the sample was taken in daytime. Where these species are absent from such samples a query indicates that they might conceivably have been present. Queries are also inserted where a sample is swamped by a large catch of *Euphausia superba*.

If the various stations in this table are compared it will be seen that at each of the seven most southerly stations (WS 544–51) the total number of organisms lies round about 6000–7000, while at the other stations the totals vary from 2000 to 24,000. *Euphausia frigida* occurs at all of the former stations at which it can be expected to be found, and at none of the latter. *Parathemisto* occurs at most of the northerly stations and at none from WS 544 onwards. *Euphausia superba* appears only in small numbers south of WS 555 and nowhere south of WS 547. *Haloptilus ocellatus* is taken only at WS 555 and at stations farther south, and *Pleuromamma* does not occur south of WS 555. The steadiness of the total numbers at WS 544–51 and the wide fluctuations at the more northerly stations is reflected in the composition of the plankton population. At the southerly stations each species is present in roughly similar numbers, while farther north no two adjacent catches are alike. At WS 536 for instance *Euphausia frigida* and certain copepods are all plentiful, while at WS 537 the same species, with the exception of *Metridia*, are either absent or much reduced. At WS 559 there was an enormous catch of *Calanus acutus* and *Metridia* was relatively abundant, while WS 539 differed from all the other stations in producing large numbers of *Thysanoessa*, all other species being scarce. Of all the samples from this line, from WS 561 to WS 555, the only two which seem to contain a similar plankton are WS 561 and WS 557, and these are widely separated from one another. In this line of stations, therefore, we can recognize two distinct faunistic areas, the more southerly one characterized by a very uniform plankton, and the more northerly one characterized, at least to the east of the South Sandwich Islands, by a sharply fluctuating plankton. Each of the two areas also seems to contain certain species which are absent from the other.

A distinction between these two areas is also found in the phytoplankton. Hart (1934) gives a chart (Fig. 47, p. 102) on which the total quantities of phytoplankton are shown for most of the stations included in Table IX. There were no phytoplankton samples for WS 544 and WS 546, but at the stations near the South Sandwich Islands the catches were variable and sometimes very large, while at the more southerly stations the catches were more uniform, and, on the average, considerably smaller. The change takes place, as with the macroplankton, between WS 543 and WS 545. There is also a qualitative change in the phytoplankton from the South Sandwich area to the southern stations, but this is not quite complete at WS 545.

No other samples are available from the eastern Weddell Sea, but Sts. 626–8 (Fig. 14) were taken about a month later on the east side of the South Sandwich Islands. At St. 627 the sample was swamped with krill, but Sts. 626 and 628 revealed two quite different types of plankton. Between South Georgia and the South Sandwich Islands we have first the William Scoresby's stations off the ice-edge in October 1928–9 (WS 287–310,

Fig. 11). Among these the plankton did not show very much fluctuation, but they cover a small area and are not very illuminating. Sts. 360–2 (Fig. 12) are also close together, but the proportions of the various copepods vary sharply, though some of the other species are a little more uniform. The samples from Sts. 528 and 530 (Fig. 14) are quite similar except that about eight times as many *Calanus acutus* were taken at the former as at the latter. It seems then that on the occasions on which these regions have been visited the most variable plankton existed to the east of the Sandwich group, while there was a slightly less variable plankton between the Sandwich group and South Georgia.

The line of stations taken in October 1930–1 from Bouvet Island to South Georgia (Sts. 459–72, Fig. 14 and inset B) does not appear to cross any faunistic boundary. It is curious that although these stations are mostly in the "old" Weddell Sea water, which has presumably drifted up from the region of fluctuating plankton, the samples at each of them show a remarkable similarity. There are differences, described on p. 127, in the occurrence of certain cold-water species, but the distribution of the numerically important species along this line is very uniform. Thus *Calanus propinquus* was the dominant copepod at every station, *Euphausia frigida* was well represented throughout, *Limacina balea* was numerous at most stations, the occurrence of *Thysanoessa* was uniform and other species occurred mostly in small numbers. Only *Euphausia superba* had an irregular distribution.

The eastern part of the Scotia Sea, that is, the triangle formed by the South Sandwich Islands, South Georgia and the South Orkneys, also contains water from the Weddell Sea. Three lines of stations have been worked across this region: Sts. 372–5 in March 1929–30 (Fig. 12), 530–3 in December 1930–1 (Fig. 14), and 618–25 in February 1930–1 (Fig. 14). The latter two lines followed the edge of the pack-ice. The numbers of the numerically important species at these three lines of stations are shown in Table X, which is arranged on the same plan as Table IX on p. 138.

Table X. *Eastern Scotia Sea*

Date	March 1930				December 1930				February 1931							
	Open sea				Ice-edge				Ice-edge							
	West			East	West			East	West							East
Station	375	374	373	372	533	532	531	530	618	619	620	621	622	623	624	625
Hour	12	17	19	21	21	21	21	21	22	10	21	10	21	10	22	10
Calanus acutus	10	100	20	350	810	990	990	720	?	29	22	1600	64	22	400	640
Rhincalanus gigas	?	—	10	200	260	120	1200	3000	?	*19*	140	?	12	*10*	30	?
Euphausia superba	60	6400	570	850	—	1	12	8	5400	136	920	2	980	3	140	2
Thysanoessa sp.	*1100*	*850*	690	480	12	92	99	41	?	*33*	100	*59*	110	*22*	150	*33*
Calanus propinquus	*110*	8100	860	6400	100	248	96	240	?	*19*	140	?	12	*10*	30	?
Chaetognatha	*170*	10	—	30	110	23	220	940	?	?	—	*420*	—	?	15	*1*
Euphausia frigida	?	*50*	800	450	59	56	18	16	?	?	64	?	5	?	29	*1*
Metridia gerlachei	?	?	?	—	6100	220	180	280	?	?	3	?	—	?	—	?
Calanus simillimus	*290*	*50*	210	—	—	—	—	—	?	?	—	?	—	?	—	?
Pareuchaeta sp.	?	?	*10*	400	80	—	—	40	?	*1*	2	*8*	56	?	110	?
Total organisms (excluding shoaling species)	*1700*	9200	2600	8500	7700	1800	2900	5400	?	*100*	920	*2500*	690	*138*	1500	*970*

The principal conclusion to be drawn from this table is that, while quite a different type of plankton was taken on each of the three lines, the plankton at the individual stations of each line was of the same type. In other words, the samples suggest that in the eastern Scotia Sea the plankton is comparatively uniformly distributed, though its constitution may differ at different times. Some species in these lines are more evenly distributed than others. In the first line *Calanus acutus* is present at each station in numbers which are very small for this species, and *Thysanoessa* increases steadily to the westward. *Calanus simillimus* appears to do the same, while *Pareuchaeta* and *Euphausia frigida* seem to become reduced, though allowance must be made for their diurnal variations. The numbers of *Calanus propinquus* are more variable. The plankton revealed by this line is thus not so uniform as it was in the eastern Weddell Sea (WS 544–51), but it is more so than in the area to the east of the Sandwich group. In the second line (WS 530–3) the numbers of *Calanus acutus* are very steady, *Rhincalanus* and the Chaetognatha decrease to the westward, *Euphausia superba*, *Thysanoessa* and *Euphausia frigida* are uniformly scarce, and the numbers of *Calanus propinquus* and *Metridia* show no important fluctuations except for the large number of the latter taken at St. 533. This, however, was something of the nature of a shoal. Thus the plankton taken on this line was very uniform, and comparable to that of the eastern Weddell Sea. On the third line also we have quite a uniform plankton. Allowance must be made for the alternate day and night stations, and it will be seen that, apart from the exceptional catch of *Calanus acutus* at St. 621, no important fluctuations occur in the numbers of each species.

THE BELLINGSHAUSEN SEA

In the Bellingshausen Sea two lines of stations have been worked westward from Adelaide Island to a point beyond Peter 1st Island. These were the 'Discovery II' stations in 1930–1 (Sts. 561–82, Fig. 14) and the 'William Scoresby' stations in 1929–30 (WS 502–8, Fig. 13). On both cruises the stations were taken at or near the ice-edge. There have also been two shorter lines of stations running north-westwards from Adelaide Island—that of the 'Discovery II' in 1930–1 (Sts. 583–97, Fig. 14) and that of the 'William Scoresby' in 1929–30 (WS 509–17, Fig. 13). Other stations in the Bellingshausen Sea lie up and down the coast of Adelaide Island, the Biscoe Islands and the Palmer Archipelago.

During the cruise of the 'Discovery II' to the western Bellingshausen Sea twelve stations were taken on the outward journey (Sts. 561–72) and ten on the return (Sts. 573–82), and these are arranged in their relative positions on the line in Table XI, as in Table IX.

Reference has already been made (p. 110) to the thin plankton of the eastern Bellingshausen Sea (near Adelaide Island, etc.), and this is clearly shown in Table XI at stations east of St. 579. At the westerly stations the plankton tends to be rich, but there is great variation in the size of the samples. However, the composition of the plankton is very similar at these stations in spite of the fluctuations in abundance. *Rhincalanus* is usually the dominant copepod, though *Calanus acutus* is more numerous at one or two stations,

Table XI. *Bellingshausen Sea*

Date	January 1931										
	West										
Station	572	571	570	573	569	574	568	575	576	567	577
Hour	20	09	22	10	11	22	22	10	21	10	10
Calanus acutus	560	880	14,000	360	400	36	20	4,600	12	4700	480
Rhincalanus gigas	1700	*2100*	4,700	*4500*	*1100*	210	1900	*12,000*	290	*840*	*9,400*
Euphausia superba	—	—	—	—	—	1	—	76	2	—	—
Thysanoessa sp.	32	?	63	*17*	*17*	3	1	*110*	73	*110*	*4*
Calanus propinquus	60	?	160	*80*	*8*	14	—	*80*	68	?	?
Chaetognatha	290	*140*	210	*480*	*180*	10	100	*470*	8	*230*	*160*
Euphausia frigida	—	*6*	—	*11*	?	—	16	?	—	?	?
Metridia gerlachei	300	*60*	160	?	*40*	—	—	?	—	?	?
Salpa fusiformis f. *aspera*	1	*39*	—	*9*	*57*	56	370	?	—	*550*	*290*
Limacina helicina	23	4	73	12	22	120	280	9	36	82	110
Total organisms (excluding shoaling species)	3100	*3200*	19,000	*5400*	*1800*	410	2300	*18,000*	490	*6100*	*10,000*

Date	January 1931										
											East
Station	566	565	578	564	563	579	580	562	581	582	561
Hour	22	10	22	22	11	10	22	22	20	10	10
Calanus acutus	160	760	900	350	780	1100	99	76	360	55	5
Rhincalanus gigas	7200	*5600*	540	160	*1200*	*470*	16	1	130	*35*	*1*
Euphausia superba	—	—	4	—	—	24	3	2	1	2	3
Thysanoessa sp.	22	*6*	15	120	*34*	*38*	250	4	96	*2*	*52*
Calanus propinquus	—	?	48	96	*920*	*16*	12	12	18	*7*	*26*
Chaetognatha	170	*410*	100	6	7	?	—	—	—	?	?
Euphausia frigida	16	?	—	—	?	?	—	—	—	?	?
Metridia gerlachei	—	?	104	—	?	*16*	2	—	34	*2*	?
Salpa fusiformis f. *aspera*	66	*4*	—	—	?	?	—	—	—	?	?
Limacina helicina	630	40	14	28	33	10	4	2	—	6	1
Total organisms (excluding shoaling species)	8300	*6900*	1700	780	*3000*	*1600*	390	100	650	*110*	*85*

and it is in fact the variations in the numbers of these two species which are responsible for the variations in the total numbers of organisms. The other species, which are not very abundant, occur in quite uniform numbers.

Table XII shows the results of the 'William Scoresby' line of stations.

WS 508 is in the region of thin plankton in the eastern Bellingshausen Sea, but heavy catches were taken at the other four and the plankton becomes progressively richer towards the west. Apart from this increasing abundance the plankton is very similar at each of these stations. It resembles that of the 'Discovery II' line in the scarcity of Euphausians and in the numbers of *Rhincalanus* and *Limacina*, but differs from it in the great abundance of *Calanus acutus*, and in the larger numbers of *Calanus propinquus* and Chaetognatha.

These two lines of stations indicate that the Bellingshausen Sea may be divided, in respect of its plankton population, into two regions: the eastern part which contains a thin plankton, and the western part which normally has a rich plankton. The quantity of plankton in the western part seems liable to vary very much from place to place, but its composition seems to be quite uniform.

Table XII. *Bellingshausen Sea*

Date	January–February 1930				
	West				East
Station	WS 503	WS 502	WS 504	WS 505	WS 508
Hour	19	13	18	14	02
Calanus acutus	31,000	21,000	13,000	13,000	640
Rhincalanus gigas	5,900	*2,200*	2,000	?	—
Euphausia superba	—	—	—	10	1
Thysanoessa sp.	17	*100*	9	*1*	20
Calanus propinquus	1,000	*510*	64	*450*	170
Chaetognatha	2,600	*1,500*	709	*120*	5
Euphausia frigida	—	?	—	?	—
Metridia gerlachei	*1,300*	*260*	*64*	?	48
Salpa fusiformis f. *aspera*	?	?	?	?	10
Limacina helicina	31	94	81	—	17
Total organisms (excluding shoaling species)	43,000	*26,000*	16,000	*13,500*	910

Various other stations have been worked in the eastern part of the Bellingshausen Sea, the most important of which are those taken by the 'Discovery II' in a line running north-westwards from Adelaide Island (Sts. 583–97, including stations on return journey). The numbers of the principal species taken are shown in Table XIII.

Table XIII. *Off Adelaide Island*

Date	January 1931														
	North-west														South-east
Station	592	591	593	590	594	589	595	588	597	587	596	586	585	583	584
Hour	02	20	10	10	16	01	00	19	12	14	05	09	05	22	01
Calanus acutus	28	8	1	6	12	3	11	4	6	15	5	3	78	66	29
Rhincalanus gigas	280	420	*100*	*1*	200	8	200	7	?	*4*	5	*2*	27	55	17
Euphausia superba	—	1	—	8	—	—	—	—	1	—	6	—	1	2	1
Thysanoessa sp.	2	2	*100*	*2*	6	20	5	2	*22*	*1*	1	*100*	28	38	12
Calanus propinquus	12	2	?	*1*	?	5	13	5	?	*3*	1	*4*	25	55	9
Chaetognatha	37	13	*4*	?	*20*	2	7	1	?	?	—	?	—	5	1
Euphausia frigida	10	—	?	?	?	1	1	—	?	?	—	?	—	—	—
Parathemisto gaudichaudi	7	8	15	—	3	—	4	1	—	—	1	—	—	—	—
Metridia gerlachei	8	—	?	?	?	—	2	?	?	?	?	?	*14*	—	7
Limacina helicina	95	40	44	22	49	4	10	—	—	7	8	3	13	2	24
Total organisms (excluding shoaling species)	570	500	*270*	37	*330*	51	280	21	*30*	*30*	22	*120*	200	220	110

It should be mentioned that the stations at the south-eastern end of the line (near Adelaide Island) were a little closer together than those to the north-west (see Fig. 14, inset A).

The table shows the same thin plankton that was found at stations east of St. 579 in Table XI. The poorest plankton of all is found in the middle, there is slightly more at the inshore end (south-east) and the largest catches at the north-west end where indeed one might expect to reach a region of richer plankton. The composition of the catches must be regarded as quite uniform. Only *Rhincalanus* varies to some extent, but where there are never more than a few hundred specimens in the samples, such fluctuations cannot be of much significance.

During her cruise in the Bellingshausen Sea the 'William Scoresby' also worked a line of stations north-westwards from Adelaide Island (WS 509–17, February 1929–30, Fig. 13, inset). This was a short line, however, and the stations were close together, so that it is of less importance here than the 'Discovery II' line. It may be mentioned that the catches were quite similar in size and composition to those in the Discovery samples, and the plankton seemed quite uniform along the line except at WS 515, where a surprisingly large catch was taken in which *Calanus acutus*, *C. propinquus*, *Metridia*, *Parathemisto* and *Thysanoessa* numbered three or four hundred each.

Other hauls taken in the Bellingshausen Sea include only some stations taken along the coastal region between Adelaide Island and the South Shetlands. There were six taken by the 'William Scoresby' at the beginning of January 1929–30 (WS 496–501, Fig. 13), five taken by the 'Discovery II' at the end of December 1930–1 (Sts. 556–60, Fig. 14), and five more by the same ship late in January of the same season (Sts. 598–603, Fig. 14). The samples taken at the ten stations of the 'Discovery II' were all very small, averaging about 130 organisms per haul. By far the largest of these was the catch taken at St. 598 which contained over 600 organisms of which *Metridia* formed the majority. At three of the 'William Scoresby' stations, however (WS 496, 497 and 501), quite large catches were taken, each containing several thousand specimens of *Calanus acutus*. None of the other species was very plentiful, but such catches are very unusual in these coastal regions.

It seems then that the eastern or coastal region of the Bellingshausen Sea is characterized by a thin plankton of fairly uniform distribution, but that here and there one or more species may become concentrated, as a result, perhaps, of some local peculiarity in the hydrological conditions.

THE ORKNEY-SHETLAND REGION

In this section those stations will be briefly considered which lie in the vicinity of the South Shetlands and South Orkneys and in the Bransfield Strait, a region characterized, as already noted, by a general scarcity of plankton.

In the Bransfield Strait three intensive surveys have been carried out, with lines of stations at short intervals, and between the South Shetland Islands and the South

Orkney Islands various stations have been taken, many of which were at the edge of the Weddell Sea pack-ice.

The three surveys of the Bransfield Strait were taken in February 1928–9, November 1929–30, and December 1930–1 (Figs. 15–17). It will not be necessary here to tabulate the numbers of each species taken at the different stations. If the catches of *Euphausia superba* are disregarded it may be said that every sample which has been taken from the Bransfield Strait has been an extremely small one, and if one sample (WS 393), which contained the exceptional quantity of 520 *Metridia*, is also disregarded, the largest catch from the three surveys contained only 300 organisms. It is known that the south side of the Bransfield Strait is occupied by Weddell Sea water, and the north side by water from the Bellingshausen Sea. The distribution of the macroplankton, however, does not appear to differ very much in different parts of the Strait, and with such small samples, many of them containing only twenty or thirty organisms, it is very difficult to establish a reliable correlation between the local hydrological conditions and the distribution of the macroplankton.

Between the South Shetland Islands and the South Orkney Islands there are no straight lines of stations, and usually only two or three stations have been taken at a time in this region, but in the 1930–1 season the 'Discovery II' worked eight consecutive stations in December along the ice-edge from near the South Orkneys towards the Bransfield Strait (Sts. 534–41, Fig. 14), and eight more in roughly the same position in March (Sts. 637–44, Fig. 14). The numbers of the principal species at these stations are shown in Table XIV.

Table XIV. *Shetland–Orkney region*

Date	December 1930–1								March 1930–1							
	West							East	West							East
Station	541	540	539	538	537	536	535	534	644	643	642	641	640	639	638	637
Hour...	23	20	17	12	06	21	10	21	06	23	18	14	09	23	05	21
Calanus acutus	76	60	37	60	?	1800	6	59	15	?	—	—	1	32	1	—
Rhincalanus gigas	2	15	25	*12*	?	40	*35*	47	1	?	—	?	?	16	1	—
Euphausia superba	10	4	68	27	7600	7	4	5	20	1800	7	590	23	810	15	1
Thysanoessa sp.	23	6	*26*	*508*	*144*	8	*83*	28	*16*	49	3	*26*	*3*	83	*19*	75
Calanus propinquus	—	4	3	?	?	30	*1*	24	1	*42*	2	?	*4*	380	*2*	72
Chaetognatha	6	360	14	*14*	?	100	*7*	5	—	?	—	?	?	—	?	—
Euphausia frigida	—	—	?	?	?	—	?	57	*1*	*220*	—	?	?	1	7	41
Parathemisto gaudichaudi	—	—	1	—	?	2	—	—	9	56	—	—	—	3	1	22
Metridia gerlachei	4	—	?	?	?	190	?	7	*22*	*1100*	?	?	*10*	2800	*8*	380
Salpa fusiformis f. *aspera*	—	—	?	?	?	79	?	89	?	*260*	?	*70*	*19*	55	*1*	300
Total organisms (excluding shoaling species)	120	450	110	*590*	?	2200	*130*	280	*65*	*1500*	5	*26*	*19*	3400	42	590

It will be seen from Fig. 14 that in both these lines the more westerly stations are closer together than the others.

This is still a definitely thin plankton, but it is richer than in the Bransfield Strait and much more variable. There are considerable fluctuations both in the total number of organisms and among the individual species. Apart from *Euphausia superba* the most variable species are *Metridia gerlachei*, *Calanus acutus* and *Salpa fusiformis*.

The other stations in this area are WS 202 (Fig. 10) which was remarkable for a heavy catch of *Metridia* (over 3000) and an exceptional number of *Parathemisto* (350), WS 380 and 381 (Fig. 11) at which the plankton was scarce except for a rather large number of Salps, and Sts. 613–15 (Fig. 14) at which Salps were again quite plentiful and other species scarce.

It appears, therefore, that the area between the South Orkneys and the South Shetlands is characterized, like the eastern part of the Bellingshausen Sea, by a plankton which is generally scarce, but which may be found here and there in comparatively large quantities, usually due to the concentration of one particular species.

THE NORTHERN ZONE

The lines of stations so far considered are those in waters which are covered by the pack-ice during a large part of the year. Those next to be considered are mostly in waters which are never reached by the ice. Numerous stations have been taken in this area and we may consider first the lines crossing Drake Passage. There are three of these lines (Figs. 11, 12, 14) and they are shown in Table XV, which gives for each station the numbers of the ten most abundant species in this region.

Table XV. *Drake Passage*

Date	February 1928–9					April 1929–30					March 1930–1				
	South				North	South				North	South				North
Station	WS 400	WS 401	WS 402	WS 403	WS 404	378	382	383	384	385	644	646	647	648	649
Hour...	10	00	13	01	13	12	01	10	20	08	06	17	00	13	23
Calanus acutus	—	17	20	32	64	13	800	800	—	—	15	—	810	64	40
Rhincalanus gigas	?	8	*170*	3500	*5100*	*79*	5200	*1000*	530	*1500*	1	11	1500	*1500*	330
Limacina balea	?	—	?	—	*10*	?	—	?	—	*40*	—	—	—	?	430
Thysanoessa sp.	*33*	—	*180*	3700	*2200*	*16*	50	*220*	150	*18*	*16*	*64*	500	*8*	290
Calanus propinquus	?	9	?	320	*64*	*8*	1900	*100*	440	?	1	—	160	*16*	88
Chaetognatha	?	—	*16*	380	*880*	?	660	*320*	370	*6300*	—	—	11	*850*	1600
Euphausia frigida	?	92	?	320	?	?	33	?	230	*1*	1	?	30	?	—
Parathemisto gaudichaudi	8	9	73	35	89	81	92	38	270	31	9	13	5	4	7
Calanus simillimus	?	—	*2*	160	?	?	—	*20*	—	*20*	*1*	*1*	160	*16*	88
Pareuchaeta sp.	?	84	?	350	*32*	?	400	*10*	310	?	?	?	40	*8*	130
Total organisms (excluding shoaling species)	*43*	290	*460*	9100	*8400*	*200*	9200	*2500*	2400	*7900*	65	89	3200	*2500*	2800

The most northerly station in each of these three lines lies close to the Antarctic convergence.

The first three stations of the 1928–9 line, the first station of the 1929–30 line and the first two stations of the 1930–1 line are in the region of thin plankton, and will be regarded as belonging to the Orkney–Shetland region. The others are in the normal plankton of the northern zone.

An inspection of Table XV will show that at WS 403 and WS 404, at Sts. 382–5, and at Sts. 647–9 there is a very uniform plankton. At all these stations *Rhincalanus* is the dominant copepod, *Limacina* is found only near the convergence, the Chaetognatha for the most part increase steadily towards the north, and *Pareuchaeta* and *Euphausia frigida* (except at St. 649) are present in moderate numbers at night stations. *Calanus acutus* and *C. propinquus* are a little variable, but *Parathemisto* has a uniform distribution in each line, except for a large catch at St. 384. *Thysanoessa* occurs in large numbers on the first line, but in smaller numbers on the other two. In general it may be said that there is a close similarity in the catches at consecutive stations across this part of the northern zone, and if one or two species, such as *Thysanoessa*, are excepted, it can be said that there was little difference between the plankton taken on the three lines.

North-east of Drake Passage there are several lines of stations lying roughly between the Falkland Islands and the South Shetlands and South Orkneys (Figs. 10, 12, 14). These stations and the principal species taken at them are shown in Table XVI.

Table XVI. *Between Falkland Islands and South Orkneys*

Date	April 1927–8		November 1929–30						March 1929–30			March 1930–1				
	South	North	South					North	South	North		South				North
Station	WS 203	WS 204	WS 474	WS 473	WS 472	WS 471	WS 470	WS 469	WS 527	WS 528	WS 529	637	636	635	634	633
Hour...	23	01	23	09	21	09	19	20	12	14	15	21	09	23	09	22
Calanus acutus	140	—	—	340	270	700	530	48	—	—	—	—	5	140	120	600
Rhincalanus gigas	940	52	1	*240*	340	*1300*	1300	660	*10*	?	?	—	*2*	580	*2200*	3,300
Limacina balea	48	5400	—	?	16	?	12	—	*10*	?	?	—	?	—	*180*	2,800
Thysanoessa sp.	190	—	160	*14*	33	*3*	1	230	*270*	*700*	*25*	75	*15*	710	*520*	4,700
Calanus propinquus	260	80	15	?	12	?	—	32	*790*	*18*	*60*	72	*3*	790	*80*	1,500
Chaetognatha	1200	1100	—	*160*	26	*400*	660	820	*670*	*60*	*10*	—	?	740	*2400*	1,400
Euphausia frigida	87	?	54	?	6	?	—	—	?	?	?	41	?	62	?	—
Parathemisto gaudichaudi	10	25	—	2	2	—	21	200	10	10	210	22	25	13	53	60
Calanus simillimus	16	160	—	?	4	?	16	—	*10*	?	?	—	?	200	?	680
Pareuchaeta sp.	96	92	—	?	—	?	?	—	?	?	?	—	?	120	*40*	880
Total organisms (excluding shoaling species)	3000	1600	240	*990*	750	*2500*	2600	2100	*1800*	*800*	*310*	590	*50*	3500	*5400*	15,000

The samples taken at WS 203 and WS 204 resemble one another only in respect of certain species. Thus the numbers of Chaetognatha, *Parathemisto*, and *Pareuchaeta* are similar, but *Rhincalanus* is the dominant copepod only at WS 203, and *Thysanoessa* occurs only at that station. The suggestion of an increase in the number of *Limacina* towards the north is in accordance with the conditions found in Drake Passage. The November line (WS 469–74) shows again the uniform plankton indicated in Drake Passage. At each station but one *Rhincalanus* is, as before, the dominant copepod, *Calanus acutus* is uniformly distributed in modest numbers and the Chaetognatha steadily increase towards the north. *Limacina*, *Thysanoessa*, *Calanus propinquus*, *C. simillimus*, and *Pareuchaeta* are scarce. WS 527–9 give curious results. The hauls were all taken in the middle of the daytime and consequently are not very reliable, but the plankton is not of the usual type found in the northern zone. The quantity is small, *Calanus* *propinquus* replaces *Rhincalanus* as the dominant copepod and the Chaetognatha diminish towards the north instead of increasing. The distribution of the plankton, however, seems to be quite uniform. In the 1930–1 line Sts. 637 and 636 are evidently in the area of thin plankton. At Sts. 635, 634 and 633, however, *Rhincalanus* is again dominant, *Calanus acutus* appears in moderate numbers, *Limacina* and the Chaetognatha increase towards the north and *Parathemisto* is evenly distributed in small numbers. The other species mostly increase towards the convergence, but the increase is in proportion to the increase in the total number of organisms, and the plankton here can be regarded actually as very uniform.

Table XVII. *Between Falkland Islands and South Georgia*

Date	February 1927–8			August 1928–9			December 1928–9			March 1928–9			
	NW		SE	NW		SE	NW		SE	NW			SE
Station	WS 140	WS 141	WS 142	WS 254	WS 255	WS 256	WS 316	WS 315	WS 314	WS 413	WS 414	WS 415	WS 416
Hour	21	17	10	13	03	01	16	19	13	13	05	17	16
Calanus acutus	260	1,500	3	—	—	16	110	130	68	—	290	670	2800
Rhincalanus gigas	400	7,500	12	?	1	160	2200	2300	260	32	2700	640	1900
Limacina balea	300	160,000	300	?	26	—	120	—	?	280	530	48	?
Thysanoessa sp.	180	2,700	52	2	130	560	6	260	2	230	150	1600	6
Calanus propinquus	3600	2,800	2	2	3	92	16	96	?	460	—	220	64
Chaetognatha	230	1,400	38	1	—	2	220	260	160	1000	440	130	9
Euphausia frigida	68	1,200	?	?	63	550	?	24	?	8	2	830	?
Parathemisto gaudichaudi	31	450	28	2	6	—	36	2700	72	26	42	50	260
Calanus simillimus	—	?	5	2	—	—	80	190	52	300	64	260	?
Pareuchaeta sp.	16	?	?	?	—	4	?	?	?	?	?	?	?
Total organisms (excluding shoaling species)	4900	18,000	150	9	210	1500	2800	6200	640	2200	3700	5500	5000

Date	April 1928–9				November 1929–30		February 1929–30						March 1930–1			
	NW			SE	NW	SE	NW					SE	NW			SE
Station	WS 430	WS 429	WS 428	WS 427	WS 466	WS 465	WS 521	WS 522	WS 523	WS 524	WS 525	WS 526	656	657	658	659
Hour	04	11	18	00	22	22	13	03	14	10	23	14	10	09	05	13
Calanus acutus	—	32	32	32	1500	224	—	96	—	—	2,600	32	—	—	6	—
Rhincalanus gigas	760	3800	670	1100	1000	2500	830	1900	1200	800	830	?	138	?	—	2
Limacina balea	1200	120	40	?	540	—	22,000	—	72	72	—	?	150	3	—	?
Thysanoessa sp.	250	130	140	16	48	800	330	3800	840	150	8,000	150	12	16	82	34
Calanus propinquus	120	220	350	990	—	—	?	320	24	?	3,000	100	?	29	52	120
Chaetognatha	730	1100	840	2	1800	1600	790	300	78	56	80	4	100	?	68	22
Euphausia frigida	—	?	350	33	—	32	?	1400	?	?	—	?	?	?	—	?
Parathemisto gaudichaudi	3	22	11	940	480	160	310	1	92	130	140	250	8	10	18	12
Calanus simillimus	56	32	450	96	5100	350	?	160	64	16	1,900	32	2	?	—	?
Pareuchaeta sp.	48	?	16	420	16	—	?	450	?	?	—	?	?	?	?	?
Total organisms (excluding shoaling species)	2100	5400	2900	3800	11,000	6300	2,300	8700	2300	1200	17,000	630	260	55	230	190

Finally, there are eight lines of stations lying between South Georgia and the Falkland Islands. These are shown in Table XVII and their positions in Figs. 10, 11, 12, 14.

Whereas other lines crossing the northern zone have at their southern or south-eastern ends an area of scarce plankton, most of these have at their south-eastern ends the rich plankton of the neighbourhood of South Georgia. The first line, however, (WS 140–2) is an exception, for in February 1927–8 the plankton was unusually thin around the north and west sides of South Georgia, and between WS 141 and WS 142 we find the familiar abrupt change from a rich to a poor plankton. It must be admitted that at these three stations the plankton is patchy. *Rhincalanus* is the dominant copepod at WS 141 and WS 142, but at WS 140 this species is far exceeded by the young stages of *Calanus propinquus*. At WS 141 the net evidently passed through a shoal of *Limacina*. Apart from these species, however, the differences between the three stations lie in the quantity rather than in the constitution of the plankton.

The next line (WS 254–6) was the only winter line across the northern zone, and is therefore hardly comparable with the others. The plankton of course was very thin, but had moderate numbers of Euphausians towards South Georgia. The plankton at WS 254, a midday station, was practically negligible.

At WS 314–16 there is again a rather sharp fall in the quantity of plankton from WS 315 to WS 314. At all three stations however *Rhincalanus* dominates the whole sample except for the exceptional catch of *Parathemisto* at WS 315. Other species are very uniform, though there is a slightly disproportionate number of *Thysanoessa* at WS 315.

At WS 413–16 the Chaetognatha increase steadily towards the convergence and *Calanus acutus* towards South Georgia. *Parathemisto* is fairly steady, but *Rhincalanus* is the most plentiful copepod only at WS 414. At WS 415 it is equalled, and at WS 416 it is exceeded by *Calanus acutus*. Euphausians are inclined to be irregular.

In the line WS 427–30 *Rhincalanus* is the principal copepod at all four stations. *Limacina* increases towards the convergence, and the Chaetognatha tend to do the same, though they fall off at WS 430. *Calanus propinquus* and *Thysanoessa* are quite evenly distributed, though the former increases a little towards South Georgia.

WS 465 is quite typical of the northern zone with its abundant *Rhincalanus* and Chaetognatha, but WS 466, which is almost on the convergence, has unexpectedly large numbers of *Calanus acutus* and *C. simillimus*.

In the line WS 521–6 there are more stations between the convergence and South Georgia than in any other. The quantity of plankton varies considerably, but this is largely due to the diurnal variations of *Thysanoessa*. At WS 522 and WS 525 the samples were taken near the middle of the night and at the other stations near the middle of the day, and at the former *Thysanoessa* was enormously abundant and at the latter relatively scarce. At WS 521–4 *Rhincalanus* was much the most abundant copepod, but at WS 525 and WS 526 (nearer to South Georgia) it was replaced by *Calanus acutus* and *C. propinquus*. *C. simillimus* was evenly distributed except at WS 525, and *Parathemisto* except at WS 522. There was the usual increase of Chaetognatha towards the convergence and a shoal of *Limacina* at WS 521.

The last line (Sts. 656–9) differs from nearly all other lines across the northern zone in the small amount of plankton taken at each station. *Parathemisto* and *Thysanoessa* are very uniform, and the Chaetognatha increase towards the convergence, but the commonest copepod at Sts. 657, 658 and 659 is *Calanus propinquus*, *Rhincalanus* being dominant only at St. 656. Apart from this, however, the plankton is similar in its make-up to the plankton found on other lines in this area.

Enough has been said now to show that the northern zone contains, during the summer, a plankton population sufficiently characteristic to form the basis of a separate faunistic area. The most important features of this plankton may be summed up as follows.

It is a population of homogeneously distributed typically warm-water species. *Rhincalanus* is generally the most abundant species and almost always has a large majority over other copepods. The Chaetognatha are nearly always present in large numbers near the convergence and in steadily decreasing numbers to the south or south-east of it. *Calanus simillimus*, *Parenchaeta* sp. and *Euphausia frigida* are nearly always present in small or moderate numbers in the night hauls. Owing to their marked diurnal variations they are rarely taken in day hauls, but it is evident that they are usually quite evenly distributed over the whole area. The occurrence of *Calanus propinquus* and *Thysanoessa* is a little irregular, but if they occur in large numbers at one station in a line across the northern zone, it is probable that they will be taken also in large numbers at other stations in that line.

In general, it can be said that, in the northern zone, the summer plankton is both uniform and stable. That is to say that, compared with other parts of the area investigated, excepting perhaps the eastern Weddell Sea, a uniform type of plankton community is to be found everywhere at a given time, and that the plankton does not alter very much from month to month or from year to year. The northern zone seems to be a little more uniform and stable in the Drake Passage than it is between the Falkland Islands and South Georgia. In the latter region, however, there is known to be an eddy in the currents near the convergence, and this might be expected to cause some irregularities in the distribution of the plankton.

FAUNISTIC DIVISIONS

We are now in a position to map out the Weddell sector of the Antarctic in respect of the different types of plankton which have been found there, and it is possible, in my opinion, to distinguish seven separate divisions. These are shown in Fig. 48 and they may be defined as follows.

(1) *The northern zone.* This zone is bounded to the north by the Antarctic convergence, and to the south by the region of scarce plankton in the vicinity of the South Shetlands, and by the beginning of the transition zone in the vicinity of South Georgia. It is characterized by a uniform and stable plankton, in which *Rhincalanus gigas* is generally predominant; the Chaetognatha and *Limacina balea* are plentiful, especially near the convergence, and the typically warm-water species are fairly evenly distributed.

(2) *The Graham Land area.* This includes the whole of the region of scarce plankton

in the neighbourhood of the South Shetlands and South Orkneys, the Bransfield Strait and eastern part of the Bellingshausen Sea. The Shetland–Orkney region and the eastern Bellingshausen Sea can be regarded as subdivisions. It is characterized normally by a very thin plankton in which typically cold-water species are well represented. In some places there may be considerable irregularity in the quantity of plankton. The

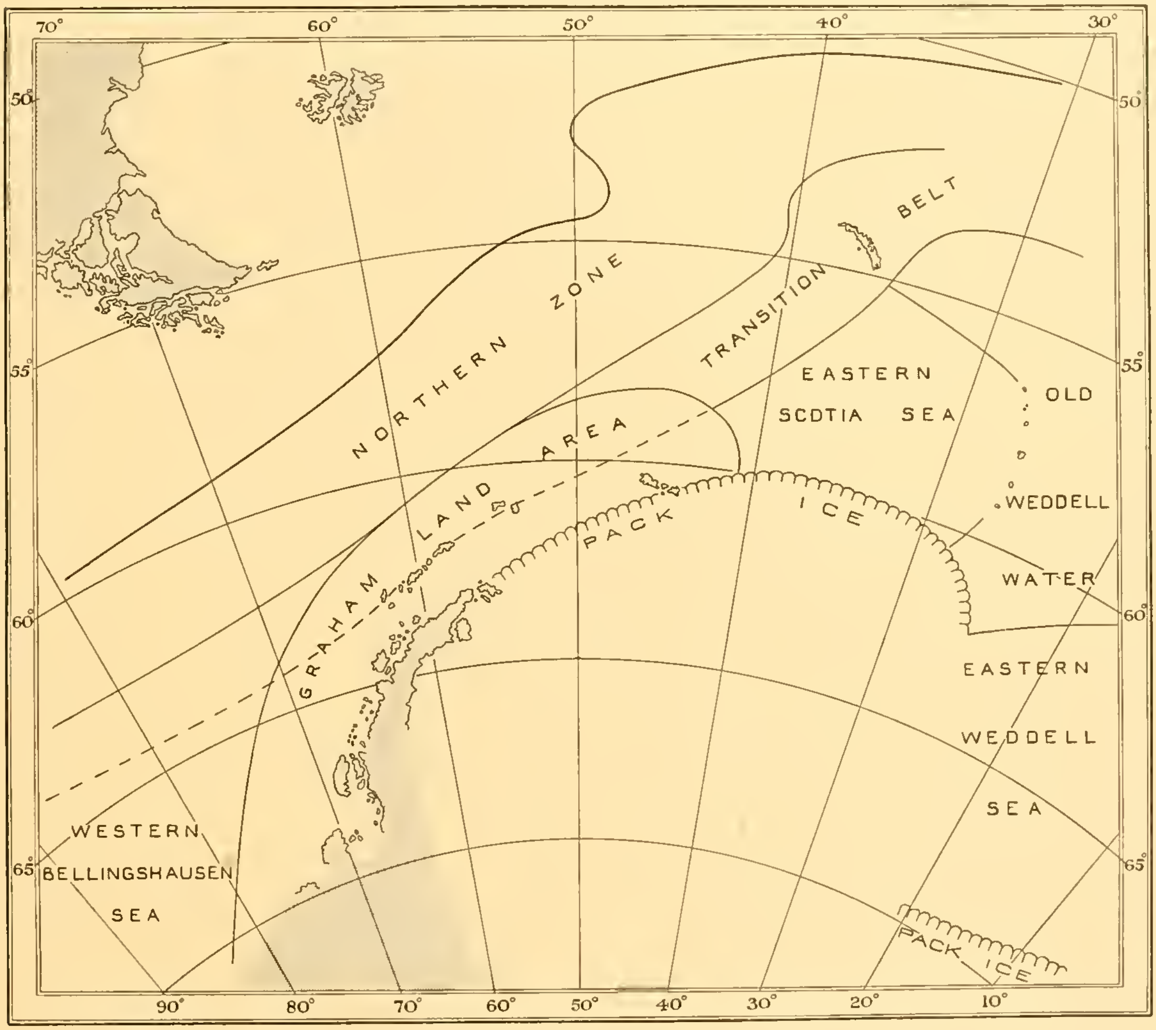

Fig. 48. Chart showing the provisional boundaries of areas in which distinctive plankton communities have been found.

limits of this area are ill-defined near the South Orkneys, and uncertain on the west side of Drake Passage.

(3) *The transition belt.* Derived from Fig. 21, p. 105. This is the belt in which the normal southern limits of the warmest water species and the northern limits of the coldest water species are found. One would expect to find the cold-water species prominent here in the early summer and the warm-water species later. This zone largely encloses the line separating the waters derived from the Bellingshausen and Weddell Seas, and may be taken to include South Georgia and the adjacent whaling grounds. Strictly

speaking it overlaps a part of the Graham Land area, which is defined on a different basis, for there is probably something of a transition zone everywhere to the south of the northern zone.

(4) *The eastern Scotia Sea.* A rough triangle, having at its corners the South Sandwich Islands, the South Orkney Islands and South Georgia. The area is characterized by a plankton which appears to be uniform but unstable. That is to say, a different type of plankton has been taken on the different lines of stations crossing this area, but the plankton was similar at consecutive stations in each line. The composition of the plankton seems to depend on the time of year, and very likely varies from one year to another.

(5) *The "old" Weddell water.* It is difficult at present to give any general definition of the plankton in this area, but it includes the unstable and heterogeneous plankton population found on the east side of the South Sandwich Islands. Its southern limit, at the time it was determined, lay between WS 544 and WS 555 (lat. 60° 40′ S, see p. 69), and north of this it may be temporarily defined as the area occupied by water which has flowed out of the Weddell Sea and passed the Scotia Arc in the vicinity of the South Sandwich Islands.

(6) *The eastern Weddell Sea.* The limits of this area are not known, but it lies south of WS 555, and, so far as can be judged from a single line of stations, the plankton is very uniform and characterized by a high proportion of the very cold-water species. It offers a marked contrast to the preceding division.

(7) *The western Bellingshausen Sea.* The exact limits of this area are also unknown, but it may be regarded temporarily as that part of the Bellingshausen Sea in which the plankton is rich in comparison with that found in the eastern part near Adelaide Island. The plankton taken here was in many ways comparable to that found in the eastern Weddell Sea, but it was rather more variable and the proportion of cold-water species was not quite so high.

It must be specially emphasized that these divisions are intended to do no more than represent the conditions as they were found at the time of investigation, and it would in fact be surprising if certain modifications of the scheme were not found to be necessary if the results of subsequent work are brought to bear on the question. It should also be mentioned that the boundaries between the different divisions are not geographically fixed lines. The Antarctic convergence may perhaps shift its position according to the time of year, and it has been seen (p. 121) that the change from the scarce plankton of the Graham Land area to the comparatively rich plankton of the northern zone has been found in quite different positions at different times. The distribution of the plankton should not, in any case, be thought of as a static pattern, but as a number of drifting communities whose formation must depend partly on their origin and the methods of propagation of the various organisms, and partly on the changing conditions through which they are carried. In the northern zone the current runs steadily from west to east with little interruption from islands, shoal waters, and varying ice conditions. This probably explains the regularity in the distribution of its plankton. The water flowing out of the Weddell Sea, on the other hand, impinges on the loop of the Scotia arc, and although the hydrological conditions in this region have not yet been worked out in detail, there can be little doubt that there are disturbances in the speed and direction of the currents. The most variable and fluctuating macroplankton was found, as we have seen, to the east of the South Sandwich Islands, and this is just where we should expect to find disturbances and eddies in the water, like the eddies formed in a river on the downstream side of a ford or the piers of a bridge. In the eastern Weddell Sea, where the drift of the water is undisturbed, we find again a uniform plankton population. Much of this area, as it is shown in Fig. 1, must contain water which is flowing westwards in the counter-current which is known to exist in the high latitudes, but the point at which the heterogeneous plankton of the old Weddell water changes to the homogeneous plankton of the eastern Weddell Sea (i.e. between WS 543 and WS 544), does not necessarily mark the division between the easterly and the westerly drift.

THE MACROPLANKTON AND THE DISTRIBUTION OF WHALES

It need hardly be pointed out that no immediate solution of the problem of the distribution of whales can be sought in a study of the general distribution of the macroplankton of the waters in which they live. A more direct connection no doubt exists between the movements of whales on the one hand and the distribution of "krill" and the hydrological conditions on the other hand. What we can hope for in a study of the associated plankton population is something in the nature of a symptom of the environmental conditions which are most favourable to the concentration of whales. The subject will not be pursued very far at the present stage, but it is worth while to mention one or two facts which suggest a link between the behaviour of whales and the distribution of the macroplankton in general.

The question is very difficult to approach because the movements and distribution of whales are influenced by more than one factor of major importance. It is known that they are migratory animals, visiting the warmer waters for purposes of breeding, and seeking their food in the cold waters of the Antarctic. We might assume then that the presence of a large concentration of whales in a particular place is to be explained on the grounds either that the whales have found there the environment which they require, or that they are on the way to, or looking for such an environment. The difficulty is to know which.

Around South Georgia and the South Shetland and South Orkney Islands whaling has been in progress for many years, and since the modern development of the factory ship the areas within which whales are caught has been vastly extended. The positions of the whaling grounds in the Atlantic sector of the Antarctic (as well as in other sectors) has been defined in recent papers by Hjort, Lie and Ruud (1932 and 1933). The charts published by these authors (1932, chart no. 1; 1933, pls. i, ii, v and vi), show that, though important changes take place during the season, most of the whaling in the

Atlantic sector is carried on at the ice-edge near the South Sandwich Islands, between Bouvet Island and the South Sandwich Islands and between the South Sandwich and South Orkney Islands. Ruud (1932, p. 76) also gives a useful chart showing the extent of the whaling grounds in the season 1929–30. If the charts of these authors are compared with Fig. 48, and it is remembered that South Georgia and the South Shetlands are also whaling areas, it will be seen that whales are sufficiently plentiful to be hunted in most of our faunistic areas, i.e. the Graham Land area (South Shetlands and South Orkneys), the transition zone (South Georgia), the eastern Scotia Sea (ice-edge whaling), and the "old" Weddell area (ice-edge whaling). During the cruises of the research ships continuous observations on whales have been made as far as weather conditions allowed, and our experience is that Blue and Fin whales may be met with anywhere in the Graham Land area, the transition zone, the eastern Scotia Sea, the "old" Weddell area, and the western Bellingshausen Sea. These are the same areas as those mentioned above in which whaling is conducted, but with the addition of the western Bellingshausen Sea in which whaling has not yet been developed. In the northern zone it has been observed that whales are very much scarcer, and in the eastern Weddell area practically none were seen. These are also the two areas (besides the Bellingshausen Sea) in which whales are not regularly hunted. In the period 1927–31 only one cruise was made in the eastern Weddell area, but during the recent second commission of the 'Discovery II' this area was revisited and I am informed that, as before, there was a notable scarcity of whales.

A comparison of Figs. 21 and 48 will show that the normal northern limit of the "krill" (*Euphausia superba*) corresponds with the southern boundary of the northern zone, and it has been seen that scarcely any "krill" was found in the eastern Weddell area (see Table IX, p. 138, WS 544–51). This no doubt accounts for the scarcity of whales in these two regions. It does occasionally happen, however, that a ship passing through the northern zone comes across a large herd of whales. Thus on November 12, 1929, when the 'William Scoresby' was in 58° 49′ S, 57° 50′ W, near the position of WS 471 (see Fig. 12, p. 80), many whales were seen in various directions from the ship, and were recorded as travelling in a southerly direction. There can be no question that these whales were on their way to the southern feeding grounds, and it would be safe to assume that any large body of whales met with in the northern zone is on its way to, or is returning from, the environment it requires in the Antarctic. Even in the areas which they commonly inhabit during the summer, the occurrence of the whales is, of course, very irregular. There are some places, however, in which they are more often found in large numbers than in other places. For instance in parts of the "old" Weddell area, especially to the east of the South Sandwich Islands, and in the eastern part of the Graham Land area around the South Orkneys and South Shetlands, enormous numbers of whales have been seen from time to time, while in the central part of the eastern Scotia Sea area large numbers of whales were rarely seen. The distribution of their food is no doubt the most important factor controlling the local distribution of whales, but there are other factors as well, for we must take into account the distinction between whales which are travelling and those which are not, and it is almost certain that the whales are influenced by the position of the pack-ice, the proximity of which is not necessary to the existence of "krill". Ruud (1932), in studying the connection between the whaling grounds and the distribution of *Euphausia superba*, points out that the "krill" is widely distributed in Antarctic waters, but suggests that the principal feeding grounds of the whales are in the "areas of convergence, backwaters, vortices of mixed layers, and in the centre of areas with a cyclonic motion", where a special concentration of "krill" is brought about. Since the present paper is concerned only with the distribution of the macroplankton as a whole, these conclusions cannot be examined in detail, but there are certain aspects of the distribution of the macroplankton which may have a bearing on them. We have seen that in the northern zone and the eastern Weddell area there are few whales and little or no "krill". These are also the two areas which apparently contain a particularly homogeneous plankton population, a fact which should presumably be attributed to the undisturbed flow of the ocean currents. In contrast to this an extremely variable plankton was found to the east of the South Sandwich Islands, and here the "krill" was abundant and Fin whales were very numerous. The complex plankton distribution suggests complex or disturbed hydrological conditions, which might be of the kind postulated by Ruud as favourable to the concentration of "krill". Around the South Orkney Islands also, and between the South Orkneys and the South Shetlands, the plankton, as we have seen, tends to be variable and patchy, and here again large numbers of whales are often seen. This apparent connection between a variable plankton and the occurrence of whales does not always hold good, however, for in the Bellingshausen Sea, between Sts. 565 and 566, and 577 and 578 (see Fig. 14) large numbers of whales were seen by the 'Discovery II', yet the plankton here could hardly be described as very variable and patchy (see Table XII).

There is reason also to believe that in certain circumstances some connection exists between the distribution of whales and the distribution of the total quantity of macroplankton. The evidence for this is inconclusive, but is worth mention. It has been shown by Kemp and Bennett (1932, p. 178) that during the first half of the whaling season at South Georgia, the whales are mostly to be found on the north-east side of the island, but that in the later part of the season there is a tendency towards a greater concentration on the south-west side. This tendency was noticeable in all four seasons of the period 1927–31. We have already seen that there is evidence to suggest a similar shift of the more abundant plankton from the north or north-east to the south or south-west side of South Georgia, and it seems possible that this shift of both whales and plankton may be due to some common cause. In particular the concentration of both whales and macroplankton on the south side of the island in February–March 1927–8, is very striking (compare Fig. 24 with Kemp and Bennett, pls. xi and xix). A further indication that concentrations of whales are connected with concentrations of macroplankton is to be found in the cruises to the Bellingshausen Sea by the 'William Scoresby' in 1929–30 and by the 'Discovery II' in 1930–1. The 'William Scoresby' took some plankton samples early in January in the eastern part of the Bellingshausen Sea (WS 496–501). Here the plankton was unexpectedly rich for these coastal regions, and large numbers of whales were seen in the vicinity. At the end of the month she travelled westwards from Adelaide Island to about 100° W, and taking stations on the return journey (WS 502–8), found a very rich plankton. During this cruise numerous whales were seen south of Peter 1st Island. From February 10–12 nine more stations were taken in the eastern Bellingshausen Sea off Adelaide Island (WS 509–17) and the plankton here was now found to be much poorer and no large numbers of whales were seen. During the next season (1930–1) the 'Discovery II' made a similar cruise, taking stations first in the eastern Bellingshausen Sea (i.e. off the Biscoe Islands and Adelaide Island) at the end of December (Sts. 556–60). Here the plankton was very thin and whales were sighted only occasionally. The ship then proceeded westwards to about the same point as that reached by the 'William Scoresby', and returned to Adelaide Island. During this part of the cruise (Sts. 561–82) a fairly rich plankton was found and, as with the 'William Scoresby' in the previous year, large numbers of whales were seen during part of the cruise, this time some distance to the north-east of Peter 1st Island. About the middle of January more stations were taken off Adelaide Island and the Biscoe Islands (Sts. 583–603) and again the plankton was scarce and very few whales were seen. The results are summarized in the following table in which the figures represent the average numbers of organisms per haul with the N 100 B. The numbers of stations upon which the averages are based are shown in brackets.

Table XVIII. *Whales and quantity of plankton in the Bellingshausen Sea*

	1929–30 ('William Scoresby')		1930–1 ('Discovery II')	
	Off Adelaide Island and Biscoe Island	Between Adelaide Island and 100° W	Off Adelaide Island and Biscoe Island	Between Adelaide Island and 100° W
Late December	— Many whales	—	102 (5 Sts.) Several whales	—
Early January	3300 (5 Sts.) Many whales	—	—	4263 (22 Sts.) Many whales
Late January	—	20,000 (5 Sts.) Many whales	113 (17 Sts.) Few whales	—
Early January	360 (8 Sts.) Several whales	—	—	—

The important point here is that the coastal region near Adelaide Island was visited four times. On three occasions the plankton was very scarce and whales were not plentiful. On the fourth occasion the plankton was about ten times as rich, and large numbers of whales were seen. This may be a coincidence, but it is suggestive, in view of the similar evidence from South Georgia, of a connection between the whales and the quantity of plankton. It is very improbable that the whales have any particular inclination to follow a rich macroplankton unless there is also a rich development of "krill", but it is quite possible that the hydrological conditions which give rise to a rich macroplankton are also in certain circumstances the conditions which provide the environment which the whales seek in the Antarctic.

It is obvious enough that the occurrence of whales does not vary regularly with the quantity of macroplankton. The Bransfield Strait, for instance, is normally exceedingly poor in plankton, and yet it is a region in which whales are known to be plentiful. We have already seen, however, that there must be more than one factor controlling the distribution of whales in the Antarctic, and consequently it cannot be expected that one set of circumstances will determine that distribution at all times and places.

SUMMARY

This paper is concerned with the plankton samples taken in Antarctic surface waters with the 1 m. oblique nets, and its object is to describe the horizontal distribution of the macroplankton as a whole. It is based on the analysis of about 600 samples collected in the period 1927–31.

The Antarctic convergence is the northern boundary of the area under consideration. Some Antarctic species are as common in the sub-Antarctic water on the north side of the convergence as they are in the Antarctic water on the south side, some occasionally stray into the sub-Antarctic water, and others are entirely confined to the south side of the convergence.

The amount of diurnal variation shown by each species has been estimated, and the average number per haul at different times of day and night plotted on graphs. It is found that there is every gradation between the species which can be caught in large numbers in the middle of the night but which are entirely absent in the middle of the day, and those which are taken equally at any time of day or night, or may even be commoner during the day. A period of daytime hours is allotted to each of the more variable species, and samples taken within that period are not regarded as valid indications of the presence or absence of the species in question.

Brief notes are given on the individual distribution of each species, and it is shown that some are typical of the colder water or high latitudes, some characterize the warmer water or lower latitudes, and others again may be taken equally in warm or cold regions.

The richness of the plankton varies greatly in different places and at different times. In the neighbourhood of the South Orkneys and South Shetlands, and in the eastern part of the Bellingshausen Sea the plankton appears always to be very scarce, possibly as a result of the upwelling of deep water. In other regions it is variable but generally very rich except during the winter months. It is possible that the boundary between the scarce plankton near the South Shetland Islands and the richer plankton of the Drake Passage may shift southwards in the latter part of the summer.

The distribution of species typical of warm or cold water is specially interesting. There is abundant evidence to show that in a given area the proportion of cold-water species in the plankton population becomes reduced as the summer goes on. There is

a high proportion of cold-water species in spring and a low proportion in autumn, and there is little doubt that the warm-water species remain dominant during the winter in spite of the lower temperature of the water. The distribution of the cold-water species appears to have some connection with the movements of the pack-ice, but in the lower latitudes, which are not reached by the pack, the same reduction takes place as the season advances. In a cold summer there is a higher proportion of cold-water species which, however, become reduced in the same way. The material, so far as it goes, suggests further that an exceptionally cold summer season in the Atlantic sector of the Antarctic may not necessarily be accompanied by a correspondingly cold season on the west side of the Drake Passage.

Different plankton communities can be distinguished in different water masses. Fig. 48 shows roughly the different areas in which a characteristic plankton population was found. These areas coincide to a large extent with different water masses. In the outer or northern zone of the Antarctic there is a uniform plankton population which undergoes little change in composition during the year. In other places, such as to the east of the South Sandwich Islands and in parts of the Orkney–Shetland region the plankton may fluctuate sharply from place to place and from time to time. It appears that where the hydrological conditions are uniform and undisturbed there is a uniform and stable plankton, and where the hydrological conditions are complex and variable there is a variable and unstable plankton population.

In the last section the connection between the macroplankton and the distribution of whales is discussed. It seems that whales are found in regions characterized by a variable plankton rather than in those with a uniform and stable plankton, and there is evidence which suggests that in certain circumstances the distribution of whales may be correlated with the distribution of the quantity of plankton.

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