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THE DISTRIBUTION OF THE STANDING CROP OF ZOOPLANKTON IN THE SOUTHERN OCEAN

BY

P. FOXTON

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INTRODUCTION

In recent years much attention has been paid to the productivity and organic resources of the seas, but there are formidable difficulties in the technique of quantitative sampling of the oceanic fauna and flora, and little is known of the relative fertility of the oceans at different times and places. Investigations on fertility are largely concerned with the primary production of phytoplankton (i.e. the amount of organic matter synthesized in a given time), but take account not only of the rate of production and consumption of both phytoplankton and zooplankton, but also of variations in the 'standing crop', i.e. the amount or density of the plankton at a given place at the time of sampling. The standing crop (which represents the amount of food available for consumers of the plankton) can be taken as an indication of fertility only with certain reservations, of which the most important is that a fertile region may yet have a small standing crop if a high rate of consumption keeps pace with a high rate of production.

The present paper, which is part of an investigation of the distribution and abundance of the southern oceanic fauna, deals with the standing crop of zooplankton, and it depends on measurements of the volume of plankton samples. These samples are all from one standard net, and in so far as no single net can equally sample all planktonic animals from the most minute to the largest and most active, it is an arbitrary part of the plankton fauna which is being measured. But it is a net which does sample animals through a considerable range of sizes, the samples are comparable with one another, and this paper is concerned with relative and not absolute quantities.

Work on this aspect of oceanography was initiated by Hensen and his co-workers on the 'Plankton Expedition'. They developed methods which have formed the basis of plankton research ever since, but as with nearly all deep-sea expeditions the observations, though distributed over wide oceanic areas, were not repeated at different times of year and therefore do not take account of seasonal variations. (The main conclusions of this and other investigations in relation to plankton production are briefly summarized in historical sequence by Dakin & Colefax, 1940.)

Perhaps the most valuable body of data collected hitherto is that of the 'Meteor' Expedition (Hentschel, 1936) which covered the central and southern Atlantic on fourteen latitudinal profiles, during which 310 stations were worked. Even so, the observations were rather widely dispersed, especially in the southern part of the area investigated, and (of necessity) they did not cover seasonal variations. This applies also to the results of the 'Dana' Expeditions (Jespersen, 1923, 1935), which cover a great geographical range mainly in sub-tropic and tropic latitudes, and to those of the 'Carnegie' (Graham, 1941; Wilson, 1942), which cruised in both Pacific and Atlantic waters.

Inshore waters in most parts of the world have been well surveyed, and among the many works on production and standing crop are those of Bigelow & Sears (1939), Clarke (1940), Redfield (1941) and Riley (1941) in America; Gundersen (1951) in Norway; Sheard (1949) in Australia; Huntsman (1919) in Canada; and Delsman (1939) in the Java Sea. Most of these studies, however, are not directly applicable to the present work because they refer to local areas and for the most part do not extend to the true oceanic fauna and flora. There are relatively few data from oceanic areas, and apart from the observations to be considered here there are in the Southern Ocean only a few 'Meteor' stations and the material collected on the B.A.N.Z.A.R. Expedition and described by Sheard (1947).

From other regions there are the results of the few expeditions already mentioned, which, although limited, have allowed something to be known of conditions in the open ocean. The 'Meteor' observations, for example, have enabled Hentschel to make valuable distinctions between regions of rich and poor plankton in the Atlantic Ocean.

In the warmer latitudes it may be that there are no very great seasonal variations in the standing crop. Nevertheless, when observations are made only at one time of year there can be no certainty that the amount measured is much indication of the amounts which may be present at other times of year. Indeed, it seems hardly possible to make true quantitative comparisons of fertility over large areas without data suitably spread in time as well as in space. It is felt that the material collected by the 'Discovery II' in the Southern Ocean allows for a new step forward because it has been taken from almost all parts of a large oceanic area—the Southern Ocean—at almost all times of year. Measurement of the volumes of samples is no doubt a crude method, but it allows many samples to be dealt with quickly and it gives an approximate estimate of the standing crop which is at least significant for large-scale or persistent differences. Furthermore, measurements from the Southern Ocean can be used to some extent as a basis for comparison of the standing crop with that of other oceanic regions.

Probably no other oceanic region is richer in life than the Antarctic, an area far greater than any other of comparable fertility. It is hoped that even a rough comparison of the abundance of plankton in different parts of the Southern Ocean, an account of the variations which take place, and an indication of the standing crop in the Antarctic compared with other regions, will contribute to what is known of the fertility of the oceans as a whole.

The features to be measured and compared are (*a*) the seasonal vertical movements between superimposed water masses, and seasonal variations in the amount of plankton, (*b*) the standing crop in different latitudes, and (*c*) the standing crop in different longitudes and faunistic areas.

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I was also fortunate to have the help and advice of many of my colleagues, and I am particularly grateful for the suggestions of both Dr T. J. Hart, who read the first draft of the paper, and Mr R. I. Currie, who read and corrected the typescript. I should also like to thank Mr A. de C. Baker, who assisted me in the initial stages of the work, and Mr J. W. S. Marr, who read and advised me on the sections relating to his special study—*Euphausia superba*.

MATERIAL

This paper is based on material collected with the 'Discovery' pattern 70 cm vertical closing net (N70V), the construction and operation of which is described in detail in Kemp, Hardy & Mackintosh (1929, pp. 183 and 199). The net provides a standard series of hauls which, by virtue of a constant speed of hauling and an accurate knowledge of the depth of closure, are more reliable for quantitative purposes than samples from horizontally or obliquely towed nets (Mackintosh, 1937, p. 371). The N70V is closed on the Nansen principle by means of a throttling rope, and Barnes (1949) maintains that significant losses occur in the catches taken by this method. It is felt, however, that the conditions which he describes do not fulfil the actual working conditions of the N70V both with regard to the method and speed of hauling and to the length of water column sampled. (The net is hauled vertically at a speed of 1 m. per sec. over a davit incorporating a spring accumulator, and the shortest closing haul is from 100 to 50 m.) As Østvedt (1955) points out, such losses, if they do occur, will only be of significance if the plankton is very unevenly distributed in depth or if the haul is a short one, i.e. 100–50 m.

Nets of the dimensions given in Kemp, Hardy & Mackintosh (1929) have been used on the ships of the Discovery Committee from 1927 until 1939. On the first post-war commissions of the R.R.S. 'Discovery II' (1950–51) and the R.R.S. 'William Scoresby' (1950) the nets were inadvertently made to slightly different measurements, and there can be little doubt that, although the same grades of silk were used, the filtering capacity of this net differed from its pre-war counterpart. In view of this discrepancy preliminary comparative tests have been made which consisted of duplicate hauls with nets of both dimensions. As a result of four paired hauls at each of six stations in the North Atlantic and Mediterranean (i.e. 48 volume measurements), it has been found that there is a fairly consistent difference, the pre-war net giving about one and a half times the catch (by volume) of the post-war net. A factor of $\frac{3}{2}$ has therefore been applied to the volume measurements of 203 samples from the 33 post-war stations used in this work. This factor must be considered as provisional, since future tests may allow the differences in filtering capacity and catching power to be more accurately gauged.

It should be noted that even if uncorrected results are used they in no way alter the principal conclusions drawn from the data, but it was deemed better to use a provisional correction rather than to ignore the difference.

At most stations there are samples from the following six routine depth intervals between the surface and 1000 m: 50–0 m., 100–50 m., 250–100 m., 500–250 m., 750–500 m., and 1000–750 m. Occasionally a deeper haul from 1500 to 1000 m. was worked, and at eight of the stations taken into account in this paper (1675, 1677–1682 and 1684) the normal shallow haul was done in two stages of 50–25 m. and 25–0 m. Here these volumes have been combined to represent a haul from 50 to 0 m.

Hydrological data are available for each station at all depths sampled by the nets, so that it is possible to view the standing crop of plankton in relation to the sea temperature and other variables and to the distribution and movements of the main water masses of the Southern Ocean. (For full details of the hydrology of the area reference should be made to Deacon, 1933, 1937; Clowes, 1938; and for a brief account Mackintosh, 1937, p. 373.)

The positions of stations from which the volumes of samples have been measured are given in tables 11 *a–f* in the appendix, and it is necessary to explain the basis on which these stations have been selected from the much greater number available in the Discovery collections. For various reasons the work of the 'Discovery II' was more concentrated in some areas and times of year than in others, and for the present work it is not necessary to make use of all of them, since the labour of measuring all the samples would be out of proportion to the objects in view. I have, however, measured 2185 samples from 366 stations, chosen so as to cover seasonal variations of the standing crop of zooplankton in as many different regions of the Southern Ocean as possible. Certain meridional lines of stations, which have been repeated in different months, are particulary suitable for this purpose. They cover a period from December 1933 to November 1934 plus October 1932 in the meridian of 80° W; April 1938 to March 1939 plus September 1936 in 0°; and April 1938 to March 1939 plus June 1936 in 20° E. The nine lines of stations in both 0° and 20° E cover all the seasons in the south-east Atlantic sector of the Antarctic and sub-Antarctic zones, and the six lines in 80° W (south-east Pacific) cover more than half the year.

From the work of Deacon (1937), Clowes (1938) and Mackintosh & Herdman (1940) it is clear that the physical and chemical features of the environment are disposed in relatively uniform zones all round the Southern Ocean, and Baker (1954) has shown that the distribution of the species of Antarctic plankton are correspondingly continuous in a circumpolar direction. It may be expected, therefore, that the seasonal cycle and latitudinal succession observed in even one transverse (meridional) section are broadly representative of the whole of the Antarctic and sub-Antarctic zones.

It is desirable to check this, however, in so far as the available data will allow. Repeated lines of stations of the kind worked in 80° W, 0° and 20° E, are not available from other parts of the Southern Ocean, but there are other lines running approximately north and south which can be used at least to show whether or not the vertical and meridional distribution of plankton is similar at a given time of year to that found in 80° W, 0° and 20° E. I have grouped together the following stations and for convenience will refer to them as the lines in 20° W (804–817 and 1990–2004), 110° E (877–887, 1720–1735 and 2152–2168) and 160° E (912–928, 1675–1684 and 2201–2209). These lines of observations cover two or three different months in each particular area, but from different years. Experience in 80° W, 0° and 20° E (see p. 205), however, has shown that year to year differences in a given area are less than the month to month variations.

All these lines of stations run approximately in a north-south direction, in which there is the greatest change in normal hydrological conditions. I have made use of stations selected from circumpolar cruises (845–875, 2213–2310 and 2838–2881), to ascertain whether or not, in comparable months, there is any great variation in standing crop from east to west, in which direction there is least hydrological change. This material also provides additional observations for the study of seasonal and regional variations.

Although this work is concerned principally with variations in the standing crop of zooplankton in the Southern Ocean it seemed worth while to extend the observations as far north as possible to gain some comparison with conditions in sub-tropic and tropic oceanic waters. For this reason I have included a line of stations across the Indian Ocean in 32° S (1736–1766), and a line of stations running north from 30° S nearly to the equator, in the meridian of 90° E (2886–2895).

In the initial planning of the work at sea complications due to diurnal migration were mitigated by working full stations at a fixed time of day (20.00 hrs., ship's time) whenever practicable, but in this paper some series of data including both day and night hauls have had to be considered. The relevant diagrams and text (p. 209) show that their comparability is unaffected by diurnal movements of the plankton.

METHODS

Before describing the method of volume measurement used in this work it is worth while to consider briefly the methods used by other workers.

Measurement of the volume of a sample as a rough estimate of relative plankton concentration was one of the earliest techniques used in the quantitative approach to plankton, and in papers by Schütt (1892) and Hensen (1895) two methods, usually termed the settlement and displacement methods, were described.

The settlement method, in which the volume is obtained by allowing the sample to settle in a graduated cylinder, has been used with success by many workers including Huntsman (1919), Hardy (1928) and Gunther (1936). The settlement volume, however, includes the volume of the liquid in the interstices between the organisms which, since this varies with their shape and compactness, makes the method very inaccurate (Hardy & Gunther, 1935, p. 27; Sheard, 1947, p. 10) and particularly unsuitable for measuring the volumes of small samples containing but a few differently shaped organisms. It is also not suitable for use at sea where steady conditions, necessary for settlement, are unusual. A variation of the method was, however, used at sea by Jespersen (1923, 1935) in his extensive studies in the Atlantic and Mediterranean, the samples being allowed to drain and settle in a graduated sieve from which the volume could be read directly. This method, however, is only suitable for large samples.

The displacement method consists essentially of filtering off the plankton on to a piece of filter paper (Sheard, 1947) or silk (Apstein, 1909; Moore, 1949) and adding it to a known volume of water. The difference in measurements gives the volume of the plankton. Many workers have used this technique, including Leavitt (1935), Bigelow & Sears (1939), Clarke (1940), Redfield (1941), Sheard (1947), Moore (1949) and Gundersen (1951). By some, notably Apstein (1909), Jacobsen & Paulsen (1912), Ussachev (1939), Berardi (1953), Ealey (1953) and Frolander (1954), the method has been elaborated by the design of special apparatus, some of which allow very small volumes to be measured.

It will be realized that neither the settlement nor the displacement method measures the absolute volume of the plankton since, in both, the moisture contained between the individual animals is included in the final volume. In the latter method, however, this error is reduced to a minimum (see p. 198), and much smaller samples, as are caught with vertical closing nets, can be measured with some accuracy. Furthermore, the displacement method is relatively quick and admirably suited to use at sea where some of the samples in the 1950–51 commission of R.R.S. 'Discovery II' were measured.

All volumes used in this work were measured by this method, the particular procedure used being as follows:

The preserved sample, after the large animals had been picked out (see p. 199), was poured into a brass funnel, the stem of which, measuring 1¼ in. diameter, was closed at its lower end by a disk of fine silk held in position by a rubber band. The use of N 50 silk, which has 200 meshes compared with 74 meshes per linear inch of N 70 silk, ensured that even the smallest organisms in the sample were retained on the disk.

Most of the liquid was allowed to drain off, the process being accelerated by placing the disk on a pad of blotting paper, great care being taken not to injure the plankton by complete drying out. The disk and plankton were then removed from the funnel and placed, care being taken not to enclose air bubbles, into a measured volume of water contained in a graduated cylinder, and the increase in volume noted. The difference in measurements minus the volume of the silk disk (0·1 cc.) gave the volume of the plankton. By measuring the volume of plankton and filter disk together, one ensures that the plankton is not damaged, as it might be by the alternative method of scraping the animals off the silk into the measured volume of water.

The size of the measuring cylinder had naturally to be suited to the size of sample, but in most cases a 25 c.c. cylinder graduated in 0·2 c.c. was used, and the volumes were measured to the nearest 0·1 c.c.

After measurement, the sample was completely washed off the silk and replaced in 10 per cent neutral formalin. The importance of not losing any of the sample need not be emphasized, and the washing of the silk was repeated a number of times, the time taken being much longer than that for the actual volume measurement. Finally, by a very brief and rough inspection a note was made of the dominant animal in the sample and any other features.

It will be obvious from the foregoing account that the inherent limitation to the accuracy of the method is the amount of liquid retained by the plankton after drainage. Samples from 70 cm. vertical closing nets, however, are on the whole small—much smaller than samples from towed nets—and, as Jacobsen & Paulsen (1912) found, for small samples this error is very small. This is also shown by the results, given in Table 1, of ten repeated measurements on samples from St. 2414. The variations in the measurements that occur at each depth in no way detract from the main conclusions to be drawn from this particular set of data, namely, that the bulk of the plankton is concentrated below 250 m., the upper 100 m. being relatively poor in plankton (see Fig. 2).

Table 1. *The results of ten repeated measurements (in cc.) of the volumes of samples from St.* 2414

	50–0 m.	100–50 m.	250–100 m.	500–250 m.	750–500 m.	1000–750 m.
1	0·2	0·4	0·7	1·6	2·5	3·1
2	0·3	0·4	0·6	1·6	2·6	3·1
3	0·2	0·4	0·7	1·3	2·5	3·2
4	0·2	0·5	0·7	1·3	2·3	3·2
5	0·2	0·4	0·5	1·3	2·3	2·7
6	0·2	0·4	0·6	1·3	2·3	2·9
7	0·2	0·4	0·6	1·4	2·2	2·8
8	0·3	0·4	0·6	1·3	2·1	2·9
9	0·2	0·3	0·6	1·4	2·3	2·7
10	0·2	0·4	0·6	1·4	2·2	3·0
Sum	2·2	4·0	6·2	13·9	23·3	29·6
Mean	0·22	0·40	0·62	1·39	2·33	2·96

The rather crude method of 'drying' the plankton on blotting paper is thus a convenient method of reducing such errors to a minimum. While the basic method of measurement remained the same throughout this work the procedure outlined above had to be variously modified when dealing with many Antarctic spring and summer shallow samples containing phytoplankton. This paper is concerned only with the variations in the standing crop of zooplankton, so that it was necessary to separate the animals from the phytoplankton and measure their volume separately. No standard treatment was possible, since among such samples there was every gradation from those rich in zooplankton and poor in phytoplankton to those in which phytoplankton predominated. Where there was only a trace of phytoplankton no attempt was made to separate it from the zooplankton, since it was considered that the amount was so small as to be immeasurable by the displacement method. Other samples, though rich in phytoplankton, contained only a few relatively large animals which could easily be picked out for separate measurement of their volume. The most difficult samples to deal with were those rich in phytoplankton and both adult and larval zooplankton organisms. To pick out the animals would be a lengthy and difficult task, and it is doubtful whether the result would be commensurate with the effort. The method adopted for a sample of this kind was to dilute it with water and pour it into a large glass funnel having its stem closed by a large-bore glass tap. The zooplankton, by virtue of its faster rate of settlement, collects at the bottom of the funnel, from which it can be run off via the tap, and measured by the standard method, after which it is preserved again with the phytoplankton. This method has the same disadvantage as the method of picking out the animals, namely, that some of the smaller forms remain in the phytoplankton and are not measured. It was considered, however, that as these are such small forms, the inaccuracy due to their omission from the final volume would not be great enough to influence any conclusions drawn from the result, the main thing being to get the best possible measure of the zooplankton volume alone rather than to measure the sample as a whole and thereby to introduce a considerable error due to inclusion of the phytoplankton. A few samples (23) defied all attempts to separate the animals, and these were not measured. Shallow hauls rich in phytoplankton are noted in Tables 11 *a–f* in the Appendix

As well as removing phytoplankton, it has also been my procedure to pick out any large animals 'om samples before measuring the volume.

As Mackintosh (1937, p. 371) has pointed out, the N70V samples only the smaller and medium-zed constituents of the plankton, and thus copepods, chaetognaths, small euphausiids and small mphipods numerically form the bulk of the catch. Often, however, comparatively large inactive nimals are caught, such as siphonophores, medusae and salps, which if they were included would icrease the volume disproportionately in relation to the number of animals present. For instance, ie 500–250 m. samples from Sts. 2379 and 806 had volumes of 0·4 and 3·2 cc. respectively. The sample 'om St. 2379, however, contained two siphonophore nectophores having a combined volume of ·8 cc., and it is obvious that if this volume were included to bring the total to 3·2 cc. any comparison etween the stations would be most misleading. Salps in some cases would influence the volumes to

Table 2. *The number of samples from which particular groups of organisms were removed and the numbers expressed as a percentage of the whole*

Organisms removed	Siphonophora	Tunicata	Medusae	Fish	*Gelatinous fragments	Phytoplankton	Amphipoda	Pteropoda	Polychaeta	Ctenophora	Euphausiidae	Unidentified crustacea	Cephalopoda	Ostracoda	Pelagonemertes
No. of samples	264	203	177	145	88	83	70	42	28	20	17	17	11	8	2
As % total no. samples	12·1	9·3	8·1	6·6	4·0	3·3	3·2	1·9	1·3	0·9	0·8	0·8	0·5	0·4	0·1

* Includes mainly salp tests and siphonophore fragments.

n even greater extent, since they are animals that occur in swarms and are hence sometimes caught n extremely large numbers. At St. 2585, for instance, in the 50–0 m. haul there were 625 salps iaving a combined volume of 169·0 cc., and these must obviously be omitted. In addition to these nactive forms there are occasional active swimming animals, such as fish, large euphausiids (e.g. krill bove 20 mm. in length) and large amphipods, which are caught by the N70V. These animals I have egarded as atypical of N70 catches and have picked them out. Table 2 gives the number of samples, xpressed as a percentage of the total number, from which animals of a particular group and phyto-lankton were extracted before the volume was measured. It is seen that by far the greater percentage icked out were animals of a gelatinous nature, the more active animals being relatively rare. (It hould be noted that this table does not give the numbers of animals but only the number of samples rom which they had been previously extracted.)

In view of the particular types of organism removed from the sample before measurement, the volumes adopted in this work may be taken to represent the variations in that part of the total standing crop of plankton composed mainly of copepods, chaetognaths and small euphausiids (which includes krill larvae). The importance of individual species volumetrically is not known. It would obviously depend upon the number and size (i.e. stage of maturity) in each sample and would vary from station to station, depth to depth and month to month. Such variations, however, are only of importance when considering the interrelationships of species, while in this case only gross changes in the bulk of zooplankton are being examined.

SEASONAL VARIATION IN THE VERTICAL DISTRIBUTION OF THE STANDING CROP OF ZOOPLANKTON

DESCRIPTION OF THE OBSERVATIONS

It has been shown by Mackintosh (1937) that one of the most marked features of the plankton cycle in Antarctic waters is that some of the most common species, including *Rhincalanus gigas*, *Calanus acutus* and *Eukrohnia hamata*, accomplish marked seasonal vertical migrations by which they maintain themselves within the limits of their environment. They drift northwards during the summer when they are concentrated both day and night in the Antarctic surface layer and southward during the winter when the greater number have moved into the warm deep current.

Although a knowledge of the relative numbers of animals caught at each depth illustrates this seasonal migration it gives little indication of its effect on the vertical distribution of the standing crop of plankton. As the volume of a sample is a function of the size of the organisms just as much as it is of the number present, it does not necessarily follow that because there has been a numerical increase there will be a rise in volume (i.e. the total mass) of the plankton. In this section, however, it will be shown that in the Antarctic and to a lesser extent sub-Antarctic zones there is a winter increase in the concentration of standing crop of zooplankton in the deeper waters comparable to the numerical increase described by Mackintosh.

Probably the best way of representing the results is to use block diagrams in which the area of a block at a particular depth (or, more precisely, in the limited column of water through which the net has been fished) is proportional to the volume of the sample taken from that depth. The results from the repeated lines in 0°, 20° E and 80° W, together with the observations in 20° W, 110° E, 160° E and 90° E, have been plotted in this fashion in Figs. 1–6. The vertical scale represents depth in metres and the horizontal scale latitude, with south to the right of the page. Stations are plotted according to their latitude except where large volumes or the proximity of stations makes this impossible. The approximate latitudes of the Antarctic convergence (A.C.) and, where possible, the sub-tropical convergence (S.T.C.) as determined from the continuous thermograph records of surface temperature, are also shown. Stations which occurred during daylight hours are indicated by a '○'. Gaps occur in the observations where samples were not available, or where the presence of phytoplankton made it impossible to measure the volume of the sample (see p. 198).

In plotting the volumes allowance has been made for the different duration of hauls at certain depths by making the width of each block equivalent to the volume of plankton for each 50 m. of the haul. For example, the width of a 50–0 m. haul is equivalent to the total volume of the sample, while the width of a 500–250 m. block is equivalent to one-fifth the volume of the sample since the haul was five times longer than the shallower haul. Width thus represents concentration per 50 m. haul (i.e. local density of plankton), and area the volume of the catch from that depth interval.

In drawing conclusions from these diagrams it should be remembered that the disposition of the water layers in the Antarctic is such that the 50–0 and 100–50 m. hauls sample the Antarctic surface layer, the 250–100 m. hauls sample partly the Antarctic surface layer and partly the warm deep layer, while the deeper hauls sample the warm deep layer exclusively. In the sub-Antarctic conditions are more complicated and no such simple distinction can be drawn. Only constant or large-scale variations are being considered, and the minor irregularities, which are usually evident from station to station, must be ignored.

The meridian of 0°, 1938–39 *season* (Fig. 1)

The April line of stations started much farther south than those in the following months and all stations were in Antarctic water. From the diagram it is apparent that while most of the standing crop of plankton was concentrated in the top 50 m. of the Antarctic surface water large volumes occurred in hauls below 250 m. at the two northernmost stations.

There were no observations in May and July, but in June (winter) the shallow hauls were relatively poor in plankton compared with those in April. The concentration of plankton in the deeper hauls, however, had increased, particularly at Antarctic and southern sub-Antarctic stations.

In August the volumes of catches at all levels were poorer than those of the previous month, but the bulk of the plankton was below 250 m. in the warm deep current, except at Sts. 2389 and 2391 where the hauls from 50 m. to the surface had large volumes consisting mainly of small euphausiids and copepods.

In September (late winter) the standing crop was still concentrated in deep water, and samples from the 750–500 m. hauls consistently gave the largest volumes. As in August there are small concentrations in the northern Antarctic surface water.

The October (spring) results show that there was a rise in the vertical distribution of the bulk of the plankton, which was concentrated above 250 m. at sub-Antarctic and Antarctic stations. This apparent upward migration of plankton seems to have proceeded further at St. 2463 which was just south of the Antarctic convergence.

In December the concentration of plankton had increased in the top 100 m. at the three southernmost stations, although at one of them (St. 2496) there was a large volume at the 500–250 m. level due to the presence of many *Rhincalanus gigas* in the sample. At two of the other sub-Antarctic stations the plankton did not appear to be concentrated above the 250–100 m. level.

In January the observations extended farther south than in the previous months owing to the recession of the ice edge. The vertical distribution was similar to that in December with the bulk of the plankton concentrated in the top 100 m. in Antarctic surface water. St. 2535 just south of the Antarctic convergence had large volumes at nearly all depths, but at the other Antarctic stations the volumes were on the whole less than in the previous month. In sub-Antarctic waters the largest concentrations were also between 100 m. and the surface compared with 250–100 m. in December.

In late February and early March the Antarctic surface layer appeared to be poor in plankton except in the region of the convergence, at St. 2586. The volumes at the sub-Antarctic stations were similar to those in the previous month.

The meridian of 20° E, 1938–39 *season* (Fig. 2)

In April the volumes of samples from Antarctic stations were not as great as those in 0°. The vertical distribution of the plankton, however, was basically the same, with the largest concentrations in the Antarctic surface layer but with large volumes also in the warm deep current. The sub-Antarctic surface waters appeared to be poor in plankton, while the volumes of the deeper hauls, particularly at St. 2348, suggest that the largest concentrations were deeper than in the Antarctic.

In July both sub-Antarctic and Antarctic surface waters were poor in plankton except at St. 2374. The volume of plankton in the deeper hauls down to 1000 m., however, had increased.

In August the concentration of surface plankton had decreased still further except for the 50–0 m. haul at St. 2412, which contained many small euphausiids. The bulk of the plankton, as in 0°, is concentrated in the warm deep layer, and in the Antarctic the largest volumes occurred at the 1000–750 and 750–500 m. levels as compared with the 500–250 m. level in July.

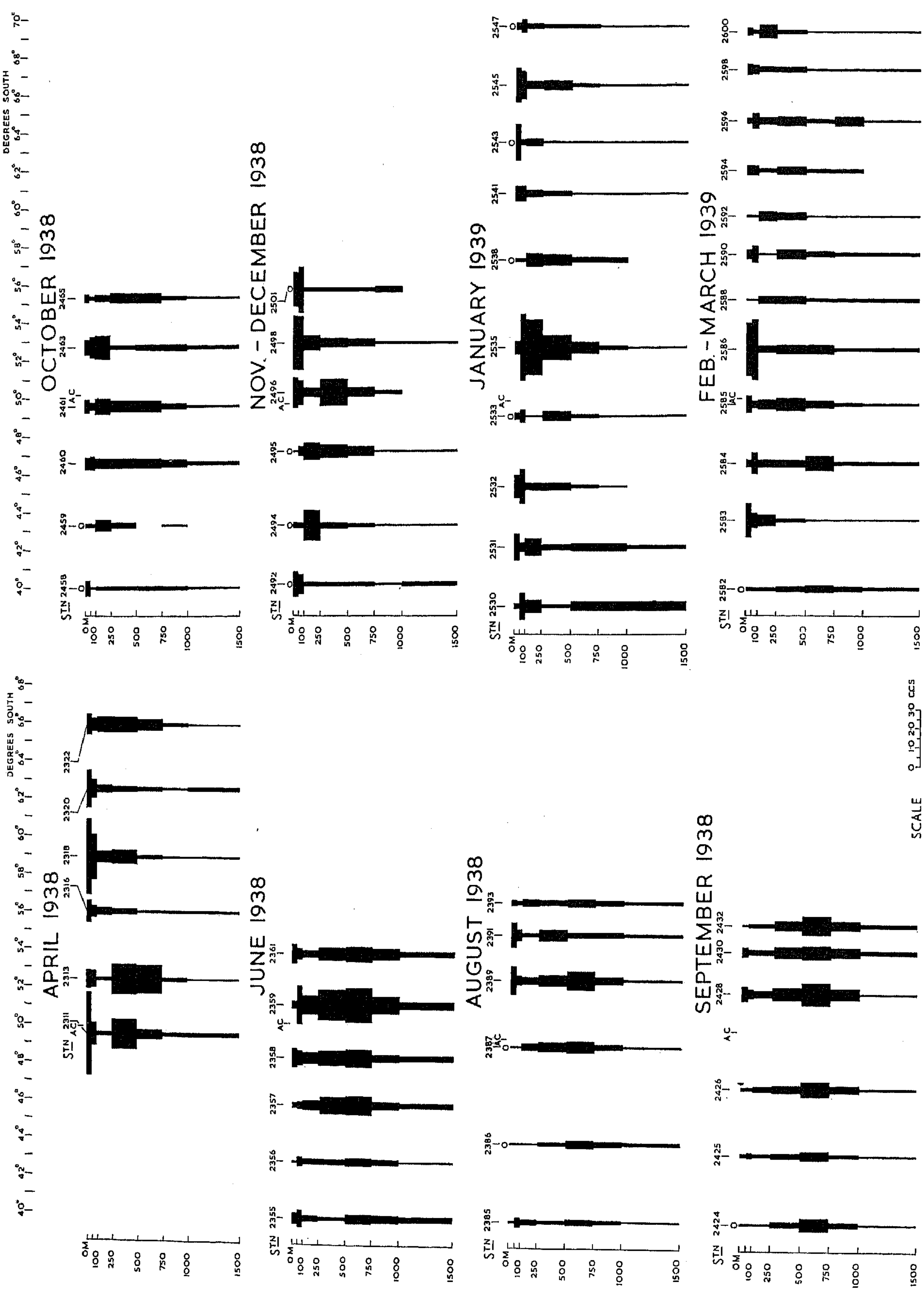

Fig. 1. Vertical distribution of the standing crop of zooplankton in 0°. (The following contractions are used in Figs. 1–6: A.C. = Antarctic convergence; S.T.C. = sub-tropical convergence; T.C. = tropical convergence.)

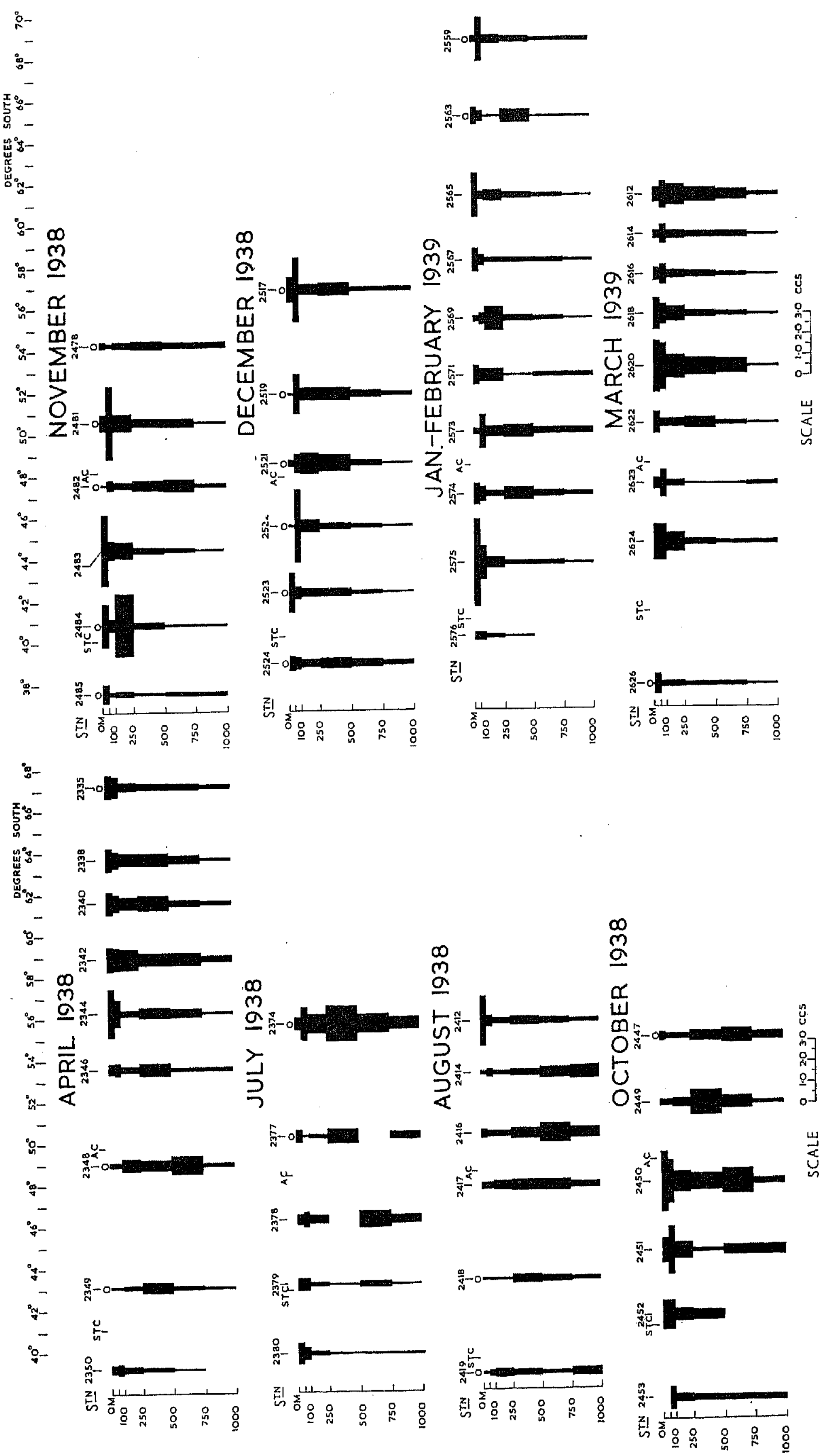

Fig. 2. Vertical distribution of the standing crop of zooplankton in 20° E.

There were no observations in September, but in October, as in 0°, there was a marked increase in the volumes at all stations, particularly in the sub-Antarctic region where there was a large concentration of plankton in the surface layer. At the Antarctic stations there was no indication of this, and the highest concentrations were in deep water though at a shallower level than they were in August.

In November most of the plankton appeared to be between 100 and 0 m. except for the exceptionally large 250–100 m. haul of 8·9 cc., due to a large number of small euphausians, at St. 2484. In the sub-Antarctic the plankton appeared to be concentrated nearer the surface (i.e. between 50 and 0 m.) than in the Antarctic, which contrasts with the vertical distribution in 0° where the reverse was the case.

In December at all stations except St. 2521 the bulk of the plankton was above 100 m. On the whole the 100–50 m. level had the highest concentration in both sub-Antarctic and Antarctic regions.

In late January and early February the standing crop of plankton was similar in vertical distribution to that in December when there was very little plankton below 250 m.

In March large concentrations in the surface layer were still evident, but at St. 2620 there was a marked increase in the volume of the deeper hauls.

The meridian of 80° W, 1933–34 *season* (Fig. 3)

Although the observations in 80° W do not present such a complete series as do those in 0° and 20° E they are of particular interest because an analysis of the same samples has formed the basis of a paper by Mackintosh (1937) which described the seasonal circulation of the macroplankton of the area. It is thus possible, in this case only, to compare the volume of a particular haul with its animal composition, and brief reference will be made to these results in the description of the volume measurements that follows.

In December 1933 the results show that the standing crop of plankton was concentrated in the sub-Antarctic and the northernmost Antarctic surface waters. The volumes at three stations, 1222, 1221 and 1220, suggest that in the southern part of the Antarctic region the plankton was still concentrated in deeper water (between 750 and 500 m.). The distribution of the volumes shows there to be a greater quantity of plankton in the sub-Antarctic than in the Antarctic zone, which is the same as the distribution of the total numbers of organisms (Mackintosh, 1937, p. 380).

In March 1934 the concentration of plankton in the surface waters had increased, and as Mackintosh (*ibid*) observed for the total numbers, the largest volumes were nearer the surface than in December. The two Antarctic stations nearest the ice edge were relatively poor in surface plankton, as in the previous month, although there is evidence that at these and the stations just north of the convergence the plankton was concentrated in deep water. The September results are rather unsatisfactory owing to the loss of part of the samples at some depths, and the volumes of these samples, which are shown in brackets in Table 11*c*, are thus minimal values. In spite of this, however, it is obvious that the surface layer in the sub-Antarctic and the Antarctic zones was very poor in plankton except at St. 1421, while the largest concentrations were at the 750–500 m. level.

In October there is definite indication that in the sub-Antarctic zone the plankton was concentrated at the 250–100 m. level. This was true also of the two northernmost Antarctic stations, in particular St. 1447. At Sts. 1449 and 1450, however, the plankton had not risen above 250 m. It is interesting to note that Mackintosh (*ibid*) observed that in this month the 250–100 m. horizon provided the greatest number of organisms.

In November there was still much plankton between 250 and 100 m., but at the Antarctic stations the 250–100 m. level was the richest.

The monthly results in 80° W compare well with those for similar months in 0° and 20° E. In each meridian the greatest concentrations of zooplankton were in the surface water during summer and autumn and in deeper water during winter. The 80° W September volumes were less at all depths than those in the other meridians, and it may be either that in winter this area is generally poorer in zooplankton or that the bulk of the plankton moves into water deeper than the range of the nets. As in other areas the October observations show a reconcentration of plankton at the shallower depths, though not quite at the high level of the greatest concentrations of November and December.

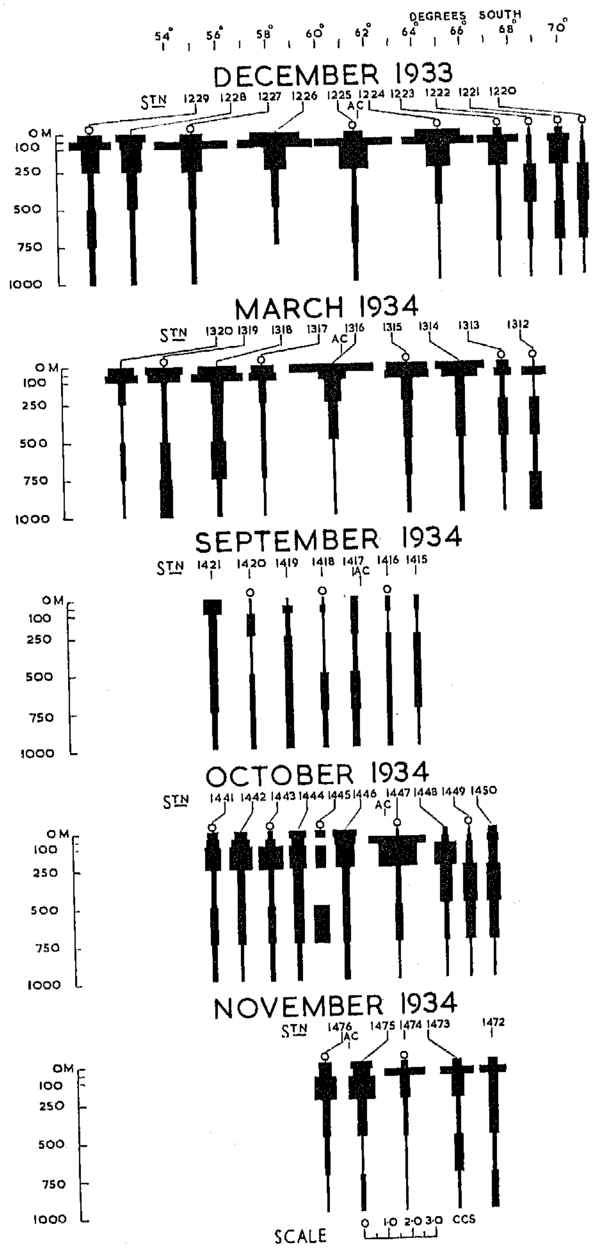

Fig. 3. Vertical distribution of the standing crop of zooplankton in 80° W.

Observations in 0°, 20° E *and* 80° W *in other years* (Fig. 4)

The observations in 0°, 20° E and 80° W present a more or less complete series extending over a 12-month period from which it has been possible to gain some idea of the vertical distribution of the standing crop in any one month. Conditions, however, may not be the same in different years, particularly in Antarctic regions where the presence or absence of pack ice can influence the biology of the whole area. In order to see what year to year differences are likely to occur, observations in these same meridians but from different years are plotted in Fig. 4. There are results for September 1936 in 0°, June 1936 in 20° E and October 1932 in 80° W.

The results in September 1936 compared with those in September 1938 (Fig. 1) show the distribution of the plankton to be essentially the same. In 1936 the shallower hauls gave higher volumes than in 1938, especially at sub-Antarctic stations. Antarctic St. 1813 showed a particularly large volume at 50–0 m., but over 50 per cent of this was due to thirteen amphipods, and if they were omitted the volume would be similar to that at St. 1812, and both would be similar to the 1938 Sts. 2428 and 2430. In both years the deeper hauls at Antarctic stations gave large volumes, while those in sub-Antarctic waters were larger in 1938.

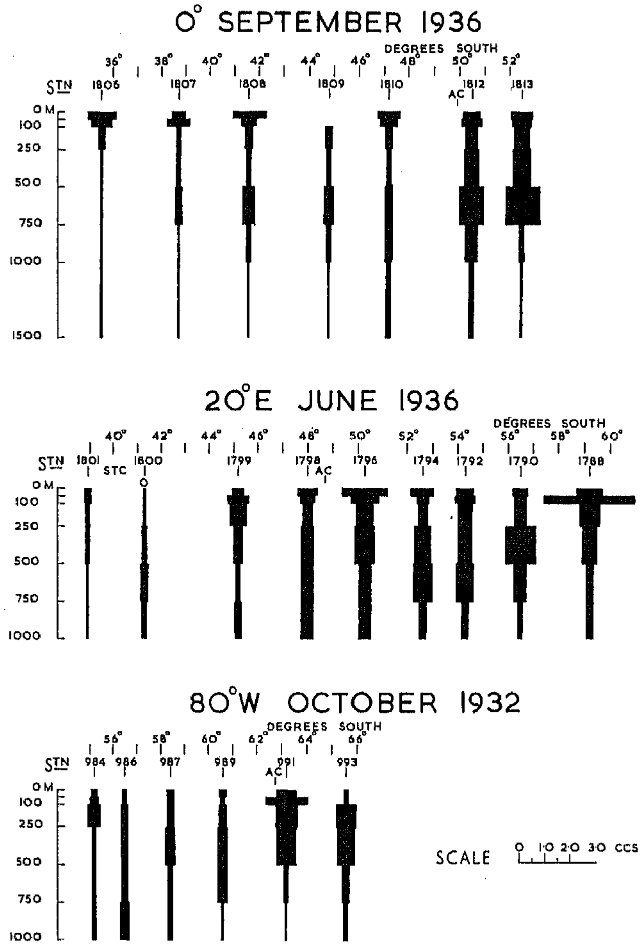

Fig. 4. Vertical distribution of the standing crop of zooplankton during September 1936 in 0°; June 1936 in 20° E; and October 1932 in 80° W.

In 20° E there are no June observations in 1938, but the 1936 series shows the presence of deep concentrations of plankton at a level intermediate between that in April and July 1938 (Fig. 2); and similarly the surface volumes were on the whole not as large as those in April but greater than those in July. The results for 1936 thus appear to fit reasonably well into the general picture presented by the 1938–39 series.

The October results for 1932 and 1934 (fig. 3) in 80° W, compare very well and show the same essential features, particularly at stations in approximately the same latitude (i.e. Sts. 984 and 1441, 991 and 1447), although the 1934 sub-Antarctic hauls were greater than those in 1932. In both years the plankton was concentrated deeper, the farther south the station.

From these three diagrams it would seem that differences from year to year are not, in these instances east, outstanding, and if the 1932 October data had been used in the 1933–34 80° W series it would : have affected the general conclusions for that meridian. This is of some importance, because the k of data has made it necessary to select the monthly series of stations in other regions, from ferent years, in an attempt to show that the vertical movement of the plankton is a general pheno- non in the whole of the sub-Antarctic and Antarctic regions and is not just peculiar to 80° W, 0° 20° E. As previously mentioned (p. 196), the number of observations in other areas is very small, t they are sufficient to allow for a comparison with observations from 80°, 0° and 20° in similar nths.

Observations in other areas (Fig. 5)

20° *W*. The observations in 20° W were not extended into sub-Antarctic waters, but they are of rticular interest because they sampled an area of the Southern Ocean greatly influenced by the eddell Drift. This current of surface water originating in the Weddell Sea has been found to play important part in the biology of *Euphausia superba*, an animal in which it is immensely rich (Marr, rsonal communication). Except in its young stages this animal is too large and active to be caught gularly by the N70V, so that the volumes from stations in this region represent the standing crop zooplankton other than the older krill.

The January 1932 volumes were similar to those from other regions, and showed a rather irregular rtical distribution of plankton but with the bulk concentrated in the top 100 m. of water at most itions. The March 1937 volumes seem typical of that month in other areas, with very large concen- itions of plankton in the Antarctic surface water.

110° *E*. These stations cover an area south of Australia from Fremantle, and they sample sub- opic, sub-Antarctic and Antarctic waters. The May 1932 results indicated late autumnal conditions, th larger hauls below 250 m., particularly at stations just north and south of the Antarctic con- rgence, while the northernmost sub-Antarctic and the southernmost Antarctic stations show large allow hauls. On the whole the conditions were not so advanced as in June in other areas.

March–April 1936 and January 1938 compare well with the same months in other areas.

160° *E*. The stations cover an area south of New Zealand. In June 1932 the volumes were small all depths, with some indication of greater concentration in deeper water at St. 919 in the Antarctic. he volumes in February 1936 and January 1938 were typical of summer months in other regions, ith most of the plankton concentrated in the surface waters. Of particular note are the exceptionally rge 50–0 and 100–50 m. catches in February.

These rather fragmentary observations in the region of 20° W, 110° E and 160° E are not sufficient give a seasonal picture of the variations of standing crop in each particular area, but when compared ith results from 0°, 20° E and 80° W, they do show that in comparable months the general pattern vertical distribution throughout those regions of the Southern Ocean which have been examined is ie same.

The meridian of 90° E, 1951 (Fig. 6)

'he Indian Ocean results are considered separately because they are the only available meridional ne of observations in tropical waters, and while a seasonal comparison is impossible they are yet of pecial interest in relation to the sub-Antarctic and Antarctic data.

The volume measurements (corrected for difference in net dimension (see p. 195)) show that the ulk of the plankton was in the upper 100 m. of water at all stations. There appeared to be little ifference between the catches at sub-tropical and tropical stations, but compared to October volumes ı sub-Antarctic and Antarctic waters the volumes of hauls at all depths were small. Of particular ote is the uniformity of the results—the vertical distribution of the plankton and the catch at each epth being about the same from station to station.

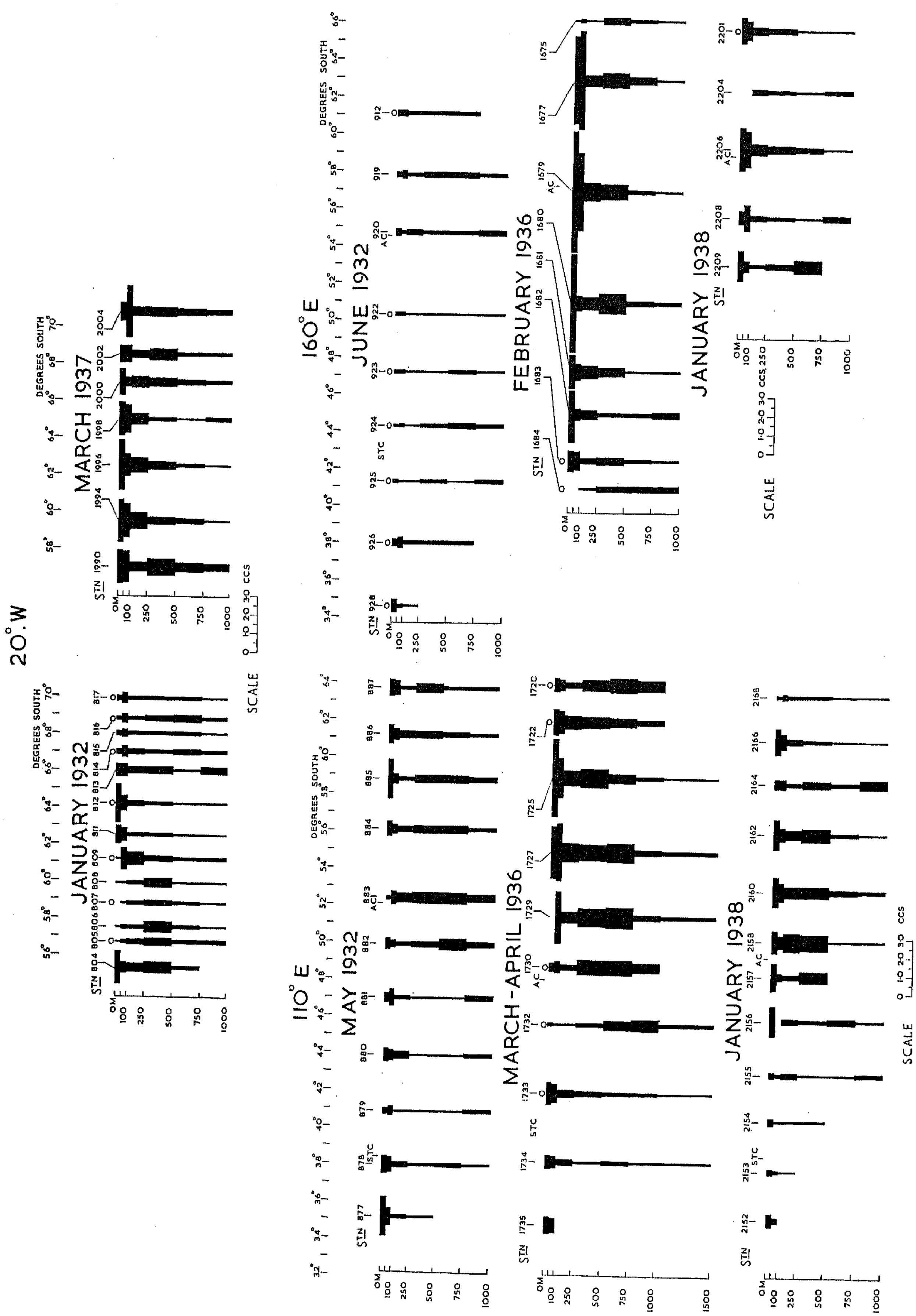

Fig. 5. Vertical distribution of the standing crop of zooplankton during 2 months near the meridian of 20° W, and during 3 months near the meridians of 110° W and 160° W.

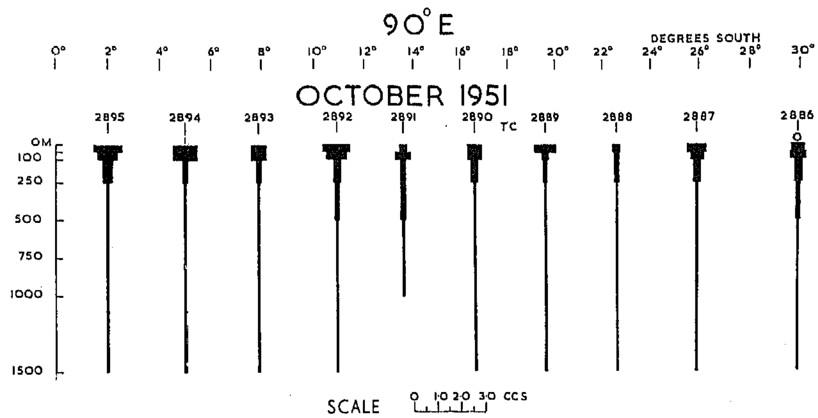

Fig. 6. Vertical distribution of the standing crop of zooplankton during October 1951, in 90° E.

AVERAGE MONTHLY VARIATIONS IN THE SUB-ANTARCTIC AND ANTARCTIC

Consideration of the individual lines of observations shows that it is reasonable to assume that in any one month the vertical distribution of the standing crop of zooplankton throughout the Southern Ocean will, on the whole, be the same. It is thus possible, by grouping observations from all areas according to month, to gain a general idea of the variations that take place in the quantity of sub-Antarctic and Antarctic zooplankton from month to month in an average year. Table 3 gives the mean monthly volume of plankton per 50 m. haul, together with the number of observations, at all depths down to 1000 m. in the sub-Antarctic and Antarctic zones. Results for the 1500–1000 m. horizon are not given owing to the inadequacy of the data; nor, for the same reason, can mean values be assessed from the few observations in sub-tropical waters. Fig. 7 is based on the data given in Table 3, and as in the previous diagrams, concentration of plankton is equivalent to width, and quantity to area of the block at each depth interval.

It should be pointed out that in this and all subsequent diagrams involving average values, it has been necessary to use observations from day and night stations, and possible variations in the vertical distribution of the plankton due to the effects of diurnal migration have been ignored. This seemed justifiable, at least in the case of sub-Antarctic and Antarctic data, because the results from those lines in which day and night stations occur, particularly those in 80° W, show no large or constant differences in the relative vertical distribution of the quantities of plankton caught.

This is not surprising since it has been shown (Mackintosh, 1937) that the three commonest organisms sampled by the N 70 V at least in 80° W, *Rhincalanus gigas*, *Eukrohnia hamata* and *Calanus acutus*, accomplish no diurnal but only seasonal migrations. Moreover, these species in adult form are relatively large, whereas the most common species showing diurnal variation in its vertical distribution, *Pleuromamma robusta*, is a copepod of small individual size. Hardy & Gunther (1935) also found *Calanus simillimus* and *Metridia gerlachii* to be diurnal migrants, but they are also small. Of the larger forms the euphausiids *Euphausia triacantha*, *E. vallentini* and *E. frigida* are known to be influenced by daylight (Hardy & Gunther, 1935; Mackintosh, 1937), but as adults they are all relatively uncommon in N 70 V net hauls. Obviously the importance of such animals volumetrically, and hence their relative importance as components in the total standing crop of plankton, is very variable, being influenced by many factors, including latitude, longitude, stage in life history, etc. As far as can be seen from the limited data available, however, diurnal variation seems to play only a minor part in directing the gross vertical distribution of the plankton, at least in sub-Antarctic and Antarctic plankton. In the tropics and sub-tropics diurnal variations are probably more important, as was found by King & Demond (1953) in the Central Pacific where shallow night hauls gave consistently larger volumes than the day ones. In this respect it is interesting to note that the variations due to time of day did not mask the major variations, which were latitudinal.

Table 3. *The monthly variation in the mean concentration (i.e. volume per 50 m. of haul) at six depth intervals in the sub-Antarctic and Antarctic. Numbers of observations are given in brackets*

Zone	Depth (m.)	January	February	March	April	May	June
Sub-Antarctic	50–0	0·94 (10)	2·42 (18)	1·84 (8)	0·60 (5)	0·72 (10)	0·34 (8)
	100–50	0·79 (9)	0·96 (18)	1·63 (8)	0·52 (5)	0·58 (11)	0·34 (8)
	250–100	0·36 (10)	0·54 (18)	0·48 (9)	0·31 (5)	0·23 (11)	0·23 (8)
	500–250	0·29 (10)	0·41 (18)	0·34 (9)	0·25 (5)	0·25 (11)	0·27 (7)
	750–500	0·32 (8)	0·34 (18)	0·33 (9)	0·37 (5)	0·26 (10)	0·29 (7)
	1000–750	0·25 (7)	0·22 (17)	0·27 (9)	0·24 (5)	0·21 (11)	0·26 (7)
Antarctic	50–0	0·89 (31)	1·73 (14)	1·93 (32)	2·12 (25)	1·00 (5)	0·63 (12)
	100–50	0·77 (32)	1·45 (16)	1·37 (38)	1·12 (25)	0·62 (5)	0·69 (12)
	250–100	0·47 (33)	0·44 (18)	0·54 (38)	0·47 (27)	0·32 (5)	0·36 (12)
	500–250	0·39 (33)	0·46 (19)	0·54 (37)	0·59 (29)	0·44 (5)	0·44 (12)
	750–500	0·19 (33)	0·25 (19)	0·41 (36)	0·49 (28)	0·39 (5)	0·46 (12)
	1000–750	0·15 (32)	0·15 (18)	0·24 (37)	0·22 (28)	0·28 (5)	0·29 (10)
Zone	**Depth (m.)**	**July**	**August**	**September**	**October**	**November**	**December**
Sub-Antarctic	50–0	0·47 (9)	0·37 (6)	0·55 (11)	0·71 (17)	1·28 (6)	0·99 (8)
	100–50	0·52 (9)	0·68 (6)	0·46 (12)	0·71 (16)	0·63 (6)	2·03 (8)
	250–100	0·27 (9)	0·31 (6)	0·26 (13)	0·60 (17)	1·13 (6)	0·75 (7)
	500–250	0·38 (8)	0·35 (6)	0·22 (13)	0·37 (16)	0·32 (6)	0·35 (7)
	750–500	0·59 (9)	0·45 (6)	0·38 (14)	0·41 (15)	0·26 (6)	0·26 (8)
	1000–750	0·38 (8)	0·25 (6)	0·20 (13)	0·23 (15)	0·13 (6)	0·15 (7)
Antarctic	50–0	0·49 (9)	0·75 (11)	0·54 (8)	0·37 (10)	0·52 (6)	0·96 (11)
	100–50	0·67 (9)	0·41 (11)	0·43 (8)	0·72 (10)	1·43 (6)	1·65 (11)
	250–100	0·37 (9)	0·32 (11)	0·30 (8)	0·72 (10)	0·59 (6)	0·59 (11)
	500–250	0·70 (9)	0·48 (11)	0·51 (8)	0·58 (10)	0·32 (6)	0·53 (11)
	750–500	0·77 (8)	0·58 (10)	0·94 (6)	0·39 (10)	0·26 (6)	0·29 (11)
	1000–750	0·52 (8)	0·32 (9)	0·41 (6)	0·19 (10)	0·19 (6)	0·14 (11)

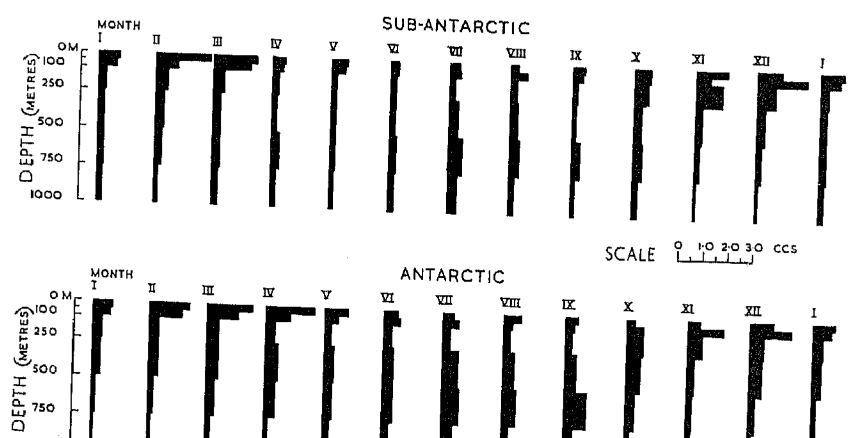

Fig. 7. Monthly mean vertical distribution of the standing crop in the sub-Antarctic and Antarctic. The number of observations and the mean concentration of plankton at each depth are given in Table 3.

Fig. 7 illustrates very clearly the seasonal variations that occur in the vertical distribution of the standing crop of plankton. In the winter months of July and August, and the early spring month of September, the bulk of the plankton is concentrated below 250 m., particularly in the Antarctic zone.

With the development of spring and then summer, the level of greatest concentration gets nearer the surface. In the Antarctic it is between 250 and 100 m. in October, and between 100 and 50 m. in November and January; and by late summer and autumn it lies between 50 m. and the surface. A similar sequence of vertical movement is also evident in the sub-Antarctic, although the winter concentration in deep water does not appear to be so marked as that in the Antarctic.

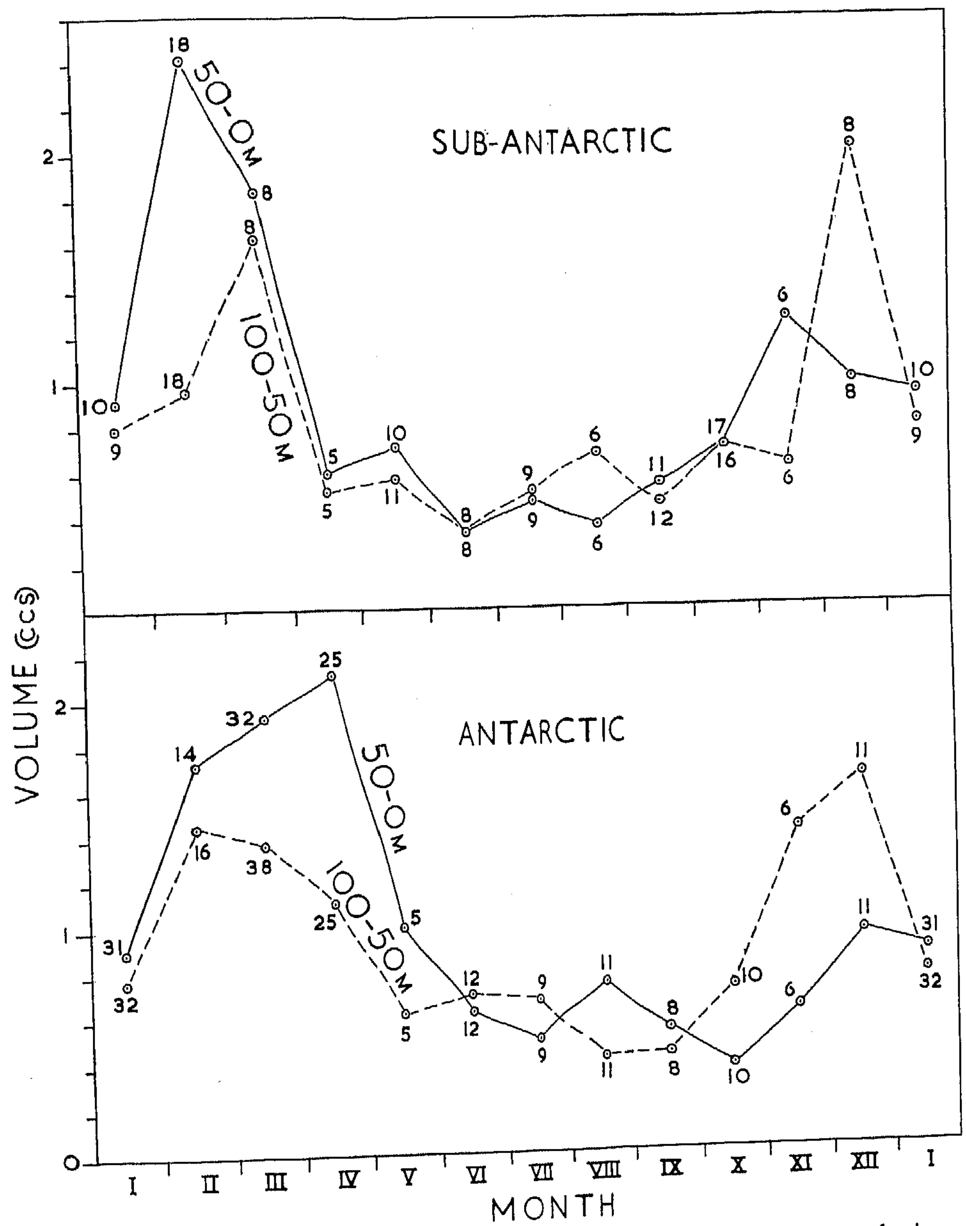

Fig. 8. Seasonal variation in the mean concentration of zooplankton in the 100–50 m. and 50–0 m. horizons of sub-Antarctic and Antarctic surface water. The numbers on each curve refer to the number of observations in each month.

From Fig. 7 and Table 3 it is also clear that the largest seasonal fluctuations in plankton density take place in the surface waters, which of course are the seat of phytoplankton production. The degree of seasonal variation is better illustrated in Fig. 8, where the mean monthly volumes of the 50–0 and 100–50 m. hauls have been plotted graphically. The highest summer mean volume is about seven times as great as the lowest winter mean volume in the sub-Antarctic, and about six times as great in the Antarctic at the 50–0 m. level. In both zones there are two main periods of increase, the first in spring reaching its maximum at the 100–50 m. level and the second in autumn at the 50–0 m.

level. The second period of increase is apparently the greatest, although in the sub-Antarctic this may be due to a single very large volume of 10·5 cc. for the 50–0 m. sample at St. 2219.

Table 4. *The monthly variation in the mean total volume of plankton (i.e. the sum of all measurements from 1000 to 0 m.). Numbers of observations are given in brackets*

Zone	January	February	March	April	May	June
Sub-Antarctic	7·03 (6)	10·15 (17)	9·44 (8)	6·36 (5)	5·72 (10)	5·51 (7)
Antarctic	6·86 (30)	9·18 (14)	10·33 (31)	12·37 (23)	8·14 (5)	8·93 (10)
Zone	**July**	**August**	**September**	**October**	**November**	**December**
Sub-Antarctic	8·61 (7)	7·25 (6)	5·78 (10)	8·28 (14)	8·87 (6)	8·92 (5)
Antarctic	13·11 (7)	9·17 (9)	11·60 (6)	9·07 (10)	7·53 (6)	9·25 (11)

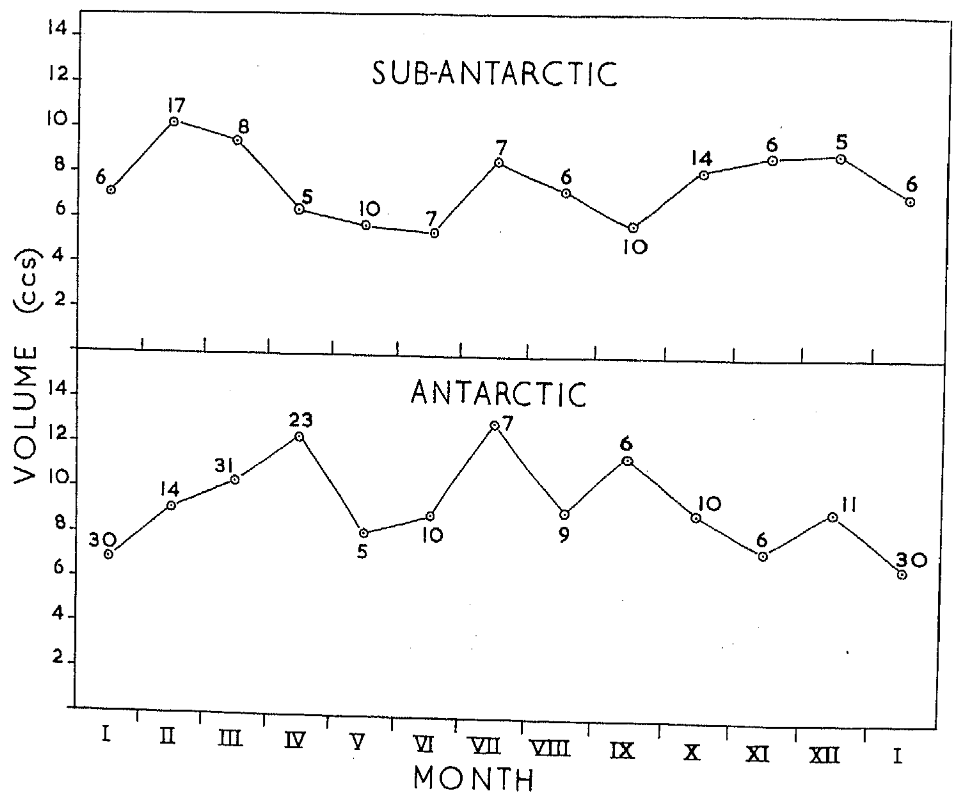

Fig. 9. Seasonal variation in the mean total volume of zooplankton in the whole water column sampled (i.e. 1000–0 m.) in the sub-Antarctic and Antarctic. Numbers on each curve as in Fig. 8.

It will be remembered that in calculating the monthly mean volumes for each depth interval the actual measurements had to be corrected to give the volume for a standard haul of 50 m. In this way variations in concentration at different levels in the whole water column can be assessed. When, however, the individual measurements at each depth are added together the resultant volume is a measure of the total standing crop of plankton in the whole water column sampled. Table 4 gives the mean monthly total volumes together with the number of observations in each month in the sub-Antarctic and Antarctic zones. It is compiled from all stations with a complete series of measurements from 1000 to 0 m., and the results are shown in Fig. 9.

The monthly mean volumes show that, compared to the surface waters, there is relatively little seasonal variation in the total volume of plankton, particularly in the Antarctic, where the July (mid-winter) volume is as great as that in April. A similar, but less marked, increase is also seen in the sub-Antarctic.

This rather unexpected result is due, without doubt, to the winter concentration of plankton in the Warm Deep Current between 1000 and 500 m., which represents a depth horizon much deeper than that of the Antarctic surface layer, which on an average extends to a depth of about 200 m.

These and the previous results discussed in this section show that in the Antarctic and to a lesser extent the sub-Antarctic there is an extensive winter vertical movement of plankton into the southerly flowing warm deep current. In this way the plankton which has summered in the northerly drifting Antarctic surface water is returned to the southward part of its environment.

For this reason the Antarctic and to a lesser extent the sub-Antarctic winter standing crop of zooplankton may be as large as the summer crop, though distributed through a greater depth of water. It should be noted, however, that in summer the zooplankton is associated with a period of great and rapid phytoplankton growth, and so the overall rate of grazing and zooplankton production is high. But in winter, when phytoplankton production is at a minimum and the bulk of the zooplankton is deep down and below the depleted euphotic zone, it is probable that zooplankton production is very slow and possibly at a standstill.

REGIONAL VARIATIONS IN THE STANDING CROP OF ZOOPLANKTON

VARIATIONS WITH LATITUDE AND TEMPERATURE

For a thorough comparison of the relative quantities of plankton in different latitudes the ideal material would include a series of meridional observations, extending from the equator to the ice-edge and repeated through the seasons. Although no such complete observations exist it is at least possible, by combining all the present data irrespective of longitude, to gain a very general idea of the major variations.

Fig. 10 shows the mean latitudinal variation at 5° intervals in the total quantity of plankton in the whole water column sampled, i.e. 1000–0 m.; it shows also the variation in the quantity of plankton in the upper 100 m. of water. The mean volumes and the number of observations in each group are given in Table 5, which takes into account 2171 of the total number of samples.

It is convenient to consider the upper 100 m. separately, since it has been shown in the previous section that the greatest seasonal changes in concentration occur in this layer. The values have been arrived at by averaging the sum of the 50–0 and 100–50 m. volumes at each station. In order to allow for these seasonal changes the data are treated in two seasonal groups: the summer group, November to April, representing the period of major increase in surface plankton concentration; and the winter group, May to October, the period of minimal surface concentration.

The 1000–0 m. values, as in the previous section, are found by summing the individual measurements of all samples between 1000 m. and the surface at those stations where a complete series exists.

As there are only ten stations between 0° and 30° S (Sts. 2886–2895) they have been omitted, and the range of observations covers sub-tropic, sub-Antarctic and Antarctic waters. Fig. 10 shows that except for the 100–0 m. winter volumes there is a gradual increase in average volume from low to high latitude reaching a maximum between 50° and 55° S, which is about four times greater than the average volume for 30–35°. This is followed, as one approaches the ice-edge, by a reduction to a volume between 65° and 70° S which is about half that between 50° and 55° S.

In summer the average quantity of plankton between 100 and 0 m. is a reflexion of the variation in the total quantity of plankton between 1000 and 0 m., which, of course, is consistent with the fact that in summer the bulk of the plankton is concentrated near the surface. In winter, however, there is no great latitudinal variation in the upper layer, and this is in contrast to the marked variation,

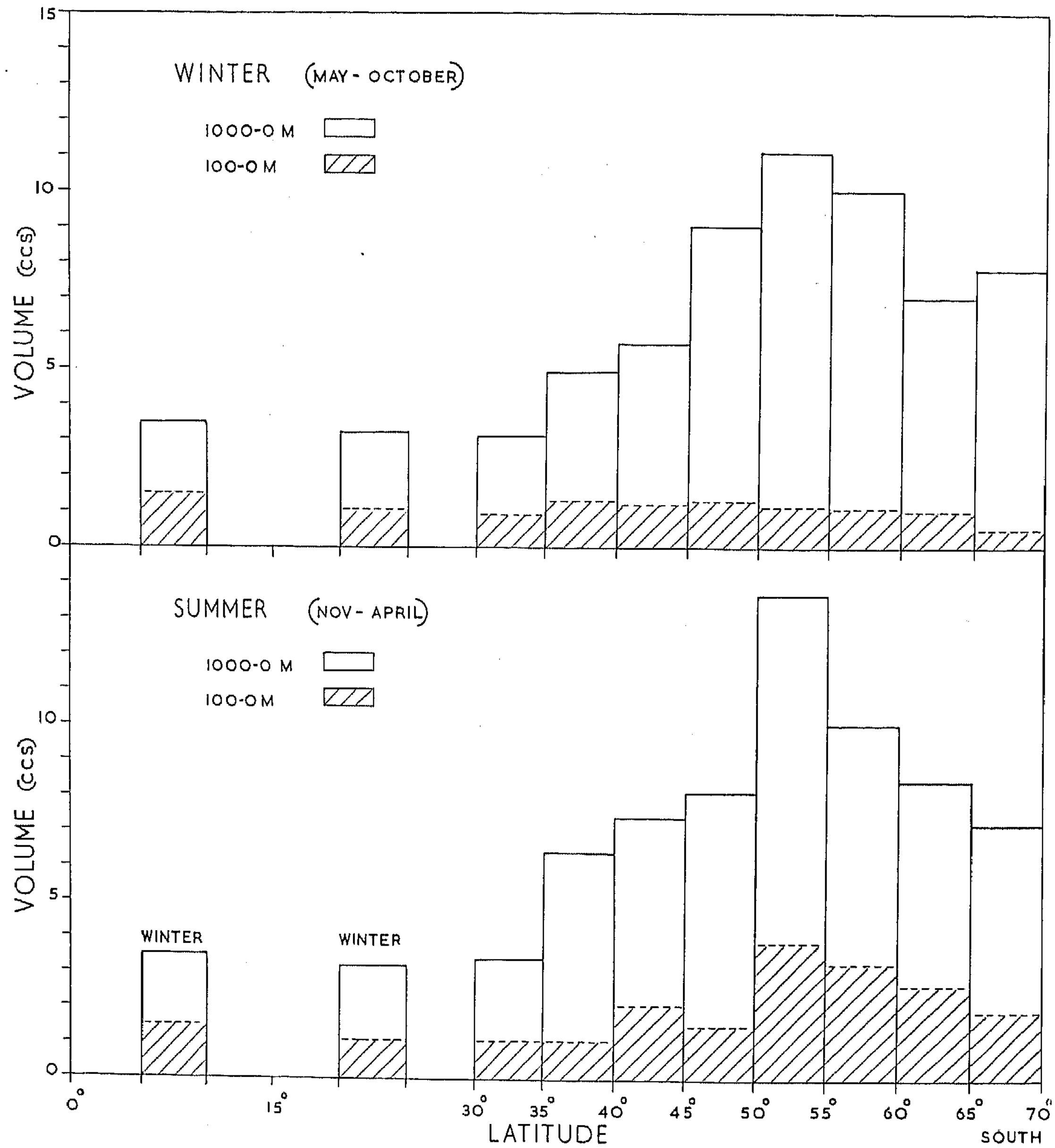

Fig. 10. Comparison of the mean quantities of zooplankton in different latitudes in winter and summer. Results are given for the 100–0 m. horizon and for the whole water column sampled (1000–0 m.). No summer observations are available between 0° and 30° S. Numbers of observations are given in Table 5.

similar to that in summer, of the total volume of plankton. This again is undoubtedly due to the seasonal vertical variation that occurs in the distribution of the plankton, the bulk of it being concentrated below 250 m. in winter, more particularly in the Antarctic but also in the sub-Antarctic.

The presentation of the data in the form of Fig. 10 has the disadvantage that it gives no indication of the range of variation in individual volume that occurs between the arbitrary latitudinal limits. In Fig. 11 all the individual total volumes from each station (i.e. 1000–0 m.) have been plotted according to their actual latitude in the form of a scatter diagram, and the latitudinal range has been

Table 5. *The variation according to latitude of the mean total volume (i.e. the sum of the measurements of all hauls between 1000 m. and the surface), and the mean volume in the upper 100 m. (i.e. the sum of the 50–0 m. and 100–50 m. measurements) in winter and summer. Numbers of observations are given in brackets*

[*Note.* Two groups of 15° interval cover the range 0–30° S; all other groups are in intervals of 5°.]

Season	Depth (m.)	Latitude (° S)				
		0–15	15–30	30–35	35–40	40–45
Winter (May–Oct.)	1000–0	3·48 (5)	3·22 (5)	3·10 (8)	4·86 (12)	5·71 (16)
	100–0	1·50 (5)	1·06 (5)	0·87 (11)	1·30 (15)	1·19 (18)
Summer (Nov.–Apr.)	1000–0	—	—	3·37 (7)	6·40 (6)	7·38 (14)
	100–0	—	—	1·08 (10)	1·08 (8)	2·09 (16)

Season	Depth (m.)	Latitude (° S)				
		45–50	50–55	55–60	60–65	65–70
Winter (May–Oct.)	1000–0	9·03 (17)	11·11 (23)	9·95 (25)	6·96 (12)	7·80 (3)
	100–0	1·31 (19)	1·15 (27)	1·11 (28)	1·04 (15)	0·53 (3)
Summer (Nov.–Apr.)	1000–0	8·07 (18)	13·65 (27)	9·98 (42)	8·36 (36)	7·20 (25)
	100–0	1·53 (20)	3·85 (28)	3·25 (46)	2·65 (38)	1·93 (25)

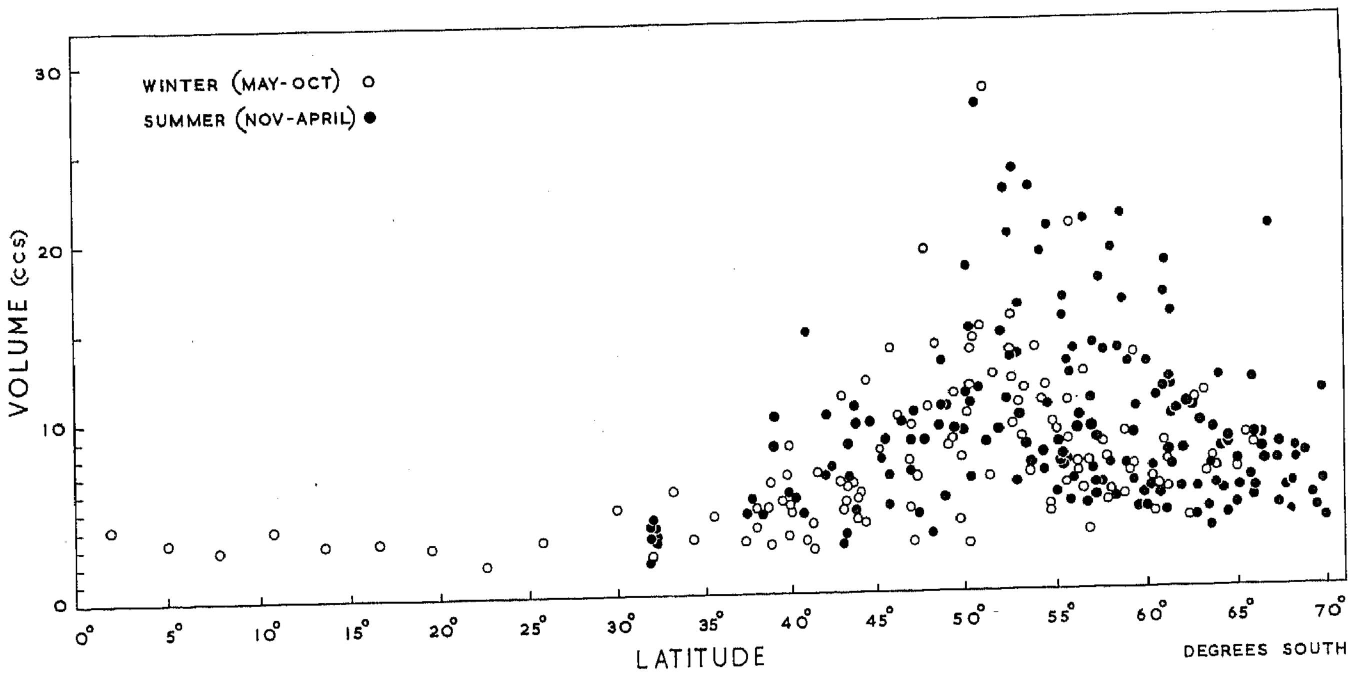

Fig. 11. Individual total volumes (i.e. 1000–0 m.) at each station plotted according to the latitude of the station. A few observations have had to be omitted for clarity.

extended from equator to ice-edge by the inclusion of the results from Sts. 2886–2895 in the Indian Ocean. It is apparent from the diagram that the greatest variation in volume occurs between 50° and 55° S, the highest latitudes being remarkable for the smallness of the catches and the lowest latitudes for the lack of variation in the individual volumes. In spite of the fact that there are so few observations north of 35° S, their difference from those in higher latitudes is most striking. Unfortunately, these are the only N70V tropical observations available, and it may be that they cover a period of poor standing crop in these latitudes. It is interesting in this respect, however, to note that King & Hida (1954, p. 49) remark upon similar latitudinal variations in range of data from the Pacific.

As previously stated, it has been necessary to combine results from all sectors of the Southern Ocean in order to get sufficient observations in all latitudes. The hydrology of the area is such that

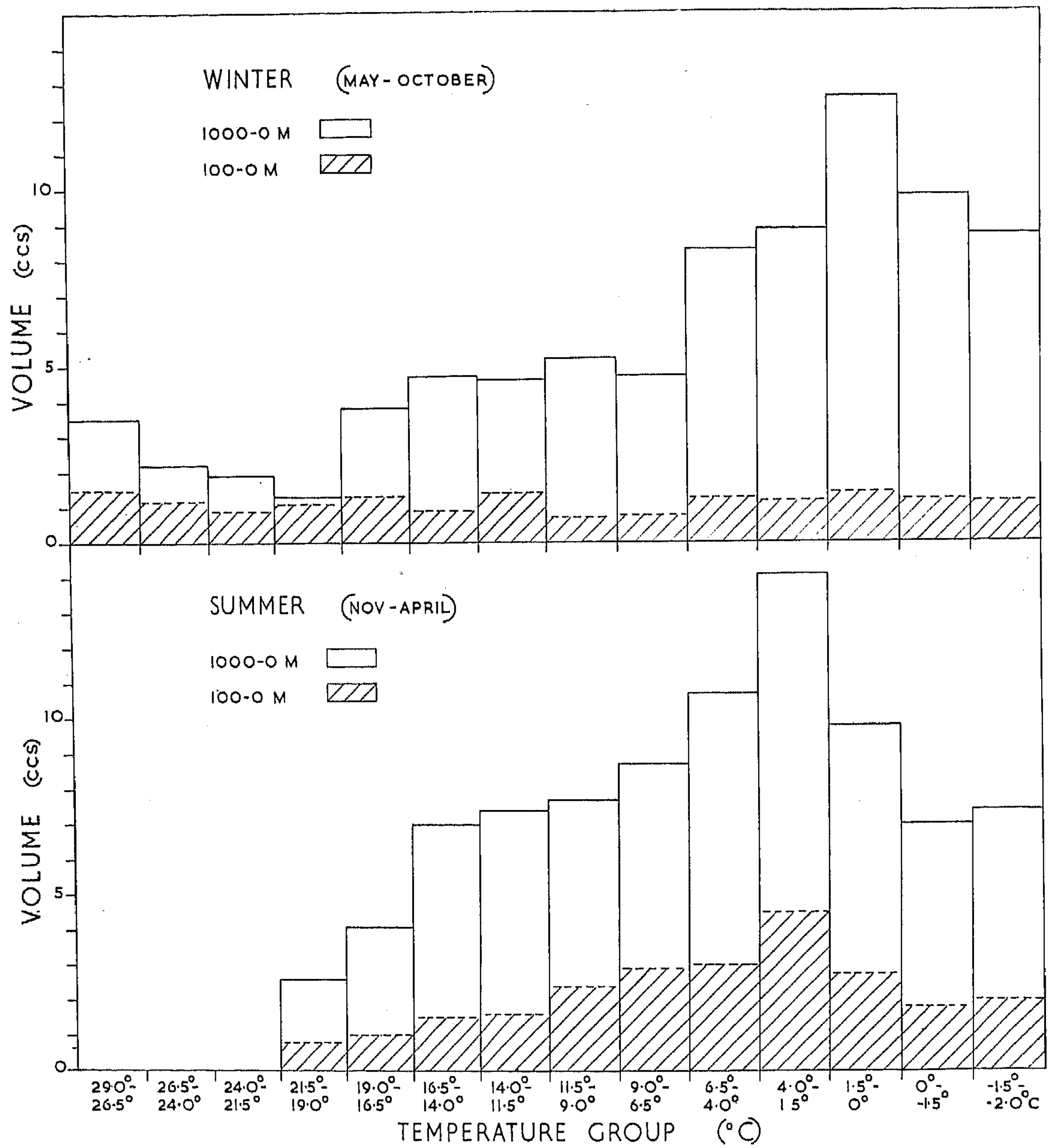

Fig. 12. Comparison of the mean quantities of zooplankton between arbitrary temperature limits in winter and summer. Results are given for the 100–0 m. horizon and for the whole water column sampled (1000–0 m). The temperature is the mean at each station for the 100–0 m. horizon. Numbers of observations are given in Table 6.

latitude is not a very realistic scale on which to compare volumes, since the position of the Antarctic Convergence—which is for many planktonic species a major influence upon their distribution—varies in such a manner that two stations in the same latitude but in different longitudes may be in quite different water masses or temperature zones. Thus in the meridian of 80° W St. 989 is 60° 38·6′ S, while in the meridian of 0° St. 2320 is 61° 10·6′ S; both are in the same approximate latitude, but the former is sub-Antarctic with a surface temperature of 3·43° C, while the latter is Antarctic with a surface temperature of 0·77° C. Any comparison of results from these two stations on a latitudinal basis would thus be misleading.

Variations in the 100–0 m. volumes are being considered, and the mean temperature of this layer at the time of sampling suggests itself as a more realistic scale on which to compare volumes, since it gives a more direct indication of the type of water from which the plankton came.

The observations previously presented in Figs. 10 and 11, have therefore been replotted in Fig. 12, based on Table 6, according to arbitrary temperature groups. The ten Indian Ocean stations which, although they cover a latitudinal range of nearly 30°, only cover a temperature range of 12° C, have been included in the winter observations. It will be noted that the temperature groups from 29·0 to 1·5° C are in intervals of 2·5° C, while the colder temperature groups are equivalent to an interval of 1·5° C. This adjustment seemed necessary owing to the great number of measurements from Antarctic waters which cover a relatively small temperature range (4·0 to −2·0° C, approximately) compared to sub-Antarctic waters (14·0–4·0° C approximately). The average volumes and the number of observations in each temperature group are given in Table 6.

Table 6. *The mean volume of plankton in the whole water column* (1000–0 *m.*) *and in the upper* 100 *m.* (100–0 *m.*) *between arbitrary temperature limits in winter and summer. Numbers of observations are given in brackets*

[*Note.* The temperatures are the mean temperatures for the 100–0 m. layer at each station.]

Season	Depth (m.)		Temperature (mean 100–0 m. ° C)						
			29·0 to 26·5	26·5 to 24·0	24·0 to 21·5	21·5 to 19·0	19·0 to 16·5	16·5 to 14·0	14·0 to 11·5
Winter (May–Oct.)	1000–0	Mean volume	3·48 (5)	3·2 (1)	2·90 (4)	2·32 (4)	3·79 (7)	4·73 (3)	4·60 (7)
	100–0	Mean volume	1·50 (5)	1·2 (1)	0·87 (4)	1·06 (8)	1·27 (7)	0·88 (5)	1·40 (8)
Summer (Nov.–Apr.)	1000–0	Mean volume	—	—	—	2·60 (2)	4·06 (7)	6·96 (5)	7·36 (5)
	100–0	Mean volume	—	—	2·60 (1)	0·84 (5)	1·03 (7)	1·46 (7)	1·57 (6)

Season	Depth (m.)		Temperature (mean 100–0 m. ° C)						
			11·5 to 9·0	9·0 to 6·5	6·5 to 4·0	4·0 to 1·5	1·5 to 0	0 to −1·5	−1·5 to −2·0
Winter (May–Oct.)	1000–0	Mean volume	5·21 (10)	4·70 (7)	8·31 (19)	8·85 (20)	12·63 (6)	9·83 (23)	8·67 (10)
	100–0	Mean volume	0·70 (10)	0·73 (8)	1·25 (22)	1·15 (22)	1·42 (10)	1·19 (25)	1·15 (11)
Summer (Nov.–Apr.)	1000–0	Mean volume	7·68 (11)	8·71 (13)	10·72 (17)	14·05 (29)	9·78 (30)	7·01 (41)	7·38 (15)
	100–0	Mean volume	2·39 (12)	2·91 (14)	2·99 (20)	4·47 (30)	2·74 (30)	1·84 (44)	1·98 (15)

From Fig. 12 it is seen that as the temperature of the water decreases the quantity of plankton in the whole water column and, except in winter, in the upper 100 m. of water increases. In summer a maximum is reached at temperatures between 4·0° and 1·5° C which is about six times the volume at temperatures between 21·5° and 19·0° C. There is a decrease in volume in waters colder than 1·5° C, but not to as low a value as the warmest temperature groups.

The winter 1000–0 m. volumes, which include the observations in 90° E, show that the colder waters are still the richest, although the maximum now occurs at temperatures between 1·5° and 0° C, owing no doubt to the seasonal cooling of the water. Apart from this there seems little seasonal change in total volume in waters colder than 4° C. In the warmer temperature groups, however, the total volume appears to be less in winter.

Comparison of Fig. 10 with Fig. 12 shows that the outstanding feature of each is that the maximum standing crop does not occur in the highest latitudes or at the lowest temperatures but in waters between 50° and 55° S (Fig. 10) and at a temperature of 4–0° C (Fig. 12).

This decrease might seem remarkable in view of the abundance of life in the colder Antarctic waters, but it will be remembered that *Euphausia superba* above 20 mm. in length are excluded from the volume measurements simply because, for all practical purposes, they are not sampled by the N 70 V. Except for the northerly region of the Weddell drift between 60° and 30° W, this species is abundant only in high latitudes and it has no counterpart farther north. If the volume of organic matter which it represents, as an element in the plankton, could properly be superimposed on the histograms in Figs. 10 and 12, there would probably be further increase up to the highest latitudes

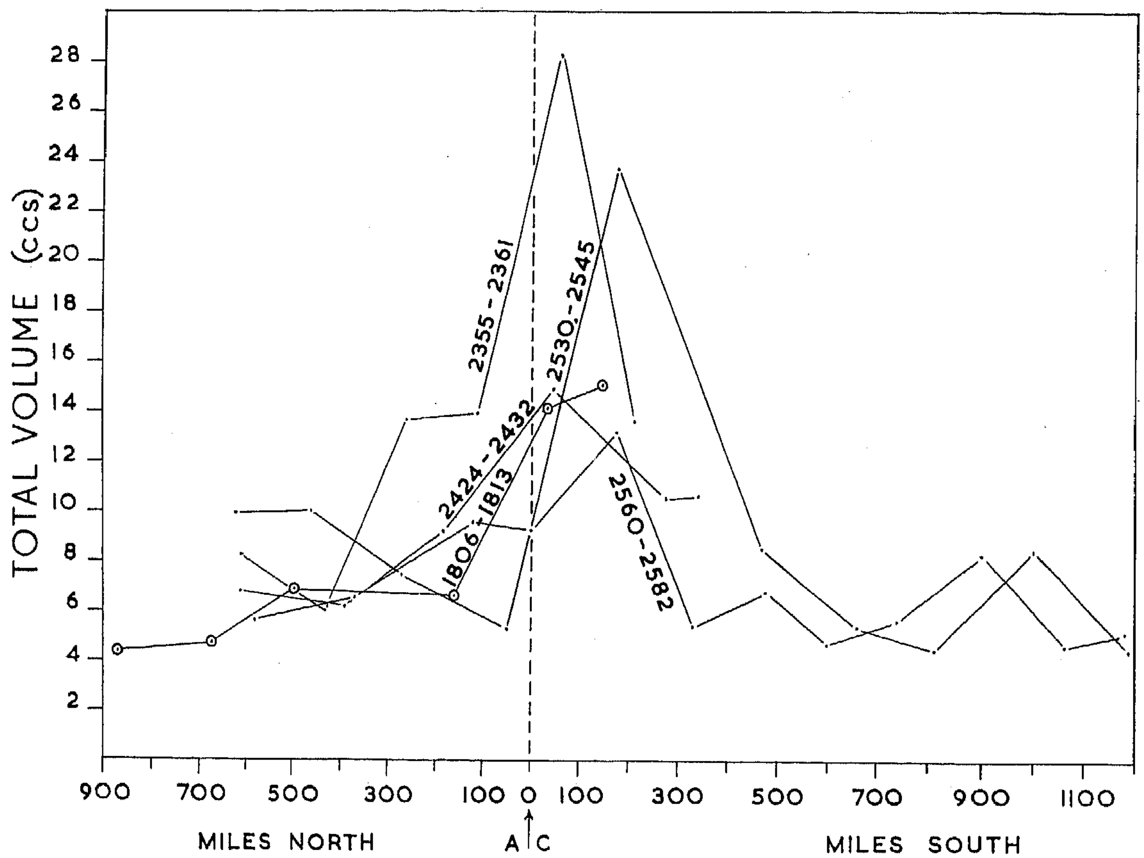

Fig. 13. The total volume at five series of stations in the meridian of 0° plotted according to the distance (in nautical miles) of the station north or south of the Antarctic Convergence. The serial numbers of the stations are shown.

and coldest waters. As an example of the remarkable concentrations of krill that do occur in those latitudes one can refer to observations made at sea; at St. WS 540 (57° 55′ S and mean temp. −0·23°C) in the Weddell Drift, for instance, a horizontal tow with a 1 m. net (N 100 H) in 36 sec. caught 13 litres (approximately) of krill. This represents a volume of plankton far greater than that of any other sample measured in this work.

While the importance of krill should not be underestimated in relation to the total standing crop of plankton in high latitude waters, it is also possible that the maximum shown in Fig. 10 between 50° and 55° S is due to the northerly drift of Antarctic surface water.

The Antarctic Convergence was crossed on forty-one occasions by the present series of observations, and 53° 20′ S—the average of its position on each occasion—lies within the area of maximum standing crop as represented in Fig. 10. It has already been noted, in the section on seasonal variations, that the largest catches are very often those at stations just south of the Antarctic Convergence.

Fig. 13 shows the total volume (1000–0 m.) at stations on five lines of observation in the meridan of 0° plotted according to their estimated position north or south of the convergence. The position of the Antarctic Convergence in each case was taken from Mackintosh (1946), and the distances are expressed in nautical miles. From the diagram it is evident that on each line there was a most marked increase in volume in a region 0–200 miles south of the Convergence. It is of interest that in the meridian of 0° there is a second smaller increase (900 miles south of the convergence) which occurs in the East Wind Drift. There are also instances of plankton concentrations near the Antarctic Convergence in other sectors, notably in 80° W at Sts. 991, 1224 and 1447; in 20° E at St. 2481; and in 160° E at St. 2206.

These increases in concentration occur in latitudes well north of those areas which have yielded the greatest catches of krill (Marr, personal communication), and in view of the fact that the Antarctic surface current moves gradually northwards the presence of large concentrations of plankton in the northern part of the Antarctic zone is consistent with the passive drift of plankton in this layer, in which it is concentrated in the summer months.

Table 7. *The mean concentration (i.e. vol. per 50 m. haul) at all depths sampled and the mean total volume (i.e. 1000–0 m.) in each zone. Allowance has been made for there being different numbers of summer and winter observations, except for the tropic zone where October observations only are available. Numbers in brackets are the totals of winter and summer observations at each depth*

Zone (m.)	50–0	100–50	250–100	500–250	750–500	1000–750	1500–1000	1000–0
Antarctic	1·05 (174)	0·90 (183)	0·46 (188)	0·51 (190)	0·45 (184)	0·26 (180)	0·14 (38)	9·75 (162)
Sub-Antarctic	1·06 (116)	0·83 (116)	0·46 (119)	0·32 (116)	0·36 (115)	0·23 (111)	0·16 (35)	7·96 (102)
Sub-tropic	0·63 (46)	0·43 (46)	0·22 (46)	0·16 (43)	0·15 (41)	0·12 (38)	0·05 (5)	3·75 (32)
Tropic	0·77 (6)	0·68 (6)	0·25 (6)	0·13 (6)	0·07 (6)	0·05 (6)	0·04 (5)	3·43 (6)

The present data have so far been treated in as detailed a manner as they allow. By using an even broader treatment, it is possible to arrive at a tentative estimate of the relative standing crops of plankton in the major geographical zones covered by the observations.

Table 7 gives the mean concentration of plankton (i.e. volume per 50 m. haul) for all depth intervals down to 1500 m., and the mean total quantity of plankton (1000–0 m.) in tropic, sub-tropic, sub-Antarctic and Antarctic zones. Allowance has been made for the difference in each zone of the number of summer and winter stations (except in the tropics, where only October results are available). The results are plotted in Figs. 14 and 15 respectively.

Fig. 14 shows that at all depths there is a general increase in concentration from tropic to Antarctic waters, and that in each zone the greatest concentration occurs in the shallowest depth horizon.

Fig. 15 gives an overall picture of a greater standing crop of plankton in the Antarctic than in any other region, the ratio tropic: sub-tropic: sub-Antarctic: Antarctic being roughly 1 : 1·3 : 2·7 : 3·3. These estimates are, of course, only tentative and refer to the limited part of the total zooplankton standing crop sampled by the N70V.

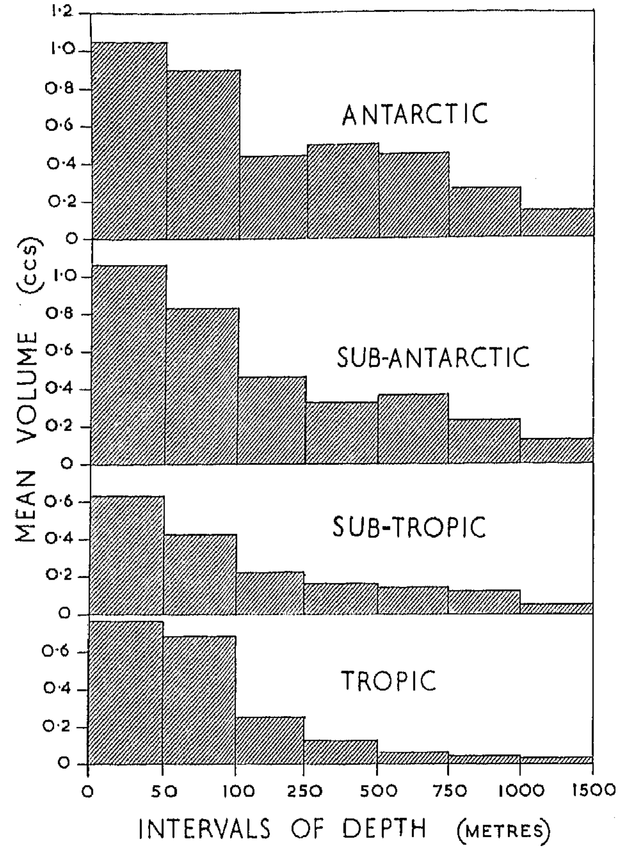

Fig. 14.

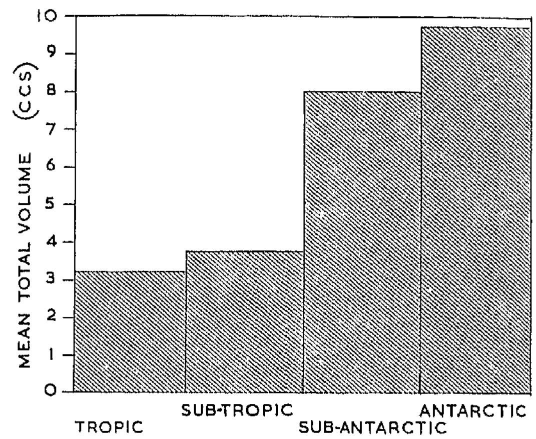

Fig. 15.

Fig. 14. Comparison of the mean concentration (i.e. volume per 50 m. haul) of zooplankton at seven intervals of depth in the Antarctic, sub-Antarctic, sub-tropic and tropic zones. This and Fig. 15 are based on results given in Table 7.

Fig. 15. Comparison of the mean total volume (1000–0 m.) in the Antarctic, sub-Antarctic, sub-tropic and tropic zones.

CIRCUMPOLAR VARIATIONS WITHIN THE ANTARCTIC ZONE

The data discussed in the previous section have shown that when the distribution of the standing crop of zooplankton is considered in a north-south direction large-scale variations are observed. These are undoubtedly related to the considerable north-south gradients that occur in the physical and chemical character of the principal water masses.

In the Southern Ocean hydrological differences in an east-west direction are small and all the main water masses, with the exception perhaps of the Antarctic Bottom Water (Deacon, 1937), have a circumpolar continuity. This is reflected, as Baker (1954) has shown, in the continuous circumpolar distribution of nearly all the commoner species of Antarctic phytoplankton and zooplankton.

Hart (1934, 1942) has shown that for the Antarctic phytoplankton there are some localized neritic areas, particularly near South Georgia, where the standing crop is exceptionally great in summer. In the Antarctic oceanic areas, however, which he provisionally divided into the Northern, Intermediate and Southern regions, the standing crop was much less, and there was little regional variation during the period of main increase. It is of some interest therefore to examine the zooplankton volumes in comparable months for any obvious regional differences within the Antarctic zone, even though the data do not allow such a detailed treatment as that of Hart (1942) or Baker (1954).

The total volume of plankton at each station (i.e. from 1000 to 0 m.), has been plotted on a circumpolar chart (Fig. 16.) together with the mean positions of the Antarctic and sub-tropical convergence and the approximate mean limits of the West Wind, Weddell, and East Wind Drifts; observations in

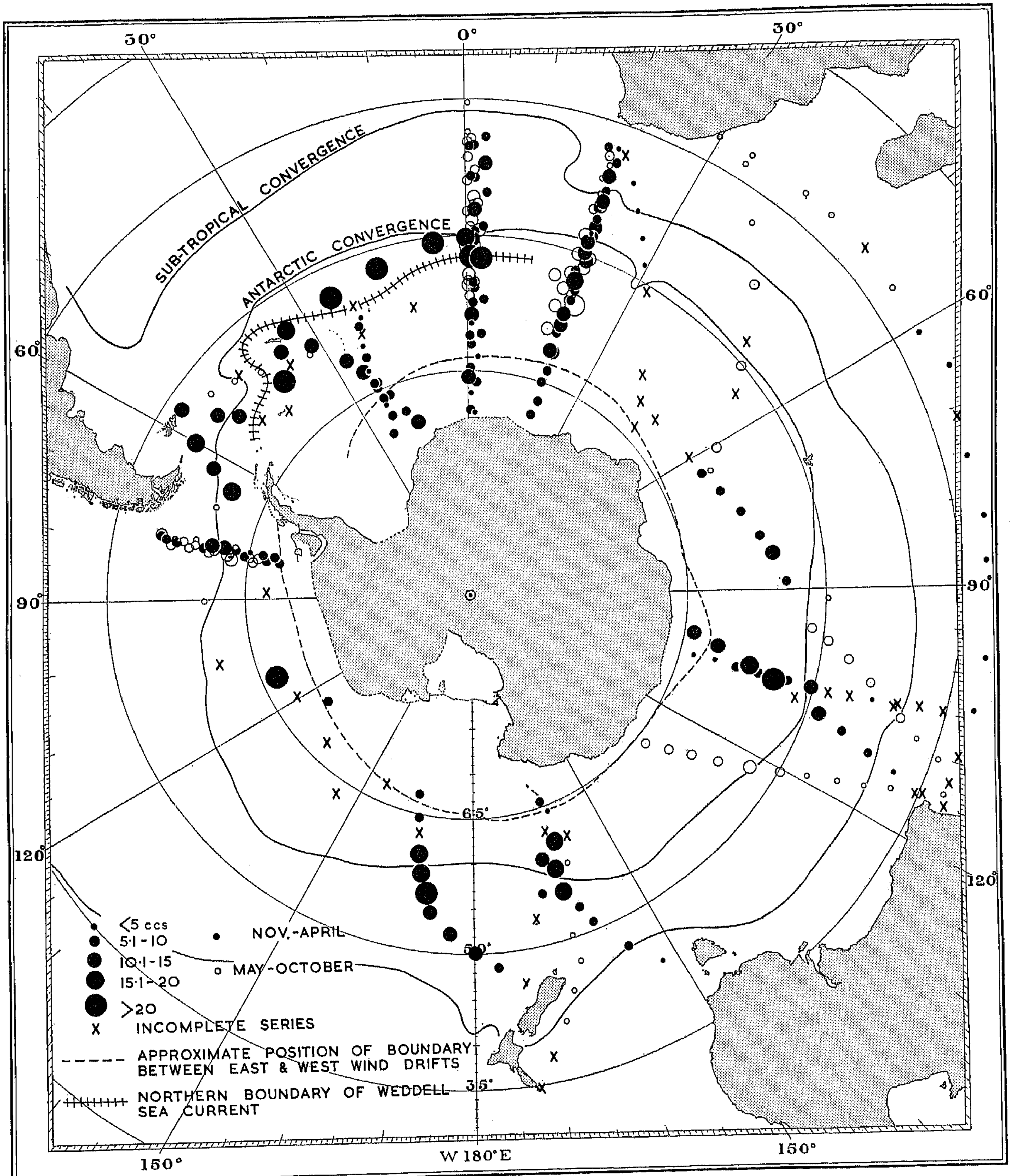

Fig. 16. The total volume of the zooplankton (1000–0 m.) at each station plotted according to the position of the station. A few observations in 0°, 20° E and 80° W have had to be omitted for clarity.

May to October are unshaded and the positions of stations with an incomplete series of hauls used elsewhere in this paper are marked with a cross.

Although there are some gaps in the observations, notably in the Pacific sector, the chart shows a number of features, some of which have been dealt with at length in previous sections. The large standing crop of plankton just south of the mean position of the Antarctic Convergence, for instance, is very evident, particularly in the Atlantic sector, and if the actual position of the convergence on each line were considered this would be more accentuated (see p. 219).

The area of Weddell Sea influence is surprisingly poor in plankton, as also is the East Wind Drift. As explained in the previous section, however, no allowance can be made for the great quantities of *Euphausia superba* which are known to occur in these regions. If this were possible it would be seen that these two surface-water drifts support perhaps the greatest concentration of plankton in the whole of the Southern Ocean.

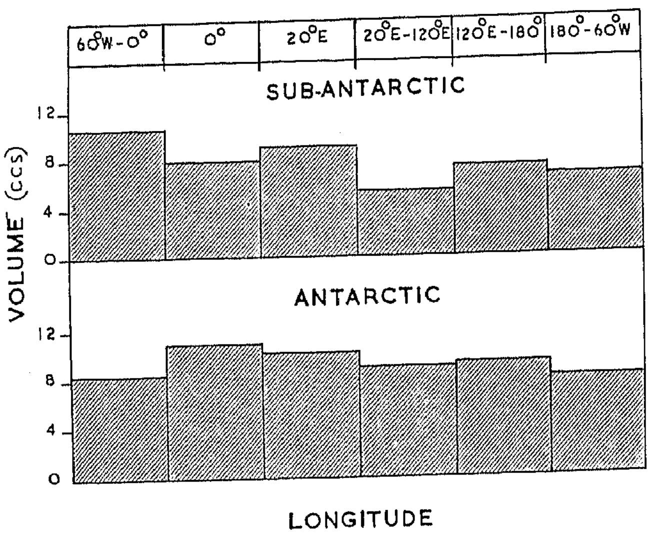

Fig. 17.

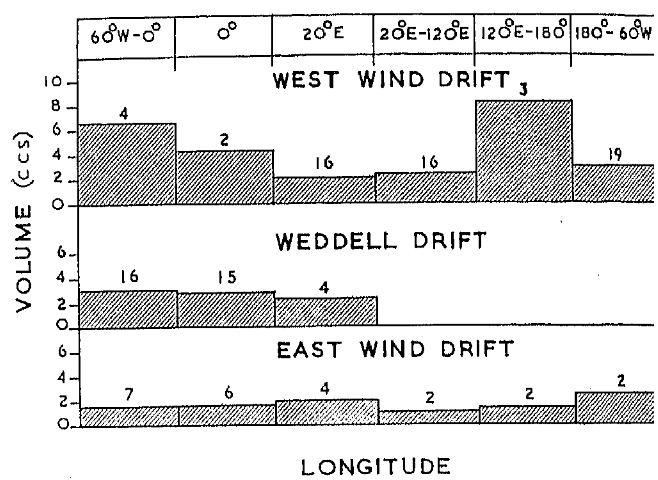

Fig. 18.

Fig. 17. Comparison of the total volume of zooplankton (1000–0 m.) in various sectors of the sub-Antarctic and Antarctic. Allowance has been made for the differences in the number of winter and summer observations in each sector.

Fig. 18. Comparison of the mean volume of zooplankton in the three principal Antarctic Surface Drifts during the main period of increase (November–April), together with the number of observations in each sector.

Table 8. *The variation in mean total volume (i.e.* 1000–0 *m.) between various sectors of the sub-Antarctic and Antarctic zones. Allowance has been made for there being different numbers of summer and winter observations in each sector. Total numbers of winter and summer observations in each sector are given in brackets*

	60° W–0°	0°	20° E	20–120° E	120° E–180° W	180–60° W
Sub-Antarctic	10·65 (5)	7·84 (28)	8·89 (19)	5·27 (15)	7·50 (16)	6·84 (18)
Antarctic	8·40 (28)	11·19 (35)	10·25 (36)	9·14 (20)	9·39 (12)	8·14 (31)

The mean total volume (i.e. 1000–0 m.) of plankton in different regions of the Antarctic, and also of the sub-Antarctic, are compared in Table 8, the results being represented diagrammatically in Fig. 17 (allowance has been made for the different numbers of winter and summer observations). The bulk of the observations are from the Atlantic sector and have been treated in three groups, 60° W–0°, 0° and 20° E. Data from the other areas have had to be treated in groups of larger intervals of longitude which correspond roughly to the main geographical divisions of the Southern Ocean, 20–120° E being the Indian Ocean sector, 120–180° the Australian-New Zealand sector, and 180–60° W the

Pacific sector. From the results it is apparent that there are no large-scale variations in the mean volumes in the different oceanic areas.

The presence in the Antarctic of three main surface drifts, the West Wind, East Wind and Weddell Drifts, suggests the possibility of comparing the east-west distribution of plankton within their approximate boundaries. For this purpose the volumes for the 100–0 m. horizon are more realistic since they are referable to the Antarctic surface layer (p. 200). The results for the main period of increase are given in Table 9 and Fig. 18, and show that the observations are too few to allow anything except tentative conclusions to be drawn from them. In the Weddell and East Wind Drifts there appears to be no large-scale regional variation. The results from the West Wind Drift are very irregular, and as the largest mean volumes occur between longitudes where there are few observations it is unlikely that the variations are significant. The figure shows, however, that, compared to the East Wind Drift, the quantity of plankton is greater in the West Wind Drift in all longitudes.

Table 9. *Comparison of the mean volume of plankton in the upper* 100 *m.* (100–0 *m.*) *of main surface drifts in different areas during the main period of increase* (*November–April*). *Numbers of observations are given in brackets*

[WWD = West Wind Drift; WC = Weddell Current; EWD = East Wind Drift]

Depth (m.)		60° W–0°			0°			20° E			20–120° E		120° E–180°		180–60° W.	
		WWD	WC	EWD	WWD	WC	EWD	WWD	WC	EWD	WWD	EWD	WWD	EWD	WWD	EWD
100–0	Mean	6·52 (4)	3·08 (16)	1·51 (7)	4·30 (2)	2·67 (15)	1·50 (6)	2·12 (16)	2·22 (4)	1·92 (4)	2·42 (16)	0·90 (2)	8·23 (3)	1·35 (2)	3·03 (19)	2·40 (2)

COMPARISON WITH THE FINDINGS OF OTHER WORKERS

The conclusions reached in the previous two sections regarding the regional distribution of the standing crop of zooplankton in the Southern Ocean may be summarized as follows.

From tropical latitudes there is a north-south gradient in the quantity of plankton which reaches a maximum between 50° and 55° S. This is an area which in most meridians lies just south of the Antarctic Convergence in the West Wind Drift. In more southerly waters there is an apparent decrease in the quantity of plankton, which may, however, be accounted for by the increased concentration of krill (a large active animal poorly sampled by the N70V except as larvae) that occurs in these regions.

In the Antarctic zone there appears to be, from existing evidence, little circumpolar variation at comparable times of the year.

It remains now to compare the major conclusions of this work with the results of other workers. Although there is a great deal of information on the distribution and variation in standing crop in all oceans of the world there is such diversity in the gear and methods used both to catch the plankton and to measure its volume that any comparison on anything except a very general basis is of doubtful value.

Much of the work is concerned with variations in coastal and offshore waters, and relatively little is known about conditions in the open ocean apart from the results of a few major oceanic expeditions on which quantitative plankton work has formed part of the programme. The relative distribution of the standing crop of plankton in the North and South Atlantic has been described in some detail by Friedrich (1950), who used the Meteor data supplemented by observations in other regions not covered by the 'Meteor'. These allowed areas of relative plankton density to be plotted on a chart in a similar fashion to that of Henschel (1936) but with the geographical range considerably extended (Friedrich, 1950, fig. 2, p. 113). It is not intended to treat the 'Discovery' data in such detail, but rather will they be compared with the results of other expeditions, including those of the 'National', 'Deutschland', 'Meteor', 'Dana', 'Carnegie', and the B.A.N.Z.A.R.E., to see by how much in each case the catches in high latitudes differed from those in low latitudes. These results must be used with reservation, since they are widely scattered in time and place, and they are derived from different methods and techniques; furthermore, in arriving at the latitudinal means plotted in Fig. 19 no allowance has been made for the east to west variations in standing crop that are known to occur in certain latitudes (e.g. that of the Sargasso Sea).

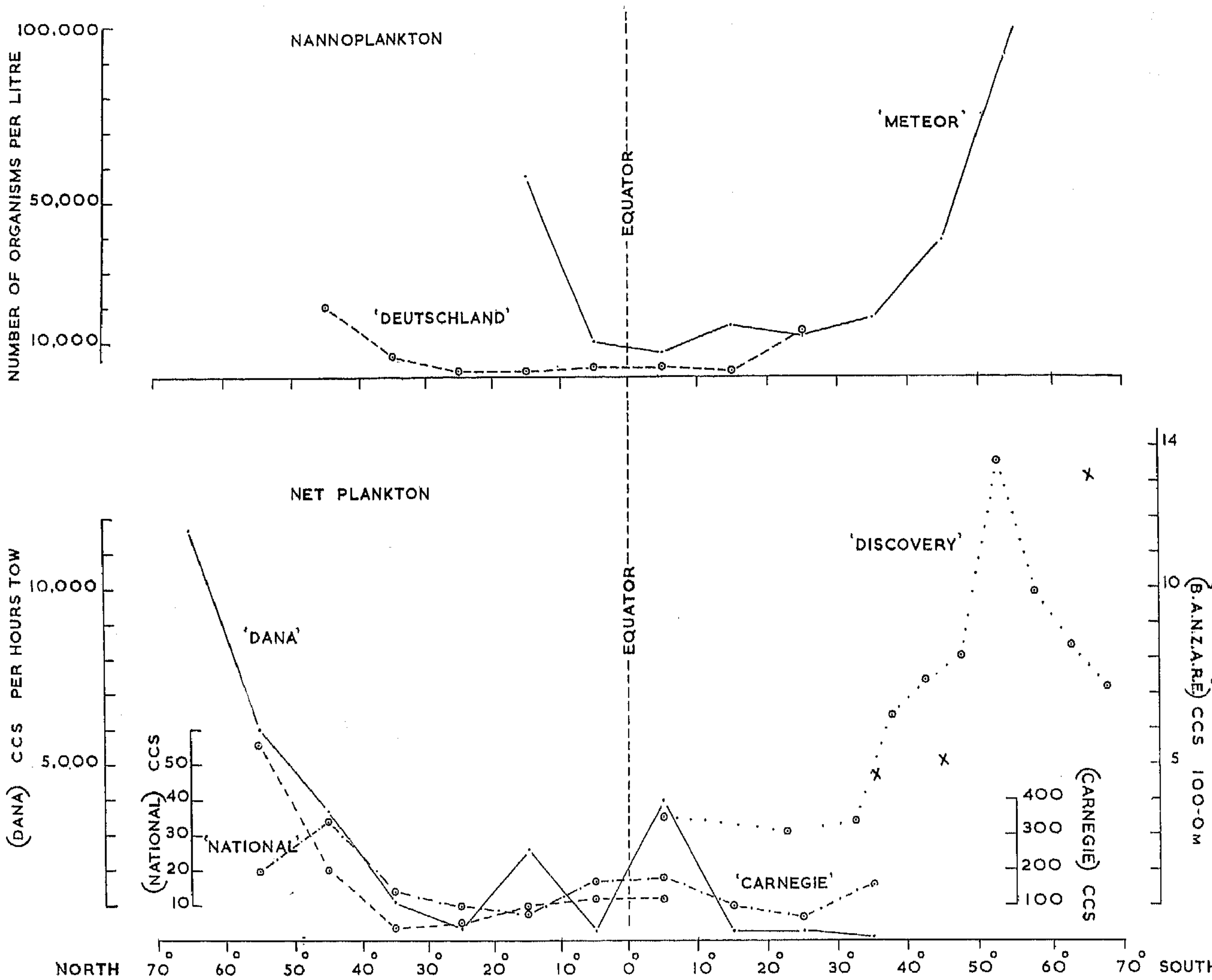

Fig. 19. The results of other expeditions compared with the summer mean total volumes (1000–0 m.) previously described in fig. 10. The few B.A.N.Z.A.R.E. results are indicated by a ×. Sources of data are given below.

Fig. 19 and Table 10 compare the results of all the expeditions with the latitudinal variations in the 1000–0 m. summer volumes which have been previously discussed in greater detail (p. 214 and Fig. 10). It should be noted that the vertical scale is different for the results of each expedition, as are the units in which some of them are expressed. The sources of the data are summarized below.

The Deutschland (Lohmann, 1919, table 6, p. 16) and Meteor results (Hentschel, 1936, table 4, p. 8) both refer to the numbers of nannoplankton organisms in 1 l. of sea water in the upper 50 m. (i.e. the mean of the 0 and 50 m. catches). As the observations are confined to the euphotic layer the counts must comprise at least 50 per cent phytoplankton and so are not strictly comparable to the net plankton catches of the other expeditions which consist principally of zooplankton. For this reason in Fig. 19, the Deutschland and Meteor results have been considered separately from the other data.

Table 10. *The results of various expeditions arranged to show the variation of catch with latitude, together with the approximate ratio between the catch in high latitudes and that in low latitudes. Numbers of observations, where available, are given in brackets*

[*Note.* The 'Deutschland' and 'Meteor' results refer to numbers of organisms, and the results of the other expeditions to the volume of the catch.]

Expedition	Author	Type of plankton	North							South							Approximate ratio high : low latitude catch
			70–60	60–50	50–40	40–30	30–20	20–10	10–0	0–10	10–20	20–30	30–40	40–50	50–60	60–70°	
'Deutschland'	Lohmann	Nanno-plankton	—	—	20,000	6,000	1,700	1,750	2,500	2,500	1,500	6,000	18,000	—	—	—	13 : 1
'Meteor'	Hentschel	Nanno-plankton	—	—	—	—	—	57,613	10,385	7,321	15,285	12,961	16,838	39,417	99,196	—	14 : 1
'National'	Hensen	Fine-net plankton	—	56·4 (17)	20·2 (11)	3·8 (34)	4·8 (10)	9·6 (8)	12·1 (14)	12·2 (32)	—	—	—	—	—	—	5 : 1
'Carnegie'	Wilson	Fine-net plankton		191 (2)	343 (8)	137 (12)	98 (13)	81 (10)	167 (12)	181 (14)	99 (27)	69 (7)	156 (11)	—	—	—	5 : 1
'Discovery II'	Sheard	Medium-net zooplankton	—	—	—	—	—	—	—	←(See Table 5)→							4·5 : 1
B.A.N.Z.A.R.E.	Sheard	Medium-net zooplankton	—	—	—	—	—	—	—	—	—	—	4·7 (2)	5·2 (7)	—	13·4 (9)	—
'Dana'	Jespersen	Macro-plankton	11,711 (59)	5,921 (26)	3,743 (14)	1,137 (51)	360 (35)	2,675 (6)	250 (1)	3,958 (3)	308 (4)	325 (2)	125 (3)	—	—	—	10 : 1

The results for the National or Plankton expedition are based on the settlement volumes of quantitative fine-net hauls mostly from *c.* 200 m. to the surface (Hensen, 1895, table 2, p. 8).

The Dana results are compiled from Jespersen (1923, fig. 1; 1935, table 36) and are the volumes (measured by drainage in a graduated sieve) of macroplankton, caught per 1 hr. tow (with *c.* 50 m. wire out) using a $1\frac{1}{2}$ or 2 m. stramin net.

The Carnegie results are those from Wilson (1942, pp. 15–168), and they represent the combined settlement volume in cc. of Pacific Ocean samples at 0 and 50 m. with $\frac{1}{2}$ and 1 m. nets.

The B.A.N.Z.A.R.E. results are the displacement volumes of vertical hauls with a 70 cm. Discovery net and are given in Sheard (1947, table 8, p. 11). As there are so few of them only the mean 100–0 m. volumes for latitudes 30–40° S, 40–50° S and 60–70° S are shown in Fig. 19; they are indicated by a cross.

The results of all the expeditions (Fig. 19) show a marked similarity of gradation, from the maximal quantities of plankton in high latitudes to the minimal values in low latitudes. There is, however, great variation in the ratio, which ranges from 14:1 ('Meteor') to 4·5:1 ('Discovery'). This is probably due both to the varying degrees of sampling in different latitudes and times of year, and to the differences in the sorts of organism caught. On the whole the greatest ratios are from nannoplankton and macroplankton catches, and were the Discovery data for these particular groups of organisms available they would probably show a comparable—if not greater—difference. Dr T. J. Hart believes that centrifuging would yield at least a 10:1 ratio for Antarctic microplankton as against that of warm seas. (This is merely a personal opinion based on unpublished results of some 120 Antarctic stations and a few sub-Antarctic and sub-tropic stations during 1933–35.) The Antarctic macroplankton would include 'krill', and again the ratio would be considerably increased, since there is no comparable form in warmer seas (see p. 218).

The smallest catches are not necessarily those nearest the equator and the Atlantic results of the 'National', 'Meteor', and 'Dana' expeditions show a marked rise in the quantity of plankton in this region. This is due largely to local areas of fertility near the Ascension and Cape Verde Islands (the *Kongo-Zunge* and *Kapeverden-Zunge* of Hentschel, 1936, fig. 2. p. 10; see also Jespersen, 1935, p. 30). The Deutschland results, in similar latitudes but in the Central Atlantic area, show a smaller increase (Lohmann, 1919, fig. 2).

In the Pacific also there is an increase in the abundance of plankton near the equator, as is shown by the Carnegie results. Graham (1941), using plankton dry weight as a measure of productivity, has confirmed this, while King & Demond (1953) have shown that the area of greatest abundance is north of the equator when related to a convergence and to the south when there is no marked convergence. In spite, however, of local areas of increase in the tropics the overall picture from Fig. 19 is one of greatest standing crop of plankton in the cold waters of high latitudes.

Of the many expeditions that have penetrated the Southern Ocean as far as the pack-ice only the B.A.N.Z.A.R.E. results have been analysed in relation to the standing crop of plankton (Sheard, 1947). The samples, which were collected during the 1930–31 summer season (November–April) from sub-Antarctic and Antarctic waters are on the whole greater in volume than those described for similar months and depths in this paper. This may, however, be due to the inclusion of gelatinous organisms or phytoplankton in the measurements given by Sheard. From his results (Sheard, 1947, table 8) it is apparent that the vertical distribution of the plankton is typical of summer months with most of the plankton concentrated in the upper 100 m. of water. There are too few observations for a close comparison to be made with the variations in a north-south direction shown from the results of other expeditions in Fig. 19. The three mean values for latitudes 30°–40° S, 40°–50° S, and 60°–70° S which are indicated by a '×' show, however, that the B.A.N.Z.A.R.E. results are not at variance with the Discovery data in so far as the greatest catches were in the Antarctic zone. Furthermore, the Antarctic volumes were also greater than those of catches with similar nets in waters off New South Wales (Sheard, 1947, p. 17).

SUMMARY

1. This paper is based on material collected with the Discovery pattern 70 cm. vertical closing net. The volumes of 2185 samples from 366 stations were measured by the displacement method, and the results are given in the Appendix.

2. The data from repeated lines of stations are treated diagrammatically. They show that throughout the sub-Antarctic and Antarctic the vertical distribution of the standing crop of zooplankton is on the whole similar in any one month.

3. The average monthly volumes of samples in the sub-Antarctic and Antarctic show that during the summer months the bulk of the zooplankton is concentrated in the surface waters day and night. But in the winter there is a migration of plankton into deep water, and the largest concentrations occur in the warm deep current.

4. There appears to be little seasonal variation in the total standing crop of zooplankton in the whole water column sampled (i.e. 1000–0 m.).

5. Regional differences are considered, and it is shown that there is a gradient in the quantity of zooplankton from low to high latitudes reaching a maximum between 50° and 55° S. The largest samples are not taken by the N70V in the highest latitudes or the coldest waters. But it is pointed out that the very large concentrations of *Euphausia superba* (above 20 mm. in length) that occur in certain regions of the Antarctic, are for all practical purposes not sampled by the N70V.

6. A tentative estimate is made of the relative standing crops of zooplankton (or that limited part of it sampled by the N70V) in the major geographical zones covered by the observations.

7. Within the Antarctic zone as a whole, there appears to be little circumpolar variation in the standing crop of zooplankton.

8. The standing crops of zooplankton in the West Wind, Weddell and East Wind Drifts are compared and, in so far as rather limited data allow, it is shown that in all sectors of the Southern Ocean the richest area is that of the West Wind Drift.

9. The results are compared in a very general way with those of other workers, and although the data are not strictly comparable, it is shown that the standing crop of zooplankton in the Antarctic is at least four times as great as that in the tropics.

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APPENDIX. TABLES 11 *a–f*

The displacement volume (in cc.) of samples taken with the 70 cm. vertical closing net, together with the sum of the volumes of all hauls between 1000 m. and the surface (i.e. 1000–0 m.). The following contractions are used to indicate in which major geographical zone the stations occurred: A = Antarctic; SA = Sub-Antarctic; ST = Sub-Tropic; T = Tropic.

* Station completed before sunset.

† Sample rich in phytoplankton. No volume measurement is given where it was impossible to separate the zooplankton from the phytoplankton (see p. 198).

( ) Some of sample missing.

Table 11 *a*. *Observations near the meridian of* 0°

Station	Date	Latitude S	Longitude	Zone	Depth (m.) 50–0	100–50	250–100	500–250	750–500	1000–750	1500–1000	1000–0
					1936							
1806	20. ix. 36	35° 28·7′	00° 18·5′ E	SA	1·2	0·9	0·9	0·6	0·5	0·3	0·3	4·4
1807	21. ix	38° 40′	00° 27·8′ E	SA	0·6	1·0	0·7	0·9	1·3	0·3	0·5	4·8
1808	22. ix	41° 36·5′	00° 28·6′ E	SA	1·4	0·6	0·9	1·0	2·3	0·7	0·7	6·9
1809	23. ix	44° 48′	00° 07·4′ E	SA	—	—	1·0	0·9	2·1	0·7	0·7	—
1810	24. ix	47° 14·8′	00° 06·2′ E	SA	0·9	0·7	0·8	1·1	1·7	1·3	1·9	6·5
1812	26. ix	50° 29·8′	00° 09·8′ E	A	0·7	0·8	1·5	3·2	5·3	2·6	2·1	14·1
1813	27. ix	52° 28′	00° 21·3′ E	A	0·9	0·8	1·7	3·6	7·5	1·0	1·1	15·5
					1938–39							
2311	11/12. iv. 38	50° 05·2′	00° 03′ W	A	4·4	1·3	0·7	8·3	2·6	0·9	2·0	18·2
2313	12. iv	52° 27′	00° 29·2′ E	A	1·1	0·9	0·7	8·4	7·9	1·0	0·8	20·0
2316	14/15. iv	57° 15·5′	01° 13·4′ E	A	1·2†	0·6†	1·1	1·4	0·4	0·6	1·0	5·3
2318	15/16. iv	58° 58·7′	01° 00′ E	A	4·0	2·3	1·8	3·6	0·7	0·3	0·5	12·7
2320	16/17. iv	61° 10·6′	00° 43·7′ E	A	2·1	0·9	1·2	1·6	1·2	0·7	1·9	7·7
2322	17/18. iv	63° 53′	00° 24·4′ E	A	1·1	0·7	2·3	4·0	2·8	0·8	1·0	11·7
2355	6/7. vii	39° 51·4′	01° 06·8′ E	SA	0·6	0·9	0·9	1·0	2·7	2·2	2·5	8·3
2356	7. vii	42° 56·8′	01° 21·2′ E	SA	0·1	0·5	0·8	1·5	1·8	1·5	1·5	6·2
2357	8/9. vii	45° 51·4′	01° 18·2′ E	SA	0·3	0·4	1·4	4·5	5·1	2·0	2·8	13·7
2358	9. vii	48° 24·6′	00° 51′ E	SA	1·0	0·8	1·7	4·2	4·3	1·9	3·3	13·9
2359	10. vii	51° 11·4′	00° 25·2′ E	A	0·4	1·9	3·0	8·6	9·7	4·5	3·8	28·1
2361	11. vii	53° 50·6′	00° 00·8′ E	A	1·0	0·6	1·3	3·5	4·2	3·0	3·5	13·6
2385	10. viii	39° 56·9′	00° 14·1′ E	SA	0·1	0·5	0·9	1·2	1·5	0·9	0·8	5·1
2386*	12. viii	44° 04·9′	00° 15·4′ E	SA	0·1	0·1	0·4	1·0	2·2	1·8	1·7	5·6
2387*	14. viii	49° 08·2′	00° 41·5′ E	SA	0·1	0·1	1·3	2·4	2·8	1·6	1·4	8·3
2389	15. viii	52° 35·3′	00° 04·5′ E	A	1·5	0·5	1·3	3·1	5·0	1·9	1·0	13·3
2391	16. viii	55° 03·3′	00° 19·1′ E	A	1·3	0·6	0·6	3·2	1·7	1·6	2·4	9·0
2393	17. viii	56° 42·3′	00° 38·3′ E	A	0·3	0·2	1·2	1·4	2·1	1·6	1·9	6·8
2424*	19. ix	39° 53·7′	00° 38·9′ E	SA	0·1	0·1	0·3	1·3	3·5	1·4	1·1	6·7
2425	20. ix	43° 28·4′	00° 41·1′ E	SA	0·2	0·3	0·6	1·7	2·4	1·0	1·2	6·2
2426	21. ix	46° 58·4′	00° 53·2′ E	SA	0·2	0·2	1·0	1·8	4·1	2·0	1·1	9·3
2428	23. ix	51° 57·7′	00° 35·8′ E	A	0·8	0·5	1·2	3·5	5·9	3·0	1·2	14·9
2430	24. ix	54° 14·1′	00° 29′ E	A	0·5	0·3	1·0	3·0	3·4	2·3	2·0	10·5
2432*	25. ix	55° 36·7′	00° 30·4′ E	A	0·1	0·1	0·5	2·7	4·9	2·3	1·8	10·6
2458*	22. x	40° 02·4′	01° 08·1′ E	SA	0·8	0·1	0·5	1·2	1·0	1·0	0·5	4·6
2459*	23. x	43° 21·1′	01° 25·7′ E	SA	0·2	0·2	1·9	1·3	—	0·6	—	—
2460	24/25. x	46° 33·6′	01° 42·8′ E	SA	0·6	0·7	1·4	2·6	2·7	1·8	2·0	9·8
2461	25. x	49° 37·6′	02° 01·4′ E	SA	0·7	0·4	2·5	2·9	3·1	1·5	0·8	11·1
2463	26. x	52° 41·8′	02° 11·4′ E	A	0·8	1·1	3·5	1·1	1·4	1·4	1·0	9·3
2465	27. x	55° 16·6′	01° 38·4′ E	A	0·4	0·2	0·9	2·6	2·6	1·2	0·6	7·9
2492*	28. xi	40° 12·8′	00° 37·6′ W	SA	1·3	1·0	0·5	1·1	1·1	0·4	1·2	5·4
2494*	30. xi	43° 18·1′	00° 54·6′ E	SA	0·3	0·3	4·9	1·3	1·1	0·4	0·8	8·3
2495*	1. xii	47° 11·2′	01° 17·5′ E	SA	0·1	0·5	2·6	3·7	2·6	0·6	1·0	10·1
2496	2 xii	50° 20·7′	01° 03·3′ E	A	1·6	1·3	1·6	6·9	2·5	0·9	—	14·8
2498	3. xii	52° 53·5′	00° 50·3′ E	A	2·8	2·8	2·4	2·5	2·0	0·7	0·8	13·2
2501*	5 xii	55° 30·2′	01° 23·7′ E	A	1·8	2·3†	0·6	1·0	1·0	1·6	—	8·3
2530	11/12. i. 39	39° 03′	02° 35′ E	SA	0·3	1·4	2·0	1·2	2·5	2·5	5·0	9·9
2531	12. i	42° 07·9′	02° 50·9′ E	SA	1·4	0·5	2·6	1·6	2·1	1·8	1·9	10·0
2532	13/14. i	45° 18·9′	03° 09·8′ E	SA	1·2	1·8	1·1	1·9	1·1	0·4	—	7·5
2533*	15. i	48° 58·4′	02° 47·1′ E	SA	0·4	0·7	0·1	2·6	1·0	0·5	0·8	5·3
2535	16. i	52° 40·8′	02° 45·4′ E	A	0·7†	3·5†	8·8	6·3	3·2	1·2	1·1	23·7
2538*	18. i	57° 11·9′	03° 33·7′ E	A	0·2†	0·2†	2·1	2·9	1·7	1·4	—	8·5
2541	19/20. i	60° 41·7′	03° 13·9′ E	A	0·8	0·8	1·3	1·3	0·7	0·4	0·4	5·3
2543*	20. i	63° 24·7′	02° 44·7′ E	A	1·9†	0·3†	1·1	0·4	0·5	0·3	0·4	4·5
2545	21. i	66° 23·7′	02° 16·2′ E	A	1·8	1·5	1·3	2·3	1·0	0·6	0·4	8·5
2547*	22. i	69° 30·2′	02° 04·7′ E	A	0·4†	0·7†	0·9	1·1	0·9	0·4	0·6	4·4
2582*	20. ii	39° 53·9′	00° 39·1′ E	SA	0·2	0·2	0·6	1·5	1·8	1·4	2·6	5·7
2583	21. ii	43° 27·6′	00° 50′ E	SA	1·8	0·8	1·7	1·0	0·5	0·7	1·4	6·5
2584	22. ii	46° 29·1′	00° 54·9′ E	SA	0·4	1·1	1·3	1·9	3·8	1·1	1·7	9·6
2585	23. ii	49° 33·4′	01° 06′ E	SA	0·9	0·4	1·4	3·7	2·0	0·8	1·1	9·2
2586	24. ii	52° 29·1′	00° 59·4′ E	A	2·8	3·2	1·1	2·7	2·5	0·8	2·1	13·1
2588	25. ii	55° 08·5′	00° 42·4′ E	A	0·1†	0·1†	1·2	2·0	1·1	1·0	1·6	5·5
2590	26/27. ii	57° 32′	00° 40·1′ E	A	0·5†	0·9	0·4	2·8	1·3	0·8	2·0	6·7
2592	27/28. ii	59° 30·7′	00° 23·6′ E	A	0·1†	0·1†	1·4	1·9	0·6	0·5	0·5	4·6
2594	28/1. iii	61° 51·7′	00° 11·7′ E	A	0·5	0·5	0·7	1·9	0·8	1·2	—	5·6
2596	1/2. iii	64° 29′	00° 12′ E	A	0·3†	0·8	1·2	2·5	1·2	2·3	1·1	8·3
2598	2. iii	67° 15·6′	00° 44·5′ E	A	0·6	0·5	0·9	1·5	0·7	0·4	0·5	4·6
[illegible]	[illegible]	6[illegible]° [illegible]′	00° 24·3′ E	A	0·4	0·2	2·0	1·2	0·6	0·7	0·6	5·1

Table 11*b*. *Observations near the meridian of 20° E*

Station	Date	Latitude S	Longitude	Zone	Depth (m.)							
					50–0	100–50	250–100	500–250	750–500	1000–750	1500–1000	1000–0
							1936					
1788	7. vi. 36	59° 11·7′	17° 01·9′ E	A	1·0	3·6	2·5	3·0	1·5	1·6	—	13·2
1790	8. vi	56° 26·9′	17° 22·9′ E	A	0·6	0·5	1·4	5·9	2·7	1·1	—	12·2
1792	9. vi	54° 20·1′	17° 53·5′ E	A	0·7	0·8	1·9	3·1	3·3	1·7	—	11·5
1794	10. vi	52° 37·5′	18° 22·7′ E	A	0·9	0·5	1·3	3·5	4·1	1·6	—	11·0
1796	11. vi	50° 19·7′	18° 40·3′ E	A	1·8†	1·1	2·0	3·9	2·3	2·5	—	13·6
1798	12. vi	48° 00·3′	18° 54·4′ E	SA	0·8	0·6	1·3	2·6	2·5	2·6	—	10·4
1799	13. vi	45° 10·1′	18° 50·5′ E	SA	0·5	0·9	2·0	2·0	1·1	1·5	—	8·0
1800*	15. vi	41° 20·3′	18° 54·3′ E	SA	0·1	0·1	0·4	0·9	1·6	0·8	—	3·9
1801	16. vi	38° 53′	18° 52·5′ E	ST	0·3	0·3	0·6	1·0	0·5	0·1	—	2·8
							1938–39					
2335*	22. iv. 38	67° 10′	20° 24·5′ E	A	1·1	1·0	1·1	1·6	1·3	1·0	—	7·1
2338	23. iv	63° 41·7′	20° 01·2′ E	A	1·1†	0·8	1·7	2·9	2·0	0·4	—	8·9
2340	24/25. iv	61° 35·4′	19° 45·9′ E	A	1·1†	0·8†	1·7	3·6	1·6	1·2	—	10·0
2342	25. iv	58° 53·9′	19° 33·9′ E	A	1·2†	1·1†	3·0	3·2	2·9	1·3	—	12·7
2344	26. iv	56° 18·4′	19° 32·6′ E	A	2·3†	1·3†	1·0†	2·8	2·1	0·3	—	9·8
2346	27. iv	53° 35·5′	19° 29·3′ E	A	0·5	0·6	0·9	3·2	1·0	0·9	—	7·1
2348*	29. iv	48° 58·1′	19° 25·5′ E	SA	0·2	0·2	1·7	2·7	4·7	0·9	—	10·4
2349*	1. v	43° 08·6′	19° 15·3′ E	SA	0·1	0·1	0·5	2·6	1·0	0·4	—	4·7
2350	2. v	39° 11·6′	19° 04·9′ E	ST	0·4	0·5	1·0	0·8	0·1	—	—	—
2372‡	16. vii	53° 10·6′	15° 47·5′ E	A	0·4	0·8	0·6	2·3	4·0	3·2	—	11·3
2374*	19. vii	55° 41·8′	21° 08·6′ E	A	0·6	1·6	2·6	8·4	4·5	2·8	—	20·5
2377*	22. vii	50° 19·8′	21° 22·2′ E	A	0·6	0·1	0·5	3·4	—	2·0	—	—
2378	23. vii	46° 20·3′	20° 41·8′ E	SA	0·5	0·7	1·2	—	4·1	1·8	—	—
2379	24. vii	43° 13′	19° 59·7′ E	SA	0·6	0·6	0·6	0·4	1·7	2·1	—	6·0
2380	25. vii	39° 51·4′	19° 18·3′ E	ST	1·0	0·6	0·6	0·5	0·4	0·2	—	3·3
2412	24. viii	55° 41·9′	20° 29·4′ E	A	2·4	0·5	0·8	1·9	1·7	1·1	—	8·4
2414	25. viii	53° 11·6′	20° 25·9′ E	A	0·2	0·4	0·7	1·6	2·5	3·1	—	8·5
2416	26. viii	50° 15·5′	20° 43·7′ E	A	0·4	0·3	0·8	2·6	4·6	2·4	—	11·1
2417	27/28. viii	47° 47·5′	20° 22·5′ E	SA	0·3	0·3	1·1	2·7	2·7	1·3	—	8·4
2418*	29. viii	43° 17·4′	19° 24·4′ E	SA	0·1	0·1	0·2	1·8	1·7	1·2	—	5·1
2419*	30. viii	38° 46·5′	19° 00·6′ E	ST	0·1	0·3	1·1	1·7	0·9	2·2	—	6·3
2447*	1. x	54° 46·6′	19° 51′ E	A	0·4	0·3	1·0	2·4	3·3	2·0	—	9·4
2449	2. x	51° 34·7′	20° 16·4′ E	A	0·3	0·3	1·3	6·1	3·0	1·2	—	12·2
2450	3. x	47° 49·2′	19° 54·6′ E	SA	2·9	2·1	3·0	3·9	5·8	1·5	—	19·2
2451	4. x	44° 27·3′	19° 43·4′ E	SA	1·2	2·3	2·3	1·2	2·5	2·4	—	11·9
2452	5. x	41° 21·2′	19° 31·2′ E	SA	1·4	1·4	1·7	2·6	—	—	—	—
2453	6. x	37° 51·2′	19° 00·4′ E	ST	—	1·1	1·3	1·3	1·3	1·4	—	—
2478*	2. xi	54° 17·3′	20° 16·4′ E	A	0·3	0·2	0·9	2·0	1·6	1·7	—	6·7
2481*	3. xi	50° 44·2′	20° 33·2′ E	A	0·8	3·5	2·5	1·8	2·2	0·6	—	11·4
2482*	5. xi	47° 43·7′	20° 03·9′ E	SA	0·1	0·5	0·9	2·7	3·2	1·1	—	8·5
2483	6. xi	43° 47·4′	20° 00′ E	SA	3·4	0·9	2·3	1·3	0·9	0·7	—	9·5
2484*	7. xi	40° 45·4′	19° 49·3′ E	SA	2·1	0·6	8·9	1·7	0·7	0·7	—	14·7
2485*	8. xi	37° 26′	19° 52·4′ E	ST	0·9	0·2	1·0	0·6	1·1	0·8	—	4·6
2517*	11. xii	56° 56·9′	19° 30·3′ E	A	1·2	3·1	1·6	2·8	1·0	1·0	—	10·7
2519*	12. xii	51° 56·8′	19° 32·4′ E	A	0·1	1·9	1·9	2·9	1·3	0·9	—	9·0
2521*	13. xii	48° 45·2′	19° 37·9′ E	A	0·3	0·9	3·0	4·2	1·4	0·6	—	10·4
2522*	14. xii	45° 38·9′	20° 15·2′ E	SA	0·1	3·5	1·9	1·3	1·0	0·7	—	8·5
2523*	15. xii	42° 24·9′	20° 09·5′ E	SA	1·9	0·6	1·2	1·9	1·1	0·4	—	7·1
2524*	16. xii	38° 58·1′	20° 10·6′ E	ST	0·7	0·6	1·3	2·4	2·1	1·2	—	8·3
2559*	27. i. 39	68° 49·7′	19° 10·5′ E	A	0·3†	2·1	1·3	1·7	1·1	1·0	—	7·5
2563*	28. i	65° 06·5′	19° 16·5′ E	A	0·8†	0·5†	0·3	3·1	0·6	0·3	—	5·6
2565	29. i	61° 16′	19° 43·5′ E	A	2·1†	0·4†	1·6	1·3	0·9	0·6	—	6·9
2567	30. i	58° 12′	19° 46′ E	A	1·1†	0·5†	0·6†	1·2	0·9	0·8	—	5·1
2569	31. i	55° 21·1′	19° 39·3′ E	A	0·3†	0·5†	3·2	1·4	0·9	0·8	—	7·1
2571	1. ii	52° 43·4′	19° 34·4′ E	A	0·9†	0·6†	1·7†	0·7	1·1	1·1	—	6·1
2573	2. ii	49° 59·1′	19° 42·4′ E	A	0·3†	1·6	1·5	3·0	1·3	1·3	—	9·0
2574	3. ii	46° 59·9′	19° 56·2′ E	SA	1·0	0·7	0·8	3·1	1·7	1·2	—	8·5
2575	4. ii	43° 43·2′	20° 00′ E	SA	4·2	1·6	1·4	1·2	1·2	0·8	—	10·4
2576	5. ii	40° 12·6′	19° 31·7′ E	ST	0·4	0·4	0·5	0·5	—	—	—	—
2612	9. iii	61° 10·3′	19° 01·4′ E	A	0·7	1·3	3·0	3·4	2·3	1·1	—	11·8
2614	10. iii	59° 17·4′	19° 10·1′ E	A	0·4	0·9	1·2	1·4	1·4	0·7	—	6·0
2616	11. iii	57° 23·9′	19° 18·3′ E	A	0·6	0·9	1·3	1·6	1·2	0·4	—	6·0
2618	12. iii	55° 21·9′	19° 27·6′ E	A	1·5	1·0	2·0	1·5	0·9	0·4	—	7·3
2620	13. iii	52° 57·1′	19° 36·8′ E	A	2·4	2·2	3·2	4·1	3·6	0·5	—	16·0
2622	14. iii	50° 19·5′	19° 43′ E	A	1·0	0·4	1·2	2·5	0·8	0·5	—	6·4
2623	15. iii	47° 26·8′	19° 37·4′ E	SA	0·5	1·3	0·9	0·4	0·5	0·8	—	4·4
2624	16. iii	44° 34·2′	19° 22·9′ E	SA	1·7	1·7	2·6	1·4	1·1	1·1	—	9·6
2626*	18. iii	37° 47′	18° 31·9′ E	ST	1·0	0·3	1·0	1·1	1·2	0·8	—	5·4

‡ Not included in fig. 2.

Table 11 *c*. *Observations near the meridian of* 80° *W*

Station	Date	Latitude S	Longitude	Zone	Depth (m.) 50–0	100–50	250–100	500–250	750–500	1000–750	1500–1000	1000–0
					1932							
984*	24. x. 32	55° 14·4′	77° 48·6′ W	SA	0·3	0·4	1·9	1·0	1·0	0·8	—	5·4
986*	25. x	56° 28·9′	79° 28·2′ W	SA	0·2	0·2	0·8	1·4	1·3	1·8	—	5·7
987*	26. x	58° 23·8′	79° 28·9′ W	SA	0·3	0·3	0·8	2·0	1·0	0·9	—	5·3
989*	27. x	60° 38·6′	79° 50·1′ W	SA	0·3	0·2	0·9	2·2	1·8	0·4	—	5·8
991*	28. x	63° 12·8′	80° 02·7′ W	A	0·8	1·7	2·8	4·0	1·2	0·5	—	11·0
993*	29. x	65° 38·7′	80° 18·6′ W	A	0·2	0·2	2·5	3·3	1·5	0·8	—	8·5
					1933–34							
1220*	13/14. xii. 33	67° 45·3′	77° 50·6′ W	A	0·1†	0·1†	0·6	2·3	2·1	0·4	—	5·6
1221*	14. xii	66° 26·1′	78° 01·7′ W	A	0·3†	0·9†	2·3	1·8	2·0	0·5	—	7·8
1222*	14. xii	65° 02·7′	78° 01·7′ W	A	0·1†	0·2†	0·5	2·3	1·0	0·6	—	4·7
1223*	15. xii	63° 31·9′	78° 01·6′ W	A	0·4	1·7	2·3	1·1	1·2	0·2	—	6·9
1224*	15/16. xii	62° 11·5′	78° 01·1′ W	A	1·9	3·0	2·9	1·5	0·7	0·4	—	10·4
1225*	16. xii	60° 53·6′	77° 58·4′ W	SA	0·8	3·2	3·6	1·1	1·5	1·1	—	11·3
1226	16. xii	59° 31·7′	78° 04′ W	SA	2·0	3·0	2·8	1·3	1·1	—	—	—
1227*	17. xii	58° 05·4′	78° 17·4′ W	SA	0·9	2·9	2·4	(1·3)	0·9	0·9	—	—
1228	17. xii	56° 39′	78° 31·7′ W	SA	1·2	0·9	(2·6)	1·8	1·0	0·9	—	—
1229*	18. xii	55° 11·3′	78° 29·6′ W	SA	0·9†	1·6†	1·9	1·1	1·3	0·8	—	7·6
1312*	10. iii. 34	68° 18′	79° 33·8′ W	A	0·1†	1·0	0·3	2·0	1·2	2·5	—	7·1
1313*	11. iii	66° 02·4′	79° 22·2′ W	A	0·5	0·7	0·6	1·8	0·9	0·6	—	5·1
1314	11. iii	64° 31·5′	79° 14·5′ W	A	2·0	1·5	1·1	1·8	0·8	0·9	—	8·1
1315*	12. iii	62° 55·1′	79° 06·3′ W	A	1·7	1·8	1·5	2·1	1·4	0·8	—	9·3
1316	12. iii	61° 27·1′	78° 58·8′ W	A	3·4	1·1	2·0	1·9	0·7	0·7	—	9·8
1317*	13. iii	59° 55·2′	79° 00·4′ W	SA	0·9	1·1	0·8	1·1	0·9	0·5	—	5·3
1318	13. iii	58° 25·8′	78° 53·8′ W	SA	(1·5)	(2·0)	1·5	2·2	3·0	1·1	—	—
1319*	14. iii	56° 56·1′	78° 46·3′ W	SA	1·5	1·1	0·7	1·0	2·2	2·6	—	9·1
1320	14. iii	55° 45·1′	78° 29·2′ W	SA	1·0	1·2	0·8	0·6	1·0	0·4	—	5·0
1415	12. ix. 34	63° 40·6′	78° 03·5′ W	A	0·2	0·2	0·4	1·6	(1·3)	(0·6)	(0·8)	—
1416*	13. ix	62° 31·5′	78° 18·3′ W	A	0·2	0·2	0·3	1·0	1·2	1·1	—	4·0
1417	13/14. ix	61° 05·2′	78° 34·2′ W	SA	0·3	0·3	1·0	0·8	1·9	1·3	—	5·6
1418*	14. ix	59° 50·5′	78° 34·3′ W	SA	(0·1)	(0·2)	(0·4)	(0·7)	1·6	1·0	—	—
1419	14/15. ix	58° 23·6′	78° 25′ W	SA	(0·1)	0·4	0·5	1·3	1·7	1·4	2·3	—
1420*	15. ix	56° 53′	78° 13·8′ W	SA	0·1	0·1	0·8	0·5	1·1	0·8	—	3·4
1421	15. ix	55° 22·2′	78° 10·9′ W	SA	0·7	0·7	0·9	1·3	1·4	(1·2)	1·3	—
1441*	26. x. 34	55° 39·3′	78° 37·6′ W	SA	0·4	0·5	1·7	1·2	1·3	0·9	—	6·0
1442	26. x	56° 48·6′	78° 25·8′ W	SA	0·5	0·7	2·8	1·4	1·3	0·5	—	7·2
1443*	27. x	57° 48·7′	78° 24·2′ W	SA	0·2	0·4	2·9	1·2	1·5	0·9	—	7·1
1444	27. x	59° 02·6′	78° 44·8′ W	SA	0·7	0·5	2·1	2·0	2·1	1·2	—	8·6
1445*	28. x	60° 06·7′	79° 17·6′ W	SA	0·4	—	1·2	—	3·0	—	—	—
1446	28. x	61° 15·5′	79° 26·4′ W	SA	1·0	0·9	2·4	1·4	1·6	0·9	—	8·2
1447*	29. x	62° 37·7′	79° 28·6′ W	A	0·1†	2·4	4·8	0·8	1·5	0·7	—	10·3
1448	29. x	63° 43·8′	79° 21·8′ W	A	0·2†	0·3†	2·7	2·3	1·2	0·5	—	7·2
1449*	30. x	65° 03·4′	79° 23·6′ W	A	0·1	0·2	0·8	3·1	2·0	0·7	—	6·9
1450	30/31. x	66° 03·1′	79° 42·2′ W	A	0·4	0·5	1·2	3·2	2·1	0·6	—	8·0
1472	14/15. xi. 34	66° 31·6′	81° 18·4′ W	A	0·4	1·1	1·2	2·1	0·9	1·3	—	7·0
1473	15. xi	63° 47·5′	80° 40·2′ W	A	0·4†	1·4	1·6	1·2	1·8	0·4	—	6·8
1474*	16. xi	62° 49·9′	80° 28·3′ W	A	0·3†	1·7	1·3	1·1	0·6	0·6	—	5·6
1475	16. xi	62° 05′	80° 19′ W	A	0·9	0·7	3·2	1·3	0·6	1·0	—	7·7
1476*	17. xi	60° 20·7′	79° 53·9′ W	SA	0·5	0·5	2·8	1·6	0·8	0·6	—	6·8

Table 11 *d*. *Observations in other areas*

Station	Date	Latitude S	Longitude	Zone	Depth (m.) 50–0	100–50	250–100	500–250	750–500	1000–750	1500–1000	1000–0
					Longitude 20° W							
804	11. i. 32	55° 30·3′	21° 02·6′ W	A	1·8†	0·6†	1·5	3·0	1·1	—	—	—
805*	12. i	56° 41·4′	20° 38·2′ W	A	0·1†	0·2†	1·0	1·9	0·8	0·9	—	4·9
806	12. i	57° 27·2′	21° 28·8′ W	A	0·1†	0·2†	0·7	3·2	1·2	0·6	—	6·0
807*	13. i	58° 47·7′	21° 40·4′ W	A	—	0·1†	0·7†	1·7	0·9	0·5	—	—
808	13. i	59° 56′	22° 20·7′ W	A	0·1†	0·1†	0·7†	2·4	0·6	0·7	—	4·6
809*	14. i	61° 09·9′	22° 36·9′ W	A	0·1†	1·2	2·1	1·6	1·1	0·8	—	6·9
811	15. i	62° 44′	23° 18·4′ W	A	1·0	0·7	0·5	0·8	0·6	0·4	—	4·0
812*	16. i	64° 12·5′	22° 57′ W	A	2·1	0·8	0·8	1·1	0·3	0·4	—	5·5
813	16. i	64° 55·9′	23° 13′ W	A	0·7	0·7	1·2	2·0	0·7	1·8	—	7·1
814*	17. i	66° 02·8′	22° 35·1′ W	A	0·3	0·6	1·0	1·1	1·5	1·1	—	5·6
815	17/18. i	66° 57·3′	22° 38·3′ W	A	0·3	0·4	0·6	1·2	1·0	0·7	—	4·2
816*	18. i	68° 09·6′	22° 01·7′ W	A	0·2	0·5	0·7	1·3	2·0	1·1	—	5·8
817*	19. i	69° 59′	23° 53′ W	A	0·3	0·5	0·6	1·0	0·8	0·6	—	3·8
1990	10. iii. 37	57° 02·2′	31° 28·5′ W	A	1·8	1·7	1·5	4·5	2·5	1·8	—	13·8
1994	12. iii	60° 35·6′	26° 40·4′ W	A	2·3†	1·8†	2·6	2·2	1·4	0·5	—	10·8
1996	13. iii	62° 32·5′	24° 32′ W	A	2·7†	1·2†	2·4	2·2	1·0	0·7	—	10·2
1998	14. iii	64° 16·4′	22° 46·6′ W	A	1·8†	1·5†	1·7	1·1	0·7	1·1	—	7·9
2000	15/16. iii	66° 00·4′	20° 54·1′ W	A	1·4†	0·5†	1·8	2·4	1·3	1·2	—	8·6
2002	16/17. iii	68° 19·5′	17° 55·2′ W	A	0·9†	0·9	1·1	2·8	1·2	0·9	—	7·8
2004	17. iii	69° 49·7′	15° 28·8′ W	A	1·0	2·8	1·4	2·7	1·8	1·3	—	11·0
					Longitude 110° E							
877	17. v. 32	35° 12·5′	114° 42·5′ E	ST	2·1	0·9	0·6	0·6	—	—	—	—
878	18. v.	38° 01′	115° 38·6′ E	ST	0·9	0·8	0·9	0·6	0·9	0·5	—	4·6
879	19. v	40° 56·7′	116° 46·5′ E	SA	0·3	0·5	0·4	0·4	0·5	0·9	—	3·0
880	20. v	43° 53·1′	117° 50·8′ E	SA	0·7	0·6	1·2	0·5	0·6	0·8	—	4·4
881	21. v	47° 00′	119° 00·3′ E	SA	0·5	0·9	0·6	0·6	0·6	1·5	—	4·7
882	22. v	49° 52·9′	120° 28·6′ E	SA	0·6	0·4	0·7	1·5	2·9	1·5	—	7·6
883	23. v	52° 54′	122° 03·8′ E	A	0·2	0·7	1·4	3·0	3·2	2·0	—	10·5
884	24. v	56° 08·3′	124° 04·8′ E	A	0·8	0·5	0·8	1·8	2·1	1·1	—	7·1
885	25/26. v	58° 50·5′	125° 54·9′ E	A	2·1	0·5	0·7	2·1	1·8	1·6	—	8·8
886	26. v	61° 12·1′	127° 52·9′ E	A	1·0	0·6	1·2	1·8	1·6	1·2	—	7·4
887	26. v	63° 41·4′	130° 07′ E	A	0·9	0·8	0·7	2·3	1·1	1·1	—	6·9
1720*	26. iii. 36	63° 59·1′	100° 11·1′ E	A	0·7	0·6	0·9	2·9	3·8	2·9	—	11·8
1722*	28. iii	61° 14·7′	102° 03·1′ E	A	1·4	1·2	2·0	3·2	2·3	1·3	—	11·4
1725	29. iii	57° 17·4′	104° 52·6′ E	A	4·2	2·1	2·3	5·1	2·5	1·2	0·8	17·4
1727	30. iii	54° 32·2′	106° 25·9′ E	A	2·8	3·1	3·1	4·7	5·0	1·7	2·0	20·4
1729	31. iii	51° 48·2′	107° 50·2′ E	A	—	2·8	1·8	4·8	5·3	1·7	1·8	—
1730*	2. iv	48° 48·9′	109° 15·5′ E	A	0·5	0·6	1·5	4·0	3·9	2·4	—	12·9
1732*	3. iv	45° 41·3′	110° 53·3′ E	SA	0·2	0·1	0·3	0·9	2·3	2·8	1·9	6·6
1733*	4. iv	42° 00·8′	112° 24·3′ E	SA	1·2	1·0	1·1	1·3	1·1	0·9	1·2	6·6
1734	5. iv	38° 20·9′	113° 27′ E	ST	0·7	0·6	1·0	0·7	0·8	0·7	0·5	4·5
1735	6. iv	34° 51·9′	114° 33·1′ E	ST	0·9	0·8	—	—	—	—	—	—
2152	30. xii. 38	35° 15·3′	114° 45′ E	ST	0·7	0·3	—	—	—	—	—	—
2153	31. xii	37° 57·6′	114° 53·7′ E	ST	0·3	0·2	0·4	—	—	—	—	—
2154	1. i. 39	40° 37·3′	115° 06·9′ E	SA	0·4	0·1	0·4	0·6	—	—	—	—
2155	2. i	43° 09·3′	115° 16·7′ E	SA	0·3	0·2	0·9	0·6	0·4	0·9	—	3·3
2156	3. i	46° 01·3′	115° 27·1′ E	SA	1·6	—	0·9	0·8	1·5	0·5	—	—
2157	4. i	48° 26′	115° 44·7′ E	SA	1·5	0·4	1·4	3·1	—	—	—	—
2158	5. i	50° 19·1′	115° 52·1′ E	A	1·2	0·7	3·0	4·5	0·6	0·5	—	10·5
2160	6. i	53° 01·4′	115° 49·5′ E	A	1·6	1·0	1·7	3·1	1·3	1·1	—	9·8
2162	7. i	56° 06·2′	115° 51·4′ E	A	1·6	0·7	1·5	3·6	1·2	0·4	—	9·0
2164	8. i	58° 48·7′	115° 43·7′ E	A	0·5	0·5	0·7	2·2	0·8	2·3	—	7·0
2166	9. i	61° 06·9′	115° 35·1′ E	A	1·4†	0·8†	0·8	0·8	0·1	0·4	—	4·3
2168	10. i	63° 29·1′	115° 26·8′ E	A	0·2	0·3	0·7	1·2	0·7	0·3	—	3·4

Table 11 *d* (*cont.*)

Station	Date	Latitude S	Longitude	Zone	Depth (m.) 50–0	100–50	250–100	500–250	750–500	1000–750	1500–1000	1000–0
					Longitude 160° E							
912*	24. vi. 32	61° 05′	158° 24·5′ E	A	0·3	0·3	0·5	0·8	1·0	—	—	—
919	25. vi	57° 50·4′	160° 23·1′ E	A	0·3	0·4	0·6	1·3	1·4	1·0	—	5·0
920	26. vi	54° 41·1′	162° 23·1′ E	A	0·4	0·2	0·8	1·1	1·0	1·3	—	4·8
922*	28. vi	50° 19·6′	163° 49·4′ E	SA	0·2	0·2	0·3	0·7	0·7	0·6	—	2·7
923*	29. vi	47° 11·7′	163° 41·4′ E	SA	0·2	0·2	0·4	0·5	0·8	0·7	—	2·8
924*	30. vi	44° 17·5′	165° 46·2′ E	SA	0·1	0·2	0·3	1·1	1·4	0·9	—	4·0
925*	1. vii	41° 20·5′	167° 55·5′ E	ST	0·2	0·1	0·3	0·8	0·4	0·8	—	2·6
926*	2. vii	38° 01·9′	170° 12·8′ E	ST	0·4	0·6	0·6	1·2	1·0	—	—	—
928*	3. vii	34° 39·2′	172° 25·9′ E	ST	0·7	0·2	0·2	—	—	—	—	—
675	5. ii. 36	64° 29·5′	161° 00·4′ E	A	0·1	0·2	0·3	1·9	0·9	0·7	—	4·1
677	6. ii	61° 05·2′	161° 47·5′ E	A	4·7	5·3	1·9	4·1	2·0	0·4	—	18·4
679	7. ii	58° 00·1′	163° 00·8′ E	A	6·3	4·2	3·0	4·0	1·1	0·5	—	19·1
680	8/9. ii	55° 20·2′	162° 49′ E	SA	5·3	0·8	2·2	5·5	1·7	0·9	—	16·4
681	9. ii	53° 16·1′	161° 57·7′ E	SA	1·8	0·9	2·0	2·3	0·5	0·6	—	8·1
682	10. ii	51° 12·8′	159° 32·3′ E	SA	2·8	0·6	1·4	1·1	1·1	1·3	—	8·3
683*	13. ii	46° 59·2′	155° 38·8′ E	SA	1·1	1·0	1·0	1·8	1·2	0·7	—	6·8
684*	14. ii	43° 45·5′	152° 00·5′ E	SA	0‡	0‡	0·4	1·6	1·3	1·3	—	4·6
201*	22. i. 39	65° 48·1′	162° 17·6′ E	A	1·4	1·0	1·1	1·6	0·7	0·4	—	6·2
204	23. i	62° 31·4′	162° 58·4′ E	A	—†	—†	1·0	0·9	0·7	0·8	—	—
206	24. i	59° 26′	165° 08·9′ E	A	2·3†	1·9†	1·9	2·2	1·4	0·4	—	10·1
208	26/27. i	55° 53·1′	167° 04·3′ E	SA	0·7	1·4	1·0	0·9	0·7	1·5	—	6·2
209	27. i	53° 07·7′	168° 56·4′ E	SA	1·6	0·6	0·5	1·6	3·3	—	—	—

‡ Sample composed entirely of Sulps.

Table 11 *e*. *Observations from circumpolar cruises*

Station	Date	Latitude S	Longitude	Zone	Depth (m.) 50–0	100–50	250–100	500–250	750–500	1000–750	1500–1000	1000–0
					Indian Ocean Sector							
845	9/10. iv. 32	38° 08′	20° 56·1′ E	ST	—	0·1	0·1	1·0	0·7	0·3	—	—
846	10. iv	40° 41·3′	23° 02′ E	ST	1·8	0·5	0·5	0·9	0·5	0·3	—	4·5
847	11. iv	43° 07·4′	25° 04·6′ E	ST	1·0	0·1	0·4	0·5	0·4	0·4	—	2·8
848	12. iv	45° 48·4′	27° 13·6′ E	SA	0·8	1·1	0·6	0·5	0·9	1·0	—	4·9
849	14. iv	48° 14·6′	29° 23·7′ E	SA	0·6	0·2	0·9	0·9	0·2	0·5	—	3·3
850	15. iv	50° 43·8′	31° 44′ E	A	1·0	—	1·8	1·3	—	—	—	—
852	18. iv	58° 39·5′	40° 03·9′ E	A	—†	—†	1·3	0·6	0·4	0·2	—	—
853	19. iv	61° 00·2′	43° 11·1′ E	A	—†	—†	1·1	0·9	0·5	0·6	—	—
854	20. iv	63° 30·2′	46° 24·9′ E	A	0·6	0·4	—	0·5	1·2	0·7	—	—
855	20. iv	61° 15′	48° 43·7′ E	A	—†	—†	—†	0·9	2·0	1·3	—	—
857	23. iv	60° 40·1′	59° 23·7′ E	A	—†	0·5	0·9	0·4	1·1	0·4	—	—
858	24. iv	60° 10·1′	63° 54·8′ E	A	0·6	0·5	1·0	1·5	1·3	0·8	—	5·7
859	25. iv	59° 19·1′	68° 51·8′ E	A	1·0	0·7	2·3	2·3	0·7	1·7	—	8·7
860	26. iv	57° 56·4′	73° 58·8′ E	A	0·8	0·5	0·6	2·4	2·6	0·1	—	7·0
861	27. iv	56° 28·9′	79° 18·2′ E	A	1·5	0·6	1·5	1·4	1·0	1·0	—	7·0
862	28. iv	55° 33·8′	83° 00·4′ E	A	3·0	1·1	1·3	1·4	4·2	1·8	—	12·8
863	29. iv	54° 15·3′	88° 22·4′ E	A	1·0	0·5	0·8	2·7	1·7	1·0	—	7·7
866	1. v	51° 22·6′	96° 26·4′ E	SA	0·6	0·6	0·6	2·8	1·1	0·7	—	6·4
867	2. v	49° 25·5′	98° 21·8′ E	SA	1·7	0·7	0·9	1·4	2·3	1·6	—	8·6
868	3. v	46° 55·4′	100° 45·6′ E	SA	0·8	0·4	0·6	1·3	2·4	1·8	—	7·3
869	4. v	43° 56·5′	103° 24·3′ E	SA	1·0	0·5	0·8	0·9	1·1	1·0	—	5·3
870	5. v	41° 41·7′	105° 16′ E	SA	—	0·7	0·6	0·6	0·5	0·5	—	—
871	6. v	39° 32·1′	107° 06·4′ E	SA	0·9	1·0	0·8	1·0	0·8	0·7	—	5·2
872	7. v	37° 09·1′	108° 47·2′ E	ST	0·6	0·4	0·2	0·7	0·5	0·6	—	3·0
873	8. v	34° 19·1′	110° 21·7′ E	ST	0·4	0·4	0·4	0·7	0·6	0·6	—	3·1
874*	9. v	32° 15·2′	112° 26·2′ E	ST	0·5	0·3	0·3	0·7	0·7	—	—	—
875	10. v	32° 12·8′	113° 48′ E	ST	0·6	0·4	0·6	0·6	1·1	0·3	—	3·6

Table 11 *e* (*cont.*)

Station	Date	Latitude S	Longitude	Zone	Depth (m.)							
					50–0	100–50	250–100	500–250	750–500	1000–750	1500–1000	1000–0
					Pacific Sector (2213–2286), *Atlantic Sector* (2288–2310)							
2213	8. ii. 38	46° 27·6′	172° 05·3′ E	SA	0·1	0·4	1·1	0·8	1·0	—	—	—
2214	9. ii	48° 38·1′	176° 08·2′ E	SA	1·3	2·1	1·6	1·2	1·9	1·2	—	9·3
2216	10. ii	50° 06·9′	179° 42·8′ E	SA	2·4	1·4	2·4	0·9	2·3	1·7	—	11·1
2217	10/11. ii	52° 21·6′	176° 11·4′ W	SA	2·6	0·5	3·7	1·1	1·1	1·7	—	10·7
2218	11. ii	54° 29·6′	172° 08·6′ W	SA	2·3	1·0	1·4	1·8	2·1	1·8	—	10·4
2219	12. ii	56° 30·5′	171° 00·8′ W	SA	10·5	1·5	1·5	2·4	3·6	1·3	—	20·8
2220	13. ii	58° 38·8′	169° 33·6′ W	SA	4·9	2·3	3·2	3·9	1·5	0·4	—	16·2
2221	14. ii	60° 56·1′	168° 20·1′ W	A	5·5	1·1	1·0	4·3	2·8	1·9	—	16·6
2223*	16. ii	63° 19·4′	167° 20·9′ W	A	—†	—†	1·9	1·6	0·8	0·5	—	—
2224	16. ii	64° 51·3′	166° 34·6′ W	A	0·4	0·5	0·9	1·8	1·3	0·9	—	5·8
2226	17. ii	67° 19·6′	165° 07·4′ W	A	0·8	1·6	1·5	2·1	1·7	0·3	—	8·0
2232	19. ii	67° 10·1′	155° 17·1′ W	A	—†	—†	—†	3·5	1·1	—	—	—
2238	21. ii	63° 40·5′	144° 26·4′ W	A	—†	—†	1·0	0·6	0·7	0·4	—	—
2244	23. ii	67° 21·8′	134° 30′ W	A	—†	0·9	1·3	1·5	0·9	0·8	—	—
2250	25. ii	69° 56·6′	125° 33·3′ W	A	1·3	1·1	1·3	1·3	0·5	0·4	—	5·9
2255	27. ii	67° 40·8′	119° 10·4′ W	A	—†	1·3†	1·6	2·4	1·3	0·4	—	—
2261	1/2. iii	66° 50·8′	111° 40′ W	A	8·9	2·4	2·3	3·6	2·5	1·6	—	21·3
2268	4. iii	70° 11·1′	100° 56·4′ W	A	—†	0·8	0·9	3·1	2·0	0·5	—	—
2274	6. iii	67° 25·3′	87° 58·4′ W	A	—†	0·9	1·4	2·4	3·2	1·5	—	—
2280	8/9. iii	64° 25·9′	75° 47·1′ W	A	—†	1·6†	1·3	2·1	0·7	0·5	—	—
2285*	10. iii.	63° 26·1′	66° 57·9′ W	A	—†	0·7†	0·7	0·8	0·9	0·7	—	—
2286	11. iii	61° 18·9′	65° 24·5′ W	A	3·1	2·6	1·1	3·6	3·7	1·4	—	15·5
2288	12. iii	58° 18·2′	62° 42·8′ W	A	2·6	1·1	0·9	2·5	4·2	2·2	—	13·5
2289	13. iii	55° 18·3′	60° 04·5′ W	SA	4·1	1·9	1·5	3·2	2·5	2·3	—	15·5
2291	20. iii	53° 02·3′	56° 20·9′ W	SA	1·1	2·3	2·9	4·1	1·9	2·2	—	14·5
2292	21/22. iii	55° 41·2′	53° 31·6′ W	SA	3·9	2·4	1·2	1·5	1·7	1·4	—	12·1
2293	22. iii	57° 34·9′	51° 06·2′ W	A	1·2	1·5	1·5	4·4	3·5	1·3	—	13·4
2295	23. iii	59° 58′	48° 28·1′ W	A	—	0·1	0·3	—	—	1·4	—	—
2298	25. iii	61° 09·6′	43° 15·6′ W	A	3·0	0·8	1·6	3·3	—	—	—	—
2300	26. iii	58° 33′	39° 54·7′ W	A	3·9	3·6	4·4	3·5	3·6	2·0	—	21·0
2302	27. iii	55° 56·3′	36° 42·9′ W	A	2·4	1·4	1·1	3·2	3·0	2·4	—	13·5
2304	4. iv	54° 03·9′	33° 54·4′ W	A	8·0	0·9	1·2	2·9	3·4	2·6	—	19·0
2306	6. iv	53° 32·4′	24° 16·4′ W	A	5·7	2·7	1·3	5·6	5·1	2·2	—	22·6
2308	8. iv	52° 14·4′	15° 07·8′ W	A	2·7	3·7	1·8	5·4	6·3	2·6	—	22·5
2310	10. iv	50° 46·2′	05° 14·1′ W	A	5·5	3·1	2·6	7·6	6·6	1·9	—	27·3
					Pacific Sector (2838–2844), *Atlantic Sector* (2845–2864), *Indian Ocean Sector* (2867–2881)							
2838	17/18. vi. 51	61° 22′	104° 01′ W	A	0·5	0·2	0·6	1·2	2·9	—	—	—
2839	19/20. vi	60° 32′	90° 23′ W	A	0·3	0·2	0·2	0·9	1·4	1·4	—	4·4
2841	21/22. vi	59° 01′	77° 38′ W	SA	0·5	0·3	0·3	1·5	2·1	2·1	—	6·8
2842	23. vi	63° 30′	77° 13′ W	A	0·5	0·3	0·6	0·6	3·9	0·6	2·1	6·5
2844	25. vi	60° 11′	70° 08′ W	A	0·2	0·2	0·5	1·2	2·0	2·1	1·4	6·2
2845	26. vi	57° 40′	65° 02′ W	SA	0·3	0·2	0·5	—	—	—	—	—
2848	5/6. vii	52° 35′	54° 51′ W	SA	0·5	0·2	0·5	2·1	2·1	—	—	—
2849	6. vii	53° 40′	51° 05′ W	SA	0·3	0·3	0·6	0·9	3·2	1·4	—	6·7
2850	7/8. vii	54° 47′	46° 55′ W	SA	0·3	0·3	0·3	0·5	1·7	2·4	2·3	5·5
2851	8. vii	56° 05′	42° 24′ W	A	0·3	0·2	0·6	1·2	1·4	2·9	1·5	6·6
2852	9. vii	57° 35′	37° 20′ W	A	0·5	0·3	0·3	1·4	2·7	0·9	0·9	6·1
2853	10. vii	58° 01′	33° 03′ W	A	0·3	0·2	0·5	1·1	2·0	1·5	—	5·6
2864*	16. vii	57° 26′	10° 21′ W	A	0·3	0·3	0·5	1·8	2·3	—	—	—
2867	17/18. viii	33° 12′	33° 50′ E	ST	1·4	1·1	1·1	1·1	0·6	0·6	—	5·9
2868	19/20. viii	38° 08′	38° 17′ E	ST	0·6	0·8	1·1	0·5	0·5	0·3	—	3·8
2869	21. viii	42° 58′	43° 31′ E	SA	1·5	3·0	1·7	1·4	2·6	0·8	1·5	11·0
2870	23/24. viii	48° 00′	48° 57′ E	A	0·8	0·5	1·2	1·5	—	—	—	—
2871	24. viii	50° 09′	51° 23′ E	A	0·5	0·5	1·5	3·6	3·0	0·9	—	10·0
2872	25. viii	52° 30′	54° 17′ E	A	0·2	0·2	0·5	2·3	3·5	—	—	—
2874	27/28. viii	57° 30′	60° 37′ E	A	0·2	0·3	1·5	3·0	2·6	0·8	—	8·4
2875	28/29. viii	59° 15′	64° 08′ E	A	0·5	0·5	0·6	2·3	2·3	0·8	—	7·0
2880	10. ix	54° 13′	84° 45′ E	A	0·9	0·5	0·6	1·7	—	—	—	—
2881	12. ix	49° 53′	91° 36′ E	SA	0·3	0·2	0·9	0·8	0·9	0·9	0·5	4·0

Table 11*f*. *Sub-tropical and tropical observations*

Station	Date	Latitude S	Longitude	Zone	Depth (m.)							
					50–0	100–50	250–100	500–250	750–500	1000–750	1500–1000	1000–0
					Across the Indian Ocean in 32° S							
1736	14. iv. 36	31° 58·1′	114° 52·2′ E	ST	2·0	0·6	0·8	2·5	1·7	—	—	—
1738*	16. iv	32° 10·6′	109° 16·3′ E	ST	0·4	—	1·4	0·9	0·8	0·8	—	—
1740	17/18. iv	32° 01·1′	103° 57·5′ E	ST	0·7	0·7	1·1	0·6	0·5	0·7	—	4·3
1742*	19. iv	31° 57·9′	97° 54·5′ E	ST	0·5	0·5	0·7	0·7	0·5	1·0	—	3·9
1744	20. iv	32° 07·2′	92° 10·8′ E	ST	0·6	0·4	0·6	0·5	—	0·3	—	—
1746*	22. iv	32° 02·1′	87° 02·5′ E	ST	0·3	0·8	0·5	0·4	1·0	0·9	—	3·9
1748	23. iv	31° 54·7′	82° 08·9′ E	ST	0·5	0·3	0·4	0·7	0·8	0·6	—	3·3
1750*	25. iv	32° 12′	75° 32·6′ E	ST	0·2	0·3	0·1	0·7	0·7	1·0	—	3·0
1752	26. iv	32° 04·5′	70° 43·9′ E	ST	0·3	—	0·4	0·5	0·7	0·5	—	—
1754*	28. iv	31° 48·9′	65° 30·3′ E	ST	0·1	0·2	0·2	0·3	0·4	0·7	—	1·9
1756	29/30. iv	32° 00′	60° 55·6′ E	ST	0·2	0·2	0·6	0·5	0·9	0·9	—	3·3
1758*	1. v	31° 55·6′	55° 06·5′ E	ST	0·2	0·1	0·4	0·6	0·8	0·9	—	3·0
1760	2. v	31° 57·6′	49° 57·4′ E	ST	0·3	0·6	0·5	—	0·6	0·2	—	—
1762*	4. v	31° 57·3′	44° 23·2′ E	ST	0·3	0·3	0·3	0·6	0·5	0·1	—	2·1
1763*	5. v	32° 05·7′	40° 44′ E	ST	0·4	0·1	0·5	0·5	0·4	0·2	—	2·1
1765*	7. v	32° 00·6′	33° 46·9′ E	ST	0·2	0·1	0·3	0·5	0·5	0·3	—	1·9
1766*	8. v	31° 54·7′	29° 48·1′ E	ST	0·5	0·5	0·5	0·5	0·7	0·5	—	3·2
					Longitude 90° E							
2886*	9. x. 51	29° 58′	90° 00′ E	ST	0·5	0·6	1·5	0·9	0·8	0·6	0·9	4·9
2887	10. x	25° 51′	90° 02′ E	ST	0·8	0·5	0·9	0·5	0·2	0·3	0·3	3·2
2888	11/12. x	22° 38′	90° 02′ E	ST	0·3	0·2	0·6	0·3	0·3	0·2	0·3	1·9
2889	12. x	19° 35′	90° 01′ E	ST	0·9	0·3	0·6	0·5	0·3	0·3	0·3	2·9
2890	13. x	16° 37′	90° 05·5′ E	T	0·6	0·6	0·8	0·6	0·3	0·3	0·3	3·2
2891	14/15. x	13° 37′	90° 00′ E	T	0·3	0·6	0·6	0·8	0·5	0·3	—	3·1
2892	15. x	10° 51′	89° 58′ E	T	1·1	0·6	0·8	0·8	0·5	0·2	0·5	4·0
2893	16/17. x	07° 52′	89° 50′ E	T	0·6	0·6	0·6	0·6	0·3	0·2	0·5	2·9
2894	17. x	05° 02′	89° 47′ E	T	0·9	0·9	0·6	0·5	0·2	0·2	0·5	3·3
2895	18/19. x	02° 00′	89° 40′ E	T	1·1	0·8	1·1	0·5	0·3	0·3	0·3	4·1