A STUDY OF THE PHYTOPLANKTON OF THE SOUTH WESTERN INDIAN OCEAN

by

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VOLUME I

Being a thesis in fulfillment of the regulations for the degree of Doctor of Philosophy at the

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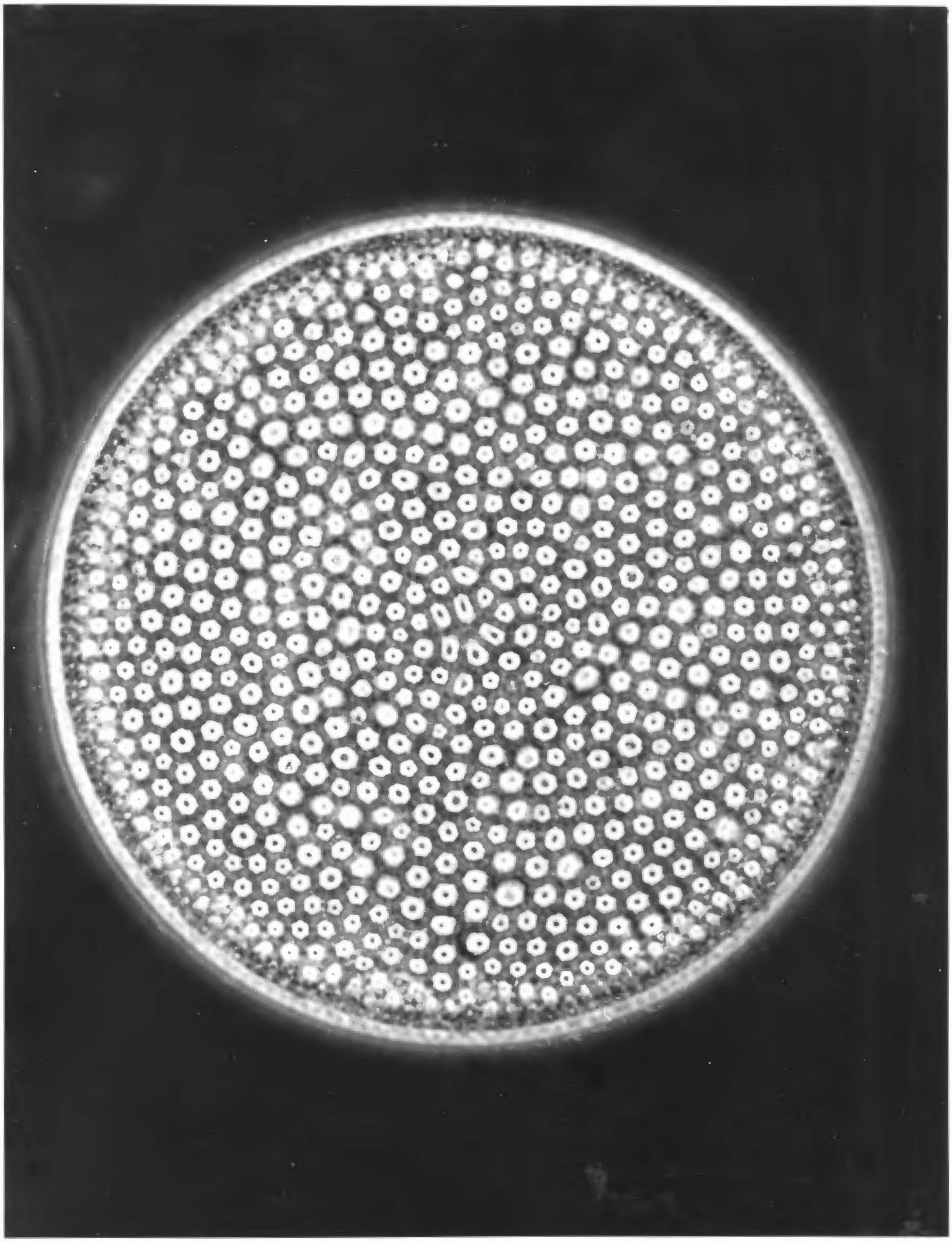

Coscinodiscus argus Ehrenberg

ACKNOWLEDGEMENTS

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SUMMARY

Although the phytoplankton of the waters off the west coast of South Africa (the Benguela Current region) has been the subject of several detailed studies in the past, data on that of the S.W. Indian Ocean has been almost entirely restricted to incidental references in the reports of expeditions which have passed through the area. Consequently, little has been known of the species composition and distribution of the phytoplankton, and nothing of its seasonal fluctuations. This study was designed to provide a broad picture of the phytoplankton of the area, the primary objective being a critical determination of the species composition. The material was collected by the S.A.S. Natal on four seasonal cruises in the area as a contribution to the International Indian Ocean Expeditions. A net-sampling technique was used to provide the maximum amount of material for quantitative analysis.

The phytoplankton was found to be extremely rich in variety, 402 taxa being identified from the 98 samples collected. Of these 233 were diatom taxa, 157 dinoflagellate taxa, and the remainder being composed of members of the Chrysophyceae (coccolithophorids), Cyanophyceae and Xanthophyceae. These are listed in the systematic section together with original references and other references used by the author for their identification. The local and general distributions of the

taxa are described, and many of the taxa are illustrated by line drawings or microphotographs. 5 new species are described, as well as 1 new variety, and it was found necessary to provide new names for several species. Full systematic details are given for all new or rare taxa.

In order to understand the hydrography of the area it was necessary to revise earlier concepts in the light of data collected concurrently with the phytoplankton during the present survey, particularly with regard to the seasonal fluctuations of conditions in the area, and consequently the hydrographic section is more detailed than is customary for the present type of study. It is sugggested that the area be subdivided into 5 zones, namely the Agulhas Current Zone, the South Western Indian Oceanic Zone, the Natal Shelf Zone, the Eastern Agulhas Shelf Zone, and the North Edge Water.

The distribution patterns of the phytoplankton are illustrated by discussing examples of each type, and the relationship of the observed distributions with the proposed hydrographic zones is discussed. It was found that there appeared to be a local, semi-permanent population of neritic species with centres of distribution in the Eastern Agulhas Shelf Zone, the species probably being spread into other zones by the action of currents. Currents were also found to be the most likely agents in introducing the many "visitor" species to the area, the Agulhas Current introducing tropical and subtropical species into the Natal Shelf Zone and the S.W. Indian Oceanic Zone, eastward-flowing local currents in the vicinity of Cape Agulhas possibly carrying temperate, neritic west-coast species into the Eastern Agulhas Shelf Zone, from which some of them spread northwards into the Natal Shelf Zone. The temperature structure and its consequent effect on nutrient concentrations in the northern offshore waters was the most likely factor limiting the northern spread of temperate and subantarctic oceanic species, as well as the spread of many species from the shelf waters into the offshore waters. In winter and spring, when the thermocline broke down in the offshore waters, and virtually homogeneous water existed in the upper 100 meters, many of the species confined to the inshore waters in the summer were widely spread in the offshore waters, and several temperate and subantarctic species spread northwards from the North Edge Water. This is thought to be a possible explanation for the isolated records of subantarctic species found in tropical waters (remnants of this northern spread), and may play a part in the formation of bipolar distributions.

Heavy concentrations of phytoplankton were found to be present at inshore stations on most cruises, particularly on the edge of the continental shelf in the Eastern Agulhas Shelf Zone, this being the region where water from moderate depths upwelled into or just below the euphotic zone on the inner edge of the Agulhas Current.

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Erratum:

Two species of diatoms were inadvertently omitted from section II. These were

Actinoptychus vulgaris Schumann
Chaetoceros tortissimus Gran

The former was identified from station 74, the stations from which the latter was recorded being indicated on table 2 in the appendix. Thus the total number of taxa recorded should read 404 instead of 402, 235 taxa of diatoms being recorded from the area.

SECTION I. INTRODUCTION.

I. 1 The origin of the study and the area concerned

In recent years oceanographic research vessels have been traversing the Indian Ocean in an attempt to explore more fully one of the lesser known maritime regions of the world. This concerted and co-ordinated venture has been termed the "International Indian Ocean Expeditions" (I.I.O.E.)

The field of investigation assigned to S. Africa in this project was the South Western Indian Ocean, i.e. the area of sea lying to the south of Madagascar and Mauritius, bounded in the west by the coast of Southern Africa and in the south by the globe-encircling West Wind Drift below 40°S.

During the period April, 1962, to January, 1963, the S. African Survey Vessel "Natal" undertook four cruises in a sector of the S.W. Indian Ocean, approximately 250,000 square miles in extent, lying off the eastern and southern coasts of S. Africa as a contribution to the I.I.O.E. The present study is the result of an analysis by the author of ~~a~~ the phytoplankton material collected by the "Natal" on these cruises.

The stations occupied by the "Natal" are shown on charts 1 to 4. The four cruises were repetitive, coinciding with the seasons of the year: April (Autumn), July (Winter), October Spring) and January (Summer). On each cruise four lines of stations roughly at right angles to the coastline were covered, the landward limits of each line corresponding to Durban, the Transkeian coast near Port St. Johns, Port Elizabeth, and Cape Agulhas. For convenience these lines have been labelled A,B,C and D respectively. Each line was between 500 and 700 miles long, stations lying roughly 50 miles apart except in the Agulhas Current and inshore area where they were closer together.

In all 98 phytoplankton samples were collected from those stations indicated by solid black circles, the open circles indicating the position of stations at which only hydrographic data was obtained.

Hydrographic conditions in the S.W. Indian Ocean are discussed in detail in Section III. However, in brief outline, it may be said that the major hydrographic feature of the area is the warm, relatively low-salinity Agulhas Current, flowing more or less strongly in a south-westerly direction closely adjacent to the east coast of S. Africa. In the offshore area the surface water is largely of subtropical origin (Clowes, 1950), with an incursion of the cold, mixed water of the Subtropical Convergence Region at certain stations on line D, the most southerly line. Inshore of the Agulhas Current over the Agulhas Bank, and extending north over the continental shelf to a point between lines B and C, there is a region where marked vertical movement of water from relatively shallow depths, 300 to 700 metres, occurs. This rise of water appears to be a factor of some importance to the Phytoplankton of that area. To the south of the Agulhas Bank the Agulhas Current comes in contact with eastward-flowing water of the West Wind Drift, merging with it in a belt of laterally-mixed water (Fukase, 1962; Darbyshire, 1964). Occasionally an eastward deflection of the Agulhas Current, i.e. the Agulhas Return Current, is recognisable along the northern margin of the belt of mixed water.

I. 2 The extent of knowledge on the phytoplankton prior to the present study

The earliest reference to species of phytoplankton from S. African waters appears to be that of Shadbolt (1854). In a short paper read to the Microscopical Society of London he described what he considered to be twenty new species of diatoms from Port Natal (Durban). He was uncertain of the exact habitat but most of the species are now known to be marine littoral inhabitants. However, there was an admixture of planktonic species in his material, notably a representative of his proposed genus Bacteriastrum.

The first work dealing solely with the phytoplankton is that of George Wallich, a retired Indian Army surgeon. In 1858 he read a paper to the Microscopical Society on the organisms he had found in the stomach contents of salps which

Chart 1

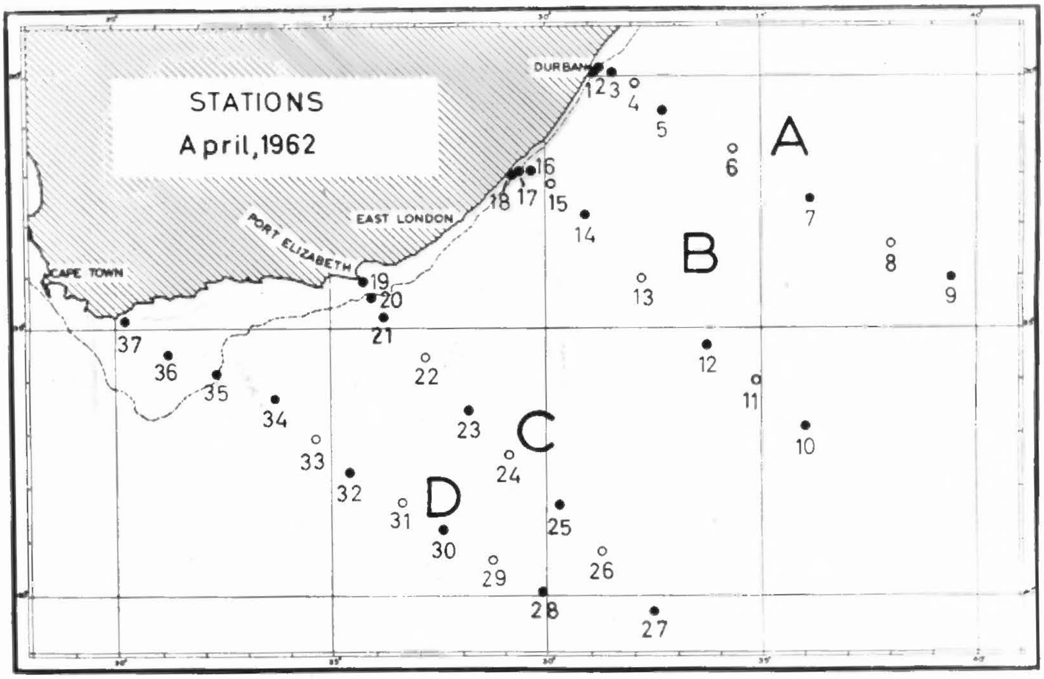


Chart 2

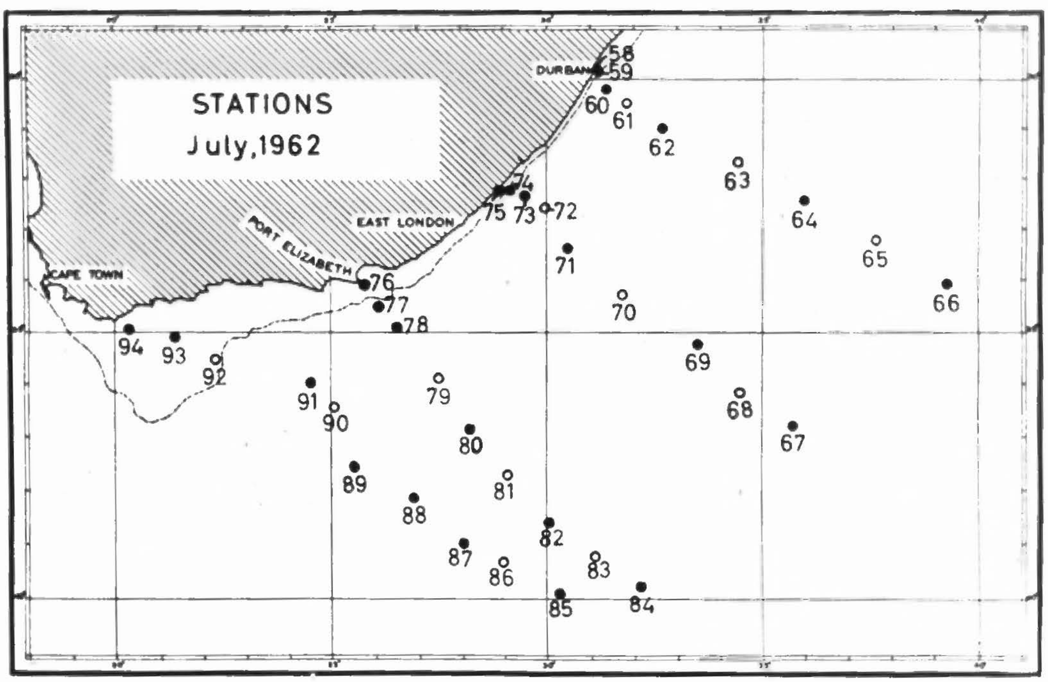


Chart 3

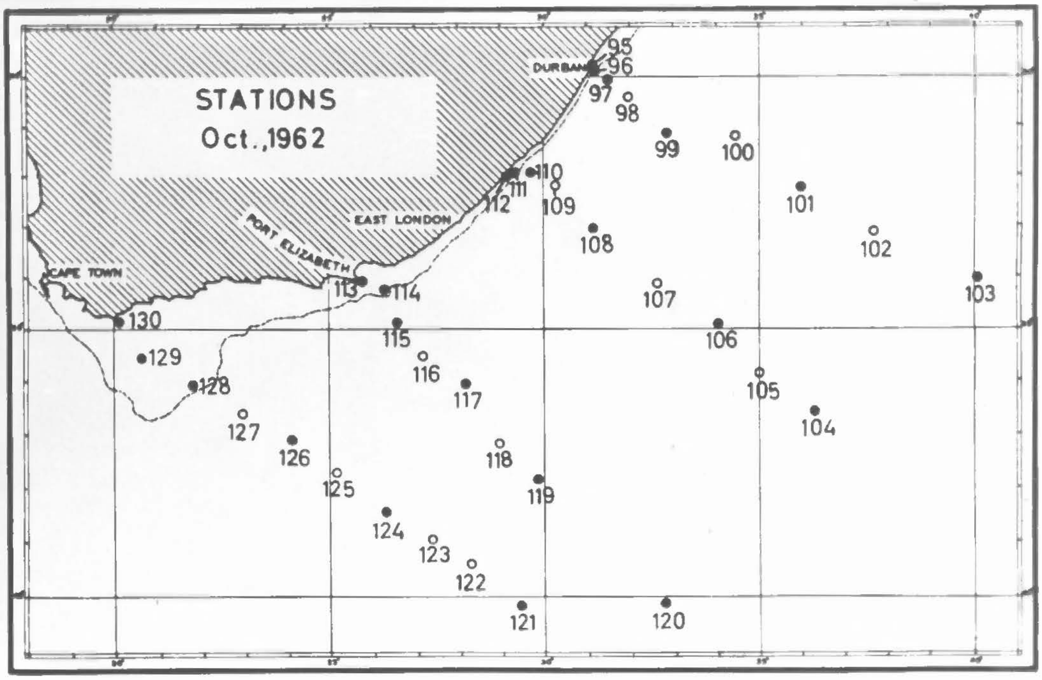
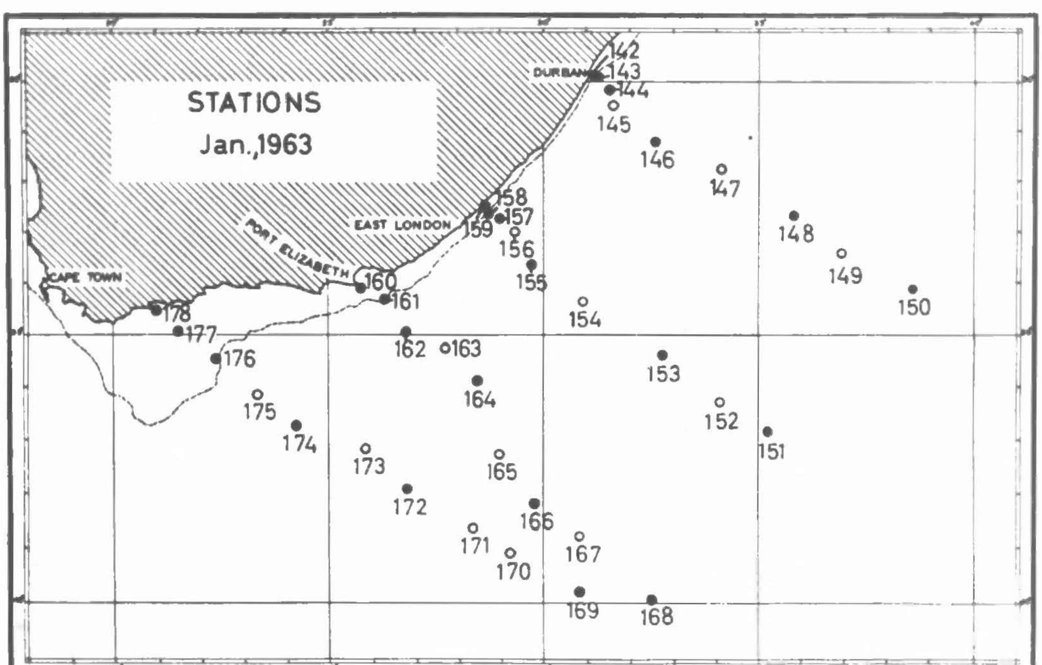


Chart 4



he had collected on a voyage to India around the Cape of Good Hope, and descriptions of 16 species by him appeared in the society's Transactions for 1860. The majority of these species were found in the Indian Ocean.

Another early, rather obscure, reference is that of Petit (1876) on a collection of sedentary diatoms from Table Bay in which he recorded 35 species, 2 of which he suggested were new. A work of a similar nature is Grunow's (1867) report on material collected by the "Novarsa" Expedition from the Cape, the material consisting for the most part of dune sand and macro-algae on, and in which diatoms were found. Although the great majority were sedentary he described several species later known to be planktonic, e.g. _Climacodium frauenfeldianum_ and _Fragilaria capensis_. Also recorded in the work are diatom species from St. Paul's Rocks in the Southern Central Indian Ocean.

The remaining references to the phytoplankton of the Cape and S.W. Indian Ocean are nearly all, like Grunow's, incorporated in the reports of oceanographic expeditions passing through the area.

Janisch's report on the diatoms of the "Gazelle" Expedition, 1873 - 76, was never published as such, although the completed plates were distributed privately during

1888 - 89. A Schmidt (1874 -) included many of Janisch's figures in the plates of his "Atlas". Also present in the "Atlas" are 22 species recorded from S. Africa, primarily from the collections of Kitton and Weissflog.

The "Challenger" Expedition, 1873 - 76, occupied several stations to the west and east of the Cape. Castracane's report (1886) on the planktonic diatoms collected by the expedition regrettably provides very little locality data. However Comber (1895) records 37 more heavily silicified species from sediments at specific localities in S. African waters : Challenger stations 138, 140, 142.

The "Valdivia" (Deutsche Tiefsee-Expedition), 1898 - 99, collected material from the Atlantic and Indian Oceans, also making a study of the Antarctic region to the south of the Indian Ocean. Of particular interest to the present study is the material collected on a short cruise from Cape Town to Port Elizabeth and back along the southern coast of the Cape over the Agulhas Bank (Valdivia stations 92 - 114). Karsten's report (1905, 1906, 1907) on the phytoplankton collected by the "Valdivia" is subdivided into three sections dealing with the Antarctic, Atlantic and Indian Oceans respectively. The material collected in the Indian Ocean comes from a line of stations traversing the central region of the Indian Ocean from south to north, and is thus far to the east of the sector under present consideration. Confusingly the results of the short cruise over the Agulhas Bank referred to above are considered in Karsten's report on Atlantic species.

Early papers of interest, dealing with adjacent Indian Ocean areas, are those of Cleve (1900, 1903); Ostenfeld & Schmidt (1901); Petit (1902); Czapek (1903); and Schröder (1906).

The "Gauss" (Deutsche Sudpolar-Expedition), 1901-03, passed through the S.W. Indian Ocean on its voyage to the Antarctic, and the report on diatoms by Heiden & Kolbe (1928) records many species from Simonstown, Durban and several oceanic stations in the area.

The only works dealing specifically with Indian Ocean dinoflagellates appear to be those of Matzenauer (1933); Steeman Nielsen (1939); and Ballantine (1961)*. Wood (1963,a) has produced a checklist of the dinoflagellates recorded from the Indian Ocean.

One of the most useful systematic references to planktonic diatoms which includes material from the S.W. Indian Ocean is that of Hendey (1937). The "Discovery II" material at his disposal included collections from a line of stations from the Cape to Aden, and several others from the S.W. Indian Ocean.

* also Taylor, 1963.

A list of diatom species recorded from Natal waters by the Division of Sea Fisheries of South Africa was given at a symposium in 1961. 56 species were listed, with 4 further identifications to generic level only. There are several publications on fresh water diatoms which include records of marine diatoms from estuaries and river mouths along the S. African coast. These are by Cholnoky (1959, 1960,a, 1960,b, 1962, 1963) and Giffen (1963).

More recent papers on adjacent Indian Ocean areas include Subrahmanyan (1946, 1958, 1959); Silva (1956, 1960); Kolbe (1957, reviewed by Hendey, 1958); and Bernard & Lecal (1960).

Work of a non-systematic nature on aspects of phytoplankton study in the Indian Ocean such as productivity, biomass estimates, pigment analyses and distribution in relation to water masses has been done by Steemann Nielsen & Jensen (1956); Bernard (1959); Kabanova (1961); Bogorov & Vinogradov (1961); Kutyurin & Lisitsin (1962); Fukase (1962); and Mitchell-Innes (1964).

Finally, mention must be made of the highly useful checklist of diatoms recorded from the Indian Ocean which has been compiled by Wood (1963,b). It is regrettable that he has included, without identifying them as such, many freshwater species from the works of Cholnoky already referred to earlier, and other freshwater East African records. Unfortunate omissions in this work include the records of Silva (1956, 1960); several from Schmidt's "Atlas" (1874 -); and Kolbe (1957.)

I. 3 The aims of the study

The preceding subsection is virtually a bibliography of studies referring to the area, having been made as complete as possible. The list may appear to be large but the great majority of the references quoted are of only incidental interest to the area concerned. The only works of major significance to the S.W. Indian Ocean are Karsten (1906); Hendey (1937); Steemann Nielsen & Jensen (1956); and Mitchell-Innes (1964), and only the latter, short, preliminary communication on productivity deals with the area specifically.

It follows that any study of the phytoplankton of the S.W. Indian Ocean at this time is still in the nature of a general exploration, a highly detailed investigation of a smaller area being inappropriate to the scanty general picture available from previous work. When the present study was initiated the number of phytoplankton species identified from the S.W. Indian Ocean was less than 100, and no attempt had been made to study the broad distribution of phytoplankton species over the area, or to relate it to prevailing hydrographic conditions.

Thus it was felt that the primary objective of the present study should be a critical determination of the species composition of the population based on as large a number of samples as would be practicable for analysis by one worker so that a reasonably adequate knowledge of the more commonly occurring species could be obtained. Perhaps the most valuable feature of the 1962 -/63 cruises of the S.A.S. "Natal" in comparison with former investigations in the area was the repetitive nature of the cruises, providing for the first time comparable material from different times of the year. This decreased, although did not eliminate, the possibility of missing species which are seasonal in occurrence in the area.

Concurrent with the collection of phytoplankton material routine hydrographic observations were made which provided the opportunity to attempt to relate the distribution of the population to the water masses present. Unfortunately data on certain factors of importance to the distribution of individual species, such as micronutrient concentration, could not be obtained, but once again this accuracy was not required in so broad a study. Rather it was hoped to be able to relate the diversity of distributional patterns observed with the major hydrographic features of the area and show how the changing seasons altered the character of the phytoplankton present.

I. 4 Methods employed

(a) Sampling.

Material was collected when the vessel was stationary by vertical hauls from 100 metres to the surface with an N50V net (mouth diameter of 50 cms., nylon, 200 meshes to the linear inch). 100 metres was chosen as the maximum working depth, Steemann Nielsen & Jensen (1956) having found that the euphotic zone often extended to 70 metres or more at off-shore stations in the Indian Ocean. Where stations were situated in depths of less than 100 metres the nets were operated to within approximately 10 metres of the sonically determined bottom. The bag of the net was hosed down to ensure that material adhering to the net was washed into the bucket at the apex of the cone. The material was preserved in 5% neutralised sea-water formalin in crown-corked glass bottles.

After each haul the nets were thoroughly washed down to avoid contamination.

(b) Analysis.

In the laboratory subsamples were taken from the settled material in the bottles. 2 ml. of the material were drawn up in a graduated pipette and placed in a 10 ml. tube to which was added 2 ml. of the supernatant liquid drawn from the surface in order to make a standard dilution, and to include any specimens which may not have settled, e.g. cyanophytes which usually exhibit positive buoyancy. When the material was plentiful 1 ml. would be taken near the surface of the settled material and 1 ml. from the bottom to allow for differing settling rates. The material in the tube was shaken vigorously to disperse the organisms, this frequently breaking up the chained species and making semiquantitive estimations of abundance easier.

Routine identifications and estimations of relative abundance were made during the examination of watermounts from the subsamples under a magnification of 200 with a phase contrast optical system. The entire area under a 2¼ x 2¼ cm. coverslip (3 drops of the subsample) was examined by traverses with the mechanical stage. Symbols were employed to represent relative abundance, the classes used being chosen to conform as closely as was convenient to equal logarithmic intervals so that some mathematical relationship was observed (except in the case of the lower two symbols below, not numerically delimited).

SYMBOL	NO. OF INDIVIDUALS	LOG_{10} OF MEAN
.	1	0
+	2-5	0.5441
++	6-20	1.1139
+++	21-50	1.5502
++++	<50	-
+++++	dominant in bloom	-

These symbols appear in the tables of species occurrence* in the Appendix, with the exception of +++++ which is replaced by a solid black square.

Relative abundance of cyanophytes and coccolithophore species were not attempted. The Cyanophyte trichomes were not uniformly buoyant in the supernant liquid in the bottles, and the coccolithophores were only present in the nets due to partial clogging of the net apertures by larger phytoplankton (a variable factor commented on in Section I. 5. b).

The detailed examination of some species required for their identification, particularly pennate diatoms, was not possible in watermounts due to poor resolution and unsuitability to oil immersion examination. In these cases permanent strewn mounts of the subsample material were made using Hyrax (N.A. 1.71, when hardened).

It was found that standard methods of preparing diatoms for permanent mounts involving removal of the cell contents by hot acid treatment (Hustedt, 1924), were too injurious to the weakly siliceous species present in plankton. Cold methods, such as those of Van der Werff (1955) and Barber (1962) were tried, but these also proved unsuitable for the author's requirements. The method of Reimann (1960), utilising acetone and pancreatin, came to the author's attention only after the work for this study was completed. A method was employed in which the cell contents remained but were cleared in a way similar to the methods used for mounting

* Relative Abundance Tables (2 and 3)

small invertebrates, i.e. transference of the material through a graded series of alcohols and clearing in xylol.

The graded series of alcohols (70%, 95%, Absolute) were made up using Ethyl Alcohol and Tertiary Butyl Alcohol in the proportions suggested by Johansen (1960).

(a) 1 cc. of the material was placed in a 10 cc. glass tube.

(b) The material was washed twice with distilled water to remove the salt and formalin by filling up the tube, shaking, allowing 4 hours to settle, and carefully drawing off the supernatant liquid.

(c) After washing, progressively stronger alcohols were substituted serially, allowing 4 hours settling time in each case.

(d) The material was then treated with a 1 : 1 mixture of Absolute alcohol and Xylol, and finally with Xylol, once again allowing 4 hour intervals.

(e) The Hyrax was applied over the area to be occupied by the coverslip on a cleaned slide.

(f) Some of the settled material in Xylol was spread on a cleaned coverslip and the Xylol drawn off with filter paper.

(g) Before the material could dry on the coverslip it was rapidly inverted onto the Hyrax on the slide.

(h) The slide was then placed on a hotplate at approximately 100°C for 3 - 4 minutes. Benzol (the solvent in the Hyrax) is driven off during the boiling. If the slide is heated too long a marked brown discolouration results.

(i) The slide was removed, the coverslip rapidly pressed down to remove bubbles and centred, the Hyrax hardening rapidly on cooling.

(j) The slide could be cleaned by scraping off the superfluous Hyrax with a scalpel.

As this method was a lengthy one usually a large number of subsamples were treated simultaneously. Centrifuging was tried as a means of shortening the intervals between stages, but the material tended to form dispersed clumps which could not be retained on decanting.

Comparison of the water mounts and the permanent mounts showed that the latter were not suitable for estimations of relative abundance as the preparation altered the proportions of the species present. Thorough washing of all pipettes after use was essential to prevent contamination during analysis.

I. 5 Possible sources of error in sampling and analysis

Possibility of error may be considered at three levels: natural non-randomness in the population, errors in sampling the population, and errors in laboratory analysis.

(a) Large-scale non-randomness and fluctuation in the population.

A basic problem to all plankton studies is the fact that the planktonic organisms are not usually distributed in a random manner in their environment. The degree of "patchiness" varies according to the hydrographic conditions (less marked in turbulent conditions) and the habit of the group. A review of the size, shape and other characteristics of phytoplankton patches has been provided by Bainbridge (1957). Perhaps the most striking demonstration of large-scale non-random distribution can be seen during water discolourations. The organisms causing the discolourations usually occur in dense patches or streaks, often many miles in extent. Such patch formations can have a serious effect on results in the sampling of small areas, being the result of abnormal conditions. They are not a serious problem in wide-scale sampling, such as the present case, where the majority of samples were from widely separated stations and large-scale distribution patterns were studied.

Since the work of early phytoplankton investigators (Cleve, 1897; Gran, 1902, etc.) it has been known that seasonal fluctuations in abundance and distribution of the phytoplankton can be of major proportions. When attempting to describe the phytoplankton population of an area it is clear that these fluctuations must be taken into account.

The seasonal fluctuations of the population have been known to differ from year to year and so, to obtain an accurate picture it is desirable that samples be taken monthly for a period of at least five years. This has not been possible in the present investigation, and discussion has been limited to the actual distribution of the recorded organisms for the four months (corresponding to the seasons) during which samples were taken.

(b) Efficiency of the sampling method.

Non-randomness can be demonstrated to exist in the microdistribution of planktonic organisms. Herdman (1907) found that two nets towed simultaneously behind a vessel occasionally yielded results which differed both qualitatively and quantitavely. Since that time many authors have confirmed this. Hasle (1954) found that the dinoflagellates sampled displayed a fairly random distribution, but one diatom present showed marked irregularities (Chaetoceros curvisetus) which could not be accounted for by water movements.

It is clear that a method should be employed which samples the maximum practicable amount of water. This was one of the reasons influencing the choice of nets in the sampling carried out during this survey. They are rapid in use and provide a large amount of material for study. In extremely sparse concentrations such as were found at a number of extreme offshore stations it is unlikely that other sampling methods (bottles in particular) would have yielded as much diatomaceous material as nets. Possibly this is the reason why Bernard and Lecal (1960) found no diatoms present at some of their stations in the Indian Ocean. For present purposes it was desirable that species were recorded even if they were present in very small numbers in the water.

Braarud (1958) provides a summary of the advantages and disadvantages of the various methods employed in phytoplankton sampling at present. He emphasises that nets are not suitable for the accurate quantative analysis of phytoplankton. This is due, for the most part, to their inefficiency in retaining small diatoms and nannoplankton, and the difficulty in calculating the amount of water sampled, as they are prone to partial clogging by the organisms sampled. However, they may be used to provide crude estimates of diatom numbers in lesser known areas, as did Hart and Currie (1960). They point out that the necessity for wide, rapid coverage "often renders crude estimates of relative frequency of greater immediate value than limited series of more accurate data."

In the present study estimates of actual numbers were not attempted, and the coccolithophores (nannoplankton) were only recorded as a contribution to the knowledge of the species composition of the area as none appear to have been recorded previously. Any attempt to estimate relative abundance of the latter group would have resulted in misleading data. Holmes & Anderson (1963) found that more than half of the photosynthetic material sampled by them passed through a net with a mesh-size of 35 μ, finer than that used in the present survey. A remarkable feature, however, noted by the author during analyses of the Indian Ocean material, was that large numbers of nannoplankton were sometimes present in the samples.

Contamination during sampling was kept to a minimum by washing the nets down thoroughly after use.

(c) Reliability of the method of analysis employed.

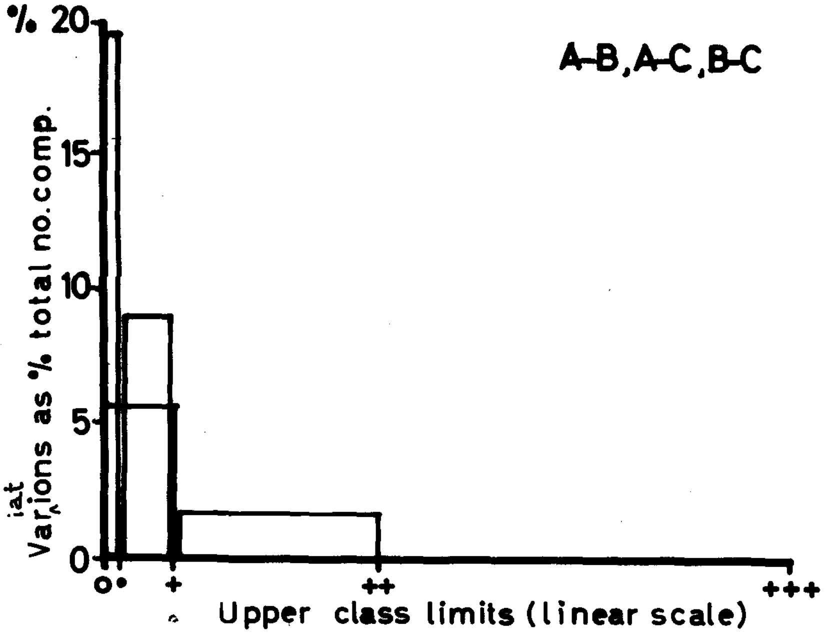
Two simple tests were carried out to check the reliability of the subsampling and the method of analysis.

A sample was chosen which was neither dense nor sparse. Three subsamples (A,B, & C) were taken by the standard method described in Section I. 4. b. A microanalysis of three drops from each of these subsamples was carried out, and two further microanalyses were performed on subsample A (Ab & Ac). The results of these may be seen in Table 1. From the table it can be seen that there are no consistent differences between any of the 3 subsamples, or between the replicates of sample A. It can also be seen that there is good agreement between the estimates of relative abundance where species occurred in numbers greater than 5 (*). A total of 46 taxa were recorded.

Diagram 1

DISTRIBUTION OF ERROR IN TEST ANALYSES.

(a)



(b)

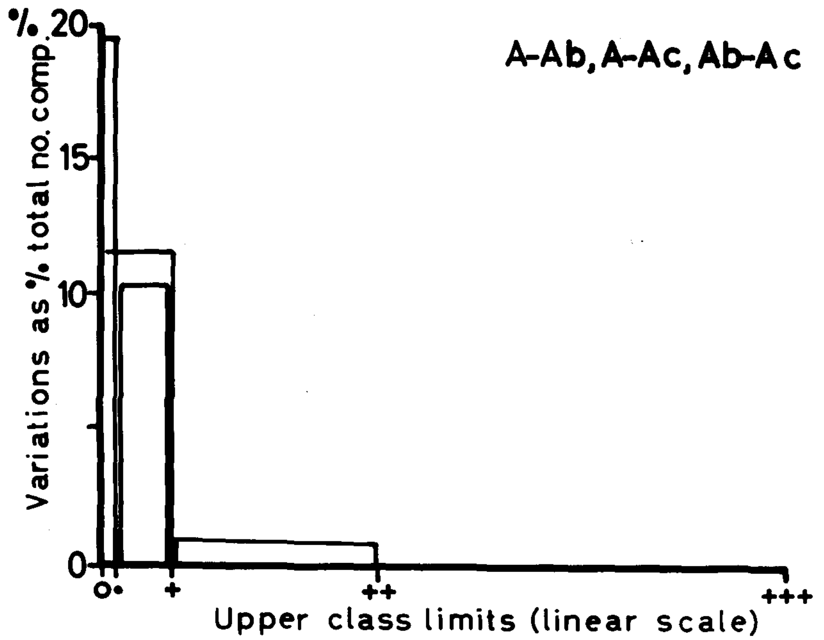


Table 1. RESULTS OF ANALYSIS RELIABILITY TEST.

SAMPLE: NIOE 93

S P E C I E S	SUBSAMPLES			REPLICATES	
	A	B	C	Ab	Ac
Chaetoceros atlanticus v. neapolitanus	•	+		+	+
compressus	•		•	•	•
decipiens	++	++	++	++	++
didymus		•			+
lorenzianus	+	+	+	+	+
peruvianus	+		•	+	
seychellarus		+			+
Climacodium frauenfeldianum	+	++	++	+	+
Corethron criophilum	+	+	+	+	+
Coscinodiscus radiatus					•
stellaris	+	+	•	•	
Coscinosira polychorda				+	
Dactyliosolen mediterraneus		•	•		•
Detonula moseleyana	++	++	++	++	++
Guinardia flaccida	+	+	+	+	•
Hemiaulus chinensis		•		•	•
Nitzschia bicapitata	•	+	•	+	•
delicatissima	++	+	+	+	+
pacifica	•	•		•	
Planktoniella sol	++	++	++	++	++
Podosira maxima				•	

Table 1. RESULTS OF ANALYSIS RELIABILITY TEST. (cont.)

SAMPLE: NIOE 93

S P E C I E S	SUBSAMPLES			REPLICATES	
	A	B	C	Ab	Ac
Rhizosolenia alata	+++	+++	+++	+++	+++
alata f. gracillima	•		•	•	•
cylindrus	•			•	
hyalina	+	•	•	+	
imbricata v. shrubsolei	+	+	+	+	+
stolterfothii	+	+	+	•	+
Skeletonema costatum	+	+	+	+	
Thalassionema nitzschioides	+	+	+	+	+
Thalassiosira subtilis	+	+	+	+	+
Thalassiothrix acuta	+		•		•
frauenfeldii	++	++	++	++	++
DINOFLAGELLATES					
Ceratium candelabrum f. curvulatum	•	•	•		•
extensum	•	•		•	+
furca v. eugrammum		•		+	+
limulus		•	•		
massiliense f. macroceroides	+	+	+	+	+
pentagonum f. robustum	•	•	•		•
tripos f. subsalum	++	++	++	++	++
vultur v. sumatranum				•	
Ceratocorys armata				•	
Dinophysis tripos		+			+

Table 1. RESULTS OF ANALYSIS RELIABILITY TEST. (cont.)

SAMPLE: NIOE 93.

S P E C I E S	SUBSAMPLES A	B	C	REPLICATES Ab	Ac
Peridinium claudicans		•	•	•	
depressum	+++	+++	+++	+++	+++
sphaericum		•		•	
Pronoctiluca pelagica	+	•	+	•	+

(Symbols as for routine analyses)

To investigate the distribution of error in relation to the number of individuals (as represented by their classes) diagrams I and II were constructed by the following procedure:

In diagram Ia pairs of cases from the subsample results (A,B, & C) were compared (A - B, A - C, B - C), numbers of discrepancies of each type, e.g. between "+" and "++", being recorded in a matrix. The total number of each type was expressed as a percentage of the total number of comparisons (3 x 46 taxa = 138) and represented graphically.

Diagram Ib was a result of comparison of cases from the replicate analyses (A - Ab, A - Ac, Ab - Ac) in the same manner.

The "Upper Class Limits" indicated along the abscissae of the diagrams are linear in scale to show the primary feature of the tests, namely that maximum discrepancies occurred between 0 and the "." and "+" classes. Where larger numbers of individuals were concerned agreement was good and no variation was found with relation to class "+++". It must be pointed out, however, that the routine analysis did provide one example of error in this class, Thalassiosira subtilis, which was recorded as "+++" in the routine analysis, but occurred only as "+" in the test. This points up a further feature of the phytoplankton which must be considered when using abundance figures for any purpose other than mere positive records. Many of species of phytoplankton occur in groups of cells rather than singly or in pairs. Chain formation is characteristic of many species, sometimes as many as 50 or more cells being linked together, e.g. species of Climacodium and Fragilaria. Thalassiosira subtilis is not one of these, but instead occurs in the form of a mass of cells imbedded in a mucilagenous matrix. In the routine analysis a portion of one of these masses occurred on the slide and thus increased the recorded value of this species. Presumably the cells occurring in the test analyses were broken free from the masses.

Holmes & Widrig (1956), in a statistical study involving the use of the Inverted Microscope (Utermöhl, 1958) for accurate quantitative estimation of phytoplankton cell numbers, found that the method was statistically sound for the estimation of cells occurring singly or in pairs (which could be considered randomly distributed in the subsample) but was less accurate for species exhibiting "contagion" (a term for the clumping or chain-forming habit). This method appears to be the most accurate yet devised for quantitative estimates of the standing crop (the population present at a given time), and was endorsed at the International Plankton Symposium of 1957. Unfortunately the requisite apparatus was not available at the time of the present investigation.

It is clear then that the present study must be limited to the consideration of crude estimates of relative abundance. The use of classes rather than actual numbers tends to absorb minor variations and this is demonstrated by the rather surprising consistency of certain *Chaetoceros* species (*lorenzianus* and *decipiens*) in the test analyses. These are chained species and it was not expected that they should have appeared as uniformly in the test as they did, even allowing for the class absorption. This can only be ascribed to chance.

Having considered the possible sources of error in outline above it is perhaps suitable at this stage to state the limits within which conclusions may be drawn.

1. Positive records have value, negative records not.
2. The relative abundance figures bear no consistant relationship to absolute numbers of species present.
3. Although relative abundance is expressed logarithmically no conclusions as to exponential growth may be reached.
4. If a species is recorded in high relative abundance it is probable that this species was present in large numbers at the station. The reverse does not apply.
5. The test showed that distinctions between classes involving 1 to 5 individuals observed should not be considered.
6. The habit of the species must be borne in mind when considering its relative abundance figures.
7. Estimates of the relative abundance of single small diatoms, nannoplankton or cyanophytes cannot be considered using the present method, although presences may be recorded.
8. The distribution patterns of rare species ascertained by the present method are incomplete.
9. It is probable that the number of species recorded in the present survey is much lower than the actual number of species present at different times of the year, although the commoner species are not likely to have been omitted (except in the case of those mentioned in 7 above).

SECTION II. SYSTEMATIC AND DETAILED DISTRIBUTIONAL DATA

The species recorded during the present survey are listed in this section under classes. Literature references are provided to allow a detailed reference to be made to each species. Modern, more readily available works are cited where possible in addition to some of the classical references. Sample and station numbers referring to the present Indian Ocean survey are prefixed by the letters NIOE, and the station localities are indicated on Charts 1 - 4. The stations from which the species were recorded are cited below the references and systematic notes, if any. The distribution patterns exhibited by the species are reviewed, and reference is made to previous records to indicate the general distribution of the species and their occurrence in the Indian Ocean.

Full descriptions and synonymy citations for each species have not been provided, these being available in the references cited, However, synonyms are given where departure from the name in common usage has been made. Original photographic or line-drawing illustrations are provided for many of the species. All rare or new taxa are fully described and illustrated. Relative abundances at the cited localities may be seen in the Relative Abundance Tables in the Appendix. All taxa are numbered serially for convenience in cross-reference.

Only references quoted in the descriptive text are given in the full reference list at the end of this study. The abbreviations of the systematic references listed beneath each species follow the general usage of the authors whose works have been consulted. In the systematic references various dates between 1927 and 1930 have been used in connection with Hustedt's 'Kieselalgen' in Rabenhorst's Kryptogamen flora. This is due to the first, and later, parts of this work being issued in fascicules. The copy of PART I in the author's possession has been bound complete and unfortunately no information on the dates or pagination of the fascicules is included. Where Hustedt has made new combinations or new taxa the actual published date, derived from other authors, is given. In all other cases the date of completion of the part (1930) is given. Similarly the date (1959) is used to refer to PART 2 except in the case of new taxa or combinations. The third paper is as yet incomplete and the fascicule dates are given for references in this part. A similar practice is used for reference to Peragallo (1897 - 1908).

In the reviews of the observed local distributions of the taxa the author has used terms which, although in standard use by phytoplanktologists, have occasionally been interpreted in different ways. For this reason the terms employed are listed below together with brief definitions indicating the sense in which they are used in the present study. Readers are referred to Hedgepeth (1957), Smayda (1958), and Hart & Currie (1960) for more detailed discussions on terminology in marine environments.

Neritic: (a) area - the water lying above the continental shelf, the outer limit of which is set at the 100 fathom line (approx. 200 metres).

(b) organism - one which habitually attains greater abundance in neritic areas but need not necessarily be confined to the area.

Oceanic: (a) area - the open ocean water lying to the seaward of the neritic boundary.

(b) organism - one which habitually achieves maximum abundance in the oceanic area although not restricted entirely to this area.

Inshore: Not used in its strictest sense, i.e. in the immediate proximity of the shore, but instead used as an adjective to describe these stations which lay in the water over the continental shelf.

Offshore: Referring to the stations in the oceanic area, particularly those in the most distal (away from the coast) sections of the lines.

Panthallassic: Organisms which show no clear preference for neritic or oceanic waters, i.e. their abundance does not seem to be related to distance from the coast or proximity of the continental shelf.

Meroplanktonic: Organisms which produce a resting spore or possess a sedentary stage in their life cycles.

Holoplanktonic: Organisms which do not produce a resting spore and are planktonic throughout their life cycles.

Tychopelagic: Organisms which are usually sedentary but are frequently found in plankton collections.

Sedentary: Organisms which are characteristically associated with a subtrate and whose presence in plankton collections can be considered to be adventitious.

Eurythermal, stenothermal, eyryhaline, stenohaline and the temperature-determined biogeographical zones, e.g.

tropical, subtropical, used in the notes on general distribution are quoted from the authors cited and their interpretations can be obtained from the references.

II. 1 Class 1 BACILLARIOPHYCEAE

Order BACILLARIALES

The arrangement of the diatom species follows that of Hendey (1954) for convenience and simplicity. The system was first proposed by Hendey (1937), and has subsequently been slightly modified by him. It differs from the more widely used system proposed by Schütt (1896) and modified by Hustedt (1930, 1959, 1960, 1961) in that the distinction between centric and pennate diatoms is not recognised above the level of suborders.

Suborder DISCINEAE

Family COSCINODISCACEAE

1. Actinocyclus curvatulus Janisch ex A. Schmidt, Atlas : pl. 57, fig. 31 (1878); Hustedt, Kieselalg. (1) : 538, fig. 307 (1930).

Locality: NIOE 124.

One specimen, 120 μ in diameter, found at an oceanic, southerly station in October.

General: First recorded by Janisch from "Tafelbaai". Grunow (1884, p. 83) recorded the species from the Cape of Good Hope under the synonym *Coscinodiscus curvulatus* var. *subocellata* Grun. It does not appear to have been recorded from the Indian Ocean by other authors.

This species is not included in the Relative Abundance Table for diatoms.

2. *Actinocyclus octonarius* Ehrenberg, Infus. als vollkom. Organ.: 172, pl. 21, fig. 7 (1838); Hendey, Discovery Rep. 16 : 262 (1937).

Syn.: *A. ehrenbergii* Ralfs in Pritchard, Infus.: 834 (1861); Rattray, Revis. Actinocyclus : 171 (1890); Peragallo, Diat. Mar. France : 414, pl. 114, figs. 1, 2 (1908); Hustedt, Kieselalg. (1) : 525, fig. 298 (1930).

System: Ralfs (1861) proposed the new name *A. ehrenbergii* to include 120 of Ehrenberg's species which he found to be distinguished on an unsound

Local.: NIOE 3, 5, 7, 60, 71, 89, 91, 159. Occasional at neritic stations, oceanic at station NIOE 159, present in material from all 4 cruises.

General: Recorded from the Gulf of Aden (Hustedt, 1930), Ascension Island (Grove, fide Rattray, 1889), in fossil deposits at Newcastle and Barbados (Firth, cited by Rattray, 1889), Cape Verde Islands (Heiden & Kolbe, 1928), in sediments from the equatorial regions of the Pacific, Indian and Atlantic Oceans (Kolbe, 1957) and particularly numerous in the Indian Ocean sediments. Mann (1937) recorded it as "sparingly present" in the Antarctic.

4. Coscinodiscus alboranii Pavillard, Rep. Danish Oceanogr. Exped. 1908 - 1910 Medit. 2, Biol. (4) : 13, fig. 16 (1925); Hustedt, Kieselalg. (1) : 425, fig. 228 (1930).

Local.: NIOE 71, 85, 87, 88, 91, 110, 115, 117, 129, 158, 159. Found occasionally in small numbers (1 - 5 individuals) at offshore stations, but not during April.

General: Apparently only previously known from the Mediterranean Sea (Pavillard, 1925 ; Hustedt, 1930).

5. Coscinodiscus argus Ehrenberg, Abh. Berl. Akad. 1838 : 129 (1840); Ehrenberg, Mikrogeol. pl. 21, fig. 2 (1854); Rattray, Revis. Coscinodiscus : 527 (1889); Hustedt, Kieselalg. (1) : 422, fig. 226 (1930) FRONTISPIECE.

System: This species has a confused systematic history due to its close resemblance to C. heteroporus Ehrenberg, C. radiatus Ehrenberg, and C. crassus Bailey. Hustedt (1930) considered C. heteroporus and C. crassus as synonyms of C. argus, whilst retaining the specific distinction between C. argus and C. radiatus on the grounds of areolation characteristics. Referring to C. argus he stated "Sie stimmen mit Cosc. radiatus in der Anordnung der Areolen und in der homogenen Schliesshautüberein, unterscheiden sich dagegen durch die von innen nach aussen an Grösse zunehmenden Areolen und durch die deutlicheren Kammeröffnungen." The identifications in the present study were based on Hustedt's description and figure (1930), p. 422, fig. 226), individuals closely resembling the description being assigned to this species, those tending towards *C. radiatus*, the more common appearance exhibited, being identified as the latter. It is clear that the taxonomic position of all species referred to above requires further study.

Local.: NIOE 62, 64, 71, 73, 78, 85.
Single individuals were recorded only during the July cruise. In general the species occurred in the northern and inshore part of the area, although station 85 was at the extreme offshore end of the most southerly line (D).

General: Rattray (1889) cited numerous localities from which this species had been recorded, including one from an "Indian Ocean sounding, by Captain Pullen (Greville!)." Hustedt (1930) regarded it as cosmopolitan and probably sedentary. If *C. heteroporus* is considered synonymous with this species then the record of Silva (1960) from Inhaca Island, Mozambique, should be included here. Kolbe (1957) recorded *C. argus* from several Indian Ocean cores.

6. *Coscinodiscus asteromphalus* var. *hybrida* Grunow, Denkschr. Akad. Wissensch. Wien, Math. - Naturw. Kl. 48 : 79, pl. c, fig. 9 (1884); Rattray, Revis. Coscinodiscus : 551 (1889); Hustedt, Kieselalg. (1) : 454, fig. 251, b (1930).

System: This is distinguished from the typical variety by its possession of a deep valve mantle on which the areolae are smaller than on the typical variety. The species has been confused with C. centralis Ehrenberg on occasions. It is most readily distinguished by the detailed structure of the areolae.

Local.: NIOE 35, 58, 96.
Rare, at inshore stations, not found in the January material.

General: Recorded from European fossil deposits (cited by Rattray, 1889), Davis Straits (Grunow, 1884), and "Yszee" (Kinker, cited by Rattray, 1889). Heiden and Kolbe (1928) recorded the variety from a number of Antartic localities. Thus it appears to have a bipolar distribution favouring low temperatures..

7. Coscinodiscus centralis Ehrenberg, Abh. Berl. Akad. 1838 : 129 (1840); Rattray, Revis. Coscinodiscus : 555 (1889); Gran, Diat. Nord. Plankt. : 33, fig. 33 (1905); Hustedt, Kieselalg. (1) : 444, fig. 243 (1930); Hendey, Discovery Rep. 16 : 245 (1937); Brunel, Phytopl. Baie Chaleurs : 53, pl. 2, figs. 1 - 6, pl. 40, fig. 3 (1962). PLATE 7, fig. 1.

System: This species is superficially similar to *C. oculus-iridis* Ehrenberg with which it has been occassionally confused. Mann (1907, p. 248) maintained that, as a result of the existence of intermediate forms (usually given varietal status) the specific boundaries were "unsusceptible of sharp definition." The specimens observed during the present survey exhibited the typical appearance of *C. centralis*.

Local.: NIOE 2, 3, 16, 20, 75, 178.
Only single specimens recorded at the above stations, with the exception of NIOE 178 where a value of "+++" was recorded for this species. At this station, close inshore at Cape Agulhas, the surface temperature was 18.98°C in the top twenty metres, a sharp thermocline with a drop in temperature to 15.5°C occurring at that depth. This was the lowest surface temperature recorded during the January cruise, surface temperature over most of the area at that time being between 25° and 20°C.

General: Hendey (1937) described the species as being temperate with a world-wide distribution. It is generally considered to be an oceanic species, although in the present survey, it occurred only at inshore stations. O'Meara (1877) recorded it from Kerguelen Island. It has also been recorded from Simonstown, Cape (Heiden and Kolbe, 1928). Mann (1937) recorded it from the Antarctic.

8. <u>Coscinodiscus</u> <u>concinnus</u> W. Smith, Syn. Brit. Diat. <u>2</u> : 85 (1856); Rattray, Revis. Coscinodiscus : 531 (1889); Peragallo, Diat. Mar. France : 424, pl. 115, fig. 12 (1908); Hustedt, Kieselalg. (1) : 441, figs. 241, 242 (1930); Hendey, Discovery Rep. <u>16</u> : 245 (1937); Cupp, Mar. Plankt. Diat. West Coast N. Amer. : 58, fig. 22 (1943); Subrahmayan, Proc. Indian Acad. Sci. <u>24</u> : 98, figs. 44, 50, 53, 54, 56 (1946).

Local.: NIOE 2, 3, 19.
A few specimens found at inshore localities near Durban and Port Elizabeth in April only.

General: Considered by Hendey (1937) to be a neritic species common in temperate and subtropical waters. It is therefore surprising that it was not found more commonly during the present survey. Possibly during months other those investigated it might occur in larger numbers over a wider area. Heiden and Kolbe (1928) recorded it from Simonstown, Cape . Kolbe (1957) found it rare in Indian Ocean cores.

9. Coscinodiscus crenulatus Grunow, Denkschr. Akad. Wissensch. Wien, Math. - Naturw. Kl. 48 : pl. D, fig. 17 (1884); Rattray, Revis. Coscinodiscus : 489 (1889); Peragallo, Diat. Mar. France : 425, pl. 115, fig. 10 (1908); Hustedt, Kieselalg. (1) : 411, fig. 219 (1930).

Local.: NIOE 115.

Rare, only one specimen 25 μ in diameter, observed in the vicinity of the Agulhas Current near Port Elizabeth in October.

General: Rattray (1889) quoted Grunow as the authority for recording this species from the Seychelle Islands, also recording it in guano from Bolivia, from salps in the Southern Ocean, and from the Balearic Islands. Hustedt (1930) cited Cleve (no reference given) as a source for the latter record, apparently having seen his material. Apart from a few records of this species in the Northern Hemisphere it seems more typically a Southern Hemisphere species. It was considered to be littoral by Hustedt (1930). Heiden and Kolbe (1928) recorded it from Simonstown, Cape, and Kolbe (1957) recorded specimens from Indian Ocean cores.

10. <u>Coscinodiscus curvulatus</u> Grunow ex. A. Schmidt, Atlas : pl. 57, fig. 33 (1878); Rattray, Revis. Coscinodiscus : 486 (1889); Peragallo, Diat. Mar. France : 423, pl. 115, fig. 7 (1908); Hustedt, Kieselalg. (1) : 406, fig. 214 (1930); Hendey, Discovery Rep. <u>16</u> : 251 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 55, fig. 17 (1943); Boden, Trans. Roy. Soc. S. Afr. <u>32</u> (4) : 346, fig. 21 (1950), Manguin, Diat. Terre Adelie : 247, pl. 22, figs. 269, 270 (1960).

Local.: NIOE 34.

One specimen in the Agulhas Current south of the Agulhas Bank.

General: Hendey (1937) described the distribution as oceanic, wide in temperate seas. Of interest to the present area are the records of Weissflog (cited by Rattray, 1889) - Table Bay; Boden (1950) - West Coast of S. Africa; Kolbe (1957) who found the species in cores restricted to an area off the African coast in the Indian Ocean; and Silva (1960) - Inhaca, Mozambique. It was also found in the Antarctic by Mann (1937) and Manguin (1960).

11. <u>Coscinodiscus</u> <u>divisus</u> Grunow, in Schneider, Naturw. Beitr. Kenntn. Kaukasus-länd : 125 (1878); Rattray, Revis. Coscinodiscus : 499 (1889); Hustedt, Kieselalg. (1) : 410, fig. 218 (1930).

Local.: NIOE 17, 108.

Single specimens from an inshore station (NIOE 17) in April and another station further offshore in the same vicinity, the Transkei coast, during October.

General: Hustedt (1930) remarked that it was probably present in all seas although it has only rarely been recorded. He suggested that it is probably littoral or neritic in distribution.

12. <u>Coscinodiscus</u> <u>excentricus</u> Ehrenberg, Abh. Berl. Akad. 1839 : 146 (1840); Rattray, Rev. Coscinodiscus : 461 (1889); Hustedt, Kieselalg. (1) : 388, fig. 201 (1930); Hendey, Discovery Rep. <u>16</u> : 242 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 52, fig. 14 (1943); Boden Trans. Roy. Soc. S. Afr. <u>32</u> (4) : 340, fig. 13 (1950).

Local.: NIOE 5, 16, 19, 20, 21, 23, 62, 78, 158, 159, 176.

Occasional, but not found in large numbers, and not recorded during the October survey.

Generally found at oceanic stations, although also at stations on the outer edge of the 100 fathom line. Estimation of the relative abundance of this species is confused due to the impossibility of distinguising it from detached valves of Planktoniella sol (Wallich) Schütt. This problem is further discussed under the latter species.

General: Numerous localities, both fossil and living, were cited by Rattray (1889). Hustedt (1930) described the distribution as oceanic and abundant in most seas. Hendey (1937) found that the specimens from around the Cape of Good Hope were unusually large. However, one exceptionally small specimen, 20 µ in diameter, was found in the present material, indicating that the size of this species is highly variable in South African waters. Heiden & Kolbe (1928) recorded the species from Simonstown, Cape. Hustedt (1958) recorded it from the South Atlantic Ocean, and Boden (1950) from the Benguella Current Region. Kolbe (1957) found the species to be one of the most common and uniformly occurring in core material from the Indian Ocean.

13. *Coscinodiscus gigas* Ehrenberg var. *gigas* Abh. Berl. Akad. 1841 : 412 (1843); Rattray, Revis. Coscinodiscus: 541 (1889); Karsten, Valdivia Indische Phytopl.: 367, pl. 35, figs. 7, 7a (1907); Hustedt, Kieselalg. (1) : 456, fig. 254 (1930); Hendey, Discovery Rep. 16 : 246 (1937).

Local.: NIOE 88, 96.

Only two specimens recorded, one from each station cited, a southerly offshore station in July, and an inshore station near Durban in October.

General: The distribution was given by Hendey (1937) as wide in tropical and subtropical seas. He found it common but not in large numbers from localities around the coast of South Africa, and suggested that it might favour high salinities. Early records and localities were cited by Rattray (1889). Karsten (1907) recorded it from the Indian Ocean, Heiden & Kolbe (1928) from Simonstown, Cape, and Boden (1950) from the Benguela Current area. Kolbe (1957) found it rarely in Indian Ocean sediments.

14. Coscinodiscus gigas var. praetexta (Janisch) Hustedt, Kieselalg. (1) : 457, fig. 255 (1927); Allen & Cupp, Ann. Jardin Bot. Buitenzorg 44 (2) : 120, fig. 16 (1935). PLATE 8, figs. 3, 4.

System: This is distinguished from the typical variety on the grounds of the sharply delimited marginal zone of coarser areolae clearly indicated in Hustedt's (1930) figure cited above, as opposed to a more gradual broader zone of marginal thickening in the typical variety.

Local.: NIOE 94, 130.

Only found at extreme inshore southerly stations over the Agulhas Bank, July and October.

General: It seems likely that the C. gigas referred to by Hart & Currie (1960) from the Benguela Current area is in fact the above variety. Hendey (private communication) has intimated that the records of C. gigas from the colder West Coast region of Southern Africa in his (1937) report were probably the variety, and informed the author that he had found it to be very common in material collected by Dr. T.J. Hart from Walvis Bay, and that it was also present in samples from the entire area of anaerobic ooze stretching some 200 miles along the coast.

It appears that in general the variety prefers colder temperatures than C. gigas var. gigas and is more typical of the West Coast of Southern Africa than the East Coast region, only occurring in tongues of colder water over the Agulhas Bank.

A bloom of this large species was noted by the present author in the waters of False Bay in February, 1963 in conjunction with large numbers of the dinoflagellate, Noctiluca miliaris Suriray.

15. Coscinodiscus granii Gough, Rep. Plankt. English Channel 1903 : 338, fig. 313 (1905) : Hustedt; Kieselalg. (1) : 436, fig. 237 (1930); Hendey, Discovery Rep. 16 : 246, pl. 13, fig. 2 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 56, fig. 21 (1943) : Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 346, fig. 20 (1950).

Local.: NIOE 1, 58, 176, 178.
Found in small numbers in material from the immediate vicinity of Durban in April and July, and from two stations over the Agulhas Bank in January.

General: This species is apparently abundant on occasions in Northern European waters (Hustedt, 1930;

Hendey, 1937). Hendey (1937) also recorded it from two stations off South West Africa, the latter record being quoted by Boden (1950). Heiden and Kolbe (1928) recorded it in Antarctic waters.

16. Coscinodiscus kützingii A. Schmidt, Atlas : pl. 57, figs. 17, 18 (1873); Rattray, Revis. Coscinodiscus : 481 (1889); Hustedt, Kieselalg. (1) : 398, fig. 209 (1930).

Local.: NIOE 162.
Two individuals found in material from a station in the Agulhas Current south of Port Elizabeth in January.

General: Found throughout the coastal regions of Northern and Western Europe (Hustedt, 1930) and also in the Arctic and Antartic regions (Grunow, fide Rattray, 1889). Karsten (1907) recorded it from the Indian Ocean.

17. Coscinodiscus lineatus Ehrenberg, Abh. Berl. Akad. 1838 : 129 (1840); Mikrogeol. : pl. 18, fig. 23, pl. 22, fig. 6, pl. 35 A, 16 - fig. 3, 17 - fig. 7 (1856); Rattray, Revis. Coscinodiscus : 472 (1889); Hustedt, Kieselalg. (1) : 392, fig. 204 (1930); Hendey, Discovery Rep. 16 : 242 (1937);

Cupp, Mar. Diat. W. Coast N. Amer. : 53, fig. 15 (1943); Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 341, fig. 14 (1950), Manguin, Diat. Terre Adélie : 249, pl. 23, fig. 273 (1960)

PLATE 7, fig. 4.

Local.: NIOE 2, 16, 30, 58, 62, 71, 85, 89, 91, 97, 101, 119, 120, 142, 172.

Occasional, in material collected on all four cruises, generally inshore in the northern part of the region and oceanic in the south.

General: This has a world-wide distribution in temperate and subtropical seas (Hendey, 1937). Recorded from the West Coast of South Africa (Boden, 1950). Common in Indian Ocean cores and of uniform occurrence over a wide area in the sediments (Kolbe, 1957). Numerous early records were cited by Rattray (1889).

18. Coscinodiscus marginatus Ehrenberg, Abh. Berl. Akad. 1841 : 142 (1843) : A. Schmidt, Atlas : pl. 62, figs. 1, 2, 3, 4, 5, 7, 9, 11, 12 (1878); Rattray, Revis. Coscinodiscus : 509 (1889); Hustedt, Kieselalg. (1) : 416, fig. 223 (1930); Hendey, Discovery Rep. 16 : 248 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 55, fig. 19 (1943).

Local.: NIOE 150.

One specimen recorded from an offshore station in January.

General: This species is found in all seas (Hustedt, 1930). It is common in temperate waters, and is possibly meroplanktonic (Hendey, 1937). Silva (1956) recorded the species from Mozambique waters.

19. Coscinodiscus marginato - lineatus A. Schmidt, Atlas : pl. 54, fig. 33 (1878); Rattray, Revis. Coscinodiscus : 474 (1889); Wolle, Diat. N. Amer.: pl. 94, fig. 16 (1894); Karsten, Valdivia Antarkt. Plytopl. : 80, pl. 6, fig. 6 (1905) PLATE 7, fig. 5.

System: This species has only rarely been recorded and so a description of the specimens found in the present material is provided below.

Valves small, solitary and disc-like, 32 - 38 μ in diameter, flattened over most of the surface, slightly curved immediately adjacent to the marked marginal zone. Areolae 4 - 5 in 10 μ, regular, hexagonal, and arranged in three tangentially crossing linear series. No central rosette or space present. Marginal zone relatively broad, 1/16 to 1/7 of a valve radius in width, striated. 7 - 9 marginal striae in 10 µ. A fine line is visible in some parts of the marginal zone dividing it into an inner and outer ring, the striae crossing it although sometimes appearing to be interrupted by it, as can be seen in the specimen illustrated.

The areolation and striation figures quoted above indicate that these features were smaller than the specimen described by Rattray (1889). C. marginato - lineatus var. antarctica Manguin (1960 : 249, pl. 3, figs. 36 - 39, pl. 23, fig. 282) represents a further diminution of size in the areolation and marginal striation.

	C. marginato-lineatus Rattray, 1889	S.W. Indian Ocean material	var. antarctica Manguin, 1960
Diam. µ	33.5	32 - 38	19.5 - 33
Areolae/10µ	3.5 - 4	4 - 5	5 - 6
Striae/10µ	6 - 8	7 - 9	10

In view of the complete range of variation in areolation and striation values Manguin's variety seems to be of doubtful value.

Local.: Four specimens from two inshore localities, Durban and the Transkei, in October.

General: The locality cited by Schmidt was Campeachy Bank, presumably within Campeche Bay in the Gulf of Mexico. Rattray (1889) and Wolle (1894) refer only to Schmidt's record. Also found by Karsten (1905) in the Indian Ocean sector of the Antarctic (Valdivia station 158).

20. Coscinodiscus nodulifer Janisch ex A. Schmidt, Atlas : pl. 59, figs. 30 - 23 (1878); Rattray, Revis. Coscinodiscus : 520 (1889); Karsten, Valdivia Indische Phytopl. : 364, pl. 36, fig. 6 (1907); Hustedt, Kieselalg. (1) : 426, fig. 229 (1930); Hendey, Discovery Rep. 16 : 248 (1937).
PLATE 7, fig. 3.

Local.: NIOE 69, 74, 80, 178.

A few specimens from inshore and offshore stations in the centre of the area in July, and inshore near Cape Agulhas in January.

General: It has been recorded from the Indian Ocean by Karsten (1907), Heiden & Kolbe (1928), and Hendey (1937), the latter from a station lying within the area under present consideration. Of great interest, particularly as this species is not usually recorded in large numbers, are the records of Kolbe (1954, 1955, 1957). He found that C. nodulifer was the commonest occurring species in the core samples he examined from the Pacific, Atlantic and Indian Ocean Equatorial areas. It was present in every core from the Indian Ocean examined, although not necessarily numerous in the material. Consequent to this, the suggestions of Hustedt (1930) that the species might be littoral is doubtful. It would seem to be a truly oceanic species of wide distribution. Rattray (1889) cited the earlier records including one from and Indian Ocean sounding.

21. Coscinodiscus obovatus Castracane, Diat. Challenger Exped. : 160, pl. 8, fig. 4, pl. 18, fig. 7, pl. 22, fig. 9 (1886); Rattray, Revis. Coscinodiscus : 538 (1889); De Toni, Syll. Alg. : 1261 (1894).

System: This appears to be the first record of the species since it was described by Castracane. Rattray (1889) described Castracane's specimens in his monograph, as did De Toni (1894). No further references to the species could be found although it is highly likely that more recent references do exist. In view of the rarity of the species the following description of the specimens observed in the present material might be of value.

Valves flattened, markedly subcircular in valve view, diameter 72 - 84 µ. Areolation 5 - 7 in 10µ at the centre, 8 - 9 in 10µ at the margin. Areolae arranged in two patterns; an outer zone approximately half the radius width in which the areolae are arranged in radiating, slightly fasciculate, lines, and an inner central zone in which the arrangement is loosely linear. There is a gradual transition between the two types of pattern.

The description above differs from Castracane's figures and Rattray's description in that the cells are subcircular rather than "roundly elliptical", and the central areolae are slightly smaller. The specimens described above have some resemblance to Rattray's variety _circularis_ in that the central area is less distinctly defined and the valve outline tends towards circular. It is unfortunate that

Rattray does not produce a figure to show if the specimens he assigned to the variety (chiefly from the collection of O'Meara) were indeed perfectly circular.

It would seem best to consider the local specimens as being intermediate between the species and the variety.

Local.: NIOE 111, 124, 142, 143.

A few specimens found inshore near Durban and the Transkei, one specimen offshore in the south, October and January.

General: All Castracane's specimens came from the Pacific Ocean. Rattray's variety circularis was recorded by him (1889) from various Atlantic Ocean localities.

22. Coscinodiscus oculus - iridis Ehrenberg, Abh. Berl. Akad. 1839 : 147 (1840); A Schmidt, Atlas : pl. 63, fig. 6, 7, 9 (1878), pl. 113, figs. 1, 3, 5, 20 (1888); Rattray, Revis. Coscinodiscus : 559 (1889); Hustedt, Kieselalg. (1) : 454, fig. 252 (1930); Hendey, Discovery Rep. 16 : 249 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 62, fig. 26 (1943); Subrahmanyan, Mar. Plankt. Diat. Madras Coast : 101, figs. 66, 67, 68, 72 (1946).

Local.: NIOE 36, 62, 74, 96, 129, 130, 144.
Not in large numbers, at inshore stations during all four cruises.

General: It is common in the oceanic waters of all seas (Hustedt, 1930; Hendey, 1937). Hendey suggested that it is probably oceanic but he found it only as in neritic areas.

23. Coscinodiscus perforatus var. cellulosus Grunow, Denksch. Akad. Wissensch. Wien, Math. - Naturw. Kl. 48 : 75 (1884); Rattray, Revis. Coscinodiscus : 572 (1889); Hustedt, Kieselalg. (1) : 447, fig. 246 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 61, fig. 25A (1943).

Local.: NIOE 60, 62, 78, 84, 111.
Present during the July and October cruises in small numbers at scattered stations, mostly inshore.

General: It is found occasionally in European waters (Hustedt, 1930), having also been found at various localities from the West Coast of S. America, Japan and in New Zealand fossil deposits (Rattray, 1889), Alaskan waters (Cupp, 1943).

24. Coscinodiscus radiatus Ehrenberg, Abh. Akad. Wiss. Berl. 1839 : 148, pl. 3, figs. 1, a - c (1840); A. Schmidt, Atlas : pl. 60, figs. 1 - 6, 9, 10, pl. 61, fig. 13, pl. 65, fig. 8 (1878); Rattray, Revis. Coscinodiscus : 514 (1889); Peragallo, Diat. Mar. France : 430, pl. 117, fig. 3 (1908); Hustedt, Kieselalg. (1) : 420, fig. 225 (1930); Hendey, Discovery Rep. 16 : 250 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer.: 56, fig. 20 (1943); Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 343, fig. 16 (1950).

System: Hustedt (1930) did not consider the separation of varieties on the basis of areolation size, such as those of Grunow, to be of systematic value and included them under the species.

Local.: NIOE 2, 3, 16, 19, 36, 88, 91, 93, 94, 110, 112, 117, 128, 178.
Commonly occurring, although not in large numbers, at all seasons, restricted to the vicinity of Cape Agulhas in January.

General: Ubiquitous, oceanic and neritic (Cupp, 1943). This type of distribution has been termed "panthalassic" by Hart and Currie (1960). Records of the species from the South African region include Rattray (1889, Saldanha Bay, guano), Heiden and Kolbe (1928, Simonstown and

24. <u>Coscinodiscus radiatus</u> Ehrenberg, Abh. Akad. Wiss. Berl. 1839 : 148, pl. 3, figs. 1, a - c (1840); A. Schmidt, Atlas : pl. 60, figs. 1 - 6, 9, 10, pl. 61, fig. 13, pl. 65, fig. 8 (1878); Rattray, Revis. Coscinodiscus : 514 (1889); Peragallo, Diat. Mar. France : 430, pl. 117, fig. 3 (1908); Hustedt, Kieselalg. (1) : 420, fig. 225 (1930); Hendey, Discovery Rep. <u>16</u> : 250 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer.: 56, fig. 20 (1943); Boden, Trans. Roy. Soc. S. Afr. <u>32</u> (4) : 343, fig. 16 (1950).

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25. Coscinodiscus reneformis Castracane, Diat. Challenger Exped. : 160, pl. 12, fig. 12 (1886); Notarisia : 753 (1889); Rattray, Revis. Coscinodiscus : 548 (1889); De Toni, Syll. Alg. : 1267 (1894). PLATE 8, fig. 1.

Synon.: C. stoschii Witt ex A. Schmidt, Atlas, sub Stoschia admirabilis Janisch : text to pl. 140, fig. 17 (1889).

Stoschia admirabilis Janisch, Diat. Gazelle Exped. ex Grunow, Bot. Central Bl. 34 : 40 (1888); A. Schmidt, Atlas : pl. 140, fig. 17 (1889); Van Heurck, Treat. : 537, fig. 283 (1896, sub S. mirabilis Janisch). S. reneformis (Rattr.) Heiden and Kolbe, Mar. Diat. Deutsche Südpol-Exped. 1901 - 1903 (1928).

System.: The systematic history of this rare and striking species is confused due to a series of errors on the part of early workers. Janisch, unaware of

Castracane's description, considered the elongate form sufficiently distinct to warrant the formulation of a new genus, Stoschia. A. Schmidt, in the text to a figure of a specimen from Janisch's collection, referred to a proposal by Witt that the species should be considered under the genus Coscinodiscus, the combination proposed, C. stoschii, ~~this~~ being illegal taxonomic procedure. Heiden and Kolbe retained Janisch's generic separation, providing the correct specific epithet but incorrectly ascribed the original description of the species to Rattray. Van Heurck's S. mirabilis was presumably an orthographic error.

As the species has only been described by Castracane and Rattray (De Toni's description is derived from Rattray) a full description of the specimens seen by the present author is given below.

Valves large, flattened, and reniform in outline. The valve surface is covered by polygonal areolation arranged in radiating lines from a central point. There is no clear central rosette or space. The length of the valve along its longest axis varies between 165 and

312 μ , with a breadth of 52 to 98 μ at the centre. Areolation size decreases gradually towards the centre and sharply at the convex margin. Areolae 5 - 8 in 10 μ at the centre, 4 - 6 μ in the zone of maximum size, and 7 - 9 in 10 μ at the margin. Chromatophores are in the form of numerous small rounded bodies.

Local.: NIOE 71, 84, 110.
Found in oceanic water, rare, in July and October.

General: Distribution of this species was given as "wide" by Castracane, but no exact localities were provided. The locality of Janisch's specimen(s ?) is not known. Van Heurck (1896) recorded the species from the West Coast of Africa. It has also been found in the South Atlantic (Heiden and Kolbe, 1928), the Antarctic (Mann, 1937), the Philippine Islands (Mann, 1937, "common there") and in a core from near the Seychelle Islands (Kolbe, 1957). The present author has also found the species from material collected near Port Elizabeth in August, 1958.

26. Coscinodiscus stellaris Roper, Quart. J. Micr. Soc. 6 : 21, pl. 3, fig. 3 (1858); Rattray, Revis. Coscinodiscus : 493 (1889); A. Schmidt, Atlas : pl. 164, fig. 4 (1891); Peragallo, Diat. Mar.

312 μ, with a breadth of 52 to 98 μ at the centre. Areolation size decreases gradually towards the centre and sharply at the convex margin. Areolae 5 - 8 in 10 μ at the centre, 4 - 6 μ in the zone of maximum size, and 7 - 9 in 10 μ at the margin. Chromatophores are in the form of numerous small rounded bodies.

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26. <u>Coscinodiscus stellaris</u> Roper, Quart. J. Micr. Soc. <u>6</u> : 21, pl. 3, fig. 3 (1858); Rattray, Revis. Coscinodiscus : 493 (1889); A. Schmidt, Atlas : pl. 164, fig. 4 (1891); Peragallo, Diat. Mar.

France : 423, pl. 116, fig. 1 (1908); Hustedt, Kieselalg. (1) : 396, fig. 207 (1930); Hendey, Discovery. Rep. 16 : 243 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 53. fig. 16 (1943). PLATE 7, fig. 6.

Local.: NIOE 36, 37, 73, 120, 128, 178. Present in material from all four cruises. Generally inshore in occurrence, particularly over the Agulhas Bank near Port Elizabeth. Found at one extreme oceanic station (NIOE 120). Usually only in small numbers with the exception of NIOE 178 where, in conjunction with *C. centralis*, it occurred in moderate numbers.

General: Hendey (1937) considered the species to be oceanic in distribution. It is widely distributed in northern and southern seas. As it may also occur in moderate numbers at inshore localities 'panthalassic' would perhaps be a better term to describe its distribution, as in the case of *C. radiatus*. Kolbe (1957) recorded a few fragmented specimens from Indian Ocean cores.

27. *Coscinodiscus tabularis* var. *eggregius* (Rattray) Hustedt, Kieselalg. (1) : 428, fig. 230 b (1927).

Sub C. *egregius* Rattray - A. Schmidt, Atlas : pl. 57, fig. 39 (1878); Peragallo, Diat. Mar. France : pl. 117, fig. 7 (1908)

Local.: NIOE 37, 101, 128, 148.

Not present during July, 1962. Rare at stations near Cape Agulhas and occurring twice from the same locality on the Durban line (NIOE 101, 148) at different times of the year.

General: The typical variety has been recorded from Table Bay (Schmidt, 1878), the Antarctic (Heiden & Kolbe, 1928), and from the S. Atlantic (Hustedt, 1958). The present variety has been found at Villefranche (Peragallo, 1908) and in Indian Ocean cores (Kolbe, 1957). Manguin (1960) recorded a new variety, *antarctica* from the Antarctic near Adelie Land.

28. *Coscinodiscus trioculatus* Taylor sp. nov. PLATE 9, fig. 1 (iconotype).

Valva minutissima, subcircularis, convexa, centra subcomplanata, cum margine hyalina distincta; areolae plurime parva, spatium centrale rosulque defectis; tres areolae multo expansae.

System: This extremely small species of *Coscinodiscus* is recorded here for the sake of completeness.

Due to its small size it is not possible to identify it under routine conditions with even a rough degree of certainty. It was discovered during electron microscopic examination of material from the station cited below. A description of it follows:

Valve extremely small, 2.8μ in diameter, subcircular, with a convex surface slightly flattened at the centre. It possesses a distinct, hyaline marginal flange 0.18μ in width. The general surface of the valve is areolate, lacking a central rosette or space. The areolae are small with an average diameter of 0.2μ, polygonal and uniform over the surface with the exception of three markedly larger and structurally different areolae on the central upper surface of the valve, the latter areolae having a diameter of 0.35 - 0.40μ. The areolae are in decussate rows over the valve surface. The three larger areolae are simply constructed with a foramen penetrating an outer and inner membrane. The smaller areolae are shallow with a poroid internal sieve-membrane. The foramina are 0.07μ wide, the finest pores having a diameter of 0.03μ.

The occurrence of larger areolae of differing structure suggests a possible link with the genus *Brightwellia* Ralfs, the latter possessing a ring of larger areolae. Rattray (1889, pp. 102, 181) has suggested a link between *Coscinodiscus* and *Brightwellia* due to the intermediate features of *C. bulliens* Schmidt and *C. asteromphalus* var. *brightwellioides* Grunow.

Local.: NIOE 85.

1 whole specimen and several identifiable fragments from a southerly oceanic station in July.

29. *Coscinosira polychorda* (Gran) Gran, Nyt Mag. Naturvid. *38* (2) : 115 (1900); Nord. Plankt. Diat. : 20, fig. 17 (1905); Hustedt, Kieselalg. (1) : 317, fig. 154 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 44, fig. 7 (1943), Brunel, Phytopl. Baie Chaleurs : 43, pl. 7, fig. 1 (1962).

Local.: NIOE 93.

One chain of individuals in colder water near Cape Agulhas, diameter of cells 18 μ.

General: Apparently not previously recorded from the southern hemisphere. It is widely distributed in temperate neritic areas in the northern hemisphere.(Hustedt, 1930; Cupp, 1943). The present author has found it occasionally in samples from False Bay near Cape Town. Brunel (1962) recorded that its optimal temperature in Eastern Canadian waters is $3^{o}C$ with a salinity optimum of 26.7‰.

30. Ethmodiscus gazellae (Janisch) Hustedt, Kieselalg. (1) : 375, fig. 196 (1927); Pavillard, Rep. Danish Oceanogr. Exped. 1908 - 1910 Medit. 2, Biol. (4) : 9, fig. 9 (1925); Hendey, Discovery Rep. 16 : 255 (1937); Kolbe, Diat. Equat. Indian Ocean Cores : 8, 33, fig. 5, pl. 4, figs. 47, 49, (1957).

Local.: NIOE 17, 18, 78, 91. From stations inshore and in the Agulhas Current during April and July.

General: This large species is known from the Mediterranean in the northern hemisphere (Hustedt, 1927; Pavillard, 1925). It is widely distributed in the southern hemisphere (Hendey, 1937). Kolbe (1957) found fragments of the valves in a few cores from the Equatorial Indian Ocean.

The cells observed in the present survey usually fragmented when placed under a coverslip due to their large size. Other smaller fragments were found at other stations but no accurate determination of the species could be made from them, although it is likely that some could have been *E. rex* (Wallich) Hendey, another extremely large species found by Mann (1907) and Kolbe (1954, '56, '57) to form enormously thick and widespread monospecific sediments in the equatorial areas of the three tropical oceans. A puzzling feature associated with this phenomenon is that, although the species is typically planktonic and its remains are super-abundant in the areas mentioned above, both it and *E. gazella* are only rarely recorded in the analysis of phytoplankton collections. Kolbe presented three possible explanations for this disparity : (1) The species has a dysphotic habitat and is thus not usually present in collections in the upper 100 metres (proposed by Karsten, 1907, but shown by Kolbe not to be supported by Karsten's own data). (2) Hendey's (1953) proposal that the species might have periods of intense reproduction, probably short in duration. The record of Collingwood (1868) cited by Kolbe has been shown to be incorrect by Hendey (1958). (3) The species is highly resistant to corrosion and thus remains evident after other diatoms have corroded away completely

To these three possible explanations the present author suggests a fourth. After the observation of a pair of individuals of *E. gazelle*, closely adherant in a rigid chain by their valve faces, in a zooplankton sample collected by an N 70 V net (coarser mesh) enquiries were made among the sorters involved in the zooplankton work. They affirmed that on a number of occasions they had observed large green, barrel-shaped cells in the zooplankton collections, these unfortunately not being recorded or retained. It is possible that the large *Ethmodiscus* cells are not commonly present in the phytoplankton samples due to a selective action of the net in much the same manner as small zooplankton tend to be excluded or incompletely sampled. This is purely speculation and must await the analysis of further material to be confirmed or otherwise disregarded.

31. *Gossleriella tropica* Schütt, Pflanzenleb. d. Hochsee : 30, fig. 7 (1893); Karsten, Valdivia Indische Phytopl. : 148, pl. 40, figs. 14 - 17 (1907); Hustedt, Kieselalg. (1) : 500, fig. 280 (1930);

Hendey, Discovery Rep. 16 : 258, pl. 12, fig. 1 (1937); Crosby & Wood, Stud. Austral. and N. Zeal. Diat. (1) : 525, pl. 32, fig. 54 (1958). PLATE 11, fig. 5.

System: When it was possible to mount specimens of this species in Hyrax it was found that in nearly all cases the surface of the valve was finely punctate, the punctae being arranged in radiating lines. The punctae were closer together near the margin and thus the lines were more visible toward the margin. The punctae were not visible in watermounts. Punctae 14 - 16 in 10μ near the centre of the valve, 20 - 22 in 10μ at the margin. The presence of internally projecting spines appears to be a variable feature.

Wood and Crosby (1959, p. 214, pl. 16, fig. 18) described a new species G. punctata, separating it on the grounds of visible punctation on the valve and two orders of spines. They did not provide counts for the number of punctae in 10μ, but from the photograph provided it is clear that the punctation is a great deal more marked than in the present specimens. However, specific separation does not seem to be warranted if the punctae are variable in development. A varietal separation would perhaps be more appropriate. The double order of spines is a feature commonly displayed among local G. tropica specimens.

Local.: NIOE 7, 10, 12, 21, 59, 64, 71, 74, 77, 89, 110, 144, 158, 162.

A purely oceanic distribution, occurring at scattered stations to the edge of the Continental shelf. Found in material from all four cruises but never present in large numbers.

General: This species has a wide distribution in tropical seas, being common in the Indian Ocean and most frequent in the region of Madagascar (Hendey, 1937).

32. Hyalodiscus parvulus Karsten, Valdivia Indische Phytopl. : 369, pl. 38, fig. 5 a, b, c (1907).

Local.: NIOE 112.

1 cell only, from the most inshore station of the Transkei line in October.

General: Apparently only recorded by Karsten (1907) at one station in the Equatorial Indian Ocean.

33. Melosira sol (Ehrenberg) Kützing, Spec. Alg. : 31 (1849); Van Heurck, Syn.: pl. 91, figs. 7 - 9 (1881);

A. Schmidt, Atlas : pl. 179, fig. 21 (1894); Karsten, Valdivia Antarct. Phytopl. : 70, pl. 1, figs. 3 - 9 (1905); Hustedt, Kieselalg. (1) : 270, fig. 114 (1930); Hendey, Discovery Rep. <u>16</u> : 234 (1937); Manguin, Diat. Terre Adélie : 237, pl. 20, fig. 240 (1960). PLATE 1, figs. 3 a, b.

Local.: NIOE 58, 62.

Rare, at two stations on the Natal line, one neritic, one oceanic, in July.

General: It is found mainly in southern oceans (Hustedt, 1930), and only occasionally in European waters. It extends into the Antarctic region (Manguin, 1960). Hendey (1937) considered it to be tychopelagic.

34. <u>Paralia</u> <u>sulcata</u> (Ehrenberg) Cleve, Bih. Kongl. Svenska Vet. Akad. Handl. <u>1</u> (13) : 7 (1873); Gran, Diat. Nord. Plankt. : 14, fig. 5 (1905); Lebour, Plankt. Diat. North. Seas : 28, fig. 9 a, b (1930).

Syn.: <u>Melosira</u> <u>sulcata</u> (Ehrenberg) Kützing, Bac. : 55, pl. 2, fig. 7 (1844); Hustedt, Kieselalg. (1) : 276, figs. 118, 119 (1930); Hendey, Discovery Rep. <u>16</u> : 235 (1937).

System: The genus *Paralia* Heiberg is distinguished from *Melosira* Agardh on the basis of the punctate-areolate structure present on the valve margin and mantle. Hustedt (1930) considered this feature to warrant only subgeneric separation. Hendey (1937) used Kützing's combination but later (1954) changed to that of Cleve. The generic distinction is followed here for simplicity in comparison with check-lists such as that of Hendey (1954).

Local.: NIOE 19, 59, 94, 96, 97, 111, 130.
Chains of the species were found at inshore stations. The relative abundance symbols are strongly influenced by the number of cells in a chain (usually broken) and are not of great significance. Not found in the January material.

General: Designated as tychopelagic by Hendey (1937). It appears to have a very wide range, being present along the coasts of most of the world oceans, although it is more abundant in colder regions - Arctic, Antarctic, N. European waters (Hendey, 1937).

35. *Planktoniella sol* (Wallich) Schütt, Pflanzenleb. d. Hochsee : 20, fig. 8 (1893); Karsten, Valdivia

Indische Phytopl. : 514, pl. 39, figs. 1 - 11 (1907); Hustedt, Kieselalg. (1) : 465, fig. 259 (1930); Hendey, Discovery Rep. 16 : 257, pl. 13, fig. 1 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 63, fig. 27 (1943); Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 348, fig. 23 (1950). PLATE 9, figs. 2, 3.

System: There is great difficulty in accurately estimating the relative abundance of this species due to the similarity of its non-loculate valves to *Coscinodiscus excentricus*. Karsten (1907, p. 514) was the first to observe that during division the locular wing does not divide, remaining attached to the parent epitheca. Thus one daughter cell lacks a wing after division and is identical in appearance to *C. excentricus*. The present author has been able to confirm this feature of the reproduction.

If the locular wing is considered to be a flotation mechanism then it is probable that the non-winged daughter cells sink following division. Hustedt (1930) was of this opinion, suggesting that after the wingless cells have sunk to the bottom new wings are formed and they rise into the plankton once more. This is also suggested by the rarity of individuals with very slight wing development in plankton collections. The presence of a marked number of wings lacking a central portion in samples in which active division was observed in the present material suggests that the winged daughter cell may also discard its wing and sink shortly after division.

Local.: NIOE 1, 2, 3, 5, 7, 10, 12, 14, 16, 17, 18, 19, 20, 21, 23, 25, 28, 34, 35, 36, 58, 59, 60, 62, 64, 66, 67, 69, 71, 73, 76, 77, 78, 80, 82, 84, 85, 87, 88, 89, 91, 93, 94, 95, 96, 97, 99, 101, 103, 104, 106, 108, 110, 111, 112, 114, 115, 117, 119, 120, 124, 126, 128, 129, 130, 142, 143, 144, 148, 150, 157, 158, 159, 162, 164, 174, 178.

One of the most commonly occurring species of diatoms in the South Western Indian Ocean. It was present in ¾ of the samples examined, usually within the range of 2 - 20 individuals per subsample. It occurred over the entire area and during all cruises, although it appeared to be most widely distributed and present in largest numbers during July. A detailed discussion of the distribution of this species will be found in section IV.

General: The species was first described by Wallich (1860, p. 38, as Coscinodiscus sol) from the Indian Ocean. Since then it has been found to be widely distributed through the warmer oceanic waters of the world (Hustedt, 1930) although also present in European and Sub-Antarctic waters. Hendey (1937) pointed out that individuals from warmer waters are characterised by large valve and wing sizes, those in colder waters near the Antarctic convergence having a small valve diameter and relatively larger wings.

36. Podosira maxima (Kützing) Grunow, Kongl. Svenska Vet. - Akad. Handl. 17 (2) : 118 (1880); De Toni, Syll. Alg. : 1361 (1894); Hustedt, Kieselalg. (1) : 285, fig. 126 (1930).

Local.: NIOE 93.

Present in small numbers at one station in cold water over the Agulhas Bank in July.

General: Apparently it has been only previously recorded from the Arctic Ocean (Grunow, 1880; Hustedt, 1930). The specimens found locally agreed closely with the description provided by Hustedt (valve diameters 142, 148 and 163 μ).

37. _Podosira montagnei_ Kützing, Bac. : 52, pl. 29, fig. 85 (1844); De Toni, Syll. Alg. : 1360 (1894); Peragallo, Diat. Mar. France : 444, pl. 120, fig. 11 (1907); Hustedt, Kieselalg. (1) : 281, fig. 122 (1930).

Local.: NIOE 143.

Rare, from an inshore station near Durban in January. Possibly a sedentary species adventitiously occurring in the plankton.

General: It is widespread in the littoral zone of the coast of Europe (Hustedt, 1930). Heiden and Kolbe (1928) recorded the variety _minor_ Grun. from Simonstown, Cape.

38. _Podosira stelliger_ (Bailey) Mann, Diat. Albatross Voy. : 242 (1907); A. Schmidt, Atlas : pl. 139, fig. 7 sub _P. maculata_ W. Smith (1882); Peragallo, Diat. Mar. France : pl. 119, fig. 5, sub _Hyalodiscus stelliger_ Bail. (1908); Hustedt, Kieselalg. (1) : 286, fig. 128 (1930); Hendey, Discovery Rep. _16_ : 236, sub _H. stelliger_ Bail (1937).

Local.: NIOE 130.

Found at the most inshore station at Cape Agulhas, rare, in October.

General: This species is common and numerous in the littoral zone of the northern temperate regions (Hustedt, 1930). It is possibly tychopelagic (Hendey, 1937). In the Southern Hemisphere it has been recorded from Simonstown, Cape (Heiden and Kolbe, 1928), the coast of Brazil (Hendey, 1937), and also from Indian Ocean cores (Kolbe, 1957).

39. Roperia tessellata (Roper) Grunow ex Van Heurck, Syn.: pl. 118, figs. 6, 7 (1881); Rattray, Revis. Auliscus : 57 (1888); Peragallo, Diat. Mar. France : 413, pl. 112, fig. 6 (1902); Hustedt, Kieselalg. (1) : 523, fig. 297 (1930).
PLATE 8, fig. 2.

Local.: NIOE 36, 62, 64, 66, 71, 73, 74, 75, 76, 78, 82, 84, 85, 87, 88, 89, 91, 94, 99, 108, 110, 111, 117, 134, 142, 143, 160, 162, 176, 177. Found occasionally during all four cruises. Most widespread in July, restricted to inshore stations during January and April. Distribution discussed further in section IV.

General: This species is frequently found in oceanic European waters (Hustedt, 1930). Also found in the Antarctic (Mann. 1937). It was recorded from the Indian Ocean by Kolbe (1957) who found it in core material, and from Inhaca by Silva (1960).

40. Skeletonema costatum (Greville) Cleve, Bih. Kongl. Svenska Vet. - Akad. Handl., 1 (1) : 7 (1873); A. Schmidt, Atlas : pl. 180, figs. 41 - 45 (1892), pl. 321, figs. 5, 6 (1920); Hustedt, Kieselalg. (1) : 311, fig. 149 (1930); Hendey, Discovery Rep. 16 : 236 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 43, fig. 6 (1943). PLATE 10, fig. 1.

Syn.: Stephanopyxis costata (Greville) Hustedt, Diat. Maracaibo : 94 (1956).

System: Hustedt, Hendey, Cupp and various other authors incorrectly cited Cleve (1878) as the original reference to the combination. The first occasion on which Cleve proposed the name was in his work on the "Sea of Java" in 1873. Hustedt's modified spelling of the genus (Sceletonema) has not been used as it is not recommended procedure.

Hustedt's combination cited in the synonymy was apparently based on the close resemblance of the fine structure of the valve with that exhibited by the genus *Stephanopyxis*. The present author has not been able to consult Hustedt's paper, and so the older combination, under which the species is widely known,has been retained pending further investigation.

Local.: NIOE 1, 2, 3, 17, 18, 19, 58, 59, 60, 62, 71, 73, 74, 76, 77, 91, 93, 95, 96, 97, 101, 111, 112, 113, 114, 142, 143, 158, 159, 160, 161, 162, 176. Present during all seasons investigated. The species exhibits one of the most restricted neritic distributions observed in the population. It commonly occurred in large numbers at close inshore stations. Further discussed in section IV.

General: Cupp (1943) described the distribution as "Neritic, widely distributed in all seas". Numerous authors, cited by Wood (1963, b) have recorded the species from the Indian Ocean and adjacent waters.

41. *Stephanopyxis palmeriana* (Greville) Grunow, Denkschr. Akad. Wiss. Wien, Math.-Naturw. Kl. 48 : 38 (1884); Karsten, Valdivia Indische Phytopl.: 373, pl. 54, fig. 9, sub var. *javanica* Grun. (1907); Hustedt, Kieselalg. (1) : 308, fig. 147 (1930); Hendey, Discovery Rep. 16 : 236 (1937);

Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 40, fig. 3 (1943).

Local.: NIOE 1, 2, 3, 18, 19, 20, 21, 35, 58, 59, 66, 73, 74, 75, 77, 80, 85, 87, 88, 91, 96, 112, 124, 142, 143, 144, 146, 158, 159, 161, 176, 177. Predominantly neritic in its distribution, although occasionally found at offshore stations. In October it was limited to the most inshore stations on the two most northerly lines. Further discussed in section IV.

General: "A pelagic diatom favouring warm water of high salinity, common in Indian Ocean, particularly around South Africa," (Hendey, 1937). Wood (1963, b) provided records of the occurrence of this species in the Indian Ocean, Kolbe (1957) being omitted. The species is also known from the Mediterranean and the Pacific Ocean. It is only rarely found in the colder West Coast waters of S. Africa (Hart & Currie, 1960).

42. <u>Stephanopyxis turris</u> (Greville & Arnott) Ralfs, in Pritchard, Infus.: 826, pl. 5, fig. 74 (1861); A. Schmidt, Atlas, pl. 130, figs. 42, 43 (1888); De toni, Syll. Alg. : 1138 (1891); Hustedt, Kieselalg. (1) : 304, fig. 140 (1930); Hendey,

Discovery Rep. 16 : 237 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 40, fig. 3 (1943); Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 329, figs. 2, 3 (1950). PLATE 10, fig. 2.

Local.: NIOE 94, 130, 160, 177, 178. Not recorded during the April survey. Distribution sharply restricted to extreme inshore stations in colder water than prevalent over the rest of the area. Not found further northward than Port Elizabeth. It apparently favours colder temperatures than *St. palmeriana*, the two species occurring concurrently at only one station (NIOE 177).

General: It is considered to be a temperate species by Hendey (1937) and Cupp (1943). It has been commonly found in the West Coast region of S. Africa (Boden, 1950; Hart & Currie, 1960), and other cold temperate regions of the world.

43. *Thalassiosira condensata* Cleve, Kongl. Svenska Vet.-Akad. Handl. 32 (8) : 22. pl. 8, figs. 12, 13 (1900); Gran, Diat. Nord. Plankt. : 20, fig. 15 (1905); Hustedt, Kieselalg. (1) : 332, fig. 169 (1930); Hendey, Discovery Rep. 16 : 238, pl. 11, 12 (1937); Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 335, fig. 8 (1950). PLATE 10, fig. 4.

Local.: NIOE 94, 97.

Found in colder water near Cape Agulhas in July, but also one chain found in material from the Agulhas Current near Durban.

General: This species is characteristically a cold temperate species having been recorded from Plymouth (Cleve, 1900), the Norwegian coast (Peragallo, 1908), the Peru Current (Hendey) and the West Coast of S. Africa (Hendey, 1937; Boden, 1950; Hart & Currie, 1960). Wood (1962) has recorded it from the Eastern Indian Ocean.

44. Thalassiosira gravida Cleve, Bih. Kongl. Svenska Vet.-Akad. Handl. 22 (3) No. 4 : 12, pl. 2, figs. 14 - 16 (1896); Gran, Diat. Nord. Plankt. : 18, fig. 12 (1905); Hustedt, Kieselalg. (1) : 325, fig. 161 (1930); Hendey, Discovery Rep. 16 : 239, pl. 11, fig. 10 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 48, fig. 11 (1943).

Local.: NIOE 85.

One chain of cells from a southerly offshore station in July.

General: This is a cold temperate species "common in neritic plankton in all northern seas" (Hendey, 1937). It has not been previously recorded from the Indian Ocean although it has been found in the Antarctic by Van Heurck (1909), Heiden & Kolbe (1928), and Mann (1937).

45. Thalassiosira rotula Meunier, in Duc d'Orleans, Camp. Arct. : 264, pl. 29, figs. 67 - 70 (1910); Hustedt, Kieselalg. (1) : 326, fig. 163 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 49, fig. 12 (1943); Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 335, fig. 7 (1950). PLATE 10, fig. 3.

Local.: NIOE 2, 3, 18, 19, 20, 25, 94, 114, 130, 143, 144, 158, 159, 160, 161, 162, 176, 178. Found to exhibit a neritic distribution in the area, reaching as far north as Durban during April and January, more confined to the south west during July and October.

General: It has been recorded off the coasts of southern and central Europe (Hustedt, 1930), California and Alaska (Cupp, 1943), West Coast of S. Africa (Boden, 1950), Arctic (Meunier, 1910), and Antarctic (Wood, 1962). The species appears to have a bipolar, neritic distribution ranging from cold to temperate conditions.

46. <u>Thalassiosira subtilis</u> (Ostenfeld) Gran, Nyt Mag. Naturvid. <u>38</u> (H2) : 117 (1900); Hustedt, Kieselalg. (1) : 330, fig. 166 (1930); Hendey, Discovery Rep. <u>16</u> : 239 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 49, fig. 13 (1943); Boden, Trans. Roy. Soc. S. Afr. <u>32</u> (4) : 337, fig. 9 (1950).

Local.: NIOE 19, 20, 59, 75, 76, 77, 78, 85, 89, 93, 95, 96, 114, 142, 143, 174.

Neritic in the area, occasionally found offshore in the south, most widespread along the coast from Cape Agulhas to Durban in July (winter), more confined during the other months to the area between Durban and Port Elizabeth.

General: Hendey (1937) found this species to be very common in the Atlantic and Southern Oceans where it exhibited an oceanic type of distribution. He found that the amount of mucilage in which the cells are imbedded is greater in the colder waters. Subrahmanyan (1958) recorded this species from the Arabian Sea, and Wood (1962) found it in the Antarctic and Indian Ocean. The species appears to have a wide temperature tolerance.

Family HEMIDISCACEAE

47. Hemidiscus cuneiformis Wallich, Trans. Micr. Soc. N.S. 8 : 42, pl. 2, figs. 3, 4 (1860); Hustedt, Kieselalg. (1) : 904, fig. 542 (1930); Hendey, Discovery Rep. 16 : 264 (1937).

System: For present purposes the author has made no attempt to distinguish the various varieties of this species. Hendey (1937) found it impossible to distinguish these due to the series of intermediate forms existing in his material. The most distinct variety in the S.W. Indian Ocean material of the present survey was H. Cuneiformis var. ventricosa (Castracane) Hustedt, considered separately in the Relative Abundance Table.

Wood (1963, b) considered Hemidiscus hardmanianus (Greville) Mann as synonymous with the above species for the purpose of records. This appears to be unnecessary, as the latter species can be readily distinguished from H. cuneiformis on the basis of its valve structure, e.g. the presence of a hyaline central area (Silva, 1960, p. 13 as Palmeria hardmaniana). H. hardmanianus was not present in the S.W. Indian Ocean material.

Local.: NIOE 10, 14, 60, 66, 69, 71, 78, 85, 89. Occasionally recorded from offshore stations during April and July (autumn and winter), mostly in the more northern part of the region.

General: Considered to be an oceanic tropical and subtropical species by Hendey (1937). However, it has been found in more temperate northern waters (Hustedt, 1930) and in the Antarctic (Mann, 1937). It has been recorded frequently from the Indian Ocean although usually under established synonyms (<u>Euodia inornata</u> Castracane, <u>E</u>. <u>radiata</u> Castracane, <u>E</u>. <u>cuneiformis</u> Castracane, etc.), the records being provided by Wood (1963, b). Hendey (1937) has recorded the species from stations around the Cape of Good Hope. Kolbe (1957) found it commonly occurring in Equatorial Indian Ocean sediments.

Family ACTINODISCACEAE.

48. <u>Actinoptychus senarius</u> (Ehrenberg) Ehrenberg, Abhandl. Akad. Wiss. Berl. 1841 : pl. 1 (1), fig. 27 (1843); Hendey, Discovery Rep. <u>16</u> : 271 (1937).

Syn.: <u>A</u>. <u>undulatus</u> (Bailey) Ralfs in Pritchard, Infus. : 839, pl. 5, fig. 88 (1861); Hustedt, Kieselalg. (1) : 475, fig. 264 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 67, fig. 29 (1943).

System: This species is still commonly referred to under the synonym cited above although Hendey (1937) has shown that Ehrenberg's combination, _A_. _senarius_, clearly has priority over it. In fact it was made the type species of the genus by Ehrenberg. Hustedt (1930) omitted to refer to _A_. _senarius_, although he provided a list of other synonyms for this species.

Local.: NIOE 36, 87, 94.

Not common in the author's material from the area, only three frustules having been observed, one from each of the stations cited above, all in the southernmost part of the area.

One of the specimens was much smaller than the range of size usually quoted, having a diameter of 7.5 μ (lowest figure quoted : 20 μ, Hustedt, 1930).

General: The species has a wide distribution in subtropical and temperate waters. It is characteristically a sedentary species, having been recorded from the Cape of Good Hope by Grunow (1867, as _undulatus_ var. _senarius_ Grun.), and from St. Lucia Bay (Northern Natal) by Cholnoky (1960).

However it frequently occurs in plankton collections (Cupp, 1943; Hendey, 1937, etc.), and its distribution spreads into the low temperatures of the Antarctic (Van Heurck, 1909; Mann, 1937, etc.). Hendey (1937) found the species to be "frequent" around S. Africa. Wood (1963, b) provided numerous references for this species in the Indian Ocean. Kolbe (1957) found the species widely distributed, but not abundant, in Equatorial Indian Ocean sediments.

49. <u>Actinoptychus splendens</u> (Shadbolt) Ralfs in Pritchard, Infus. : 840 (1861); A. Schmidt, Atlas : pl. 153, figs. 3, 7 - 10, 12, 16, 17, 19 - 21, etc. (1890); Van Heurck, Syn. : pl. 191, figs. 1, 2, 4, pl. 120, fig. 6, pl. 122, fig. 6 (1881); Hustedt, Kieselalg. (1) : 478, fig. 265 (1930); Hendey, Discovery Rep. <u>16</u> : (1937).

Local.: NIOE 115.
One specimen found in material collected from the Agulhas Current in October near Port Elizabeth.

General: It has been found commonly in the coastal areas of all oceans (Hustedt, 1930). Hendey (1937) suggested that it is probably an oceanic species, but this is unlikely as the species occurs commonly in collections of sedentary littoral diatoms and is only occasionally found in planktonic material. The Steer Collection, a collection of slides of sedentary marine diatoms from numerous localities around the S. African coast, contains numerous specimens of this beautiful species (present author's observations). Indian Ocean records include Petit (1902) from Madagascar, Skvortzow (1930) from Ceylon, and Wood (1962) from the Eastern Indian Ocean. Hendey (1937) reported the species as rare off the coasts of S. Africa.

50. Asterolampra marylandica Ehrenberg, Ber. Berl. Akad. 1844 : 76, fig. 10 (1845); A. Schmidt, Atlas : pl. 137, figs. 19 - 21 (1889); Peragallo, Diat. Mar. France : 404, pl. 110, fig. 2 (1908); Hustedt, Kieselalg. (1) : 485, figs. 270, 271 (1930); Hendey, Discovery Rep. 16 : 268 (1937).

Local.: NIOE 5, 21, 23, 60, 91, 99, 106, 110, 111, 164. Occasional on all four cruises, generally at oceanic stations in or on the outer fringe of the Agulhas Current, i.e. in lower salinity water than was prevalent further offshore.

General: The species has a wide distribution in subtropical waters (Hendey, 1937). Recorded from the Indian Ocean by numerous authors including Cleve (1900 a,b), Karsten (1907), Heiden & Kolbe (1928), Hendey (1937) and Wood (1962).

Hendey's observation that the species appears to favour water of high salinity is not borne out by the local distribution, the species not being found in the higher salinity area, i.e. extreme offshore stations. It appears to be present in the area under investigation due to horizontal transport from the north.

51. Asteromphalus arachne (Brébisson) Ralfs in Pritchard, Infus. : 837, pl. 5, fig. 66 (1861); A. Schmidt, Atlas : pl. 38, figs. 3, 4 (1876); Rattray, Revis. Coscinodiscus : 665 (1889); De Toni, Syll. Alg. : 1417 (1894); Hustedt, Kieselalg. (1) : 493, fig. 276 (1930). PLATE II, fig. 1.

Local.: NIOE 150.
1 specimen recorded from an extreme offshore station in subtropical surface water in January, 1963.

General: Previously recorded from the S. Indian Ocean by Heiden & Kolbe (1928). Other Indian Ocean records include Leuduger-Fortmorel (1878,

- Ceylon), Mann (1937) and Wood (1962). Mann (1937) also recorded the species from the Antarctic region, and it has been found in European waters (Hustedt, 1930). The species is only rarely found in the cited localities and its distribution is imperfectly known. It appears to be predominantly oceanic and cosmopolitan.

Kolbe (1957) has found it rarely in cores from the Equatorial Indian Ocean.

52. Asteromphalus diminutus Mann, Diat. Australas. Antarct. Exped. 1911 - 14 : 25, pl. 2, figs. 3, 4, (1937); Kolbe, Rep. Swedish Deep-Sea Exped. 1947 - 1948 9 (1) : pl. 1, fig. 2 (1957)
PLATE 11, fig. 4.

System.: The only distinction between this species and A. antarcticus Castr. (1886, p. 135, pl. 16, fig. 11) appears to be the straightness of the umbilical lines in the latter species, a rather dubious character for specific seperation.

Local.: NIOE 150.
1 specimen (illustrated) at an oceanic station in January, 1963.

General: Apparently it has only been previously recorded by Mann (1937) and Kolbe (1957) from the Antarctic and sediment in the Equatorial Indian Ocean respectively.

53. Asteromphalus flabellatus (Brébisson) Greville, Q.J. Micr. Sci. 7 : figs. 4, 5 (1859); A. Schmidt, Atlas : pl. 38, figs. 10, 11, 12 (1876); Rattray, Revis. Coscinodiscus : 662 (1889); De Toni, Syll. Alg. : 1414 (1894); Peragallo, Diat. Mar. France : 406, pl. 110, figs. 4, 5 (1902); Hustedt, Kieselalg. (1) : 498, fig. 279 (1930); Allen & Cupp, Plankt. Diat. Java Sea : 123, fig. 22 (1935); Subrahmanyan, Proc. Indian Acad. Sci. 24 : 105, figs. 81, 85 (1946).

Local.: NIOE 88.
One specimen recorded from a southern offshore station in July, 1962.

General: Recorded from the Indian Ocean by numerous authors, particularly in the vicinity of the East Indies (Wood, 1963, b). It has also been found in the Antarctic (Karsten, 1905, etc.). Hustedt (1930) considered it to be a littoral form frequently occurring in the plankton, i.e. tychopelagic. Silva (1956) found it to be rare in the waters off Mozambique.

54. <u>Asteromphalus</u> <u>hepactis</u> (Brébisson) Ralfs in Pritchard, Infus. : 838, pl. 8, fig. 21 (1861); Rattray, Revis. Coscinodiscus : 664 (1889); De Toni, Syll. Alg. : 1416 (1894); Hustedt, Kieselalg. (1) : 494, fig. 269 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer.: 69, fig. 32 (1943).

Local.:9 NIOE 2, 3, 16, 36, 62, 74, 75, 76, 77, 85, 87, 95, 114, 128, 142, 144, 178.
Commonly found in material from all four cruises but not in large numbers. Distribution almost entirely restricted to the Agulhas Current and inshore of it, particularly north of East London.

General: It is common in European waters and "frequently met with around South Africa" (Hendey, 1937). Numerous Indian Ocean references have been cited by Wood (1963, b), and in addition Silva (1956) recorded it from Mozambique waters. Kolbe (1957) found a few specimens in one of his Indian Ocean cores.

55. <u>Asteromphalus</u> <u>indicus</u> Silva, Estud. Microplanct. Mar. Mozambique : 34, pl. 3, fig. 4 (1956).

System.: Silva's description lacks a latin diagnosis, but this does not invalidate the species as the limiting date for the compulsory inclusion of a latin description for new algal species has been set at the 1st January, 1958 (Art. 36, Int. Code Bot. Nomencl., 1961). An English description of the species is provided below as the original is in Portuguese and the present author's specimens provide additional information on several features.

Valve circular, diameter 50 - 71 μ , slightly convex, divided into subtriangular sectors by 10 to 11 hyaline rays, one of which is markedly narrower than the others. The rays taper towards the margin of the valve where each is equipped with a small spine. A hyaline central area, approximately one third of the total diameter of the valve, results from the conjunction of the rays, and the umbilical lines thus formed are relatively straight, joining the centro-lateral area which extends slightly beyond the centre of the valve. The centro-lateral area is more or less constricted.

Local.: NIOE 3, 35, 59, 62, 74, 78, 87.
Found during April and July, 1962, rare, at stations situated in or adjacent to the Agulhas Current.

General: Silva (1956) first recorded the species from the inshore water off Mozambique. No further records have come to hand. Its presence in the area under present study appears to be due to southward transport by the Mozambique Current into the Agulhas Current.

56. Asteromphalus robustus Castracane, Atti Accad. Pontif. N. Linc. 28 : 393, pl. 6, fig. 5 (1875); A. Schmidt, Atlas : pl. 38, fig. 9 (1876, unnamed, fide Hustedt, 1930); Hustedt, Kieselalg. (1) : 496, fig. 278 (1930).
PLATE II, figs. 3, 4.

Local.: NIOE 162.
Two individuals were observed from an oceanic station in January, 1963.

General: This appears to be a first record for the Indian Ocean. Wood (1963, b) has indicated that the records of several earlier authors were the result of misidentifications. The specimens observed by the present author conformed closely to the description provided by Hustedt (1930). It has been occasionally recorded from the Mediterranean and Northern European waters.

57. Asteromphalus sarcophagus Wallich, Trans. Micr. Soc. N.S. 8 : 47, pl. 2, fig. 12 (1860); Pritchard, Infus. : 838 (1861); Rattray, Revis. Coscinodiscus : 666 (1889); De Toni, Syll. Alg. : 1417 (1894); Heiden & Kolbe, Mar. Diat. Deutschen Südpolar-Exped. : 506 (1928). PLATE I, fig. 2, PL. 11, fig. 2.

Syn.: Asterolampra sarcophagus (Wallich) Greville, Trans. Micr. Soc. 8 : 124 (1860).

System.: Specimens of this species have apparently only been seen by Wallich and Heiden & Kolbe, all other references cited above referring to Wallich's material. Due to the rarity of the species it is perhaps worthwhile to provide an amplification of the description of the above authors.

Valve oblong, 31 - 45 μ in length, inflated laterally in the centre, slightly nearer the end away from the median ray, maximum width varying between 19 and 22 μ. Six rays are present on the valve, the median ray being considerably narrower than the others. The four lateral rays are slightly curved and all are bluntly rounded at the margin where each possesses a small spine. The shape of the centro-lateral space appears to be variable, the specimen illustrated on plate 1, fig. 2 differing from Wallich's illustrated specimen in this respect. Areolation in the sectors is hexagonal and the areolae are relatively large, 4 - 6 in 10 μ. A further difference between the specimen illustrated on plate 1 and Wallich's specimen lies in the outline showing a greater degree of indentation in the former. Heiden & Kolbe (1928) do not figure or describe their specimens, providing dimensions and locality only.

The other specimen figured on plate II, fig. 2, represents another type of variation in that the sides of the valve are perfectly straight. This could be considered as "variety planomarginatus" but the author is reluctant to formulate new subspecific taxa at this stage having seen only two specimens of the species.

Local.: NIOE 35, 178.
One specimen from the core of the Agulhas Current in April, 1962, and one from the vicinity of Cape Agulhas in January, 1963

General: To date this species apppears to have been recorded only from the Indian Ocean, and it is exceedingly rare. Wallich's locality cannot be fixed with accuracy as his material came from the gut of salps. Heiden & Kolbe (1928) recorded several specimens from $25^{\circ}9'S$, $55^{\circ}59'E$, further east than the area under present discussion.

Suborder AULACODISCINEAE

Family Eupodiscaceae

58. Aulacodiscus kittonii Arnott ex Pritchard, Infus. : 844, pl. 8, fig. 24 (1861); A. Schmidt, Atlas, pl. 36, figs. 3 - 9 (1876); Rattray, Revis. Aulacodiscus, 39 (1888); Hustedt, Kieselalg. (1) 506, fig. 283 (1930).

Local.: NIOE 37.

One station close inshore in April, 1962.

General: This is a sedentary species recorded from numerous localities : New Zealand, Monterey Bay (Arnott, 1861); Lofoten Islands (Joergensen *fide* Hustedt, 1930), etc. The only previous Indian Ocean record appears to be that of Leuduger-Fortmorel (1893) who found the species in the East Indies.

59. <u>Aulacodiscus</u> <u>kittonii</u> var. <u>africana</u> (Cottam) Rattray, Revis. Aulacodiscus : 40 (1888); A. Schmidt. Atlas : pl. 36, figs. 1, 2 (1876), pl. 41, figs. 7 - 10 (1875), pl. 104 fig. 1 (1886); Peragallo, Diat. Mar. France : pl. 112, fig. 2 (1902); Hustedt, Kieselalg (1) : 508, fig. 284 (1930).

System: The figures quoted above from Schmidt's Atlas and Peragallo are referred to in the works as <u>Aulacodiscus</u> <u>johnsonii</u> Arnott ex Pritchard. However Hustedt (1930) has shown that it is the above variety which is in fact figured.

Local.: NIOE 19.
One specimen from one station close inshore on line B in April, 1962.

General: A sedentary taxa, found previously in the Mediterranean (Peragallo, 1908) and widely distributed along the West Coast of Africa (Schmidt, 1876; Hustedt, 1930). It has apparently not been recorded from the Indian Ocean before.

60. <u>Aulacodiscus</u> <u>petersii</u> Ehrenberg. Ber. Berl. Akad. 1845 : 361 (1846); Rattray, Revis. Aulacodiscus : 29 (1888); De Toni, Syll. Alg. : 1115 (1894);

Peragallo, Diat. Mar. France : 412, pl. 112, fig. 1 (1902); Hustedt, Kieselalg. (1) : 505, fig. 282 (1930).

Local.: NIOE 58.
Two specimens from a sample taken close inshore near Durban (line A) in July, 1962.

General: A sedentary species. Previously recorded from Durban by Shadbolt (1854, as *Eupodiscus crucifer* Shadb.). Rarely found in the Mediterranean (Peragallo, 1908).

Suborder BIDDULPHIINEAE

Family BIDDULPHIACEAE

61. ***Biddulphia aurita*** (Lyngbye) de Brébisson & Godey, Consid. sur les Diat. : 12 (1838); A. Schmidt, Atlas : pl. 120, figs. 5 - 10, pl. 122, figs. 1 - 8, 28 (1888); Peragallo, Diat. Mar. France : 381, pl. 98, figs. 3 - 6 (1908); Gran, Diat. Nord. Plankt. : 105 (1905); Hustedt, Kieselalg 1 : 846 (1930); Cupp, Mar. Plankt. Diat. W. Coast

N. Amer. : 161, figs. 112A, 1 - 3 (1943).

Local.: NIOE 97, 111, 114, 158, 159.
Single or paired individuals observed at a few inshore stations on lines A,B, and C in July and October, 1962.

General: A sedentary species commonly found in inshore plankton collections, i.e. tychopelagic. It appears to be cosmopolitan, occurring in largest numbers in cold waters, and is found in both Arctic (Cupp, 1943) and Antarctic (Karsten, 1905) waters. Wood (1963, b) provided numerous references to the species in the Indian Ocean. It has not been recorded from the S.W. Indian Ocean previously.

62. Biddulphia chinensis Greville, Trans. Micr. Soc. 14 : 81, pl. 9, fig. 16 (1866); A. Schmidt, Atlas : pl. 122, figs. 22, 23, 24 (1886); Gran, Diat. Nord. Plankt. : 107 (1905); Hustedt, Kieselalg. (1) : 837, fig. 493 (1930); Subrahmanyan, Proc. Indian Acad. Sci. 24 : 154, figs. 281, 289 (1946). PLATE 12, fig. 1.

System.: Greville's original spelling has been retained in accordance with recommended taxonomic procedure. The orthographic variant "sinensis" *is used for this species by some authors.*

Local.: NIOE 2, 3, 58, 60, 74, 75, 77, 80, 94, 96. Occasionally recorded from the Agulhas Current and inshore near Durban, spreading south in July where it was furthest offshore at station 80. Not recorded from material collected in January.

General: Müller Melchers (1952) provided a detailed description of the distribution of this species. He concluded that it was ubiquitous, and that in some regions, e.g. the east coast of S. America and the northern North Atlantic, it could be used as an indicator of warm currents. It is interesting to consider the local distribution outlined above in the light of his conclusions. It can be seen that in general the observed distribution confirms Müller Melcher's conclusions, the species apparently being introduced into the area by the Agulhas Current. The reason for its absence from the Agulhas Current in January (when the current was strong) is not clear, but the species may not have been observed as it was never present in large numbers.

Wood (1963, b) provided numerous records of the species in the Indian Ocean, most of the records being confined to the northern and north-eastern parts. Heiden & Kolbe (1928) recorded the species from Simonstown (near Cape Town).

63. _Biddulphia laevis_ var. _schmidtii_ Forti, AttiR. Inst. Veneto _69_ (3) : 1264 (1910); Hustedt, Kieselalg. (1) : 854 (1930).

Local.: NIOE 94.

One specimen from the vicinity of Cape Agulhas in July. Little is known of the habit and distribution of this variety. The var. _laevis_ is commonly found in rivers, estuaries, and the coastal waters of Europe. It is euryhaline, judging by its distribution. The species has been recorded from weakly saline waters on the Natal coast by Cholnoky (1960). Its appearance in the plankton appears to be adventitious.

64. _Biddulphia longicruris_ Greville, Q.J. Micr. Sci. _7_ : 163, pl. 8, fig. 10 (1859); Hendey, Discovery Rep. _16_ : 276 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 154, fig. 111 A (1 - 3) (1943); Boden, Trans. Roy. Soc. S. Afr. _32_ : 396, figs. 79, 80 (1950). PLATE 12, fig. 2.

Local.: NIOE 112.

Two specimens recorded from an inshore station on line B in October, 1962.

General: This is a temperate to subtropical species (Hendey, 1937). Wood (1963, b) provided Indian Ocean records for the species. Hendey found the species frequently in Peru Current material, and Hart & Currie (1960) recorded it from the Benguella Current as "frequent and typical though never abundant, in spring samples."

65. Biddulphia mobiliensis Bailey, Amer. J. Sci. 48 : 336, pl. 4, fig. 24 (1845); Van Heurck, Synopsis : pl. 101, fig. 4 (1881); A. Schmidt, Atlas : pl. 122, figs. 20, 21 (1888); Hustedt, Kieselalg. (1) : 840, fig. 495 (1930); Hendey, Discovery Rep. 16 : 276, pl. 12, fig. 9 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 153, fig. 110 (1943); Boden, Trans. Roy. Soc. S. Afr. 32 : 394, fig. 77 (1950). PLATE 12, fig. 3.

System.: Hendey (1937) attributes this species to Grunow (in Van Heurck, 1881) for reasons not apparent in his publication. Bailey's description appears to be perfectly valid.

The species is very similar to B. regia (Schultze) Ostenfeld from which it is distinguished according to Hustedt (1930), by several minor characters, namely, a shorter apical axis and weaker silicification. From Cupp's (1943) figures and text it is clear she has included specimens of B. regis under B. mobiliensis.

Local.: NIOE 1, 2, 19, 20, 58, 59, 73, 74, 75, 76, 77, 94, 95, 96, 111, 112, 114, 115, 128, 130, 142, 143, 158, 160, 161, 162, 176, 178.
The commonest representative of Biddulphia encountered. Commonly found in samples from inshore stations on all lines and in material collected on each of the four cruises. Found in maximum relative abundance (++) at stations 19, 94, and 161, i.e. over the Agulhas Bank in April, July and January.

General: "Widely distributed in both hemispheres .... often associated with the coastal flora, and sometimes found in great numbers" - Hendey (1937). There are numerous records of the species from the Indian Ocean (Wood, 1963, b).

66. _Biddulphia_ _regia_ (Schultze) Ostenfeld, Meddel. Komm. Havunders. Ser. Plankt. _1_ (6) : 7, fig. 3 (1908); Hustedt, Kieselalg. (1) : 838, fig. 494 (1930); Hendey, Discovery Rep. _16_ : 278, pl. 12, figs. 2, 3 (1937).

Local.: NIOE 80, 130.

Rare, two specimens observed, one from an offshore station on line C in July, th other from the vicinity of Cape Agulhas (inshore, line D) in October.

General: A common neritic species in the North Sea and Mediterranean (Hustedt, 130). It has been recorded from the Indian Ocean to the south of Madagascar by Hendey (1937), and also from the Antarctic by Van Heurck (1909, as _B. baileyi_ W. Smith). Wood (1963, b) provided two other references to records of the species from Ceylon and the west coast of Australia.

67. _Biddulphia_ _tridens_ (Ehrenberg) Ehrenberg, Ber. Berl. Akad. 1840 : 205 (1841).

Syn.: _B._ _tuomeyi_ (Bailey) Roper, Trans. Micr. Soc. _7_ : 8, pl. 1, figs. 1, 2, (1859); A. Schmidt, Atlas : pl. 118, figs. 1 - 7, 13 - 18, pl. 119, figs. 1 - 8, 15 - 17 (1886); Peragallo, Diat. Mar. France : 377, pl. 93, figs. 3, 4 (1908);

Hustedt, Kieselalg. (1) ; 834, fig. 491 (1930).

PLATE 12, fig. 4.

System.: Roper (1859), aware that Ehrenberg's specific epithet had priority over Bayley's "tuomeyi", nevertheless rejected it in favour of the latter on the grounds that the name was inappropriate to cells which had one to twelve lobes. Due to the common usage of Roper's combination there are reasonable grounds for conserving it, but until such time as this is done officially Ehrenberg's combination must be considered as the only valid one.

Local.: NIOE 111.

A pair of cells observed in material from an inshore station on line B in October. As the species is usually considered as sedentary its presence in the plankton is probably adventitious.

General: This species is common and widely distributed in the littoral zones of southern Europe and warmer areas (Hustedt, 1930). Wood (1963, b) provided several references to records of the species from the Indian Ocean. In addition to these Shadbolt (1854) found the species in material from Durban (Port Natal, as Denticella margaritifera), and it has been observed in cores from coastal areas in the Equatorial Indian Ocean by Kolbe (1957, as *B. tuomeyi*).

68. *Cerataulina pelagica* (Cleve) Hendey, Discovery Rep. 16 : 279 (1937).

Syn.: *C. bergonii* (H. Peragallo) Schütt, in Engler & Prantl, Naturl. Pflanzenf. 1 (1) : 95 (1896); Peragallo, Diat. Mar. France : 389, pl. 106, figs. 6, 7 (1908); Gran, Diat. Nord. Plankt. : 101, fig. 132 (1905); Hustedt, Kieselalg. (1) : 869, fig. 517 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Aner. : 1~~5~~67, fig. 117 (1943).

System.: Hendey (1937) has given clear reasons why this species, commonly known under the synonym cited above, should bear Cleve's specific epithet. Further, he has shown that the combination *C. bergonii* should be ascribed to Schütt and not to H. Peragallo as has usually been done.

Local.: NIOE 1, 2, 5, 9, 12, 18, 19, 20, 34, 36, 58, 59, 60, 62, 73, 74, 75, 76, 77, 80, 91, 96, 101, 108, 112, 115, 117, 124, 128, 158, 159, 160, 161.

A common species, occasionally abundant at inshore stations on lines A, B, and C.

Highest relative abundance estimates (+++ at station 73) recorded for July but present on all four cruises. Not confined to the shelf zones but characteristically occurring in greater abundance over the continental shelf.

General: Considered to be neritic, temperate to tropical, by Hustedt (1930) and Cupp (1943). Numerous references from the tropical and subtropical Indian Ocean (Wood, 1963, b). Kolbe (1957) recorded resting spores of the species from one inshore Indian Ocean core, also reporting it as "frequent" in a plankton sample from the west coast of India. Hart & Currie (1960) recorded the species from the vicinity of Walvis Bay on the west coast of S. Africa, but not from the most southern part of the area they surveyed.

69. Climacodium biconcavum Cleve, Treat. Phytopl. Atlantic & Tribut. : 22, pl. 2, figs. 16, 17 (1897); Gran, Diat. Nord. Plankt. : 100, fig. 130 (1905); Karsten, Valdivia Atlant. Phytopl. : 172, pl. 28, fig. 10 (1906); Hustedt, Kieselalg. (1) : 777, fig. 454 (1930); Lebour, Plankt. Diat. Northern Seas : 189, fig. 149 (b) (1930);

Hendey, Discovery Rep. 16 : 287, pl. 12, fig. 13 (1937). PLATE 1, figs. 4, 5.

System.: The author experienced difficulty in distinguising this species from Hemiaulus membranaceus Cleve. The smaller specimens observed (pl. 1, fig. 5) closely resembled Hustedt's description and figure of the species and also Karsten's figure. Cleve's original description and figures are poor. However, the published figures possess a distinctive feature not commented on by the above authors, i.e. the corners of the valves are characteristically protruberant and constricted. This feature is indicated in outline in Karsten's and Hustedt's figures but not distinctly.

There was a complete range in size and shape from the smaller specimens to the larger (pl. 1, fig. 4) and when chain formation occurred the ends of the cells overlapped in a characteristic alternate manner. This type of overlapping is shown clearly in Cleve's original figure for Hemialus membranaceus (Diat. Sea of Java, p. 6, pl. 1, fig. 5, 1873). It seems that with an increase in the width (as seen in girdle view) of the cells the shape of the foramina between the cells becomes elongated, and it does not seem inconceivable that the valve surfaces could become almost parallel, as in the case of Cleve's original figure of *Hemiaulus membranaceus*.

It is interesting to note that Schröder's *Climacodium japonicum* seems to bridge the difference between the large specimens (pl. 1, fig. 4) and Cleve's *Hemiaulus membranaceus*. Further confusion is added by the fact that Ostenfeld (1902) considered that *Climacodium biconcavum* should be transferred to the genus *Eucampia*.

Clearly the genera *Climacodium*, *Eucampia* and *Hemiaulus* are closely related, and further study is required to clarify their relationship to one another, and the status of problematic species such as those mentioned above.

Local.: NIOE 1, 2, 3, 18, 19, 21, 35, 58, 59, 60, 62, 64, 73, 74, 75, 77, 78, 110, 111, 112, 142, 143, 144, 157, 158, 162, 164, 175.

Predominantly distributed in the Agulhas Current and inshore of it. Common but not abundant on all cruises. It was restricted to inshore stations on line B in October.

April and January. A detailed description and discussion of the observed distribution of this species is provided in Section IV.

General: Oceanic, widely distributed in tropical and subtropical seas. It has been recorded from the area under present survey by Hendey (1937). Numerous Indian Ocean records are listed by Wood (1963,b).

71. Ditylum brightwellii (West) Grunow in Van Heurck, Synopsis : 196, pl. 114 (1885); A. Schmidt, Atlas: pl. 152, figs. 10 - 13 (1890); Peragallo, Diat. Mar. France : 395, pl. 96, figs. 6 - 11 (1908); Hustedt, Kieselalg. (1) : 784, figs. 457 - 459 (1930); Hendey, Discovery Rep. 16 : 284, pl. 12, figs. 5, 6 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 148, figs. 107 A - B (1943).

Local.: NIOE 60, 74, 75, 77, 94, 96, 111, 113, 114, 128, 130, 159, 178.

Not present in material from the April survey. Present in small numbers at inshore stations mainly in the south west. Most widespread in July. Locally abundant at stations 94 and 160 (Cape Agulhas and Port Elizabeth in October and January respectively).

General: Common in European waters, neritic (Hustedt, 1930), a south temperate species off the West Coast of North America (Cupp, 1943), also subtropical in the Indian and Pacific Oceans (Hendey, 1937). Recorded from near Cape Town by Robinson (1948) and Boden (1950). Several Indian Ocean references are provided by Wood (1963,b).

The known distribution of this species suggests that it is commonest and most abundant in temperate waters although it is also found in subtropical and antarctic waters.

72. Ditylum sol (Grunow) De Toni, Syll. Alg. : 1018 (1894); A. Schmidt, Atlas : pl. 152, figs. 4, 5, 9 (1890, fide Hustedt, 1930) Hustedt Kieselalg. (1) : 787, fig. 460 (1930); Hendey, Discovery Rep. 16 : 285, pl. 12, fig. 4 (1937); Subrahmanyan, Proc. Indian Aca. Sci. 24 : 149, fig. 266 (1946).

Local.: NIOE 2, 17, 58, 60, 62, 74, 75, 77, 80, 84, 87, 95, 96, 117, 143, 144, 158, 159, 161, 176.

Occasional in samples from all four cruises, never more than 5 specimens per subsample present. Found at inshore stations on lines

A and B, and at offshore stations in the south. Found furthest south, i.e. stations 80, 84 and 87, in July.

General: A tropical species (Hustedt, 1930; Hendey, 1937), "probably oceanic" (Hendey). Wood (1963,b) provided several references to the species in the Indian Ocean. Hendey (1937) found the species in the S. Atlantic Ocean and around the Cape of Good Hope.

It appears that its presence in the sector of the S.W. Indian Ocean investigated is due to southward transport by the Agulhas Current system.

73. Eucampia cornuta (Cleve) Grunow in Van Heurck, Synopsis : pl. 95 b, fig. 5 (1885); Karsten in Engler & Prantl, Naturl. Pflanzenf. 2 : 237, fig. 280 (1928); Hustedt, Kieselalg (1) : 774, fig. 452 (1930); Hendey, Discovery Rep. 16 : 286, pl. 12, fig. 10 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 146, fig. 104 (1943).

Local.: NIOE 2, 5, 12, 18, 19, 58, 59, 60, 62, 64, 71, 73, 74, 75, 77, 78, 80, 85, 87, 88, 91, 95, 96, 97, 99, 103, 108, 111, 112, 114, 115, 119, 121, 124, 128, 142, 143, 144, 157, 158, 159, 161, 176.

Common and moderately abundant (++, occasionally +++) at stations on all four cruises. Most widespread in July, confined to neritic and Agulhas Current stations in October.

General: An oceanic species with a wide distribution in tropical and subtropical seas (Hendey, 1937). Hendey found that it occurred particularly frequently off the east coast of Africa. Wood (1963,b) has provided other Indian Ocean references.

74. Eucampia zoodiacus Ehrenberg, Ber. Berl. Akad. 1839 : 151 (1840); Gran, Diat. Nord. Plankt. : 98, fig. 126 (1905); Hustedt, Kieselalg. (1) : 772, fig. 451 (1930); Hendey, Discovery Rep. 16 : 286, pl. 12, fig. 7 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 145, fig. 103 (1943).

Local.: NIOE 14, 18, 19, 25, 74, 75, 95, 112, 130, 142, 143, 159, 160, 176.

Found in the vicinity of Port Elizabeth on all four cruises, and near Durban in October and January only. It exhibited a markedly neritic distribution.

General: Given as a south temperate species of the W. Coast of N. America by Cupp (1943). Common in northern European waters and in the Mediterranean (Hustedt, 1930). Recorded from one station off the east coast of Africa by Hendey (1937). Further Indian Ocean references are listed by Wood (1963,b).

75. *Hemiaulus chinensis* Greville, Ann. Mag. Nat. Hist. 16 (591) : pl. 5, fig. 9 (1856); Peragallo, Diat. Mar. France : 392, pl. 94, figs. 3 - 5 (1908); Hustedt, Kieselalg. (1) : 875, fig. 519 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 168, fig. 119 (1943); Subrahmanyan, Proc. Indian Acad. Sci. 24 : 159, figs. 307 - 309, 313 (1946).

System.: The orthographic variant "*sinensis*" is rejected in favour of that used by the original author.

The specimens in the S.W. Indian Ocean area are in general more elongated than those from other areas, particularly with regard to the processes which may reach 30 - 40μ in length. This leads to a superficial resemblance with *H. hauckii*. Furthermore, the sculpturing on the valve is difficult to observe in some specimens and there is a possibility of confusing the two species in this area.

Local.: NIOE 5, 7, 9, 10, 12, 16, 17, 58, 59, 60, 62, 64, 66, 69, 71, 73, 74, 76, 77, 78, 80, 84, 85, 87, 88, 91, 93, 95, 96, 97, 99, 101, 103, 108, 110, 111, 112, 114, 115, 117, 121, 124, 128, 142, 143, 157, 158, 159, 161, 178.

Common and occasionally present in large numbers at both inshore and offshore stations on all four cruises; most widespread in July.

General: It was considered to be a neritic, warm water species by Hustedt (1930) and Cupp (1943). There are numerous records of the occurrence of this species in the Indian Ocean (Wood, 1963,b).

In view of the local distribution it would seem preferable to consider the species as panthallassic rather than neritic.

76. Hemiaulus hauckii Grunow in Van Heurck, Synopsis : pl. 103, fig. 10 (1881); Peragallo, Diat. Mar. France: 398, pl. 95, fig. 6 (1908); Hustedt, Kieselalg. (1) : 874, fig. 518 (1930); Hendey, Discovery Rep. 16 : 285, pl. 12, fig. 14 (1937); Cupp,

Mar. Plankt. Diat. W. Coast N. Amer. : 168, fig. 118 (1943).

Local.: NIOE 5, 110, 111, 128, 144, 148, 150, 155, 157, 162, 164, 174.

Occasionally present at offshore and inshore stations, not present in July material, widespread over the offshore area and locally abundant in January.

General: Formerly considered to a neritic species (Hustedt, 1930), termed "Oceanic?" by Hendey (1937), and found in both provinces by Cupp (1943). It is found in largest numbers in tropical waters, but spreads into temperate regions. Hendey recorded the species as "very common" of the east coast of Africa. Wood (1963,b) has provided further Indian Ocean references.

It is apparent that this species can be considered as panthallassic in distribution.

77. Isthmia enervis Ehrenberg, Infus. : 207, pl. 16, fig. 6 (1838); W. Smith, Syn. British Diat. 2 : 52, pl. 48 (1856); Peragallo, Diat. Mar. France : 375, pl. 92 (1908); Hustedt, Kieselalg. (1) : 866, fig. 516 (1930).

Local.: NIOE 142, 160.

A few individuals were present in extreme inshore samples from the January cruise. Their presence in the plankton is presumably adventitious as the species is characteristically sedentary.

General: Ubiquitous in the littoral zone of all oceans (Hustedt, 1930). Specimens of the species are common in collections of sedentary diatoms from various localities around the coast of S. Africa (the present author's observations). Wood (1963,b) has listed references to the species in Northern and Western Indian Ocean waters.

78. Streptotheca thamesis Shrubsole, J. Queckett Micr. Club, Ser. 2, 4 : 260 pl. 13, figs. 4 - 6 (1890); Gran, Diat. Nord. Plankt. : 101, fig. 131 (1905); Hustedt, Kieselalg. (1) : 779, fig. 455 (1930); Hendey, Discovery Rep. 16 : 287, pl. 12, fig. 11 (1937); Cupp, Mar. Plankt. Diat. West Coast N. Amer. : 147, fig. 106 (1943).

Local.: NIOE 17, 19, 20, 58, 59, 74, 75, 77, 95, 96, 112, 113, 114, 115, 142, 143, 144, 159, 161, 176.

Local.: NIOE 142, 160.

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78. <u>Streptotheca</u> <u>thamesis</u> Shrubsole, J. Queckett Micr. Club, Ser. 2, <u>4</u> : 260 pl. 13, figs. 4 - 6 (1890); Gran, Diat. Nord. Plankt. : 101, fig. 131 (1905); Hustedt, Kieselalg. (1) : 779, fig. 455 (1930); Hendey, Discovery Rep. <u>16</u> : 287, pl. 12, fig. 11 (1937); Cupp, Mar. Plankt. Diat. West Coast N. Amer. : 147, fig. 106 (1943).

Local.: NIOE 17, 19, 20, 58, 59, 74, 75, 77, 95, 96, 112, 113, 114, 115, 142, 143, 144, 159, 161, 176.

Recorded in small numbers from inshore stations on all four cruises. It extended as far north as Durban in July, October and January.

General: A neritic species with a wide distribution in temperate and subpolar seas (Hendey, 1937).

From the local distribution it would appear that the species can survive in subtropical conditions such as those near Durban ($\pm$ 23°C).

79. *Triceratium alternans* Bailey, Smithsonian Contrib. Knowl. *2* (3) : 14, pl. 1, figs. 55, 56 (1851); Peragallo. Diat. Mar. France : 377, pl. 103, fig. 1 (1908); Hustedt, Kieselalg. (1) : 825, fig. 488 (1930). PLATE 12, fig. 5.

Syn.: *Biddulphia alternans* (Bail.) Van Heurck, Synopsis: pl. 113, figs. 4, 5, 7 (1881); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 166, fig. 115 (1943).

System.: Species of several genera were grouped by Van Heurck (1881) under the genus *Biddulphia*. However, as Hendey (1937) has pointed out, this resulted in the only feature common to all species of *Biddulphia* being an angularity of outline. The present author has followed Hustedt (1930) in retaining the species under *Triceratium*, the genus under which it was first described.

Local.: NIOE 94.

Two joined individuals were observed from the vicinity of Cape Agulhas in July.

General: The only previous records of this sedentary species in the Indian Ocean appear to be those of Leuduger-Fortmorel (1878, as _T. variabile_) and Subrahmanyan (1946, 1958), both in the Northern Indian Ocean. Hustedt (1930) recorded it as "nicht selten" on European coasts, also commenting that it is found as long chains in plankton collections.

It seems possible that the species is tychopelagic, although its presence in plankton samples may be purely adventitious.

80. _Triceratium antediluvianum_ (Ehrenberg) Grunow, Diat. Novarea Exped.: 24 (1870); Gran, Diat. Nord. Plankt. : 111, fig. 147 (1905, sub _Biddulphia vesiculosa_ Boyer); Peragallo, Diat. Mar. France : 383, pl. 102, figs. 1 - 7 (1908); Hustedt, Kieselalg. (1) : 810, fig. 472 (1930)

Local.: NIOE 112.

Two specimens were observed in material from the most inshore station on line B in October, 1962.

General: This is a widely distributed sedentary species, common and occasionally abundant on the Atlantic coasts of Europe and America (Hustedt, 1930). There appear to be only two previous records of the species from the Indian Ocean : Leuduger-Fortmorel (1878, Ceylon, as *Amphitetras*) and Cleve (1901, Java, under several synonyms). Its presence in plankton collections is probably adventitious.

81. *Triceratium favus* Ehrenberg, Abh. Berl. Akad. 1839 : 159, pl. 4, fig. 10 (1841); Gran, Diat. Nord. Plankt. : 109, fig. 147 (1905, sub *Biddulphia favus*); Peragallo, Diat. Mar. France : 385, pl. 99, figs. 1, 2, 3 (1908); Hustedt, Kieselalg. (1) : 798, figs. 462, 463 (1930).

Local.: NIOE 76.

One individual found in inshore material from Port Elizabeth in July.

General: A widely distributed sedentary diatom, abundant on the coasts of Europe (Hustedt, 1930). Wood (1963,b) has provided numerous references to the species in the Indian Ocean.

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82. Bacteriastrum comosum Pavillard, Rech. sur les diat. pélag. du Golfe du Lion : 29, pl. 1, fig. 3 (1916); Ikari, Bot. Mag. Tokyo 41 : 428, fig. 8 (1927); Hustedt, Kieselalg. (1) : 622, fig. 361 (1930); Hendey, Discovery Rep. 16 : 306 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer.: 99, fig. 58 (1943).

Local.: NIOE 2, 5, 7, 9, 10, 12, 14, 23, 34, 58, 60, 62, 69, 71, 73, 75, 77, 78, 80, 84, 87, 91, 96, 99, 103, 108, 112, 114, 115.

Present in moderate numbers at oceanic stations in April, July and October, 1962. Extends into the inshore area on lines A and B and occasionally inshore on line C. It was commonest in the northern offshore region. Maximum abundance (+++) was recorded at stations 12 and 78, an offshore station on line B in April, and a station on the edge of the continental shelf on line C in July respectively.

General: This is an oceanic, subtropical species (Cupp, 1943). Hendey (1937) found the species "in considerable quantity" off the east coast of

Africa, considering it to be probably neritic. It has been recorded from all the major oceans, and there are several references to the species in the Indian Ocean (Wood, 1963,b). In addition to these there is the reference of Silva (1956) from the coast of Mozambique. This is another case of the spread of oceanic species into the neritic zone on lines A and B, suggesting that the Natal coastal shelf is strongly under the influence of the Agulhas Current.

83. Bacteriastrum elongatum Cleve, Treat. Phytopl. Atlantic & Trib. : 19, pl. 1, fig. 19 (1877); Gran, Diat. Nord. Plankt. : 58, fig. 73 (1905); Ikari, Bot. Mag. Tokyo 41 : 425, fig. 5,a (1927); Hustedt, Kieselalg. (1) : 617, fig. 357 (1930); Hendey, Discovery Rep. 16 : 307 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 99, fig. 57 (1943).

Local.: NIOE 12, 73, 74, 77, 78, 80, 85, 91, 108, 112, 114, 115, 121, 124.

Found at only one offshore station on line B in April, neritic and oceanic stations on lines B, C, and D in July and October, and not present in January. It occurred in only small numbers (+ - ++). It apparently has a more southern distribution than B. comosum in this region.

General: An oceanic species found in temperate waters (Cupp, 1943). Wood (1963,b) has provided the Indian Ocean references for this species, omitting Silva (1956) from Mozambique waters.

84. Bacteriastrum furcatum Shadboldt, Trans. Micr. Soc., N.S., 2 : 14, pl. 1, fig. 1 (1854).

Syn.: B. curvatum Shadboldt, loc. cit. : 14, pl. 1, fig. 2 (1854).

B. delicatulum Cleve, Fifteenth ann. Rep. Fish. Board Scotland (3) : 298, fig. 15 (1897); Gran, Diat. Nord. Plankt. : 58, fig. 72 (1905); Ikari, Bot. Mag. Tokyo 41 : 424, fig. 4 (1927); Hustedt, Kieselalg. (1) : 612, fig. 353 (1930); Hendey, Discovery Rep. 16 : 307 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 96, fig. 55 (1943).

System.: Shadboldt was unaware of the complete form of this species, describing only dissociated valves. It is no doubt for this reason that he was unaware of the dimorphic nature of the awned valves and thus considered the valves as belonging to separate species. The valves he described and figured are identical to the terminal and internal valves of _B. delicatulum_, a similarity noted by both Ikari and Hustedt although they did not follow the rules of priority by using Shadboldt's epithet.

Local.: NIOE 99, 101, 103, 124, 126, 148, 155, 162, 176.

Not identified in the April of July material. Present in small numbers at scattered offshore stations in October and January.

General: An oceanic, temperate species (Cupp, 1943). Hendey (1937) recorded it occasionally in S. African waters (as _B. delicatulum_). It was first described by Shadboldt (1854) from Durban (Port Natal). There are many other Indian Ocean references (Wood, 1963,b under _B. delicatulum_) Heiden & Kolbe (1928) recorded it (as _B. delicatulum_) from Simonstown, S. Africa.

85. _Bacteriastrum hyalinum_ Lauder var. _hyalinum_, Trans. Micr. Soc., N.S., _12_ : 6, pl. 3, fig. 7 (1864); Ikari, Bot. Mag. Tokyo _41_ : 422, fig. 2 (1927); Hustedt, Kieselalg. (1) : 615, fig. 354 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer

96, fig. 56-A (1943); Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 367, fig. 46 (1950).

Local.: NIOE 75, 89, 94.

Recorded in small numbers (+ - ++) at a few stations, neritic on lines B and D, and oceanic on line D, in July only.

General: The typical variety is distributed in colder waters than the variety princeps discussed below. It is widely distributed in the North Atlantic (Hustedt, 1930) and is common in the colder parts of the eastern Pacific Ocean (Cupp, 1943). It has been recorded by Boden (1950) and Hart & Currie (1960) from the west coast of S. Africa. The majority of references provided by Wood (1963,b) for this species refer to the variety princeps (he did not distinguish between them) andhhe also included B. minus Karsten under this species, a misconception which possibly originates from Mill's Index (1933) where the two species are considered synonymous. This is further discussed under B. minus in the present study. The variety hyalinum has certainly been recorded from the Madras coast of India (Subrahmanyan, 1946) and the vicinity of Java (Allen & Cupp, 1935) and so it does appear to spread into tropical and subtropical areas.

Its presence at the local stations cited above appears to be due to transport from the west coast region.

86. Bacteriastrum hyalinum var. princeps (Castracane) Ikari, Bot. Mag. Tokyo 41 : 423, fig. 3 (1927); Hustedt, Kieselalg. (1) : 615, fig. 355 (1930); Hendey, Discovery Rep. 16 : 308 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 98, fig. 56-B (1943); Subrahmanyan, Proc. Indian Acad. Sci. 24 : 127, figs. 165, 168 (1946).

Local.: NIOE 5, 17, 18, 19, 20, 23, 36, 73, 74, 75, 76, 101, 144, 178.

Occurring primarily at inshore stations over the Agulhas Bank but also found offshore on line A. Confined to one offshore station (101) in October. It was locally abundant (+++) at stations 36, 74, and 101.

General: Hendey (1937) found the variety to be very common "around South Africa". Hustedt (1930) and Cupp (1943) both considered it as occurring in warmer water than the variety hyalinum.

Most of the Indian Ocean records of this variety refer to the northern subtropical regions (Wood, 1963,b; see note under the variety hyalinum).

87. Bacteriastrum minus Karsten, Valdivia Atlant. Phytopl. : 171, pl. 33, fig. 21 (1905); Mangin, Soc. Linn. de Bordeaux, Actes, 65 : 27, text fig. (1911); Ikari, Bot. Mag. Tokyo 41 : 426, fig. 6 (1927); Subrahmanyan, Proc. Indian Acad. Sci. 24 : figs. 164, 167 (1946, sub B. hyalinum ? Lauder); Silva, Micropl. Mar. Mocambique : 37, pl. 4, fig. 5 (1956). PLATE 13, fig. 1.

System: This easily identifiable species, first described from the vicinity of Port Elizabeth, has been frequently confused with B. hyalinum Lauder. The reason for this is not clear as the two species differ from one another in the manner in which the setae (or awns) of adjacent cells cross one another. In B. minus the adjacent setae merely touch at the cross-over point without any marked degree of fusion, whereas in B. hyalinum the adjacent setae fuse with one another for some distance before bifurcating distally.

The chain of cells described and figured originally by Karsten was imbedded in a gelatinous material, but this feature does not appear to be the usual case, none of the other authors cited having observed this. The specimens in the present author's material were also quite free of mucilage.

Local.: NIOE 18, 19, 20, 21, 34, 35, 58, 59, 62, 73, 74, 77, 80, 84, 114, 115, 124, 143, 158, 161.

Present in the inshore areas of line B and C on all cruises, locally abundant (+++ - ++++) at stations 18, 19, 20, and 73. It spread northward to Durban (inshore line A) in July and January, and appeared to be carried offshore in the south in July and October. The region between Port Elizabeth and Port S. Johns appears to be its centre of distribution in the area.

General: Previously recorded from Port Elizabeth (Karsten, 1906), the northwest coast of Africa (Mangin, 1911), Japanese waters (Ikari, 1927), the coast of India (Czapek, 1909; Subrahmanyan, 1946) and the coast of Mozambique (Silva, 1956).

It appears to be a subtropical to temperate neritic species.

88. Bacteriastrum varians Lauder var. varians, Trans. Micr. Soc., N.S., 12 : 6, figs. 1 - 5 (1864); Karsten, Valdivia Atlant. Phytopl. : 170, pl. 34, fig. 1 (1905); Gran, Diat. Nord. Plankt. : 57, fig. 71 (1905); Ikari, Bot. Mag. Tokyo 41 : 421, fig. 1 (1927); Allen & Cupp, Ann. Jard. Bot. Buitenzorg 44 (2) : 133, fig. 48 (1935); Hendey, Discovery Rep. 16 : 308 (1937); Subrahmanyan, Proc. Indian Acad. Sci. 24 : 127, figs. 170, 171, 172, 175 (1946).

Local.: NIOE 58, 59, 60, 62, 64, 71, 73, 74, 77, 78, 80, 84, 85, 91, 95, 96, 103, 110, 111, 113, 115, 124, 142, 161, 178.

Not apparently present in April. Super-abundant (+++++) at station 58 near Durban in July, and abundant (+++ - ++++) at surrounding stations, also spreading down into the southern offshore region in the same month. Again recorded from Durban (+++) in October when it was present at offshore stations on line A and inshore stations on lines B & C. InnJanuary it was restricted in small numbers to imshore stations at Durban (A), Port Elizabeth (C) and Cape Agulhas (D).

General: Hendey (1937) considered the species to be oceanic with a tropical distribution, having recorded it as frequent around the coast of S. Africa. There are numerous references to the occurrence of the typical variety in the Indian Ocean (see Wood, 1963,b).

Although it also occurred at both northern and southern oceanic regions in the area under study it achieved maximum abundance at neritic stations and it is possible that the typical variety is actually neritic.

89. Bacteriastrum varians var. hispidum (Castracane) Schröder, Vischr. naturf. Ges. Zurich 51 : 347, fig. 11 (1906); Allen & Cupp, Ann. Jard. Bot. Buitenzorg 44 (2) : 133, fig. 49 (1935). PLATE 3, fig. 4.

Local.: NIOE 62, 74, 99, 112, 161.

Usually only one chain observed in subsamples from each of the above stations, all Agulhas Current or inshore stations on lines A and B (the latter on line C). Not recorded from the April material.

General: This variety has only been rarely recorded from tropical Indian Ocean and Far East waters. It appears to be introduced to the area under study by the Agulhas Current.

Family CHAETOCERACEAE

When Ehrenberg (1844) formulated the genus <u>Chaetoceros</u>, he described two species, <u>Ch</u>. <u>dichaeta</u> and <u>Ch</u>. <u>tetrachaeta</u>, the endings of which indicate that he considered the genus to be neuter in gender. Since that time authors have either followed him or altered the endings to the masculine gender. The present author has been informed by Prof. T.J. Haarhoff, Professor of Classics (retired) of the University of Witwatersrand, that the ending of the genus is undoubtedly masculine, and so the species listed below have been treated accordingly.

90. <u>Chaetoceros</u> <u>aequatorialis</u> Cleve, Bih. K. Svenska Vet.-Akad. Handl. <u>1</u> (11) : 10, pl. 2, fig. 9 (1873); Karsten, Valdivia Indische Phytopl. : 389, pl. 45, figs. 1a, 1b, 1c (1907); Hendey, Discovery Rep. <u>16</u> : 294 (1937).

Local.: NIOE 71, 78, 80, 84, 85, 87, 88, 89, 91, 95, 96, 97, 99, 101, 103, 108, 111, 112, 114, 115, 120, 124, 128, 142, 143, 144.

Occurring at most offshore stations on lines C and D in July, widespread over the area in

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Local.: NIOE 71, 78, 80, 84, 85, 87, 88, 89, 91, 95, 96, 97, 99, 101, 103, 108, 111, 112, 114, 115, 120, 124, 128, 142, 143, 144.

Occurring at most offshore stations on lines C and D in July, widespread over the area in

October, confined to three stations near Durban in January. It usually occurs as single cells in the area. Not present in April. It extended into the inshore area on lines A and B only, this being a common phenomenon with regard to oceanic species in the area.

General: "An oceanic species, widely spread throughout the Indian Ocean" (Hendey, 1937). He recorded it from the area under present survey. Wood (1963,b) listed several others who have recorded the species from the Indian Ocean. It has also been recorded from the western Pacific Ocean in the vicinity of the East Indies.

91. Chaetoceros affinis Lauder f. affinis, Trans. Micr. Soc., N.S. 12 : 68, pl. 8, fig. 5 (1864); Peragallo, Diat. Mar. France : 478, pl. 129, figs. 2, 3, 7, pl. 130, figs. 1 - 4 (1904); Hustedt, in A. Schmidt, Atlas : pl. 323, figs. 1, 2, pl. 325, Mar. Plankt. Diat. W. Coast N. Amer. : 125, figs. 78-A (1, 2)(1943); Brunel, Phytopl. Baie Chaleurs : 114, pl. 27, fig. 1 (1962).

Local.: NIOE 1, 2, 5, 7, 9, 10, 12, 17, 18, 19, 20, 21, 34, 36, 58, 59, 60, 62, 69, 71, 73, 74, 75, 76, 77, 80, 84, 85, 87, 88, 89, 91, 95, 96, 99, 101, 104, 108, 111, 112, 113, 114, 115, 119, 121, 124, 142, 143, 144, 158, 159, 160, 178.

A common species, widespread over the area in July and October, more confined to neritic stations in April and January. It achieved maximum abundance (+++ - ++++) at inshore stations north of Port Elizabeth, particularly in July.

General: A widespread form, neritic, occurring in the temperate zones of all oceans (Hustedt, 1930; Cupp, 1943). It has been recorded by several authors from the Indian Ocean (Wood, 1963,b) but, surprisingly, not by Hendey (1937). It is also known to extend into Antarctic waters (Wood, 1960).

92. Chaetoceros affinis forma inflatospinosus Taylor, nom. nov., PLATE 3, fig. 3.

Syn.: Ch. femur Schutt, Ber. Deutsch. Bot. Ges. 13 : 45, pl. 5, fig. 21 (1895).

System.: Several species of Ch. affinis possessed unusual inflations on the setae. The inflations were characteristically lanceolate in shape, arising a short distance from the bases of the setae. They were approximately 8 μ in length and 2 - 3 μ in width.

Schütt (1895) figured and described virtually identical cells collected from the S. Equatorial Current of the Atlantic Ocean as Ch. femur. In addition to the clearly recognisable affinity to Ch. affinis which his figure exhibits, the specimens observed by the present author were indistinguishable from individuals of Ch. affinis present in the same samples (except with regard to the inflations). The author has not retained Schütt's name as it is a substantive, and a new name has been proposed at the rank of forma for Ch. femur Schütt.

The phenomenon of inflations on the setae does not seem to be limited to Ch. affinis, as Castracane (1886, p. 79), and Heiden & Kolbe (1928, pl. 9, figs. 171, 172) encountered specimens bearing similar inflations in Antarctic waters. These appear to the present author to be forms of Ch. atlanticus although the above authors considered them to be new species : Ch. radiculum and Ch. bulbosum respectively.

It is not inconceivable that the inflations are related to a specific physiological condition, possible resting stages or an abnormal condition, i.e. a response of a neritic species to an oceanic environment.

Local.: NIOE 5, 71, 108, 111.

Rarely encountered at scattered offshore stations in April, July and October. Station 111 is nearer the coast on the inner edge of the Agulhas Current.

General: Only previously recorded from the tropical Atlantic Ocean (Schütt, 1895).

93. *Chaetoceros affinis* var. *willei* (Gran) Hustedt, Kieselalg. (1) : 697, fig. 398 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 126, fig. 78-C (1943); Brunel, Phytopl. Baie Chaleurs : 116, pl. 27, fig. 2 (1962).

Local.: NIOE 74, 75, 108, 110, 112, 115, 124, 130.

With the exception of station 124, the variety was confined to the neritic zone. It occurred along the coast from line B southwards in July and October, only, never in large numbers.

General: Occasional off the Atlantic coast of Europe (Hustedt, 1930), "not common" off California (Cupp, 1943). Apparently not previously recorded from the Indian Ocean.

It is possibly a cold-temperate variety, present in the inshore zone of the S.W. Indian

Ocean due to the presence of colder water there. Brunel (1962) suggested that the variety was probably more oceanic than the type, but this is not borne out by the local distribution.

94. Chaetoceros anastamosans Grunow in Van Heurck, Synopsis : pl. 82, figs. 6 - 8 (1881); Hustedt, Kieselalg. (1): 743, fig. 429 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 140, fig. 96, (1943).

Local.: NIOE 62.

One chain of cells observed at an offshore station on line A in July.

General: Found off the coast of S. Europe and at points in the Mediterranean (Hustedt, 1930). A south-temperate species off the W. Coast of N. America (Cupp, 1943). Ostenfeld & Schmidt (1901) recorded the species from the Red Sea. No other Indian Ocean records are known to the author.

95. Chaetoceros atlanticus Cleve var. atlanticus, Bih. Kongl. Svenska Vet.-Akad. Handl. 1 (13) : 11, pl. 2, fig. 8 (1873); Gran, Diat. Nord. Plankt. : 64,

fig. 74 (1905); Hustedt, in A. Schmidt, Atlas : pl. 337, figs. 1, 2 (1921); Hustedt, Kieselalg. (1) : 641, fig. 363 (1930); Hendey, Discovery Rep. 16 : 290 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 103, fig. 59-A (1943); Brunel, Phytopl. Baie Chaleurs : 86, pls. 9, 10 (1962).

Local.: NIOE 73, 91, 97, 101, 110.

Present at scattered offshore stations in July and October only. It occurred concurrently with the varieties listed below, both of which were far more abundant than the typical variety.

General: Common and abundant in northern Arctic and boreal waters (Hustedt, 1930). An oceanic species, also common in southern waters from the tropics to the Antarctic (Manguin, 1960), but achieving maximum abundance in south temperate areas (Hendey, 1937). A few Indian Ocean records are listed by Wood (1963).

96. Chaetoceros atlanticus var. neapolitanus (Schröder) Hustedt, Kieselalg. (1) : 645, fig. 366 (1930); Hendey, Discovery Rep. 16 : 290 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 104, fig. 59-B, d, e (1943); Boden, Trans. Roy. Soc.

fig. 74 (1905); Hustedt, in A. Schmidt, Atlas : pl. 337, figs. 1, 2 (1921); Hustedt, Kieselalg. (1) : 641, fig. 363 (1930); Hendey, Discovery Rep. 16 : 290 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 103, fig. 59-A (1943); Brunel, Phytopl. Baie Chaleurs : 86, pls. 9, 10 (1962).

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S. Afr. 32 (4) : 373, fig. 48 (1950).

Local.: NIOE 5, 7, 9, 10, 12, 14, 16, 17, 21, 23, 30, 34, 58, 59, 60, 62, 64, 66, 69, 71, 73, 74, 75, 77, 78, 80, 84, 85, 87, 88, 89, 91, 93, 96, 97, 101, 108, 110, 111, 112, 114, 115, 117, 119, 120, 124, 126, 143, 162, 164, 174, 176.

This was one of the commonest taxa in the area, being extremely widespread in July and October. In July it was present at virtually every station (only four stations at which it was not recorded). It was most abundant (+++ - ++++) at offshore stations in July, less so in October, and sparse in January.

General: An oceanic, temperate to subtropical form, frequently found around the coast of Africa (Hendey, 1937). Abundant off the S. Coast of California (Cupp, 1943). Also extends into the Antarctic (Hendey, 1937). Not recordeddby many authors from the Indian Ocean (for references see Wood, 1963,b) but this is most likely to be due to its not being distinguished from the type.

97. Chaetoceros atlanticus var. skeleton (Schütt) Hustedt, Kieselalg. (1) : 643, fig. 365 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 104,

fig. 59-B, b, c (1943); Takano, Bull. Jap. Soc. Sci. Fish. 19 (12) : ? (1954, reference from Hart & Currie, 1960, p. 216).

Local.: NIOE 2, 5, 12, 16, 23, 60, 62, 67, 73, 78, 85, 89, 91, 95, 96, 97, 108, 111, 120, 124, 146.

This variety was occasional at offshore stations in April, July and October. Recorded from only one station in January. Not as abundant as var. neapolitanus, but commonly present in the same samples.

General: Considered by Hustedt (1930) to be chiefly distributed in warmer seas. Nevertheless, it has been known to extend into the Antarctic (Van Heurck, 1909, as Ch. skeleton Schütt). Cleve (1900a) and Ostenfeld (1915) appear to be the only other references to this variety in the Indian Ocean.

98. Chaetoceros aurivillii Cleve, Kongl. Svenska Vet.-Akad. Handl. 35 (5) : 54, pl. 8, fig. 10 (1901)

PLATE 2, fig. 1.

Syn.: Ch. seychellarum Karsten, Valdivia Indische Phytopl. : 387, pl. 43, fig. 4 (1907); Hustedt, in A. Schmidt, Atlas : pl. 327, figs. 12, 13 (1920); Hendey, Discovery Rep. 16 : 296 (1937).

System.: Although Cleve's original description is adequate, his figures are rather sketchy and poor, and this has no doubt led to the neglect which has befallen his species (the species is not listed in Mill's Index, 1933 nor by Wood, 1963,b). Nevertheless the present author is of the opinion that both Cleve and Karsten were describing the same species. The only feature possessed by Karsten's species which is not mentioned or shown by Cleve is the indentation between the valve mantle and the girdle, and this indentation is variable in degree in the specimens observed by the present author although always present if the specimens are carefully examined. Cleve's omission could be due to hasty examination but in any case this would be a poor feature on which to base specific separation, particularly as it is variable.

A further distinction between the species which might be pointed out is the angularity of the valves when seen in girdle view, or the angularity of the foramina, but these have also been seen to be variable.

If Ch. seychellarum is indeed synonymous with Ch. aurivillii, as suggested above, then

_Ch_. _seychellarum_ var. _australe_ Manguin (1960, p. 289, pl. 11, fig. 118, pl. 12, figs. 119 - 123) has to be changed to _Ch_. _aurivillii_ var. _australis_ (Manguin) Taylor comb. nov.

Local.: NIOE 2, 5, 9, 17, 18, 19, 20, 34, 37, 58, 59, 62, 66,73, 74, 75, 77, 78, 80, 84, 85, 96, 112, 158, 159.

Commonly found at inshore stations on lines A & B on all cruises. Widespread in the northern and central oceanic parts in April and October, extending inshore to Cape Agulhas in April. Most abundant (+++) at stations 19, 78, 80 in April (19) and October.

General: Recorded (as _Ch_. _seychellarus_) in the Indian Ocean and the Antarctic (Wood, 1963, b). Cleve originally described the species from Java.

99. _Chaetoceros_ _borealis_ Bailey, Smithsonian Contrib. Knowl. _7_ : 8, figs. 22, 23 (1854); Gran, Diat. Nord. Plankt. : 73, fig. 87 (1905); Hustedt, Kieselalg. (1) : 661, fig. 375 (1930); Hendey, Discovery Rep. _16_ : 292 (1937); Brunel, Phytopl. Baie Chaleurs : 97, pl. 15 (1962).

Local.: NIOE 62, 159, 160.

Rare, recorded in July and January only from relatively inshore stations on lines A and B. Only a few chains of cells observed in each case.

General: An oceanic species with a wide distribution in polar and temperate seas (Hendey, 1937). Found in small numbers near S. Georgia by Hendey (1937). Most abundant in northern polar waters (Hustedt, 1930). Brunel (1962) is of the opinion that it is eurythermal and euryhaline, this explaining its bipolar distribution and its presence in areas such as the S.W. Indian Ocean.

100. Chaetoceros brevis Schütt, Ber. Deutsche Bot. Ges. 13 : 38, fig. 4 (1895); Gran, Diat. Nord. Plankt. : 83, fig. 100 (1905); Hustedt, in A. Schmidt, Atlas : pl. 344, fig. 7 (1921); Hustedt, Kieselalg. (1) : 707, fig. 403 a & b (1930); Hendey, Discovery Rep. 16 : 302 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 129, fig. 82 (1943).

Local.: NIOE 142, 143, 146, 158, 159.

The above distribution is incomplete as the species was only identified with certainty whilst analysing the material from the January cruise

(cruise IV). It is likely that the species was present in the material from earlier cruises but was confused with *Ch. holsaticus*.

The above stations are inshore stations on lines A and B in January, 1962.

General: Common in the Atlantic and Indian Oceans, frequent around the coast of Africa (Hendey, 1937). Neritic, temperate to subtropical (Cupp, 1943).

101. *Chaetoceros capricornianus* Taylor, nom. nov.

Syn.: *Ch. indicus* Subrahmanyan, Proc. Indian Acad. Sci. **24** : 133, figs. 197, 205, 210 (1946); non *Ch. indicum* Karsten, Valdivia Indische Phytopl. : 387, pl. 43, fig. 2 (1907).

System.: The name given to his new species by Subrahmanyan (1946) is pre-occupied by that of Karsten (1907). For this reason the present author has supplied the above name for Sybrahmanyan's species.

The species bears a close resemblance to *Ch. lorenzianus* and *Ch. paradoxus*. Subrahmanyan's fig. 210, which illustrates the characteristics of the narrow girdle-view by which the species is distinguished from *Ch. lorenzianus*, exhibits an appearance which is very similar to *Ch. paradoxus* (compare with PLATE 3, fig. 2 of the present work).

The status of this species is uncertain, and further observations are required before its taxonomic status can be established.

Local.: NIOE 45, 115, 117, 119, 158.
Recorded from scattered inshore and offshore stations, mostly in October, but also from one station in January. Apparently introduced into the area by the Agulhas Current. The species was most abundant (+++) at stations 115 and 117, offshore stations on line C.

General: Only previously recorded by Subrahmanyan (1946) from the Madras Coast of India.

102. *Chaetoceros coarctatus* Lauder, Trans. Micr. Soc., N.S. 12 : 78, pl. 8, fig 8 (1864); Gran, Diat. Nord. Plankt. : 68, fig. 80 (1905); Karsten, Valdivia Indische Phytopl. : pl. 31, fig. 3 (1907); Hustedt, Kieselalg. (1) : 655, fig. 370 (1930); Hendey, Discovery Rep. 16 : 293, pl. 6, figs. 7, 8 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 107, fig. 62 (1943).

Local.: NIOE 5, 7, 9, 12, 17, 18, 35, 62, 73, 97.

Found primarily in the offshore region on lines A and B in April, but also present at inshore stations on line B where maximum abundance (+++) occurred. Only present at scattered offshore stations in July and October, not present in January. The species is apparently introduced into the area by the Agulhas Current.

General: An oceanic species widely distributed in tropical and subtropical seas. It was frequently observed in the Indian Ocean off the east coast of Africa by Hendey (1937). There are numerous references to this species in the Indian Ocean (see Wood, 1963,b).

An interesting feature observed in connection with this species is that throughout its distribution range (Atlantic, Indian and Pacific Oceans) it is very commonly infested with cells of Vorticella oceanica Zacharias (see comments in Hendey, 1937, and Cupp, 1943). In the S.W. Indian Ocean material examined by the present author chains were more frequently associated with V. oceanica than without it.

Ch. coarctatus is apparently more frequent in the S.W. Indian Ocean than the present survey revealed, judging by Hendey's (1937) observations.

103. <u>Chaetoceros</u> <u>compressus</u> Lauder, Trans. Micr. Soc., N.S., <u>12</u> : 78, pl. 8, fig. 6 (1864); Gran, Diat. Nord. Plankt. : 78, fig. 93 (1905, sub <u>Ch</u>. <u>contortum</u> Schütt); Hustedt, Kieselalg. (1) : 684, fig. 388 (1930); Hendey, Discovery Rep. <u>16</u> : 300 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 119, fig. 74 (1943); Brunel, Phytopl. Baie Chaleurs : 110, pl. 25 (1962). PLATE 14, fig. 3.

System.: This species is highly variable in form. The most reliable feature used in its identification, i.e. the pairs of differentiated setae occurring at points along the chain, are frequently not present on broken sections of chains. For this reason the estimates for relative abundance given in the Relative Abundance Table must be considered to be under-estimations.

Local.: NIOE 2, 12, 18, 20, 36, 58, 59, 60, 62, 66, 71, 73, 75, 77, 78, 80, 84, 87, 91, 93, 101, 103, 108, 111, 112, 114, 115, 121, 124, 126, 130, 142, 143, 158, 159, 161, 162, 164, 176.

Present at scattered stations in April, very widespread in July and October, more confined to the Agulhas Current and inshore of it in January. This species was particularly abundant (++++) on the margin of the Agulhas Current in the north in July (stations 60, 62, 73) and near Port Elizabeth (st. 115) in October.

General: Although considered to be a boreal species by Hendey (1937), Cupp (1943) found it "a very important species" in the water off Southern California and in the warm water of the Gulf of California. It is very widely distributed, attaining maximum numbers in neritic zones. Wood (1963,b) has listed numerous references to the species in the Indian Ocean.

104. Chaetoceros concavicornis Mangin, Compt. rend. Acad. Sci. 164 : 704 & 707, figs. 5 (1), 6, 7 (1917); Gran, Diat. Nord. Plankt. : 71, fig. 85 (1905); Hustedt, Kieselalg. (1) : 665, fig. 376 (1930); Brunel, Phytopl. Baie Chaleurs : 90, pl. 12 (1962).

Local.: NIOE 110.

Recorded in moderate numbers (++) from one station on the edge of the continental shelf on line B in October.

General: An oceanic, boreal-arctic species (Gran, 1905 as Ch. criophilum; Hustedt, 1930; Brunel, 1962).

The isolated recordsof the species in the S.W. Indian Ocean is inexplicable. There is little doubt as to the accuracy of the identification as, due to its unusual appearance in the area, the author carefully checked it against the references at hand (cited above). Wood (1963,b) has indicated that it has been identified by him from the Indian Ocean in the Australian region.

105. Chaetoceros constrictus Gran, Norske Nordh.-Exped., Bot., Protoph. : 17, pl. 1, figs. 11 - 13 (1897); Gran, Diat. Nord. Plankt. : 80, fig. 96 (1905); Hustedt, in A. Schmidt, Atlas : pl. 338, fig. 1 (1921); Hustedt, Kieselalg. (1) : 694, fig. 395 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 122, fig. 76 (1943); Brunel, Phytopl. Baie Chaleurs : 112, pl. 26, figs. 1, 2 (1962).

Local.: NIOE 58, 59, 60, 62, 71, 73, 74, 75, 77, 80, 84, 85, 88, 96, 99, 114, 124, 130.

Moderately abundant (++ - +++) at inshore stations in July and October only. Spreads far offshore in the south (lines C and D).

General: A neritic, temperate species, spreading into arctic and tropical waters (Cupp, 1943; Brunel, 1962; Wood, 1960). It has been previously recorded from the Indian Ocean by Subrahmanyan (1958, Arabian Sea).

106. Chaetoceros convolutus Castracane, Diat. Challenger Exped. : 78, text fig. (1886); Gran, Diat. Nord. Plankt. : 69, fig. 82 (1905); Hustedt, Kieselalg. (1) : 668, fig. 378 (1930); Hendey, Discovery Rep. 16 : 293 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 110, fig. 67 (1943); Manguin, Diat. Terre Adélie : 279, pl. 8, figs. 94 - 97, pl. 9, fig. 98 (1960).

Local.: NIOE 9, 18, 21, 23, 28, 30.

Present in small numbers at scattered oceanic stations (st. 18 neritic) in April only.

General: An oceanic, arctic and boreal form in the North Atlantic and Pacific Oceans (Hustedt, 1930, Cupp, 1943). Hendey (1937) found the species in the tropical Atlantic, in the Antarctic region, and at one station in the S.W. Indian Ocean in September. Also recorded from the Indian Ocean by Heiden & Kolbe (1928). It is commoner in the Antarctic region, but apparently spreads right through the tropics.

107. <u>Chaetoceros</u> <u>costatus</u> Pavillard, Bull. Soc. Bot. France <u>58</u> : 24, fig. 1 B, c (1911); Ikari, Bot. Mag. Tokyo <u>40</u> : 530, fig. 13 (1926); Hustedt, Kieselalg. (1) : 699, fig. 399 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 127, fig. 79 (1943).

Local.: NIOE 16, 19, 20, 30, 58, 59, 74, 77, 85, 101, 111, 142, 144, 158, 159, 160, 161, 176.

Present at inshore stations on all cruises, distribution most restricted in October. Highest concentrations (+++) at stations 19, 20, near Port Elizabeth in April. Apparently carried offshore in the south in April and July.

General: Neritic in warm water (Hustedt, 1930; Cupp, 1943). Remarkably, this species does not appear to have been recorded from the Indian Ocean previous to this study. It has been identified in the Atlantic Ocean, the Mediterranean, the seas around Japan, and the coast of California and therefore has a wide distribution in temperate and subtropical waters.

108. Chaetoceros criophilus Castracane f. criophilus, Diat. Challenger Exped. : 78, text fig. (1886); Karsten, Valdivia Antarkt. Phytopl. : 118, pl. 15, fig. 8 (1905); Hendey, Discovery Rep. 16 : 295, pl. 13, fig. 7 (1937); Manguin, Diat. Terre Adélie : 279, pl. ■, figs. 99, 100, pl. 27, figs. 328, 329 (1960).

Local.: NIOE 84, 87.

Observed in small numbers from southern offshore stations in the vicinity of the Subtropical Convergence region, in July.

General: It is very common in the Antarctic region, and may be considered to be characteristic of water of Antarctic and sub-Antarctic origin (Hendey, 1937). This form does not appear to have been recorded from the Northern Hemisphere as yet.

109. Chaetoceros criophilus forma okamurai (Ikari) Taylor, stat. et. comb. nov. PLATE 2, fig. 4.

Syn.: Ch. okamurai Ikari, Bot. Mag. Tokyo 42 : 248, fig. 2 (1928).

System.: The resemblances between Ch. criophilus and Ch. okamurai appear to be two great to warrant specific separation. The latter is more weakly silicified with more slender setae than the former, and may be characterised by shape of the foramina between the cells which are more quadrangular than in Ch. criophilus.

As indicated earlier, Ch. criophilus typically has a sub-antarctic to antarctic distribution, whereas Ch. okamurai has been recorded from the warmer waters of Japan (Ikari, 1928). It is well known that the same species in tropical and polar waters frequently exhibits phenotypic variation, and the major differences between the two species above are consistent with the type of changes observed in other species in various environments. For this reason the present author suggests that Ch. okamurai is a warm-water form of Ch. criophilus.

Local.: NIOE 78, 80, 95, 108, 115, 150.

Recorded from closer inshore stations than the typical form in July. Also present at northern inshore and offshore stations in October and January. Never abundant.

General: Previously recorded from Japanese waters (Ikari, 1928).

110. Chaetoceros curvisetus Cleve, Vidensk. Udb. Kanonbaad. Haucks Togt. danske Have : 55 (1889); Gran, Diat. Nord. Plankt. : 91, fig. 116 (1905); Hustedt, in A. Schmidt, Atlas : pl. 340, figs. 5, 6, 7 (1921); Hustedt, Kieselalg. (1) 737, fig. 426 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 137, fig. 93 (1943); Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 387, fig. 67 (1950).

Local.: NIOE 94, 161.

Recorded in small numbers from inshore stations near Cape Agulhas and Port Elizabeth in July and January respectively.

General: A neritic, temperate species (Cupp, 1943). It is very common in the Benguela Current area off the West Coast of S. Africa, having been recorded from there by Boden (1950) and Hart & Currie (1960). The latter found it present on all the surveys of the area they undertook.

Wood (1963,b) has listed several references to the species in the Indian Ocean under Ch. secundus Cleve which he considers to be synonymous with Ch. curvisetus Cleve. There is undoubtedly a strong resemblance between Cleve's earlier figures and description of Ch. secundus and the later Ch. curvisetus, and they may well be one and the same species. For the present the author prefers to leave this species under its more familiar name.

111. Chaetoceros dadayi Pavillard, Bull. Soc. Bot. de France 60 : 131, fig. 2B (1913); Hustedt, Kieselalg. (1) : 658, fig. 372 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 109, fig. 64 (1943).

Local.: NIOE 9, 10, 17, 35, 164.

It occurred in small numbers at scattered oceanic stations in April and January only.

General: A rare species, oceanic in tropical-temperate waters. Recorded from the Mediterranean (Hustedt, 1930), the W. Coast of America (Cupp, 1943); and the Indian Ocean (Wood, 1962).

An interesting feature of this species is that it is always associated with the loricae of one of several tintinnid species.

112. Chaetoceros danicus Cleve, Pelag. Diat. Kattegat : 55 (1889); Gran, Diat. Nord. Plankt. : 70, fig. 83 (1905); Hustedt, Kieselalg. (1) : 659, fig. 373 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 109, fig. 65 (1943); Brunel, Phytopl. Baie Chaleurs : 88, pl. 11 (1962.

Local.: NIOE 2, 5, 10, 12, 17, 19, 66, 67, 71, 77 80, 99, 111, 114, 115, 121, 124, 128, 130, 151, 178.

Present at offshore stations on all four cruises. Most widespread and furthest south (line D) in October, at other times chiefly on lines A and B. Recorded from only two stations in January. Never found in large numbers.

General: Considered to be a neritic, euryhaline, cold temperate species (Hustedt, 1930; Cupp, 1943). Prefers low salinities (Brunel, 1962, gives optimal salinity as 12.8‰).

Considering the general distribution of the species its distribution in the S.W. Indian Ocean must be considered as atypical. Wood (1963,b) had provided a few records of the species in the Indian Ocean.

113. Chaetoceros decipiens Cleve, Bih. Kongl. Svenska Vet.-Akad. Handl. 1 (13) : 11, pl. 1, fig. 5 (1873); Gran, Diat. Nord. Plankt. : 74, fig. 88 (1905); Hustedt, in A. Schmidt, Atlas : pl. 321, fig. 20 (1920), pl. 343, figs. 17, 18 (1921); Hustedt, Kieselalg. (1) : 675, fig. 383 (1930);

Hendey, Discovery Rep. 16 : 298 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 115, figs. 70 A & B (1943); Brunel, Phytopl. Baie Chaleurs : 99, pls. 21 & 22 (1962).   PLATE 14, fig. 2.

Local.: NIOE 1, 2, 17, 18, 19, 32, 36, 75, 76, 93, 94, 95, 108, 112, 129, 130, 159, 160, 161, 176, 178.

A markedly neritic distribution, the only offshore record (st. 32) possibly being the result of transport off the bank. The species was present on lines B, C, and D at all times, extending to Durban (line A) in April and October only. Heavy concentrations (++++) were recorded at stations 1, 94, and 130 in April, July and October respectively. Stations 94 and 130 were both at Cape Agulhas, station 1 being at Durban.

General: Considered by most authors to be an oceanic species, "usually regarded as Arctic or sub-Arctic" (Hendey, 1937). It is widely distributed, and is common in water off the West Coast of S. Africa (Hart & Currie, 1960). It extends into tropical parts of the Indian Ocean (see Wood, 1963,b for references).

Its neritic distribution in the S.W. Indian Ocean is interesting as there are several temperate and subantarctic oceanic species, e.g. Ch. borealis, which appear to extend northwards into the area in the neritic zone along the east coast of S. Africa. More will be said of this in Section IV.

114. Chaetoceros densus Cleve, Seasonal Distrib. Atlant. Plankt. Organ. : 299 (1901); Gran, Diat. Nord. Plankt. : 67, fig. 79 (1905); Hustedt, Kieselalg. (1) : 651, fig. 368 (1930).

Local.: NIOE 58, 59, 60, 64, 66, 69, 73, 74, 75, 77.

It was present in July only. Widespread on lines A and B, and at an inshore station on line C. Not in large numbers (+ - ++)

General: Widely distributed in the Arctic, North Sea, and extending into the Mediterranean (Hustedt, 1930). Also recorded from the Antarctic (Heiden & Kolbe, 1928). It appears to be an oceanic, cold temperate species which can extend into the tropics.

Considering its world distribution its distribution in the S.W. Indian Ocean is somewhat enigmatic. Although it was present in July, the month when other subantarctic species appear to spread north into the offshore area, the species was almost entirely limited to the more northern lines (A & B).

115. Chaetoceros denticulatus Lauder f. denticulatus, Trans. Micr. Soc., N.S., 12 : 79, pl. 8, fig. 9 (1864); Hustedt, in A. Schmidt, Atlas : pl. 337, fig. 7 (1921); Subrahmanyan, Proc. Indian Sci. 24 : 129, figs. 188, 190 (1946). PLATE 2, fig. 2.

Local.: NIOE 78, 80, 85, 114, 142.

Recorded from three southern oceanic stations in July, one inshore station near Port Elizabeth in Octoberm and one inshore station near Durban in January. Most numerous (++) at station 78, the edge of the Agulhas Bank near Port Elizabeth in July.

General: This species appears to be limited to the Indian and the western Pacific Oceans, and is probably oceanic. There are numerous records of the presence of the species in the tropical Indian Ocean and in the vicinity of the East Indies (see Wood, 1963,b for references). Its detailed distribution is as yet unknown, but it appears that its presence in the S.W. Indian Ocean results from southward transport by the Agulhas Current from the tropical Indian Ocean. In addition to the references given by Wood (1963,b) it has been recorded from Mozambique waters by Silva (1956, as _Ch_. _atlanticus_).

116. _Chaetoceros_ _denticulatus_ forma _latus_ Hustedt, in A. Schmidt, Atlas : pl. 324, figs. 6, 7 (1920); Ikari, Bot. Mag. Tokyo _42_ : 250, fig. 5, b (1928, sub _Ch_. _indicum_ Karsten). PLATE 2, fig. 3.

Syn.: _Ch_. _nanodenticulatum_ Okamura, Bot. Mag. Tokyo _21_ : 11, text fig. (1907); Allen & Cupp, Ann. Jard. Bot. Buitenzorg _44_ (2) : 136, fig. 54 (1935).

System.: As pointed out by Allen & Cupp (1935) there is a close resemblance between Okamura's species and Hustedt's form. It is, in fact, impossible to distinguish between them and they are thus considered to be synonymous. The present author prefers to follow Hustedt in considering this to be a form of _Ch_. _denticulatus_, and not a separate species as proposed by Okamura. Okamura's specific epithet does not have priority over Hustedt's infraspecific epithet (Int. Code Nomencl., Art. 60, 1961).

The present author does not agree with Wood (1963,b) who apparently considered Ch. nanodenticulatum synonymous with Ch. indicum Karsten. The latter can easily be distinguished by its smoothly concave valves and protuberances on one pair of setae only.

Local.: NIOE 78.

Recorded in small numbers (+) from one station at the edge of the Agulhas Bank near Port Elizabeth in July. Mixed with the typical variety.

General: This form has been recorded from the sea of Java (Allen & Cupp, 1935) and from Japan (Ikari, 1928) under both synonyms.

117. Chaetoceros diadema (Ehrenberg) Gran, Norske Nordh. Exped., Bot. Protoph. : 20, pl. 2, figs. 16 - 18 (1897); Gran, Diat. Nord. Plankt. : 84, fig. 102 (1905); Brunel, Phytopl. Baie Chaleurs : 122, pl. 27, fig. 4, pl. 30, figs. 1 - 5 (1962).

Syn.: Ch. subsecundus (Grunow) Hustedt, Kieselalg. (1) : 709, fig. 404 (1930); Cupp, Mar. Plankt. Diat.

W. Coast N. Amer. : 130, fig. 83 (1943).

System.: Ehrenberg, in his Mikrogeologie (1854), described a curious form as Syndendrium diadema. Gran (1897) showed this to be the resting spore of species of Chaetoceros and made the above combination. Hustedt (1930) rejected Ehrenberg's specific epithet on the grounds that it was associated with a "false genus", i.e. the genus was composed of resting spores only. He chose instead the epithet subsecundus, this being derived from Grunow's (1881) Chaetoceros distans var. subsecunda which he showed to be synonymous.

The rejection of a genus does not invalidate the specific epithet and, as there is no doubt that the resting spore and the chained form are one and the same species, Gran's combination would seem to be the correct one.

Local.: NIOE 19, 58, 59, 62, 94, 95.

Recorded in small numbers (++) from Port Elizabeth in April, Durban and Cape Agulhas in July, and Durban only in October. Not recorded in the January material.

General: A meroplanktonic neritic species favouring arctic to temperate conditions (Gran, 1905;

Cupp, 1943). Recorded from the West Coast by Boden (1950) and Hart & Currie (1960). Recorded from the S. Indian Ocean by Heiden & Kolbe (1928.)

118. Chaetoceros didymus Ehrenberg var. didymus Ber. Berl. Akad. 1845 : 75 (1846), - Mikrogeol. pl. 35 A, figs. 17/5 and 18/4 (1854); Gran, Diat. Nord. Plankt. : 79, fig. 94 (1905); Hustedt, Kieselalg. (1) : 688, fig. 390 (1930); Hendey, Discovery Rep. 16 : 301 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 121, fig. 75A (1943).

Local.: NIOE 17, 19, 36, 58, 59, 60, 62, 69, 71, 73, 74, 75, 76, 77, 78, 80, 84, 85, 88, 89, 91, 94, 97, 99, 108, 111, 121, 124, 128, 142, 143.

Extremely widespread in July, recorded from 19 of the 25 stations sampled, being absent at several extreme offshore stations on lines A and B, and scattered inshore stations on lines B and D. In April the species was confined to inshore stations on lines B, C, and D. In October the distribution was more oceanic, particularly in the south. In January the species was confined to two inshore stations in the vicinity of Durban. It was most abundant (+++) at stations 84 and 124, southern offshore stations in July and October respectively.

General: Considered to be a widely distributed neritic, temperate species by Hustedt (1930), Hendey (1937) and Cupp (1943). Hendey found that the species occurred frequently around the coast of S. Africa. There are numerous references to this species in the S.W. Indian Ocean (Wood, 1963,b).

119. Chaetoceros didymus var. aggregatus Mangin, Ann. Inst. Oceanogr. 6 (1) : 49, fig. 37 (1912); Hustedt, Kieselalg. (1) : 691, fig. 394 (1930).

Local.: NIOE 124.

A short chain of cells observed in a sample from an offshore station on line D in October, 1962. Occurred with the type.

General: Mangin's record from Brest (N. Atlantic) appears to be the only previous record of this rare variety.

120. Chaetoceros didymus var. protuberans (Lauder) Gran & Yendo, Vidensk. Skrift 1 mat.-naturv. Kl. 1913 (8) : 12 (1914); Hustedt, in A. Schmidt, Atlas : pl. 326, fig. 1, 5 (1920); Hustedt, Kieselalg. 1 : 690, fig. 392 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 121, fig. 75B, a (1943).

Local.: NIOE 59, 62, 84, 89, 91, 96, 114, 115, 117, 119, 121, 124, 126, 130, 142, 143, 178.

Not as common as the typical variety, usually occurring mixed with it, except in the case of line C in October where it was more widespread. Not present in April, equally restricted in January (although also present at an inshore station near Cape Agulhas at the same period).

General; This variety has a warmer distribution than the typical variety in other areas (Hustedt, 1930). Recorded from the N. Indian Ocean (see references in Wood, 1963, b).

121. Chaetoceros difficilis Cleve, Kongl. Svenska Vet.-Akad. Handl. 34 (1) : 20, pl. 8, figs. 16 - 18 (1900); Gran, Diat. Nord. Plankt. : 86, fig. 106 (1905); Hustedt, Kieselalg. (1) : 715, fig. 408 (1930); Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 385, fig. 65 (1950).

Local.: NIOE 94.

Occurring in small numbers at a station in the immediate vicinity of Cape Agulhas in July, 1962. Possibly transported from the West Coast region by local currents as in the case of Ch. curvisetus.

General: Recorded from the northern Atlantic (Gran, 1905), the Antarctic (Heiden & Kolbe, 1928) and the west coast of Australia (Crosby & Wood, 1958). It appears to be a neritic, cold-temperate species, also having been recorded from the Benguella Current area (Boden, 1950; Hart & Currie, 1960) where it is common.

122. Chaetoceros diversus Cleve, Bih. Kongl. Svenska Vet.-Akad. Handl. 1 (11) : 9, pl. 2, fig. 12 (1873); Gran, Diat. Nord. Plankt. : 87, fig. 107 (1905); Peragallo, Diat. Mar. France : 487, pl. 135, fig. 4 (1908); Hustedt, in A. Schmidt, Atlas : pl. 322, figs. 2, 3 (1920), pl. 338, fig. 4 (1921); Hustedt, Kieselalg. (1) : 716, fig. 409 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 132, fig. 87 (1943).

Local.: NIOE 18, 62, 64, 67, 71, 73, 74, 77, 87, 97, 99, 108, 110, 111, 115, 124, 128, 129, 143, 176.

Most widespread in July and October, restricted to one inshore station on line B in April, and two inshore stations on lines A and D in January. It occurred at both offshore and inshore stations scattered over most of the area in July, not occurring as far offshore in

October except in the case of line D (station 124). Never found in large numbers (max. ++). Possibly introduced into the area from the north by the Agulhas Current.

General: A tropical - subtropical neritic species (Cupp, 1943). There are numerous references to the species in the Indian Ocean (Wood, 1963,b).

123. Chaetoceros eibenii (Grunow) Meunier, Mém. Mus. R. Hist. Nat. Belgique 7 : 15 (1913); Ikari, Bot. Mag. Tokyo 29 (458) : 52, figs. 1, 2 (1925); Hustedt, Kieselalg. (1) : 653, fig. 369 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 106, fig. 61 (1943); Subrahmanyan, Proc. Indian Acad. Sci. 24 : 128, figs. 179 - 181 (1946).

Local.: NIOE 17, 18, 19, 58, 59,,73, 75, 94, 95, 143, 158, 160.

A markedly restricted neritic distribution, confined to inshore stations on lines B and C in April, lines A, B and D in July, line A in October and January. Not in large numbers (+ - ++).

General: This is a neritic species, having been recorded from the coastal areas of Europe (Hustedt, 1930), Japan (Ikari, 1928), India (Subrahmanyan, 1946), and the Pacific coast of America (Cupp, 1943). Wood (1963, b) has listed further Indian Ocean references.

124. Chaetoceros holsaticus Schütt, Ber. Deutsche Bot. Ges. 13 : 40, fig. 9 (1895); Gran, Diat. Nord. Plankt. : 85, fig. 105 (1905); Hustedt, in A. Schmidt, Atlas : pl. 343, figs. 5 - 8 (1921); Hustedt, Kieselalg. (1) : 714, fig. 407 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 131, fig. 85 (1943).

Local.: NIOE 62, 64, 67, 69, 71, 80, 85.

An oceanic distribution, recorded from scattered offshore stations in July only. Found only in small numbers. Possibly confused with Ch. brevis Schütt (see note under that species).

General: A neritic, cold water species (Cupp, 1943). Hustedt (1930) has indicated that it is abundant in low-salinity areas, i.e. the Baltic Sea.

From the local distribution it appears that the species can exist under oceanic conditions. Its presence in the area possibly results from a northward invasion from the cold, lower salinity water south of the Subtropical Convergence region.

It apparently extends into the northern Indian Ocean, having been recorded from India by Subrahmanyan (1946, 1958).

125. Chaetoceros imbricatus Mangin, Ann. Inst. Oceanogr. 4 (1) : 53, fig. 41 (1912); Hustedt, Kieselalg. (1) : 766, fig. 448 (1930). PLATE 3, fig. 1.

System.: Due to the inadequate description and figures of Mangin this species was listed under "Unvollständig bekannte Arten" by Hustedt (1930) who reproduced his figures. This small species is not uncommonly encountered in S.W. Indian Ocean material and the author has provided a figure of a typical chain of cells.

Apparently the cell contents of this species have not been observed previously, and the author is able to report that the chromatophores, fairly large and irregularly shaped, vary between 4 and 6 per cell in the local population (one cell in the chain figured appears to have 3 chromatophores but this is due to super-imposition of one upon another).

Hustedt has described the setae as lacking a basal portion, but this is no doubt based on Mangin's figure. In the local population the setae of the adjacent cells were joined for a short distance before diverging. Another feature not commented on previously is the fine spirillations on the distal portions of the setae.

Local.: NIOE 9, 10, 12, 14, 16, 18, 21, 66, 71, 78, 87, 99, 108, 110, 148, 158, 164, 166, 174.

Found on all four cruises, occurring in small numbers (+ - ++) at inshore and oceanic stations on lines A and B, oceanic only on lines C and D. More commonly found on the northern lines than further south. Most widespread on lines A and B in April and January, occurring at the most offshore stations on these lines.

General: Apparently only previously recorded from the Atlantic Ocean near Brest (Mangin).

From the local distribution it would seem to be a subtropical species.

126. *Chaetoceros laciniosus* Schütt, Ber. Deutsche Bot. Ges. 13 : 38, fig. 5 (1895); Gran, Diat. Nord. Plankt. : 82, fig. 99 (1905); Hustedt, Kieselalg. (1) : 701, figs. 401 a & b. (1930); Hendey, Discovery Rep. 16 : 301 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 128, fig. 80 (1943).

System.: This species closely resembles *Ch. pelagicus* Cleve. Hendey (1937) and Cupp (1943) distinguish the two by pointing out that *Ch. laciniosus* usually has two chromatophores and is larger (girdle width approx. 14 μ).than *Ch. pelagicus* which has only one chromatophore. However Cupp's figures of the two species show that the chromatophores are somewhat variable in both species. In any event these features would seem to be insufficient to warrant specific separation.

For present purposes the author has considered them separately, but further study may well indicate that one is a form or variety of the other.

Local.: NIOE 18, 19, 20, 59, 62, 74, 91, 95, 101, 104, 108, 114, 124.

Occasionally recorded at scattered inshore and offshore stations in April, July and October. Not present in January. Maximum abundance (+++) at station 91 situated on the edge of the Agulhas Bank (line D) in July.

General: Considered a neritic species by Hendey (1937) and Cupp (1943). The species is apparently widely distributed in temperate waters, but also extends into subtropical and tropical regions. Wood (1963,b) lists numerous records of the species in the N. Indian Ocean. It has also been recorded from the Antarctic (Mann, 1937).

127. Chaetoceros lauderii Ralfs, Trans. Micr. Soc., N.S. 12 : 77, pl. 8, figs. 3, 4 (1864); Gran, Diat. Nord. Plankt. : 77, fig. 92 (1905); Hustedt, in A. Schmidt, Atlas : pl. 341, figs. 5, 6, 7 (1921); Hustedt, Kieselalg. (1) : 683, fig. 387 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 118, fig. 73 (1943).

System.: The specimens observed by the author were most easily referable to those figured by Cupp (1943), particularly with regard to the shape of the bases of the setae.

Local.: NIOE 114.

Recorded from one station over the shelf near Port Elizabeth. Present in small numbers (+).

General: A neritic, temperate species (Cupp, 1943). Hustedt (1930) regarded it as more characteristically present in warmer seas. Wood (1963,b) has provided several references to the species in the Indian Ocean.

128. <u>Chaetoceros lorenzianus</u> Grunow, Verh. zool. bot. Ges. Wien <u>13</u> : 157, pl. 5, fig 13 (1863); Gran, Diat. Nord. Plankt. : 76, fig. 90 (1905); Hustedt, in A. Schmidt, Atlas : pl. 321, figs. 18, 19 (1920); Hustedt, Kieselalg. (1) : 679, fig. 385, (1930); Hendey, Discovery Rep. <u>16</u> : 299 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 118, fig. 71 (1943); Brunel, Phytopl. Baie Chaleurs : 105, pls. 18, 19 (1962).

Local.: NIOE 1, 2, 3, 5, 7, 9, 10, 12, 16, 17, 18, 19, 20, 21, 23, 28, 32, 34, 35, 36, 37, 58, 59, 60, 62, 64, 66, 67, 69, 71, 73, 74, 75, 76, 77, 78, 80, 82, 84, 85, 87, 88, 89, 91, 93, 94, 95, 96, 97, 99, 101, 103, 104, 108, 110, 111, 112, 113, 114, 115m 117, 119, 121, 124, 126, 128, 130, 142, 143, 144, 157, 158, 159, 161, 162, 172, 176.

The most widespread and abundant species of phytoplankton recorded on the survey, present in 77 of the 98 samples analysed. In July it was present at every station in the area, and virtually every station in April and October. In January it was restricted to the inshore sections of all lines.

It achieved maximum abundance (+++++) at station 18, the most inshore station on line B in April, 84, 85, 87, 88, 89, 91, 95, 96, 97, 99, 101, 104, 108, 110, 111, 112, 114, 115, 117, 119, 121, 124, 128, 142, 143, 144, 176.

This species had a similar distribution pattern to _Ch. lorenzianus_ but usually occurred in less abundance in the samples. Maximum abundance (++++) was recorded at stations 77, 78, 91, and 108, primarily stations on the outer edge of the shelf or in the Agulhas Current in July and October. The distribution was not quite as wide as _Ch. lorenzianus_, the species not being present when the latter was only present in minimal numbers. In January the species was confined to inshore stations near Durban and one isolated station in the south on line D.

The distribution is further discussed in section IV.

General: Considered to be a tropical to subtropical species by Hendey (1937) and Cupp (1943). Wood (1963,b) has listed many authors who have recorded the species from the Indian Ocean.

130. _Chaetoceros myriapodus_ Mangin, Ann. Inst. Oceanogr. _4_ (1) : 53, fig. 41 (1913); Hustedt, Kieselalg. (1) : 765, fig. 447 (1930). PLATE 5, fig. 8.

System.: This species is distinguished from several others which closely resemble it on the grounds that the terminal cells lack outermost setae and are slightly more convex than the cells within the chain. Mangin provided no information on cell contents, but the individuals illustrated in the present work each possessed one parietal chromatophore. Hustedt (1930), who included this species among his "unvollständig bekannte Arten", suggested that the outermost valves represented the primary valves of germinated resting spores, this explaining their lack of setae. If this is the case, and it seems to be a reasonable suggestion, then there is little reason to distinguish the species from Ch. debilis Cleve which it resembles in all respects except for the terminal cells. However, until resting spores can be seen within the chain this cannot be determined with certainty.

Local.: NIOE 94.

Several short chains observed in a sample from a station close inshore near Cape Agulhas in July.

General: Originally recorded from Brest (N. Atlantic) by Mangin. Subrahmanyan (1958) identified the species in the Arabian Sea. This appears to be the only previous record of the species in the Indian Ocean.

It is interesting to note that the local record was from a station which, according to the presence of certain species, e.g. *Ch. curvisetus* and *Ch. difficilis*, appears to have been in water originating from the west coast region. *Ch. debilis* is fairly common on the west coast (Hart & Currie, 1960) and this, circumstantial though it undoubtedly is, suggests further that the species is one and the same as *Ch. debilis*.

131. *Chaetoceros neglectus* Karsten, Valdivia Antarkt. Phytopl. : 119, pl. 16, fig. 5 (1905); Hendey, Discovery Rep. *16* : 303 (1937). PLATE 15, fig. 2.

System.: In general impression cells of this species resemble those in parts of the chain of *Ch. compressus*, but it may be distinguished from the latter species by its single chromatophore and smaller size.

Local.: NIOE 62, 67, 75, 77, 115, 157.

Observed in small numbers (+ - ++) from scattered inshore and offshore stations, mostly in July, but also in October and January.

General: Considered to be a typical Antarctic diatom by Hendey (1937). Not previously recorded from the Indian Ocean although there are several records of the species in the Antarctic (see Wood, 1963, b).

Its presence in the S.W. Indian Ocean is probably due to the same factors which allow a northward spread of cold-water species in winter in this area, the October and January records possibly being of remnants of this northern spread.

132. Chaetoceros paradoxus Cleve, Bih. Kongl. Svenska Vet.-Akad. Handl. 1 (11) : 10, pl. 3, fig. 16 (1873); Allen & Cupp, Ann. Jard. Bot. Buitenzorg 44 (2) : 140, fig. 67 (1935); Subrahmanyan, Proc. Indian Acad. Sci. 24 : 139, figs. 230, 232 (1946).
PLATE 3, fig. 2.

System.: In narrow girdle view this species closely resembles Ch. capricornianus but is readily distinguishable in broad girdle view. There appear to be two types of valve structure in this species: that in which the valve is sharply angled (e.g. as shown by Cleve and in Allen &

Cupp, fig. 67,a) and that in which the cells are more rounded e.g. Allen & Cupp, fig. 67 and the present author's figure).

Local.: NIOE 74.

One chain (as figured) recorded from a station on the inner edge of the core of the Agulhas Current in July.

General: Recorded by several authors from the vicinity of the East Indies. Also found near India, and in the Indian Ocean (see Wood, 1963, b, for references).

Probably present in the area due to southward transport by the Agulhas Current.

133. Chaetoceros parallelis Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 389, fig. 70 (1950).

System.: Boden rather oddly refers the reader to a paper "in press" for the original description of this species whereas, in fact, the above reference constitutes valid publication and is therefore the type description. The present author has not been able to discover in which journal his "in press" paper was published.*

Local.: NIOE 169.

One cell observed at an extreme offshore southern

* Later found to be in Trans. Roy. Soc. S. Afr. 32 (3) : 233 - 234 (1950), and thus an earlier reference.

Cupp, fig. 67,a) and that in which the cells are more rounded e.g. Allen & Cupp, fig. 67 and the present author's figure).

Local.: NIOE 74.

One chain (as figured) recorded from a station on the inner edge of the core of the Agulhas Current in July.

General: Recorded by several authors from the vicinity of the East Indies. Also found near India, and in the Indian Ocean (see Wood, 1963, b, for references).

Probably present in the area due to southward transport by the Agulhas Current.

133. Chaetoceros parallelis Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 389, fig. 70 (1950).

System.: Boden rather oddly refers the reader to a paper "in press" for the original description of this species whereas, in fact, the above reference constitutes valid publication and is therefore the type description. The present author has not been able to discover in which journal his "in press" paper was published.*

Local.: NIOE 169.

One cell observed at an extreme offshore southern

* Later found to be in Trans. Roy. Soc. S. Afr. 32 (3) : 233 - 234 (1950), and thus an earlier reference.

station in January.

General: Previously described from the West Coast of S. Africa (Boden).

134. Chaetoceros pelagicus Cleve, Bih. Kongl. Svenska Vet.-Akad. Handl. 1 (13) : 11, pl. 1, fig. 4 (1873); Gran, Diat. Nord. Plankt. : 83, fig. 101 (1905); Hustedt, Kieselalg. (1) : 704, fig. 402 (1930); Hendey, Discovery Rep. 16 : 302 (1937); Cupp, Mar. Plankt. W. Coast N. Amer. : 129, fig. 81 (1943). PLATE 15, fig. 1.

System.: See note under Ch. laciniosus Schütt.

Local.: NIOE 94, 103, 104, 115.

Recorded in small numbers from the vicinity of Cape Agulhas in July, and from offshore stations on lines A and B in October.

General: Considered to be anneritic species by Hustedt (1930) and Cupp (1943). Recorded from one subantarctic station to the south of S. Africa by Hendey (1937). It appears to be temperate in its distribution. Hendey notes that its distribution is similar to Ch. laciniosus, but Cupp found it to be more northern in its distribution off the west coast of N. America than the latter species. There are several records of the species in the Indian Ocean (see Wood, 1963, b).

135. Chaetoceros pendulus Karsten, Valdivia Antarkt. Phytopl. : 118, pl. 15, fig. 7 (1905); Hendey, Discovery Rep. 16 : 295 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 114, fig. 69 (1943).
PLATE 13, fig. 2.

Local.: NIOE 9, 10, 12, 30, 36, 58, 59, 60, 62, 67, 71, 73, 77, 95, 96, 103, 110, 111, 115, 124, 128, 146, 148, 150, 153, 155, 162, 164, 169, 174.

Found, usually in small numbers, at oceanic stations over most of the area on all four cruises. Spreads into inshore stations on lines A and B. Maximum abundance (+++) was recorded at stations 73 and 153, oceanic stations on line B in July and January respectively.

General: Considered to be a neritic species by Hendey (1937) who found it to be common in the S. Atlantic Ocean near Cape Horn. It was originally described from the Antarctic, and has been found in the S. Indian Ocean (Wood, 1963, b).

The distribution in the S.W. Indian Ocean leads the present author to doubt Hendey's neritic designation for the species. It was more commonly present in the oceanic region. Its presence inshore on lines A and B reflects the distribution of several oceanic species which spread into the inshore area on those lines only, e.g. Ditylum sol, Chaetoceros denticulatus, etc.

136. Chaetoceros peruvianus Brightwell f. peruvianus, Q.J. Micr. Sci. 4 : 107, pl. 7, figs. 16 - 18 (1856); Gran, Diat. Nord. Plankt. : 70, fig. 84 (1905); Hustedt, Kieselalg. (1) 671, fig. 380 (1930); Hendey, Discovery Rep. 16 : 296,,pl. 13, fig. 6 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer.: 113, fig. 68 (1943).

Local.: NIOE 2, 5, 9, 10, 12, 14, 16, 17, 18, 19, 20, 21, 23, 28, 30, 32, 34, 35, 36, 37, 58, 59, 60, 62, 64, 66, 67, 69, 71, 73, 74, 76, 77, 78, 80, 84, 85, 88, 89, 91, 94, 95, 96, 97, 99, 101, 103, 108, 110, 111, 112, 114, 115, 119, 120, 121, 124, 126, 128, 130, 142, 143, 148, 155, 157, 158, 159, 161, 162, 164, 169, 172, 174, 178.

One of the commonest and widespread species of phytoplankton in the S.W. Indian Ocean, but usually found in small numbers (unlike Ch. lorenzianus and Ch. messanensis). It was slightly more sparse in January than during the other months investigated.

General: This is panthallassic species (considered oceanic by Hendey, 1937) due to its presence in similar abundance at both inshore and offshore stations (see Hart & Currie, 1960 : 208). There are numerous references to the species in the Indian Ocean (Wood, 1963, b).

137. Chaetoceros peruvianus forma gracilis (Schröder) Hustedt, Kieselalg. (1) : 672, fig. 381, b (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 114, fig. 68, d - f (1943).

System.: Hendey (1937) has pointed out that in his material there was a complete range of variation in specimens of Ch. peruvianus encompassing all the known varieties and forms, and he felt that distinguising the subspecific ranks served no useful purpose.

Whilst existence of a complete range of variation is undoubtedly true, this being the case in the present author's material as well, it would seem that if variation is due to the influence of the environment, i.e. phenotypic rathern than genotypic, then the distinction of forms might be of value in ecological studies. For this reason the above form is distinguished here.

Local.: NIOE 142, 144, 161.

This distribution is incomplete, the distinction between this form and the forma typica only being recognised at the start of the analysis of the January material.

In January it was observed in small numbers at inshore stations on lines A and C.

General: Recorded as rarer than the typical form in the Mediterranean (Schröder, 1900, as var. gracilis). Hustedt (1930), and Cupp (1943) do not provide any information on the distribution of this form, and so it is premature to speculate on its ecological relationship with its environment at present.

138. Chaetoceros pseudocrinitus Ostenfeld, Nyt Mag. Naturvid. 39 (4) : 300, fig. 11 (1901); Gran, Diat. Nord. Plankt. : 90, fig. 114 (1905); Hustedt, Kieselalg. (1) : 733, fig. 422 (1930); Hendey, Discovery Rep. 16 : 304 (1937).

Local.: NIOE 101, 103, 119.

Present in small numbers at scattered offshore stations in October only.

General: This species has a neritic distribution in the N. Atlantic (Hustedt, 1930). Hendey (1937) retained the neritic designation but recorded it from an offshore station in the area under present study. There appear to be no other records of the species in the Indian Ocean.

139. Chaetoceros pseudocurvisetus Mangin, Bull. Soc. Bot. France 57 : 350, fig. 4 (1910); Ikari, Bot. Mag. Tokyo 40 : 529, fig. 12 (1926); Hustedt, Kieselalg. (1) : 739, fig. 427 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 138, fig. 94 (1943).

System.: Wood (1963, b) apparently considered this species, like Ch. curvisetus Cleve, to be synonymous with Ch. secundus Cleve. There is a good case for considering Ch. curvisetus and Ch. secundus as one and the same species, but Ch. pseudocurvisetus can be easily distinguished from other species on the basis of its highly characteristic protuberances on the valves which lead to an unmistakable appearance of the foramina. Thus the present author considers Mangin's species to be distinct and valid.

Local.: NIOE 1, 17, 18, 19, 20, 35, 58, 59, 60, 62, 66, 73, 74, 75, 77, 78, 84, 85, 91, 112, 142, 158, 159, 161, 162, 176.

A markedly neritic distribution. It spread furthest offshore in July. It was confined to only one station, inshore on line B, in October. Characteristically spread throughout the shelf area on all lines but only on the outer edge of the Agulhas Bank on line D (stations 35, 91 and 176). It achieved maximum abundance (+++) at stations 17, 19 (April), 75 (July), and 161 (January), all of these being inshore stations on lines B and C.

General: A neritic, subtropical to tropical species (Cupp, 1943). It does not appear to have been recorded from the Indian Ocean prior to the present study, although there are several records from adjacent areas, e.g. Allen & Cupp (1935) from the Java Sea.

140. Chaetoceros radicans Schütt, Ber. Deutsch. Bot. Ges. 13 : 48, fig. 27 (1895); Gran, Diat. Nord. Plankt. : 93, fig. 119 (1905, sub Ch. scolopendra Cleve); Hustedt, in A. Schmidt, Atlas : pl. 340,

figs. 8 - 11 (1921); Hustedt, Kieselalg. (1) : 746, fig. 431 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 141, fig. 97 (1943).

Local.: NIOE 7, 9, 10, 12, 19, 20, 34, 60, 62, 69, 71, 77, 80, 84, 85, 94, 101, 108, 111, 112, 114, 115, 119, 124, 159.

Found, usually in moderate numbers (++), at northern offshore stations and southern inshore and offshore stations. In January the species was recorded from only one station (NIOE 159) inshore on line B. In general it was nearer the coast in October than in April and July. Maximum abundance (+++) was recorded at stations 9, 12 (April) and 124 (October), all offshore stations.

General: Considered by Gran (1905) and Cupp (1943) to be a temperate neritic species.

In view of the local distribution it would perhaps be better to consider the species as panthallassic.

141. Chaetoceros rostratus forma glandazii (Mangin) Taylor, sta. et comb. nov. PLATE 13, fig. 3.

Syn.: Ch. glandazi Mangin, Bull. Soc. Bot. France 57 : 346, fig. 2 (1910); Hendey, Discovery Rep. 16 :

292 (1937); Silva, Estud. Microplanct. Mar. Mozambique : 39, pl. 5, fig. 1 (1956).

System.: This is distinguished from the typical form on the grounds of its elongate central processes which result in adjacent cells being widely separated,* and by the angularity of the frustules when seen in girdle view. The setae of adjacent cells do not cross one another in the proximal portions of the setae.

In the systematic history of this taxon there are two extremes in treatment, ranging from the authors cited above who considered it to be a distinct species, to Hustedt (1930, p. 660) who considered it to be completely synonymous with <u>Ch</u>. <u>rostratus</u> Lauder and made no distinction between the two at any level.

Whilst agreeing with Hustedt (1930) in the viewpoint that specific separation is not appropriate, the presentaauthor is of the opinion that the differences between the two are sufficient to warrant infraspecific distinction, and that a distinction at the level of forms would be of value to ecological studies.

Local.: NIOE 59, 103, 104, 106, 111, 114, 115, 121, 124, 130, 158, 162, 176, 178.

* Mangin (1910, p. 347) has illustrated cells of this form with short processes, and thus the angularity of the valves would seem to be the most reliable criterion for distinction of the forms.

Not present in April, only found at one inshore station on line A (Durban) in July. Fairly widespread in October, being recorded from offshore stations on the northern lines, and both inshore and offshore further south. Recorded from four inshore stations (lines B, C and D) in January. Usually only present in small numbers (+). Maximum abundance (++) was recorded at stations 114 and 124, an inshore station near Port Elizabeth and an offshore station on line D respectively.

General: Recorded from the Atlantic Ocean (Mangin, 1910) and the Indian Ocean (Hendey, 1937; Silva, 1956). The Indian Ocean records are both from localities immediately to the north of the area under present consideration. It is probably carried south by the Mozambique and Agulhas Currents. There is not sufficient data as yet to determine whether the form is oceanic or neritic.

142. Chaetoceros socialis Lauder, Trans. Micr. Soc., N.S., 12 : 77, pl. 8, fig. 1 (1864); Gran, Diat. Nord. Plankt. : 96, fig. 123 (1905); Hustedt, Kieselalg. (1) : 751, fig. 435 (1930); Hendey, Discovery Rep. 16 : 305 (1937); Cupp, Mar.

Plankt. Diat. W. Coast N. Amer. : 143, fig. 100 (1943). PLATE 15, fig. 3.

Local.: NIOE 94.

One large aggregation of cells observed in an inshore station near Cape Agulhas in July.

General: A neritic species widely distributed in temperate and subantarctic waters (Hendey, 1937; Cupp, 1943). It is locally abundant off the west Coast of S. Africa (Hart & Currie, 1960), and its presence at the cited locality is further indication of the presence of water from the west coast at the station in question. (see comments under *Ch. curvisetus* and *Ch. difficilis*).

143. *Chaetoceros teres* Cleve, Bih. Kongl. Svenska Vet.-Akad. Handl. 22 Afd. 3 (5) : 30, fig. 7 (1896); Gran, Diat. Nord. Plankt. : 77, fig. 91 (1905); Hustedt, in A. Schmidt, Atlas : pl. 342, fig. 4 (1921); Hustedt, Kieselalg. (1) : 681, fig. 386 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 118, fig. 72 (1943); Brunel, Phytopl. Baie Chaleurs : 108, pls. 23, 24 (1962).

Local.: NIOE 1, 20, 71, 73, 74, 77, 78, 85, 91, 94, 95, 96, 104, 110, 111, 112, 114, 115, 124, 142, 143, 158, 159, 161.

A predominatly neritic distribution, spreading offshore in October. Extending from Durban to Cape Agulhas (line D) in July and October.

General: A neritic, meroplanktonic species preferring boreal to temperate conditions (Brunel, 1962). It has been recorded from the W. Coast of S. Africa by Boden (1950) and Hart & Currie (1960). Its presence in the area might be due to seeding from the W. Coast area.

144. Chaetoceros tetras Karsten, Valdivia Atlant. Phytopl. : 167, pl. 32, fig. 10 (1906); Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 377, fig. 55 (1950).

Local.: NIOE 74.

One chain observed in the vicinity of Port St. Johns (line B) in July.

General: First recorded by Karsten (1906) from Cape Town, S. Africa. The only other records of this species appear to be those of Boden (1950) and Hart & Currie (1960) from the W. Coast of S. Africa. It possibly spreads north in the inshore part of the area under study after being introduced from the West Coast.

145. <u>Chaetoceros</u> <u>tetrastichon</u> Cleve, Treat. Phytopl. Atlantic & Trib. : 22, pl. 1, fig. 7 (1897); Gran, Diat. Nord. Plankt. : 69, fig. 81 (1905); Hustedt, Kieselalg. (1) : 657, fig. 371 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 108, fig. 63 (1943). PLATE 14, fig. 1.

Local.: NIOE 9, 10, 14, 16, 99, 110, 162.

Recorded from oceanic stations in April, October and January, not frequent. Principally found on the northern lines, A and B, extending to line C in January (at only one station in this month).

General: An oceanic species occasionally found in tropical to temperate waters (Cupp, 1943). Wood (1963, b) lists seven references to the species in the Indian Ocean.

The absence of the species from the area in July is interesting as it coincides with the general spread northwards of cold-temperate species into the area.

146. <u>Chaetoceros</u> <u>wighamii</u> Brightwell, Q.J. Micr. Sci. <u>4</u> : 108, pl. 7, figs. 19 - 36 (1856); Gran, Diat. Nord. Plankt. : 88, fig. 111 (1905); Hustedt, in A. Schmidt, Atlas : pl. 339, fig. 10, pl. 342,

fig. 5 (1921); Hustedt, Kieselalg. (1) : 724, fig. 414 (1930).

Local.: NIOE 96.

One chain recorded from an inshore station near Durban in October.

General: This species is euryhaline, being found in weakly saline coastal waters of Europe (Hustedt, 1930). It has also been recorded from Indian Ocean coasts by several authors (Wood, 1963, b).

Suborder SOLENIINEAE

Family CORETHRONACEAE

147. Corethron criophilum Castracane, Diat. Challenger Exped. : 85, pl. 21, fig. 14 (1886); Hendey, Discovery Rep. 16 : 325, figures on plates 7 & 8 (1937). PLATE 1, fig. 1.

System.: Hendey united all the known species of this genus, C. valdiviae Karsten, C. hystrix Hensen, C. inerme Karsten, C. murrayanum Castracane, C. pelagicum Brun, and C. hispidum Castracane under the species above, distinguishing the

the various forms as "phases". Most of the specimens seen by the present author in the S.W. Indian Ocean material corresponded to his "pelagicum phase", differing from the other phases in its large diameter and shorter connective zone. The material from station 94, where a maximum abundance (+++) was recorded, had cells of the "criophilum" or "type phase" in it.

Local.: NIOE 20, 28, 32, 36, 59, 60, 62, 69, 71, 73, 74, 77, 78, 80, 87, 88, 89, 91, 94, 95, 96, 99, 101, 103, 108, 112, 113, 114, 115, 117, 119, 120, 124, 126, 128, 130, 142, 144, 161, 164, 178.

Recorded in small numbers (usually 1 or 2 cells per subsample) from offshore stations on lines C and D in April, in the Agulhas Current and southern offshore stations in July, widespread at extreme inshore and offshore stations on all lines in October, and restricted to inshore stations on lines A, C and D in January.

General: Hendey (1937) considered the "pelagicum phase" to occur in warmer waters than the other phases, occurring in all oceans. He found it in small numbers around S. Africa. The "criophilum phase" was recorded by him from Antarctic waters and the S. Atlantic Ocean.

The local distribution of these two phases supports Hendey's conclusions.

Family LEPTOCYLINDRACEAE

148. Dactyliosolen mediterraneus H. Peragallo, Diatomiste 1 : 104, pl. 13, figs. 8, 9 (1892); Gran, Diat. Nord. Plankt. : 25, fig. 27 (1905, sub D. tenuis Cleve); Peragallo, Diat. Mar. France : 456, pl. 122, figs. 5, 6 (1908, fig. 5 sub D. bergonii H. Perag.); Hustedt, Kieselalg. (1) : 556, fig. 317 (1930); Hendey, Discovery Rep. 16 : 324, pl. 6, figs. 4, 5, 6 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 77, fig. 38 (1943). PLATE 16, fig. 1, PL. 22, fig. 1.

Local.: NIOE 1, 2, 3, 5, 7, 9, 12, 14, 18, 19, 21, 32, 34, 58, 59, 60, 62, 64, 66, 71, 73, 74, 75, 78, 80, 87, 88, 89, 91, 93, 95, 96, 97, 99, 101, 103, 108, 110, 111, 117, 128, 130, 142, 146, 148, 150, 158, 159, 161, 164, 177, 178.

One of the most common species in the area, but only occurring in small numbers. It was extremely widespread, occurring at extreme inshore and extreme offshore stations on all cruises. It was slightly more abundant (++) at inshore and offshore stations on lines A and B in April.

General: Described as neritic, "sporadically oceanic", by Cupp (1943) who found it to be widespread and fairly common off the west coast of N. America. Hendey (1937) recorded it at only two stations, both of which lay to the south-east of Port Elizabeth. It has been recorded off the west coast of S. Africa by Hart & Currie (1960), and from the Indian Ocean by several authors (Wood, 1963, b). It also extends into Antarctic waters (Heiden & Kolbe, 1928; Crosby & Wood, 1958). The species appears to be virtually ubiquitous in distribution.

149. Detonula moseleyana (Castracane) Gran, Nyt. Mag. Naturv. 38 (2) : 113 (1900). PLATE 4, figs. 1, 2.

Syn.: Lauderia? moseleyana Castracane, Diat. Challenger Exped. : 90, pl. 24, fig. 9 (1886); Castracane, Notarisia : 758 (1889); H. Peragallo, Diatomiste 1 : 105, pl. 13, fig. 10 (1892); De Toni, Syll. Alg. : 772 (1892).

System: Mills, in the supplement to his Index (1935) cited Gran's combination as a synonym for

"Lauderia mos. v. elegans, Cast. Chall. p. 90, 24/9". It is not clear ~~whether~~ where he saw mention of the variety he quoted as in the copy of Castracane's report in the author's possession no mention is made of the variety, either in the general text or in the text to the plate cited.

However this is of little consequence as the species undoubtedly belongs to the genus Detonula. The species was very common in the S.W. Indian Ocean material, and the present author was able to examine the species in detail in Hyrax mounts. All the specimens examined possessed one ring of marginal spinulae and lacked a central spine.

As the species has only been observed on rare occasions a description of the specimens in the author's material is provided below:

Large, cylindrical cells, 28 - 60 μ in diameter, with flattened valves, united into rigid chains by the close contact of adjacent valves. A single row of marginal spinulae are present on the valve margin. The spinulae are difficult to see in water mounts. Castracane referred to them as "granulated terminal bands", not indicating that they occurred in only one row.

There are numerous, collar-like intercalary bands on which there are fine rows of areolae. One of the bands is commonly darker that the others (a feature shown in Castracane's figure), this possibly being associated with cell division in some manner. The chromatophores are numerous rounded or slitted bodies. The parietal nucleus is strikingly visible, and is usually surrounded by chromatophores.

There appear to be two forms of this species, individuals near the coast being generally broad with a length varying between 60 and 100 μ. (PL. 4, fig. 1). Further offshore the cells are elongated and narrower, with fewer, wider intercalary bands (PL. 4, fig. 2), their length usually being between 150 and 212 μ. There is a gradual gradation both in form and distribution between the two. Unfortunately during the microscopic analysis of the material the author made no distinction between the two and so their distribution cannot be considered separately.

Local.: NIOE 1, 2, 3, 17, 18, 20, 35, 36, 58, 59, 60, 62, 64, 66, 67, 69, 73, 74, 75, 76, 77, 78, 80, 87, 89, 91, 93, 94, 96, 97, 101, 112, 113, 124, 130, 142, 143, 158, 159, 160, 161, 178.

A primarily neritic distribution, although the species spread into the offshore area in July and October. In April and January it was more confined to inshore stations. Maximum abundance (+++) was recorded at stations 60 and 73, both on the edge of the Agulhas Current on lines A and B in July.

The local distribution of this species is discussed further in section IV.

General: The species was first described by Castracane from the Sea of Arafura (East Indies). Ostenfeld (1903) recorded it from the Gulf of Siam, and Ostenfeld and Schmidt (1901) found it in Red Sea material.

150. Guinardia flaccida (Castracane) H. Peragallo, Diatomiste 1 : 107, pl. 13, figs. e, 4 (1892); Gran, Diat. Nord. Plankt. : 24, fig. 25 (1905); Peragallo, Diat. Mar. France : 459, pl. 122, figs. 1, 2, 3 (1908); Hustedt, Kieselalg. (1) : 562, fig. 322 (1930); Hendey, Discovery Rep. 16 : 321, pl. 11, fig. 5 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 78, fig. 50 (1943).

Local.: NIOE 2, 3, 12, 16, 17, 18, 19, 20, 35, 58, 59, 60, 62, 64, 66, 73, 74, 75, 76, 77, 78, 80, 84, 85, 91, 93, 112, 113, 128, 130, 142, 143, 158, 160, 161, 176, 178.

A very similar distribution to that of Detonula moseleyana above. Maximum abundance (+++) was recorded at stations 18 and 60, and inshore station on line B in April and a station on the inner edge of the core of the Agulhas Current in July. It was most widespread over the area in July.

General: A neritic, temperate species (Cupp, 1943). Hendey (1937) found it frequently around the Cape of Good Hope, and there are numerous references recording the species in the Indian Ocean (Wood, 1963, b).

61. Lauderia annulata Cleve, Bih. Kongl. Svenska Vet. Akad. Handl. 1 (11) : 8, pl. 1, fig. 7 (1873); Allen & Cupp, Ann. Jard. Bot. Buitenzorg 44 (2) : 124, fig. 25 (1935); Subrahmanyan, Proc. Indian Acad. Sci. 24 : 111, figs. 100, 102 (1946).

Syn.: L. borealis Gran, Nyt. Mag. Naturvid. 38 : 110, pl. 9, figs. 5 - 9 (1900); Gran, Diat. Nord. Plankt. : 23, fig. 22 (1905); Hustedt, Kieselalg. (1) : 549, fig. 313 (1930); Hendey, Discovery Rep. 16 : 240 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer.: 74, fig. 35 (1943).

System.: The author is unable to find any means of distinguishing between the above species using the cited references. Mill's (1934) considered them to be synonymous but incorrectly considered _L. borealis_ Gran to be the valid name (rule of priority). Subrahmanyan (1946) also considered them to be synonymous. Hustedt, 1930, p. 550) stated, with regard to the two species : "die spezifische Trennung beider Arten steht nur auf schwachen Füssen", the basis for separation lying in the form of the chromatophores and the relative robustness of the species. In the present author's material the chromatophores of the individuals were highly variable in form, ranging from small lobed structures to large stellate bodies, and there was a complete range in the degree of robustness of the cells, from cells in which the intercalary bands were not discerniable in water mounts, to those in which they were patently visible in water mounts. Hustedt's assertion that they tend to be distributed in different areas is not a sufficient criterion on which to base a specific separation and, in any case, does not seem to be tenable, various authors having recorded _L. annulata_ in European waters, and _L. borealis_ in tropical areas.

Indian Ocean records of _L. borealis_ include those of Czapek (1909) and Hendey (1937).

Thus there seem to be no reasonable grounds for the separation of these species and Cleve's name must be considered as valid, predating Gran's description of _L. borealis_. As the size and shape of the chromatophores does not seem to be related to the robustness of the frustules the author cannot discern any definable forms of this species.

Local: NIOE 2, 17, 18, 19, 20, 58, 59, 60, 62, 64, 71, 73, 74, 75, 77, 78, 80, 84, 85, 93, 95, 112, 113, 114, 115, 130, 142, 143, 161, 162, 176.

A common species at inshore stations on all lines on all four cruises. Spread into the offshore regions in July. Maximum abundance (+++) recorded at stations 114 and 161, both from the same locality near Port Elizabeth in October and January.

General: A neritic species with a wide distribution in all oceans. Hendey (1937, under _L. borealis_) considered it to be an oceanic species, but most of the records of it are from coastal areas. Wood (1963, b) has provided the many Indian Ocean records of this species separately under both names.

152. Schrőderella* delicatula (Peragallo) Pavillard forma delicatula, Bull. Soc. Bot. France 60 : 126 (1913); Hustedt, Kieselalg. (1) : 551, fig. 314 (1930); Hendey, Discovery Rep. 16 : 241 (1937); Subrahmanyan, Proc. Indian Acad. Sci. 24 : 111, fig. 104 (1946). PLATE 4, fig. 3.

System.: Unlike Lauderia annulata Cleve there appear to be two readily identifiable forms of this species. Several authors, such as Pavillard (1925) and Hendey (1937), considered them to be sufficiently distinct to be separate species - S. delicatula and S. schrőderii* However Hustedt (1930) pointed out that he had observed intermediate forms between the two, and so considered them as one species, making no subspecific distinctions between them. As intermediate forms exist it would certainly not be consistent with the general concept of a species to regard them as separate at that level. Nevertheless there does seem to be some ecological significance in the forms corresponding to the species above. As Hendey (1937) has indicated, the schrőderii* form is, in general, distributed in colder waters than the typical form. This is borne out by the records of other authors and the present author's observations. In the colder

* More correctly "Schroederella" and "Schroederii".

waters off the west coast of S. Africa the <u>schröderii</u> form is common, whereas in the warm waters off the east coast of S. Africa, the typical "<u>delicatula</u>" form prevails.

The references cited beneath the original reference all discuss and figure what might be regarded as the typical form of the species, corresponding to Peragallo's (1888, p. 81, pl. 6, fig. 46) description, the earliest referring to this species (as <u>Lauderia delicatula</u>). The cells are elongated, with flattened valves, and distinct areolation on the intercalary bands. A further feature of this form is that the breaks in the intercalary bands are usually arranged in an interrupted spiral series. Hendey (in personal comm.) has informed the author that the latter feature is not constant.

Local.: NIOE 1, 2, 3, 10, 12, 17, 18, 58, 59, 60, 62, 64, 67, 71, 73, 74, 75, 77, 78, 80, 84, 85, 91, 95, 96, 99, 106, 111, 117, 124, 143, 158, 159.

Occurring on all four cruises at neritic stations on lines A and B. In April the form spread into the offshore region on lines A and B. In July it was widely spread at inshore and offshore stations on alllines. In October it was at inshore stations on line A, an offshore station on line B, and at a few isolated offshore stations on lines C and D. In January it was entirely confined to inshore stations on lines A and B. Maximum abundance (+++) was recorded in the vicinity of Durban on all cruises (stations 2, 60, 95, 96, and 143).

General: This appears to be a neritic, subtropical form. Wood (1963, b) provided references of the species from the Indian Ocean, indicating those which referred to the "_schröderii_" form (as _Detonula_ _schröderii_). Hendey (1937) found the typical form to be very common around S. Africa.

153. _Schröderella_ _delicatula_ forma _schröderii_* (Bergon) Taylor, stat. et. comb. nov. PLATE 4, fig. 4, PL. 16, fig. 2.

Syn.: _Lauderia_ _schroderi_ Bergon, Bull. Stat. Biol. Soc. Sci. d' Arcachon _3_ : 69 (1902).
Schröderella _schröderi_ (Bergon) Pavillard, Rep. Danish Oceanogr. 1908 - 10 Medit. _2_ (4) : 23 (1925); Hendey, Discovery Rep. _16_ : 241 (1937).
Schröderella _delicatula_ sensu Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 75, fig. 36 (1943).

System.: See note under _S_. _delicatula_ f. _delicatula_

*More correctly "_schroederii_".

This form is distinguished from the typical form by its characteristically short, broad cells, the valves of which show no flattening in girdle view but instead curve into a larger central depression than in the typical form. The gaps in the intercalary bands are randomly distributed, and the markings on them resolve as lines of punctae in Hyrax mounts. A curious feature often seen in this form is the variable distinctness of the intercalary bands on each cell (see figure).

Local.: NIOE 18, 19, 20, 94, 95, 96, 111, 112, 113, 115, 128, 130, 142, 143, 158, 159, 160, 161, 162, 176, 178.

This form was restricted to the inshore areas on all cruises. In April it was only present on lines B and C, spreading over the entire shelf area from Durban to Cape Agulhas in October and January. In July it was only present at station 94 near Cape Agulhas. It achieved maximum abundance (++++) at station 161 near Port Elizabeth in January, but was also present in fairly large numbers (+++) at stations 19, 20, 94, 112 and 113 (April, July & October).

General: This was considered to be the cold-water form of the species by Hendey (1937) who found it to be abundant in material from the Peru Current. It has been recorded from the west coast of S. Africa by Boden (1950, as indicated by his figure). It is difficult to establish whether the various Indian Ocean records of this form (under its various synonyms) do indeed refer to it, as in most cases descriptions and figures were not given. The record of Karsten (1907) refers to the typical form. Hendey (1937) recorded this form from several stations to the south of S. Africa and one in the area under present study.

It is interesting to note that the form was restricted to the inshore waters of the area where cold water upwells on the inner edge of the Agulhas Current. Both forms were present simultaneously at several stations. These stations were situated in highly stratified water where there was a sharp drop in temperature within the upper 100 metres, and it is not inconceivable that the typical form was in the warm water above the thermacline and the "forma *schröderii*" in the cooler water below it. This is purely speculation as the sampling method provided no information on the vertical distribution of the species.

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154. <u>Rhizosolenia</u> <u>acuminata</u> (Peragallo) Gran, Diat. Nord. Plankt. : 50, fig. 5 a, (1905); Hustedt, Kieselalg. (1) : 605, fig. 350 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 94, fig. 53 (1943).

Local.: NIOE 5, 12, 18, 20, 112, 114, 158.

Present in small numbers at a few inshore and offshore stations in April, October and January.

General: This species is considered to be an oceanic subtropical or temperate species by Cupp (1943). There are a few records of the species from the N. Indian Ocean (Wood, 1963, b).

155. <u>Rhizosolenia</u> <u>alata</u> Brightwell forma <u>alata</u>, Q.J. Micr. Sci. <u>6</u> : 96, pl. 5, fig. 8 (1858); Gran, Diat. Nord. Plankt. : 56, fig. 68, b, c (1905); Hustedt, Kieselalg. (1) : 600, fig. 344 (1930); Hendey, Discovery Rep. <u>16</u> : 310 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 90, fig. 52-A (1943).

System.: This form corresponds to Gran's forma <u>genuina</u>. Hendey (1937) considered the forms of this species to be "phases" in accordance with his views on subspecific variation. Hustedt (1930) also put forward doubts as to significance of the various forms as he had observed them to occur simultaneously in some localities. The forms are retained here for purposes of comparison with other studies.

Local.: NIOE 5, 12, 17, 18, 19, 20, 21, 30, 34, 58, 64, 66, 67, 71, 73, 74, 75, 76, 77, 78, 80, 84, 85, 87, 88, 89, 91, 93, 94, 95, 96, 97, 99, 101, 104, 108, 110, 111, 112, 113, 114, 119, 120, 142, 143, 157, 158, 160, 161, 176, 177, 178.

A very common taxon in the area, being widely distributed on all lines on all four cruises. Its distribution was limited to scattered stations in April, and to inshore stations in January. It was not usually present in large numbers, local abundances of "++++" being recorded at stations 113 and 178, inshore stations at Port Elizabeth and Cape Agulhas in October and January respectively.

General: An oceanic species widely distributed in temperate and subtropical waters (Hendey, 1937, referring to the typical form). There are twenty-three references to the species in the Indian Ocean and adjacent waters (Wood, 1963, b).

The local distribution, with maximum abundance occurring at neritic stations, suggests that the typical form should be considered neritic or panthallassic, rather than oceanic.

156. Rhizosolenia alata forma gracillima (Cleve) Gran, Diat. Nord. Plankt. : 56, fig. 68, d (1905); Hustedt, Kieselalg. (1) : 601, fig. 345 (1930); Hendey, Discovery Rep. 16 : 310 (1937, as "phase"); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 92, fig. 52-B (1943); Subrahmanyan, Proc. Indian Acad. Sci. 24 : 121, fig. 147 (1946).

System.: The above combination is frequently attributed to Grunow (1881). This is not strictly correct as Grunow described the form as a variety. The authorship of the combination, if used, should be attributed to Gran.

Local.: NIOE 1, 3, 7, 9, 10, 14, 23, 25, 27, 28, 32, 34, 35, 37, 58, 59, 60, 62, 64, 66, 69, 71, 73,74, 76, 77, 78, 80, 85, 88, 89, 93, 94, 95, 96, 97, 101, 104, 110, 113, 115, 120, 126, 129, 143, 144, 153, 158, 161, 164, 166, 168, 169, 172, 174, 176, 178.

This form is even more widely distributed than the typical form, being present at most stations sampled on all the cruises with little difference between the various months. However it was in smaller numbers than the typical form at most stations.

General: Hendey (1937) considered this form (or "phase") to be neritic and more common in subtropical waters. He found it to be common in the area under study, spreading north of Madagascar. He also found it to be common in subantarctic waters. Wood (1963, b) has listed four references to this form in the Indian Ocean, omitting Hendey (1937) and Subrahmanyan (1946).

157. Rhizosolenia alata forma indica (Peragallo) Hustedt in A. Schmidt, Atlas : pl. 317, figs. 11, 12, 13 (1920); Hustedt, Kieselalg. (1) : 602, fig. 346 (1930); Hendey, Discovery Rep. 16 : 311 (1937, as "phase"); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 93, fig. 52-C (1943); Subrahmanyan, Proc. Indian Acad. Sci. 24 : 123, figs. 144, 148, 149, 155 (1946).

System.: This form is attributed here to Hustedt and not to Ostenfeld (1901) for the same reason as given under the preceding form.

Local.: NIOE 2, 5, 17, 18, 19, 20, 35, 36, 37, 58, 59, 60, 62, 64, 66, 67, 69, 73, 75, 76, 77, 78, 80, 85, 94, 95, 96, 112, 121.

Not as common as the other forms recorded. It was entirely absent from the January material. It was most widely distributed in July when it was present in small numbers at inshore and offshore stationsoon all lines. In April it occurred mostly at inshore stations.

General: Considered to be distributed in warmer waters than the typical variety by Cupp (1943). This was not clearly shown in the local distribution. It is likely that many of the Indian Ocean records of the species included this form among them. Cleve, in his papers dealing with the Indian Ocean distinguished this form (as _Rh. corpulenta_), and Subrahmanyan (1946) recorded it from the Madras Coast of India.

158. _Rhizosolenia bergonii_ H. Peragallo, Diatomiste _1_ : 110, pl. 15, fig. 5 (1892); Gran, Diat. Nord. Plankt. : 51, fig. 60 (1905); Peragallo, Diat. Mar. France : 463, pl. 123, fig. 4 (1908); Hustedt, Kieselalg. (1) : 575, fig. 327 (1930); Hendey, Discovery Rep. _16_ : 312 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 81, fig. 43 (1943). PLATE 16, fig. 4.

Local.: NIOE 1, 2, 14, 17, 18, 23, 25, 28, 30, 32, 34, 36, 58, 59, 60, 62, 64, 66, 67, 69, 71, 73, 74, 75, 76, 77, 78, 80, 84, 85, 87, 88, 91, 95, 96, 99, 101, 103, 104, 108, 110, 111, 112, 114, 115, 119, 110, 121, 124, 126, 128, 142, 143, 158, 160, 161, 166, 168, 176.

A very common species in the area, particularly widespread in July and October. In April and January it was present chiefly at inshore stations on lines A and B, occurring further offshore as well as inshore in the south. Maximum abundance (+++) was recorded at stations 30, 34, and 71, oceanic stations in the south in April and on line B in July.

General: Generally considered to be a subtropical, oceanic species (Hendey, 1937; Cupp,1943). The local distribution, in which it was encountered in greater numbers in the south near the Subtropical Convergence region, does not quite fit this designation. There are many records of the species in the Indian Ocean (Wood, 1963, b).

159. Rhizosolenia calcar-avis Schultze in Müller's Archiv. f. Anat., Phys. u. Wissensch. Med. 1858 : 339, pl. 13, figs. 5 - 10 (1858); Gran, Diat. Nord. Plankt. : 54, fig. 66 (1905); Hustedt, Kieselalg. (1) : 592, fig. 339 (1930); Hendey, Discovery

Rep. 16 : 312, pl. 11, fig. 14 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 89, fig. 51 (1943).

Local.: NIOE 5, 18, 23, 34, 58, 59, 60, 62, 71, 73, 74, 75, 76, 77, 78, 84, 91, 95, 96, 97, 99, 108, 110, 111, 112, 114, 115, 129, 143, 144, 160, 162.

Occurring primarily at inshore or Agulhas Current stations. It was found near Durban and Port Elizabeth on all four cruises but was absent from inshore stations on lines B and D in January. It spread to several isolated offshore stations in the south in July. Maximum abundance (+++) was recorded at station 5, this apparently being a localised abundance.

General: Hendey (1937) observed this species frequently in material from the eastern side of S. Africa. It is generally considered to be a tropical to subtropical species, beingaabundant in the Mediterranean (Hustedt, 1930). There are numerous references to the species in the Indian Ocean (Wood, 1963, b).

160. Rhizosolenia castracanei H. Peragallo, Bull. Soc. Hist. Nat. Toulouse 22 : 93, pl. 6, fig. 42 (1888); Karsten, Valdivia Indische Phytopl. : 164,

pl. 30, fig. 14 (1907); Peragallo, Diat. Mar. France : 463, pl. 123, fig. 9 (1908); Hustedt in A. Schmidt, Atlas : pl. 318, fig. 5 (1920); Hustedt, Kieselalg. (1) : 607, fig. 351 (1930); Hendey, Discovery Rep. 16 : 313 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 94, fig. 54 (1943).

Local.: NIOE 7, 9, 155, 157.

Rare in the area. Recorded in small numbers from northern oceanic stations in April and January only. Possibly transported south into the area by the Agulhas Current.

General: Considered to be a temperate, oceanic species by Hendey (1937). Hustedt (1930) and Cupp (1943) considered it to be tropical. The latter seems to be more correct, judging by the local distribution. It has been recorded from the Indian Ocean by a few authors (Wood, 1963, b).

161. Rhizosolenia cylindrus Cleve, Phytopl. Atlantic & Trib. : 24, pl. 2, fig. 12 (1897); Gran, Diat. Nord. Plankt. : 49, fig. 56 (1905); Hustedt, Kieselalg. (1) : 572, fig. 325 (1930); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 80, fig. 42 (1943).

PLATE 16, fig. 3.

Local.: NIOE 2, 5, 12, 18, 19, 20, 21, 28, 30, 32, 34, 36, 58, 60, 62, 64, 71, 74, 78, 80, 84, 85, 97, 99, 101, 103, 104, 108, 115, 117, 119, 124, 142, 143, 144, 157, 158, 160, 161.

Occasional at inshore and offshore stations on all cruises, never in large numbers. Restricted to inshore stations on lines A, B and C in January.

General: A neritic, subtropical to tropical species (Cupp, 1943). It has been recorded from the Indian Ocean by several authors (Wood, 1963, b).

162. *Rhizosolenia delicatula* Cleve, Kongl. Svenska Vet.-Akad. Handl. 32 (8) : 28, fig. 11 (1900); Gran, Diat. Nord. Plankt. : 48, fig. 52 (1905); Karsten, Valdivia Atlant. Phytopl. : 163, pl. 29, fig. 8 (1906); Hustedt, Kieselalg. (1) : 577, fig. 328 (1930); Hendey, Discovery Rep. 16 : 315 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 83, fig. 44 (1943).

System.: The author experienced difficulty in distinguishing this species from what may have been large cells of *Leptocylindrus danicus* Cleve in water mounts. This was due to the difficulty in observing the marginal spine in water mounts, and due to possible misidentifications by some of the authors listed above. For example Karsten (1906) and Cupp (1943, fig. 44, c) figure cells with slightly convex valves and, in the case of Karsten, numerous rounded chromatophores as Rh. delicatula. These features are more characteristic of Leptocylindrus danicus. Typical cells of Rh. delicatula, i.e. with flattened valves, visible marginal spine, and few large chromatophores, were present in the material but, in addition the author has included atypical specimens showing the features mentioned above under this species.

Local.: NIOE 18, 19, 20, 36, 58, 59, 60, 73, 75, 76, 84, 85, 89, 91, 94, 95, 96, 99, 104, 111, 112, 113, 115,117, 119, 120, 124, 143, 160, 161, 162, 176, 178.

The species occurred generally in small numbers at northern and southern inshore stations on all cruises. In July it was also present at two extreme southern offshore stations (84 and 85), possibly due to transport off the shelf by the Agulhas Current. In October it spread further into the offshore area than on other cruises.

General: A temperate, neritic species (Hendey, 1937). It has been recorded from the Arabian Sea by

Cleve (1903) and from the Antarctic by Boden (1949).

163. Rhizosolenia fragilissima Bergon, Bull. Soc. Sci. d' Arcachon, Stat. Biol. 6 : 49, pl. 1, figs. 9, 10 (1903); Gran, Diat. Nord. Plankt. : 48, fig. 53 (1905, sub Rh. faeröensis Ostenf.); Hustedt, Kieselalg. (1) : 571, fig. 324 (1930); Hendey, Discovery Rep. 16 : 315 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 80, fig. 41 (1943).

Local.: NIOE 59, 60, 62, 74, 101, 115, 159.

Not present in April and rare at a few scattered stations on the other cruises. The highest value for the species (++) was recorded at station 62, an offshore station on line A in July.

General: Hendey (1937) recorded it, sometimes in considerable quantities, from the coastal waters of S. Africa, and considered it to be a neritic species. Cupp (1943) found it to have a temperate to boreal distribution of the W. Coast of N. America. There are several Indian Ocean records of this species (see Wood, 1963, b).

164. Rhizosolenia hebetata forma semispina (Hensen) Gran, Fauna Arctica 3 (3) : 527 (1904); Gran, Diat.

Nord. Plankt. : 55, fig. 67, b (1905); Hustedt, in A. Schmidt, Atlas : pl. 319, figs. 14 - 16 (1920); Hustedt, Kieselalg. (1) : 592, fig. 338 (1930); Hendey, Discovery Rep. 16 : 315 (1937, as "phase"); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 88, fig. 50-B (1943); Manguin, Diat. Terre Adelie : 268, pl. 5, figs. 67, 68, pl. 27, figs. 323, 324 (1960).

Local.: NIOE 7, 9, 12, 18, 21, 32, 34, 37, 71, 77, 78, 95, 96, 119, 120, 128, 146, 148, 150, 153, 155, 157, 162, 164, 166, 168, 172.

A primarily oceanic distribution. The form was most widely distributed in April and January, particularly in the latter month when it was present at oceanic stations on all four lines. Maximum abundance (+++) was recorded at stations 7, 9, and 164, oceanic stations on line A in April and line C in January.

General: Hendey (1937) found this species to be present off the west coast of S. Africa, but not off the east coast. It is a warm-water summer form off the west coast of N. America (Cupp, 1943). It has been frequently recorded from the Indian Ocean and the Antarctic, the references being given by Wood (1963, b).

165. Rhizosolenia hyalina Ostenfeld in Ostenfeld & Schmidt, Vid. Med. Naturh. Foren. Kjøbenhaven 25 : 160, fig. 11 (1901); Hustedt, in A. Schmidt, Atlas : pl. 319, figs. 11 - 13 (1920); Silva Microplanct. Superfic. Inhaca : 15, pl. 20, fig. 3 (1960).

Syn.: Rh. pellucida Cleve, Kongl. Svenska Vet.-Akad. Handl. 35 (5) : 23, pl. 8, fig. 4 (1901).

System.: Ostenfeld's epithet slightly predates that of Cleve.

Local.: NIOE 58, 60, 62, 64, 73, 74, 75, 76, 77, 78, 85, 89, 91, 95, 96, 110, 111, 112, 113, 124, 129, 142, 143, 158, 159, 161.

Not present in the April material. Present in small numbers at inshore stations on the other cruises, spreading out to oceanic stations on lines A and D in July.

General: It has been recorded from the Red Sea (Ostenfeld & Schmidt, 1901), the East Indies (Cleve, 1901, Malaya) and the Indian Ocean (Wood, 1962). Silva (1960) recorded it from the vicinity of Inhaca Island, Mozambique.

166. Rhizosolenia imbricata Brightwell var. imbricata, Q.J. Micr. Sci. 6 : 95, pl. 5, fig. 6 (1858); Hustedt, in A. Schmidt, Atlas : pl. 315, figs. 11 - 15

(1914); Hustedt, Kieselalg. (1) : 580, fig. 331 (1930); Hendey, Discovery Rep. 16 : 316 (1937). PLATE 16, fig. 5.

Local.: NIOE 3, 5, 18, 58, 62, 75, 78, 84, 85, 96, 128, 142, 143.

Recorded in small numbers from scattered inshore stations on all four cruises, spreading offshore in the south in July.

General: Hendey (1937) recorded the typical variety from one station in the area under present study. Hustedt (1930) was of the opinion that the typical variety had a warm-water distribution. Wood (1963, b) has listed the numerous references to the typical variety in the Indian Ocean.

167. *Rhizosolenia imbricata* var. *shrubsolei* (Cleve) Schröder, Vierteljahrsschr. Naturf. Ges. Zurich 51 : 346 (1906); Gran, Diat. Nord. Plankt. : 52, fig. 63 (1905, sub *Rh. shrubsolei* Cleve); Hustedt, Kieselalg. (1) : 584, fig. 332 (1930); Allen & Cupp, Ann. Jard. Bot. Buitenzorg 44 (2) : 129, fig. 36 (1935); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 84, fig. 47 (1943).

Local.: NIOE 2, 20, 28, 32, 35, 36, 37, 58, 59, 60, 62, 64, 66, 67, 69, 71, 73, 75, 76, 78, 80, 84, 85, 87, 88, 89, 91, 93, 94, 108, 110, 112, 117, 119, 120, 121, 124, 142, 143, 144, 158, 159, 160, 161, 164, 176, 178.

Present in the area in small numbers on all cruises. It was very widespread in July, occurring at 22 out of 25 of the stations at which phytoplankton samples were taken. During the other months it was more restricted to inshore stations, both northern and southern.

General: This variety has a colder distribution than the typical variety, being common in temperate areas, e.g. northern European waters (Hustedt, 1930), but spreading into the tropical Indian Ocean and adjacent areas (Cleve, 1903; Allen & Cupp, 1935).

168. Rhizosolenia robusta Norman ex Pritchard, Infus. : 866, pl. 8, fig. 42 (1861); Gran, Diat. Nord. Plankt. : 50, fig. 57 (1905); Hustedt, Kieselalg. (1) : 578, fig. 330 (1930); Hendey, Discovery Rep. 16 : 317, pl. 11, fig. 13 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 83, fig. 46 (1943); Subrahmanyan, Proc. Indian Sci. 24 : 115, figs. 118, 119, 120, 124 (1946).

System.: The specimens observed were usually broken, possibly due to the coverslip crushing them.

Local.: NIOE 58, 60, 62, 71, 73, 80, 89, 108, 160.

Rare in the area. Not present in the April material, and recorded from only one inshore and one offshore station in October and January respectively.

General: An oceanic, tropical to subtropical species (Hendey, 1937). Hendey recorded it in small numbers from several stations in the area under present study, and also further north in the vicinity of Madagascar. There are numerous references to the species in the Indian Ocean which are listed by Wood (1963, b).

169. Rhizosolenia setigera Brightwell, Q.J. Micr. Sci. 6 : 95, pl. 5, fig. 7 (1858); Gran, Diat. Nord. Plankt. : 53, fig. 64 (1905); Hustedt, in A. Schmidt, Atlas : pl. 320, figs. 6, 7, 8 (1920); Hustedt, Kieselalg. (1) : 588, fig. 336 (1930); Hendey, Discovery Rep. 16 : 318 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 88, fig. 49 (1943).

Local.: NIOE 1, 2, 18, 19, 20, 58, 59, 60, 62, 64, 73, 74, 75, 76, 77, 78, 80, 84, 85, 87, 88, 91, 94, 95, 96, 97, 99, 101, 104, 111, 112, 113, 114, 115, 121, 124, 126, 130, 142, 144, 151, 153, 158, 159, 161, 164, 176, 178.

A common species at inshore stations on all cruises. It spread offshore in July and, to a lesser extent, October. Maximum abundances were recorded at station 18 (+++), an inshore station in April, and station 130 (+++++) near Cape Agulhas in October.

General; Given as a eurythermal and euryhaline neritic species by Hustedt (1930). Hendey (1937) considered that it favoured cold water. In the latter respect it is interesting to note that the species was exceptionally abundant in a temperature of 15.8°C at station 130, this temperature being markedly lower than that prevailing over most of the area in October. Nevertheless, judging by the Indian Ocean records of this species (given in Wood, 1963,b), it spreads into the most tropical parts of the ocean.

170. <u>Rhizosolenia stolterfothii</u> H. Peragallo, Bull. Soc. Hist. Nat. Toulouse <u>22</u> : 82, pl. 6, fig. 44 (1888); Gran, Diat. Nord. Plankt. : 49, fig. 55 (1905); Karsten, Valdivia Atlant. Phytopl. : 162, pl. 29, fig. 8 (1906); Hustedt, in A. Schmidt, Atlas : pl. 320, figs. 4, 5 (1920); Hustedt, Kieselalg. (1) : 578, fig. 329 (1930); Hendey, Discovery Rep. <u>16</u> : 319, pl. 11, figs. 7, 8

(1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 83, fig. 45 (1943).

System.: In the various references cited above which include synonymy all the authors concerned list Eucampia striata Stolterfoth (1879, p. 385) as a synonym. The author has been unable to verify this as that particular work was not accessible to him. However, if this is true then the valid combination for this species should undoubtedly be Rh. striata as Stolterfoth's description must be considered the first publication of the species irrespective of which genus he assigned it to.

Local.: NIOE 1, 2, 3, 12, 17, 18, 19, 20, 35, 58, 59, 60, 62, 64, 66, 69, 71, 73, 74, 75, 76, 77, 78, 80, 84, 85, 88, 89, 91, 95, 96, 101, 103, 111, 112, 113, 114, 115, 117, 121, 124, 126, 129, 142, 143, 144, 158, 159, 161, 176.

A superficially similar distribution to Rh. setigera, being common at neritic stations on all lines on all cruises. Maximum abundances for this species were recorded at stations 18, 113 and 161 (all +++), an inshore station on line B in April, and inshore stations near Port Elizabeth in October and January.

This, in fact, closely resembles the distribution of <u>Bacteriastrum</u> <u>minus</u> and several other species which seem to have a centre of distribution between Port Elizabeth and Port St. Johns (line B).

General: Hendey (1937) recorded the species off the Natal coast in small numbers. It has been frequently recorded from the Indian Ocean (Wood, 1963, b), is common in the Mediterranean, and is widely spread in European coastal waters (Hustedt, 1930).

171 <u>Rhizosolenia</u> <u>styliformis</u> Brightwell var. <u>styliformis</u>, Q.J. Micr. Soc. <u>6</u> : 95, pl. 5, fig. 5, a – d (1858); Gran, Diat. Nord. Plankt. : 54, fig. 65 (1905); Hustedt, in A. Schmidt, Atlas : pl. 316, figs. 1 – 4, 8 – 11 (1914); Hustedt, Kieselalg. (1) : 584, fig. 333 (1930); Hendey, Discovery Rep. <u>16</u> : 320, pl. 11, figs. 15 – 17 (1937); Cupp, Mar. Plankt. W. Coast N. Amer. : 87, fig. 48–A (1943).

Local.: NIOE 2, 13, 16, 17, 18, 21, 23, 32, 34, 35, 36, 37, 59, 71, 74, 84, 89, 91, 94, 101, 108, 113, 115, 129, 150, 155, 157, 159, 162, 164, 168, 172, 176.

Found at scattered inshore and offshore stations on all lines on all cruises. A maximum abundance of "+++" was recorded at station 2 near Durban in April. It was more widely distributed in April and January than in July and October.

General: Hendey (1937) considered the species to be one of the commonest representatives of Rhizosolenia, being widely distributed in all oceans. It is oceanic (Cupp, 1943), and has been frequently recorded from the Indian Ocean (for references, see Wood, 1963, b).

172. Rhizosolenia styliformis var. latissima Brightwell, Q.J. Micr. Soc. 6 : 95, pl. 5, fig. 5, e (1858); Hustedt, Kieselalg. (1) : 586, fig. 335 (1930); Allen & Cupp, Ann. Jard. Bot. Buitenzorg 44 (2) : 130, fig. 40 (1935); Subrahmanyan, Proc. Indian Acad. Sci. 24 : 118, figs. 130 - 132, 143 (1946).

Local.: NIOE 5, 7, 75, 80, 96, 112, 142, 144, 158.

Rare at inshore and offshore stations on lines A and B on all cruises. Spread south to one station on line C in July.

General: This variety is usually found in warmer water than the typical variety (Hustedt, 1930). It has been recorded from the Indian Ocean by several authors, usually under the synonym *Rh. polydactyla* Castracane (Wood, 1963, b).

173. *Rhizosolenia styliformis* var. *longispina* Hustedt in A. Schmidt, pl. 316, figs. 5 - 7 (1914); Hustedt, Kieselalg. (1) : 586, fig. 334 (1930); Allen & Cupp, Ann. Jard. Bot. Buitenzorg 44 (2) : 130, fig. 39 (1935); Subrahmanyan, Proc. Indian Acad. Sci. : 118, figs. 126 O 129 (1946).

Local.: NIOE 1, 3, 5, 7, 9, 10, 12, 21, 36, 37, 60, 110, 111, 129, 130, 143, 144, 146, 155, 162, 177, 178.

Chiefly a summer distribution, being restricted to a few inshore stations in July and October, whereas it was fairly widespread in April and January. A heavy localised abundance of "++++" was recorded at station 129 near Cape Agulhas in October.

General: This variety has been recorded from the N. Atlantic Ocean (Hustedt, 1930), the Pacific Ocean (Allen & Cupp, 1935; Cupp, 1943) and the Indian Ocean (Subrahmanyan, 1946, 1958.)

Suborder ARAPHIDINEAE

Family FRAGILARIACEAE

174. <u>Asterionella japonica</u> Cleve ex Gran, Diat. Nord. Plankt. : 118, fig. 160 (1905); Hendey, Discovery Rep. <u>16</u> : 333, pl. 11, fig. 3 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 188, fig. 138 (1943); Subrahmanyan, Proc. Indian Acad. Sci. <u>24</u> : 170, figs. 361, 371 (1946); Hustedt, Kieselalg. (2) : 254, fig. 734 (1959*); Brunel, Phytopl. Baie Chaleurs : 147, pl. 41, fig. 1 (1962).

System.: Most authors refer this species to Čleve & Möller's collection of named slides, for the original reference. However, as Hendey (1937) has pointed out, their name is a <u>nomen nudum</u>, and a description was first provided by Gran (1905).

Local.: NIOE 18, 19, 20, 34, 58, 75, 87, 94, 95, 96, 97, 99, 111, 112, 113, 114, 115, 120, 128, 130, 143, 159, 161, 162, 164, 166, 176, 178.

Characteristically common to abundant at inshore sta tions on lines B, C, and D on all cruises It extended north to line A in July. Very heavy abundances (+++++) were recorded at stations 112, 114 and 161, inshore stations on lines B and C

* See note page 29.

in October and January. This appears to be another neritic species (see Bacteriastrum minus) which has its centre of distribution between Port Elizabeth and Port St. Johns.

General: A widespread neritic, temperate species (Hendey, 1937; Cupp, 1943) occasionally recorded from the Indian Ocean (Wood, 1963, b).

175. *Fragilaria linearis* Castracane, Diat. Challenger Exped. : 56, pl. 19, fig. 9 (1886); Heiden & Kolbe, Mar. Diat. Deutsch. Südpol.-Exped. 1901 - 03 : 550, pl. 6, fig. 128 (1928); Hendey, Discovery Rep. 16: 331 (1937). PLATE 17, figs. 1, 2.

System.: In girdle view in water mounts this species can be easily confused with *Fr. oceanica* Cleve or *Fr. karstenii* Boden. However it has a characteristic valve shape, being plane-sided with rounded apices. Furthermore the striae count is 8 - 10 in 10μ, as opposed to 11 - 14 in 10μ for the other two species (counts given by Hustedt, 1959 and Boden, 1950).

An interesting phenomenon associated with many of the chains observed in material from

Cape Agulhas was the attachment of sponge spicules to either end of the chains (pl. 17, fig. 1).

Local.: NIOE 77, 94, 95, 97, 130.

Recorded from the vicinity of Port Elizabeth and Cape Agulhas in July, and from Durban and Cape Agulhas in October. It was most abundant (+++) at station 94.

General: Records of this species are rare, and all are from the Antarctic region (some as Fr. curta Van Heurck).

176. Plagiogramma vanheurckii, Grunow in Van Heurck, Syn. : pl. 36, fig. 4 (1880); Peragallo, Diat. Mar. France : pl. 82, fig. 6 (1908); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 180, fig. 129 (1943); Boden, Trans Roy. Soc. S. Afr. 32 (4) : 405, fig. 85 (1950); Hustedt, Kieselalg. (2) : 112, fig. 638 (1959).

Local.: NIOE 130.

A few chains recorded from an inshore station near Cape Agulhas in October, possibly transported from the west coast region.

General: A tychopelagic species. It has been recorded from the West Coast of S. Africa by Boden (1950), and from the Indian Ocean by Wood (1962).

Pseudoeunotia doliolus (Wallich) Grunow in Van Heurck, Syn. : pl. 35, fig. 22 (1880); Peragallo, Diat. Mar. France : pl. 82, fig. 27 (1908); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 190, fig. 140 (1943); Hustedt, Kieselalg. (2) : 259, fig. 737 (1959). PLATE 17, fig. 3.

Local.: NIOE 16, 25, 27, 28, 32, 77, 78, 80, 85, 87, 88, 101, 103, 117, 119, 120, 126, 128, 143.

Primarily an oceanic distribution. The species was restricted to the southern lines in April and July, but spread northwards in October and January. The distribution of this species is discussed in greater detail in section IV.

General: The species was first described by Wallich (1860, as Synedra doliolus) from the Indian Ocean. Other Indian Ocean records include those of Cleve (1900 a, b, 1903), Schröder (1906) Wood (1962). Hustedt (1959) considered it to be a warm-water species but the local distribution does not confirm this.

Family TABELLARIACEAE

178. Grammatophora marina (Lyngbye) Kützing, Bacill. : 128, pl. 17, fig. 24, pl. 18, fig. I, 1 - 5 (1844); W. Smith, Syn. British Diat. 2 : pl. 42m fig. 314 (1856); Peragallo, Diat. Mar. France : pl. 87, figs. 6 - 8 (1908); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 174, fig. 125-A (1943); Hustedt, Kieselalg. (2) : 43, fig. 569 (1959).

Local.: NIOE 111.

Rare. Recorded from an inshore station on line B in October.

General: A tychopelagic species. Found on the shores of all oceans (Hustedt, 1959). There are several records of the species in the Indian Ocean (see Wood, 1963, b).

179. Licmophora lyngbyei (Kützing) Grunow in Van Heurck, Syn. : 158, pl. 46, fig. 1 (1880); Lebour, Plankt. Diat. North. Seas : 203, fig. 165 (1930); Hendey, Discovery Rep. 16 : 337 (1937).

Syn.: L. abbreviata Agardh, Consp. crit. diat. : 42 (1831); Peragallo, Diat. Mar. France : pl. 85, figs. 8 - 13 (1908); Cupp, Mar. Plankt.

Diat. W. Coast N. Amer. : 177, fig. 127 (1943); Hustedt, Kieselalg. (2) : 66, fig. 590 (1959).

System.: Hendey (1937) has outlined the complex systematic history of this species, showing that L. abbreviata Agardh must be considered invalid and that the above combination is the valid one for the species.

Local.: NIOE 2, 3, 19, 21, 35, 97, 111, 119, 120, 162.

Recorded from inshore stations on all lines, but not present in the July material.

General; A tychopelagic species, cosmopolitan in distribution. (Cupp, 1943).

180. Synedra gaillonii (Bory) Ehrenberg, Abh. Berl. Akad. 1830 : 129 (1830); Ehrenberg, Infus. als volkom. Organ. : pl. 17, fig. 2 (1838); Peragallo, Diat. Mar. France : 315, pl. 80, figs. 6, 7 (1908); Hustedt, in A. Schmidt, Atlas : pl. 306, figs. 9 - 13 (1914); Hustedt, Kieselalg. (2) : 195, fig. 690 (1959).

10 — 270 µ

Local.: NIOE 34, 58, 60, 64, 66, 78, 80, 84, 85, 87, 89, 91, 99, 103, 111, 112, 115, 124, 128, 164.

Found in small numbers at scattered inshore and offshore stations on all cruises. Most widespread in July and October. It occurred in slightly larger numbers (++) at station 85 in the extreme south in July.

General: The species has been recorded from the Cape of Good Hope by Grunow (in Van Heurck, 1881, as S. capensis Grun.) and Heiden & Kolbe (1928, Simonstown). It is a euryhaline coastal species, being found in brackwater and the coastal waters of Europe (Hustedt, 1959). Other Indian Ocean records include Leuduger-Fortmorel (1893) and Wood (1962).

181. Synedra hennedyana Gregory, Trans. Roy. Soc. Edinburgh 21 (4) : 60, pl. 6, fig. 108 (1857); Peragallo, Diat. Mar. France : 313, pl. 78, figs. 8, 9 (1908); Hustedt, in A. Schmidt, Atlas : pl. 305, figs. 1 - 3 (1914); Hustedt, Kieselalg. (2) : 223, fig. 713 (1959).

Local.: NIOE 3, 88.

Recorded from a northern and southern offshore station in April and July respectively. It was slightly more abundant (++) at the latter station.

General: A rarely recorded species. Most of the records refer to its occurrence in the Mediterranean.

Hustedt (1959) considered it to be a littoral species. The only Indian Ocean records of this species are those of Leuduger-Fortmorel (1878, 1893) and Cleve (1901). Ferguson, Wood '61

182. Synedra indica Taylorosp. nov. PLATE 5, figs. 1, 2, & 3.

Cellulae parvae, singulae, valvis elongatis in medio inflatis terminisque nonnumquam subinflatis, 8 - 23μ longae, 1.5 - 3μ latae (transapicales); pseudoraphe tenuis sinuosa; striae transapicales 20 - 24 in 10μ , striis apicalibus obsoletis transcurrentes.

Loc. typ. : In Oceano Indico; 31°01'S, 32°41'E.

Iconotypus: Tab. 5, fig. 1.

System.: This small species of Synedra could only be identified with certainty in Hyrax mounts. The cells occurred singly. The elongated valves had an apical axis of 8 - 23μ in length, being inflated in the centre, the width varying between 1.5 and 3μ . The apices were slightly inflated in some specimens. No mucilage pores or terminal spines were discernable. Numerous transapical striae, 20 - 24 in 10μ , connected with a 'zig-zag' narrow pseudoraphe, and faint apical striae were visible.

Local.: NIOE 87, 117, 119, 124, 164.

It was present in moderate numbers (+++) at a southern offshore station in July, and in smaller numbers at several southern offshore stations in October and January. It is possibly a subantarctic species spreading north from the subtropical Convergence Region.

184. *Synedra pelagica* Hendey, Discovery Rep. 16 : 335 (1937). PLATE 5, figs. 4 a, b, & c.

Syn.: *S. spathulata* Schimper ex Karsten, Valdivia Antarkt. Phytopl. : 124, pl. 17, fig. 11 (1905).

System.: Neither Hendey nor Schimper have provided costae/striae counts for this species and so it is difficult to identify it with certainty. The illustrated specimen was superficially similar to their descriptions and figures but showed no twisting as is apparently sometimes the case with this species. The specimen observed was shorter in apical axis than is usual for this species being 308 μ, with a maximum width of 6 μ. There was a broad, hyaline pseudoraphe, mucilage pores at both ends of the cell, and two small spines at one end. The short costae were seen to be crossed by a fine longitudinal striae which bisected the spaces between.

Local.: NIOE 21

One specimen identified from a Hyrax mount of material from a station on line C in April.

185.. *Synedra regalis* Taylor sp. nov. PLATE 5, fig. 5 a,b, & c.

Cellulae robustae, 520 - 570μ longae, solitariae, 5 - 7μ latae (transapicales); valvis costatis, costae 10 - 13 in 10μ, areolae seriebus excentricalibus 10 - 13 in 10μ, ocellum cum poro magno gelatinoso apice utroque sed solum uno apice duos spinulos praesentibus, inter costas binis seriebus pororum parvissimorum visis.

Loc. typ.: In Oceano Indico; 31° 01'S, 32° 41'E.

Iconotypus: Tab. 5, fig. 5

System.: This robust species appears to belong to the subgenus *Ardissonia*. The cells were 520 - 570μ in length (apical axis) and 5 - 7μ in width with no median or terminal inflations. A complex patterning was visible on the valves. Laterally there were series ofcchambers (the "kammer" of Hustedt, 1959), each with a central opening. Coarse costae, 10 - 13 in 10μ, crossed the valve, and between each a double series of fine pores or thin areas in the wall could be seen. The pores nearest the chambers on one side were large and single. A large ocellus with a mucilage pore was present at each end, and a pair of small spines were present at one end of the valve.

Local.: NIOE 62.

Several specimens (+) were observed at an offshore station on line A in July.

186. <u>Synedra</u> <u>reinboldii</u> Van Heurck; Diat. Exped. Antarct. Belg. : 23, pl. 3, fig. 35 (1909); Heiden & Kolbe, Mar. Diat. Deutsch. Südpol-Exped. 1901 -03: 562 (1928). PLATE 5, fig. 6 a,b.

System.: Wood (1963,b) considered <u>S. pelagica</u> Hendey to be synonymous with this species. However they can be readily distinguished by the fact that the latter has fine marginal striae whereas <u>S. reinboldii</u> has widely spaced marginal "granules". The author's specimens were shorter than Heiden & Kolbe's specimens. However the cell-width and granulae counts agree with their description. The cells were 150 - 170 μ long, 4.5 - 5μ in width with approximately 8 granules in 10 μ. Small mucilage pores were present at each end. No terminal spines were seen.

Local.: NIOE 21.

Several specimens found in material from a station on line C in April.

General: This is typically an Antarctic species but it was also recorded from the S. Atlantic Ocean by Heiden & Kolbe (1928).

187. Synedra stricta Karsten, Valdivia Atlant. Phytopl. : 173, pl. 30, fig. 19 (1906); Hendey, Discovery Rep. 16 : 335 (1937).

Local.: NIOE 77, 78, 114.

Recorded in small numbers (+ - ++) from the vicinity of Port Elizabeth in July and October.

General: Karsten first described the species from Port Elizabeth. Hendey (1937) found the species to be common around S. Africa, suggesting that it might be a neritic species.

188. Thalassionema elegans Hustedt, Diat. Antarkt. & Südatlant.: 140, pl. 9, fig. 93 (1958).

System.: This species closely resembles Synedra reinboldii Van Heurck, and in particular the shorter specimens of it described and figured in the present study. The only differences between the two appear to be the absence of terminal inflations in *T. elegans* and the fact that the marginal granulae (or punctae) are 9 - 10 in 10 μ in the latter.

Local.: NIOE 94.

One specimen from an inshore station near Cape Agulhas in July.

General: Recorded from the S. Atlantic and the Antarctic by Hustedt (1958).

189. *Thalassionema nitzschioides* (Grunow) Hustedt, Kieselalg. (2) : 244, fig. 725 (1932); Hendey, Discovery Rep. *16* : 336 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 182, fig. 133 (1943). PLATE 18, fig. 2.

Syn.: *Thalassiothrix nitzschioides* Grunow in Van Heurck, Syn. : pl. 43, figs. 6 - 12 (1881); Gran, Diat. Nord. Plankt. : 117, fig. 158 (1905).

System.: The valid combination is usually attributed to Grunow. However, as Hendey (1937) has pointed out Grunow did not make the combination, and it should in fact be attributed to Hustedt (1932).

Local.: NIOE 1, 2, 3, 5, 10, 12, 16, 17, 19, 20, 21, 25, 36, 58, 59, 60, 62, 66, 73, 74, 75, 77, 78, 80, 84, 85, 87, 88, 91, 93, 94, 95, 96, 99, 101, 106, 111, 112, 113, 114, 115, 117, 119, 128, 130, 142, 143, 144, 159, 160, 161, 162, 164, 176, 178.

One of the most common and widespread species in in the area. Maximum abundance (+++ - ++++) was recorded at inshore stations on all the lines on all cruises. The species was confined to the inshore area in January.

General: Hendey (1937) found the species, sometimes in considerable numbers, around S. Africa. It is a neritic species with a world-wide distribution, and there are many references to its occurrence in the Indian Ocean (Wood, 1963, b, listed under Thalassiothrix nitzschioides).

190. Thalassiothrix acuta Karsten, Valdivia Atlant. Phytopl. : 173, pl. 30, fig. 19 (1906); Hendey, Discovery Rep. 16 : 335 (1937).

System.: This species is very similar in general form to T. vanhöffenii Heiden & Kolbe. It is perhaps significant that the author found that in water mounts T. acuta was readily identifiable using Karsten's description and figure. However, in Hyrax mounts similar specimens were found to be T. vanhöffenii on the basis of the detailed structure of the valves.

There seems to be a duality of systems in use in studies of this type - "water mount systematics" and "permanent mount systematics", typified by the contrast in detail between Karsten's and Heiden & Kolbe's studies. Naturally, the greater detail is preferable but it is difficult, if not impossible, to ascertain with certainty whether species such as the two mentioned above are one and the same when either one cannot be identified under various magnifications. For the present the author retains the two species as being distinct, but with the reservations mentioned above.

Local.: NIOE 1, 2, 3, 5, 7, 9, 10, 12, 14, 17, 18, 19, 20, 21, 23, 24, 35, 36, 37, 58, 59, 62, 64, 66, 67, 69, 71, 73, 74, 75, 76, 77, 78, 80, 82, 84, 85, 88, 91, 93, 95, 96, 99, 101, 103, 108, 110, 111, 112, 113, 114, 115, 119, 120, 121, 124, 128, 142, 143, 158, 160, 162, 164, 172, 176, 178.

An extremely wide distribution, occurring on all lines on all four cruises. In January it was restricted to inshore stations. It did not occur in large numbers at most stations, but abundances of "+++" were recorded at stations 12, station near Durban in October. It was absent from the offshore region in January.

General: A widespread, temperate oceanic species (Cupp, 1943). There are numerous references to the occurrence of the species in the Indian Ocean listed by Wood (1963, b).

192. *Thalassiothrix heteromorpha* Karsten, Valdivia Indische Phytopl. : 397, pl. 46, fig. 11 (1907).

Local.: NIOE 32, 59, 69, 71, 73, 87, 95, 96, 101, 103, 104, 115, 119, 120, 121, 124, 126, 128, 160, 162, 164, 168, 172, 176, 178.

Recorded from only one southern offshore station in April. In October it was present at inshore and oceanic stations scattered over the whole area, achieving a maximum abundance (+++) at station 119. In January it was found only at stations on lines C and D, whereas in July it was chiefly on lines A and B.

General: The species appears to have been recorded only from Indian Ocean (Karsten, 1907) and the Antarctic (Mann, 1937).

193. *Thalassiothrix longissima* (Cleve) Cleve & Grunow, Kongl. Svenska Vet.-Akad. Handl. 17 (2) : 108 (1880); Gran,

Diat. Nord. Plankt. : 116, fig. 157 (1905); Karsten, Valdivia Antarkt. Phytopl. : 124 (1905); Hendey, Discovery Rep. 16 : 336 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 184, fig. 134 (1943); Hustedt, Kieselalg. (2) : 247, fig. 726 (1959).

Local.: NIOE 12, 32, 58, 85, 87, 88, 91, 94, 103, 108, 115, 120.

An interesting distribution further discussed in section IV.

In general it was confined to the southern part of the area occurring in maximum abundance at station 85 (+++). However in October it spread north throughout the area. It was not present in January.

General: Hendey (1937) observed it, sometimes in "enormous quantities", around S. Africa and to the south of it. It is also found in the colder waters of the northern seas. Although it might be considered a cold-water species it has been recorded in small numbers from tropical waters, e.g. Cleve (1900,b) and Schröder (1906) from the N. Indian Ocean area.

194. <u>Thalassiothrix vanhöffenii</u> Heiden & Kolbe, Mar. Diat. Deutsch. Süd-Pol. Exped. 1901 - 03 : 566, pl. 6,

figs. 124, 125 (1928).

System.: See note under *T. acuta* Karsten.

Local.: NIOE 62, 85.

Recorded in small numbers from a northern and a southern offshore station in July.

General: Heiden & Kolbe (1928) recorded the species from the S. Atlantic Ocean. There do not seem to be any further records of this species.

Suborder RAPHIDIOIDINEAE

(No species of this suborder recorded)

Suborder MONORAPHIDINEAE

Family ACHNANTHACEAE

195. *Achnanthes longipes* Agardh, Consp. crit. diat. : 58 (1832); Van Heurck, Syn. : pl. 26, figs. 13 - 16 (1881); Peragallo, Diat. Mar. France : pl. 1, figs. 4 - 12 (1908); Hustedt, Kieselalg. (2) : 427, fig. 878 (1959).

Local.: NIOE 95.

One short chain found in material from an inshore station near Durban in October.

General: This is a sedentary species, common on European coastlines (Hustedt, 1959). The present author has found both this species and *A. brevipes* commonly in collections of sedentary material from both the east and west coasts of S. Africa. Its presence in plankton collections is probably adventitious. There are several references to the species in the Indian Ocean (Wood, 1963, b). In addition, Cholnoky (1963) has recorded the species from littoral material in False Bay, Cape.

196. *Cocconeis scutellum* forma *parva* Grunow in Van Heurck, Syn. : 29, figs. 8, 9 (1881); Van Heurck, Treat. : 287, pl. 8, fig. 339 (1896); Hustedt, Kieselalg. (2) : 338, fig. 791 (1959).

System.: Considered to be a variety by Hustedt (1959).

Local.: NIOE 76.

One cell recorded from an inshore station near Port Elizabeth in July.

General: A European littoral form (Hustedt, 1959). The species has been recorded frequently from the Indian Ocean, but apparently not this form of it. Its presence is probably adventitious in plankton collections.

Suborder BIRAPHIDINEAE

Family NAVICULACEAE

197. __Amphora__ __lineolata__ (Ehrenberg) Grunow in Van Heurck, Syn.: pl. 1, figs. 13, 23 (1881); Cleve, Syn. Navic. Diat. (2) : 126 (1895); Van Heurck, Treat. : 138, pl. 1, fig. 10, (1896); Peragallo, Diat. Mar. France : 225, pl. 50, figs. 10, 11, 12 (1908); Subrahmanyan, Proc. Indian Acad. Sci. __24__ : 184, fig. 407 (1946).

Local.: NIOE 143.

One specimen recorded from an inshore station near Durban in January.

General: This species is widely distributed but rare in marine and estuarine waters. There are several references to the occurrence of the species in the Indian Ocean (Wood, 1963, b).

198. __Amphiprora__ __alata__ (Ehrenberg) Kützing, Bac. : 107, pl. 3, fig. 63 (1844); Pritchard, Infus. : 921, pl. 13, figs. 5 - 7 (1861); Van Heurck, Syn. : pl. 22, figs. 11 - 14 (1881); Cleve, Syn. Navic. Diat. (1) : 15 (1894); Peragallo, Diat. Mar. France : 184, pl. 37, figs. 6 - 9 (1908).

Local.: NIOE 17.

One cell recorded from an inshore station on line B in April.

General: A littoral species, possibly tychopelagic, widespread in distribution. It has been recorded from the Indian Ocean by Wood (1962). Cholnoky (1960, b) found it in material from a swamp near the outlet of the Umlazi River in Natal. It is most likely a euryhaline species.

199. Amphiprora medulica Peragallo, Diat. Mar. France : 185, pl. 38, fig. 21 (1898).

Local.: NIOE 71

One cell recorded from an offshore station on line B in July.

General: This species appears to have been only previously recorded from the Bay of Biscay (Medoc) by Peragallo.

200. Mastagloia rostrata (Wallich) Hustedt, Kieselalg. (2) : 572, fig. 1007 (1933); Wood, Trans. Roy. Soc. New Zealand 88 (4) : 687, pl. 54, fig. 127 (1961). PLATE 18, figs. 4, 5.

Syn.: Stigmaphora rostrata Wallich, Trans. Micr. Soc., N.S. 8 : 43, pl. 2, figs. 5, 6 (1860); Karsten, Valdivia Indische Phytopl. : 399, pl. 47, fig. 3

(1907); Silva, Contrib. Estud. Micropl. Mar. Moçambique : 51, pl. 8, figs. 6, 7 (1956).

System.: The length of the terminal protuberances is highly variable, from fairly short (pl. 18, fig. 4) to extremely long (pl. 18, fig. 5). Furthermore some individuals show a certain angularity of the valves, as shown in pl. 18, fig. 4, although the cells are more commonly smooth-sided.

Local.: NIOE 7, 62, 101, 111, 146, 148, 150, 157, 162, 164.

An oceanic distribution, found chiefly at the offshore stations on lines A and B. It was most widespread in January, achieving a maximum abundance of "++" at station 146.

General: It has been recorded from the Indian Ocean by the authors cited above and also by Grunow (1867). It would seem to be a tropical to subtropical species virtually confined to the Indian Ocean. It does however spread into the Western Pacific Ocean, having been recorded from the East Indies and the Tasman Sea (Wood, 1961).

If the species was not so rare it would be a useful indicator of subtropical to tropical Indian Ocean water.

201. Mastagloia woodiana Taylor nom. nov. PLATE 5, fig. 7.

Syn.: Stigmaphora capitata Brun, Mem. Soc. Phys. Hist. Nat. Genève 32(2/1) : 45, pl. 11, fig. 13 (1891).

Mastagloia capitata (Brun) Cleve, Syn. Navic. Diat. (2) : 151 (1895); Hustedt, Kieselalg. (2) : 571, fig. 1006, a (1959) - non M. capitata Grev.

Mastagloia brunii Wood, Trans. Roy. Soc. New Zealand 88 (4) : 685), pl. 53, fig. 115 (1961) - non M. bruni A. Schmidt.

System.: Cleve (1895) transferred Stigmaphora capitata Brun to the genus Mastagloia. However he retained Brun's specific epithet, apparently unaware that the name was preoccupied by M. capitata Greville (1862, p. 235, pl. 10, fig. 11). In consequence to this Wood (1961) gave the species the name M. brunii. Regrettably this name is also preoccupied (as M. bruni A. Schmidt, 1893, pl. 188, fig. 27). The species is here renamed after E.J. Ferguson Wood.

The following distributional data referes to the typical variety, i.e. M. woodiana var. woodiana.

Local.: NIOE 101, 103, 11, 150, 158, 162, 164.

Recorded in small numbers from offshore stations in October and January. In October it was restricted to the northern area, i.e. lines A and B, but it spread further south to line C in January.

General: It has been previously recorded from the Indian Ocean, and the East Indies, the Coral Sea, and from the stomachs of fish caught in Lake Macquarie, New South Wales (Leuduger-Fortmorel, 1893; Cleve, 1901; and Wood, 1961).

202. *Mastagloia woodiana* var. *lanceolata* (Wallich) Taylor nov. comb.

Syn.: *Stigmaphora lanceolata* Wallich, Trans. Micr. Soc., N.S., 8 : 43, pl. 2, figs. 7, 8 (1860).
Mastagloia capitata var. *lanceolata* (Wall.) Hustedt, Kieselalg. (2) : 571, fig. 1006, b (1933).

System.: See note under previous taxon. Hustedt's combination cannot be used as the specific epithet has been shown to be preoccupied.

Local.: NIOE 146, 157.

Recorded in small numbers (+ and ++ respectively) from stations in the Agulhas Current in January.

General: This variety appears to be almost entirely confined to the Indian Ocean. It has been recorded (under the synonyms listed above) by

Wallich (1860), Grunow (1867), Leuduger-Fortmorel (1893), Karsten (1907), Heiden & Kolbe (1928), and Wood (1962).

In the area under present survey it could be used as an indicator of Agulhas Current water although it is of limited use as it is rare in occurrence in the area.

203. Navicula gigantea Hustedt, Kieselalg. (3/1) : 40, fig. 1194 (1961).

System.: Hustedt's description does not provide any indication of variation in this species, presumably being based on only one or a few specimens. The individuals observed by the present author provide some indication of this. The figures quoted below which are underlined are the present author's observations, those not underlined being quoted from Hustedt.

Length : 320 - 371 μ

Breadth : 42 - 45 μ

Transapical striae : 16 - 20 in 10 μ

Apical striae : 22 - 28 in 10 μ

It can be seen that the specimens observed by the author (four in all) were larger, and with slightly coarser striation, than those observed by Hustedt.

Local.: NIOE 78.

In small numbers from an offshore station on line C in July (Agulhas Current).

General: Hustedt's (1961) specimens were obtained from the South China Sea. The species has not been recorded from the Indian Ocean prior to the present survey.

204. <u>Navicula</u> <u>hendeyana</u> Taylor sp. nov.m PLATE 6, fig. 9.

Cellulae parvae, apicibus rotundatis subinflatisque, medio etiam inflatae, 9 - 15μ longae, 3 - 4μ latae (transapicales); raphe subrecta, tenuis; pori centrales indistincti; striae transapicales area centrale excepta proxime congestae, 30 - 38 in 10μ, in zona media radiantes, crassiores, distantiores inordinato abbreviatae.

Loc. typ.: In Oceano Indico; 34^{o} 53' S, 26^{o} 28' E.

Iconotypus: Tab. 6, fig. 9.

System.: Small naviculoid cells with rounded, slightly inflated ends and also inflated at the centre. Length 9 - 15μ, width (transapical) 3 - 4μ. Raphe narrow and fairly straight. Central pores difficult to see. There is a small, irregularly shaped central area caused by a shortening of the striae. The transapical striae over most of the valve are close together, 30 - 38 in 10μ. In the central inflated portion of the valve the striae are more radially arranged and are coarser and more widely spaced, a striking feature which facilitates identification of the species.

The striation in this species is very similar to *N. tsitsikammae* Cholnoky (1959) in the manner in which the central striae differ from the others, but the striation is finer in *N. hendeyana* and the shape of the cells is quite different. They may nevertheless be more closely related to one another than at the generic level.

Local.: NIOE 78.

A large number (++++) of cells of this species were observed in a Hyrax mount of material from the vicinity of Port Elizabeth in July.

205. *Navicula* sp. 1. PLATE 6, fig. 10.

System.: Only one specimen of this species was seen. It could not be identified using the literature available. The cell was small, 16.5μ long and 3.2μ wide, with capitate-rostrate ends. No striation was visible on the valve. The raphe was straight, the central nodules being close together and the terminal nodules slightly deflected in opposite directions.

Local.: NIOE 21.

A station near Port Elizabeth in April.

206. __Navicula__ sp. 2. PLATE 6, fig. 11.

System.: As in the case of the species above only one specimen was observed. In general shape it resembled Sp. 1. but differed in that the ends of the valves were more gradually tapered. Distinct transapical striae, 24 - 26 in 10μ, were visible on the valve. The raphe was straight, with a small central area. The terminal nodules had short projections, both being deflected in the same direction. Length of the valve 17.8μ, width 4μ.

Local.: NIOE 21.

A station near Port Elizabeth in April.

207. __Pleurosigma directum__ Grunow in Cleve & Grunow, Beitr. Kennt. Arkt. Diat. : 53 (1880); Peragallo, Le Diat. __1__ : 14, pl. 5, fig. 29 (1891); Karsten, Valdivia Antarkt. Phytopl. : 127, pl. 18, fig. 5 (1905); Hendey, Discovery Rep. __16__ : 348 (1937); Silva, Contrib. Estud. Micropl. Mar. Mocambique : 50, pl. 8, fig. 4 (1956).

Local.: NIOE 30, 37, 71, 73, 74, 77, 80, 84, 86, 91, 99, 101, 104, 110, 111, 112, 115, 119, 128.

Only present in small numbers. Restricted to two southern stations in April. Spread north into the area in July and October. Not recorded in January. Maximum abundance (++) recorded at station 91, a station on the edge of the Agulhas Bank on line D in July.

General: Originally recorded from the Arctic, this species has been frequently recorded from the Antarctic as well. It is not a discontinuous bipolar distribution, however, as can be seen from the local distribution and records such as Subrahmanyan (1958) who found it in material from the Arabian Sea.

208. Pleurosigma karstenii Taylor nom. nov.

Syn.: P. capense Karsten, Valdivia Atlant. Phytopl. : 175, pl. 34, fig. 5 (1906); Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 414, fig. 94 (1950), non P. capense Petit (1876).

System.: The name Pleurosigma capense is preoccupied by Petit (1876). For this reason a new name has been provided.

Local.: NIOE 94.

One specimen observed in material from the vicinity of Cape Agulhas in July.

General: The species was first described by Karsten (1906) from the southwestern portion of the area under present survey. Since then it has been recorded from the West Coast of S. Africa by Boden (1950), from the Arabian Sea by Subrahmanyan (1958), and from the Indian Ocean by Wood (1962).

209. Pleurosigma minutum Grunow ex Cleve, Syn. Navic. Diat. (1): 41, pl. 4, fig. 19 (1894); Peragallo, Diat. Mar. France : 164, pl. 33, fig. 11 (1908). PLATE 18, fig. 1.

Syst.: The name was first applied by Grunow to a specimen in the collection of Cleve & Möller (no. 136). However this cannot be considered as a valid publication, and the original reference is here attributed to the description of the species which appeared in Cleve's "Synopsis of the Naviculoid Diatoms".

Local.: NIOE 111.

One specimen, 53μ in length, recorded from an inshore station on line B in October.

General: This species does not appear to have been recorded from the Indian Ocean previously. The early records refer to its presence in the North Sea.

210. *Pleurosigma normanii* Ralfs in Pritchard, Infus. : 919 (1861); Cleve, Synop. Navic. Diat. (1) : 40 (1894); Allen & Cupp, Ann, Jard. Bot. Buitenzorg *44* (2) : 157, fig. 106 (1935); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 196, fig. 148 (1943).

System.: This species resembles *P. affine* Grunow closely, and the two have been considered as synonymous by some authors who, however, have usually retained Grunow's name in preference for that of Ralfs'. This is incorrect procedure as Ralfs' epithet predates that of Grunow. The specimens observed by the author resembled the typical *P. normanii*, having finer striation and more acute apices than *P. affine*.

Local.: NIOE 36, 58, 67, 76, 87, 89, 108, 112, 162.

Recorded in small numbers from scattered stations on all four cruises.

General: Wood (1963, b) lists several records of the species from the Indian Ocean. In addition to these there is the record of Cholnoky (1963) from False Bay, Cape (Steenbras River mouth).

211. <u>Stauroneis membranacea</u> (Cleve) Hustedt, Kieselalg. (2) : 833, fig. 1176 (1959).

Syn.: <u>Navicula membranacea</u> Cleve, Treat. Phytopl. Atlantic & Trib. : 24, pl. 2, figs. 25 - 28 (1897); Gran, Diat. Nord. Plankt. : 123, fig. 166 (1905); Hendey, Discovery Rep. <u>16</u> : 345, pl. 11, fig. 4 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 193, fig. 142 (1943).

Local.: NIOE 58, 59, 60, 74, 75, 78, 87, 91, 114, 117, 119, 160.

Not recorded from the April material. Found in small numbers at inshore stations on lines A, B and C in July, October and January. It was found at isolated offshore stations in the south as well.

General: A neritic species usually found in temperate waters (Cupp, 1943; Hustedt, 1959). It has been recorded by several authors as occurring in the Indian Ocean (see Wood, 1963, b).

212. <u>Stauroneis polynesiae</u> (Brun) Hustedt, Kieselalg. (2) : 836, fig. 1179 (1959); Brun, Le Diat. <u>2</u> : pl. 17, fig. 105 (1895, sub <u>St</u>. <u>tahitiana</u> var. <u>polynesiae</u>).

Local.: NIOE 73, 74.

Present in small numbers at two stations on line B in July.

General: Apparently only previously recorded from the western Pacific Ocean (Hustedt, 1959).

213. Tropidoneis antarctica (Grunow) Cleve, Syn. Navic. Diat. (1) : 24 (1894); Karsten, Valdivia Antarkt. Phytopl. : 128, pl. 18, fig. 7 (1905); Hendey, Discovery Rep. 16 : 350 (1937); Manguin, Diat. Terre Adélie : 321, pl. 17, fig. 195, 196, 197, pl. 31, fig. 381 (1960).

Local.: NIOE 62.

One specimen, 208 μ long, observed from a station on line A in July.

General: An antarctic species usually restricted to the region to the south of the Antarctic Convergence. However Cleve (1900a) recorded it as far north as 43°S in the S. Indian Ocean. The local record is a further example of the northward spread of the cold water species into the area in July.

214. Tropidoneis lata Cleve, Syn. Navic. Diat. (1) : 28, pl. 3, figs. 3, 4 (1894).

Local.: NIOE 77, 87, 91, 103, 112.

Found in small numbers at scattered stations on lines B and C in July, and lines A and B in October.

General: Cleve appears to be the only author to refer to this species prior to the present survey.

215. *Tropidoneis lepidoptera* (Gregory) Cleve, Syn. Navic. Diat. (1) : 25 (1894); Peragallo, Diat. Mar. France : 188, pl. 39, figs. 1, 2 (1908); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 197, fig. 149 (1943). PLATE 18, fig. 3.

System.: The author did not attempt to distinguish between the various varieties of this species as no specimens could be successfully mounted in Hyrax.

Local.: NIOE 2, 19, 23, 25, 28, 34, 58, 60, 62, 64, 80, 84, 89, 91, 95, 96, 97, 101, 104, 111, 112, 128, 142, 143, 157.

Present at inshore stations near Durban on all four cruises and at scattered stations over the rest of the area. Its distribution was most restricted in January when it was only present at inshore stations on lines A and B.

General: This species is considered to be a littoral form by most authors, but it would seem better to consider it as tychopelagic. There are several records of the species from Indian Ocean listed by Wood (1963, b). Cholnoky (1960, b, 1963) has recorded it from various localities on the coast of S. Africa.

216. _Tropidoneis proteus_ Karsten, Valdivia Indische Phytopl. : 398, pl. 47, fig. 1 (1907); Hendey, Discovery Rep. _16_ : 350 (1937).

Local.: NIOE 62.

Only one large specimen with an apical axis of 216 μ observed in material from an offshore station on line A in July.

General: The species has apparently only been recorded from the Indian Ocean (Karsten, 1907; Hendey, 1937). Hendey's record is from a locality close to the local one cited above.

Family BACILLARIACEAE

217. _Bacillaria paxillifer_ (O.F. Müller) Hendey, Trans. Roy. Micr. Soc., Ser. 3, _71_ (1) : 74 (1951).

Syn.: *Nitzschia paradoxa* (Gmelin) Grunow in Cleve & Grunow, Beitr. Kennt. Arkt. Diat. : 85 (1880); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 206, fig. 159 (1943).

System.: Hendey (1951) has provided a detailed systematic history of the species and given a complete synonymy. Some authors have incorrectly ascribed the combination to Heiberg (who made the combination *Nitzschia paxillifer*). Crosby & Wood (1959) ascribed the combination to Nitzsch but this could not be checked by the present author.

Local.: NIOE 16, 17, 28, 73, 95, 96, 111, 112, 114, 128, 158, 159, 161, 176.

Chains of this species were recorded from inshore stations on all four cruises. It was occasionally encountered at scattered offshore stations. A maximum abundance (+++) was recorded at station 111, an inshore station on line B in October.

General: This is a widespread tychopelagic species, found in all seas. There are numerous references to the presence of this species in Indian Ocean waters (see Wood, 1963, b). The record of Cholnoky (1963) should be added to these.

218. Nitzschia angustissima Van Heurck, Diat. Exped. Antarct. Belg. : 20, pl. 3, fig. 59 (1909).

Local.: NIOE 34.

Several specimens of this rare species were observed at a station on the edge of the Agulhas Bank on line D in April.

General: Van Heurck's record of the species from the Antarctic appears to be the only previous record of this species.

219. Nitzschia bicapitata Cleve, Öfvers. Kongl. Svenska Vet.-Akad. Förhandl. 1900 (8) : 933, fig. 12 (1900); Heiden & Kolbe, Mar. Diat. Deutsch. Südpol-Exped. 1901 - 03 : 666 (1928); Hustedt, Diat. Antarkt. & Südatlantik : 169, pl. 13, figs. 176 - 190 (1958). PLATE 6, figs. 1 - 4

System.: This interesting small species exhibits a wide range of variation in form as can be seen from the figures provided in this study and those provided by Hustedt (1958). Despite the range in size the striae count remains within the range of 30 - 40 in 10 μ. Plate 6, fig. 1 illustrates an extremely large specimen (51 μ long). Such large specimens were occasionally observed in pairs, adhering to one another along the parallel sides of the valves.

Nitzschia pubens Cholnoky (1960, b, p. 102, pl. 7, fig. 307) resembles this species very closely but apparently lacks the characteristic central gap in the keel punctae.

Local.: NIOE 58, 62, 76, 85, 91, 101, 103, 104, 106, 111, 117, 119, 120, 128, 129, 144, 150, 157, 158, 159, 169, 178.

Widespread over the area in July, October and January. Maximum abundance (+++) was recorded at stations 62 and 178, an offshore station on line A in July and an inshore station near Cape Agulhas in January.

General: This species occurs in both the northern and southern hemispheres. Cleve (1900a) found it in material from the Färöe Channel and in the S. Indian Ocean south to 45°S. Heiden & Kolbe (1928) recorded it in the tropical Atlantic and the S. Indian Ocean. Hustedt (1958) described and figured specimens from the N. Atlantic in the latitude of 64°N, as well as from the S. Atlantic south to 63°S. He also found it in material from the Gulf of Siam.

220. *Nitzschia closterium* (Ehrenberg) W. Smith, Syn. Brit. Diat. 1 : 42, pl. 15, fig. 120 (1853); Gran,

Diat. Nord. Plankt. : 129, fig. 172 (1905); Hustedt, in A. Schmidt, Atlas : pl. 352, pl.11, fig. 1 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 200, fig. 153 (1943); Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 416, fig. 99 (1950).

Local.: NIOE 2, 3, 14, 16, 17, 18, 21, 28, 34, 35, 36, 37, 60, 73, 76, 96, 97, 99, 114, 155, 158.

Most widespread in April when it was present, generally in small numbers, at inshore stations on all lines and offshore stations on line D. In July it was only present at relatively few stations, inshore on lines A and B, and similarly in October where it was present at inshore stations on lines A and C. In January it was present at only two inshore stations on line B.

General: A neritic species found in all seas. Wood (1963, b) lists several records to the species in the Indian Ocean and also several Antarctic records.

221. *Nitzschia delicatissima* Cleve, Treat. Phytopl. Atlantic & Trib. : 24, pl. 2, fig. 22 (1897); Gran, Diat. Nord. Plankt. : 130 (1905); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 204, fig. 158 (1943); Boden, Trans. Roy. Soc. S. Afr. 32 (4) : 415,

fig. 98 (1950). PLATE 6, fig. 5.

System.: This species is virtually impossible to distinguish from N. *barkleyi* Hustedt and narrow specimens of N. *pacifica* Cupp in water mounts. In Hyrax mounts straie could be resolved on all specimens. The author here includes specimens with very fine striation, i.e. approximately 30 striae in 10μ, under this species which was originally described as lacking striae by Cleve. The specimens examined in Hyrax mounts did not have the characteristic central gap in the keel punctae found in N. *barkleyi* Hustedt.

Due to the uncertainty involved in identifying the species in water mounts the relative abundance figures provided in the table in the appendix must be considered as being liable to considerable error.

Local.: NIOE 30, 34, 58, 64, 73, 74, 75, 76, 87, 89, 93, 108.

Recorded from southern stations in April and northern inshore stations in July.

General: A widespread neritic species with a bipolar distribution (Karsten, 1906). Cleve (1900, d) recorded the species from the S. Indian Ocean.

222. *Nitzschia lanceolata* var. *quincuncata* Taylor var. nov.
PLATE 19, figs. 4 a, b.
Ex var. *lanceolata* differt a suis striis quae in quincuncibus ordinantur.

Syst.: This differs from the typical variety chiefly in the arrangement of the striae on the valve. Whereas in the typical variety the striation appears to be arranged in transapical rows crossed by apical lines, in the present variety the striae are clearly arranged in quincunx. The dimensions of the figured specimen are: length 104 μ, width 9 μ, striae 12 in 10 μ, keel punctae 6 - 7 in 10 μ with a small central gap. Wallich (1860, pl. 48, pl. 4, fig. 20) figured a specimen which might possibly be this variety.

Local.: NIOE 103.

One specimen found in material from an extreme offshore station on line A in October.

223. *Nitzschia longissima* (de Brébisson) Ralfs in Pritchard, Infus. : 783 (1861); Van Heurck, Treat. : 404, pl. 17, fig. 568 (1896); Allen & Cupp, Ann. Jard.

Bot. Buitenzorg 44 (2) : 163, fig. 121 (1935); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 200, fig. 154 (1943); Subrahmanyan. Proc. Indian Acad. Sci. 24 : 191, figs. 435 - 437 (1946).

Syn.: N. gazellae Karsten, Valdivia Antarkt. Phytopl. : 128, pl. 18, fig. 9 (1905).

System.: N. gazellae represents the extreme range of elongation in this species and thus could be considered a form or a variety, depending upon whether it appears to be a phenotypic variant only or whether the variation is genetically determined. Unfortunately it was not distinguished from the typical N. longissima during the microscopic analysis of the material and so its distribution cannot be considered separately.

Local.: NIOE 3, 7, 16, 17, 19, 21, 28, 30, 32, 34, 35, 37, 58, 59, 60, 62, 64, 66, 69, 71, 73, 74, 75, 77, 80, 84, 85, 88, 94, 95, 96, 99, 101, 103, 108, 111, 112, 114, 117, 121, 124, 130, 144, 150, 151, 157, 158, 159, 162, 164, 169, 176, 177, 178.

The species was very widespread over the area on all four cruises, being encountered at both extreme inshore and offshore stations. It was most plentiful (+++) at stations 28 and 30 in the southern offshore region in April.

General: A tychopelagic species recorded from all seas. Wood (1963, b) listed several Indian Ocean and Antarctic records of the species.

224. Nitzschia marina Grunow in Cleve & Grunow, Beitr. Kennt. Arct. Diat. : 70 (1880); Peragallo, Diat. Mar. France : 272, pl. 72, fig. 24 (1908); Kolbe, Diat. Equat. Pacific Cores : 40, pl. 3, figs. 38 - 40 (1954); Kolbe, Diat. Equat. Indian O. Cores : 39, pl. 1, fig. 7 (1957).

Local.: NIOE 12, 117, 119.

Rare, in small numbers at isolated oceanic stations in April and October.

General: This species is not frequently recorded. The early records refer to its presence in the N. Atlantic. Kolbe (1954, 1955, 1957) found it present in Pacific and Atlantic Ocean sediments and frequently in Indian Ocean sediments. It has also been recorded from the Antarctic (Mann, 1937).

225. Nitzschia migrans Cleve, 15th Ann. Rep. Fish. Board Scotland : 300, fig. 9 (1897); Gran, Diat. Nord. Plankt. : fig. 177 (1905); Peragallo, Diat. Mar. France : 299, pl. 72, fig. 25 (1908,

sub *Pseudonitzshia sicula* var *migrans*); Heiden & Kolbe, Mar. Diat. Deutsch. Südpol-Exped. 1901 - 03 : 671 (1928, sub *Pseudonitzschia migrans*).

Local.: NIOE 25, 32, 34, 36, 37, 95, 96, 103, 128, 150, 169, 176,

Usually only one specimen observed per subsample. Found at scattered inshore and offshore stations in April, October and January.

General: A species not recorded by many authors. It was first described from the N. Atlantic Ocean. Hustedt (1958) found it in the subantarctic region of the S. Atlantic, and it has been recorded from the Antarctic by Van Heurck (1909) and Heiden & Kolbe (1928). It would thus seem to be chiefly distributed in colder waters. However Cleve (1900, b) recorded it from the Red Sea.

226. *Nitzschia pacifica* Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 204, fig. 157 (1943); Hustedt, Diat. Antarkt. & Südatlant. : 177, pl. 13, figs. 193, 194 (1958). PLATE 6, fig. 6.

System.: The author was able to examine large numbers of specimens of this species. In none of them was he able to discern the central gap in the keel punctae found by Hustedt in specimens he assigned to this species. As in the case of *N. delicatissima* this species is difficult to identify with certainty in water mounts. A further difficulty is that it can be easily confused with *N. pungens* var. *atlantica* Cleve, and to a lesser extent, *N. seriata* Cleve. When examining large populations of this species from the vicinity of Port Elizabeth the author found that, whilst the great majority of specimens resembled Cupp's description, there were a small number of specimens which could also be identified as one of the other species mentioned above. Clearly this problem must be investigated further to determine the exact limits of each species. For the present the author has retained each species and when a specimen was found which conformed to the original description of each it was recorded as such, but the possibility of a species complex is strongly suggested by the present author's observations. *N. seriata* was most easily distinguishable from the others due to its shape and coarser striation. Furthermore it tended to be distributed in the south. Off the west coast of S. Africa the majority of specimens resemble the typical *N. seriata*, whereas off the east coast *N. pacifica* is the commonest form present.

Local.: NIOE 1, 2, 3, 5, 7, 9, 10, 12, 14, 16, 17, 18, 19, 20, 21, 23, 25, 27, 28, 30, 32, 34, 35, 36, 37, 58, 59, 62, 66, 69, 71, 73, 75, 76, 77, 78, 80, 82, 84, 85, 88, 91, 93, 94, 95, 96, 97, 99, 101, 103, 104, 106, 108, 111, 112, 113, 114, 115, 117, 119, 120, 121, 124, 126, 130, 142, 143, 144, 157, 158, 159, 160, 161, 162, 164, 169, 172, 176, 177, 178.

One of the commonest and most abundant species of phytoplankton in the area. In April it was present at every station sampled, sometimes in enormous numbers (+++++) at inshore stations on lines B and C. It was absent from some extreme offshore stations in July, but in October it was present at virtually every station although in smaller numbers than in April. In January it was confined to the inshore portions of all lines except in the south.

It appeared to have a centre of distribution over the shelf between Port Elizabeth and Port St. Johns (lines C and B), spreading out in all directions. Its presence at offshore stations in the south in January might be due to transport off the shelf.

General: It was first described from the waters off Southern California where it was sometimes present in large numbers (Cupp, 1943). Hustedt (1958) found it in the S. Atlantic and Wood (1962) recorded it from the Indian Ocean.

227. Nitzschia panduriformis var. continua Grunow in Cleve & Grunow, Beitr. Kennt. Arct. Diat. : 70 (1880); Van Heurck, Syn. : 172, pl. 58, fig. 6 (1881); Peragallo, Diat. Mar. France : 269, pl. 70, figs. 11, 12 (1908); Allen & Cupp, Ann. Jard. Bot. Buitenzorg 44 (2) : 162, fig. 118 (1935).

Local.: NIOE 119, 130, 159.

Rare. Recorded from isolated inshore and offshore stations in October and January.

General: The variety was first recorded from the Arctic. Peragallo (1908) found it present in the Mediterranean. Heiden & Kolbe (1928) recorded it from the Cape Verde Islands, and Allen & Cupp (1935) found it in the Java Sea.

228. Nitzschia pungens var. atlantica Cleve, Treat. Phytopl. Atlantic & Trib. : 24, pl. 2, fig. 24 (1897); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 202, fig. 156 (1943).

System.: See note under _N. pacifica_ Cupp. Distinguished chiefly by the poorly developed keel punctae and the striae count.

Local.: NIOE 60, 62, 73.

Found at several northern stations in July only.

General: Considered to be a neritic temperate species by Cupp (1943). Its distribution is uncertain due to its possible confusion with other _Nitzschia_ species.

229. _Nitzschia seriata_ Cleve, Vega-Exped. Vetensk. Iakttag. _3_ : 478, pl. 38, fig. 75 (1883); Gran, Diat. Nord. Plankt. : 130, fig. 174 (1905); Peragallo, Diat. Mar. France : 300, pl. 72, fig. 28 (1908, sub _Pseudonitzschia seriata_); Hendey, Discovery Rep. _16_ : 352 (1937); Cupp, Mar. Plankt. Diat. W. Coast N. Amer. : 201, fig. 155 (1943).
PLATE 6, fig. 7.

System.: See note under _N. pacifica_ Cupp. The specimen illustrated is typical of the west coast population and those found in the south of the area under present study.

Local.: NIOE 30, 32.

Present in small numbers (+ - ++) at two southern offshore stations. Mixed with _N. pacifica_ Cupp.

General: A neritic species usually distributed in colder waters than _N. pacifica_. Cupp (1943) found that it was present off the Alaskan coast. Gran (1905) considered it to be an arctic species. It is common and seasonally abundant off the west coast of S. Africa (Boden, 1950; Hart & Currie, 1960; and personal observations). Wood (1963, b) has listed several records of the species from the Antarctic. A number of the Indian Ocean records of the species might possibly be due to confusion of the species with _N. pacifica_.

230. _Nitzschia sicula_ var. _bicuneata_ (Grunow) Taylor nov. comb.

PLATE 6, fig. 8.

Syn.: _Pseudonitzschia sicula_ var. _bicuneata_ (Grunow) Peragallo, Diat. Mar. France : 299, pl. 72, fig. 26 (1908).

System.: Grunow's original use of the combination with reference to a specimen in the collection of Cleve and Möller (nos. 208 - 210) cannot be considered valid publication, and Peragallo's generic separation of some forms into _Pseudonitzschia_ is no longer held by most authorities.

Nitzschia sicula var. *rostrata* Hustedt (1958, p. 180) is very similar to the forms described by Peragallo as var. *bicuneata*. The specimen observed and figured by the present author (pl. 6, fig. 8) was more elongated and consequently relatively narrower than either Peragallo's or Hustedt's specimens, but the striae count (7 - 8 in 10μ) was similar to the latter's count for var. *rostrata*. The local specimens also differed in that distinct keel punctae were discernable, and the apices were assymetrical in shape.

Local.: NIOE 60, 103.

Two specimens recorded, one from a northern offshore station on line A in July, and one from the vicinity of Cape Agulhas in October.

General: No locality was given by Peragallo (1908). The species has been recorded by Heiden & Kolbe (1928) from the tropical Atlantic, the S. Atlantic and the tropical Atlantic and the S. Indian Ocean. Hustedt (1958) recorded the var. *rostrata* from the vicinity of Kerguelen Island in the Southern Ocean.

231. *Nitzschia sigma* var. *rigida* (Kützing) Grunow, Alg. & Diat. Kaspich. Meere : 119 (1878); Van Heurck,

Syn. : pl. 66, fig. 2 (1881). PLATE 19, fig. 2.

System.: The specimen figured in the present study was 80 μ long, 8 μ in width at the centre, with 9 - 10 keel punctae in 10 μ. Striae could not be seen as the specimen was observed in a water mount.

Local.: NIOE 114.

One specimen recorded from a station near Port Elizabeth in October.

General: The species is widely distributed on the coastlines of all seas. The variety has been recorded from the Cape Verde Islands by Heiden & Kolbe (1928, as N. rigida). Wood (1963, b) has listed references to the species in the Indian Ocean.

As the species and its varieties are usually littoral in habitat the presence of the above variety in a plankton collection is probably adventitious.

232. Nitzschia spathulata var. hyalina (Gregory) Grunow in Van Heurck, Syn. : 177, pl. 62, fig. 9 (1881); Peragallo, Diat. Mar. France : 285, pl. 73, fig. 5 (1908). PLATE 19, fig. 1.

Local.: NIOE 178.

One specimen recorded from an inshore station near Cape Agulhas in January.

General: Recorded from a few widely separated localities, both fresh water and marine - North Sea (Van Heurck, 1881), Normandie (Peragallo, 1908), Sumatra (Leuduger - Fortmorel, 1893).

233. Nitzschia sp. PLATE 19, fig. 3.

This extremely small species was found occurring epiphytically on an empty frustule of Rhizosolenia styliformis. In the photomicrograph several individuals can be seen. In general form they resembled the genus Nitzschia but it was impossible to see whether they possessed a raphe of any type. Most of the cells were between 16 - 20 μ long and about 2 μ wide. However one cell with greatly elongated apices can be seen. It is approximately 50 μ long but, like the others, only 2 μ wide. It is possibly the same species as the others. The chromatophores appear to single or double and centrally placed. Similar small cells were observed on the empty carapace of a copepod at another station.

Local.: NIOE 108, 124.

Observed at offshore stations on line B and line D in October.

373. <u>Peridinium</u> <u>divergens</u> Ehrenberg, Ber. Akad. Wiss. Berlin, 1840 : 201 (1840, e.p.); Lebour, Dinofl. North. Seas : 127, pl. 26, fig. 2 (1925); Schiller, Dinofl. (2) : 226, fig. 222 (1937); Wood, Aust. J. Mar. & Freshw. Res. <u>5</u> (2) : 248, fig. 139 (1954).

Local.: NIOE 2, 3, 5, 16, 19, 20, 77, 78, 80, 84, 85, 87, 99, 113.

This species was found in small numbers at inshore and Agulhas Current stations on lines A, B and C in April. In July it was present at only two stations, one offshore on line A, and one inshore on line C (Port Elizabeth). It was absent from the January material. It has been occasionally recorded from the Indian Ocean (see Wood, 1963, a).

374. <u>Peridinium</u> <u>elegans</u> Cleve forma <u>elegans</u>, Kongl. Svenska Vet.-Akad. Handl. <u>34</u> (1) : 16, pl. 7, fig. 15 (1900); Matzenauer, Bot. Archiv <u>35</u> : 471, fig. 57 (1933); Schiller, Dinofl. (2) : 254, fig. 252 (1937); Wood, Aust. J. Mar. & Freshw. Res. <u>5</u> (2) : 249, fig. 141 (1954).

Local.: NIOE 75, 78.

Single specimens were found at stations on or near the edge of the shelf on lines B and C in July, 1962. It has been recorded occasionally from the Indian Ocean by other authors (see Wood, 1963, a).

375. Peridinium elegans forma granulatum (Karsten) Schiller, Dinofl. (2) : 255, fig. 253 (1937); Matzenauer, Bot. Archiv. 35 : 471, fig. 58 (1933, sub P. divergens granulatum Karst.).

Local.: NIOE 16. 21, 35, 62, 94, 95, 128, 142, 144.

Recorded in small numbers from single stations on lines B, C and D in April. In July it was present at a northern offshore station on line A, and a southern inshore station near Cape Agulhas, and from similar localities in October. In January it was only present near Durban (inshore line A). This form has been previously recorded from the Indian Ocean by Matzenauer (1933).

376. Peridinium globulum var. quarnerense Schröder, Mitt. Zool. Stat. Neapel 14 : 18 (1900); Schiller, Dinofl. (2) : 184, fig. 186 (1937).

Local.: NIOE 95, 128.

Found only at shelf stations near Durban and Cape Agulhas in October, 1962. This variety has been previously recorded from the Indian Ocean by Matzenauer (1933, as P. quarnerense Schröd.).

377. Peridinium granii (Ostenfeld) Paulsen, Medd. Komm. f. Havunders., Serie Plankton 1 : 15, fig. 18 (1907); Lebour, Dinofl. North. Seas : 124, pl. 25, fig. 2 (1925); Schiller, Dinofl. (2) : 189, fig. 188, a - r (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 238, fig. 116 (1954).

Local.: NIOE 161.

One specimen was observed in material from an inshore station near Port Elizabeth in January. It has been recorded from the Indian Ocean by Matzenauer (1933), Subrahmanyan (1958) and Wood (1962).

378. Peridinium heteracanthum Dangeard, Bull. Inst. Oceanogr. Monaco (491) : 7, fig. 4 (1927); Matzenauer, Bot. Archiv. 35 : 480, fig. 72 (1933); Schiller, Dinofl. (2) : 206), fig. 199 (1937); Silva, Mem. Junta Invest. Ultram. (18) : 40, pl. 23, figs. 7-9 (1960).

Local.: NIOE 157.

One specimen recorded from an offshore station on line B in January, 1963. It has been previously recorded from the Indian Ocean by Matzenauer (1933) and Silva (1960).

379. Peridinium latispinum Mangin, Phytopl. Anatarct. 1902 - 1904 1 : 81, fig. 24, 1 (1926); Schiller, Dinofl. (2) : 193, fig. 190, A (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 240, fig. 119 (1954).

Local.: NIOE 17, 28.

Recorded from an inshore station on line B and a southern offshore station on line D in April, 1962. This appears to be a new record from the Indian Ocean.

380. Peridinium leonis Pavillard, Trav. Inst. Bot. Montpellier (4) : 32, fig. 6 (1916); Lebour, Dinofl. North. Seas : 112, pl. 21, fig. 1, a - d (1925); Matzenauer, Bot. Archiv. 35 : 456, fig. 29, a (1933); Schiller, Dinofl. (2) : 236, fig. 236 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 251, fig. 148 (1954).

Local.: NIOE 159.

Found in small numbers at an inshore station on line B in January, 1963. Indian Ocean records include those of Matzenauer (1933), Subrahmanyan (1958), and Wood (1962).

381. Peridinium marielebouriae Paulsen, Minist. Fomento Inst. Espan. Oceanogr. (4) : 69. fig. 40 (1930); Schiller, Dinofl. (2) : 239, fig. 239 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 253, fig. 149 (1954).

Local.: NIOE 114.

Recorded from an inshore station near Port Elizabeth in October, 1962. Schiller (1937) has listed the Indian Ocean as one of the localities from which this species has been recorded.

382. Peridinium minusculum Pavillard, Mem. Univ. Montpellier 2 : ? (1905); Lebour Dinofl. North. Seas : 138, pl. 29, fig. 3 (1925, sub Minuscula bipes); Schiller, Dinofl. (2) : 194, fig. 190, B (1937).

System.: Both Lebour and Schiller omit the page reference for the original use of this combination and, as the journal was not available for the present author to consult, it could not be ascertained. Lebour (1925) considered the plate arrangement of this species to be sufficiently distinct to warrant the formation of a new genus, Minuscula.

Local.: NIOE 128.

One specimen was found at a station on the edge of the Agulhas Bank on line D in October, 1962. This is apparently a new record for the Indian Ocean region.

383. Peridinium minutum Kofoid, Univ. Calif. Publ. Zool. 3 : 310, pl. 31, figs. 42 - 45 (1907); Schiller, Dinofl. (2) : 141, fig. 140 (1937).

Local.: NIOE 73.

One specimen was observed in material from an offshore station on line B in July, 1962. The species has been recorded from the Indian Ocean region by Subrahmanyan (1958).

384. Peridinium monocanthum Broch, Kongl. Svenska Vet.-Akad. Handl. 45 (9) : 50, fig. 25 (1910); Lebour, Dinofl. North. Seas : fig. 41, e (1925); Schiller, Dinofl. (2) : 201, 196 (1937);

Wood, Aust. J. Mar. & Freshw. Res. 5 (2): 242, fig. 123 (1954).

Local.: NIOE 19.

One specimen was found in the vicinity of Port Elizabeth in April, 1962. This is a cold-water species which has been recorded from the Indian Ocean by Wood (1962).

385. *Peridinium nipponicum* Abé, Sci. Rep. Tokyo Imp. Univ. 2 (4) : 396, pl. 16 (1927); Matzenauer, Bot. Archiv. 35 : 480, fig. 73, a, b (1933); Schiller, Dinofl. (2) : 207, fig. 202 (1937).

Local.: NIOE 142.

One specimen recorded from an inshore station near Durban (line A) in January, 1963. It has been previously recorded from the Indian Ocean by Matzenauer (1933) and Wood (1962).

386. *Peridinium oceanicum* Vanhöffen, Grönland Exped. Ges. Erdkunde Berlin 2 : pl. 5, fig. 2 (1897); Lebour, Dinofl. North. Seas : 120, fig. 36, b (1925); Schiller, Dinofl. (2) : 260, fig. 256 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 256, fig. 157 (1954).

Local.: NIOE 71, 95, 96, 111, 112, 120, 124, 126, 128, 142, 160, 176.

Recorded from one offshore station on line B in July. It was found at inshore stations on lines A and B, and at offshore and inshore stations on lines C and D in October. In January it was restricted to scattered inshore stations. It was not present in the April material. The species has been recorded from the Indian Ocean by many authors (see Wood, 1963, a).

387. Peridinium ovum Schiller, Oesterr. Bot. Z. (61) : fig. 1, A - D (1911); Schiller, Dinofl. (2) : 208, fig. 205 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 244, fig. 128 (1954).

Local.: NIOE 117.

One specimen found at an offshore station on line C in October, 1962. This appears to be a first record for the Indian Ocean.

388. Peridinium pedunculatum Schütt, Ergebn. Plankton-Exped. der Humboldt-Stift. 4 : pl. 14, fig. 47 (1895); Paulsen, Peridin. Nord. Plankt. : 48, fig. 59 (1908); Schiller, Dinofl. (2) :

211, fig. 208 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 244, fig. 130 (1954).

Local.: NIOE 114.

One specimen, resembling that figured by Wood (1954), was observed in material collected from a station near Port Elizabeth in October, 1962. Wood (1963, a) has listed several Indian Ocean records of this species.

389. *Peridinium pellucidum* (Bergh) Schutt, Ergebn. Plankton-Exped. der Humboldt-Stift. 4 : pl. 14, fig. 45 (1895); Paulsen, Peridin. Nord. Plankt. : 49, fig. 61 (1908); Lebour, Dinofl. North. Seas : 134, pl. 28, fig. 2 (1925); Schiller, Dinofl. (2) : 212, fig. 209 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 245, fig. 131 (1954).

Local.: NIOE 97.

One specimen found at an offshore station on line A in October, 1962. This species has been identified from the Indian Ocean by several authors (see Wood, 1963, a).

390. *Peridinium pentagonum* var. *latissimum* (Kofoid) Schiller; Dinofl. (2) : 242, fig. 242 (1937); Wood,

Aust. J. Mar. & Freshw. Res. 5 (2) : 253, fig. 150 (1954).

Local.: NIOE 19, 20, 21, 37, 75, 76, 77, 85, 113, 114, 119, 160, 176.

Present at inshore stations near Port Elizabeth on all cruises. In April, July and January it also spread onto line D. This variety has been recorded from the Indian Ocean by a few authors (listed by Wood, 1963, a).

391. Peridinium pyriforme Paulsen, Medd. Kom. Havunders., Serie Plankt. 1 (5) : 13, fig. 15 (1907); Paulsen, Peridin. Nord. Plankt. : 46, fig. 57 (1908); Lebour, Dinofl. North. Seas : 126, fig. 38 (1925); Schiller, Dinofl. (2): 194, fig. 191 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 239, fig. 118 (1954, sub P. piriforme).

Local.: NIOE 106.

One specimen was found at an offshore station on line B in October, 1962. Wood (1963,a) has listed two records of this species from waters adjacent to the Indian Ocean.

Aust. J. Mar. & Freshw. Res. 5 (2) : 253, fig. 150 (1954).

Local.: NIOE 19, 20, 21, 37, 75, 76, 77, 85, 113, 114, 119, 160, 176.

Present at inshore stations near Port Elizabeth on all cruises. In April, July and January it also spread onto line D. This variety has been recorded from the Indian Ocean by a few authors (listed by Wood, 1963, a).

391. Peridinium pyriforme Paulsen, Medd. Kom. Havunders., Serie Plankt. 1 (5) : 13, fig. 15 (1907); Paulsen, Peridin. Nord. Plankt. : 46, fig. 57 (1908); Lebour, Dinofl. North. Seas : 126, fig. 38 (1925); Schiller, Dinofl. (2): 194, fig. 191 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 239, fig. 118 (1954, sub P. piriforme).

Local.: NIOE 106.

One specimen was found at an offshore station on line B in October, 1962. Wood (1963,a) has listed two records of this species from waters adjacent to the Indian Ocean.

392. Peridinium remotum Karsten, 'Valdivia' Indische Phytopl. : 417, pl. 53, fig. 5 (1907); Matzenauer, Bot. Archiv. 35 : 473, fig. 61 (1933); Schiller, Dinofl. (2) : 262, fig. 258 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 249, fig. 140 (1954).

Local.: NIOE 178.

One specimen was identified from material collected at an inshore station near Cape Agulhas in January. The species was first described from the Indian Ocean by Karsten (1907). The record of Matzenauer (1933) is apparently the only other Indian Ocean record of this species.

393. Peridinium solidicorne Mangin, Phytopl. Antarct. 1902 - 1904 : 80, fig. 23 (1926); Matzenauer, Bot. Archiv. 35 : 218, fig. 69 (1933); Schiller, Dinofl. (2) : 218, fig. 215 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 247, fig. 135 (1954).

Local.: NIOE 18.

One specimen was found at an inshore station on line B in April, 1962. It has been previously recorded from the Indian Ocean by

Matzenauer (1933) and Wood (1962).

394. Peridinium sphaericum Okamura, Rep. Imp. Bur. Fish. Japan 1 : 14, pl. 4, figs. 71, 72 (1912); Schiller, Dinofl. (2) : 214, fig. 210 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 246, fig. 132 (1954).

Local.: NIOE 146.

One specimen was recorded from an offshore station on line A in January, 1963. The species has been recorded from the Indian Ocean by Matzenauer (1933, as var. gracilis), Silva (1960), and Ballantine (1961), the latter authors identifying it from Inhaca Island (Mozambique) and Zanzibar respectively.

395. Peridinium steinii Jörgensen, Bergens Mus. Aarb. 1899 (6) : 38 (1900); Lebour, Dinofl. North. Seas : 125, pl. 25, fig. 4 (1925); Schiller Dinofl. (2) : 196, fig. 192 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 240, fig. 120, a (1954).

Local.: NIOE 157.

Several specimens were found at an offshore station on line B in January, 1963. The species has been identified frequently from the Indian Ocean by various authors (listed by Wood, 1963, a).

396. Peridinium tenuissimum Kofoid, Bull. Mus. Comp. Zool. Harvard 50 : 176, pl. 5, fig. 34 (1907); Matzenauer, Bot. Archiv 35 : 477, fig. 68 (1933); Schiller, Dinofl. (2) : 215, fig. 211 (1937); Wood, Aust. J. Mar. & Freshw. 5 (2) : 246, fig. 133 (1954).

Local.: NIOE 124.

One individual of this species was observed in material from a southern offshore station on line D in October, 1962. It has been previously recorded from the Indian Ocean by Karsten (1907), Matzenauer (1933), and Wood (1962).

397. Peridinium tristylum Stein, Naturges. der arthrodelen Flagell. : pl. 9, figs. 15 - 17 (1883); Schiller, Dinofl. (2) : 216, fig. 212 (1937).

Local.: NIOE 17, 19, 20, 21, 25, 58, 142.

In April this species was present in small numbers at inshore stations on lines B and C, spreading offshore on line C. It was also found in the vicinity of Durban in

July and January. Ostenfeld & Schmidt (1901) found it present in the Red Sea and Gulf of Aden, and it was recorded from the northern Indian Ocean by Matzenauer (1933).

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398. Blepharocysta splendor-maris (Ehrenberg) Ehrenberg, Festschr. z. Feier d. 100 Jähr. Best. d. Ges. Naturf. Freunde zu Berlin : 1 (1873); Paulsen, Peridin. Nord. Plankt. : 93, fig. 126 (1908); Lebour, Dinofl. North. Seas : 160, fig. 52, c (1925); Schiller, Dinofl. (2) : 477, fig. 550 (1937).

Local.: NIOE 27.

One specimen was found at an extreme southern offshore station in April, 1962. The species has been identified from the Indian Ocean previously by Ostenfeld & Schmidt (1901), Schröder (1906), and Wood (1962).

399. Podolampas bipes Stein, Naturges. der arthrodelen Flagell. : pl. 8, figs. 6 - 8 (1883); Paulsen, Peridin. Nord. Plankt. : 92, fig. 125 (1908);

Lebour, Dinofl. North. Seas : 160, fig. 52, b (1925); Schiller, Dinofl. (2) : 474, fig. 544 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 316, fig. 351,a (1954).

Local.: NIOE 35, 60.

Recorded in small numbers from a southern station on the edge of the Agulhas Bank (line D) in April, and a northern Agulhas Current station near Durban in July. Wood (1963, a) has listed the numerous records of this species from the Indian Ocean.

400. Podolampas elegans Schütt, Ergebn. Plankt.-Exped. der Humboldt-Stift. 4 : pl. 18, fig. 57 (1895); Lebour, Dinofl. North. Seas : 160, fig. 53 (1925); Schiller, Dinofl. (2) : 475, fig. 546 (1937).

Local.: NIOE 71.

One specimen of this species was found at an offshore station on line B in July, 1962. It has been identified from the Indian Ocean region by Schröder (1906), Matzenauer (1933), and Wood (1962).

401. Podolampas palmipes Stein, Naturges. der arthrodelen Flagell. : pl. 8, figs. 9 - 11 (1883);

Paulsen, Peridin. Nord. Plankt. : 92, fig. 24 (1908); Lebour, Dinofl. North. Seas : 159, fig. 52, a (1925); Schiller, Dinofl. (2) : 475, fig. 547 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 317, fig. 252 (1954).

Local.: NIOE 10, 28, 30, 101, 120, 124, 144, 162.

The species was found in small numbers at northern and southern offshore stations in April, October and January. Its distribution was closer inshore in the latter month than at the two earlier months. Wood (1963, a) has listed the Indian Ocean records of this widely distributed species.

402. Podolampas spinifer Okamura, Rep. Imp. Bur. Fish. Japan 1 : 17, pl. 2, figs. 35, 36 (1912); Pavillard, Trav. Inst. Bot. Univ. Montpellier, serie mixte (4) : 41, pl. 2, figs. 6, 7 (1916); Schiller, Dinofl. (2) : 476, fig. 548 (1937).

Local.: NIOE 153.

Only one specimen of this species was seen, in material from an offshore station on line B in January, 1963. It has been recorded from the Indian Ocean by Wood (1962), earlier records being from the Sea of Japan and the western Mediterranean.

II. 6. Summary of new taxa and nomenclatural revisions.

During the course of identifying the taxa present a certain amount of systematic revision was necessary, leading to nomenclatural alterations and the description of several new taxa. For convenience in reference these are listed below with their taxon numbers appended in brackets.

Chaetoceros affinis var. inflatospinosus nom. nov. (92)
Chaetoceros capricornianus nom. nov. (101)
Chaetoceros criophilus forma okamurai stat. et comb. nov. (109)
Chaetoceros rostratus forma glandazii stat. et comb. nov. (141)
Coscinodiscus trioculatus sp. nov. (28)
Mastagloia woodiana nom. nov. (201)
Mastagloia woodiana var. lanceolata comb. nov. (202)
Navicula hendeyana sp. nov. (203)
Nitzschia lanceolata var. quincuncata var. nov. (222)
Nitzschia sicula var bicuneata comb. nov. (230)
Pleurosigma karstenii nom. nov. (212)
Schroederella delicatula forma schroederii stat. et comb. nov. (153)
Synedra indica sp. nov. (182)
Synedra ossiformis sp. nov. (183)
Synedra regalis sp. nov. (186)

In addition to these, Brachydinium capitatum F. Taylor (257), a new genus and species of the dinococcales was

Note: Chaetoceros aurivillii var. australis (Mangin) comb. nov. arises out of the relegation of Ch. seychellarus to a synonym. See p. 143.

described by the author (Taylor, 1963) from the material under study.

SECTION III. HYDROGRAPHIC CONDITIONS IN THE S.W. INDIAN OCEAN.

In order to understand the environment of the phytoplankton under study it is necessary to consider in some detail both the general and specific conditions in which the organisms occurred. In the present section the origins and the fluctuation of conditions in the various water masses will be discussed.

Routine hydrographic observations were made on all stations where the phytoplankton samples were collected, and the raw data has been published by Shipley & Zoutendyk (1964). Darbyshire (1964) has presented certain aspects of the data in his study of the current systems of the area.

The horizontal temperature distribution charts were prepared by Mr. P. Zoutendyk, and diagram 7 is reproduced from Darbyshire's paper.

III. 1. <u>General circulation in the S.W. Indian Ocean</u>.

The classic outline of circulation in this area has been provided in many publications, such as those of Willimzik (1929), Clowes & Deacon (1935), Dietrich (1935), Sverdrup <u>et al</u>

(1942), Clowes (1950), and the U.S. Navy Hydrographic Office (1960). However, more recent observations, e.g. Mallory (1961), Darbyshire (1964), have indicated that some modifications to the general pattern of circulation are necessary, and the following description includes these.

In the sector of the S.W. Indian Ocean under discussion (shown on charts 1 - 4 in section I) the major hydrographic feature is the Agulhas Current. This is a warm, low salinity current flowing in a southwesterly direction down the eastern and southern coasts of South Africa, its position corresponding approximately to the outer edge of the continental shelf. As the shelf is narrow off the Natal Coast the current lies close to the coast, diverging away from the coast in the southwest where the shelf expands into the Agulhas Bank. The distance of the core of the current from the coast is most variable in the southwest and is apparently influenced by prevailing winds. Warm Agulhas Current water may on occasions flow over the Agulhas Bank. The strength of the current is variable. Darbyshire (1964) calculated that in 1962 the Agulhas Current was strongest in April and weakest in October; the strength of the current being apparently independent of prevailing winds in the S.W. Indian Ocean and dependant on the strength of the S. Equatorial Current from which it originates.

The Agulhas Current is generally considered to be the result of the union of two components, the East Madagascar

Current and the Mozambique Current, both of which are derived from the westward-flowing S. Equatorial Current as a result of its striking the northern tip of Madagascar and the coast of East Africa respectively. Early workers considered that the south-flowing Mozambique Current was a constant contributor to the Agulhas Current, but Menache (1961) has shown that during October, 1957, and possibly in October, 1958, the Mozambique Current did not appear to link up with the Agulhas Current, a large eddy being developed in the Mozambique Channel. In this respect it is interesting to recall Darbyshire's (1964) observation that the Agulhas Current was weakest in October, 1962. If the phenomenon observed by Menache is annual one might suggest that when the Agulhas Current is weakest the East Madagascar Current contribution forms the bulk of Agulhas Current water with a negligible contribution through the Mozambique Channel. This has yet to be established but the possibility cannot be overlooked. Macnae (1962) has suggested that the degree of impingement of the S. Equatorial Current on Madagascar, greatest when the current is in its most southern position, i.e. the southern summer, ~~and that this~~ influences the current pattern in the Mozambique Channel. Taken with Menache's observations this seems to be a reasonable speculation but once again further evidence is required.

From the above it would seem that the strength of the Agulhas Current is determined by two major factors: the strength of the S. Equatorial Current, and its position, i.e. whether it is in a northerly or southerly position.

The north-south shift of the S. Equatorial Current and the Subtropical Convergence Region is well known, both occurring furthest south in the southern summer. It is not surprising, therefore, that evidence presented later in this section indicates a similar north-south movement of the westward extension of the East Madagascar Current.

The deflection of the Agulhas Current away from the coast in the southwest is thought to be due to the influence of Corioli's force and the expansion of the continental shelf. To the south of the Agulhas Bank the current comes in contact with the general eastward flow of the circum-polar West Wind Drift. The extent of southward penetration of the Agulhas Current appears to depend on its strength. From Darbyshire's (1964) computed surface current pattern for October, 1962, it can be seen that the Agulhas Current barely reaches 36°S when it is at its weakest.

The concept of an Agulhas Return Current, i.e. an eastwardly deflected continuation of the Agulhas Current resulting from its contact with West Wind Drift and Corioli's force, seems to require modification. Evidence given later in this section shows that in three of the four months investigated no clearly recognisable core of warm water was present to the east of the most southward penetration of the Agulhas Current, this being detectable only in January. At other times the well developed eastward flow in this region appears to have no connection with the Agulhas Current, having a more obvious relationship with the West Wind Drift. Thus the Agulhas Return Current may be a temporary feature, most markedly developed in the summer months.

During the rest of the year Agulhas Current water, although undoubtedly deflected eastwards, does not appear to form a definite current but merges with the West Wind Drift water to the south and the subtropical surface water to the east. Until recently the Subtropical Convergence, where subtropical surface water and subantarctic surface water meet, has been considered as always lying to the south of 40°S near S. Africa. However, more recent evidence has shown that the region of mixing between these waters, termed by Fukase (1962) as "North Edge Water of West Wind Drift", extends well north of this latitude in a meander in the eastward-flowing current to the southeast of South Africa. The meander corresponds in position to the Agulhas Plateau which rises to a depth of approximately 3000 m. Sverdrup et al (1942) have demonstrated that Central Water in the S. Indian Ocean results from sinking in a region corresponding to the later-named "North Edge Water of West Wind Drift".

An interesting phenomenon relating to the region of mixing between surface waters has been observed recently. This is the existence of not one, but two, surface temperature discontinuities to the south of S. Africa and in the region of other times the well developed eastward flow in this region appears to have no connection with the Agulhas Current, having a more obvious relationship with the West Wind Drift. Thus the Agulhas Return Current may be a temporary feature, most markedly developed in the summer months.

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An interesting phenomenon relating to the region of mixing between surface waters has been observed recently. This is the existence of not one, but two, surface temperature discontinuities to the south of S. Africa and in the region of

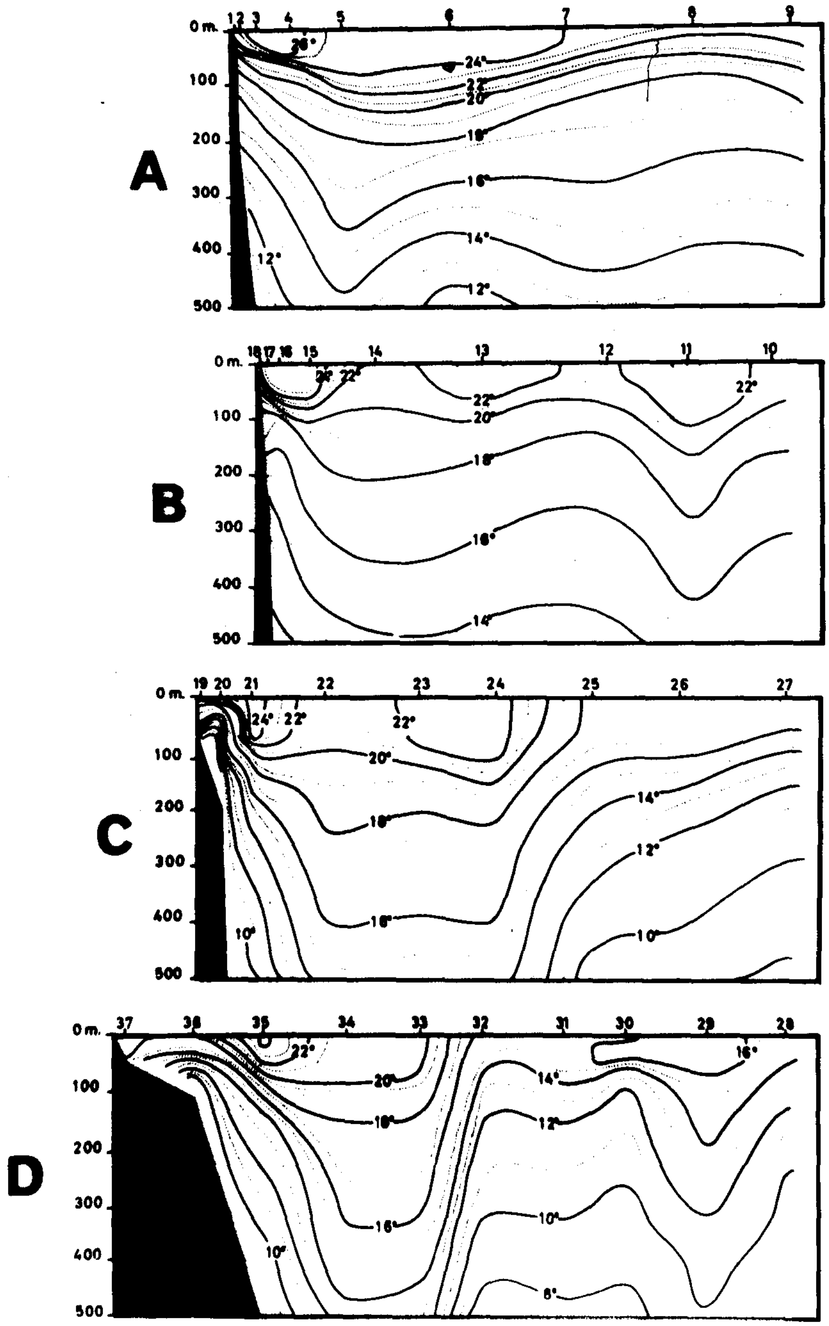
Crozet and Kerguelen Islands, as reported by Fukase (1962), Delépine (1963), and Darbyshire (1964). Fukase considered the more southerly one to indicate the position of the Subtropical Convergence (mean temperature, 13°C) and named the other as the "Agulhas Convergence" (mean temp. 18°C). However the distance between the two appears to vary considerably, being greatest in the region of the islands. At times, i.e. in April, 1962, they appeared to run together to the south of S. Africa. Thus it seems advisable to reiterate Defant's (1938) contention that the Subtropical Convergence is a region of convergence, and to add that its northern and southern boundaries are indicated by surface temperature discontinuities. The degree of lateral mixing between the surface waters to the north and south will determine the thickness of the North Edge Water and the distance apart of the temperature discontinuities. Fukase's "Agulhas Convergence" seems to be an unfortunate name as it implies a distinct point of sinking of surface water related to the Agulhas Current, the former not being proved to date, and the latter inappropriate to the apparently related double-discontinuity phenomenon to the north of Crozet and Kerguelen Islands. For present purposes the author adheres to Defant's concept, and terms the two discontinuities, when present, as the North Edge Discontinuity, the more southerly of the two, and the Subtropical Discontinuity, corresponding to Fukase's Agulhas Convergence. When only one is manifest the latter term is preferred as it relates directly to the

Subtropical Convergence Region.

A feature of great significance to the phytoplankton population of the inshore areas is the marked vertical movement of water on the inner edge of the Agulhas Current to the southwest of East London where the current moves away from the coast. This results in the presence of water of less than 12^{o}C over the bottom of the continental shelf all the year round. The cold water is usually overlaid by a thin layer of warm water, only a few metres thick, near Port Elizabeth, but it reaches the surface on occasions over the Agulhas Bank. Very cold water, $\pm$ 10^{o}C, has been reported close inshore along the southern coast of S. Africa (Korringa, 1956), and it seems likely that this is localised upwelling of the water covering the surface of the Agulhas Bank referred to above. The vertical profiles of temperature distribution given in this study, diagrams 2 to 5, indicate the rise of water on the inner edge of the Agulhas Current quite clearly, and also show that the northward limit varies between lines B and C, being furthest north in January, 1963. Steemann Nielsen & Jensen (1956), and Mitchell-Innes (1964), have shown that the rise of water in this region is associated with the presence of high phosphate concentrations within or immediately below the euphotic zone.

Diagram 2

Diagram Temperature: 0 - 500m. April'62



Diagrams 2 - 5 : Vertical profiles of the temperature in the upper 500 m. Station positions are indicated.

Diagram 3

Diagram Temperature: 0-500 m. July'62

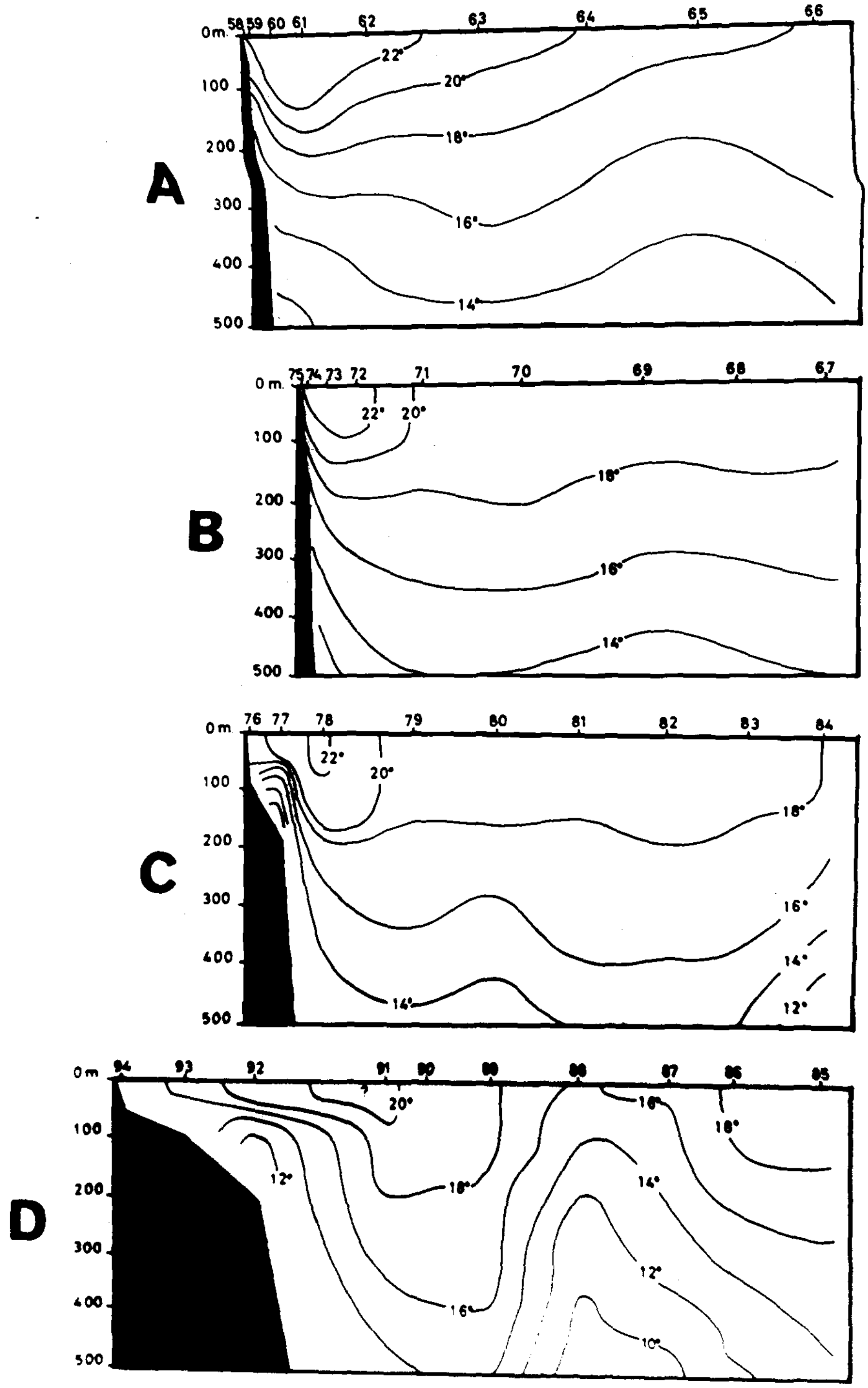


Diagram 3

Diagram Temperature: 0-500 m. July'62

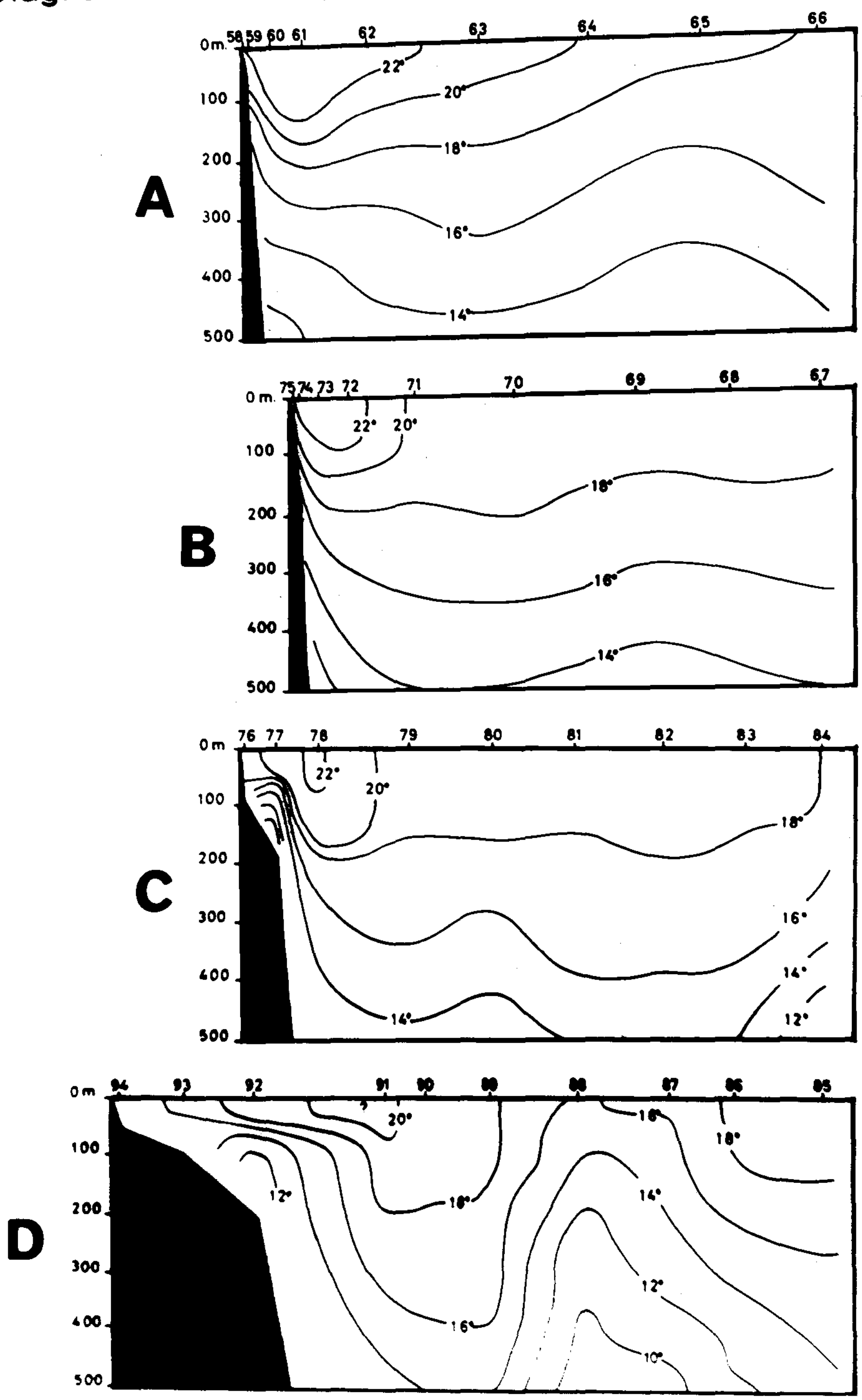


Diagram 4

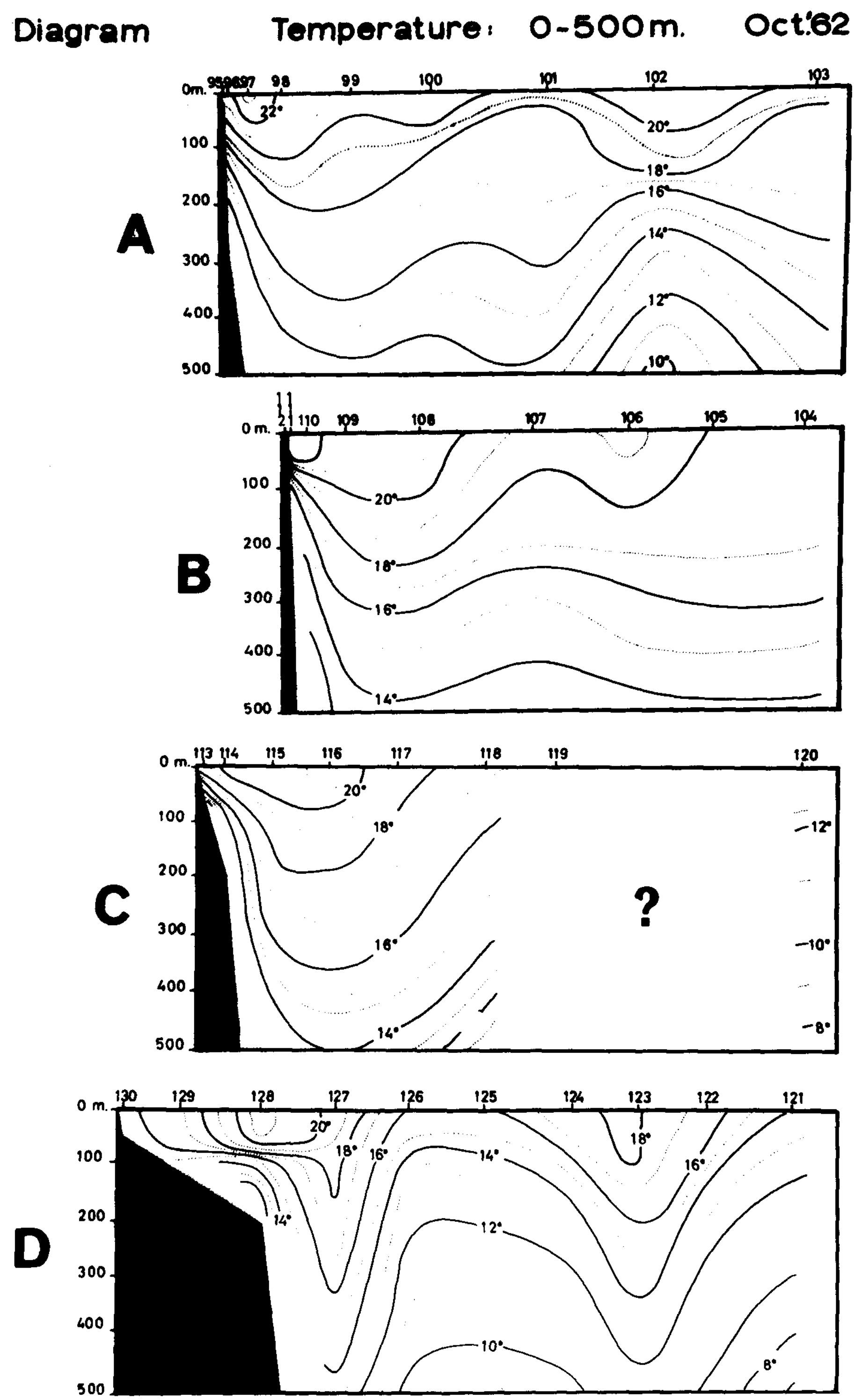
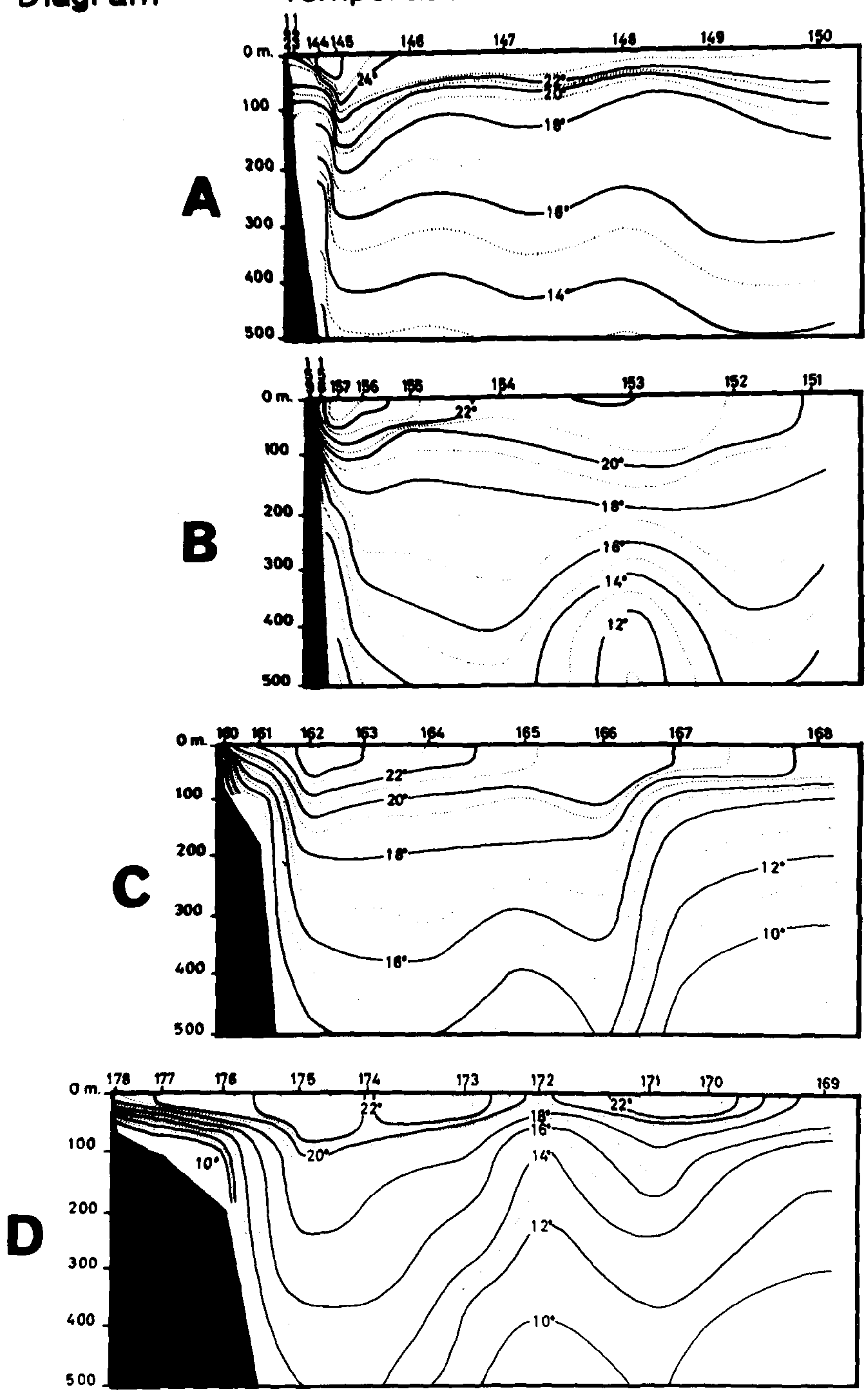


Diagram
Temperature: 0-500m. Oct.'62
A
B
C
D
0m.
100
200
300
400
500
98
99
100
101
102
103
22°
20°
18°
16°
14°
12°
10°
110
109
108
107
106
105
104
113
114
115
116
117
118
119
120
?
8°
130
129
128
127
126
125
124
123
122
121

Diagram 5

Diagram Temperature: 0-500m. Jan.'63



III. 2. Prevailing conditions in the upper 100 meters.

In the following descriptions temperature characteristics have been described in detail as they provide a convenient means of recognising major hydrographic features within this area. Salinity, oxygen and other data from Shipley & Zoutendyk (1964) are described verbally. No phosphate determinations were made on the first two cruises, and only at scattered localities on the later cruises. For this reason use has been made of phosphate data collected by the research vessel "Africana II" in the S.W. Indian Ocean concurrent with the July, 1962 cruise of the S.A.S. "Natal" and presented by Darbyshire (1964).

Several T/S diagrams for entire columns of water are given for April, 1962 to show characteristics of S.W. Indian Ocean water masses and also as a contribution to the hydrographic knowledge of the area, the T/S diagrams of Darbyshire (1964) being prepared in a different manner (mean curves for whole lines of stations) and providing information of another type.

(a) April, 1962.

Darbyshire (1964) has calculated the surface currents within the region from dynamic height data relative to the 1000 db. surface. He found the Agulhas Current to be potentially strongest at this period, flowing at a rate of

50 cms./sec. along the Natal coast. He indicated the probable presence of two eddies influencing offshore stations on lines A and B. Stations 30 - 32 are situated in the North Edge Water to the south of the Subtropical Discontinuity. A large, irregularly shaped anticyclonic eddy lay in the angle between the Agulhas Current and the North Edge Water.

Chart 5 shows the horizontal distribution of isotherms at a depth of 50 m., and diagram 2 the vertical distribution of temperature in the upper 500 m. along lines A, B, C and D. The chart to a large extent mirrors Darbyshire's computed current patterns, showing clearly the southern intrusion of cold North Edge Water and the warm Agulhas Current flowing south-westwards along the coast gradually cooling from north to south. It also shows the presence of cold water on the inner edge of the Agulhas Current penetrating as far north as East London at the 50 m. depth.

In general the profile of line A shows the core of the Agulhas Current close to the coast with temperatures above 26°C. A thermocline, involving a change of approximately 6°C is clearly developed within the upper 100 m. Stations 3 and 4 are situated in the core of the current. The isotherms show a very slight rise close inshore. On line B conditions are similar to line A, the temperature within the core at stations 15 - 17 having fallen from 26° to 25°C. The thermocline is less clearly defined than on line A, and the surface water of stations 11 and 13 represents southward extensions of warm surface water from the north, presumably under the influence of the eddies in this region figured by Darbyshire. The isothermal rise inshore is of the same order as in line A. The temperature structure on line C is more complex. Near Port Elizabeth, the inshore extremity of the line, there is a pronounced rise of the isotherms on the inner edge of the current, cold water from 10^{o} O 18^{o}C lying over the shelf, overlain by a thin layer of warm 20^{o}C water only a few meters thick. The core of the current, at station 21, is further away from the coast, and is narrow and wedge-shaped, the temperature having fallen to 24^{o}C. The surface temperature decreases eastward to approximately 17^{o}C at the offshore end of the line. On line D the cooler water on the inner edge of current reaches the surface over the Agulhas Bank where surface temperatures of less than 18^{o}C were recorded (station 36). The core of the current is much smaller than further north and lies further away from the coast. The North Edge Water shows as wedge of cold water influencing stations 30 - 32 where the surface temperatures are below 16^{o}C, with 13^{o}C water within the upper 100 m. Water of less than 10^{o}C lies over the bank as on line C.

The salinity distribution is closely linked with the observed circulation and temperature structure. The Agulhas Current has a lower salinity than the surrounding water, gradually increasing southwards from approx. 35.25‰ in the core on line A to 35.36‰ on line D. The water on the inner

Chart 5

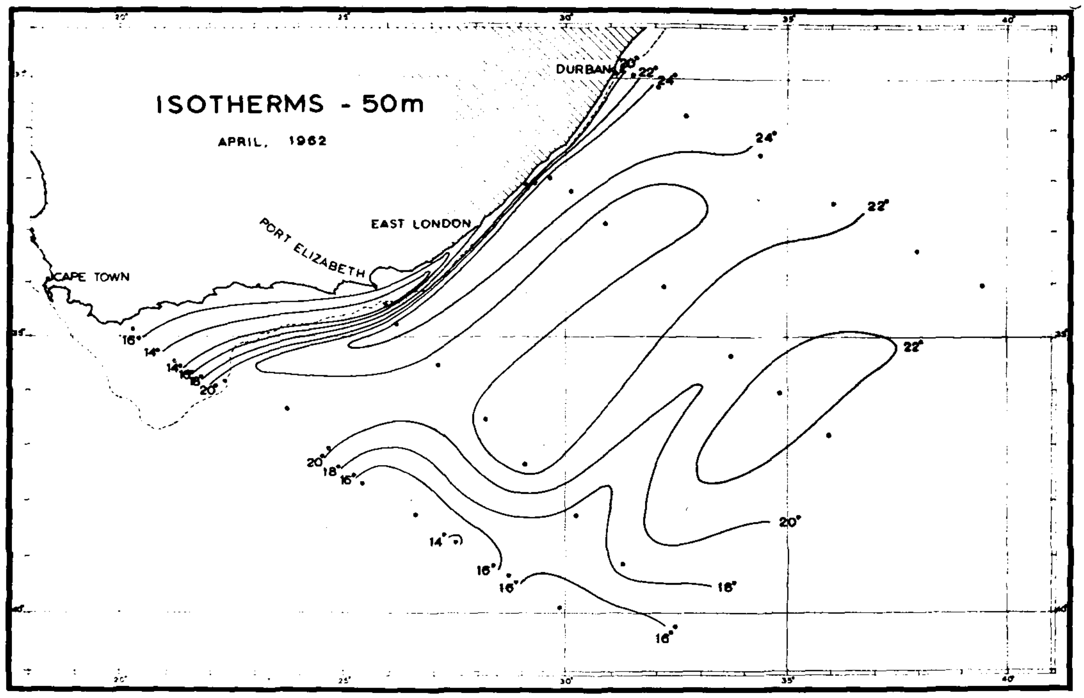


Chart 6

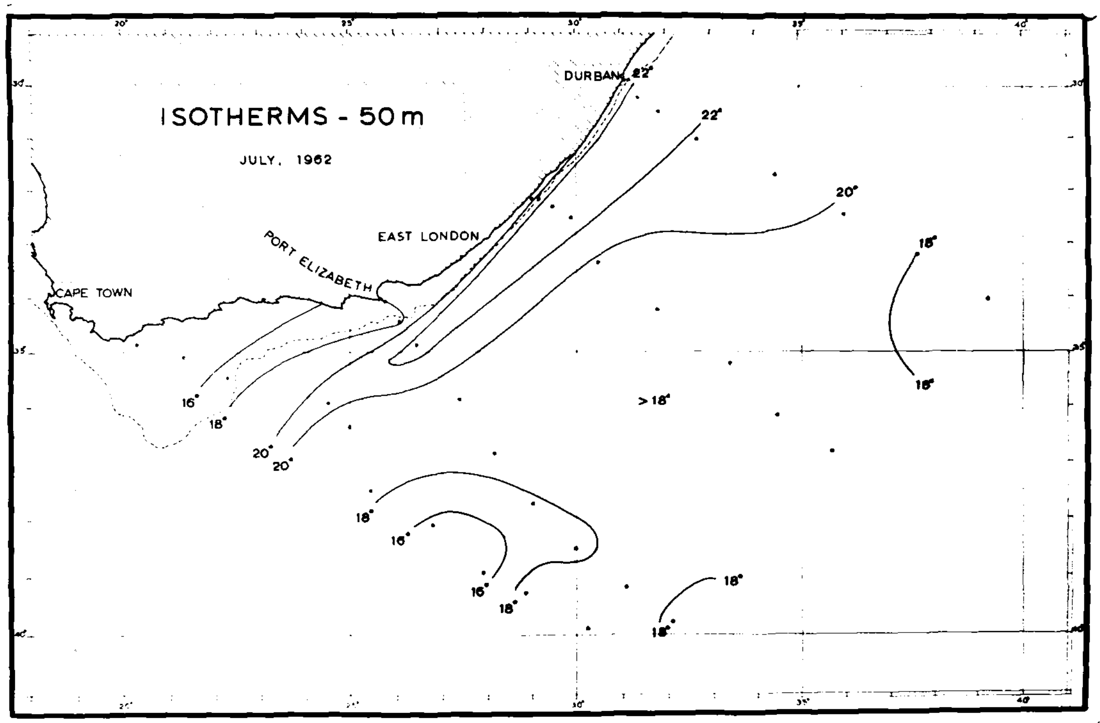


Chart 7

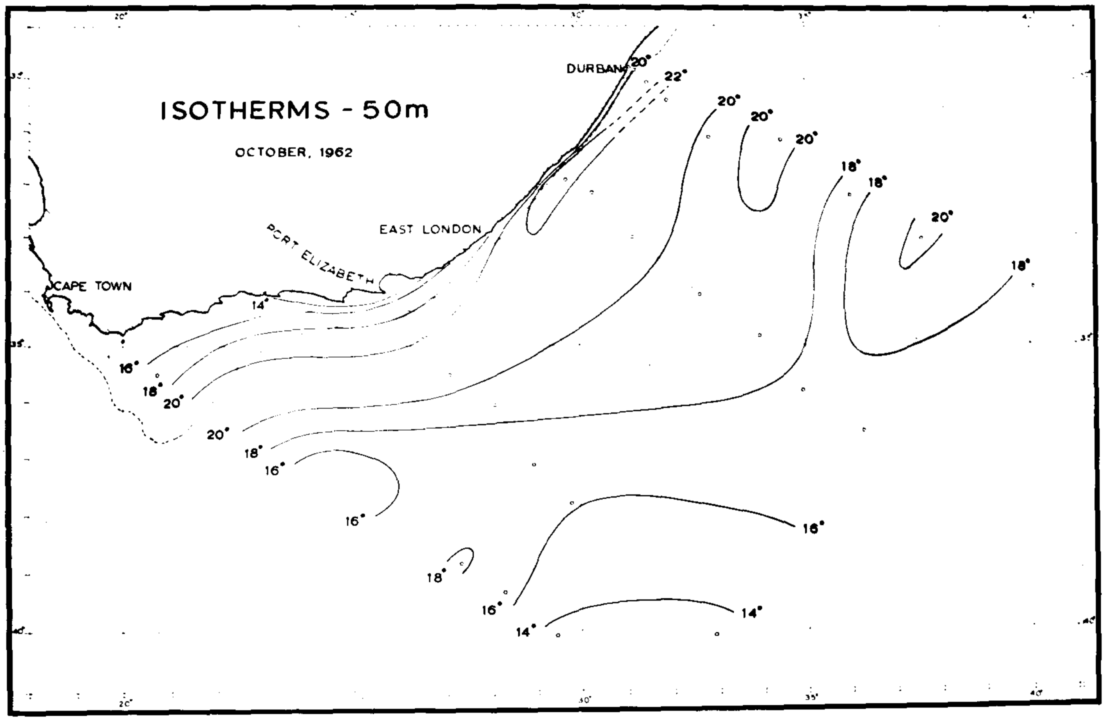


Chart 8

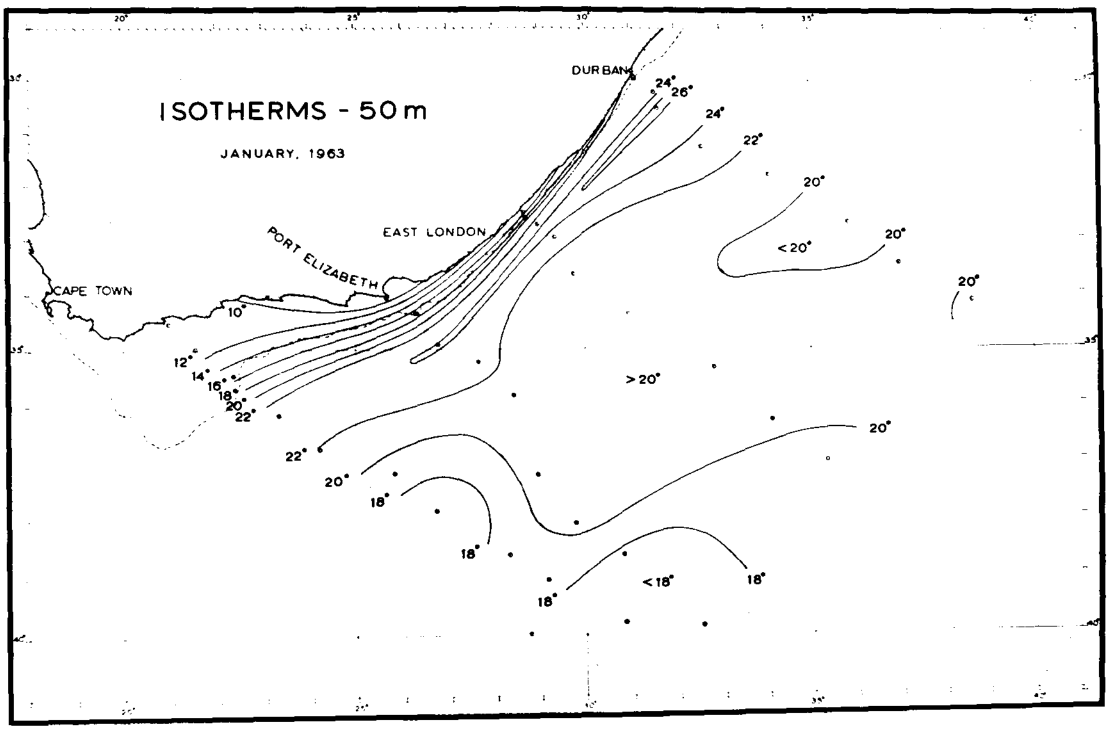


Diagram 6 a

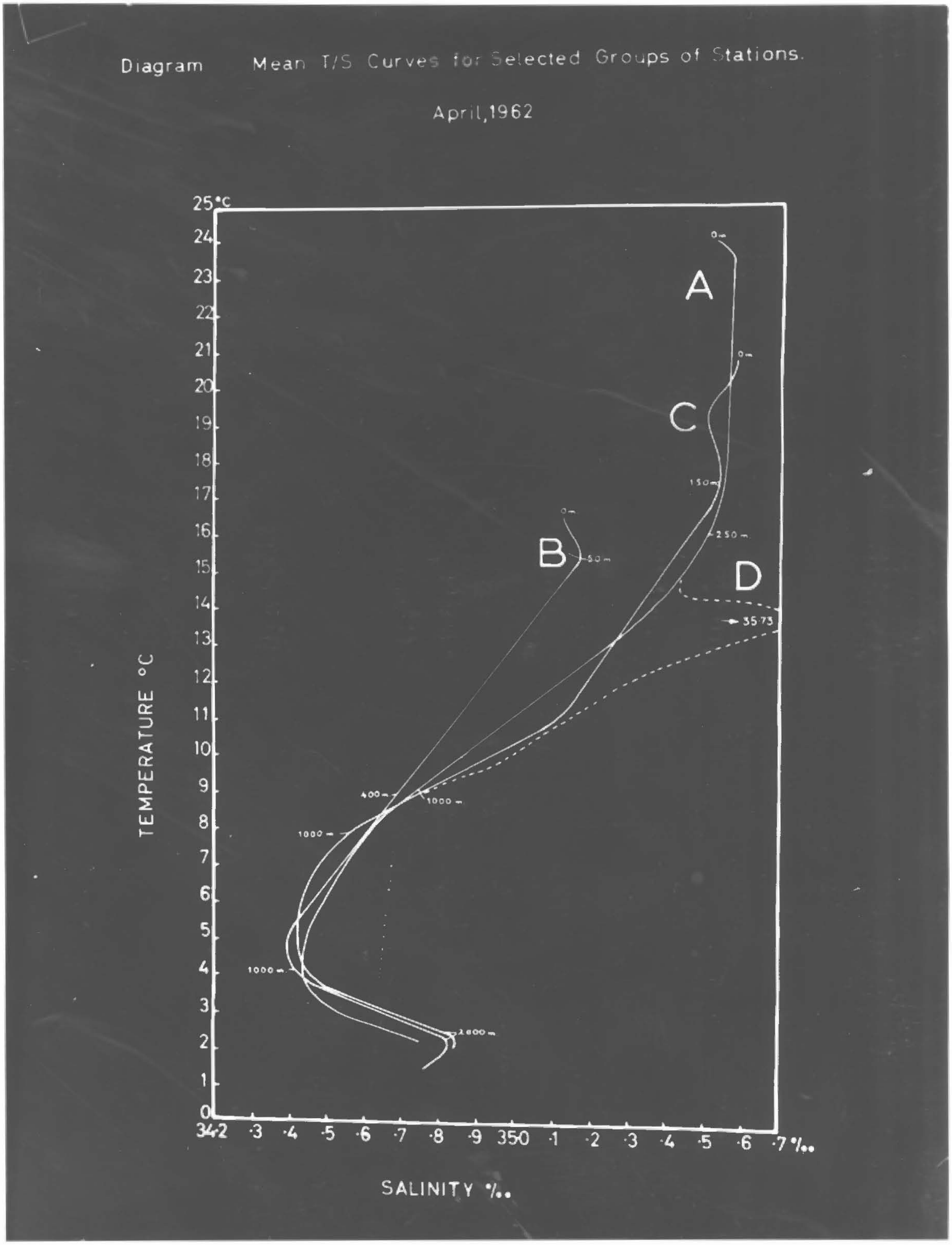
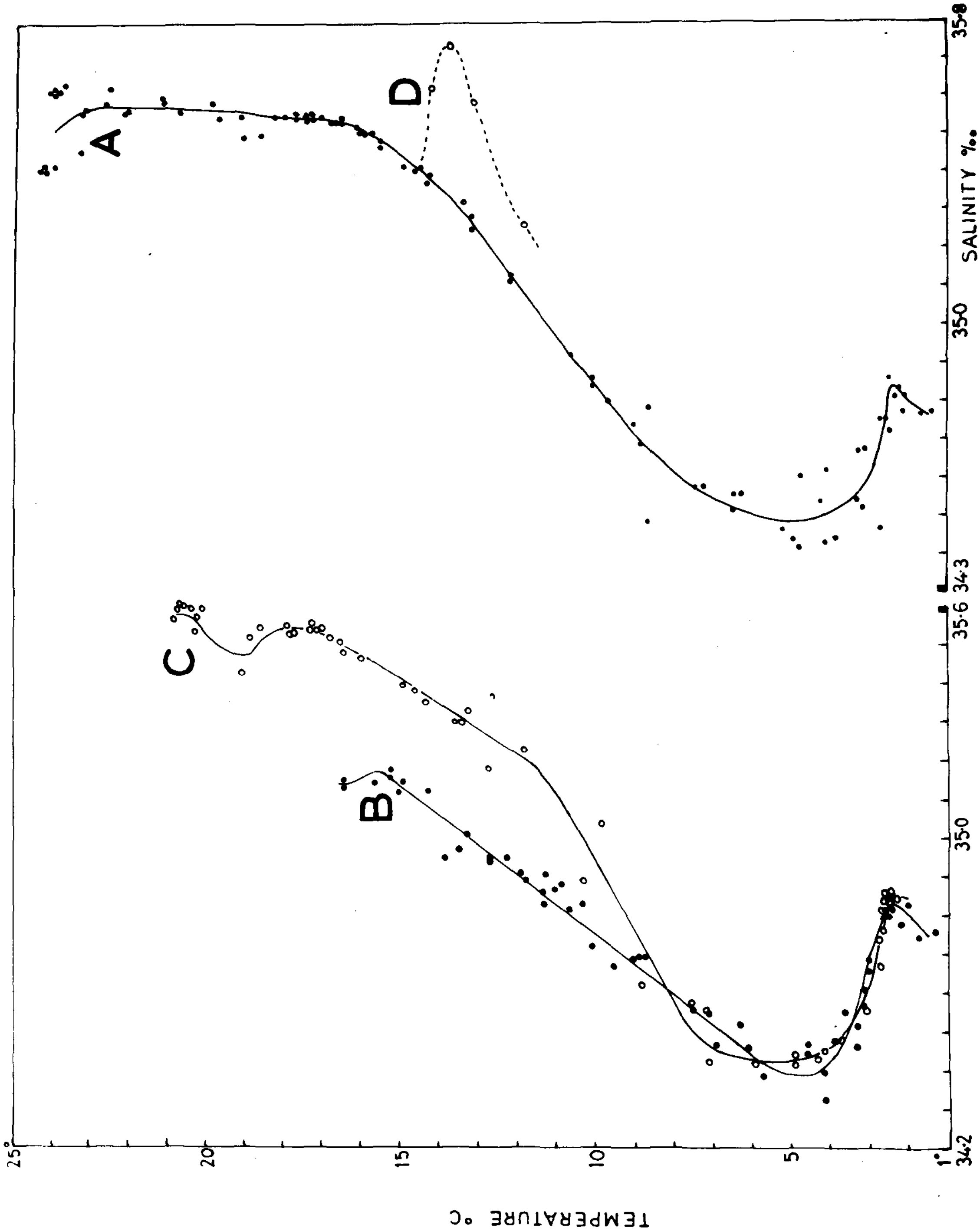


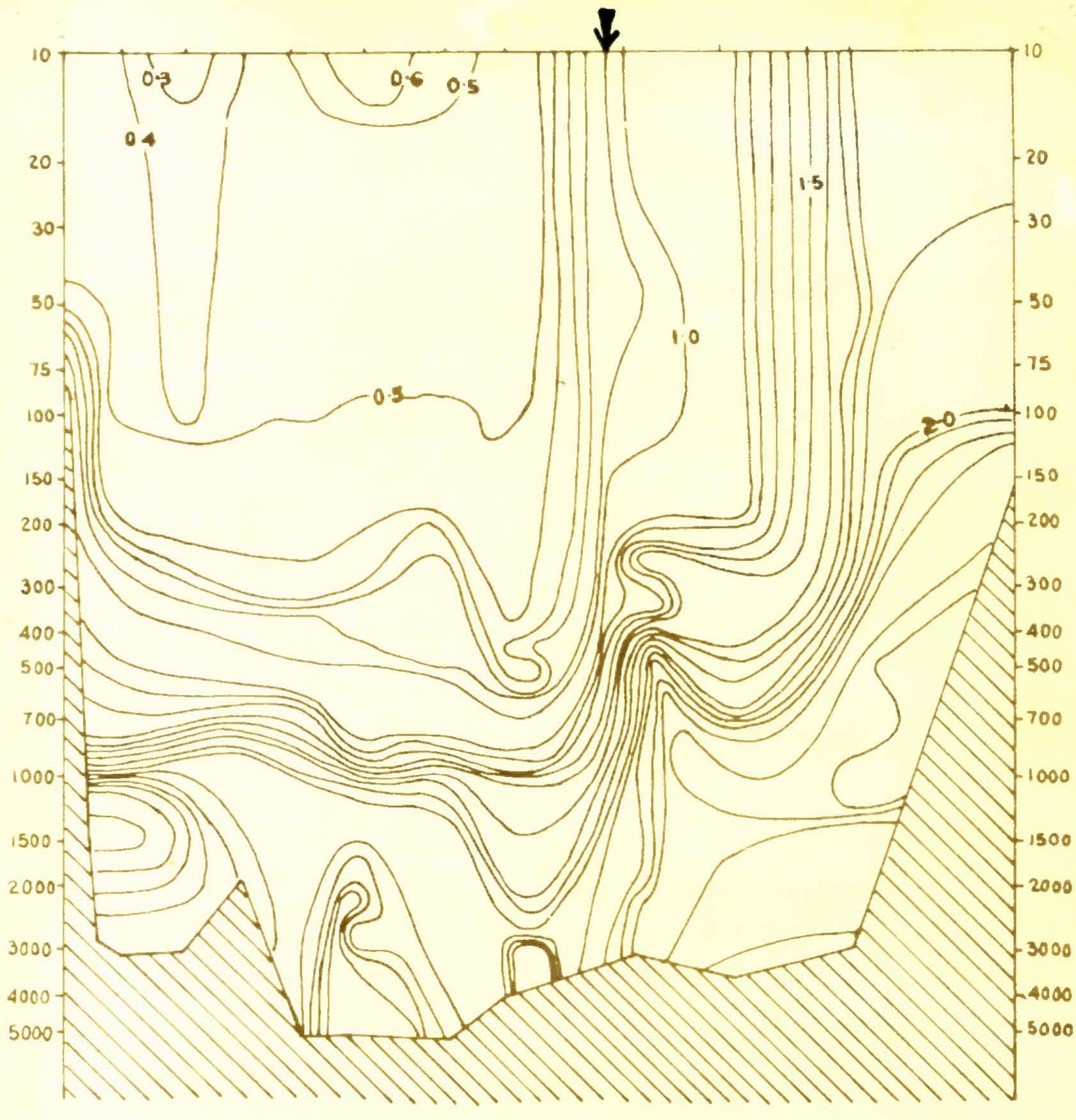
Diagram Mean T/S Curves for Selected Groups of Stations.
April, 1962
A
B
C
D
TEMPERATURE °C
SALINITY ‰
35·73

Diagram 6 b



Showing the points through which the curves in 6 a were drawn.

Diagram 7



The vertical distribution of inorganic phosphates on a line from Durban (to the left) to the Crozet Islands (to the right) in July, 1962. The arrow indicates the approximate southern limit of the area under present study (after Darbyshire, 1964).

edge of the current has very similar salinities to those in the core of the current, 35.25 - 35.38‰. The subtropical surface water of the offshore areas is generally of the order of 35.4 - 35.6‰. The cold North Edge Water has a lower surface salinity than the rest of the area, stations 30 - 32 lying in water with a salinity of 35.15 - 35.18‰. This water nevertheless has a markedly greater density than the tropical and subtropical waters, having a σt value of 26.06 as opposed to 25.53 for the upwelled inshore water and 22.29 - 23.81 for the core of the Agulhas Current.

Darbyshire (1964) constructed oxygen profiles for this and the following cruises and found no coherent pattern displayed. Due to the complexity of factors influencing oxygen values this is not surprising. In general it may be said that surface oxygen values increase southwards, and that oxygen minima were present at a depth of approximately 75 m. below the Agulhas Current, a more complex situation with several decreases of differing order lying at greater depths at offshore stations. Highest surface values of 5.1 - 5.6 mls. O_2/litre were found in the North Edge Water and adjacent to it.

In order to clarify and confirm the hydrographic observations of other workers in the area, notably Clowes & Deacon (1935), Clowes (1950), Fukase (1962) and Orren (1963) Temperature/Salinity curves were constructed in the manner of Helland-Hansen (1916) to obtain an indication of the water masses present in various parts of the area. Mean curves for the T/S values of selected groups of stations were drawn, the grouping of the stations being based on the above temperature and salinity observations. Darbyshire (1964) constructed mean T/S curves for the entire lines A, B, C and D, each curve closely resembling those of the other lines. However, as has been indicated above, a single line of stations, particularly with regard to the southernmost line D, may cross several distinct hydrographic regions, e.g. the intrusion of North Edge Water, and the water mass features of these are not reflected in his curves.

Diagrams 6(a) and 6(b) show the mean T/S curves of three groups of stations. Curve A is a mean curve representing the T/S characteristics of randomly selected stations in the offshore subtropical area, stations 7, 13, 21 and 23. Comparison of this curve with those presented by the workers referred to above show that it may be considered a typical representation of the water mass characteristics of the S.W. Indian Ocean. Helland-Hansen (1916) suggested that a T/S curve may be thought of as several interconnected linear components, each linear section representing a zone of mixing between one water mass and another. Subsequent workers, such as Sverdrup __et al__ (1942), have modified this concept slightly in that they consider each component to represent a distinct water mass rather than a region of mixing, lines of equal density being used to show mixing of water masses. Any point on the curve, i.e. a certain T and S value, may be considered as indicative of a water type. The upper, almost vertical section of curve A represents subtropical surface water extending to a depth of approximately 250 m. Below this is an oblique linear section whose T/S values are indicative of Central water in the S. Indian Ocean, i.e. a line drawn through the points T-9°C, S-34.75‰, and T-18°C, S-35.55‰. The Central water extends to a depth of 1000 m. The lowest salinity values of approximately 34.45‰ indicates the presence of Antarctic Intermediate water between 1000 and 1200 m., and below this a rise in salinity results from the presence of North Atlantic Deep water which flows around S. Africa and enters the S. Indian Ocean (Clowes, 1950).

A curious anomaly was the striking salinity maximum of 35.73‰ at 545 m. recorded at station 23, shown as the broken curve D. Comparable values were not found at any of the surrounding stations at any depth. The possibility of an error in this result is not great as the density figures for this station indicate a stability of the water column, and there was a corresponding oxygen minimum of 3.73 mls. O_2/litre at the same depth, considered to be indicative of "old" water by some authors. There is a faint possibility that this might be an isolated remnant of high salinity "Red Sea" water, shown by Clowes & Deacon (1935) to penetrate south through the Mozambique Channel at certain times of the year.

Curve B represents stations 30 - 32, already shown to lie in a cold-water intrusion from the south and lying to the south of the Agulhas Convergence. From diagram 3 it can be seen that, apart from lacking a warm upper layer of water and being in general of a lower salinity than the stations represented by curve A, it differ s in another aspect: the angle the linear "Central water" section makes with the axes of the graph. Clowes (1950), and Orren (1963) consider this angle to be characteristic for a given Central water mass. They, and Sverdrup et al (1942), have shown that the angles exhibited by S. Atlantic Central Water and S. Indian Central Water are very similar. Clowes (1950) found that in the region to the south-west of the Cape and in the upwelled water near Saldaha Bay on the west coast of S. Africa the corresponding linear section of the curve was steeper in angle than typical Central water from either ocean.

A comparison of Curve B with Clowes' figures 12 and 13 (upwelled water at Saldanha Bay) shows them to be almost identical. It may be pointed out here that the coldest water overlaying the Agulhas Bank has T/S characteristics which conform to the steeper curve B and Clowes' figures (an example is discussed later on page 426). It is tempting to make the suggestion that both the upwelled water near Saldanha Bay and that on the Agulhas Bank originate from the sinking of North Edge Water to the south of South Africa where it apparently has a slower rate of salinity decrease in relation to temperature decrease than further east and west, but such a suggestion is purely speculative, much greater evidence being south of the Agulhas Convergence. From diagram 3 it can be seen that, apart from lacking a warm upper layer of water and being in general of a lower salinity than the stations represented by curve A, it differ s in another aspect: the angle the linear "Central water" section makes with the axes of the graph. Clowes (1950), and Orren (1963) consider this angle to be characteristic for a given Central water mass. They, and Sverdrup et al (1942), have shown that the angles exhibited by S. Atlantic Central Water and S. Indian Central Water are very similar. Clowes (1950) found that in the region to the south-west of the Cape and in the upwelled water near Saldaha Bay on the west coast of S. Africa the corresponding linear section of the curve was steeper in angle than typical Central water from either ocean.

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Curve C, representing the mean T/S characteristics of stations 33 and 34 lying between the North Edge Water and the Agulhas Current on line D, indicates the presence of a double Central Water structure. There is a linear section from 150 m. to 500 m. which resembles North Edge Water in its angle but is shifted to the right (more saline). Below 600 m. the curve is deflected sharply to the left, the angle more closely resembling that of S. Indian Central Water extending to 1000 m.

No data on phosphate concentration in the area during this month is available.

From the above description of prevailing conditions in April, 1962, it appears that stations 3, 4, 15, 16, 17, 21 and 35 were situated in the core of the Agulhas Current. Stations 30, 31 and 32 were in North Edge Water. Cold, upwelled water was present in the upper 100 m. at stations 19, 20, 36 and 37 on lines C and D.

(b) July, 1962.

Computed surface currents for this period are shown by Darbyshire (1964) to have essentially the same pattern as for April, 1962, but the Agulhas Current is weaker in strength, and southwest of Port Elizabeth the current lies further away from the coast. There is still a large, weak anticyclonic eddy in the angle formed by the Agulhas Current and the North Edge Water and there are indications of one large eddy (cyclonic) influencing the outermost stations on lines A and B.

The temperature structure, shown in chart 6 and diagram 3, was more uniform over most of the area and cooler. The core of the Agulhas Current had a temperature of 23°C in the north, falling, as in April, by 2°C to 21°C in the southwest with a similar tendency to decrease in size and become wedge-shaped in the southwest. There were no signs of thermoclines on any of the lines except those at inshore stations resulting from the rise of cold water, and for most of the area the upper 100 m. was composed of virtually homogeneous water of 18° - 19°C. North Edge Water lay further south at this time of the year only directly influencing station 88 on line D. The inner edge upwelling along the southern section of the Agulhas Current is as strongly marked as in April, temperatures of less than 9°C and 11°C overlaying the shelf on lines C and D respectively. Also, as in April the colder upwelled water only reaches the surface on line D and the upper 50 - 60 m. near Port Elizabeth is composed of water above 18°C.

In July the salinities within the core of the Agulhas Current were higher than in April, ranging from approximately 35.36‰ in the north to 35.47‰ in the southwest, the lowest surface salinities being recorded on the inner edge of the core as indicated by the temperature profiles. Inshore of the current the surface salinities were in general the same as or lower than those in the current. The general offshore region was characterised by surface salinities between 35.52 - 35.60‰, similar to those recorded in April.

The single station under the influence of North Edge Water, station 88, was in water of lower salinity than the general offshore region, the upper 100 m. having a salinity varying between 35.21 and 35.41‰. This is not as low as that recorded from stations in a similar locality in April, but due to the North Edge Water lying further south in July, station 88 appeared to be situated on the northern fringe rather than in the middle of the zone of lateral mixing which constitutes the North Edge Water.

The recorded oxygen values, as in April, show no clear cut patterns. Surface values were slightly higher in the core of the current than in April being between 4.0 and 4.5 mls. O_2/litre. Offshore surface values were slightly higher, 4.5 to 5.0 mls. O_2/litre, and no distinct oxygen minimum layer formation was evident. Values above 5.0 mls. O_2/litre were recorded from the North Edge Water station 88 (6.17 mls. O_2/litre at the surface) and from inshore stations on line D.

Although no measurements of phosphate were made during the July, 1962 cruise of the S.A.S. "Natal" another research vessel, the "Africana II" made inorganic phosphate determinations along a line of stations from Durban in the north to Crozet Island in the south east at the same time. Darbyshire (1964) has incorporated these results in his paper, and his figure 11 c, reproduced here as diagram 7, provides a profile of the vertical phosphate distribution along the "Africana II" line referred to above. The line extends considerably further south than the area under present consideration, crossing both the North Edge and Subtropical Discontinuities. The arrow inserted above the diagram indicates the approximate southern limit of the area in question in this study. From the diagram it can be seen that in the upper 100 metres in the northern part of the line the inorganic phosphate values were between 0.3 and 0.6 ug-atom PO_4-P/litre, with a slight rise of richer water near Durban, and rapid increases at the discontinuities, the general trend being an increase in surface values southwards.

In the present study in July, 1962, stations 60, 61, 62, 73, 78, and 91 were situated in the core of the Agulhas Current, stations 76, 77, 92, 93 and 94 in the inshore region of upwelling, and station 88 was in the northern fringe of North Edge Water.

(c) October, 1962.

Darbyshire (1964) computed the Agulhas Current to be weakest in strength during this month, having a rate of flow of 20 cms./sec. near Durban and decreasing southwards. The west-to-east flow south of 35°S influences all stations offshore of the Agulhas Current on lines C and D, and there is an eddy (cyclonic) influencing the outermost stations on line A.

From the above it is not surprising that the core of the Agulhas Current is smaller and not as clearly defined as in the other months investigated (see chart 7 and diagram 4). The range in temperature in the core from north to southwest is from 23°C to 21°C, the core lying a similar distance from the coast on line D as in April, 1962. The vertical distribution of isotherms is not as uniform as in July. Signs of upwelling are still evident inshore on lines C and D, but are not as marked as at other months. The shelf to the south of Port Elizabeth had a bottom temperature of less than 12°C, but the surface temperatures over it lay between 17° and 20°C. The large gap in the vertical temperature profile of line C in diagram 6 is due to a force 9 gale blowing at the time of data collection which resulted in several stations having to be abandoned.

Of great interest, however, is the vertical thermal structure at station 120, the most offshore station on line C, occupied after the gale had abated. Here remarkably cold water existed in the upper 500 m., surface temperature being below 14°C, the upper 100 m. having a temperature between 12° and 14°C. Several other feautres suggest that this and station

121 were situated in North Edge Water, e.g. low salinity values.

The salinity of the core of the Agulhas Current was lower in this month than in July, 1962, increasing southwestwards from 35.30 to 35.38‰. Inshore surface salinities were variably higher or lower than the current. Extreme offshore stations, as in other months, had high surface salinities in the region of 35.53 to 35.62‰, with the exception of the most offshore stations on lines C and D which had the lowest surface salinities of the area, 35.17 - 35.29‰, supporting the suggestion above that stations 120 and 121 were situated in North Edge Water.

Oxygen values were once more confused, surface values closely approximating 5.0 mls. O_2/litre over most of the area, being slightly higher offshore than inshore except in the region near Port Elizabeth. An oxygen minimum layer was most clearly evident beneath the Agulhas Current core in the north at a depth of 120 to 150 m.

Scattered inorganic phosphate values are available for this cruise, being mainly confined to the inshore and Agulhas Current part of the area. In general the total phosphate content of the upper 100 m. was low, varying between 0.09 (the most offshore station, 107, investigated in this manner) and 0.54 ug-atom PO_4-P/litre, and mostly between 0.1 and 0.2 ug-atom PO_4-P/litre. An exception to this was the value of 0.70 ug-atom PO_4-P/litre recorded at a depth of 30 m. in the upwelled water near Port Elizabeth (station 113). To a lesser extent there appears to be a slight rise of higher nutrient water further north adjacent to the coast where values of between 0.31 and 0.38 ug-atom PO_4-P/litre were recorded at depths of 20 and 30 m. The average inorganic phosphate content of the upper 100 m. in this month was lower than the "Africana II" values recorded during July, 1962.

From the preceding data it appears that stations 97, 110, 116 and 128 were in the core of the Agulhas Current, stations 120 and 121 in North Edge Water (and also to a lesse extent stations 125 and 126), and stations 113, 114, 129 and 130 in the inshore region of upwelling.

(d) January, 1963.

The strength of the Agulhas Current during this month, according to Darbyshire (1964), was between 20 and 30 cms./sec. and was thus stronger than in July and October, 1962, but not as strong as in April, 1962. The meander in the easterly flow over the Agulhas Plateau region is evident in this month, as in all former months, but it was in a more southerly position than in other months.

Surface temperatures over the greater part of the area were high, between 20° and 23°C, highest temperatures occurring in the core of the Agulhas Current with a decrease southwestward the upwelled water near Port Elizabeth (station 113). To a lesser extent there appears to be a slight rise of higher nutrient water further north adjacent to the coast where values of between 0.31 and 0.38 ug-atom PO_4-P/litre were recorded at depths of 20 and 30 m. The average inorganic phosphate content of the upper 100 m. in this month was lower than the "Africana II" values recorded during July, 1962.

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Surface temperatures over the greater part of the area were high, between 20° and 23°C, highest temperatures occurring in the core of the Agulhas Current with a decrease southwestward of 3° from 26° to $23^{\circ}C$. Chart 8 and diagram 5 show features of the temperature distribution in this month. The vertical profile of line A indicates the presence of a strongly developed thermocline in the upper 100 m., as in April, 1962. An interesting feature on line B is the indication of a rise of cold water into the surface layers close inshore, this phenomenon being restricted to lines C and D in the other months investigated. On line C upwelling is evident near Port Elizabeth, and also over the Agulhas Bank on line D, although in the latter case the cold water was covered by warm Agulhas water in a stratified manner. Water immediately above the shelf on lines C and D had a temperature of less than $10^{\circ}C$. The vertical profile of line D shows two pockets of warm, $23^{\circ}C$, water offshore of the Agulhas Current core, possibly related to the Agulhas Return Current in whose path, as shown in Darbyshire's (1964) fig. 4d, corresponds to the stations at which the high temperatures occurred (stations 170, 171 and 173, core at station 175).

Salinity in the core of the Agulhas Current varied from 35.15 to 35.42‰, increasing southwestwards. Surface salinity in the general offshore region was between 35.56 and 35.60‰. Stations 168 and 169, the most offshore stations on lines C and D, had lower surface salinities than the rest of the offshore area, between 35.30 and 35.39‰, and were possibly on the fringe of North Edge Water. Inshore of the Agulhas current surface salinities were lower than the current.

Surface oxygen values were generally lowest in the Agulhas Current, varying between 3.83 and 4.66 mls. O_2/litre. Offshore surface values were in the vicinity of 4.80 mls. O_2/litre, and the highest values were found in water in or near the fringe of North Edge Water. Station 172, situated in the coldest southern surface water had a surface value of 5.23 mls. O_2/litre. A high surface value was also recorded at station 160 near Port Elizabeth (5.17 mls. O_2/litre). Of interest was the presence of an oxygen minimum layer at a depth of 100 - 150 m. below the Agulhas Current on lines A and B, minima at other stations lying much deeper, generally below 1000 m., and not as clearly apparent.

The only direct data on inorganic phosphate concentration for the January cruise is that for station 143, the second most inshore station on line A near Durban. Here values of 0.39, 0.38 and 0.60 ug-atom PO_4-P/litre were recorded for depths of 10, 50 and 100 m. respectively. These values are slightly higher than those recorded from the same locality in October where a surface value of 0.15 ug-atom PO_4-P/litre was recorded.

The Galathea Expedition made inorganic phosphate determinations in the S.W. Indian Ocean in January, 1951. Steemann Nielsen & Jensen (1956) have provided phosphate figures for the area in the table appended to their report. Between 35° and 40°S they recorded offshore surface values of 0.1 to 0.2 ug-atom PO_4-P/litre. They found nutrient rich water to be present over the Agulhas Bank, and in the lower part of the euphotic zone offshore on the same latitude (corresponding to stations in the centre of line C). In the vicinity of Durban, where the compensation depth was at approximately 30 m. they found a high rate of photosynthesis in the surface water: 5.0 mg. C/m^3/hour at 18000 lux, and this was associated with the presence of water with an inorganic phosphate value of 0.7 ug-atom PO_4-P/litre at a depth of 70 m., actual surface values being low. They concluded that the nutrients below the compensation depth were constantly supplied to the euphotic layer. High surface phosphate values were recorded from inshore stations to the north of the present area.

In January, 1962, stations 144, 146, 156, 157, 162, 163, 175 and 176 appeared to be situated in the core of the Agulhas Current. Station 172 was in the northern fringe of North Edge Water, stations 168, 169, 170, 171 and 173 being influenced by it to a lesse extent. Inshore stations 159, 160, 177 and 178 were in a region of cold upwelling water, although it did not reach the surface on line D.

III. 3. A proposed hydrographic zonation of the area.

It is apparent from the preceding description of general and prevailing conditions that the área of the S.W. Indian Ocean surveyed included several distinct hydrographic regions in the upper 100 m., and that the boundaries of these and the conditions within them were subject to seasonal variation. Even the most preliminary attempt to relate the phytoplankton population to its environment would be of little consequence if these aspects were not taken into consideration.

For convenience in discussion the present author has proposed a subdivision of the area into several zones, each with a distinctive hydrographic character, and in section V it will be seen to what extent the distribution of the phytoplankton conforms to this subdivision. Chart 9 shows the proposed zonation of the area, the stippled areas indicating the approximate boundaries of the zones, being broadest where marked seasonal variation occurred. The general direction of currents is also shown on this chart.

A. The Agulhas Current zone.

This is a southward extension along the east coast of Southern Africa of surface water from the Equatorial region of the Indian Ocean. The zone is composed of the core of the Agulhas Current and closely adjacent water derived directly from it. It is defined by arbitrarily chosen temperatures, one for summer and autumn, and the other for winter and spring. Due to cooling of the current in a southwesterly direction the zone is widest in the north and is confined to the narrow core in the southwest. The salinity, which is lower than for surface water over most of the area surveyed, increases towards the southwest. Salinity is not a suitable criterion for the delimitation of the zone as the surface salinity pattern inshore of the Agulhas Current is confused due to an admixture of low salinity water resulting from land drainage and upwelling.

During January and April, i.e. summer and autumn, the Agulhas Current was strongest and temperatures in the zone highest. The core of the current had a surface temperature of 26°C near Durban, cooling to 23°C in the southwest off the Agulhas Bank. The 23°C isotherm is used here to delimit the zone during these months. 23°C has been used by Deacon (1937) to indicate the boundary between tropical and subtropical surface water in the S. Indian Ocean, and so the entire zone during January and April may be considered to be tropical in character. Surface salinities within the core of the current during these months ranged from 35.15 ‰ near Durban to 35.42‰ in the southwest. Surface oxygen values showed a similar increase southwestwards from approx. 3.8 mls./litre near Durban to 4.8 mls./litre off the Agulhas Bank. An oxygen minimum layer of the order of 1 to 2 mls. O_2 less than the surface value was found to be present below the Agulhas Current core at a depth of between 75 and 150 m. on lines A and B only. Little is known of the phosphate concentration in the zone during these months but it may be higher than in water further offshore (Steemann Nielsen & Jensen, 1956).

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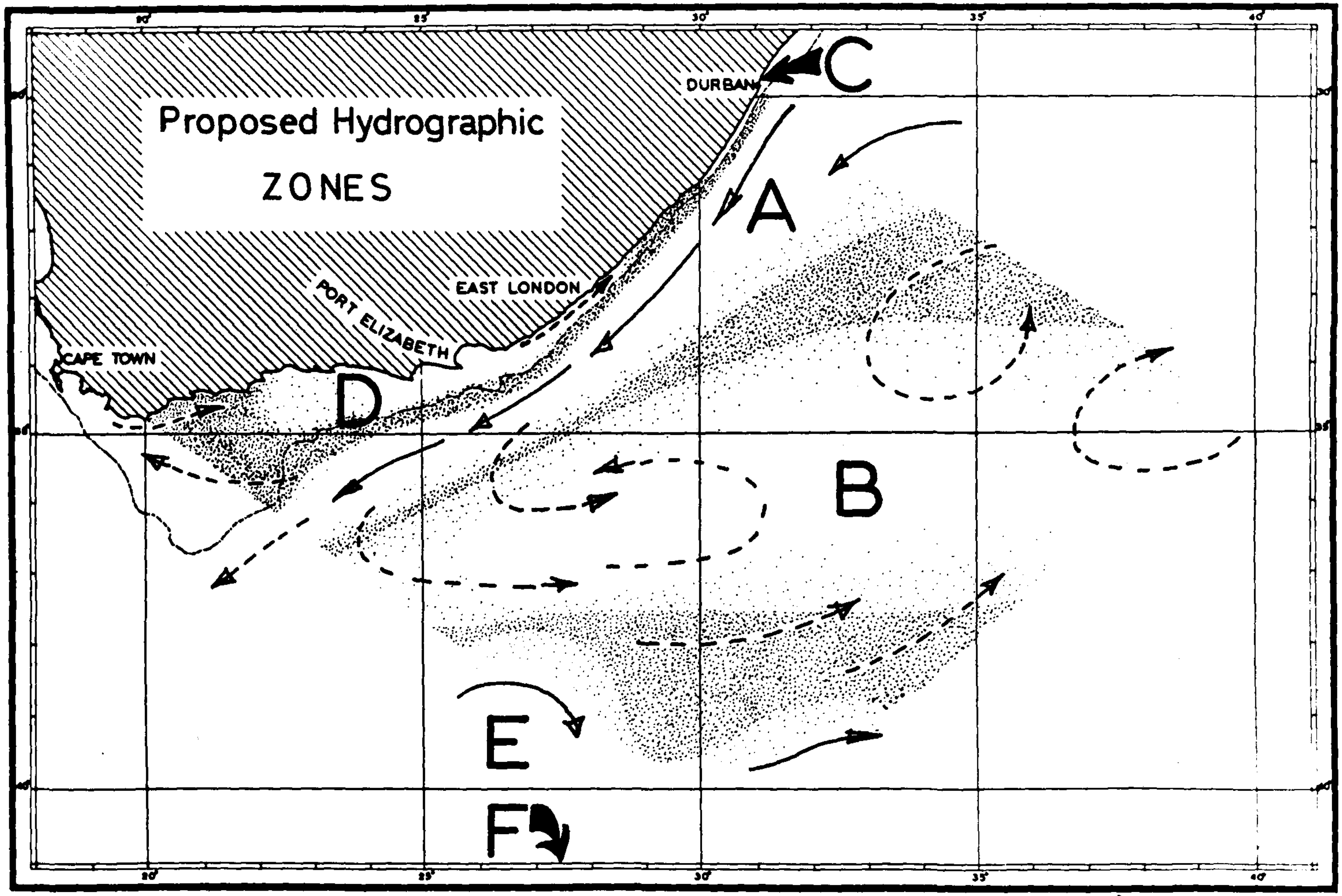

For an explanation of this chart see pages 418 - 431.

In July and October, corresponding to winter and spring, the Agulhas Current was weakest, particularly in the latter month (Darbyshire, 1964). Surface temperatures were lower in the core of the current than during summer and autumn, ranging from 23°C near Durban to 21°C in the southwest. The 21°C isotherm is considered as the boundary for July and October, and the whole zone may be termed subtropical during these months. It was not as sharply distinct from the surrounding zones as in January and April. Salinity in the core of the current increased southwestwards from 35.30‰ near Durban to 35.47‰ in the southwest, oxygen values increasing from 4.0 to 4.9 mls./litre in the same direction. Inorganic phosphate values were highest in the surface water in July, 0.3 to 0.5 ug-atom PO_4-P/litre, and slightly less in October, 0.1 to 0.3 ug-atom PO_4-P/litre.

During the months investigated the zone as defined above was entirely composed of the "Warm Agulhas Water" of Darbyshire (1964), and here an additional distinction between tropical conditions, above 23°C, and subtropical conditions, below 23°C, has been made. Darbyshire gives the lower temperaturelimit of tropical water as 20°C, but the present author prefers to follow Deacon's (1937) temperature distinction.

B. The South Western Indian Oceanic zone.

This zone covers most of the offshore part of the area surveyed. The upper 100 m. is composed of subtropical surface water (Clowes, 1950), and the zone is the south-western sector of the large, general, anticyclonic circulation of the Southern Indian Ocean. Several small eddies, both anticyclonic and cyclonic, appear to be present periodically in the zone, usually in the northern part, and in the angle between the Agulhas Current and North Edge Water. The Agulhas Return Current is generally poorl developed, merging with this zone and with the North Edge Water to the south. It is bounded by the Agulhas Current zone in the west (the 23°C or 21°C isotherm, depending on the season as described above) and by a convergence region in the south. For purposes of discussion the zone's southern limit can be set at the midpoint of the Subtropical Discontinuity.

Surface temperatures decrease eastwards of the Agulhas Current and also southwards, with a rapid decrease at the Subtropical Discontinuity. During January and April, the warmest months, the temperature in the upper 100 m. lay between 18°C and 22°C and a thermocline was stongly developed in the northern part of the area within the upper 100 m. In the colder months the temperature over wide parts of the zone was 17°C to 19°C, the water in the upper 100 m. being virtually homogeneous. The northern thermocline broke down completely in July and started to reappear in October. The surface salinity over most of the zone was fairly constant during the months investigated, typically 35.56 to 35.60 ‰, lowest values being found in the west and south. Oxygen values in the upper 100 m. were very variable, exhibiting no clear-cut pattern, approximate limits being 3.6 to 5.6 mls./litre, lowest values generally being found near the Agulhas Current zone, with highest values near the southern boundary.

C. The Natal Shelf Zone.

This is defined as the water lying over the narrow continental shelf between the Agulhas Current zone and the Natal coast. Its southern boundary is the northern limit of upwelling into the euphotic zone on the inner edge of the Agulhas Current, this being a variable geographic position as the northern limit of upwelling apparently moves north and south with the seasons. Generally this southern boundary was situated to the south of Port St. Johns (Approximately the landward limit of line B) but the vertical temperature profile for January shows that it reached Port St. Johns in this month (line B).

In hydrographic characteristics this zone is very similar to zone A, the Agulhas Current zone, most of the water present being apparently derived from the Agulhas Current. The temperatures are slightly lower than in the current, and the salinities are similar or lower than the current depending upon the degree of outflow of river water. Coastal currents of variable direction and strength are present close inshore (Anderson, 1964).

With regard to phytoplankton distribution this zone may be considered as neritic, as opposed to zones A and B which are oceanic. The restriction of certain species to neritic zones is not fully understood at this time, but apart from explanations relating to life histories, such as that of Gran (1902), it is becoming clear that the inshore areas of the oceans are apparently characterised by subtle environmental features, i.e. higher concentrations of land-derived micronutrients, which may influence not only the species composition but also the total phytoplankton population present. Steemann Nielsen & Jensen (1956) suggest that tropical inshore areas can support large populations of phytoplankton due to a rapid regeneration of nutrients by the bacterial flora on the surface of the continental shelf, the regenerated nutrients being readily available to the euphotic zone due to its close proximity. Presumably turbulent conditions inshore are sufficient to ensure a continuous supply to the phytoplankton above, and true upwelling may not be required under these conditions. Whatever the factors are which make neritic areas suitable for some species of phytoplankton it is assumed here that the Natal Inshore zone also possesses them.

The northern limit of this zone is not defined in this study. It is thought that it possibly extends northwards along the Natal coast, gradually becoming more tropical in character, but there may be other factors present further north off the coast of Mozambique which would make the distinction of the latter from the Natal Inshore zone desirable. This is purely speculation as very little data on inshore conditions to the north of the area surveyed is at hand.

D. The Eastern Agulhas shelf zone.

This zone can be defined as the inshore region over the continental shelf where upwelling on the inner edge of the Agulhas Current is strongest, reaching the euphotic zone, although sometimes not quite reaching the surface. The water over the shelf in this zone is characterised by a great range of temperature between the surface and immediately over the bottom, and is apparently composed of water derived from the Agulhas Current and from sinking in the Subtropical Convergence region. The coldest water, in the region of $9^{\circ} - 11^{\circ}C$, which may reach the surface periodically close inshore along the southern coast of South Africa, has T/S characteristics which resemble the upwelled water off the southwestern coast of South Africa. For example, the coldest water overlying the shelf at station 77 on the present survey had a temperature of $9.53^{\circ}C$ and a salinity of 34.86‰, characteristics which show a strong similarity to both North Edge Water (see diagram C) and the "mixed" Central water found to upwell in the vicinity of Saldanha Bay by Clowes (1950). Zoutendyk (personal comm.) has found that inshore water along the south coast of South Africa has, at some times of the year, identical T/S characteristics to that off the west coast.

Steemann Nielsen & Jensen (1956) found high phosphate values to be present within the euphotic zone in the vicinity of Port Elizabeth, this being associated with the upwelling in the area. As has been pointed out in the descriptions of prevailing conditions, in general the upwelled water only reaches the surface over the Agulhas Bank, being overlaid by a shallow layer of warm water north of Port Elizabeth.

The zone has been called the "Eastern" Agulhas Shelf zone as the water over most of the Agulhas Bank proper in the west is subject to considerable mixing and may be considered a transition area. Welsh (1964), investigating current direction and strength at a point over the Agulhas Bank in December, 1961 found that the current was weak and variable, being related to tidal influences rather than an ocean current such as the Agulhas Current. At other times it appears that some of the Agulhas Current may flow over the bank. It is also possible that oceanic S. Atlantic water may flow over the Agulhas Bank. Observations by the present author and Mr. John Grindley of the South African Museum on hydrographic conditions and plankton in False Bay near Cape Town suggest that both Indian and Atlantic oceanic water may enter the bay periodically. This is confirmed by Welsh (personal comm.). For these reasons the southwestern boundary of the Eastern Agulhas shelf zone cannot be fixed with any confidence where these variable conditions prevail, and each station occupied in the extreme southwest must be considered independantly to determine its zonal affinities.

E. North Edge Water.

The name above is a contraction of Fukase's (1962) "North Edge Water of West Wind Drift." It refers to a belt of water lying immediately to the north of the West Wind Drift region which has been found to the south of South Africa and further east in the vicinity of Marion, Crozet, and Kerguelen Islands. The presence and position of a convergence between subantarctic and subtropical surface waters, the Subtropical Convergence, has long been known, but it is only in recent years that the concept of a distinct belt of water lying between the two surface waters has been put forward. Fukase based his concept on the discovery that instead of only one surface temperature discontinuity being apparent he found a second rapid change in surface temperature to the north of 40°S with a mean isothermal value of 18°C as compared with 13°C for the more southerly one. Between the two concentrations of isotherms he found a belt of water with intermediate characteristics of the two surface water masses. He coined the name "Agulhas Convergence" for the more northerly concentration of isotherms. This name is perhaps unfortunate as it implies a definite hydrographic condition related to the Agulhas Current or the Agulhas region, whereas more recent data shows that it is not restricted to the Agulhas region and it is not a constant feature. Delepine (1963) found essentially the same phenomenon as Fukase's in the region of Crozet and Kerguelen Islands although, apparently unaware of Fukase's paper, he considered the possibility that it resulted from the influence of the islands on the Subtropical Convergence. Darbyshire (1964) has confirmed the presence of this phenomenon in both Fukase's and Delépine's localities and, although he makes little comment on it, certain features indicated in his figures shed further light on defining the phenomenon. It becomes clear from the work of the above authors and the data presented here that where the subtropical and subantarctic surface water meet in the Southern Indian Ocean lateral mixing takes place (as suggested by Fukase, 1962) resulting in a belt of mixed water of varying width which may be associated with one discontinuity or two depending on the degree and nature of the mixing. It is interesting to note that the diagrams of surface distribution of salinity and temperature given by Clowes (1950) suggest a continuous belt of this mixed water extending from the South Atlantic into the S. Indian Ocean, and furthermore that the similarities between the T/S characteristics of North Edge Water, upwelled water off Saldanha Bay on the west coast of South Africa, and the cold water lying immediately over the Agulhas Bank indicate that the upwelled water originates from the sinking of North Edge Water. It appears that the double-discontinuity phenomenon is most strikingly developed in the Agulhas Region due to the high range of temperature between Agulhas Current water and the Subantarctic Surface water.

Further evidence, i.e. charts 5 - 8, suggests that the North Edge Water moves north and south with the seasons, its width below South Africa possibly being influenced by the strength of the Agulhas Current which, when at its strongest, might be expected to compress its width. For example, in April, 1962, when the current was strongest, there was an almost continuous convergence region from 18°C to 13°C with a slight concentration of isotherms around 18°C marking the "Agulhas Convergence" or Subtropical Discontinuity.

Darbyshire's (1964) figures indicating computed surface currents show that there was a strong easterly flow of water in this zone irrespective of the presence of a true Agulhas Return Current, i.e. an eastward directed extension of the Agulhas Current. A warm core of water flowing eastwards such as would be expected from the usual concept of an Agulhas Return Current, was only apparent in the vertical temperature profile for January, 1963 (diag. 7, line D, stations 170, 171 and 173) and not at any other month investigated. Darbyshire rather cryptically states that the Agulhas Return Current merges with the West Wind Drift, and Fukase believed the "Agulhas Convergence" to mark the position of the Agulhas Return Current. However, it seems that although there is a strong easterly-flowing current between 35° and 40°S present during all months investigated this bears no relationship to the Agulhas Current, and during the summer a weakly developed Agulhas Return Current may be recognisable along its northern boundary.

North Edge Water, as here defined, is the convergence region between subtropical and subantarctic surface waters resulting from lateral mixing of the two, with a surface temperature range of 18° to 13°C, and a salinity range of approx. 35.55 to 35.15‰. Inorganic phosphate values in this zone appear to be higher than in surface water to the north. This is indicated by diagram 7 which shows that the North Edge Water had surface values between 0.6 and 1.0 ug-atoms PO_4-P/litre in July, 1962. Inorganic phosphate concentration can be of value in tracing water of similar origins, and in this respect it is of interest to note that at a depth of 30 m. at station 113 near Port Elizabeth in October, 1962, a value of 0.70 ug-atom PO_4-P/litre was recorded. This is by no means conclusive evidence confirming the origin of upwelled water near Port Elizabeth as being in the North Edge Water zone, as the phosphate records are derived from different months and also it was not possible to construct a vertical profile of the water between that station of the North Edge Water, but it is added here as a further indication of the possibility.

In chart 9 an additional zone, F, has been indicated, representing the subantarctic West Wind Drift region. Unfortunately none of the lines of stations occupied during the present survey extended fully into this zone, and it is indicated in the chart for the sake of completeness.

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SECTION IV. ASPECTS OF THE PHYTOPLANKTON DISTRIBUTION

In this section an attempt will be made to distill some of the major features of the distribution of the phytoplankton of the area from the detailed distributions of the large number of taxa present (outlined in section II) and to ascertain to what extent the general hydrograhpic features, desceibed in section III, influence them.

IV. 1. Some theoretical considerations.

One of the most striking features of the distribution of the phytoplankton of the area at first glance was the great variety of patterns exhibited by the species. Virtually every type of pattern was represented in the area. No two species or taxa exhibited identical distributions in the area although a few were closely similar. The great majority of the species exhibited fluctuations in their distribution during the seasons investigated, some of which were striking.

One is reminded of the words of Lewis Gough (1905) on his first impressions when trying to relate the plankton of the English Channel with current movements:

"... I started with the supposition that the plankton would show distinctly the direction and position of the currents of the English Channel. To test this supposition maps of the distribution of single species were first constructed, in order to find out which species might be distinctive of waters of different origins.

In doing this a remarkable fact came out at once. No two plankton organisms had quite the same distribution at the same season. This certainly did not point to currents as being, in the area under investigation, the chief factor in the distribution of the plankton; for it such were the case, how could some species spread out in one direction, say from west to east, while others spread out in another direction, say from north to south."

Gough went on to suggest that the plankton of that area was more characterised by changes from oceanic to neritic species, apparently unrelated to current movements. The interest in his findings, apart from the parallel to the present author's initial impressions almost fifty years later, is that his initial confusion was the result of using one early concept of the general distribution of phytoplankton, his thesis embodying another.

For the reader interested in the detailed evolution of ideas relating to this problem there are the reviews of Patrick (1948) and Smayda (1958). Perhaps the first important concept was that of Schütt (1893) who considered that currents could be characterised by the flora within them. Basically this was a sound principle as it embodied the idea that phytoplankton species are highly sensitive to their physico-chemical environment, a fact borne out by later experimentation. However, it was used by early workers in an oversimplified manner with little cognisance of the changing conditions in a current as it travels. Cleve (1897) extended Schütt's ideas into a scheme of "plankton types", characterising the various water masses of the North Atlantic by certain "indicator species". Cleve's system worked tolerably well for that area, particularly in the vicinity of Scandinavia, but foundered when it was too rigidly applied to other regions.

Slightly before Cleve's elucidation of his system Haeckel (1890), in a work which contributed many of the terms in current usage in plankton studies, proposed that species occurring near the coast should be termed 'neritic' and those away from the coast 'oceanic'. He also suggested the terms 'meroplanktonic', 'holoplanktonic' and 'tychopelagic', these referring to the type of life-cycle exhibited by the species with relation to sedentary and planktonic stages.

Whilst neritic species are most frequently meroplanktonic, i.e. with a resting stage on the bottom, and oceanic species frequently holoplanktonic, being entirely independant of the bottom in all stages of their life cycle, Gran's (1902) practice of considering the linked terms to be synonymous was incorrect. Gough (1905) has pointed out in detail the different usages of the terms by Haeckel and Gran, and Smayda (1958) has given examples of species which contradict Gran's assumption. Gran elaborated a system of "plankton elements" which subdivided the phytoplankton of a given region into populations similar to those of Cleve but more directly associating species with the actual hydrographic conditions present and subdividing them into oceanic and neritic subgroups. This system was more realistic than that of Cleve, but suffered in that the influence of currents on the populations was, to a large extent, neglected. Naturally both systems were based on observed facts and a careful synthesis of the two is used by most modern workers. Gran's system is applied chiefly to the semi-permanent populations in an area, and Cleve's to species which are introduced into the area by horizontal water movements, i.e. "visitor species".

In addition to the terms oceanic and neritic, Hart & Currie (1960) have revived the term 'panthallassic' to refer to species whose distribution does not seem to be related in any manner with distance from the coast. Smayda (1958), feeling that the use of neritic and oceanic to refer to phytoplankton distribution was unsuitable, and apparently unaware of the existence of 'panthallassic', suggested a new set of terms: paractic (of the coast), anoictic (in the open sea) and adiaphoric (indifferent). Whilst these have the advantage of being carefully defined by their originator, it is felt that they are not sufficiently different from Haeckel's terms, as originally defined, to be of value. The present author has defined his use of the various terms employed in this study in an introductory note to section II.

The fact that little progress has been made towards determining the factors governing the distribution of a certain species in a given area at a given time can perhaps be attributed to the complexity of factors influencing the distribution of the species. Braarud (1962) has listed fourteen theoretical factors which may influence the distribution of phytoplankton species. These were broadly subdivided into autecological and environmental factors:

(a) Autecological factors -

1. Temperature tolerance range and temperature-growth curve.
2. Salinity tolerance and salinity-growth curve.
3. Light-growth curve.
4. Nutrient requirements and tolerance range.
5. Motility and flotation properties.
6. Life-cycle features.
7. Growth rate range.
8. Competitive characteristics.

(b) Environmental factors -

9. Range and seasonal changes in temperature, salinity, density, light supply and nutrient supply.
10. Grazing selectivity.
11. Horizontal currents.
12. Vertical transport.
13. Bathymetrical conditions.
14. Environmental barriers.

Another difficulty is that very little is known of the autecology of the great majority of phytoplankton species. This is, for the most part, due to the difficulty of obtaining successful pure cultures of the species. However inrrecent years advances, such as the recognition of heterotrophy in certain species of centric diatoms (Lewin, 1953), have stimulated experimental studies and it is hoped that many of the imponderable factors listed above will be elucidated. A further complication arises from the possibility that different physiological strains may exist within the same species. Braarud (1951), in a study on the effect of salinity upon the division rates of certain dinoflagellate and coccolithophorid species, discussed this possibility, although he found that two different clones of *Prorocentrum micans* had essentially similar salinity-growth curves. The apparent differences between optimal growth parameters for the same species in culture and under natural conditions, e.g. the distribution of *Skeletonema costatum* and the experimental results of Curl & McLeod (1961), tend to support this possibility. Further, Wood (1964), in a study of the temperature-salinity relationships of a large number of species of diatoms and dinoflagellates and their distribution in Australasian waters, concluded that nine distinct communities were present in the region, and that cosmopolitan species, such as *Thalassiothrix longissima*, could be subdivided into separate populations on the basis of their temperature-salinity characteristics.

Margalef (1961) has approached the problem from a broader point of view, drawing his data on the world distribution of species from published reports and entering all environmental data available for each species on punched cards, thus ascertaining the tolerance ranges of each species from its natural distribution.

Whatever the approach, it is clear that at present distributional studies are limited to attempts to determine the major factors influencing the distribution of phytoplankton species and there is still a great danger of over-simplification.

In a study such as the present one, which was not designed for the purpose of determining the environmental parameters with any degree of accuracy or even the exact numbers of cells present, the safest course to take would seem to be the determination of the types of distribution patterns exhibited by the species in the area, and to discover in what manner they are related to the various water masses present. In this way a general picture might emerge, such generalities still being of interest in an area about which so little is known with regard to the phytoplankton.

IV. 2. Examples of distributional patterns in the area.

In charts 10 - 17 an attempt has been made to plot the horizontal distribution of several of the more common or interesting species in the area. The method of presentation is somewhat unusual in that symbols have been employed for each species, the density of the symbols being related to the relative abundances recorded. This was the only means of simultaneously plotting the distributions of a number of species with any clarity. Contours were not included as this would have implied an accuracy greater than was warranted by the method of sampling and estimation of relative abundances.

It is highly debateable as to whether interpolation between such widely spaced stations is realistic, but all the species plotted were either very widely distributed over the area or were limited to isolated stations, and it seems therefore that, provided discussion is limited to the salient features only, the picture presented conforms reasonably well with the actual horizontal distributions of the species concerned.

The most suitable species to consider first under this heading would be endemics. It is doubtful, however, that there are species restricted to the area under study. Technically all the new taxa could be considered as endemics, since they have not been recorded from any other region, but there are reasons why the author does not consider them to be true endemics. Firstly, they were considered new taxa only after high power examination in permanent mounts, a type of observation not usually employed in routine surveys, and there is a strong possibility that they have been confused with other taxa previously. This applies particularly to the species of Synedra described, as species of this genus are often identified on the basis of characteristics visible under low powers. Secondly the great majority of marine phytoplankton species are extremely widespread throughout the world oceans even though many of them may be only of rare occurrence. This is due for the most part to the continuity of the major oceans in the south and the liability of most species to be transported horizontally by current systems. The history of

Key to the symbols employed on Charts 10 - 17.

Group A : Charts 10 - 13

Planktoniella sol (Wall.) schutt

Climacodium frauenfeldianum Grun.

Skeletonema costatum (Grev.) Cleve

Detonula moselyana (Castrac.) Gran

Pseudoeunotia doliolus (Wall.) Grun. in V. H.

Thalassiothrix longissima (Cleve) Cleve & Grun.

Group B ; Charts 14 - 17

Nitzschia pacifica Cupp

Gossleriella tropica Schutt

Roperia tesselata (Roper) Grun. in V. H.

Mastagloia rostrata (Wall.) Hust.

Chaeteroceros borealis Bail.

Chaeteroceros curvisetus Cleve

Chart 10

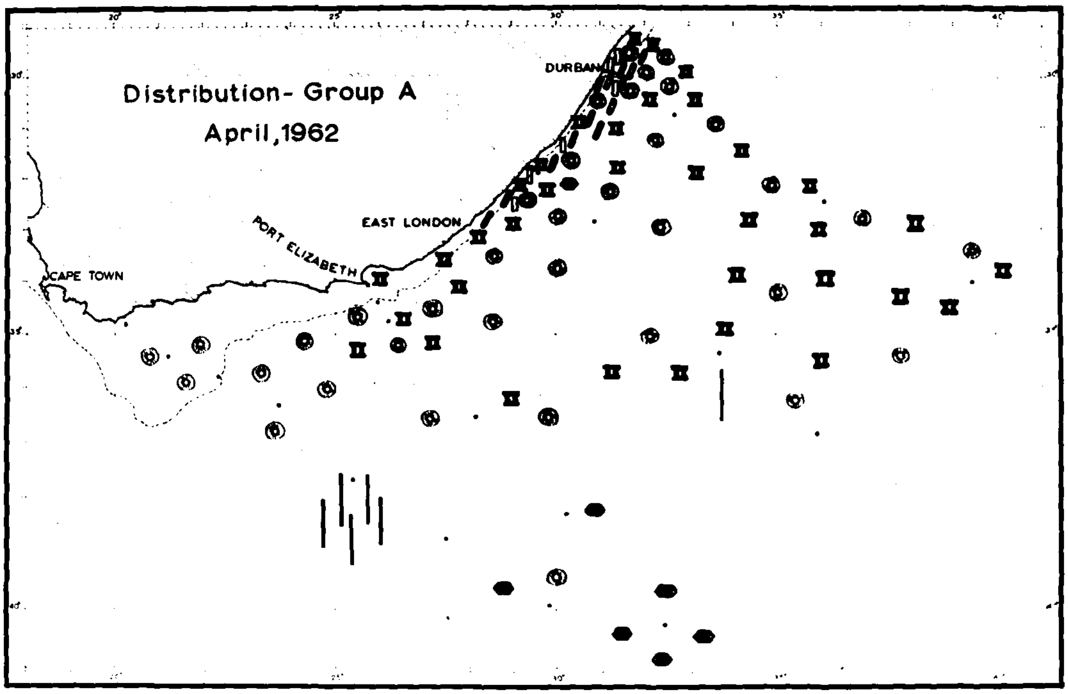


Chart 11

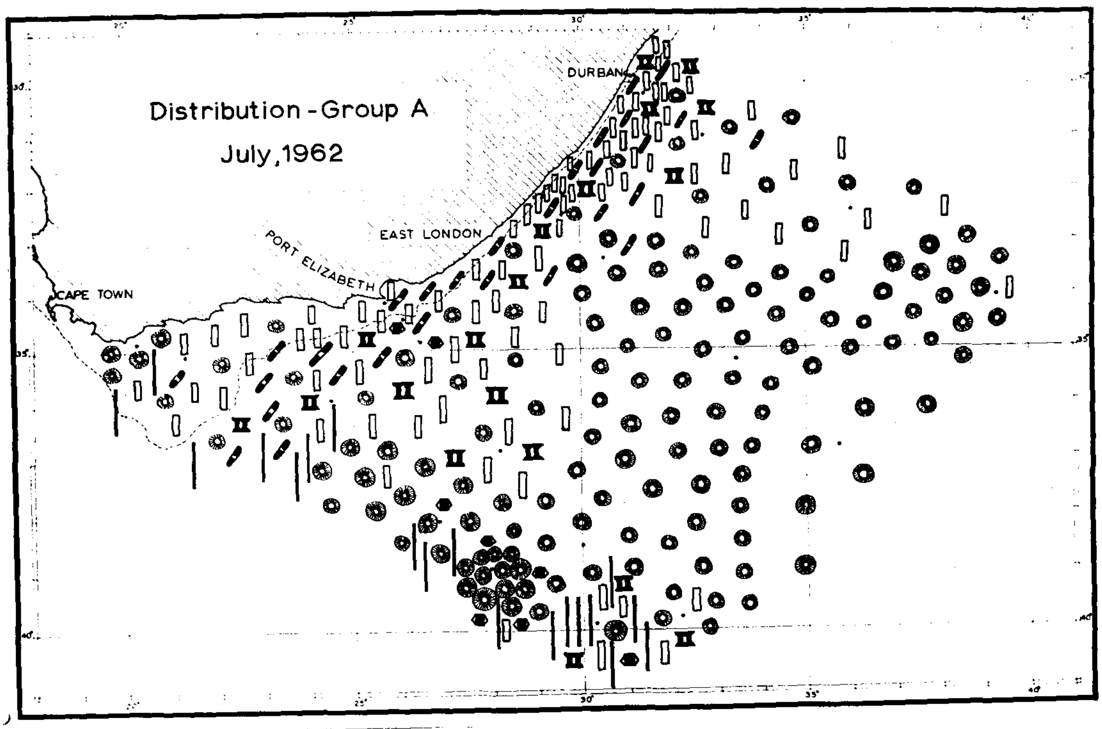


Chart 14

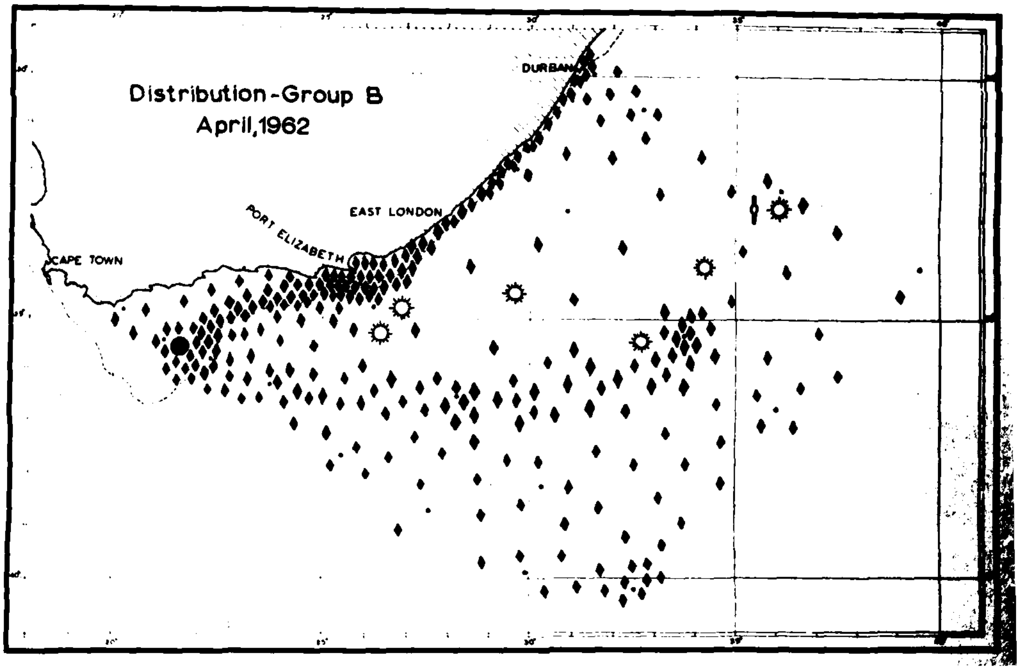


Chart 15

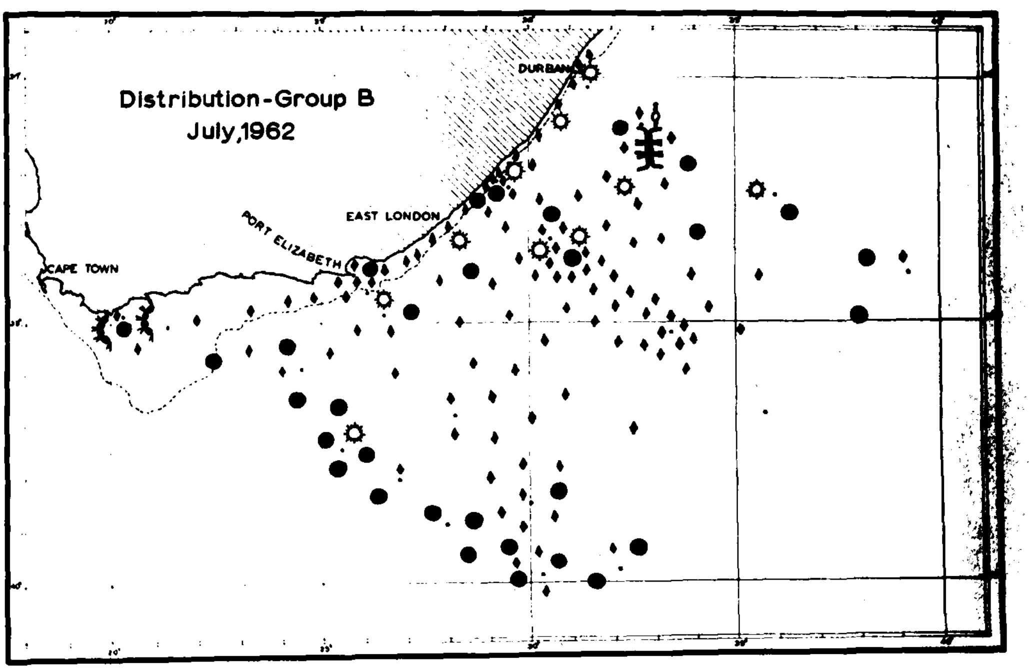


Chart 16

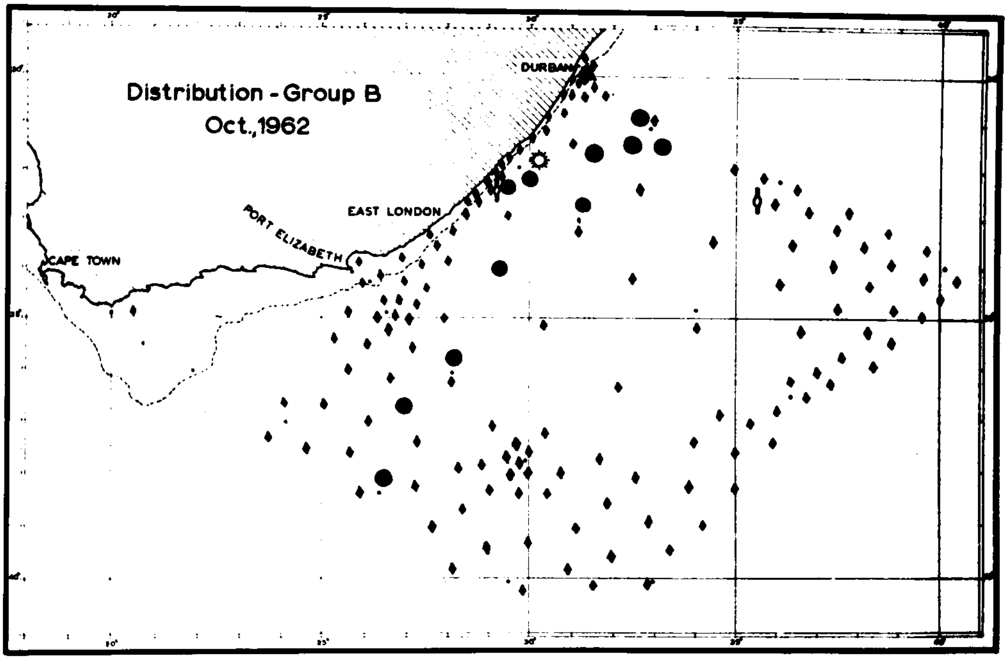
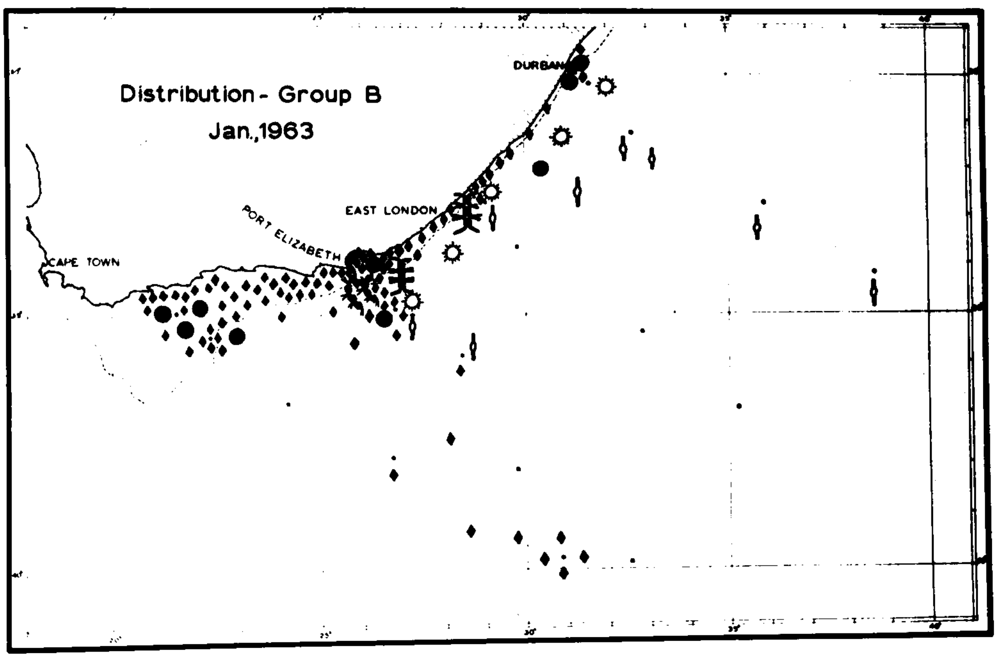


Chart 17



the distribution of a species such as *Biddulphia chinensis* (see Müller Melchers, 1952) is a good example of the type of factors involved. The area under present survey was not confined on all sides by boundaries likely to limit the distribution of phytoplankton, the apparent hydrographic subdivisions (see section III. 3) all being continuous with waters adjacent to the area.

Thus it would seem best to consider first species which either appear to have a centre of distribution in the area or can be considered characteristic of the area for other reasons.

(a) *Planktoniella sol* (Wall.) Schutt (taxon no. 35) - a common, widespread, oceanic species in the area. Charts 10 - 13.

This species, incidentally, first described from the Indian Ocean by Wallich (1860), is one of the most commonly encountered species of phytoplankton in the offshore waters of the S.W. Indian Ocean. Its world distribution has been described by Smayda (1958) who concluded that it was a eurythermal, stenohaline, circumtropical oceanic species. He suggested that it was mainly confined to tropical and subtropical waters due to its apparent lower salinity tolerance value of 33.76‰, with a mean value of 35.71‰. Its absence from inshore waters is possibly attributable to the lower salinities commonly prevailing in coastal waters, the distribution of a species such as *Biddulphia chinensis* (see Müller Melchers, 1952) is a good example of the type of factors involved. The area under present survey was not confined on all sides by boundaries likely to limit the distribution of phytoplankton, the apparent hydrographic subdivisions (see section III. 3) all being continuous with waters adjacent to the area.

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The local distribution of this species, shown on charts 10 - 13, presents several interesting features. In general it seemed to occur in belts of varying density parallel to the coast and at a variable distance from it. While it spread over the entire offshore area in July and October (winter and spring), in April and January (autumn and summer) it was generally confined to the offshore waters north of 37°S. The species was also found at certain stations over the continental shelf, i.e. in the neritic zone, and is possibly an indicator of the influence of oceanic water at these stations. This was the case in Natal coastal waters and in the south-west near Cape Agulhas. The presence of many oceanic species over the Natal shelf region suggests that this narrow neritic zone is strongly under the influence of the Agulhas Current oceanic water, only the most inshore stations a few miles from the coast being truly neritic in the character of the phytoplankton present (more will be said of this later in the general discussion). The picture is more complicated with regard to the presence of oceanic species over the southern portion of the Agulhas Bank for this is a region of considerable mixing of water (see section III). The presence of Planktoniella sol over this shelf region cannot be considered indicative of Agulhas Current water as the species is also present in South Atlantic oceanic water (Hart & Currie, 1960) and the current diagrams of Darbyshire (1964) provide little evidence of current direction over the Agulhas Bank. However, its presence there in April could have been due to the Agulhas Current as Darbyshire's current diagram for this month shows an apparent deflection of the current over the Agulhas Bank.

The highest relative abundances recorded for the species (+++ - ++++) were in the offshore waters in July (winter) when it appeared to form a relatively dense belt seaward of the Agulhas Current. Average salinities for the upper 100 m. were higher in this belt (approx. 35.50‰) than in the Agulhas Current. However the maximum relative abundance was found to be at a station on the northern boundary of North Edge Water where salinities were lower than most of the area, lying between 35.41 and 35.22‰ in the upper 100 m. If the species is considered to favour high salinities it would seem that this increase in abundance was due to some other factor, possibly an increase of nutrients, as there is indirect evidence (diag. 7) that inorganic phosphate values were higher in the North Edge Water at this month than over the rest of the area. Similarly the absence of the species from the high salinity offshore waters in April and January might also have been due to other factors than salinity and temperature.

Thus in general the species tended to occur in the higher salinity offshore waters for most of the year, but its maximum relative abundance and absence from south-eastern parts of the area at different months were probably due to other factors, the most likely being nutrient concentration.

Another common oceanic taxon, *Chaetoceros atlanticus* var. *naepolitanus*, had a similar distribution pattern, but occurred at neritic stations more frequently than *P. sol*.

(b) *Nitzschia pacifica* Cupp (tax. no. 226) - a common neritic species also of importance in the offshore waters. Charts 14 - 17.

This species was first described in 1943 and has not been recorded by many authors since that time, so its world distribution is imperfectly known. It is widely distributed along the west coast of North America from Alaska to Southern California, sometimes occurring in great abundance (Cupp, 1943). Hustedt (1958) found it present in the South Atlantic Ocean from 44°S to 61°S, and Crosby & Wood (1959) noted that it was common to the south of New Zealand. Wood (1960) found it in the Antarctic sector of the Indian Ocean. It is surprising that it was not recorded by Fukase (1962) from the waters to the south of S. Africa but it is possible that he confused it with *N. seriata* and *N. pungens* var. *atlantica*, both of which were recorded by him, the former in large numbers in the Subantarctic Region.

From the charts it can be seen that the species was widely distributed over the whole area in July and October, with maximum concentrations at shelf stations, particularly near Port Elizabeth, in April and January. The distribution in April, 1962 was particularly interesting (chart 14). During this month it was present in high relative abundance (+++ - ++++) at all inshore stations from Durban to Cape Agulhas, with a very heavy relative abundance (+++++) at Port Elizabeth. Over the Agulhas Bank in the south-west it tended to occur in larger numbers towards the edge of the shelf than further inshore. In the offshore waters it was scattered over the whole area but occurred in greater relative abundance (+++) at southern stations. Particularly interesting was the apparent belt of uniform relative abundance which seemed to spread eastwards from the Agulhas Bank to the centre of the offshore area through stations 35, 34, 23 and 12. These stations correspond approximately with the position of the Agulhas Return Current, Darbyshire (1964) indicating a broadly flattened anticyclonic gyral in much the same position at this month. The stations concerned were not notably similar to one another in temperature or salinity characteristics, or particularly different from those around them, and the only suggestion which can be put forward is that the species appears to be carried off the shelf from its zone of maximum relative abundance into the offshore waters by horizontal transport. It appears to be able to survive for some length of time in oceanic waters, remaining scattered over the entire offshore area during the winter and spring months (charts 15 and 16) with moderate relative abundances (+++) at scattered stations. In summer (January) it once more occurred in high relative abundance at shelf stations near Port Elizabeth but the offshore population was considerably reduced to a few records in the south of the area.

N. pacifica appeared to be a species of major importance in the area, with a centre of distribution over the shelf near Port Elizabeth, from which it was carried offshore by currents in April, surviving in the oceanic waters during July and October, but vanishing from them in January when it had a second climax in the inshore waters.

This type of distribution, i.e. species with neritic maxima but widely distributed in the offshore area for most of the year is distinctive of many of the more common species in the area such as Chaetoceros lorenzianus, Chaetoceros messanensis, and Thalassionema nitzschioides. In having a centre of distribution near Port Elizabeth it resembled other common neritic species such as Bacteriastrum minus and Asterionella japonica.

(c) Skeletonema costatum (Grev.) Cleve (tax. no. 40) - a common neritic species restricted to the shelf region or closely adjacent waters. Charts 10 - 13.

The autecology of this species has been studied experimentally by Curl & McLeod (1961) and discussed in detail by Braarud (1962). It is widely distributed in the coastal waters of the world oceans, with a very variable seasonal distribution possibly related to specialised nutrient requirements, and is meroplanktonic in its life cycle.

In the area under study it was almost entirely restricted to the shelf waters or the Agulhas Current adjacent to the shelf. Its occurrence along the coast was not uniform, apparently varying with the season. In April it extended from Durban in the north to the vicinity of Port St. Johns (inshore line B). In July it extended the entire distance from Durban to the Agulhas Bank, but was mainly present in the Agulhas Current, and it was also found furthest offshore in this month. In October its distribution was in the inshore waters from Durban to Port Elizabeth, and in January it once more spread southwards to the Agulhas Bank. Maximum relative abundances (+++ - ++++) occurred near Durban in April and October (autumn and spring) and inshore on line B in October.

The general impression given by the local distribution pattern is that the species was concentrated mainly in the northern inshore waters but spread southwards during July and January due to current transport. Its absence from offshore waters during winter (July) when other neritic species such as *Nitzschia pacifica* were spread offshore confirms observations by other authors that the species cannot survive for any extended period in offshore waters. Its concentration in the warm waters of the Natal coast is interesting as Curl & McLeod (1961) recorded a maximum cell division rate for the species at temperatures of $20^{\circ} - 30^{\circ}C$ in enriched water, a result which was at odds with the findings of many observers who noted high concentrations of the species in cold boreal waters. The Natal waters in which it occurred in large numbers had an approximate temperature range of $21^{\circ} - 25^{\circ}C$ in the upper 50 m., this conforming with Curl & McLeod's experimental results.

As the species is often abundant in colder coastal waters it is difficult to explain why it was absent from the vicinity of Port Elizabeth in April when other neritic species were recorded in heavy relative abundances from there at that month. It might possibly have been due to exclusion by the dominant species such as Nitzschia pacifica and Chaetoceros lorenzianus, but this is doubtful as both species were also present in fairly heavy abundances with it in the Natal Coastal waters. It seemed, therefore, that the species requires some unknown nutrient which was below the limiting concentration for it in the waters over the shelf south-west from Port Elizabeth in April and October, and that this factor might also be responsible for its absence from the extreme offshore waters.

(d) _Mastagloia rostrata_ (Wall.) Hust. (tax. no. 200) - a tropical, oceanic species, rare in the Agulhas Current and offshore waters. Charts 14 - 17.

This species, first described from the Indian Ocean, has only been recorded from the Indian Ocean and the western Pacific Ocean in the vicinity of the East Indies and Australia. Judging from the records of Karsten (1907), Heiden & Kolbe (1928), Silva (1956) and Wood (1961) it is a tropical to subtropical oceanic species. There is, however, one surprising record of the species from the Indian Ocean sector of the Antarctic by Mann (1937).

The local distribution, shown on the charts, was restricted entirely to the Agulhas Current or the northern offshore waters. It was rare, only occurring in small numbers at the stations from which it was recorded. Its most southern penetration was to line C in January, and it was only present at one northern station in July (winter).

It could be considered a "visitor" species (an apt term employed by Smayda, 1958) to the area, its presence being attributable to a southward transport from tropical waters by the Agulhas Current. Its sparseness, and the lack of records further south than line C suggest that, as conditions gradually changed in the Agulhas Current they became unfavourable to the species and the individuals dropped out of the surface waters.

It would seem that it, and the other species such as _Mastagloia woodiana_, _Gossleriella tropica_ (also shown on charts 14 - 17), *Asterolampra marylandica*, and all species of *Asteromphalus* recorded, were remnants of a tropical flora carried southwards into the area where they soon died out. If they were not so sparse they might be useful as indicator species of Agulhas Current water in the region to the south of S. Africa where the Agulhas Current mixes with South Atlantic water and the subantarctic surface water of the West Wind Drift. It is difficult to relate the Antarctic record of Mann (1937) with the other distributional data for this species. It can only be pointed out that Mann found a surprising number of tropical and subtropical species present as remnants in Antarctic waters.

(e). *Climacodium frauenfeldianum* Grun. (tax. no. 70) - an oceanic, tropical to subtropical species seasonally widespread in the northern offshore waters. Charts 10 - 13.

This species has a wide distribution in tropical and subtropical waters throughout the world. It was common in the Agulhas Current of northern offshore waters of the S.W. Indian Ocean, its distribution showing marked seasonal changes.

An examination of the charts shows that it was always present in the Agulhas Current, although its spread southwards varied considerably, being most extensive in July and January when individuals reached Agulhas Current stations on line D. Its distribution was most restricted in October when it was only present in the Agulhas Current as far south as line B with one record slightly further offshore on line A.

It was most widespread during April and January (autumn and summer) when it was distributed over a characteristically wedge-shaped area whose narrow apex was orientated towards the south-west. This conforms in general to the contours of the horizontal distribution of temperature charts (5 - 8 in section III), suggesting a relationship between the distribution of the species and the water temperature, the species not being found in water of less than 18°C.

This species seems to have a wider temperature tolerance than the purely tropical species mentioned in the preceding example, but it was absent from the colder waters offshore in the south. It is interesting to note that, as with Planktoniella sol, it occurred close inshore on the Natal Coast (lines A and B), but was generally absent from the shelf waters further south (with the exception of a station near Port Elizabeth)in April), a further indication that the Natal Coast is strongly under the influence of oceanic waters.

It can also be considered a "visitor" species to the area, probably being transported from warmer waters to the north. There were many other species which exhibited a similar distribution pattern, among them Ditylum sol, Eucampia cornuta, Hemiaulus chinensis, Bacteriastrum comosum Chaetoceros aequatorialis, Chaetoceros aurivillii, Chaetoceros denticulatus, Chaetoceros diversus, Chaetoceros imbricatus and <u>Chaetoceros pendulus</u>.

(f) <u>Thalassiothrix longissima</u> (Cleve) Cleve & Grun. (tax. no. 193) - a bipolar oceanic species seasonally extending into warmer waters. Charts 10 - 13.

This species has been most frequently recorded from cold, polar waters, sometimes occurring in large numbers, but it has occasionally been found in tropical waters, e.g. in the Read Sea by Cleve (1900, b). Cleve considered its presence in the Red Sea as indicative of an Antarctic origin for some of the water there, an idea which has received little support since that time. However, the local distribution of this species might, to some extent, give a key to the presence of antarctic and subantarctic species in tropical areas.

In April the species was found at a station close to the edge of the North Edge water in the south-west of the offshore region, a few cells also being found at an isolated offshore station further north. In July it was still confined chiefly to the offshore stations in the south-west. However in October it was present in small numbers at scattered stations over the entire offshore area. In January it appeared to vanish from the area entirely.

This distribution suggests that the species was confined to the southern offshore waters in autumn and winter (April and July) due to the existence of some barrier which prevented its northward spread. However, this barrier appeared to break down in Spring (October), allowing a northward spread off the species in the offshore waters. By summer (January) conditions were again unsuitable for it in the northern offshore, and it was also absent further south in the area. It is difficult at this stage to determine what the exact nature of the barrier might have been. There was little variation in the temperature and salinity of the offshore waters to the north of the North Edge Water. However, there were marked changes in the temperature structure of the offshore waters in the north (line A) with the seasons (see diagrams 2 - 5 in section II). In autumn and summer a well-developed thermocline was present in the northern offshore waters, this breaking down completely in winter and only being weakly developed in spring. This seems to play a role in regulating the offshore spread of many of the neritic species in the area, the vertical mixing of the water probably repleni replenising the nutrients in the euphotic zone, and it is possible that species from the south also spread into the offshore waters during this period of mixing. The reason why _Th. longissima_ was not spread northward in July (winter) but only in October (spring) could have been due to a time lag in the northward transport of the species. With so little data on nutrient concentrations and other parameters of importance to the distribution of phytoplankton species only speculative comment is possible.

The distribution of *Pseudoenotia doliolus* (shown also on charts 10 - 13) mirrors the above distribution to a certain extent. Cleve (1900, b) also linked the distribution of this species with *Th. longissima*, considering them both to be characteristic of S. Indian Ocean waters. It is difficult to explain why *Ps. doliolus* has a southern oceanic distribution, as most authors, e.g. Cupp (1943), Hustedt (1959) are of the opinion that it is a tropical to subtropical littoral species. In the author's material it was present at only one neritic station (near Durban in January), all other records being from extreme offshore stations.

Other antarctic and subantarctic species which appeared in the offshore waters in winter and spring were *Chaetoceros concavicornis*, *Chaetoceros criophilus*, *Chaetoceros neglectus*, *Fragilaria linearis*, *Nitzschia angustissima*, *Pleurosigma directum*, *Synedra reinboldii*, *Tropidoneis antarctica*, and the dinoflagellate *Ceratium lineatum*.

(g) *Chaetoceros curvisetus* Cleve (tax. no. 110) - a neritic, temperate species apparently introduced into the area by inshore currents from the West Coast area. Charts 14 - 17.

This is a neritic species commonly found in northern and southern temperate and cold waters. It is commonly present in the Benguela current region of the west coast of South Africa (Boden, 1950; Hart & Currie, 1960) and sometimes occurs in large numbers in Cape waters (present author's observations.)

In the S.W. Indian Ocean it was only present at inshore stations in the south-western part of the area, never extending further north or east than Port Elizabeth, in July and January. An interesting feature of the samples in which it occurred was that several other typically West Coast species were also present in them, e.g. *Stephanopyxis turris*, mixed with others common in the area. At station 94, from which it was recorded in July, the temperature of the upper 50 m. was approximately 15°C, the coldest water near the surface over the whole area. At station 191 the surface temperature was fairly high (22.4°C) but there was a sharp drop of temperature between 20 and 50 m. (to 17.0°C). It is known that the currents over the Agulhas Bank are highly variable (Welsh, 1964), and local easterly-flowing currents do occasionally flow areound Cape Agulhas. It is likely that these carry members of the West Coast phytoplankton flora with them, introducing them into the inshore waters of the east coast where the higher temperatures off the Natal coast may limit their penetration northwards.

Other taxa common off the west coast of S. Africa with a similar distribution to *Ch. curvisetus* in the S.W. Indian Ocean are *Stephanopyxis turris*, *Chaetoceros borealis* (also shown on charts 14 - 17), *Chaetoceros difficilis*, *Chaetoceros tetras*, *Bacteriastrum hyalinum* var. *hyalinum*, *Ditylum brightwellii*, and the dinoflagellate *Dinophysis tripos*. Some typically west coast species extend up the east coast as far as Durban, e.g. *Chaetoceros curvisetus*, *Chaetoceros diadema*, and *Nitzschia seriata*, these apparently being able to tolerate the higher temperatures off the Natal Coast more easily.

IV. 3. *General features of the distribution*.

From the relative abundance tables (2 and 3 in the appendix)mit can be seen that diatoms were far more significant in the phytoplankton than the dinoflagellates, both in relative abundance and in number of taxa present at each station. Dinoflagellates were only of notable abundance in one sample, that from station 160 and even at this station the diatoms were in heavier abundance than the dinoflagellates, *Nitzschia pacifica* being particularly abundant (+++++). For the most part the dinoflagellates occurred in small numbers at scattered oceanic stations. The commonest and most widespread taxa of dinoflagellates were *Ceratium massiliense* (two varieties), *Ceratium pentagonum* f. *robustum*, *Ceratium tripos* (two varieties, three forms), *Ceratium extensum*, *Ceratium longirostrum*, *Ceratium teres* and *Peridinium claudicans*. Most of these were most widely distributed in April (autumn) and some of them were completely absent at one month or another. In contrast to this the commonest diatoms tended to be most widely distributed over the area in July (winter) and were present in material from all four cruises. The diatoms tended to be restricted to the inshore and Agulhas Current stations in January (summer). With the exception of species such as Noctiluca scintillans and Congruentidium compressum most of the dinoflagellates were oceanic or panthallasic in their distribution, whereas the majority of the diatoms were most abundant at neritic stations or stations on the edge of the continental shelf.

A notable feature of the dense concentrations of phytoplankton at neritic and edge of the shelf stations was the large number of taxa present. For example, at station 62, on line A in July, a total of 89 taxa were recorded (75 diatom taxa and 14 dinoflagellate taxa), excluding any species of cyanophytes, xanthophytes or coccolithophores which were not recorded in that month. Furthermore it was seldom that only one species occurred in large numbers. Usually dense concentrations were made up of large numbers of several species and it was sometimes difficult to determine which was the dominant species. An example of this was the sample from station 18, the most inshore station on line B in April, in which there were 10 species occurring with a relative abundance of "+++" or more, particularly large numbers of Bacteriastrum minus, Chaetoceros lorenzianus and Nitzschia pacifica being present (++++ - +++++).

If it is true that high relative abundances are indicative of large standing crops, then it is clear that large standing crops were present at inshore stations fro for most of the year. It is unfortunate for the purposes of comparison with other areas that estimates of total cell numbers could not be made with the sampling technique used, but productivity estimates by other authors, i.e. Steemann Nielsen & Jensen (1956) and Mitchell Innes (1964), have shown that between 0.5 and 1.0 g $C/m^2/day$ is produced at some inshore stations near Port Elizabeth and Durban at some seasons of the year. These values will be discussed later in section V.

The significance of the groups represented by only a few species, i.e. the Cyanophyceae, Chrysophyceae and Xanthophyceae, (not indicated in the relative abundance tables) should not be underestimated as certain representatives of these groups, e.g. Trichodesmium thiebaultii and Halosphaera viridis were commonly present in the material and the former in particular appeared to be quite heavily abundant at certain Agulhas Current stations. Also, the works of Bernard (1959) and Bernard & Lecal (1960) have shown that coccolithophores (Chrysophyceae) may be the most important producers of tropical Indian Ocean waters.

SECTION V. DISCUSSION AND CONCLUSIONS.

V. 1. Discussion.

In section III. 3 a hydrographic zonation of the area under study was proposed. The extent to which the observed distribution of the phytoplankton was related to this (refer to chart 9) can now be discussed.

(a) The Agulhas Current Zone: This was described as a southward extension of tropical/subtropical surface water down the east coast of South Africa, characterised by temperatures above 23°C in January and April (summer and autumn, when the current was strongest) and above 21°C in July and October (winter and spring). Salinities varied between 35.15‰ and 35.47‰, lowest salinities being found in the core of the current near Durban. Comparing chart 9 with charts 10 - 17 (on which the distribution of several species have been plotted), and with the detailed distributional data given in section II, it is not surprising to note that several of the diatom species which may be considered as tropical and oceanic in character, e.g. *Gossleriella tropica*, *Asterolampra marylandica*, *Mastogloia rostrata* and *Mastogloia woodiana* were virtually confined to this zone. None of the species mentioned were present in large numbers, being rare in occurrence and vanishing almost completely from the plankton to the southwest of line C (approximately 35°S). None of the dinoflagellate species showed any clear correlation between their distributions and this zone, the oceanic species tending to be spread throughout this zone and the Southwestern Indian Oceanic Zone.

While species such as Gossleriella tropica and Asterolampra marylandica cannot be used as indicator species of the Agulhas Current in its most south-westward extension due to their presence in S. Atlantic tropical and subtropical waters, the two species of Mastogloia mentioned would seem to be valuable in this respect, never, to the author's knowledge, having been recorded from the S. Atlantic region. In fact they appear to be entirely confined to the Indian Ocean and Western Pacific Ocean. However their value as indicators is severely limited by their rarity in the water concerned.

It would seem that the Agulhas Current Zone is a region where tropical and subtropical Indian Ocean species are introduced to the area, those with more tropical requirements dying out as the water gradually becomes colder and increases in salinity to the south-west. The subtropical oceanic species, such as Climacodium frauenfeldianum, Eucampia cornuta, Hemiaulus chinensis, Bacteriastrum comosum and Chaetoceros pendulus, probably also introduced into the area by the Agulhas Current, have a wider distribution, being more common in the Agulhas Current zone but also spreading into the Natal Shelf Zone and the South Western Indian Oceanic Zone.

A further feature of interest is that the distribution of certain neritic species which have a centre of distribution over the shelf between Port Elizabeth and Port St. Johns, e.g. Bacteriastrum minus and Nitzschia pacifica, suggests that they may be carried off the margin of the shelf by the Agulhas Current and introduced into the general offshore region by the deflection of the current eastwards.

(b) The South Western Indian Oceanic Zone.

The water of the upper 100 m. of this zone may be considered as subtropical surface water characterised by temperatures of between 17° and 21°C, temperature decreasing eastwards and southwards. Salinities were higher than in the Agulhas Current, approximately 35.56 to 35.60‰. In section III a notable feature of this zone was shown to be the formation of a marked thermocline in the north lying at a depth of approximately 60 to 100 m. in summer and autumn (January and April), while the thermocline broke down completely in winter (July), virtually homogeneous water being found in the upper 100 m.

In general the phytoplankton present in this zone was very sparse and could be considered as a reduced subtropical oceanic population. However, there was a marked seasonal variation in the phytoplankton of this zone. For example, in summer many of the species which were present in the zone vanished from it entirely and phytoplankton was extremely sparse. This was also true to a lesser extent in autumn. However, in winter and spring many species which were confined to more inshore waters spread into the zone, e.g. Nitzschia seriata, and it was also during these months that species generally confined to southern colder waters spread northwards, e.g. Thalassiothrix longissima.

It would seem that this spread of species into the zone is related in some way to the breakdown of the thermocline. It is possible, although there is no direct evidence for this, that nutrient levels dropped in the water above the thermocline, the breakdown of the thermocline allowing a replenishment of nutrients in the euphotic layer from the water below. If this is so then it is likely that the diatoms as a whole were limited in this zone by nutrient concentrations. The distribution of dinoflagellates in this zone did not show the same seasonal fluctuations. However, it is known that in general they have lower nutrient requirements than diatoms (see Barker, 1935) and this tends to support the above theory. Also, Steemann Nielsen & Jensen (1956) found that productivity values decreased eastwards from the South African coast. In fact, the productivity at one station, corresponding approximately in position to the most extreme offshore station on line B, was the lowest recorded anywhere in the Indian that they are composed of an unusually large number of species. This is due in part to the presence of many oceanic species mixed with the neritic population. For example, subtropical oceanic species such as *Chaetoceros pendulus* and *Bacteriastrum comosum* are commonly found at stations situated under ten miles from the coast. They do not seem to occur over the shelf south of Port St. Johns. A similar situation apparently exists in the distribution of chaetognaths (zoo-plankton) of the area (Stone, personal comm.).

There appeared to be very little vertical movement of the subsurface waters on the inner edge of the Agulhas Current in this zone and it might seem strange therefore that nutrients were not depleted in the euphotic layer by the heavy concentrations of phytoplankton present. However there would seem to be two possible means of replenishment of nutrients in this zone other than by upwelling of subsurface waters. The first of these is a supply of nutrients derived from the land, the Natal coast being characterised by a large number of relatively swift-flowing rivers which empty into the sea, particularly in summer when heavy rainfall occurs. Secondly, Steemann Nielsen & Jensen (1956), in discussing the high productivity found at certain inshore stations in tropical waters, suggested that it may be due to a rapid rate of regeneration of the nutrients by bacteria situated on the bottom, turbulence being sufficient to replenish the shallow waters situated above the shelf.

(d) The Eastern Agulhas Shelf Zone.

This is the shelf water found to the south of the preceding zone and extending westwards along the southern coast of S. Africa to the Agulhas Bank proper where it loses its distinct hydrographic characteristics in the highly variable current systems which exist over the bank. It is characteristically a neritic zone where the water shows a strong thermal stratification, a shallow layer of warm water (frequently only a few meters thick), apparently derived from the Agulhas Current, overlaying markedly colder water. The range in temperature between the surface water and the water immediately over the bottom near Port Elizabeth was commonly of the order of 9°C, the surface water averaging 20°C and that on the bottom averaging 11°C. The cold bottom water was apparently the result of upwelling on the inner edge of the Agulhas Current as it diverged from the land, causing a "Wake stream" effect similar to that found on a larger scale in connection with the Gulf Stream (Rossby, 1936).

The phytoplankton at stations situated in this zone reflected this temperature structure in an interesting manner. While many of the species present, such as Chaetoceros lorenzianus, Skeletonema costatum and Detonula moseleyana were common to both this zone and the Natal Shelf Zone, a number of species commonly inhabiting colder waters were also occasionally present in the material. The latter could be broadly subdivided into two types: cold-temperate neritic species commonly found in waters off the west coast of S. Africa such as *Chaetoceros curvisetus*, *Stephanopyxis turris* and *Thalassiosira rotula*, and rarely-found antarctic and subantarctic oceanic species such as *Chaetoceros borealis* (found at the edge of the shelf).

A further interesting point in connection with the phytoplankton of this zone was that it was here that several common neritic species, seasonally widespread over most of the area under study, apparently had centres of distribution. Examples of these were *Nitzschia pacifica*, *Bacteriastrum minus*, *Asterionella japonica*, *Lauderia annulata*, *Rhizosolenia stolterfothii*, and the dinoflagellate *Dinophysis caudata*. The mechanism causing a spread of these species into other zones was probably current influence, the Agulhas Current appearing to carry species off the shelf in the south-west from where they were spread into the general offshore area (the South Western Indian Oceanic Zone), a spread northwards into the Natal Shelf Zone probably being due to northward-flowing coastal currents.

(e) North Edge Water.

This is the water resulting from lateral-mixing between the subtropical surface water and the subantarctic surface water of the West Wind Drift region (the latter to the south of the area under study). It was present in the area in the form of a northward meander of the subtropical convergence region. The water had intermediate characteristics between the waters of which it is composed, with a temperature ranging between 13° and 18°C, salinities being lower than in the rest of the area (35.15‰ to 35.55‰). Indirect evidence, i.e. determinations made to the east of the area, suggests that at some seasons at least, phosphate values are higher than in the subtropical surface water, but not as high as the subantarctic surface water (see diag. 7 in section III).

Only a few stations in the area were situated directly in the North Edge Water, although many of the offshore stations on line D were situated on the fringe of it. At these stations the phytoplankton present was found to have mixed subtropical and temperate characteristics with a few subantarctic species being present. Such species as _Thalassiothrix longissima_, _Chaetoceros criophilus_ (typical form), _Chaetoceros neglectus_, and _Synedra ossiformis_ were found mixed with the subtropical flora (_Planktoniella sol_, etc.) at stations in this zone. As has already been discussed above, when considering the South Western Indian Oceanic Zone, the above species were found to spread northwards in July and October and it is suggested that the barrier which restricts their northward spread in summer and autumn breaks down in winter. This is possibly limited in some manner with the breakdown of thermoclinic conditions in the northern offshore water. When the barrier is reformed the following summer remnants of this northward spread of temperate and subantarctic species remain in the subtropical waters from which, it is presumed, they soon vanish. However, this type of phenomenon may explain the occasional, rare records of species such as Thalassiothrix longissima in tropical Northern Indian Ocean waters (e.g. Cleve, 1900, b from the Red Sea).

A type of distribution described in section IV which relates to a transition region rathern than a zone is the appearance of a number of temperate neritic species found at inshore stations near Cape Agulhas at some seasons, sometimes spreading eastward as far as Port Elizabeth. Species such as this were Stephanopyxis turris, Ditylum brightwellii, Chaetoceros curvisetus, Chaetoceros tetras, and Bacteriastrum hyalinum (typical variety). All these are commonly found off the west coast of S. Africa and it seems possible that they were present to the east of Cape Agulhas due to an eastward flow of water past Cape Agulhas. The water was apparently rapidly mixed with the water in the Eastern Agulhas Shelf Zone, many species common to the east coast waters also being present in the samples from which they were recorded. There is indirect evidence to show that temperature is the main limiting factor restricting the northward spread up the east coast of these temperate species. For example, Chaetoceros decipiens, a very common oceanic species off the west coast, was only present in the shelf waters off the east coast, its northward spread probably being related to the cold subsurface water present in the Eastern Agulhas Shelf Zone. However, it was present in the Natal Shelf Zone in April and October. Its heavy abundance (++++) at station 1 near Durban would appear to be an anomaly not explicable by the above theory.

Thus the general picture would seem to be that the only species having a centre of distribution in the area are neritic species occurring chiefly in the Eastern Agulhas Shelf Zone, tropical and subtropical "visitor" species being introduced into the area by the Agulhas Current, neritic temperate species being introduced from the west coast by local, easterly-flowing currents inshore near Cape Agulhas, and oceanic temperate and subantarctic "visitor" species spreading northwards into the S.W. Indian Oceanic Zone following the breakdown of the thermocline in that zone in winter and spring.

It is interesting to compare the phytoplankton off the east coast with that of the west coast of S. Africa. Hart & Currie (1960) have provided a survey of the Benguela Current waters off the coast of S.W. Africa based on a comparable amount of material to that collected in the present survey. They recorded approximately 150 taxa of "protophyta" from a total of 92 samples, considering this to be indicative of a rich microflora of the area. It is apparent that, with 402 taxa recorded from 98 samples in the S.W. Indian Ocean area, the microflora of the waters off the east coast of

S. Africa are far richer in variety. The present study did not lend itself to quantitative comparison between the two regions. The Benguela Current area is well known for its generally high productivity, Steemann Nielsen & Jensen (1956) recording values of between 0.46 and 2.5 g.C/m^2/day in the area (the highest productivity recorded during the Galathea cruise, 3.8 g.C/m^2/day, was recorded off Walvis Bay in a bloom of Gymnodinium galatheanum, this being an anomalous record). However, they also found relatively high productivity rates at inshore stations off the east coast (0.1 to 0.59 g.C/m^2/day) during late summer, productivity values decreasing rapidly eastwards into the offshore waters. Mr. D. Sacks, who made several scattered productivity measurements during the January (summer) cruise of the "Natal", has made some of his results available to the author at the time of writing this section (too late to be included in the earlier sections). These substantially confirm the tentative conclusions drawn from the relative abundance data. His lowest estimate was 0.069 g.C/m^2/day for station 155, an offshore station on line B, and the highest was 1.21 g.C/m^2/day from station 161, a station on the edge of the shelf near Port Elizabeth. The qualitative analysis of phytoplankton for this station suggested that Asterionella japonica was the chief producer.

A comparison between the species composition of the east and west coasts reveals further distinctions between the two. On the west coast most of the species listed as "dominants" by Hart & Currie (1960) may be considered to be temperate species whereas the typical species off the east coast are, in general, subtropical species (with the exception of several temperate species occurring in the Eastern Agulhas Shelf Zone and in the North Edge Water). The following table, 4 (2 and 3 being in the appendix), illustrates this point by comparing the species of several genera with regard to their common appearance in each area.

Table 4. Common species of diatoms found within several genera occurring in east and west coast waters.

Genus ~~West~~	West Coast spp.	East Coast spp.
Bacteriastrum	hyalinum v. hyalinum	hyalinum v. princeps comosum varians
Chaetoceros	curvisetus decipiens difficilis tetras	pseudocurvisetus lorenzianus messanensis atlanticus vars.
Ditylum	brightwellii	sol
Stephanopyxis	turris	palmeriana
Eucampia	zoodiacus	cornuta
Nitzschia	seriata delicatissima	pacifica pungens v. atlantica
Thalassiothrix	longissima	acuta heteromorpha

The species were by no means restricted to the areas under which they are listed above, but may be considered typical of the areas due to their relative abundance in each region.

In section IV several possible indicator species of Agulhas Current and eastern coastal waters were suggested. They are Chaetoceros denticulatus, Mastagloia rostrata, Mastagloia woodiana and Congruentidium compressum, all species which have been only recorded from the Indian and Western Pacific Oceans. In addition, the presence of tropical oceanic species such as Gossleriella tropica, Chaetoceros equatorialis, Chaetoceros tetrastichon and Ceratocorys horrida to the west of Cape Agulhas would strongly suggest the presence of Agulhas Current water although they are also found in tropical Atlantic waters.

Little has been said of the dinoflagellates occurring in the area under study. This has not been due to personal preference, but to two problems in discussing the distribution. Firstly, although there were many taxa recorded, the great majority were only present in small numbers at scattered stations (see Table 3 in the appendix), distribution patterns being patchy in appearance and liable to be incomplete due to the small numbers recorded (see section I.5). Secondly, it is likely that many of the dinoflagellates species were inadequately sampled, living at greater depths than 100 m. Steemann Nielsen (1939) subdivided the Ceratia of the Indian and West Pacific Oceans into three types depending upon the depths at which maximum concentrations of the species occurred: Euphotic (0 - 50 m.), Mesophotic (50 - 100 m.), and Oligophotic (100 - 200 m.). As the material in the present study was collected by hauls from 100 m. to the surface it is clear that the bulk of the Oligophotic species were not adequately sampled. It is perhaps significant that the Ceratia found most frequently in the material, e.g. *Ceratium massiliense*, *Ceratium extensum* and *Ceratium teres*, were all classified as Euphotic species by Steemann Nielsen (1939), whereas *Ceratium praelongum* and *Ceratium ranipes*, both Oligophotic species, were only found in small numbers at scattered stations. A further difficulty is that many species of dinoflagellate undergo phototactic vertical migrations (Hasle, 1950), the collections being made at different times of the day or night.

The frequency of *Ceratium massiliense* in the area is interesting as Wood (1954) found it to be a dominant form indicative of Western Australian waters. It does not seem to be particularly abundant in the Northern Indian Ocean or tropical Indian Ocean waters, occurring chiefly in more subtropical or temperate S. Indian Ocean waters. It cannot be considered an indicator species of Indian Ocean waters as it has also been found to be present in other oceans, e.g. in west coast waters by Hart & Currie (1960).

With regard to the seasonal variations in distribution of the phytoplankton of the area it has been pointed out in section IV that the diatoms tended to be most widely distributed and abundant in offshore waters in winter (July), being very sparse in the offshore waters in summer (January). This was possibly linked with the nutrient concentrations in the euphotic zone. In the inshore waters seasonal fluctuations were not as apparent and difficult to describe without recourse to actual cell numbers, being found in high relative abundance on all lines on all four druises. Mitchell-Innes (1964) found that the productivity rate in the shelf water near Durban varied considerably throughout the year, being highest in spring and autumn.

The dinoflagellates were generally most widely distributed in the offshore waters, but occurred in largest numbers at some inshore stations, e.g. station 160. Most of the commonest species were most widespread in autumn (April, see table 3).

The results of this study are remarkably similar to those obtained by Subrahmanyan (1959) in a quantitative study of the phytoplankton of the west coast of India. For example, in that subtropical region diatoms were also the dominant group represented, forming the bulk of phytoplankton present. It is becoming increasingly clear that tropical and subtropical waters of the Indian Ocean can be high in productivity and in number of species, particularly in shelf waters and divergence regions where there is a rapid replenishment of nutrients (see Steemann Nielsen, 1959).

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V. 2. <u>Main observations and conclusions</u>.

The phytoplankton of the area is extremely rich in the number of species present. Approximately twice as many species were recorded in this survey as were recorded in a comparable survey of waters off the west coast of S. Africa. The species composition appears to have many similarities with the phytoplankton off the west coast of India, one of the few areas studied intensively in the Indian Ocean to date.

The diatoms were the largest group present in the material, both in number of species present and in relative abundance. Of these the centric diatoms, and in particular the genera <u>Chaetoceros</u> and <u>Rhizosolenia</u>, were predominant, although certain pennate species of the genera <u>Nitzschia</u>, <u>Thalassionema</u> and <u>Thalassiothrix</u> were also common and occasionally abundant in the material. An unusually large number of species of the centric genus <u>Coscinodiscus</u> were recorded, but these were usually only present in small numbers.

The dinoflagellates were the second largest group represented in the material. At none of the stations were they present in greater relative abundance than the diatoms. The genera represented by the largest number of species were <u>Ceratium</u> and <u>Peridinium</u>. It is likely that the unarmoured species were under-estimated due to unsuitable preservation and difficulty in identification. "Oligophotic" species were not fully sampled.

A few species of the Cyanophyceae and Xanthophyceae were recorded, two of these (*Richelia intracellularis* and *Solenicola setigera*) living in association with certain species of diatoms. Also present were several species of Chrysophyceae (coccolithophorids), the relative abundance of which could not be estimated by the methods of collection and analysis employed.

A study of the hydrographic data available revealed that it would be unrealistic to consider the region as one zone due to the presence of two distinct water masses (subtropical surface water and North Edge water) in the surface waters of the area, and five zones were recognised in the area on the basis of hydrographic characteristics. Three of these could be considered as being tropical to subtropical and the others temperate in constitution. Seasonal fluctuations in conditions within the zones, and with regard to their position, were found to be striking.

Currents appeared to have the major influence on the distribution of phytoplankton in the area, both from the point of view of horizontal transport, and with regard to associated phenomena such as the upwelling of water from moderate depths into or just below the euphotic zone on the inner edge of the Agulhas Current, the latter being most marked where the current moved away from the coast.

The temperature structure in the euphotic zone in the northern offshore waters also appeared to be a factor influencing the distribution of phytoplankton in these waters, particularly with regard to the diatoms, the species being most widespread in the offshore waters after the breakdown of thermoclines in winter and spring. The work of other authors suggests that nutrient levels in the euphotic zone increase upon breakdown of the thermocline, and this is probably the factor directly influencing the phytoplankton rather than the temperature structure which acts indirectly upon it.

The breakdown of the thermocline, with the resultant presence of virtually homogeneous water, slightly cooler, in the upper 100 m. in winter and spring, also apparently allows the northward spread of temperate and subantarctic oceanic species into the northern offshore waters, the species vanishing from these waters after the reformation of the thermocline, although remnants may remain for an undetermined period in the warmer water.

An examination of the various types of distribution pattern exhibited by species in the area indicates that there is a local, semi-permanent population whose centre of distribution is situated in the Eastern Agulhas Shelf Zone (roughly the shelf water between Port Elizabeth and Port St. Johns), this being composed chiefly of neritic species. Tropical and subtropical "visitor" species are apparently introduced into the area by the Agulhas Current. Temperate, neritic "visitor" species common off the west coast of S. Africa appear to be introduced by eastward-flowing local currents in the vicinity of Cape Agulhas, spreading northwards in the shelf waters to a greater or lesser extent, possibly depending on their temperature tolerances. Subantarctic and temperate oceanic "visitor" species spread northward into the offshore waters in winter and spring following the breakdown of the thermocline in those waters, disappearing from the area following the redevelopment of the thermocline.

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