

A STUDY OF THE PHYTOPLANKTON OF THE
SOUTH WESTERN INDIAN OCEAN

by

F. J. R. TAYLOR

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II. 2.

CLASS CHRYSOPHYCEAE

CHRYSOMONADALES

Family COCCOLITHOPHORIDACEAE

In recent years a steadily increasing number of species of this group have been examined under the electron microscope and it has become clear that the exact identification of many of the species is only possible under this type of examination. During the course of the present investigation the author observed surprisingly large amounts of nannoplankton in some of the net samples. Although many of the species were not identifiable under standard microscopic examination several of the larger, more distinctive species could be identified with the limited literature on this group available to the author. As records of coccolithophore species from the Indian Ocean are extremely rare (the only ones known to the author being Subrahmanyam, 1958, and Bernard & Lecal, 1960) the following species have been listed as a

somewhat meagre contribution to the distributional knowledge of a group which appears to be of more than passing significance in the productivity of the offshore waters of the Indian Ocean. The stations cited are those from which the organisms (or their plates) were identified, and give no indication of their distribution or abundance in the area.

234. Anthosphaera robusta (Lohmann) Kamptner, Ann. Naturhist.

Mus. Wien 51 : 86, pl. 9, figs. 91 - 94 (1941); Halldal & Markali, Nytt Mag. Bot. 2 : 117, pl. 1, figs. a - g (1953). PLATE 20, fig. 5.

System.: The figure illustrates a cell which appears to be incomplete, differentiated "buccal plates" being lacking. The median slits in the coccoliths are clearly visible and a lateral view of one of them is indicated by the arrow. The coccoliths are approximately $2.5 - 3\mu$ in length, and the broad diameter of the cell is 12μ .

Local.: NIOE 117 - one specimen.

235. Calciosolenia granii var. Cylindrothecaeformis Schiller,

Naturwiss. 3 : 207 (1915); Schiller, Arch. Protistenk. 51 : 27, pl. 2, figs. 21, 22 (1925); Kamptner, Ann. Naturhist. Mus. Wien 51 : 92 &

108, pl. 12, figs. 132, 133 (1941).

Local.: NIOE 153, 162, 164, 176, 178.

One specimen observed at each of the above stations.

236. Calciosolenia tenuis Bernard & Lecal, Bull. Inst.

Oceanogr. Monaco (1166) : 21, fig. 9 (1960).

PLATE 20, fig. 1.

Local.: NIOE 117.

One specimen. This species was first described from the Indian Ocean at a station east of Madagascar.

237. Coccolithus leptoporus (Murray & Blackman) Schiller in

Rabenhorst, Krypt. Flora 10 (2) : 245 (1930);

Kamptner, Ann. Naturhist. Mus. Wien 51 :

94, pl. 13, figs. 137 - 139 (1941); Black &

Barnes, J. Roy. Micr. Soc., Ser. 3, 80 : 143,

pl. 24, figs. 3, 4 (1961). PLATE 20, fig. 2.

System.: Only coccoliths of this species were seen.

The one figured is unusually large for the species, being 12μ in diameter. However, most of the coccoliths observed were between 7 and 8μ in diameter.

Local.: NIOE 117.

Coccoliths of the species were numerous in this sample. They were observed in several other samples as well but were unfortunately not recorded at the time.

238. Cyclococcolithus fragilis (Lohmann) Bernard & Lecal,
Bull. Inst. Oceanogr, Monaco (1166) : 18, fig.
8 (1960).

Local.: NIOE 103.

A large number of cells of this species were observed at the above station, an extreme offshore station on line A in October. Bernard & Lecal (1960) found this species at all the stations in the Indian Ocean that they had material from, sometimes in large numbers down to a depth of 1000 metres.

239. Discosphaera tubifer (Murray & Blackman) Ostenfeld, Zool.
Anz. 22 : 200 (1899); Lohmann, Arch. Protistenk.
1 : 141, pl. 5, figs. 47, 48, 50 (1902);
Lemmermann, Coccosph. Nord. Plankt. : 40, fig.
132 (1908). PLATE 20, figs. 6 a, b.

Local.: NIOE 151.

One cell observed in material from an extreme offshore station on line B in October.

Coccoliths of the species were numerous in this sample. They were observed in several other samples as well but were unfortunately not recorded at the time.

Cyclococcolithus fragilis (Lohmann) Bernard & Lecal,

Bull. Inst. Oceanogr, Monaco (1166) : 18, fig. 8 (1960).

Local.: NIOE 103.

A large number of cells of this species were observed at the above station, an extreme offshore station on line A in October. Bernard & Lecal (1960) found this species at all the stations in the Indian Ocean that they had material from, sometimes in large numbers down to a depth of 1000 metres.

239. Discosphaera tubifer (Murray & Blackman) Ostenfeld, Zool.

Anz. 22 : 200 (1899); Lohmann, Arch. Protistenk. 1 : 141, pl. 5, figs. 47, 48, 50 (1902); Lemmermann, Coccosph. Nord. Plankt. : 40, fig. 132 (1908). PLATE 20, figs. 6 a, b.

Local.: NIOE 151.

One cell observed in material from an extreme offshore station on line B in October.

240. Helicosphaera carterii (Wallich) Kamptner, Arch. Protistenk.

100 : 21, figs. 17 - 19 (1954); Black & Barnes,
J. Roy. Micr. Soc., Ser. 3., 80 : 139, pls. 22,
23 (1961). PLATE 20, figs. 3, 4.

Local.: NIOE 117.

Only coccoliths of this species were observed.
They were common in material from the above
station.

II. 3. CLASS CYANOPHYCEAE

NOSTOCALES

Family NOSTOCACEAE

241. Nostoc sp. (possibly N. planktonicum Poretzky).

PLATE 21, figs. 3, 4.

System.: Cells of a species of Nostoc were sometimes
present in large numbers in the net material.
The cells formed loose chains, commonly as a
single row of cells and sometimes in a double
row. The cells themselves were spherical,
3 - 6 μ in diameter. Sometimes aggregations
of rugose-walled cysts were observed (pl. 21,

fig. 4) which were similar to those described by Bernard & Lecal (1960, p. 22, figs. 10 - 13).

Local.: NIOE, 93, 104, 151, 153, 169, 174, 176.

The above distribution is incomplete as records of the occurrence of this species were only kept for the material of the July, October and January cruises. On these cruises it was present at scattered stations over the area. It appeared to be most abundant at station 93, an inshore station near Cape Agulhas in July.

Bernard & Lecal (1960) found the species to be one of the most abundant forms of phytoplankton in the Indian Ocean samples. A most interesting discovery by them was that the species achieved a maximum abundance at a depth of 1000 m. at an oceanic station to the east of Madagascar.

242. Richelia intracellularis Schmidt in Ostenfeld & Schmidt, Vidensk. Medd. Dansk. Naturh. Foren. Kjøbenhavn 25 : 146, fig. 2 (1901); Wille, Schizoph. Nord. Plankt. : 26, fig. 23 (1908).

Local.: No station records were kept of this common parasite of diatoms. It was particularly common in various species of Rhizosolenia, but it occasionally occurred in species such as

Hemiaulus hauckii and Dactyliosolen mediterraneus.
Rhizosolenia bergonii and Rhizosolenia styliformis
 appear to be particularly prone to invasion by
 this species. In some samples virtually every
 specimen of either of the Rhizosolenia species
 above was found to be parasitised.

Family OSCILLATORIACEAE

243. Trichodesmium hildebrandtii Gomont, Monogr. Oscill. :

197, pl. 6, fig. 7 (1892); Desikachary, Cyanoph.:
 245, pl. 42, fig. 3 (1959). PLATE 21, fig. 2.

Local.: NIOE, 153, 155, 157, 161.

The species' distribution in April, July and
 October was not recorded. In January it was
 found in moderate numbers, mixed with
T. thiebaultii, at several offshore stations
 on line B and one inshore station on line C.

244. Trichodesmium thiebaultii. Gomont, J. de Bot. 4 : 356

(1890); Gomont, Monogr. Oscill. : 197, pl. 6,
 figs. 2 - 4 (1892); Desikachary, Cyanoph. : 243,
 pl. 42, figs. 4, 5 (1959). PLATE 21, fig. 1.

Local.: NIOE, 142, 143, 144, 153, 155, 157, 158,
 159, 161, 162, 164, 168, 169, 172.

As with T. hildebrandtii, no records of the distribution of the species was kept during the analysis of the April, July and October material. In January it was present in large numbers over most of the offshore area. It occurred in greatest numbers in or near the Agulhas Current, i.e. at stations 142, 143 and 164.

II. 4. CLASS XANTHOPHYCEAE

HETEROCOCCALES

Family CHLOROTHECIACEAE

245. Solenicola setigera Pavillard, Acad. Sci., C.R., 163 :
 65, text fig. (1916); Cupp, Mar. Plankt. Diat.
 W. Coast N. Amer. : 25, fig. 38 (1943).
 PLATE 22, fig. 1.

System.: This interesting epiphyte was found only on cells of the diatom Dactyliosolen mediterraneus, clumps of it occurring in the manner illustrated in the figure.

Local.: NIOE 12, 62, 87, 103, 117, 161.

Found at scattered stations on all four cruises.
 Rare.

Family HALOSPHAERACEAE

246. Halosphaera viridis Schmidt, Mitt. Zool. St. Neapel 1 :

67, pl. 3 (1878); Brunel, Phytopl. Baie Chaleurs :
205, pl. 65 (1962). PLATE 22, figs. 2, 3.

Local.: NIOE, 97, 104, 108, 110, 111, 119, 128,
146, 160, 155, 166, 174.

The above distribution is incomplete as records of the occurrence of this species were not kept during the analysis of the April and July material. In October and January it was present at scattered offshore stations, occasionally in moderate numbers (+++ at stations 108 and 166).

II. 5.

CLASS DINOPHYCEAE

The arrangement below follows that of Schiller (1933, 1937), the most comprehensive work on the group to date. It is evident that, in a group such as this which includes both autotrophic and holozoic organisms, either a botanical or a zoological classification may be used. In this study a botanical system has been followed to keep the presentation of systematic data uniform, but this is purely for the purposes of convenience.

Reference can be made to Paulsen (1949) and Wood (1954) for recent discussions of the problems of classification in this group. Due to the difficulty inherent in culturing species of dinoflagellates there is considerable doubt as to which constitute useful criteria for the separation of species and even a cursory glance through Schiller's work reveals close similarities between many of the species. The present author has not been in a position to attempt as critical a study of the species of this group as was possible with the diatoms due to insufficient available literature. The great majority of taxa were identified from Schiller (1933, 1937), with further aid from Wood (1954) and earlier references when available. Several of them appear to be new records for the Indian Ocean region.

DESMOCAPSALES

Family DESMOCAPSACEAE

247. Desmocapsa gelatinosa Pascher, Ber. deutsche Bot. Ges. 32: 160 (1914); Schiller, Dinofl. (1) : 11, fig. 5 (1933)

Local.: NIOE 159.

A large gelatinous mass of cells of this rare species was observed in material from an inshore station on line B in January. In all respects the colony closely resembled the original description.

DINOCOCCALES

Family DINOCOCCACEAE (PHYTODINIACEAE e.p.)

248. Brachydinium capitatum F. Taylor, J.S. Afr. Bot. 29 (2) : 75, pl. 7 (1963). PLATE 23, fig. 3.

Local.: NIOE 30, 71.

Two cells, described and figured in the original description, were observed at offshore stations on lines C and B in April and July respectively. Plate 23, fig. 3 is reproduced from Taylor (1963).

249. Pyrocystis fusiformis (Wyville Thompson) Murray, Rep. Sci. Res. Challenger Exped. 1 : 937, fig. 338 (1885); Matzenauer, Bot. Arch. 35 : 439, fig. 3 (1933); Schiller, Dinofl. (2) : 486, fig. 557 (1937);

Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 318,
fig. 256, a (1954). PLATE 23, fig. 2.

Local.: NIOE 73, 150.

Observed in small numbers at an Agulhas Current station on line B in July, and an extreme offshore station on line A in January. Wood (1963, a) has listed several records of this species in the Indian Ocean, to which may be added that of Silva (1956), from Mozambique waters.

250. Pyrocystis lunula Schütt in Engler & Prantl, Naturl.

Pflanzenf. 1 (B) : 3, fig. 2 (1896); Kofoed & Swezy, Mem. Univ. California 5 : 229, text fig. J, pl. 5, fig. 55 (1921, sub Gymnodinium lunula); Schiller, Dinofl. (2) : 488, fig. 559 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 319, fig. 257 (1954). PLATE 23, fig. 1.

Local.: NIOE 76, 155.

Observed in small numbers at an inshore station on line C in July, and an Agulhas Current station on line B in January. Wood (1963, a) has listed the Indian Ocean references to this species. In addition to these there is the record of Silva (1956, as P. elegans) from Mozambique waters.

251. Pyrocystis pseudonotiluca^c Wyville Thompson in Murray,
 Proc. Roy. Soc. London 24 : 532, pl. 21;
 Murray, Rep. Sci. Res. Challenger Exped. 1 :
 935, figs. 335 - 337 (1885); Schiller, Dinofl.
 (2) : 485, fig. 556 (1937); Wood, Aust. J. Mar.
 & Freshw. Res. 5 (2) : 318, fig. 255 (1954).

Local.: NIOE 35, 60, 62, 64, 66, 74, 75, 76, 80, 82,
 85, 93, 108, 110, 111, 128,

The commonest species of Pyrocystis in the area.
 It occurred at one Agulhas Current station on
 line D in April, was widespread over the area
 in July, was present at inshore and Agulhas
 Current stations on lines B and D in October,
 and was absent from the January material. It
 was not usually present in large numbers, a
 maximum abundance (++) being recorded at station
 62 on line A in July.

252. Pyrocystis rhomboides Matzenauer, Bot. Arch. 35 : 441,
 fig. 5 (1933); Schiller, Dinofl. (2) : 489, fig.
 560 (1937).

Local.: NIOE 76, 96, 97, 111.

This was recorded from one inshore station on
 line C in July, and several Agulhas Current stations
 on lines A and B in October. Never in large

numbers. This species appears to be limited in distribution to the Indian Ocean.

THECATALES

Family PROROCENTRACEAE

253. Exuviella marina Cienkowski, Trav. Soc. Nat. St. Petersburg.

12 : 159, figs. 36, 37 (1881); Lebour, Dinofl.

North. Seas : 13, pl. 1, fig. 1 a - d (1925);

Schiller, Dinofl. (1) : 20, fig. 15 (1933);

Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 178,

fig. 1 (1954). PLATE 27, fig. 1.

Local.: NIOE 110, 157.

Only two cells of this species were seen, one at each of the above stations which, perhaps coincidentally, were situated in the same vicinity (inshore line B) in October and January. It has been previously recorded from the Indian Ocean by Wood (1962).

254. Prorocentrum micans Ehrenberg, Organ. Richt. kleinst.

Raumes : 307 (1833); Lebour, Dinofl. North.

Seas : 16, pl. 1, fig. 5 (1925); Schiller,

Dinofl. (1) : 35, fig. 37 (1933); Wood, Aust.
J. Mar. & Freshw. Res. 5 (2) : 179, fig. 5 (1954).

Local.: NIOE 18, 25, 32, 113, 117, 158, 161, 178.

Found in small numbers at inshore stations in lines B, C and D in April, October and January. It spread into the offshore area on lines C and D. There are numerous references to the occurrence of the species in the Indian Ocean, and it has been found in discoloured water off the west coast of S. Africa (Hart & Currie, 1960) and in "red tide" water in False Bay, Cape (Grindley & Taylor, 1964).

255. Prorocentrum obtusidens Schiller, Arch. Protistenk. 61 :
57, fig. 15 (1928); Schiller, Dinoflag. (1) :
44, fig. 48 (1933).

Local.: NIOE 178.

One cell was observed in material from the vicinity of Cape Agulhas in January, 1963. This species has not been previously recorded from the Indian Ocean or the west coast of S. Africa. It was originally described from the Mediterranean.

256. Prorocentrum obtusum Ostenfeld, Wiss. Ergebn. Aralsee
Exped. 8 : 161, pl. 5, figs. 27, 28 (1908);

Schiller, Dinofl. (1) : 32, fig. 33 (1933).

Local.: NIOE 111.

One cell was observed in material from an inshore station on line B in October, 1962. This appears to be a new record for the Indian Ocean.

257. Prorocentrum rostratum Stein, Naturges. der arthrodelen
 Flagell. : pl. 1, figs. 16, 17 (1883); Schiller,
 Dinofl. (1) : 43, fig. 47 (1933); Wood, Aust.
 J. Mar. & Freshw. Res. 5 (2) : 181, fig. 7 (1954).

Local.: NIOE 155.

One cell was observed in material from a station on line B in January, 1963. It has been previously recorded from the Indian Ocean by Wood (1962).

258. Prorocentrum schillerii Böhm in Schiller, Dinofl. (1) :
 38, fig. 40 (1933).

Local.: NIOE 73.

A remarkable abundance of this species (++++)
 was found at one isolated station on line B in
 July, 1962. This could not be related to
 temperate or salinity factors as it was not
 present at adjacent stations with closely
 similar T/S conditions in the upper 100 m.
 (T = 23⁰, S = 35.3‰). The species has not

recorded from the Indian Ocean prior to the present survey.

259. Prorocentrum scutellum Schröder, Mitt. Zool. Stat.

Neapel 14 : 14, pl. 1, fig. 12 (1900); Paulsen, Peridin. Nord. Plankt. : 8, fig. 5 (1908); Lebour, Dinofl. North. Seas : 16, text fig. 4 b (1925); Schiller, Dinofl. (1) : 34, fig. 35 (1933); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 179, fig. 4 (1954).

Local.: NIOE 150.

One cell of this species was observed in material from an extreme offshore station on line A in January, 1963.

DINOPHYSIALES

260. Dinophysis acuminata Claparède & Lachmann, Mem. Inst.

Genevois 6 (1) : 408, pl. 20, fig. 17 (1859); Paulsen, Peridin. Nord. Plankt. : 15, fig. 13 (1908); Lebour, Dinofl. North. Seas : 80, pl. 12, fig. 2 a, c (1925); Schiller, Dinofl. (1) : 120, fig. 113 (1933); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 196, fig. 38 (1954).

Local.: NIOE 113, 130.

Found in small numbers at inshore stations on lines C and D in October only. Indian Ocean references are limited to Wood (1954) and Subrahmanyam (1958). Hart & Currie (1960) have recorded the species from the west coast of S. Africa.

261. Dinophysis caudata Saville-Kent, Man. Infus. : 455, 460 (1881); Cleve, Fifteenth Ann. Rep. Fish. Board Scotland : 26, pl. 1 (1897); Paulsen, Peridin. Nord. Plankt. : 12, 19, fig. 20 (1908); Czapek, S.-B. Akad. Wiss. Wien, math.-naturw. Kl. 118 (1): 8, fig. 5 (1909); Schiller, Dinofl. (1) : 153, fig. 145 (1933); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 201, fig. 49 (1954).

Local.: NIOE 75, 111, 158, 160.

Found at the same locality on three cruises, i.e. the most inshore station on line B, during July, October and January. In the latter month it spread to the most inshore station on line C as well. The inshore area between lines B and C would appear to be the centre of distribution for this species in the area.

There are numerous references to the presence of the species in the Indian Ocean (Wood, 1963,a).

262. Dinophysis fortii Pavillard, Bull. Soc. Bot. France 70 : 881 (1923); Kofoed & Skogsberg, Mem. Mus. Comp. Zool. Harvard 51 : 253, fig. 18, 7 (1928); Schiller, Dinofl. (1) : 134, fig. 127 (1933); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 198, fig. 45 (1954).

Local.: NIOE 160.

Found in moderate waters (++) at an inshore station near Port Elizabeth in January, 1963. It has previously been recorded from the Indian Ocean by Matzenauer (1933) and Wood (1954, 1962).

263. Dinophysis miles Cleve, ["]Ofvers. Kongl. Vet.-Akad. Forhandl. (8) 1030, text fig. 1 (1900); Schiller, Dinofl. (1) : 160, figs. 147, 148 (1933); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 203, fig. 52 (1954); Silva, Contrib. Estud. Micropl. Mar. Mocambique : 55, pl. 9, figs. 4, 5 (1956).

Local.: NIOE 74, 76.

Two specimens of this species were seen from inshore stations on lines B and C in July. It is one of the commonest species of dinoflagellates in the Indian Ocean, having been recorded by numerous authors. The record of Silva (1956) should be added to those listed by Wood (1963,a).

264. Dinophysis monacantha Kofoid & Skogsberg, Mem. Mus.

Camp. Zool. Harvard 51 : 283, fig. 37, 2, 3
(1928); Schiller, Dinofl. (1) : 144, fig. 136
(1933).

Local.: NIOE 35.

Only one specimen of this species was observed.
It was present in material from an Agulhas
Current station on line D in April, 1962. The
species does not appear to have been recorded
previously from the Indian Ocean.

265. Dinophysis nias Karsten, Valdivia Indische Phytopl. :

262, 421, 473, 540, pl. 47, fig. 7 (1907); Kofoid
& Skogsberg, Mem. Mus. Comp. Zool. Harvard 51 :
303, fig. 42, 1 (1928); Schiller, Dinofl. (1) :
149, fig. 141 (1933).

Local.: NIOE 7, 9.

Recorded from offshore stations on line A in
April, 1962. The species was originally
described from the Indian Ocean, but does not
seem to have been recorded since then from this
ocean.

266. Dinophysis schüttii Murray & Whitting, Trans. Linnean

Soc. London 2, Bot. (5) : 331, pl. 31, fig. 10

(1899); Paulsen, Peridin. Nord. Plankt. : 12.
18, fig. 19 (1908); Schiller, Dinofl. (1) :
147, fig. 140 (1933); Silva, Contrib. Estud.
Micropl. Mar. Mocambique : 55, pl. 9, fig. 3
(1956).

Local.: NIOE 21.

One specimen was observed in material from an
Agulhas Current station on line C in April.
Wood (1963, a) has listed several Indian Ocean
references to the species, omitting Silva
(1956).

267. Dinophysis tripos Gouret, Ann. Mus. Hist. Nat. Marseille,
Zool. 1 : 114, pl. 3, fig. 53 (1883); Lebour,
Dinofl. North. Seas : 82, fig. 22 (1925);
Schiller, Dinofl. (1) : 159, fig. 146 (1933);
Wood, Aust. J. Mar. & Freshw. Res. 5 (2) :
202, fig. 51 (1954).

Local.: NIOE 20, 21, 28, 35, 36, 58, 59, 76, 77, 85,
88, 93, 94, 96, 103, 129, 142, 178.

One of the commonest species in the area. It
was present at neritic stations over most of
the area but spread offshore in the south. It
was present inshore on line D on all cruises,
^{ex}~~extending~~ to the inshore stations on line A in

July, October and January. Although ususally only present in small numbers, moderate abundance (++ - +++) was recorded at stations 35, 36 and 76, inshore stations on line D in April and an inshore station on line C in July. There are a few records by other authors of its occurrence in the Indian Ocean (see Wood, 1963,a). It was found to be common off the west coast of S. Africa by Hart & Currie (1960) and its presence in the S.W. Indian Ocean might possibly be due to a seeding of the inshore area by transport around Cape Agulhas of west coast water.

268. Phalacroma cuneus Schütt, Ergebn. Plankton-Exped. d. Humboldt-stift. 4 : 148, pl. 3, fig. 14 (1895); Kofoed & Skogsberg, Mem. Mus. Comp. Zool. Harvard 51 : 124, figs. 12, 13 (1928); Schiller, Dinofl. (1) : 84, fig. 76 (1933); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 187, fig. 20 (1954).

Local.: NIOE 108, 110.

Recorded from stations on line B, possibly in the Agulhas Current, in October, 1962. Wood (1963, a) has listed several references to the presence of the species in the Indian Ocean.

269. Phalacroma doryphorum Stein, Naturges. der arthrodelen

Flagell. : 23, pl. 19, figs. 1 - 4 (1883);
 Kofoed & Skogsberg, Mem. Mus. Comp. Zool.
 Harvard 51 : 175, fig. 23, 1 - 5 (1928); Schiller,
 Dinofl. (1) : 99, fig. 91 (1933); Wood, Aust.
 J. Mar. & Freshw. Res. 5 (2) : 191, fig. 30
 (1954).

Local.: NIOE 159, 168.

Recorded from an inshore station on line B, and
 an extreme offshore station on line C, in
 January, 1963. Only present in small numbers.
 There are several Indian Ocean records of this
 species (see Wood, 1963, a).

269. Phalacroma ovum Schütt, Ergebn. Plankton-Exped.

Humboldt - Stift. 4 : 90 (1895); Kofoed & Skogsberg,
 Mem. Mus. Comp. Zool. 51 : 118, fig. 11 (1928);
 Schiller, Dinofl. (1) : 81, fig. 73 (1933);
 Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 186,
 fig. 17, (1954).

Local.: NIOE 112, 150, 162.

Single specimens were observed in material from
 an inshore station on line B in October, and
 offshore stations on lines A and C in January.
 Wood (1954, 1962) appears to be the only previous

author to record the species from the Indian Ocean.

271. Phalacroma pulchellum Lebour, J. Mar. Biol. Ass. U.K.

12 : 817 (1922); Lebour, Dinofl. North. Seas : 77, pl. 11, fig. 2 (1925); Schiller, Dinofl. (1) : 63, fig. 56 (1933); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 184, fig. 9 (1954).

Local.: NIOE 5.

One specimen recorded from an offshore station on line A in April, 1962. It has only previously been recorded from the Indian Ocean by Wood (1954), the locality being well to the south in the vicinity of the Antarctic Convergence.

272. Phalacroma rudgei Murray & Whitting, Trans. Linnean Soc.

London 2, Bot. (5) : 331, pl. 31, fig. 6 (1899); Paulsen, Peridin. Nord. Plankt. : 19, fig. 22 (1908); Lebour, Dinofl. North. Seas : fig. 20, e (1925); Schiller, Dinofl. (1) : 66, fig. 59 (1933); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 185, fig. 13 (1954).

Local.: NIOE 36.

Recorded from an inshore station on line D in April, 1962. The species has been previously recorded from the Indian Ocean by Schröder (1906)

and Wood (1962).

Family AMPHISOLENIACEAE

273. Amphisolenia bidentata Schröder, Mitt. Zool. Stat. Neapel 14 : 20, pl. 1, fig. 16 (1900); Kofoed & Skogsberg, Mem. Mus. Comp. Zool. Harvard 51 : 409, fig. 54, 1 - 4, 56, 1 (1928); Schiller, Dinofl. (1) : 178, fig. 169 (1933); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 205, fig. 55 (1954).

Local.: NIOE 16, 17, 21, 97, 146.

Found in small numbers at inshore stations on lines B and C in April, an inshore station on line A in October, and an offshore station on line A in January. It is a common species in the Indian Ocean, particularly in the tropical, oceanic regions, having been recorded from there by a number of authors (see Wood, 1963, a).

274. Amphisolenia globifera Stein, Naturges. der arthrodelen Flagell. : 24, pl. 21, figs. 9, 10 (1883); Paulsen, Peridin, Nord. Plankt. : 20, fig. 23 (1908); Lebour, Dinofl. North. Seas : 84, fig. 23, a (1925); Schiller, Dinofl. (1) : 174, fig.

161 (1933).

Local.: NIOE 32, 78.

Recorded in small numbers from an offshore station on line D in April, and an Agulhas Current station on line C in July. It has been previously recorded from the Indian Ocean by Cleve (1901, 1903) and Wood (1962).

275. Amphisolenia schröderii Kofoed, Bull. Mus. Comp. Zool.

Harvard 50 : 201, pl. 13, fig. 81 (1907);

Kofoed & Skogsberg, Mem. Mus. Comp. Zool.

Harvard 51 : 400, fig. 49, pl. 10, figs. 3, 4 (1928); Schiller, Dinofl. (1) : 176, fig. 165 (1933).

Local.: NIOE 91.

One specimen observed in material from a station on the edge of the Agulhas Bank on line D in July, 1963. The only previous Indian Ocean record appears to be that of Wood (1962).

Family ORNITHOCERCACEAE

276. Ornithocercus carolinae Kofoed, Bull. Mus. Comp. Zool.

Harvard 50 : 205, pl. 15, fig. 92 (1907);

Kofoid & Skogsberg, Mem. Mus. Comp. Zool.

Harvard 51 : 572, fig. 89, pl. 17, figs. 1, 6 (1928); Schiller, Dinofl. (1) : 206, fig. 196 (1933); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 210, fig. 64 (1954).

Local.: NIOE 5, 7, 9, 16, 17, 21, 23, 34, 62, 64.

Most widely distributed on line A in April, decreasing southwards, present at only one Agulhas Current station on line D in the same month. In July it was present at two offshore stations on line A. Matzenauer (1933) recorded the species from the vicinity of Cape Guardafui on the east coast of Africa (this record was omitted by Wood, 1963, a).

277. Ornithocerus magnificus Stein, Naturges. der arthodelen Flagell. : pl. 23, figs. 1, 2 (1883); Schutt, Ergebn. Plankton-Exped. der Humboldt-Stift. 4 : 112, pl. 4, fig. 21, 9, pl. 5, fig. 21, 1, 3 - 8 (1895); Kofoid & Skogsberg, Mem. Mus. Comp. Zool. Harvard 51 : 529, figs. 79, 80, pl. 16, fig. 3. (1928); Schiller, Dinofl. (1) : 198, fig. 190 (1933); Wood, Aust. J. Mar. & Freshw. Res. 5 (2): 208, fig. 60 (1954). PLATE 24, fig. 1.

Local.: NIOE 66, 80, 84, 85, 104, 106.

Recorded from northern and southern offshore stations on line B in October. It was never present in large numbers. It has often been recorded from the Indian Ocean (see Wood, 1963, a).

278. Ornithocerus quadratus Schütt, Bot. Ztg. 58 : 5, figs.

1 - 4, 12, 13 (1900); Kofoed & Skogsberg, Mem. Mus. Comp. Zool. Harvard 51 : 561, fig. 85, 5, 86, 87, 88 (1928); Schiller, Dinofl. (1) : 204, figs. 194, 195 (1933); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 209, fig. 63 (1954).
PLATE 24, fig. 2.

Local.: NIOE 10, 66, 110, 144, 153, 158, 159, 164.

Present in small numbers at single stations on lines A and B in April, July and October. In January it was more widespread on lines A and B, and extended south to station 164 on line C. The record of Silva (1956) should be added to those Indian Ocean references listed by Wood (1963, a).

279. Ornithocerus splendidus Schütt, Pflanzenl. der Hochsee :

272, fig. 82 (1893); Kofoed & Skogsberg, Mem. Mus. Comp. Zool. Harvard 51 : 521, figs. 77, 78, pl. 16, figs. 2, 4, pl. 17, fig. 3 (1928); Schiller, Dinofl. (1) : 196, fig. 189 (1933);

Wood, Aust. J. Mar. & Freshw. Res. 5 (2) :
207, fig. 59 (1954).

Local.: NIOE 158.

Only one specimen of this species was observed, in material from the second-most inshore station on line B in January, 1963. It has been occasionally recorded from the Indian Ocean (see Wood, 1963, a, for references).

280. Ornithocerus steinii Schütt, Bot. Ztg. 58 : figs. 5, 6 (1900); Kofoid & Skogsberg, Mem. Mus. Comp. Zool. Harvard 51 : 551, figs. 83, 84, pl. 16, fig. 1 (1928); Schiller, Dinofl. (1) : 202, fig. 192 (1933); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 209, fig. 62 (1954).

Local.: NIOE 66, 110, 146, 153.

A few specimens were observed at single stations on line A in July and October, and at two stations in January, one on line A and the other on line B. There are a few records of the presence of the species in the Indian Ocean (see Wood, 1963, a).

GYMNODINIALES

Family GYMNODINIACEAE

281. Gymnodinium biconicum Schiller, Arch. Prot^{ti}stenk. 62 : 143,
fig. 19 (1928); Schiller, Dinofl. (1) : 337,
fig. 342 (1933).

Local.: NIOE 113.

A single specimen of this species was observed in material from the vicinity of Port Elizabeth in October, 1962. It has not been previously recorded from the Indian Ocean. The species is very similar to G. voukii Schiller.

Family NOCTILUCACEAE

282. Noctiluca scintillans (Macartney) Kofoid & Swezy, Free-living Unarm. Dinofl. : 407, fig. KK (1921);
Lebour, Dinofl. North. Seas : 69, fig. 17 (1925);
Schiller, Dinofl. (1) : 553, fig. 582 (1933,
sub N. miliaris Sururay). PLATE 25, fig. 1.

System.: In all the confusion present in the systematic history of both the genus and its single species (detailed in Kofoid & Swezy, 1921, pp. 411 - 413)

two features stand out clearly. The generic name has been preoccupied by Linneus in the 10th edition of his "Systemae Naturae" (1758) as a synonym for a marine annelid, and the epithet scintillans (Macartney, 1810) has priority over miliaris (Suriray in Lamarck, 1816).

Due to the use of the name Noctiluca by virtually all planktologists since the early part of the 19th century, and its disuse as an annelid name since the references of Linneus, there is a good argument for its conservation in its present application.

Local.: NIOE 2, 17, 18, 19, 20, 25, 34, 35, 36, 37, 58, 59, 60, 64, 66, 67, 69, 71, 76, 77, 78, 84, 85, 89, 94, 95, 96, 97, 114, 130, 160, 176, 178.

This species is commonly found in the material from neritic stations on all lines, occasionally in moderate numbers (+++, at stations 17 and 18). It was most sparse in January. Its presence at occasional offshore stations, e.g. station 25, is probably due to transport off the shelf. The species is often cause of red-water in False Bay near Cape Town (present author's observations) and it is common in water off the west coast of

S. Africa (Hart & Currie, 1960). There are surprisingly few records of the species from the Indian Ocean, and they all refer to its presence in waters off India. Bhimichar & George (1950) reported a very heavy bloom of the species, apparently causing a set-back to coastal fisheries, off the Indian coast.

Family PRONOCILUCACEAE

283. Pronociluca pelagica Fabre-Domerque, Ann. de Micrographie 1 : 356, pl. 3, figs. 9, 10 (1889); Pavillard, Bull. Soc. Bot. France, Ser. 4, 22 : 365 (1922); Lebour, Dinofl. North Seas : 18, fig. 6 (1925); Schiller, Dinofl. (1) : 268, fig. 258 (1933); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 216, fig. 74 (1954). PLATE 26, figs. 2, 3.

Local.: NIOE 93, 177, 178.

A few specimens were observed in material from the vicinity of Cape Agulhas in July and January. Wood (1962) has recorded the species from the Indian Ocean. Marshall (1933) found it present in small numbers throughout the year in the lagoon of the Great Barrier Reef.

284. Pronoctiluca spinifera (Lohmann) Schiller, Dinofl. (1) :

270, fig. 259 (1933); Wood, Aust. J. Mar. &

Freshw. Res. 5 (2) : 217, fig. 75 (1954).

PLATE 26, fig. 1 a, b.

Local.: NIOE 177.

Only one specimen of this species was observed.

It was present at a station^t over the Agulhas

Bank in January, 1963, It has been recorded

previously from the Indian Ocean by Wood (1962).

PERIDINIALES

Family CERATIACEAE

285. Ceratium arietinum forma detortum (Stålwe) Jørgensen,

Rep. Danish Oceanogr. Exped. 1908/10, 2 (J1) :

62, fig. 61 (1922); Schiller, Dinofl. (2) :

404, fig. 444, b (1937); Wood, Aust. J. Mar. &

Freshw. Res. 5 (2) : 295, fig. 221, b, c (1954).

System.: In a footnote to the original description of
the species Cleve (Kongl. Svenska Vet.-Akad.
Handl. 34, no. 1, p. 13, 1900) pointed out that
it was the same as that described by Jørgensen
as Ceratium tripos arcuatum forma heterocampta

(Bergens Mus. Aarbog 1899, 6, pl. 2, fig. 11). Cleve was unaware of Jørgensen's combination whilst preparing his manuscript and it would appear that, as the two are synonymous, and Jørgensen's combination predates that of Cleve, the species should be correctly known as Ceratium heterocamptum (Jørgensen). However, as the present author was unable to refer to Jørgensen's paper referred to, the widely used combination of Cleve has been retained.

Local.: NIOE 62, 111, 128.

Recorded in small numbers from Agulhas Current stations on line A in July, line B in October, and line D in January. Wood (1963, a) has listed several references to the presence of the species in the Indian Ocean, but the early authors did not distinguish between the various forms of the species.

286. Ceratium arietinum forma gracilentum Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10, 2 (J1) : 62, fig. 62 (1922); Schiller, Dinofl. (2) : 404, fig. 444, c (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 295, fig. 221, d (1954).

Local.: NIOE 85.

A single specimen was recorded from an extreme

southern offshore station in July, 1962.

287. Ceratium arietinum forma regulare Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10, 2 (J1) : 62, fig. 60 (1922); Schiller, Dinofl. (2) : 404, fig. 444, a (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 295, fig. 221, a (1954).

Local.: NIOE 120, 124, 146, 153, 164, 166.

Occasional at southern offshore stations in October, and northern and southern offshore stations in January.

288. Ceratium breve (Ostenfeld & Schmidt) Schröder, Vierteljahrschr. Naturf. Ges. Zurich 51 : 358 (1906); Schiller, Dinofl. (2) : 391, fig. 429 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 288, fig. 209 (1954).

Local.: NIOE 119, 129.

Two specimens were observed at stations in October, one oceanic on line C, and one over the Agulhas Bank on line D. The species was first described (as a variety of C. tripos) from the Red and Arabian Seas. Since then it has been recorded from the Indian Ocean by several authors (see Wood, 1963, a). Steemann Nielsen

(1939) found it to be extremely widespread throughout his Indian Ocean material, recording it from the area under present survey.

289. Ceratium buceros forma inclinatum (Kofoid) Schiller, Dinofl. (2) : 415, fig. 456, c (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 302, fig. 231, b, c (1954).

Local.: NIOE 124.

One specimen was recorded from an offshore station on line D in October. The species has been recorded from the Indian Ocean under various synonyms by several authors (listed by Wood, 1963, a). However, they did not distinguish between the various forms.

290. Ceratium buceros forma leptosomum (Jørgensen) Schiller, Dinofl. (2) : 415, fig. 456, d (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 302, fig. 231, d (1954).

Local.: NIOE 62.

One specimen recorded from an offshore station on line A in July.

291. Ceratium candelabrum forma commune Bøhm, Bot. Arch. 31 : 351, figs. 1, 2 (1931); Schiller, Dinofl. (2) :

365, fig. 401 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 273 (1954).

Local.: NIOE 36, 37.

Found in moderate numbers (++) at two stations in the vicinity of Cape Agulhas in April. The species has often been recorded from the Indian Ocean, but there is little data as to the presence of the forms (see Wood, 1963, a, for references).

292. Ceratium candelabrum forma curvulatum Jørgensen, Rep.

Danish Oceanogr. Exped. 1908/10, 2 (J1) : 15, fig. 6 (1920); Schiller, Dinofl. (2) : 365, fig. 402 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 273, fig. 187, a (1954).

Local.: NIOE 3, 5, 12, 16, 19, 20, 28, 66, 71, 76, 84, 89, 99, 103, 108, 110, 150, 157, 164, 166.

The commonest form of the species in the area. It was present in small numbers at scattered stations over the area in April, July and January. In October it was restricted to stations on lines A and B.

293. Caratium candelabrum forma depressum (Pouchet) Bøhm,

Bernice P. Bishop Mus. Bull. 87 : 8, fig. 3, a,c,d

(1931); Schiller, Dinofl. (2) : 366, fig. 403;
 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5
 (2) : 273, fig. 187, b (1954).

Local.: NIOE 35, 177, 178.

Present in moderate numbers (+ - ++) from stations near Cape Agulhas in April and January. Steemann Nielsen (1939), who considered it to be a subspecies, has recorded it from the area under present survey.

294. Ceratium carriense Gourret forma carriense, Ann. Mus.

Hist. Nat. Marseille, Zool. 1 : pl. 4, fig. 57
 (1833); Böhm, Bot. Arch. 31 : 363 (1931);
 Schiller, Dinofl. (2) : 425, fig. 464 (1937);
 Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 308
 (1954).

System.: The species is very similar to C. massiliense, and the present author has identified as this form (carriense) only those specimens which agreed closely with the original description and particularly with Schiller's fig. 464, b.

Local.: NIOE 23, 25, 129, 176.

Found in small numbers at offshore and inshore stations on lines C and D in April, October and January. Wood (1963, a) has listed several

records of the species in ^{the} Indian Ocean, most of which refer to the forma volans but some refer to the typical form.

295. Ceratium carriense forma volans (Cleve) Jørgensen, Int. Rev. Hydrob. & Hydrogr. 4, suppl. (1) : figs. 148, 149 (1911); Schiller, Dinofl. (2) : 426, fig. 465 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 309, fig. 236, a (1954).

Local.: NIOE 71, 164.

Two specimens were observed from an offshore station on line B in July and an offshore station on line C in January. The form was originally described (as C. volans) from the Atlantic by Cleve (1900, c).

296. Ceratium cephalotum (Lemmermann) Jørgensen, Int. Rev. Hydrob. & Hydrogr. 4, suppl. (1) : 10, fig. 10 (1911); Steemann Nielsen, Unders. Verbreit. Biol. & Variat. Ceratien sùdl. Stiller Ozean : 7, fig. 2 (1934); Schiller, Dinofl. (2) : 356, fig. 388 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 271, fig. 185 (1954).

Local.: NIOE 110.

Only one specimen of this interesting species was observed, in material from an Agulhas Current

station on line B in October. Wood (1963, a) has listed several records of this species in the Indian Ocean.

297. Ceratium concillans Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10 : 72, fig. 69 (1920); Steemann Nielsen, Unders. Verbreit. Biol. & Variat. Ceratien südl. Stiller Ozean : 22, fig. 49 (1934); Schiller, Dinofl. (2) : 396, fig. 435 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 290, fig. 213 (1954).

Local.: NIOE 62, 128, 142, 146, 150.

Found occasionally at offshore stations on line A in July and January. It was also found at a southern station on line D in October. It has been recorded from the Indian Ocean by Karsten (1907), Steemann Nielsen (1939), and Wood (1954, 1962).

298. Ceratium declinatum forma brachiatum Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10 : fig. 64 (1920); Schiller, Dinofl. (2) : 406, fig. 445, b (1937).

Local.: NIOE 157, 162.

Found in small numbers at two offshore stations on lines C and D in January, 1963. The species

was first described by Karsten (1907) from the Indian Ocean, but this form does not appear to have been recorded previously from the Indian Ocean.

299. Ceratium digitatum Schütt, Ergebn. Plankton-Exped. der Humboldt-Stift. 4 : pl. 12, fig. 42 (1895); Steemann Nielsen, Unders. Vebreit. Biol. & Variat. Ceratien südl. Stiller Ozean : 8, fig. 5 (1934); Schiller, Dinofl. (2) : 358, fig. 392 (1937).

Local.: NIOE 9.

Several individuals were observed in material from an offshore station on line A in April, 1962. It has been recorded from the Indian Ocean previously by Karsten (1907); Steemann Nielsen (1939) and Wood (1962).

300. Ceratium extensum (Gourret) Cleve, Kongl. Svenska Vet.-Akad. Handl. 35 (5) : 215 (1901); Lebour, Dinofl. North. Seas : 146, fig. 146, a (1925); Steemann Nielsen, Unders. Verbreit. Biol. & Variat. Ceratien südl. Stiller Ozean : 14, fig. 24 (1934); Schiller, Dinofl. (2) : 380, fig. 419 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 283, fig. 203, a (1954).

Local.: NIOE 3, 5, 7, 9, 10, 12, 14, 16, 17, 19, 20, 21, 23, 25, 27, 28, 30, 32, 58, 91, 93, 95, 115, 117, 119, 120, 142, 153, 162, 164, 166, 168, 169, 172.

Widely distributed on all lines in April.

Only recorded from two stations in July (northern and southern), and stations on lines A and C in October. In January it was widely distributed in the south on lines C and D. It was fairly abundant (+++ - +++) at stations 9, 28, and 30 in April. See Wood (1963, a) for Indian Ocean references.

301. Ceratium falcatifforme Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10 : 40, fig. 29 (1920); Schiller, Dinofl. (2) : 378, fig. 417 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 282, fig. 201 (1954).

Local.: NIOE 27, 30, 87, 88, 160, 162, 174, 176.

Recorded from southern stations in the vicinity of the Subtropical Convergence region in April, July and January. In the latter month it was also present near Port Elizabeth. It has been previously recorded from the Indian Ocean by Karsten (1907), Steemann Nielsen (1939), and Wood (1954, 1962).

Local.: NIOE 3, 5, 7, 9, 10, 12, 14, 16, 17, 19, 20, 21, 23, 25, 27, 28, 30, 32, 58, 91, 93, 95, 115, 117, 119, 120, 142, 153, 162, 164, 166, 168, 169, 172.

Widely distributed on all lines in April.

Only recorded from two stations in July (northern and southern), and stations on lines A and C in October. In January it was widely distributed in the south on lines C and D. It was fairly abundant (+++ - +++) at stations 9, 28, and 30 in April. See Wood (1963, a) for Indian Ocean references.

301. Ceratium falcatifforme Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10 : 40, fig. 29 (1920); Schiller, Dinofl. (2) : 378, fig. 417 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 282, fig. 201 (1954).

Local.: NIOE 27, 30, 87, 88, 160, 162, 174, 176.

Recorded from southern stations in the vicinity of the Subtropical Convergence region in April, July and January. In the latter month it was also present near Port Elizabeth. It has been previously recorded from the Indian Ocean by Karsten (1907), Steemann Nielsen (1939), and Wood (1954, 1962).

Local.: NIOE 3, 5, 7, 9, 10, 12, 14, 16, 17, 19, 20, 21, 23, 25, 27, 28, 30, 32, 58, 91, 93, 95, 115, 117, 119, 120, 142, 153, 162, 164, 166, 168, 169, 172.

Widely distributed on all lines in April.

Only recorded from two stations in July (northern and southern), and stations on lines A and C in October. In January it was widely distributed in the south on lines C and D. It was fairly abundant (+++ - +++) at stations 9, 28, and 30 in April. See Wood (1963, a) for Indian Ocean references.

301. Ceratium falcatifforme Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10 : 40, fig. 29 (1920); Schiller, Dinofl. (2) : 378, fig. 417 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 282, fig. 201 (1954).

Local.: NIOE 27, 30, 87, 88, 160, 162, 174, 176.

Recorded from southern stations in the vicinity of the Subtropical Convergence region in April, July and January. In the latter month it was also present near Port Elizabeth. It has been previously recorded from the Indian Ocean by Karsten (1907), Steemann Nielsen (1939), and Wood (1954, 1962).

302. Ceratium falcatum (Kofoid) Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10 : 39, fig. 28 (1920); Schiller, Dinofl. (2) : 377, fig. 417 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 281, fig. 200 (1954).

Local.: NIOE 94, 104, 108, 164.

Recorded in small numbers from an inshore station near Cape Agulhas in July, and from southern offshore stations in October and January. Wood (1963, a) has provided Indian Ocean references for this species.

303. Ceratium furca var. bergii (Jørgensen) Schiller, Dinofl. (2) : 367, fig. 404 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 274, fig. 189, a (1954).

Local.: NIOE 164.

One specimen of this variety was identified in material from an offshore station on line C in January. It has been recorded from the Indian Ocean by numerous authors (see Wood, 1963, a).

304. Ceratium furca var. eugrammum (Ehrenberg) Schiller, Dinofl. (2) : 368, fig. 405, a (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 275, fig. 189, b, c (1954).

System.: Schiller assigned the variety to Jørgensen, but this is incorrect, as Jørgensen considered it to be a subspecies.

Local.: NIOE 93, 113, 114, 160, 162, 176, 177, 178.

Found at stations over the shelf in the southwest on lines C and D in July, October and January. It occurred in moderate abundance (+++) at station 160 near Port Elizabeth. There are a few references to the presence of this variety in the Indian Ocean (see Wood, 1963, a).

305. Ceratium fusus var. seta (Ehrenberg) Jørgensen, Int. Rev. Hydrobiol. & Hydrogr. 4, suppl. (1) : 29, fig. 55 (1911); Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10 : 41, fig. 30 (1920); Schiller, Dinofl. (2) : 379, fig. 418, d (1937).

Local.: NIOE 2, 23, 27, 28, 32, 34, 35, 36, 60, 64, 66, 67, 84, 91, 96, 110, 112, 120, 121, 124, 126, 148, 155, 174.

Recorded in small numbers from scattered stations on all cruises, chiefly in the south. There are many references to the presence of the species in the Indian Ocean (see Wood, 1963, a), but the early authors did not

distinguish between the various varieties of the species. It is probable that they were referring to this variety as the only other (var. shüttii) is a cold-water form.

306. Ceratium geniculatum (Lemmermann) Cleve : ? ; Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 279, fig. 197 (1954).

System.: Schiller (1937, p. 375) has referred the above combination to Cleve's "Plankton from the Indian Ocean and Malay Archipelago" (1901), giving no page or figure reference numbers. This appears to be an error as the present author can find no mention of the species in the work referred to, or in any other works of Cleve's prior to the use of the combination by Karsten (1907, p. 415, pl. 50, fig. 3).

Local.: NIOE 62, 76, 128.

Single specimens were observed at each of the above stations, i.e. a northern and southern station in July, and an Agulhas Current station on line D in October. Other Indian Ocean records of this species are those of Karsten (1907), Steemann-Nielsen (1939) and Wood (1962).

307. Ceratium gibberum forma dispar (Pouchet) Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10 : 70, fig. 67 (1920); Schiller, Dinofl. (2) : 398, fig. 436 (1937).

Local.: NIOE 60, 108.

Two specimens of this form were recorded from offshore stations on lines A and B in July and October respectively. The species has been recorded by many authors as being present in the Indian Ocean (see Wood, 1963, a) but the forms were not distinguished by most of them.

308. Ceratium gibberum forma subaequale Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10 : 70, fig. 68 (1920); Schiller, Dinofl. (2) : 398, fig. 437 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 290, fig. 214, c (1954).

Local.: NIOE 84.

One specimen was present at a southern offshore station in July, 1962.

309. Ceratium gravidum Gourret, Ann. Mus. Hist. Nat. Marseille, Zool. 1 : 58, pl. 1, fig. 15 (1883); Steemann Nielsen, Unders. Verbreit. Biol. & Variat. Ceratien südl. Stiller Ozean : 8, figs. 3, 4 (1934);

307. Ceratium gibberum forma dispar (Pouchet) Jørgensen, Rep.

Danish Oceanogr. Exped. 1908/10 : 70, fig. 67
(1920); Schiller, Dinofl. (2) : 398, fig. 436
(1937).

Local.: NIOE 60, 108.

Two specimens of this form were recorded from offshore stations on lines A and B in July and October respectively. The species has been recorded by many authors as being present in the Indian Ocean (see Wood, 1963, a) but the forms were not distinguished by most of them.

308. Ceratium gibberum forma subaequale Jørgensen, Rep. Danish

Oceanogr. Exped. 1908/10 : 70, fig. 68 (1920);
Schiller, Dinofl. (2) : 398, fig. 437 (1937);
Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 290,
fig. 214, c (1954).

Local.: NIOE 84.

One specimen was present at a southern offshore station in July, 1962.

309. Ceratium gravidum Gourret, Ann. Mus. Hist. Nat. Marseille,

Zool. 1 : 58, pl. 1, fig. 15 (1883); Steemann
Nielsen, Unders. Verbreit. Biol. & Variat.

Ceratien südl. Stillen Ozean : 8, figs. 3, 4 (1934);

Schiller, Dinofl. (2) : 357, fig. 389 (1937);
 Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 272,
 fig. 186 (1954).

Local.: NIOE 157, 159.

Recorded in small numbers from inshore stations on line B in January. The species has been recorded from the Indian Ocean by several authors (listed by Wood, 1963, a) including Steemann Nielsen (1939) who found it present at a station in the south-west of the area under present survey.

310. Ceratium hexacanthum forma spirale (Kofoid) Schiller,
 Dinofl. (2) : 422, fig. 462, c (1937).

Local.: NIOE 5.

One specimen of this curious form was observed in material from an offshore station on line A in April. The species has been frequently recorded from the Indian Ocean previously but apparently not this form.

311. Ceratium horridum Gran, Rep. Norweg. Fish. & Mar. Invest.
2 (5) : 54, 193, 194 (1902); Bøhm, Arch.
 Protistenk. 75 : 41, fig. 86 (1931); Schiller,
 Dinofl. (2) : 413, fig. 455 (1937); Wood, Aust.

J. Mar. & Freshw. Res. 5 (2) : 300, fig. 230
(1954).

Local.: NIOE 27.

This species occurred in moderate numbers at an extreme southern offshore station in April.

The only previous Indian Ocean records of this species appear to be those of Subrahmanyam (1958) and Wood (1962).

312. Ceratium hircus Schröder, Ber. Deutsche Bot. Ges. 27 : 211, fig. 2 (1909); Jørgensen, Int. Rev. Ges. Hydrob. & Hydrogr. 4, suppl. (1) : 18, fig. 27 (1911); Schiller, Dinofl. (2) : 369, fig. 406 (1937).

Local.: NIOE 27, 36, 37, 77, 89, 108.

Found chiefly at inshore and offshore stations on lines C and D in April and July. In October one specimen was recorded from an offshore station on line B. It was present in fairly large numbers (+++) near Cape Agulhas in July. The species has not been recorded from the Indian Ocean prior to the present survey, the early records being restricted to the West Indies region.

313. Ceratium incisum (Karsten) Jørgensen, Int. Rev. Ges.

Hydrob. & Hydrogr. 4, suppl. (1) : 19, figs. 29, 30 (1911); Schiller, Dinofl. (2) : 370, fig. 407, b (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 275, fig. 190 (1954).

Local.: NIOE 76.

One specimen of this species was found at an inshore station near Port Elizabeth in July. Wood (1963, a) has listed several references to the presence of the species in the Indian Ocean.

314. Ceratium inflatum (Kofoid) Jørgensen, Int. Rev. Ges. Hydrob.

& Hydrogr. 4, suppl. (1) : 25, figs. 45, 46, 48, a (1911); Böhm, Arch. Protistenk. 75 : 14, fig. 10 (1931); Schiller, Dinofl. (2) : 376, fig. 415 (1937); Wood, Aust. J. Mar. & Freshw. 5 (2) : 281, fig. 198 (1954).

Local.: NIOE 62, 71.

Recorded in small numbers from offshore stations on lines A and B in July. It has been recorded occasionally from the Indian Ocean prior to the present survey (see Wood, 1963, a).

315. Ceratium karstenii Pavillard forma karstenii, Bull. Soc.

Bot. France 54 : 152 (1907); Schiller, Dinofl.

(2) : 393, fig. 431 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 289, fig. 211 (1954).

Local.: NIOE 1, 3, 7, 9, 12, 21, 25, 71, 146, 164, 166.

Occasionally found in small numbers at stations on lines A, B and C in April, line B in July, and lines A and C in January. It did not appear to be present in the October material. Numerous authors have recorded its presence in the Indian Ocean (see Wood, 1963, a).

316. Ceratium karstenii forma robustum (Karsten) Jørgensen, Int. Rev. Ges. Hydrob. & Hydrogr. 4, suppl. (1) : 54, fig. 118 (1911); Schiller, Dinofl. (2) : 394, fig. 432 (1937).

Local.: NIOE 64.

It was recorded in small numbers from an offshore station on line A in July.

317. Ceratium kofoidii Jørgensen, Int. Rev. Ges. Hydrob. & Hydrogr. 4, suppl. (1) : 23, figs. 38, 39 (1911); Schiller, Dinofl. (2) : 373, fig. 412 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 278, fig. 195 (1954).

Local.: NIOE 18.

One specimen was observed in material from an inshore station on line B in April. It has been

rarely recorded from the Indian Ocean (see Wood, 1963, a).

318. Ceratium lineatum (Ehrenberg) Cleve, Kongl. Svenska Vet.-Akad. Handl. 32 (3) : 36 (1899); Schiller, Dinofl.(2) : 372, fig. 410 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 277, fig. 192 (1954).

Local.: NIOE 28, 64.

Two specimens of this species were seen, one at an extreme southern station in the vicinity of the Subtropical Convergence region, and one further north at an offshore station on line A in July. It is interesting to note that this species is considered by Wood (1964) to be an indicator of water of a subantarctic origin, and its local distribution, scant though it may be, supports the other observed records of the northward spread of subantarctic species into the area in July (winter). The other Indian Ocean records of this species, listed by Wood (1963, a) are probably remnants of this type of northern spread.

319. Ceratium limulus Gourret, Ann. Mus. Hist. Nat. Marseille, Zool. 1 : 33, pl. 1, fig. 7 (1883); Steemann

Nielsen, Unters. Verbreit. Biol. & Variat.
 Ceratien südl. Stiller Ozean : 24, fig. 45
 (1934); Schiller, Dinofl. (2) : 407, fig. 448
 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5
 (2) : 296, fig. 223 (1954).

Local.: NIOE 71, 120, 128.

Recorded in small numbers from an offshore station on line B in July, and two southern offshore stations in October. The species has been recorded from the Indian Ocean by several authors (see Wood, 1963, a).

320. Ceratium longirostrum Gouret, Ann. Mus. Hist. Nat.

Marseille, Zool. 1 : 55, pl. 4, fig. 65 (1883);
 Schiller, Dinofl. (2) : 376, fig. 416 (1937);
 Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 281,
 fig. 199 (1954).

Local.: NIOE 5, 28, 32, 69, 71, 73, 76, 77, 78, 80,
 85, 99, 101, 103, 106, 108, 146, 162.

In general this species occurred at offshore stations in the north (line A) and inshore further south (line C). It was present in moderate numbers (++) at stations 28, 99 and 108 in April and October. It has been recorded occasionally from the Indian Ocean by other authors (see Wood, 1963, a).

321. Ceratium lunula Schimper ex Chun, Aus den Tiefen des Weltmeeres : 73, text. fig. a (1900); Schimper ex Karsten, 'Valdivia' Atlant. Phytopl. : pl. 20, fig. 12 (1906); Schiller, Dinofl. (2) : 399, fig. 439 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 291, fig. 215 (1954).

Local.: NIOE 148.

One specimen was recorded from an offshore station on line A in January, 1963. There are several prior records of the species' occurrence in the Indian Ocean (see Wood, 1963, a).

322. Ceratium macroceros (Ehrenberg) Cleve, Göteborgs K. Vetensk. och. Vitterhets. Handl. 17 : 227 (1900); Karsten, 'Valdivia' Atlant. Phytopl. : 145, pl. 22, fig. 29 (1906); Paulsen, Peridin. Nord. Plankt. : 81, fig. 109 (1908); Schiller, Dinofl. (2) : 428, fig. 468 (1937); Wood, Aust. J. Mar. & Freshw. 5 (2) : 310, fig. 238a (1954). Non. C. macroceras Shrank (1802).

System.: Cleve transferred Peridinium macroceros Ehrenberg to the genus Ceratium. However, it would appear that the combination C. macroceros was preoccupied by that of Shrank (now considered a synonym of C. hirundinella, see Schiller, 1937,

321. Ceratium lunula Schimper ex Chun, Aus den Tiefen des Weltmeeres : 73, text. fig. a (1900); Schimper ex Karsten, 'Valdivia' Atlant. Phytopl. : pl. 20, fig. 12 (1906); Schiller, Dinofl. (2) : 399, fig. 439 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 291, fig. 215 (1954).

Local.: NIOE 148.

One specimen was recorded from an offshore station on line A in January, 1963. There are several prior records of the species' occurrence in the Indian Ocean (see Wood, 1963, a).

322. Ceratium macroceros (Ehrenberg) Cleve, Göteborgs K. Vetensk. och. Vitterhets. Handl. 17 : 227 (1900); Karsten, 'Valdivia' Atlant. Phytopl. : 145, pl. 22, fig. 29 (1906); Paulsen, Peridin. Nord. Plankt. : 81, fig. 109 (1908); Schiller, Dinofl. (2) : 428, fig. 468 (1937); Wood, Aust. J. Mar. & Freshw. 5 (2) : 310, fig. 238a (1954). Non. C. macroceras Shrank (1802).

System.: Cleve transferred Peridinium macroceros Ehrenberg to the genus Ceratium. However, it would appear that the combination C. macroceros was preoccupied by that of Shrank (now considered a synonym of C. hirundinella, see Schiller, 1937,

p. 359). Unfortunately the present author was not able to refer to Shrank's publication and so has left the species under Cleve's name for the purposes of this study. Steemann Nielsen (1939) attributed the above combination to Vanhöffen but gave no reference.

Local.: NIOE 16, 95, 96, 97, 174.

Recorded in small numbers from Agulhas Current stations on line A in April and also from a southern offshore station in January. It has been recorded from the Indian Ocean by numerous authors (see Wood, 1963, a) including Steemann Nielsen (1939) who found it present at several "Dana" stations in the area under present study.

323. Ceratium massiliense var. armatum (Karsten) Jørgensen, Int. Rev. Ges. Hydrob. & Hydrogr. 4, suppl. (1) : 66, fig. 146 (1911); Schiller, Dinofl. (2) : 424, fig. 463, b (1937, as forma); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 308, fig. 235, b (1954, as forma).

Local.: NIOE 3, 14, 25, 27, 28, 32, 34, 35, 36, 58, 64, 66, 75, 76, 77, 78, 80, 85, 87, 88, 91, 111, 120, 121, 124, 128, 142, 159, 176, 177.

This variety was commonly present in small numbers at offshore stations over the whole area

in April and July. In October it was restricted to the southern lines only, and in January it was found at inshore stations only. It was often found to be mixed with the variety macroceroides (below). A comparison of the local distributions of the two, most easily seen by reference to the Relative Abundance Table for Dinoflagellates in the appendix, has led the present author to doubt Schiller's designation of the taxa as forms, and to retain Jørgensen's varietal separation of them.

The species has been recorded from the Indian Ocean by several authors. In addition to those listed by Wood (1963, a) there is the reference of Bernard & Lecal (1960). Steemann Nielsen (1939) recorded the species from several stations situated in the area under present study.

324. Ceratium massiliense var, macroceroides (Karsten)

Jørgensen, Int. Rev. Ges. Hydrob. & Hydrogr. 4, suppl. (1) : 66, fig. 463, a (1911); Schiller, Dinofl. (2) : 424, fig. 463, a (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 308, fig. 235, a (1954).

Local.: NIOE 1, 2, 3, 5, 7, 9, 10, 12, 14, 16, 17, 18, 19, 20, 21, 23, 25, 30, 34, 58, 60, 62, 67, 69, 71, 74, 76, 77, 78, 80, 84, 85, 89, 93, 96, 99, 101, 103, 104, 108, 110, 111, 112, 117, 128, 142, 143, 144, 146, 153, 155, 158, 166, 176, 177, 178.

Widely distributed in moderate numbers (+ - +++) in the inshore and offshore areas in April, July and October. In January it was more restricted to inshore waters. Although found on all lines at all seasons it tended to be more continuously distributed in the north, only occurring at scattered stations in the south. If the former variety, robusta is combined with the distribution of this variety then the resultant distribution covers virtually every station sampled in April and July.

The species may be considered to be the most characteristic dinoflagellate of the sector of the Indian Ocean investigated.

325. Ceratium minutum Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10 : 34, figs. 21 - 23 (1920); Lebour, Dinofl. North. Seas. : 145, pl. 30, fig. 4 (1925); Schiller, Dinofl. (2) : 374, fig. 413 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2):

279, fig. 196 (1954).

Local.: NIOE 28.

A few specimens of this species were observed in material from an extreme offshore station in the south near the Subtropical Convergence region in April. The species has been previously recorded from the Indian Ocean by Schröder (1906) and Wood (1954, 1962).

326. Ceratium paradoxides Cleve, Kong. Svenska Vet.-Akad. Handl. 34 (1) : 15, pl. 7, fig. 14 (1900); Jørgensen, Int. Rev. Ges. Hydrob. & Hydrogr. 4, suppl. (1) : 57, fig. 123 (1911); Steemann Nielsen, Unders. Verbreit. Biol. & Variat. Ceratien südl. Stiller Ozean : 24, fig. 55 (1934); Schiller, Dinofl. (2) : 408, fig. 449 (1937); Wood, Aust. J. Mar. & Freshw. 5 (2) : 296 (1954). PLATE 27, fig. 3.

Local.: NIOE 9, 35, 36, 58, 89, 119, 146.

Found in small numbers at a few widely scattered stations in April (lines A and D). In July it was inshore near Durban and offshore on line D. In October it was present at an offshore station on line C, and in January at an offshore station on line A. It has been previously

recorded from the Indian Ocean by Schröder (1906) and Steemann Nielsen (1939).

327. Ceratium pentagonum forma robustum (Cleve) Jørgensen, Int. Rev. Ges. Hydrob. & Hydrogr. 4, suppl. (1) : 20, fig. 32 (1911); Schiller, Dinofl. (2) : 371, fig. 408, a (1937).

Local.: NIOE 2, 3, 14, 25, 30, 35, 36, 37, 58, 62, 73, 76, 77, 78, 84, 85, 88, 91, 108, 110, 111, 112, 113, 114, 117, 121, 142, 143, 144, 146, 150, 153, 155, 160, 162, 164, 174, 176, 177, 178.

A common species in the area. In April it was found at offshore stations on lines A, B and C, and at stations over the Agulhas Bank on line D. In July it was present at inshore stations on lines A, B, and C, and offshore on line D. In October it was absent from stations on line A, but was otherwise similar to the July distribution pattern. In January it was similar to the April distribution pattern, i.e. more widely spread on the northern lines. It was never present in large numbers at any station. It has been recorded by several earlier authors as being present in the Indian Ocean (see Wood, 1963, a). Steemann Nielsen (1939) found the species

by Wood (1963, a).

330. Ceratium porrectum Karsten, 'Valdivia' Indische Phytopl. :
 pl. 51, fig. 6 (1907); Jørgensen, Int. Rev.
 Ges. Hydrob. & Hydrogr. 4, suppl. (1) :
 35, figs. 63, 64 (1911); Schiller, Dinofl.
 (2) : 389, fig. 427, a (1937); Wood, Aust. J.
 Mar. & Freshw. Res. 5 (2) : 287, fig. 207
 (1954).

Local.: NIOE 128, 178.

This species was observed only at stations on the Agulhas Bank in October and January. It occurred in moderate numbers (+++) at stations 178 near Cape Agulhas. It was originally described by Karsten (1907) from the vicinity of the Seychelles Islands, and has since been recorded from the Indian Ocean by Wood (1962).

331. Ceratium praelongum (Lemmermann) Kofoed, ? : 182 (1907);
 Schiller, Dinofl. (2) : 356, fig. 387 (1937).

The author was unable to determine in which of Kofoed's '1907' publications the combination was proposed as Schiller (1937) did not distinguish them in his literature citations and several of Kofoed's papers published in

that year were not available to the author for study.

Local.: NIOE 96.

One specimen was recorded from a station near Durban in October. The species has been recorded from the northern and eastern regions of the Indian Ocean (see references listed by Wood, 1963, a, and chart 3 in Steemann Nielsen, 1939), but not from the S.W. Indian Ocean prior to the present study.

332. Ceratium pulchellum forma eupulchellum Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10 : 50, fig. 46 (1920); Schiller, Dinofl. (2) : 386, fig. 422 (1937); Wood, Aust. J. Mar. & Freshw. ^{Res.} 5 (2); 286, fig. 206, a (1954).

Local.: NIOE 96, 128, 129, 150, 155, 157, 162, 178.

Recorded in small numbers from inshore stations on lines A and D in October. In January it was present at offshore stations on the northern lines and inshore stations in the southwest. Wood (1963, a) has listed the Indian Ocean references to the species and to this form (as a variety), omitting that of Silva (1956).

333. Ceratium pulchellum forma semipulchellum Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10 : 50, figs. 43, 44 (1920); Schiller, Dinofl. (2): 387, fig. 423 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 286, fig. 206, b, c (1954).

Local.: NIOE 164, 176, 178.

Found in small numbers at southern offshore and inshore stations in January only. Wood (1963, a) has listed several Indian Ocean references to this form (as a variety).

334. Ceratium ranipes forma palmatum (Schröder) Jørgensen, Rep. Danish Oceanogr. Exped. 1908/10 : 82, fig. 76 (1920); Schiller, Dinofl. (2) : 410, fig. 451, b (1937).

Local.: NIOE 69, 71, 97.

Recorded in small numbers from two adjacent offshore stations on line B in July, and from a station near Durban in October. Most of the Indian Ocean references listed by Wood (1963, a) refer to this form of the species.

335. Ceratium schmidtii Jørgensen, Int. Rev. Ges. Hydrob. & Hydrogr. 4, suppl. (1) : 50, figs. 110, 111 (1911); Böhm, Arch. Protistenk. 75 : 24, fig. 22 (1931); Schiller, Dinofl. (2) : 400, fig.

440 (1937); Wood, Aust. J. Mar. & Freshw. Res.
5 (2) : 291, fig. 216 (1954).

Local.: NIOE 5, 7, 9, 10, 16, 17, 18, 20, 21, 25, 28,
 32, 34, 36, 58, 69, 73, 82, 84, 85, 87, 89, 91,
 103, 108, 144, 155, 157, 158, 161, 178.

A fairly common species in April when it was present in small numbers at offshore and inshore stations over most of the area. In July it was most widespread at southern offshore stations. In October it was only present at two isolated offshore stations on lines A and B, and in January it was more limited to inshore stations on all lines. It has been recorded from the Indian Ocean by several authors (see Wood, 1963, a) including Steemann Nielsen (1939) who found it at a station over the Agulhas Bank as well as further north of the area under present study.

336. Ceratium schröterii Schröder, Vierteljahrschr. Naturf. Ges. Zurich 51 : 308, fig. 43 (1906); Schiller, Dinofl. (2) : 358, fig. 391 (1937).

Local.: NIOE 87, 108.

Two specimens were observed, one at a southern offshore station (line D) in July, and one at

an offshore station on line B in October.

The species has been previously recorded from the Indian Ocean by Schröder (1906); Silva (1956) and Wood (1962).

337. Ceratium setaceum Jørgensen, Int. Rev. Ges. Hydrob. & Hydrogr. 4, suppl. (1) : 23, figs. 40, 41 (1911); Steemann Nielsen, Unders. Verbreit. Biol. & Variat. Ceratien südl. Stiller Ozean : 12, fig. 16 (1934); Schiller, Dinofl. (2) : 373, fig. 411 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 278, fig. 194 (1954).

Local.: NIOE 17, 74, 128, 144, 158, 160, 161, 174.

Recorded from inshore stations only. In April and July it was present at one station on line B. In October it was found on the edge of the Agulhas Bank on line D, and in January it was present at inshore stations on all lines. Steemann Nielsen (1939) found it to have a similar distribution to Ceratium pentagonum in the Indian Ocean. Other Indian Ocean references have been given by Wood (1963, a).

338. Ceratium symmetricum Pavillard, Mem. Univ. Montpellier 2 : 52, pl. 1, fig. 4 (1905); Steemann Nielsen,

Unters. Verbreit. Biol. & Variat. Ceratien
südl. Stiller Ozean : 19, figs. 40, 41
(1934); Schiller, Dinofl. (2) : 401, fig.
441 (1937); Wood, Aust. J. Mar. & Freshw.
Res. 5 (2) : 292, fig. 217 (1954).

Local.: NIOE 64, 106.

Recorded in small numbers from northern
offshore stations in July and October.
It has been previously identified from the
Indian Ocean by Karsten (1907), Steemann
Nielsen (1939), and Wood (1954, 1962).

339. Ceratium teres Kofoed, Univ. Calif. Publ. Zool. 3 :
308, pl. 29, figs. 34 - 36 (1907); Jørgensen,
Rep. Danish Oceanogr. Exped. 1908/10 : 28, fig.
18 (1920); Schiller, Dinofl. (2) : 372, fig.
409 (1937); Wood, Aust. J. Mar. & Freshw.
Res. 5 (2) : 277, fig. 193 (1954).

Local.: NIOE 2, 3, 5, 7, 9, 10, 12, 14, 16, 17,
21, 23, 25, 34, 58, 59, 60, 71, 73, 80, 91,
95, 99, 101, 103, 110, 111, 115, 146, 148,
150, 164.

A common species in the northern part of the
area in April when it was widely distributed
on lines A and B and more restricted to

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

inshore areas in the south. In July it was not present in the most offshore regions but occurred on all lines further inshore. In October it was restricted to the northern lines A and B. In January it was found at offshore stations on lines A and C. It has been previously recorded from the Indian Ocean by Steemann Nielsen (1939, including two stations in the area under present survey), Wood (1954, 1962) and Subrahmanyam (1958).

340. Ceratium trichoceros (Ehrenberg) Kofoed, Univ. Calif.

Publ. Zool. 4 (7) : 388 (1908); Steemann Nielsen, Unters. Verbreit. Biol. & Variat. Ceratien südl. Stiller Ozean : 27, fig. 68 (1934); Schiller Dinofl. (2) : 430, fig. 470 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 311, fig. 239 (1954).

Local.: NIOE 21, 23, 96, 110, 111, 160, 161, 166, 174.

Occasionally present, chiefly at offshore stations. In April it was recorded from two stations on line C. It was not present in the July material. In October it was closer inshore on lines A and B, and in

January it was found further south, inshore and offshore on lines C and D. The species has often been recorded from the tropical regions of the Indian Ocean (see Wood, 1963, a). Steemann Nielsen (1939) found it occurring northwards from Cape Agulhas through the area under present study.

341. Ceratium tripos (O.F. Müller) Nitzsch. Beitrag Infus. oder Naturbeschr., Zerkarien & Bazillarien : 4 (1817); Paulsen, Peridin. Nord. Plankt. : 77, figs. 102 - 107 (1908); Lebour, Dinofl. North. Seas : 148, pls. 32, 33 (1925); Schiller, Dinofl. (2) : 382, fig. 421 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 284 (1954).

System.: This highly variable species is represented by several varieties and forms in the area, namely var. atlanticum Ostenfeld, forma balticum Schütt, forma ponticum Jørgensen, and forma subsalum Ostenfeld. There were many intermediates between these in the S.W. Indian Ocean material and these are listed under C. tripos without distinction in the Relative Abundance Table for

dinoflagellates. The commonest recognisable form in the area was f. subsalum. A separate consideration of each of these forms would be of dubious value (they are listed separately in the table) and they are here considered together.

Local.: NIOE 2, 3, 5, 9, 10, 17, 21, 28, 35, 36, 37, 58, 62, 64, 69, 71, 73, 76, 78, 80, 84, 85, 88, 89, 91, 93, 94, 95, 96, 103, 104, 106, 108, 110, 111, 112, 113, 114, 115, 119, 130, 142, 153, 158, 160, 161, 174, 177.

The species was widely distributed at northern offshore stations and southern inshore stations in April. In July it spread further offshore in the south with moderate numbers (+++) of the forma subsalum present over the Agulhas Bank near Cape Agulhas. In October it was once more widespread on the northern lines. In January it was sparse, being recorded mainly from scattered inshore stations. The record of Bernard & Lecal (1960) should be added to the Indian Ocean records of this species listed by Wood (1963, a).

342. Ceratium vultur var. sumatranum (Karsten) Steemann

Nielsen, Unders. Verbreit. Biol. & Variat.
Ceratien südl. Stiller Ozean : 27, figs.
65, 66 (1934); Schiller, Dinofl. (2) :
419, fig. 460 (1937); Wood, Aust. J. Mar..
& Freshw. Res. 5 (2) : 305, fig. 233, d
(1954).

Local.: NIOE 16, 17, 21, 93, 96.

Recorded in small numbers from stations on
the edge of the shelf on lines B and C in
April, a southern shelf station (line D)
in July, and an inshore station near Durban
in October. This variety has been
frequently recorded from the Indian Ocean
(see Wood, 1963, a).

Family CERATOCORYACEAE

343. Ceratocorys armata (Schütt) Kofoid, Univ. Calif. Publ.

Zool. 6 : 181 (1910); Schiller, Dinofl. (2) :
444, fig. 486 (1937); Wood, Aust. J. Mar. &
Freshw. Res. 5 (2) : 314, fig. 243 (1954).

Local.: NIOE 17, 77, 87, 95, 115, 117, 142.

Found in small numbers at an inshore station
on line B in April, two southern stations in

July (one inshore, one offshore), an inshore station near Durban and two offshore stations on line C in October, and at an inshore station near Durban in January. It has been previously recorded from the Indian Ocean by Ostenfeld & Schmidt (1901), Schröder (1906), Matzenauer (1933) and Wood (1962), the earlier authors using various synonyms.

344. Ceratocorys gourretii Paulsen, Minist. Fomento Inst. Espan. Oceanogr. (4) : fig. 488 B (1930); Schiller, Dinofl. (2) : 446, fig. 488 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 314, fig. 244 (1954).

Local.: NIOE 7, 66, 128.

Single individuals observed at an offshore station on line A in April, a similar locality in July, and a southern station on the edge of the Agulhas Bank in October. Wood (1963, a) has listed a few records of this species from the Indian Ocean, to which that of Silva (1956) should be added.

345. Ceratocorys horrida Stein, Naturges. der arthrodelen Flagell. : 20, pl. 6, figs. 4 - 11 (1883);

Kofoed, Univ. Calif. Publ. Zool. 6 : 180
(1910); Schiller, Dinofl. (2) : 443, fig.
485 (1937); Wood, Aust. J. Mar. & Freshw.
Res. 5 (2) : 313, fig. 242 (1954).

PLATE 27, fig. 2.

Local.: NIOE 97, 108, 114, 129, 143, 144.

This species was observed in small numbers
at Agulhas Current and inshore stations on
lines A, B, C and D in October, and at two
stations on line A near Durban in January.
It has been frequently recorded from tropical-
subtropical Indian Ocean waters (see Wood,
1963, a).

Family CONGRUENTIDIACEA

346. Congruentidium compressum Abé, Sci. Rep. Tokyo Imp.

Univ. 2 (4) : 419, fig. 36 (1927);

Matzenauer, Bot. Archiv 35 : 481, fig. 75
(1933); Schiller, Dinofl. (2) : 321, fig.
337 (1937).

Local.: NIOE 130, 160.

Recorded in small numbers from an inshore
station near Cape Agulhas in October, and in

moderate numbers (+++) at an inshore station near Port Elizabeth in January. The only authors to have seen this interesting species before are those cited above, Abé describing it originally from Mutsu Bay, Japan, and Matzenauer finding it to be present in the Gulf of Aden. From these and the local localities it would appear to be a neritic species confined to the Indian Ocean and western Pacific Ocean. If this is so it would prove a useful indicator species of water from the Indian Ocean in the hydrographically confused area to the south of South Africa. The local specimens were smaller than those seen by Abé and Matzenauer, the smallest being 48μ in length and 38μ in broad width. However in thickness (narrow width) they were similar, all being between 14μ and 16μ .

Family GLENODINIACEAE

347. Glenodinium lenticula (Bergh) Schiller, Dinofl. (2) :
103, fig. 95 (1937).

Local.: NIOE 28, 34, 157.

Single specimens observed at two southern stations on line D in April, and at a station on line B in January. It has not been previously recorded from the Indian Ocean. The present author has also seen this species in inshore samples from the vicinity of Walvis Bay, South West Africa.

Family GLENODINIOPSIDACEAE

348. Pyrophacus horologicum Stein var. horologicum, Naturges. der arthrodelen Flagell. : pl. 24, figs. 8 - 13 (1883); Schiller, Dinofl. (2) : 87, fig. 73 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 221, fig. 84, a (1954).

Local.: NIOE 36, 66, 76, 78, 84, 94, 96, 97, 103, 106, 110, 111, 120, 130, 176, 177, 178.

Confined to inshore stations in the south on line D in April and January, but spreading northward in July and October. It has been frequently recorded from the Indian Ocean. Records omitted by Wood (1963, a) are those of Silva (1956) and Bernard & Lecal (1960).

349. Pyrophacus horologicum var. steinii Schiller, Dinofl. (2) : 87, fig. 74 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 221, fig. 84, b, c (1954).

Local.: NIOE 58.

One specimen was observed in material collected from an inshore station near Durban in July. Subrahmanyam (1958) has recorded this variety from the Arabian Sea.

Family GONIODOMACEAE

350. Goniodoma polyedricum (Pouchet) Jørgensen, Bergens Mus. Aarb. 6 : 33 (1899); Lebour, Dinofl. North. Seas : 90, fig. 26 (1925); Schiller, Dinofl. (2) : 438, fig. 479 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 313, fig. 241 (1954).

Local.: NIOE 108, 146, 157, 162.

Found in small numbers at an offshore station on line B in October, and at single offshore stations on lines A, B and C in January. Wood (1963, a) has listed the earlier Indian Ocean references to this species.

Family GONYAULACEAE

351. Gonyaulax ceratocoroides Kofoid, Univ. Calif. Publ.

Zool. 6 : 182 (1910); Schiller, Dinofl.

(2) : 309, fig. 321 (1937).

Local.: NIOE 157.

Only one specimen observed in material from a station inshore on line B in January.

This appears to be a first record of the species from the Indian Ocean.

352. Gonyaulax diacantha (Meunier) Schiller, Dinofl. (2) :

300, fig. 309 (1937); Wood, Aust. J. Mar.

& Freshw. Res. 5 (2) : 264, fig. 178 (1954).

Local.: NIOE 128.

One specimen was found at a station on the edge of the Agulhas Bank on line D in

October. This also appears to be a first record for the Indian Ocean area.

353. Gonyaulax diegensis Kofoid, Univ. Calif. Publ. Zool.

8 : 217, pl. 13, figs. 21 - 24, pl. 16,

fig. 40 (1911); Lebour, Dinofl. North. Seas :

95, pl. 13, fig. 5 (1925); Schiller, Dinofl.

(2) : 281, fig. 285 (1937); Wood, Aust. J.

Mar. & Freshw. Res. 5 (2) : 259, fig. 164
(1954).

Local.: NIOE 176.

A few specimens were observed in material from a station on the edge of the Agulhas Bank on line D in January. It has been recorded from the Indian Ocean by Wood (1954, 1962), and Subrahmanyam (1958).

354. Gonyaulax glyptorhyncus Murray & Whitting, Trans. Linn. Soc. London 2, Bot. (5) : 324, pl. 28, fig. 3 (1899); Kofoed, Univ. Calif. Publ. Zool. 8 : 201 (1911); Schiller, Dinofl. (2) : 301, fig. 310 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 260, fig. 167 (1954).

Local.: NIOE 34.

One specimen was observed in material collected from a southern offshore station on line D in April. The species has been previously recorded from the Indian Ocean by Wood (1962).

355. Gonyaulax monocantha Pavillard, Trav. Inst. Bot. Univ. Montpellier 4 : 21, pl. 1, fig. 78 (1916); Schiller, Dinofl. (2) : 287, fig. 293 (1937);

Wood, Aust. J. Mar. & Freshw. Res. 5 (2) :
260, fig. 169 (1954).

Local.: NIOE 9, 25, 28.

Single specimens were found at northern and southern offshore stations in April only. It has been previously recorded from the Indian Ocean by Wood (1962).

356. Gonyaulax pacifica Kofoid, Bull. Mus. Comp. Zool. Harvard 50 : 308, pl. 30, figs. 37 - 39 (1907); Kofoid, Univ. Calif. Publ. Zool. 8 : 235, pl. 15, fig. 35 (1911); Schiller, Dinofl. (2) : 290, fig. 297 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 261, fig. 170 (1954).

Local.: NIOE 14.

One specimen was present in material from an offshore station on line B in April. Previous Indian Ocean references include those of Karsten (1907, as Steiniella cornuta) and Wood (1954, 1962).

357. Gonyaulax polygramma Stein, Naturges. der arthrodelen Flagell. : pl. 4, figs. 15, 16, 17 (1883); Paulsen, Peridin. Nord. Plankt. : 28, fig.

36 (1908); Lebour, Dinofl. North. Seas :
 94, pl. 13, fig. 4 (1925); Schiller, Dinofl.
 (2) : 292, figs. 300, 301 (1937); Wood,
 Aust. J. Mar. & Freshw. Res. 5 (2) : 261,
 fig. 172 (1954); Taylor, J.S. Afr. Bot.
28 (3) : 237, pl. 1, figs. 1 - 5 (1962).

System.: Taylor (1962) has shown that there is a
 possibility that several species of
Gonyaulax (known as the "polygramma group")
 may in fact be developmental stages of this
 species. For the purposes of this study
 only those specimens closely resembling
 the original description have been identified
 as this species.

Local.: NIOE 2, 9, 27, 28, 30, 32, 34, 101, 103m
 114, 150, 176.

Found in small numbers at scattered northern
 and southern offshore and inshore stations in
 April, October and January. The species
 has frequently been recorded from the Indian
 Ocean (see Wood, 1963, a). Grindley &
 Taylor (1962, 1964) have described red-water
 and a mass mortality of marine fauna in False
 Bay, Cape, resulting from a bloom of this
 species.

358. Gonyaulax spinifera (Claparède & Lachmann) Diesing,
Sitz.-Ber. Akad. Wiss. Wien, math.-natur.
Kl. 52 : 96 (1866); Kofoed, Univ. Calif.
Publ. Zool. 8 : 209, pl. 10, figs. 8 - 10,
pl. 16, fig. 39 (1911); Schiller, Dinofl.
(2) : 297, fig. 305 (1937); Wood, Aust. J.
Mar. & Freshw. Res. 5 (2) : 263, fig. 174
(1954).

Local.: NIOE 73, 142.

Two specimens were observed, one in material from an offshore station on line B in July, and the other an inshore station on line A in January. Wood (1963, a) has listed several Indian Ocean records of this species.

359. Gonyaulax turbynei Murray & Whitting, Trans. Linn. Soc. London 2, Bot. (5) : 323, pl. 28, fig. 4 (1899); Kofoed, Univ. Calif. Publ. Zool. 8 : 225, pl. 17, fig. 44 (1911); Lebour, Dinofl. North. Seas : 94, fig. 28, c (1925); Schiller, Dinofl. (2) : 299, fig. 307 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 263, fig. 175 (1954).

Local.: NIOE 35, 150.

Recorded in small numbers from a southern inshore station in April, and a northern

offshore station in January. Taylor (1962) showed that this species could, in fact, be an early stage in the formation of the theca of G. polygramma. This hypothesis is further supported by the local distributions of the two (compare on the Relative Abundance Table for dinoflagellates), in that G. turbynei occurred at an adjacent station to G. polygramma in April, and the two were together in the same sample in January. G. turbynei has been previously recorded from the Indian Ocean by Schröder (1906), Matzenauer (1933), and Wood (1954, 1962).

Family HETERODINIACEAE

360. Heterodinium gesticulatum Kofoid, Univ. Calif. Publ.

Zool. 3 : 165 (1907); Schiller, Dinofl. (2) : 347, fig. 378 (1937).

Local.: NIOE 60.

One specimen observed in material from an offshore station on line A in July. This appears to be a new record for the Indian Ocean region.

Family OXYTOXACEAE

361. Oxytoxum curvatum (Kofoid) Kofoid, Univ. Calif. Publ.

Zool. 8 : 287 (1911); Schiller, Dinofl.

(2) : 452, fig. 497 (1937).

Local.: NIOE 112.

One specimen found at an inshore station on line B in October, 1962. The species has been recorded from the Indian Ocean by Wood (1962).

362. Oxytoxum elegans Pavillard, Trav. Inst. Bot. Univ.

Montpellier 4 : 43, pl. 2, fig. 4 (1916);

Schiller, Dinofl. (2) : 464, fig. 530 (1930).

Local.: NIOE 60.

One specimen observed in material from an offshore station on line A in July.

Previous Indian Ocean records are those of Matzenauer (1933) and Wood (1962).

363. Oxytoxum gladiolum Stein, Naturges. der Arthrodelen

Flagell. : pl. 5, figs. 6, 7 (1883); Lebour,

Dinofl. North. Seas : 141, fig. 44, b (1925);

Schiller, Dinofl. (2) : 453, fig. 501 (1937).

Local.: NIOE 28, 155.

Family OXYTOXACEAE

361. Oxytoxum curvatum (Kofoid) Kofoid, Univ. Calif. Publ.

Zool. 8 : 287 (1911); Schiller, Dinofl.

(2) : 452, fig. 497 (1937).

Local.: NIOE 112.

One specimen found at an inshore station on line B in October, 1962. The species has been recorded from the Indian Ocean by Wood (1962).

362. Oxytoxum elegans Pavillard, Trav. Inst. Bot. Univ.

Montpellier 4 : 43, pl. 2, fig. 4 (1916);

Schiller, Dinofl. (2) : 464, fig. 530 (1930).

Local.: NIOE 60.

One specimen observed in material from an offshore station on line A in July.

Previous Indian Ocean records are those of Matzenauer (1933) and Wood (1962).

363. Oxytoxum gladiolum Stein, Naturges. der Arthrodelen

Flagell. : pl. 5, figs. 6, 7 (1883); Lebour,

Dinofl. North. Seas : 141, fig. 44, b (1925);

Schiller, Dinofl. (2) : 453, fig. 501 (1937).

Local.: NIOE 28, 155.

Several specimens were recorded from a southern offshore station (line D) in April, and an offshore station on line B in January. It has been previously recorded from the Indian Ocean region by Ostenfeld & Schmidt (1901) and Schröder (1906).

364. Oxytoxum scolopax Stein, Naturges. der Arthrodelen
 Flagell. : pl. 5, figs. 1 - 3 (1883);
 Lebour, Dinofl. North. Seas : 141, fig. 44, c
 (1925); Schiller, Dinofl. (2) : 453, fig.
 502 (1937); Wood, Aust. J. Mar. & Freshw.
 Res. 5 (2) : 315, fig. 245 (1954). PLATE 27,
 fig. 4.

Local.: NIOE 9, 27, 28, 30, 32, 34, 71, 73, 101,
 117, 120, 164.

Found occasionally at scattered offshore stations on all cruises. It was most widespread and moderately abundant (+++) on line D in April. Wood (1964) found this species to be widespread throughout the tropical and subtropical water masses of the Australian region, and it has often been recorded from the Indian Ocean (see Wood, 1963, a). The record of Silva (1956) from

the waters off Mozambique, is the nearest record to the area under present survey (omitted by Wood, 1963, a).

- 365, Oxytoxum tessellatum (Stein) Schütt, *Ergebn. Plankton-Exped. der Humboldt-Stift.* 4 : 160, pl. 17, fig. 52 (1895); Schiller, *Dinofl.* (2): 462, fig. 526 (1937).

Local.: NIOE 62.

One specimen was observed in material from an offshore station on line A in July, 1962. Earlier Indian Ocean records of this species have been listed by Wood (1963, a).

366. Pavillardinium spinosum (Kofoid) G. De Toni ?, *Notorelle di nomencl. Algal.* (6) : ? (1936). - see note in Schiller, *Dinofl.* (2) : 570. (1937).

Syn.: Murrayella spinosa Kofoid, *Bull. Mus. Comp. Zool. Harvard* 50 : 192, pl. 9, fig. 57 (1907); Schiller, *Dinofl.* (2) : 449, fig. 493 (1937).

System.: The present author has only Schiller's authority for de Toni's proposed generic name, Pavillardinium, to replace Murrayella Kofoid, not having had opportunity to refer to de Toni's work. The name Murrayella

is undoubtedly pre-occupied, having been applied to a genus of the Rhodophyceae (Murrayella Schmitz 1893, Nuova Notarisia ser. 4, p. 227). It is not known whether de Toni did, in fact, make the combination used in this study.

Local.: NIOE 97.

One specimen was identified from material collected from an offshore station near Durban in October, 1962. This appears to be a new record for the Indian Ocean.

Family PERIDINIACEAE

367. Peridinium bimucronatum Schiller, Dinofl. (2) : 266, fig. 265 (1937).

Local.: NIOE 19, 161.

Two specimens were found in material collected from the vicinity of Port Elizabeth in April and January. The species has not been recorded from the Indian Ocean prior to the present survey.

368. Peridinium breve Paulsen, Medd. Komm. f. Havunders., Serie Plankton 1 : 13 (1907); Lebour, Dinofl.

North. Seas : 132, fig. 41, c (1925);
 Schiller, Dinofl. (2) : 198, fig. 194 (1937);
 Wood, Aust. J. Mar. & Freshw. Res. 5 (2) :
 241, fig. 121 (1954).

Local.: NIOE 114.

One individual was observed in material from an inshore station near Port Elizabeth in October, 1962. It has been previously recorded from the Indian Ocean by Matzenauer (1933).

369. Peridinium claudicans Paulsen, Medd. Komm. f. Havunders.,
 Serie Plankton 1 : 16, fig. 22 (1907); Lebour,
 Dinofl. North. Seas : 123, pl. 25, fig. 1
 (1925); Schiller, Dinofl. (2) : 249, fig. 250
 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5
 (2) : 255, fig. 154 (1954).

Local.: NIOE 1, 17, 18, 19, 20, 21, 27, 28, 35,
 36, 58, 59, 62, 71, 75, 78, 85, 91, 93, 97,
 114, 119.

Fairly common at inshore stations in April. In July it was more scattered over the area. It was only present at three stations in October, and absent from the January material. A moderate abundance (++) was recorded at

stations 18, 19 and 20 inshore on lines B and C in April. Wood (1963, a) has listed several Indian Ocean references for this species.

370. Peridinium decipiens Jørgensen, Bergens Mus. Aarb., 1899, 6 : 40 (1900); Lebour, Dinofl. North. Seas : 132, fig. 41 (1925); Schiller, Dinofl. (2) : 265, fig. 264 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 237 (1954).

Local.: NIOE 28.

One specimen was found at an extreme southern offshore station in April, 1962. Matzenauer (1933) has recorded the species from the Indian Ocean.

371. Peridinium depressum Bailey, Smithson. Contrib. Knowl. 7 : 12, figs. 33, 34 (1855); Lebour, Dinofl. North. Seas : 119, pl. 23, figs. a - f (1925); Schiller, Dinofl. (2) : 250, fig. 251 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 255, fig. 155 (1954).

Local.: NIOE 21, 89, 93, 128, 129, 142.

Found in the vicinity of Cape Agulhas in July and October. In April it was present

near Port Elizabeth, and in January near Durban. It was not usually in large numbers, although a moderate abundance (++) was recorded at station 93. Wood (1954) has pointed out that this species may be confused with P. divergens on occasions. The various Indian Ocean records of this species have been listed by Wood (1963, a).

372. Peridinium diabolium Cleve, Kongl. Svenska Vet.-Akad. Handl. 34 (1) : 16, pl. 7, figs. 19, 20 (1900); Lebour, Dinofl. North. Seas : 135, pl. 29, fig. 2 (1925); Schiller, Dinofl. (2): 204, fig. 198 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 243, fig. 125 (1954).

Local.: NIOE 60, 62, 64, 89, 91, 96, 99, 115, 121, 142.

Present in small numbers at stations on line A in July, October and January. It was also present at scattered stations in the south (lines C and D) in July and October. The record of Silva (1956, as P. longipes) should be added to the Indian Ocean records listed by Wood (1963, a).

near Port Elizabeth, and in January near Durban. It was not usually in large numbers, although a moderate abundance (++) was recorded at station 93. Wood (1954) has pointed out that this species may be confused with P. divergens on occasions. The various Indian Ocean records of this species have been listed by Wood (1963, a).

372. Peridinium diabolium Cleve, Kongl. Svenska Vet.-Akad. Handl. 34 (1) : 16, pl. 7, figs. 19, 20 (1900); Lebour, Dinofl. North. Seas : 135, pl. 29, fig. 2 (1925); Schiller, Dinofl. (2): 204, fig. 198 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 243, fig. 125 (1954).

Local.: NIOE 60, 62, 64, 89, 91, 96, 99, 115, 121, 142.

Present in small numbers at stations on line A in July, October and January. It was also present at scattered stations in the south (lines C and D) in July and October. The record of Silva (1956, as P. longipes) should be added to the Indian Ocean records listed by Wood (1963, a).

near Port Elizabeth, and in January near Durban. It was not usually in large numbers, although a moderate abundance (++) was recorded at station 93. Wood (1954) has pointed out that this species may be confused with P. divergens on occasions. The various Indian Ocean records of this species have been listed by Wood (1963, a).

372. Peridinium diabolium Cleve, Kongl. Svenska Vet.-Akad. Handl. 34 (1) : 16, pl. 7, figs. 19, 20 (1900); Lebour, Dinofl. North. Seas : 135, pl. 29, fig. 2 (1925); Schiller, Dinofl. (2): 204, fig. 198 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (2) : 243, fig. 125 (1954).

Local.: NIOE 60, 62, 64, 89, 91, 96, 99, 115, 121, 142.

Present in small numbers at stations on line A in July, October and January. It was also present at scattered stations in the south (lines C and D) in July and October. The record of Silva (1956, as P. longipes) should be added to the Indian Ocean records listed by Wood (1963, a).

373. Peridinium divergens 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. 5 (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. Peridinium elegans Cleve forma elegans, Kongl. Svenska Vet.-Akad. Handl. 34 (1) : 16, pl. 7, fig. 15 (1900); Matzenauer, Bot. Archiv 35 : 471, fig. 57 (1933); Schiller, Dinofl. (2) : 254, fig. 252 (1937); Wood, Aust. J. Mar. & Freshw. Res. 5 (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), Subrahmanyam (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), Subrahmanyam (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 Subrahmanyam (1958).

384. Peridinium monacanthum 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.

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

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 Jørgensen, 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 Kofoed, 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).

Family PODOLAMPACEAE

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

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 sicala 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. General circulation in the S.W. Indian Ocean.

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 et al

(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 Coriolis'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 Coriolis'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

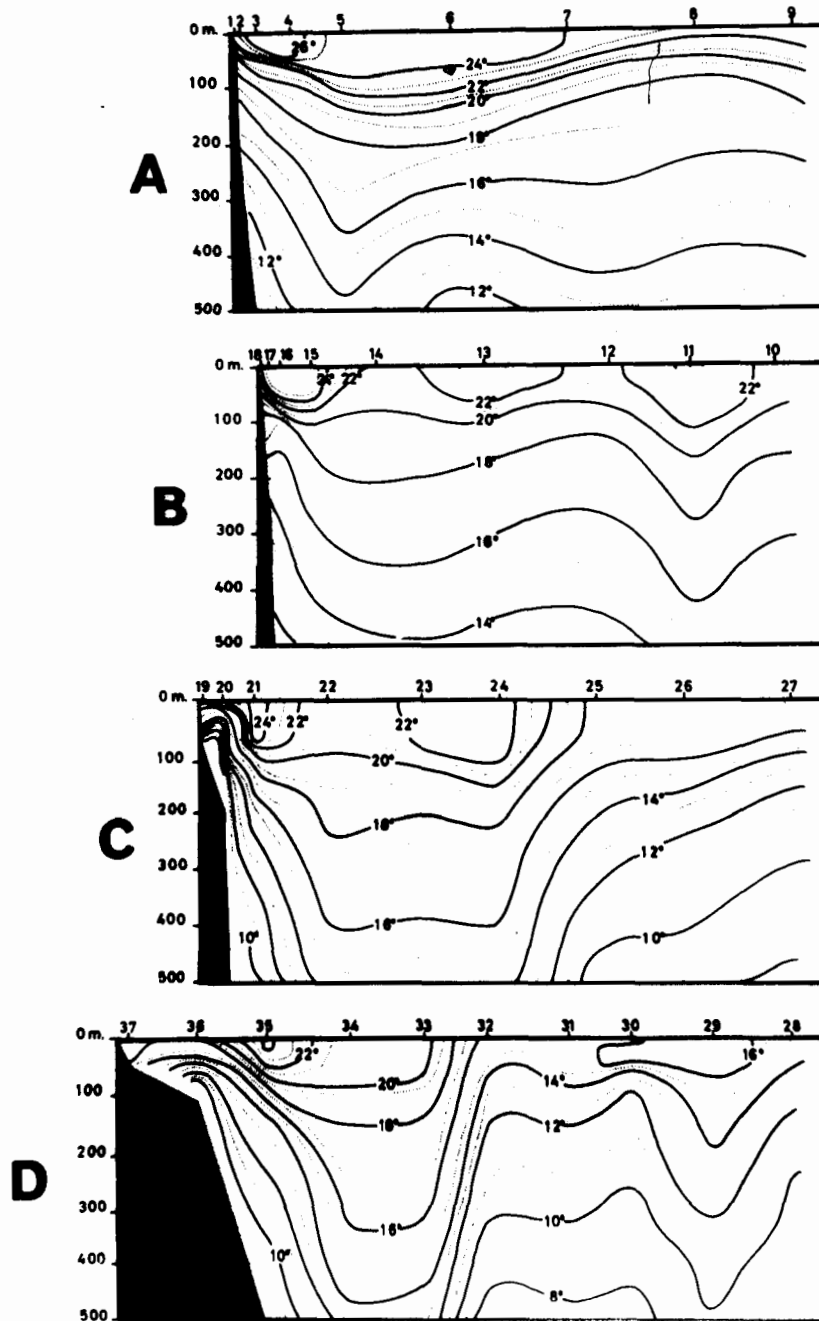
Crozet and Kerguelen Islands, as reported by Fukase (1962), Delépine (1963), and Darbyshire (1964). Fukase considered the more southerly one to indicate the position of the Subtropical Convergence (mean temperature, 13°C) and named the other as the "Agulhas Convergence" (mean temp. 18°C). However the 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°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, $\pm 10^{\circ}\text{C}$, 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.

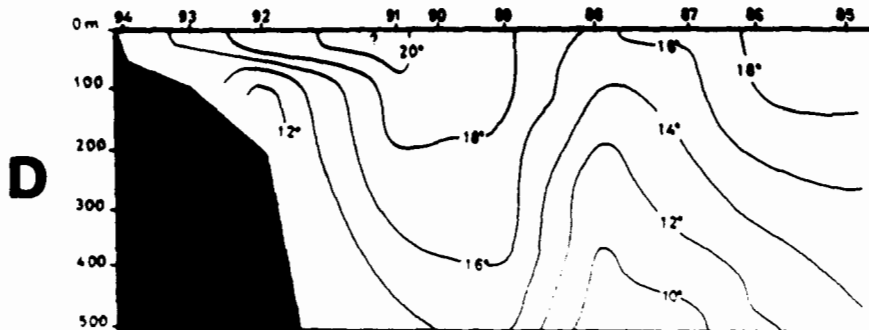
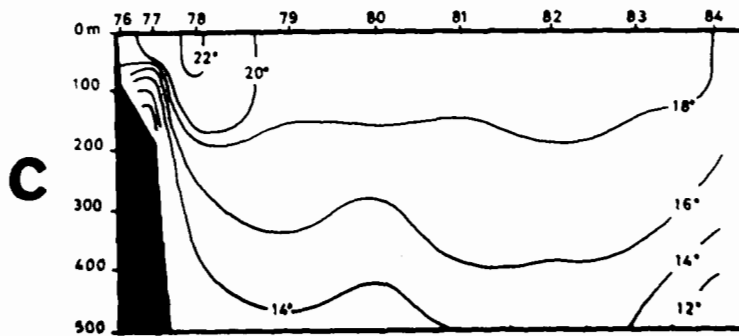
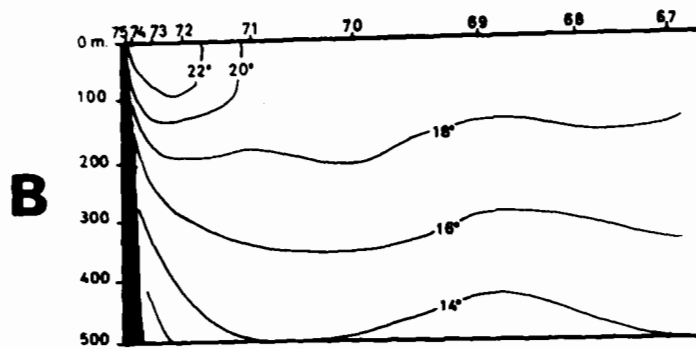
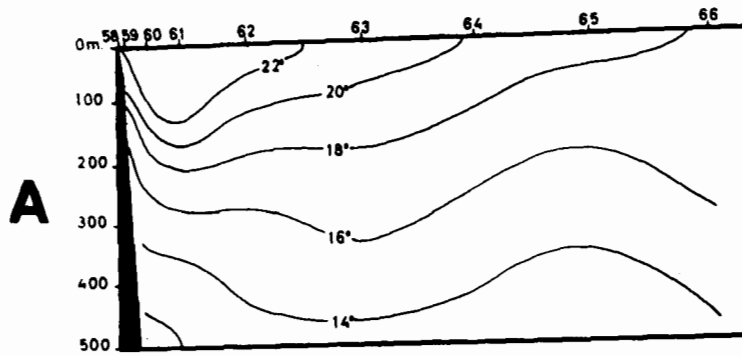
Diagram 2

Diagram Temperature: 0 - 500m. April '62



Diagrams 2-5: Vertical profiles of the temperature in the upper 500m. Station positions are indicated.

Diagram Temperature: 0-500 m. July '62



Diagram

Temperature: 0-500m.

Oct '62

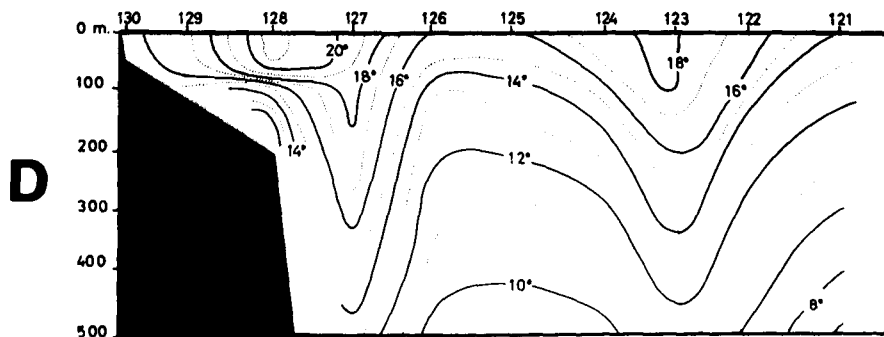
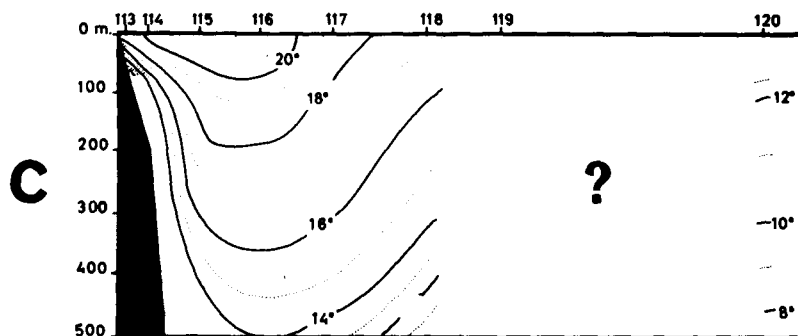
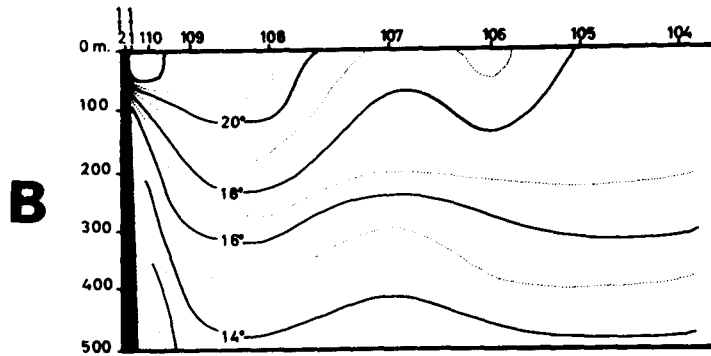
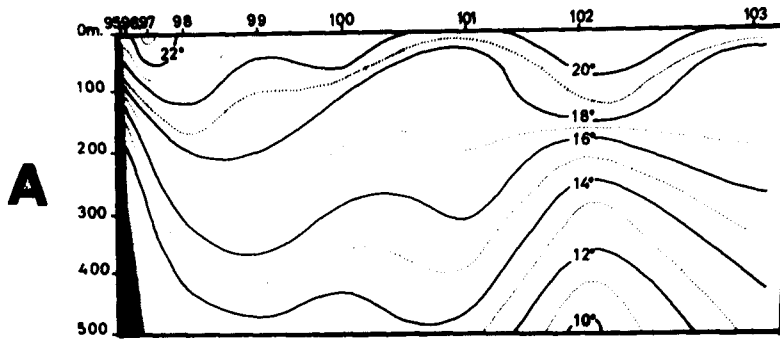
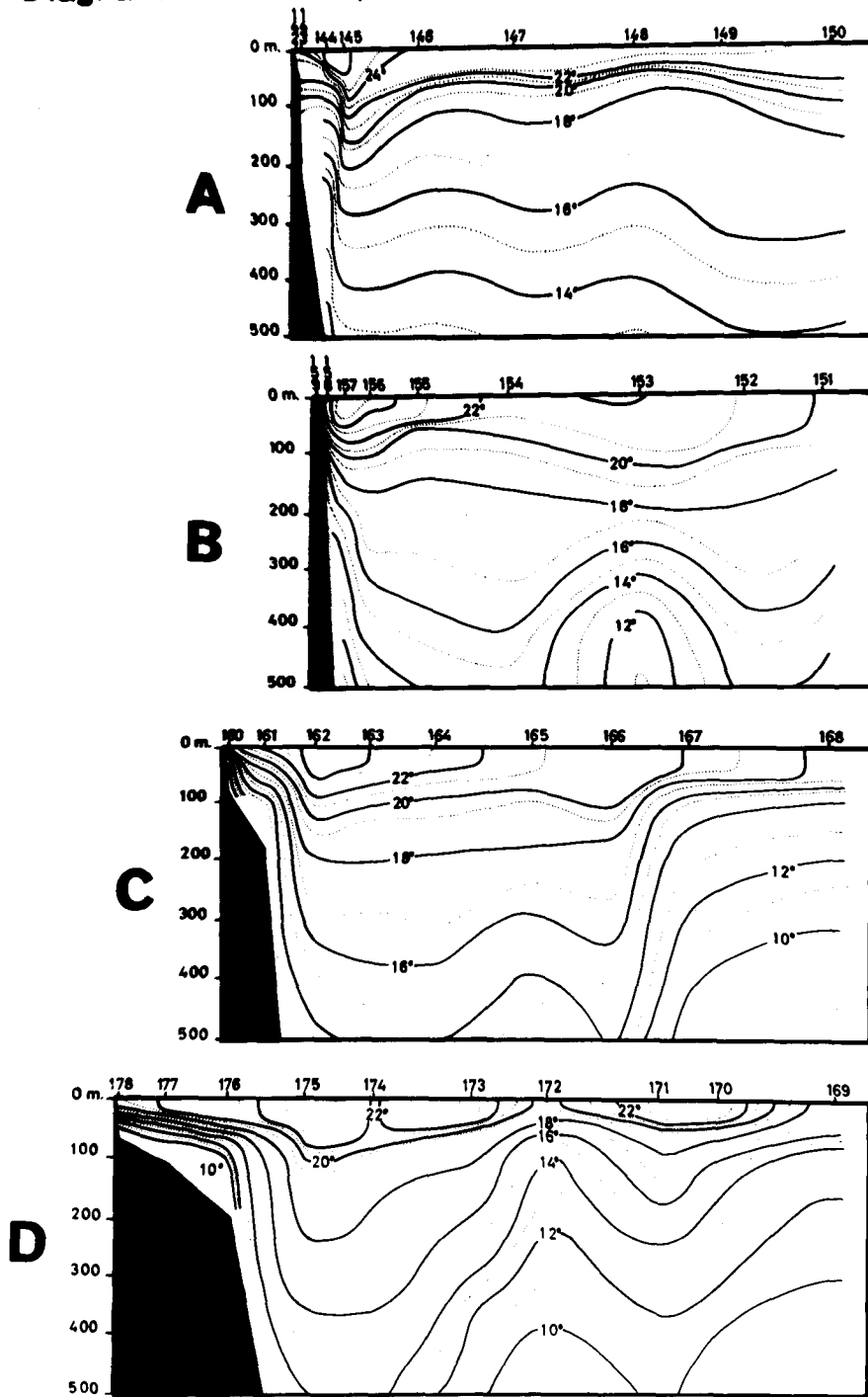


Diagram Temperature: 0-500m. Jan'63



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° to 18°C lying over the shelf, overlain by a thin layer of warm 20°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°C . The surface temperature decreases eastward to approximately 17°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°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°C , with 13°C water within the upper 100 m. Water of less than 10°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

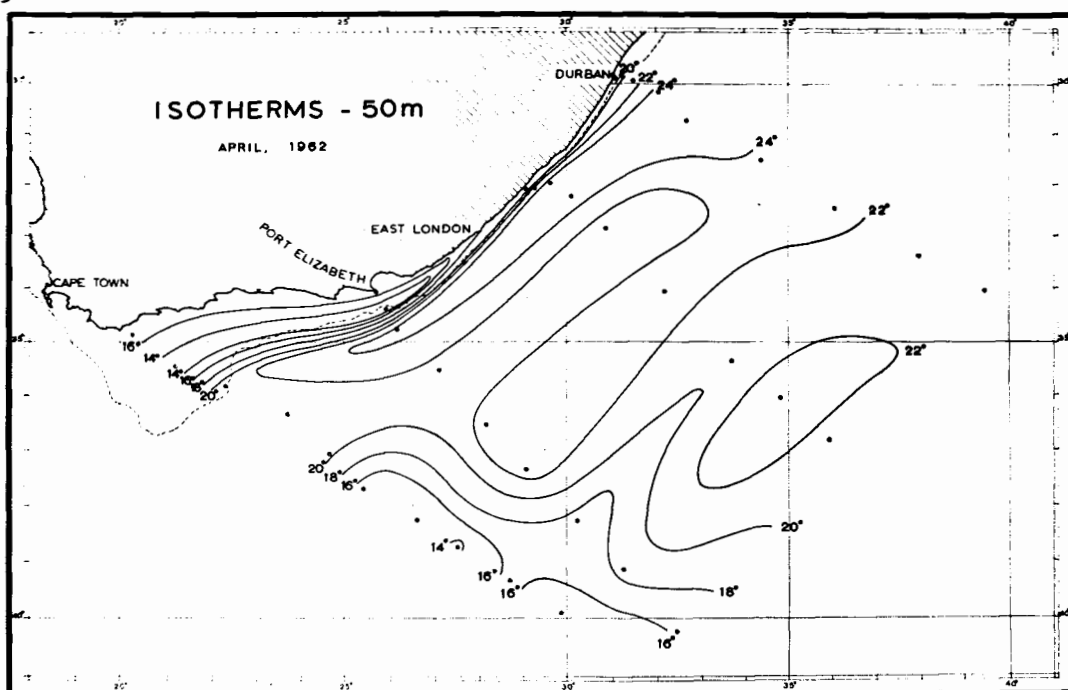


Chart 6

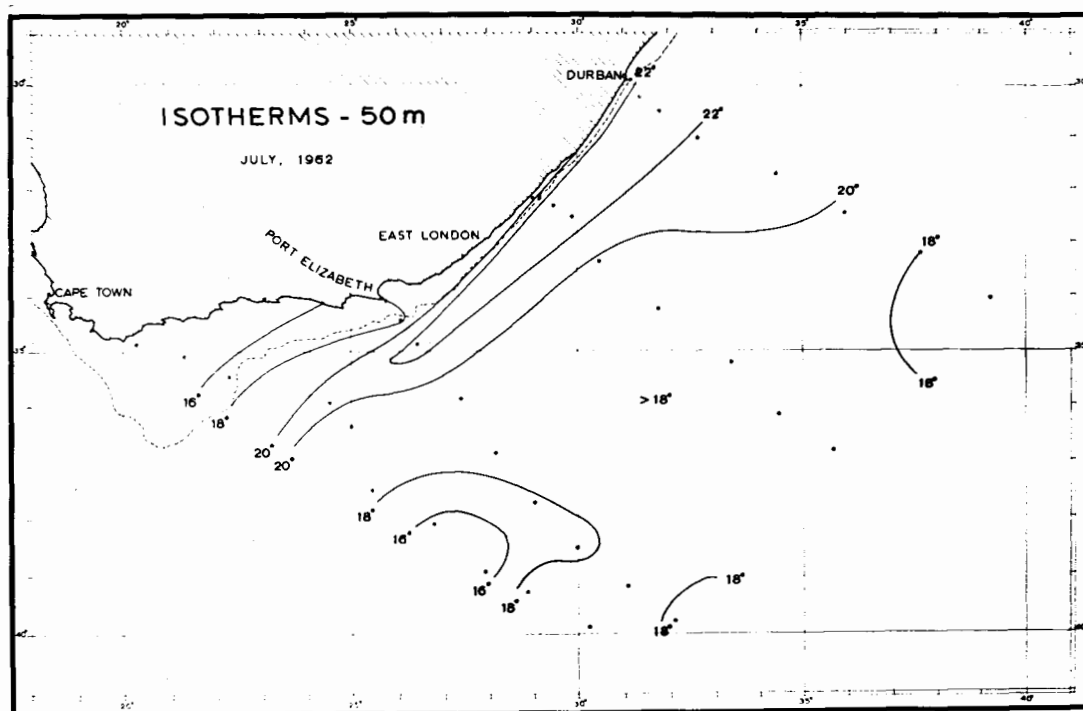


Chart 7

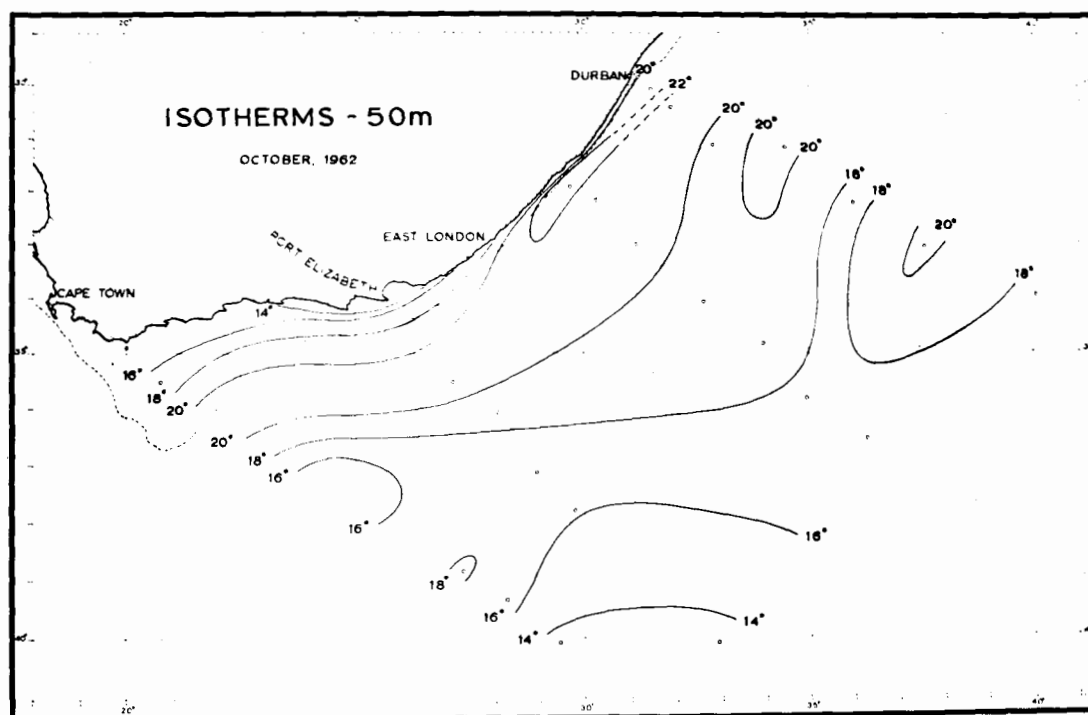


Chart 8

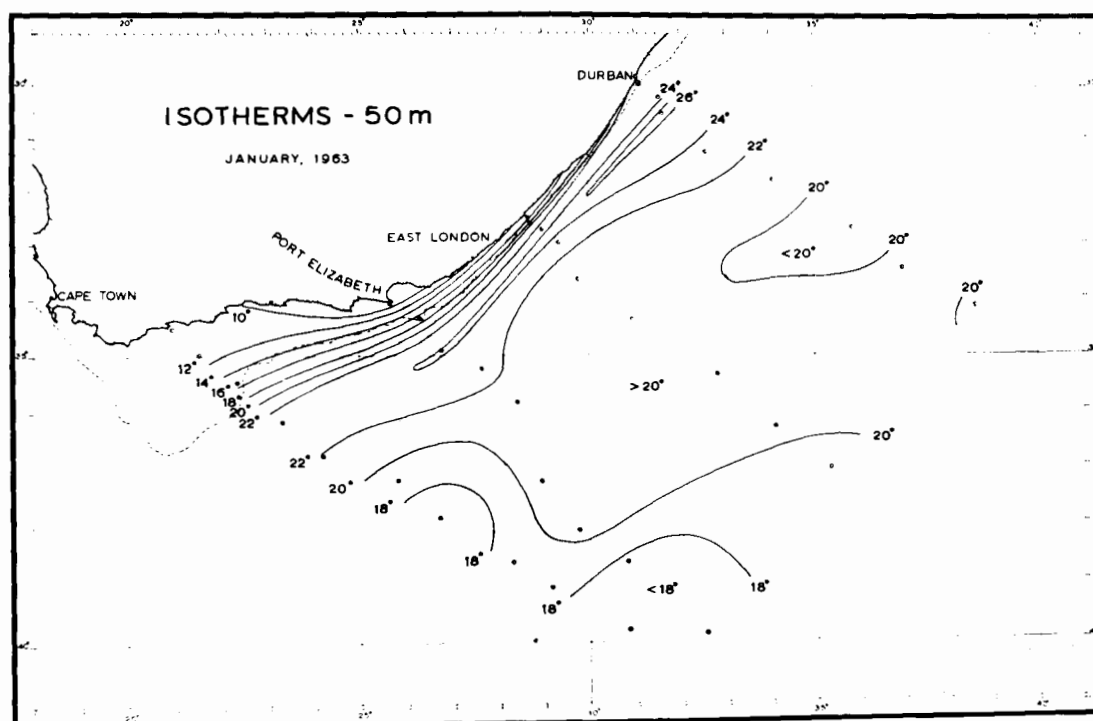
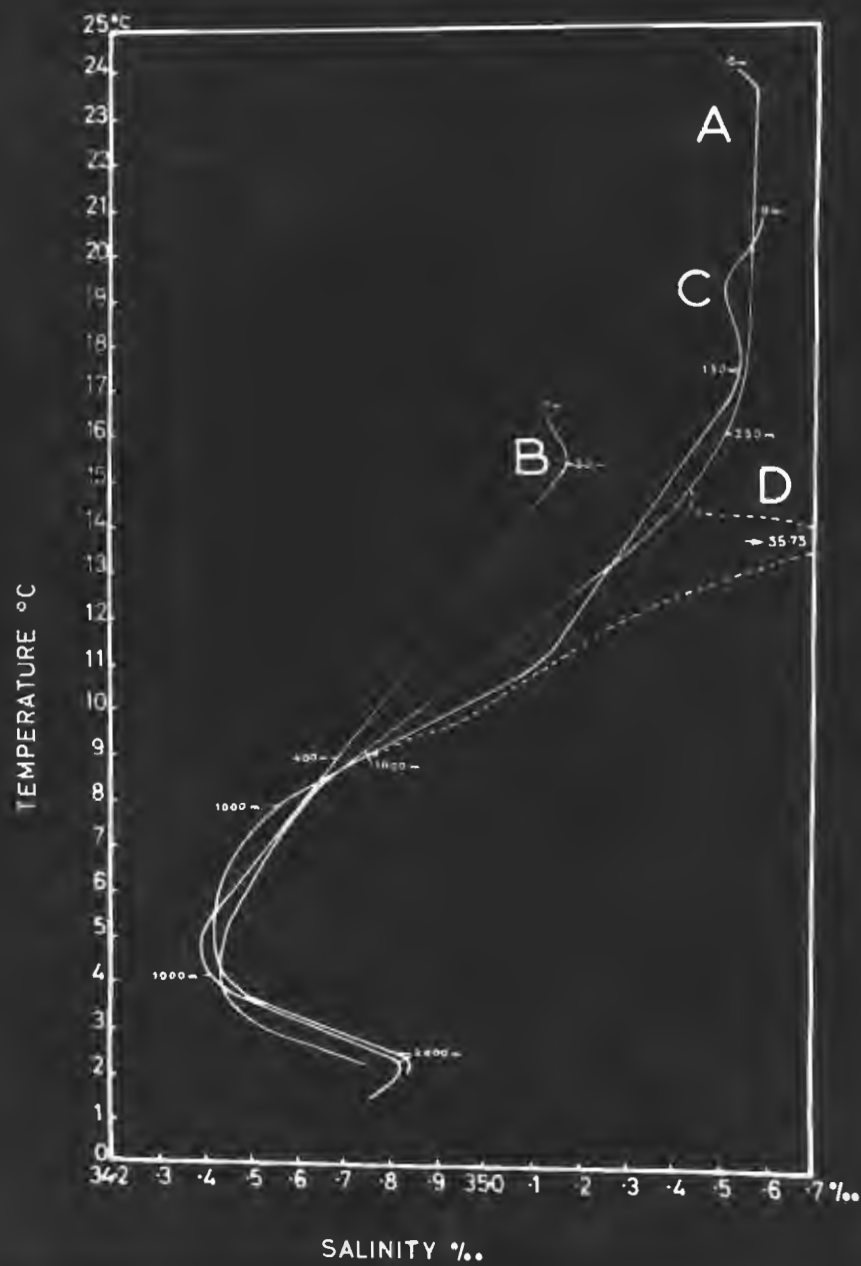
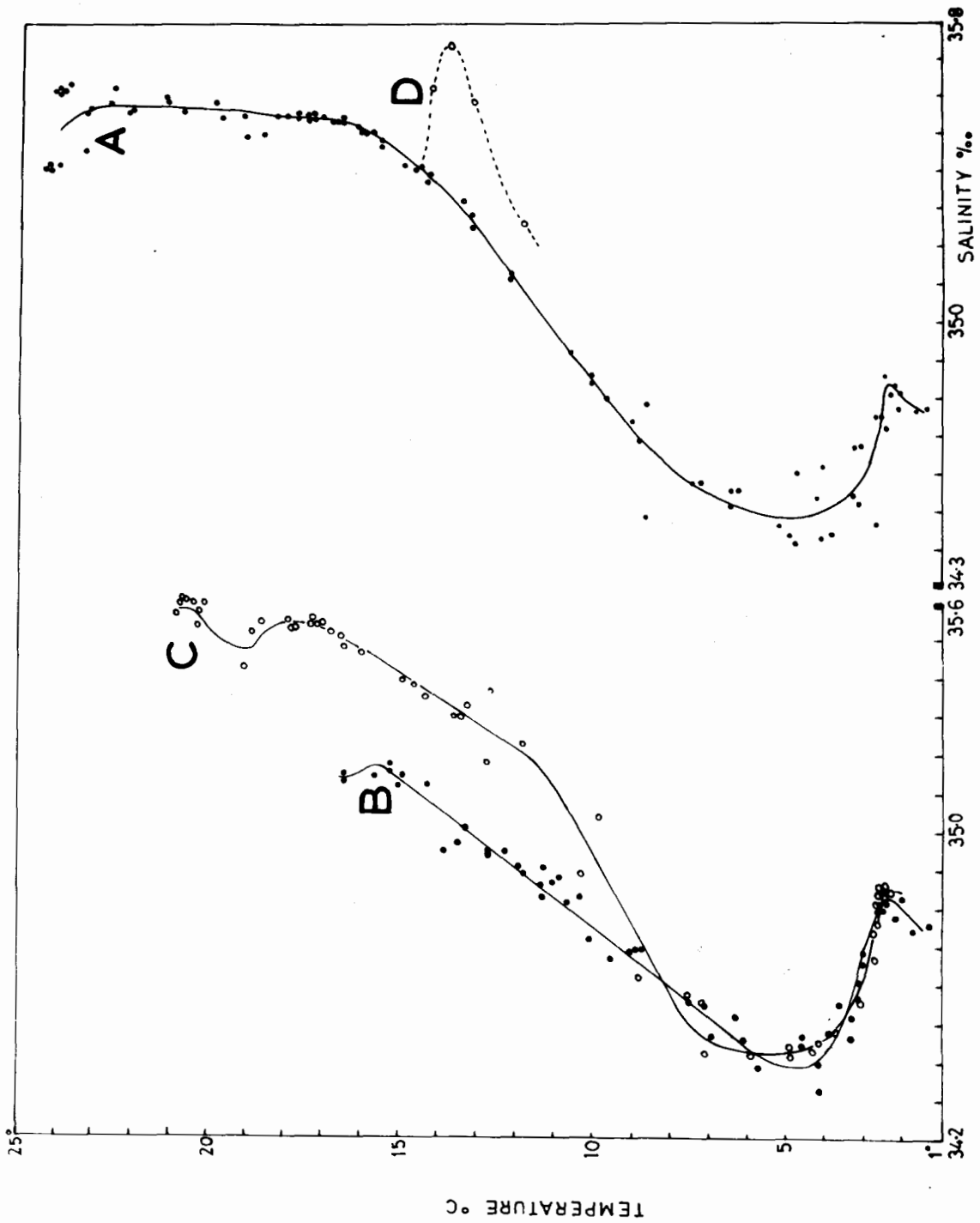


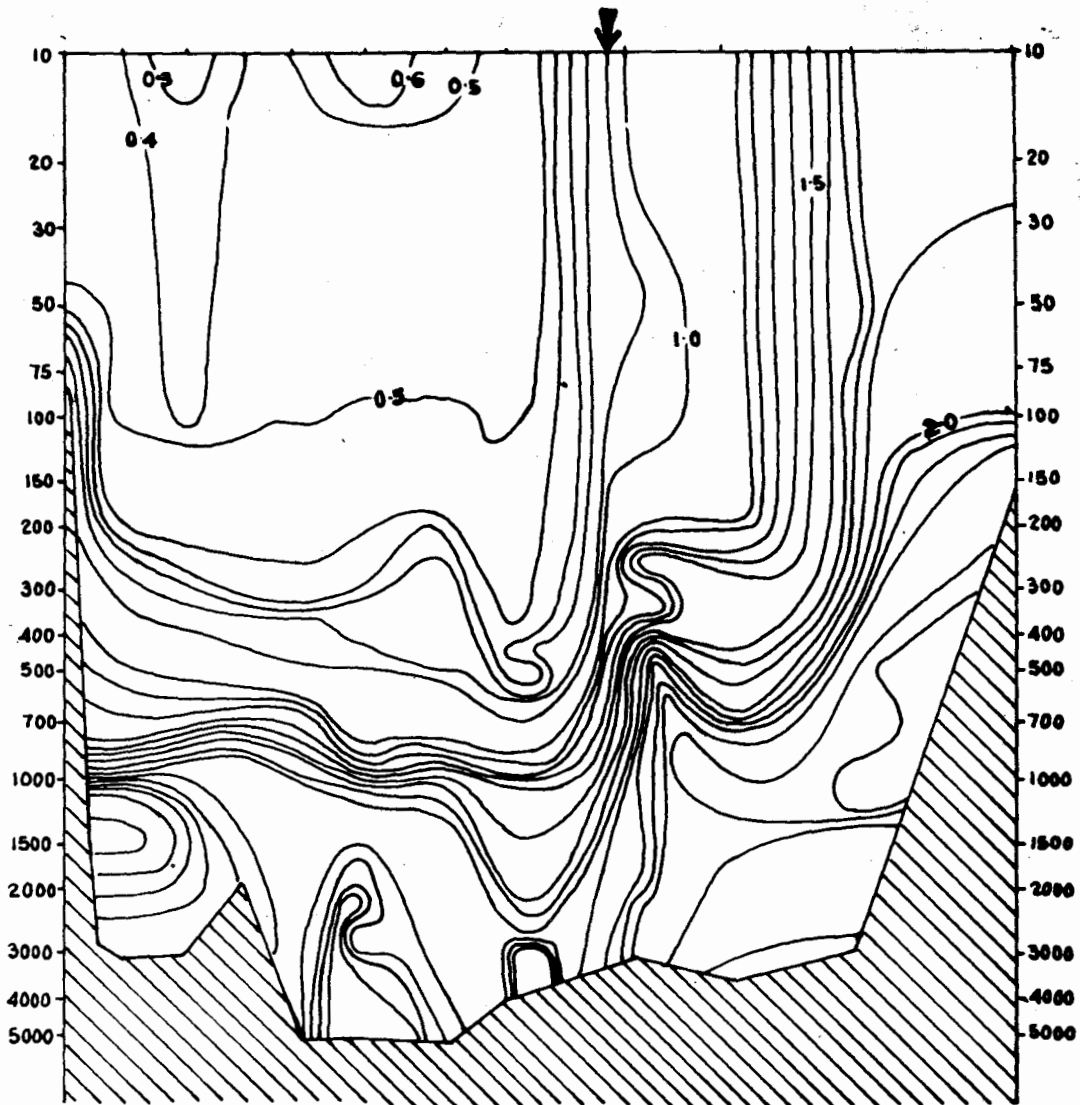
Diagram Mean T S Curves for Selected Groups of Stations

April, 1962





Showing the points through which the curves in 6 a were drawn.



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 σ_t 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.E. 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 $T=9^{\circ}\text{C}$, $S=34.75\text{‰}$, and $T=18^{\circ}\text{C}$, $S=35.55\text{‰}$. 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 B. 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 differs 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 Saldanha 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

required to substantiate it.

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 $18^{\circ} - 19^{\circ}\text{C}$. 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 $\mu\text{g-atom PO}_4\text{-P/litre}$, 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 features 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 ml. 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 $\mu\text{g-atom PO}_4\text{-P/litre}$, and mostly between 0.1 and 0.2 $\mu\text{g-atom PO}_4\text{-P/litre}$. An exception to this was the value of 0.70 $\mu\text{g-atom PO}_4\text{-P/litre}$ 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 $\mu\text{g-atom PO}_4\text{-P/litre}$ 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 lesser 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

of 3° from 26° to 23°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°C . The vertical profile of line D shows two pockets of warm, 23°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/m³/hour at 18000 lux, and this was associated with the presence of water with an inorganic phosphate value of 0.7 ug-atom PO₄-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 lesser 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 area of the S.W. Indian Ocean surveyed included several distinct hydrographic regions

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It is apparent from the preceding description of general and prevailing conditions that the area 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.

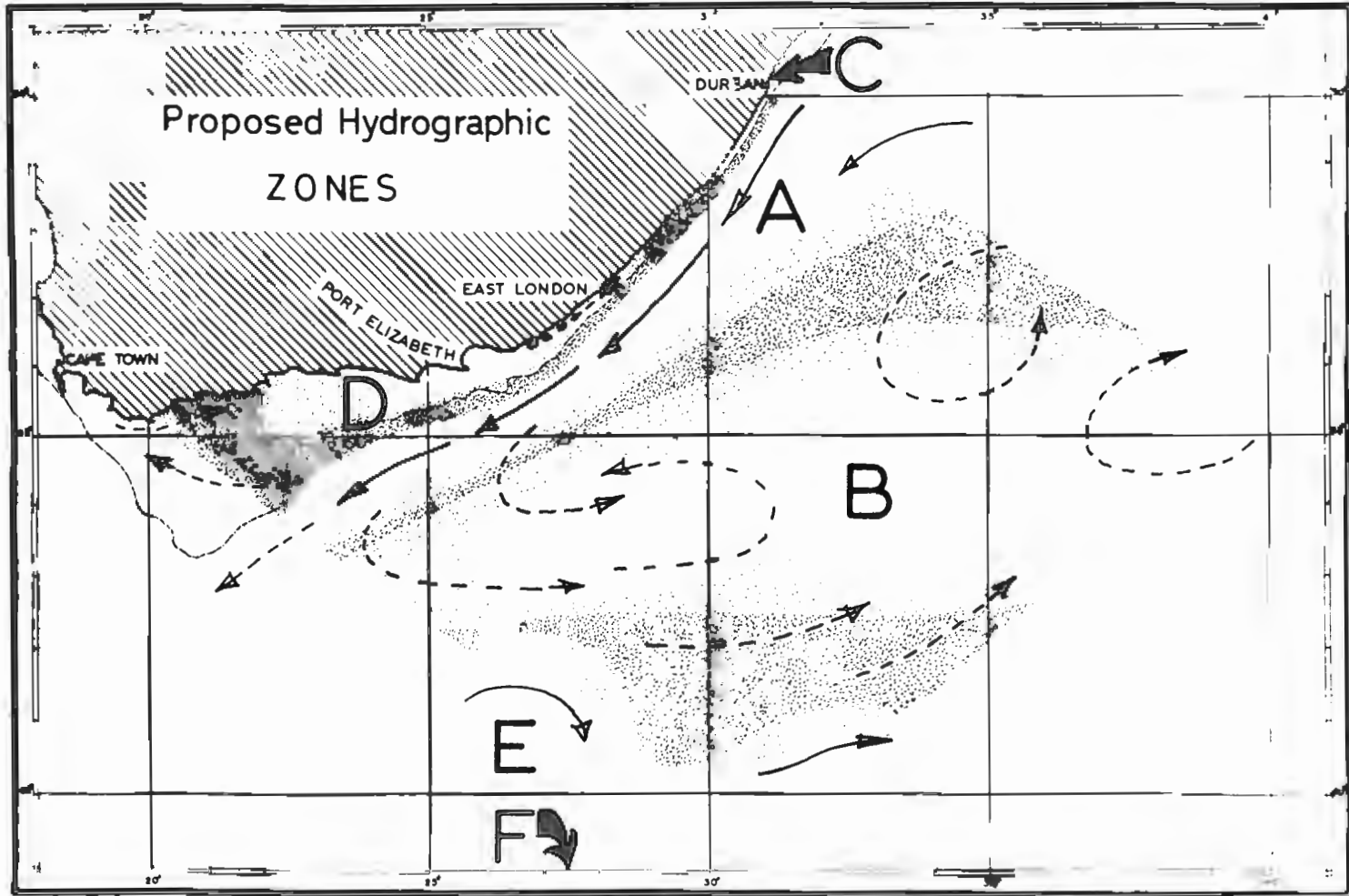
For convenience in discussion the present author has proposed a subdivision of the area into several zones, each with a distinctive hydrographic character, and in section V it will be seen to what extent the distribution of the phytoplankton conforms to this subdivision. Chart 9 shows the proposed zonation 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 (Steedmann Nielsen & Jensen, 1956).



or 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 $\text{PO}_4\text{-P}$ /litre, and slightly less in October, 0.1 to 0.3 ug-atom $\text{PO}_4\text{-P}$ /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 temperature limit 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

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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 poorly 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 strongly 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 ml./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 $9^{\circ} - 11^{\circ}\text{C}$, 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°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.

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 "Aguilhas Convergence" for the more northerly concentration of isotherms. This name is perhaps unfortunate as it implies a definite hydrographic condition related to the Aguilhas Current or the Aguilhas region, whereas more recent data shows that it is not restricted to the Aguilhas 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 $\mu\text{g-atoms PO}_4\text{-P/litre}$ 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 $\mu\text{g-atom PO}_4\text{-P/litre}$ 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.

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 hydrographic features, described 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 if 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 independent 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 'panthalassic' 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 'panthalassic', suggested a new set of terms: paractic (of the coast), anoctic (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 in recent 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 nicans 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 Gurl & 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.) Grun
- ⊕ *Pseudoeunotia dolliolus* (Wall.) Grun. in V. H.
- *Thalassiothrix longissima* (Cleve) Cleve & Grun.

Group B ; Charts 14 - 17

- ♦ *Nitzschia pacifica* Cupp
- ☀ *Gossleriella tropica* Schutt
- ⊗ *Roperia tessellata* (Roper) Grun. in V. H.
- ⊖ *Mastagloia rostrata* (Wall.) Hust.
- ⌘ *Chaeteroceros Borcalis* Bail.
- ⌘ *Chaeteroceros curvisetus* Cleve

Chart 10

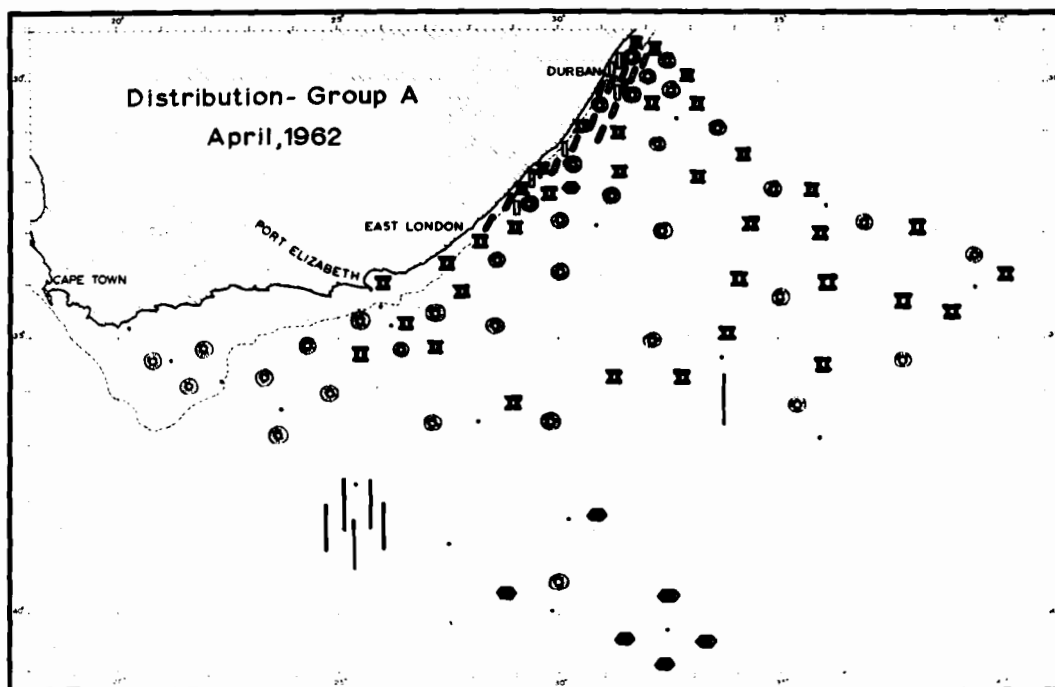


Chart 11

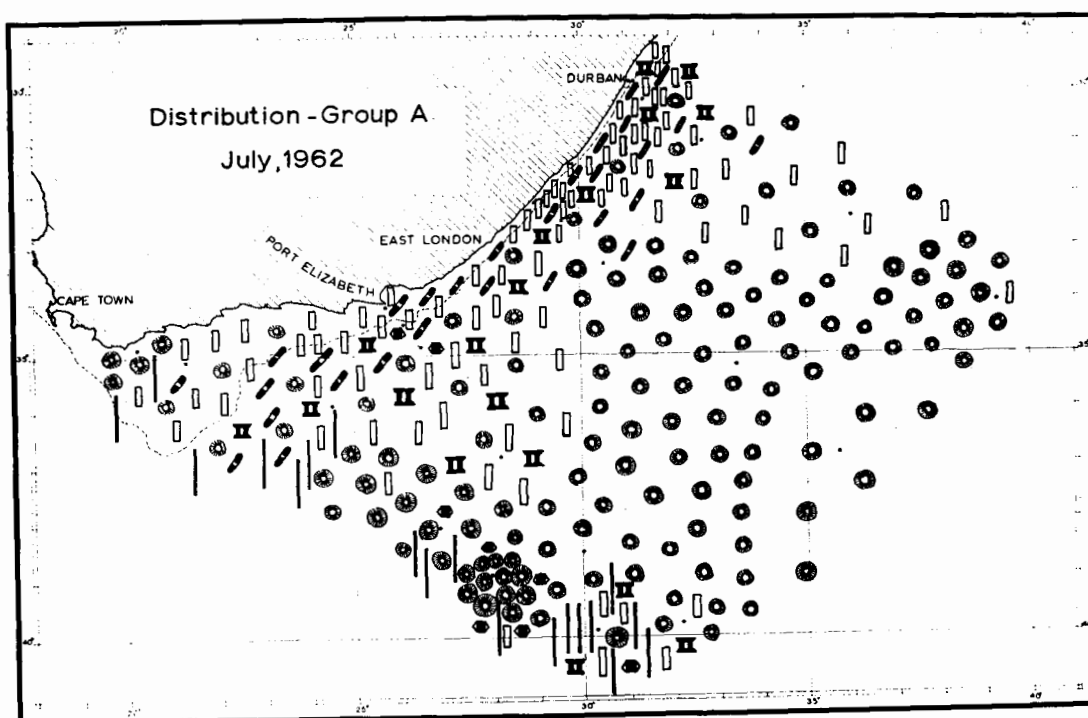


Chart 12

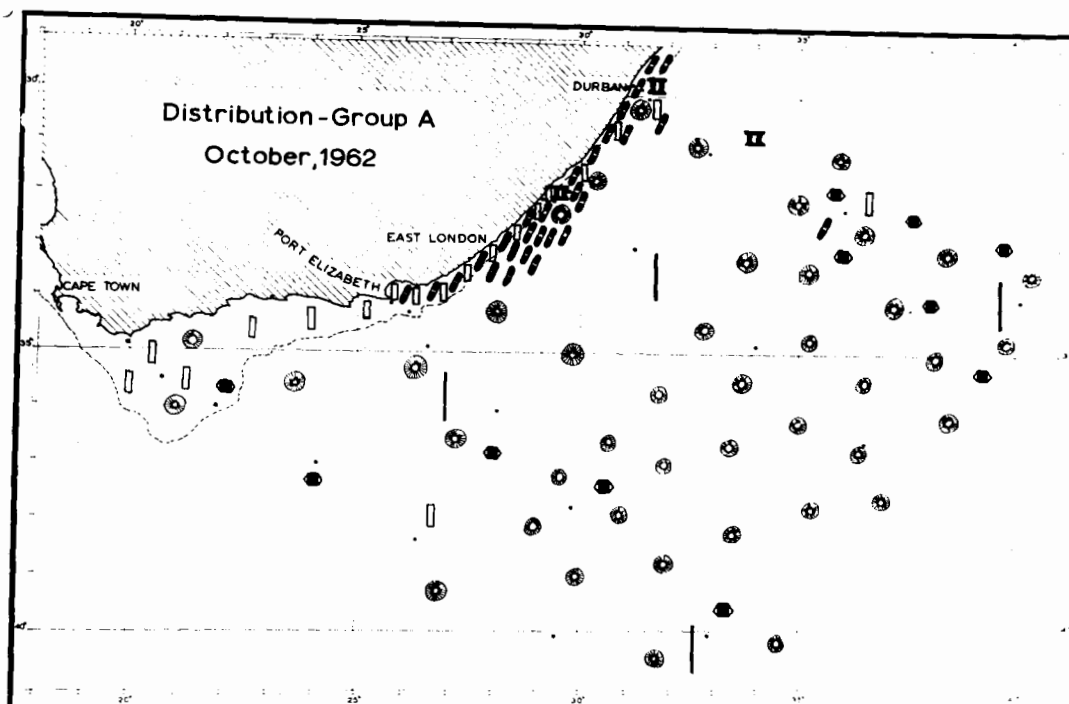


Chart 13

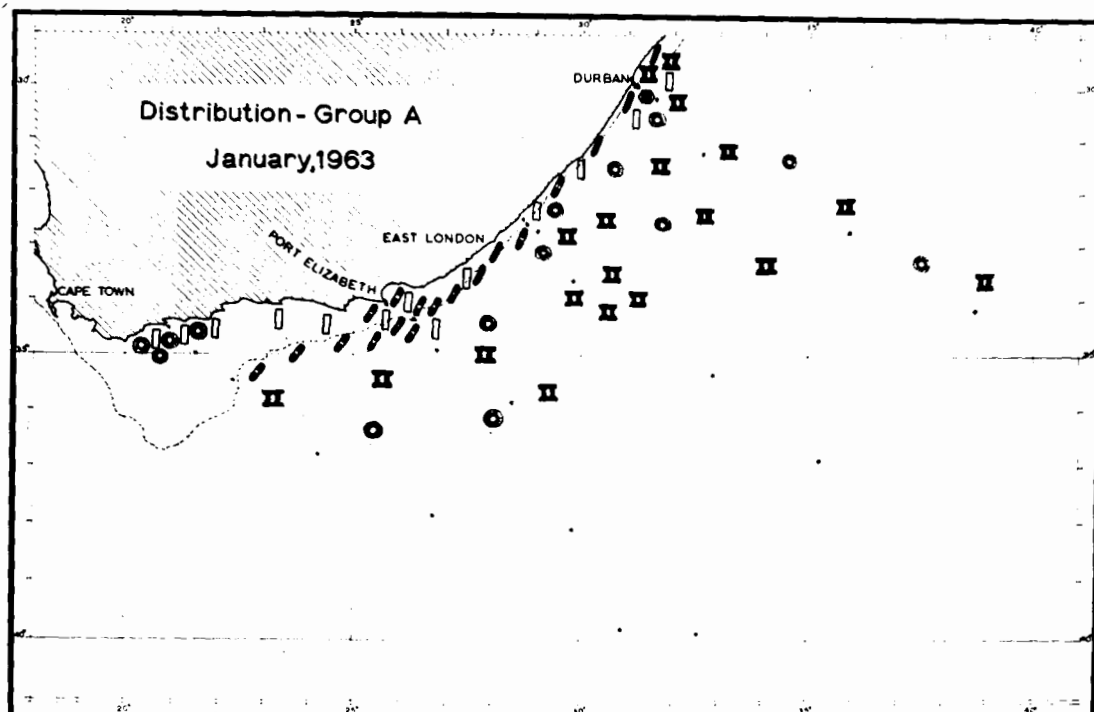


Chart 14

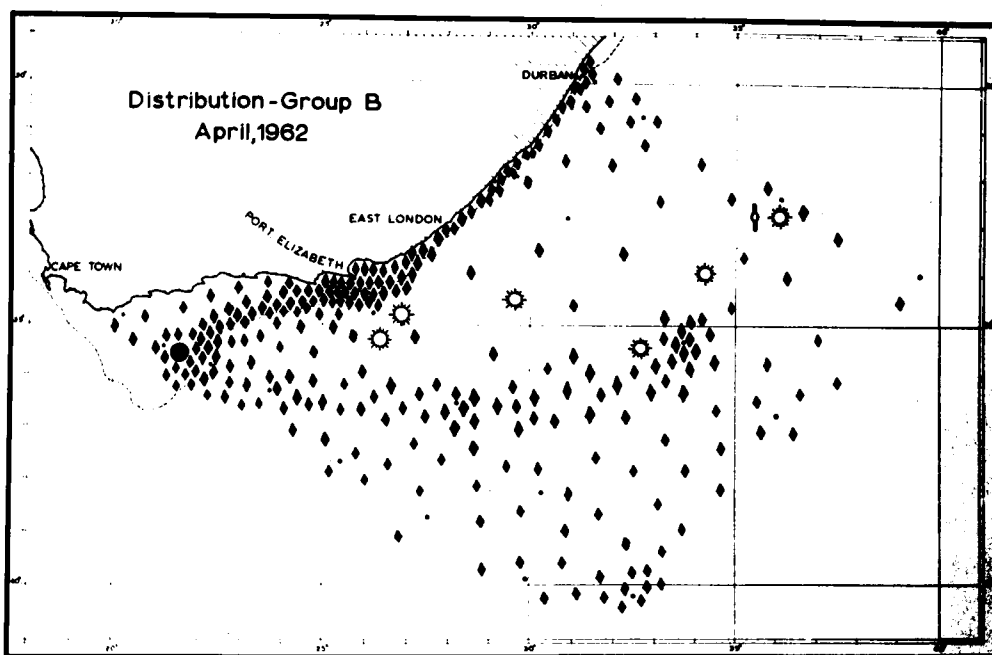


Chart 15

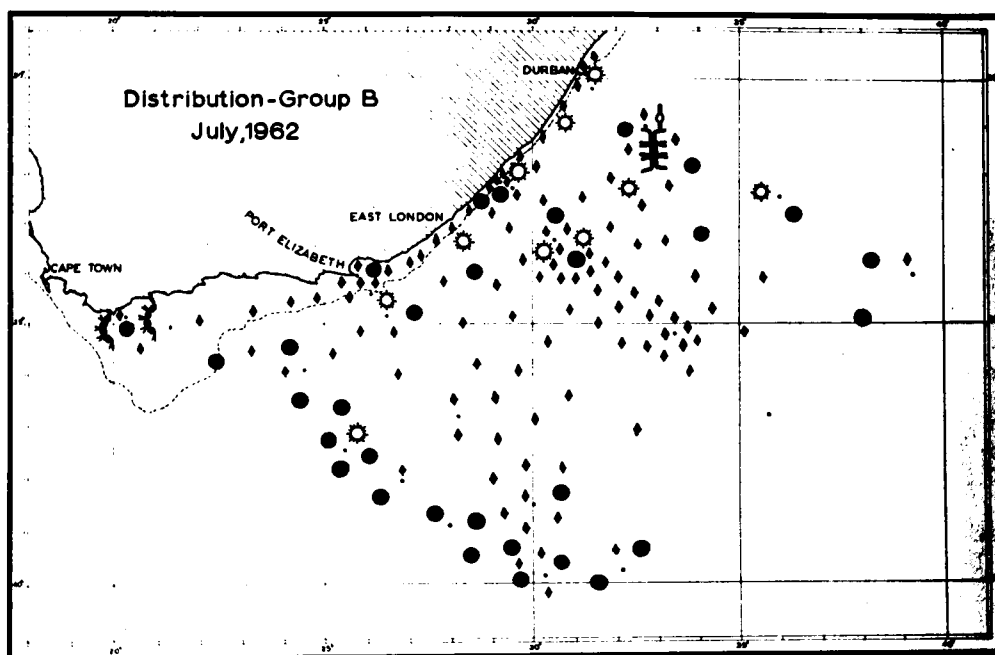


Chart 16

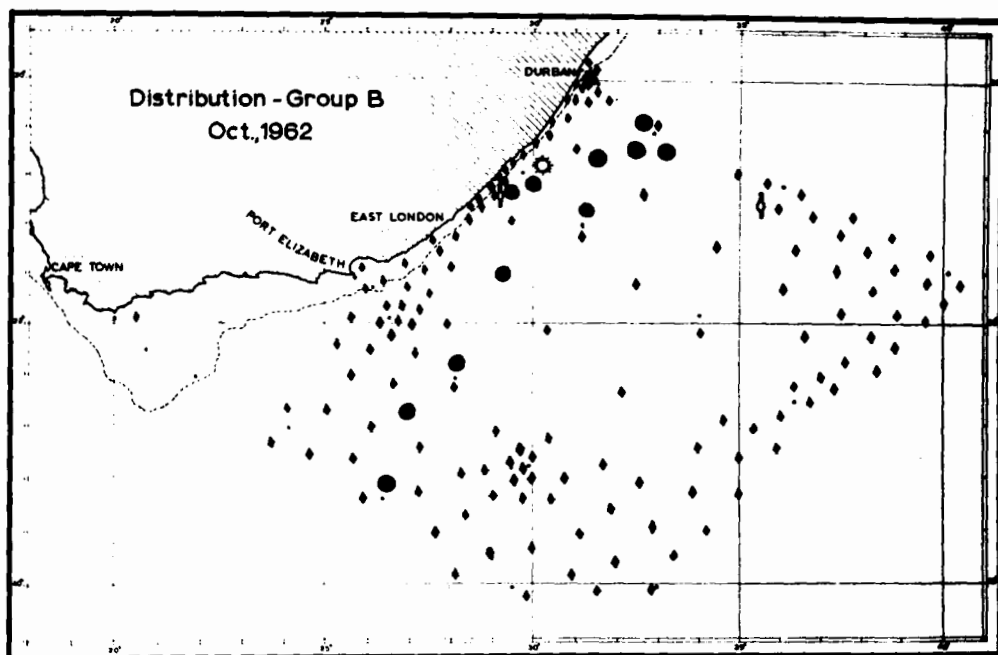
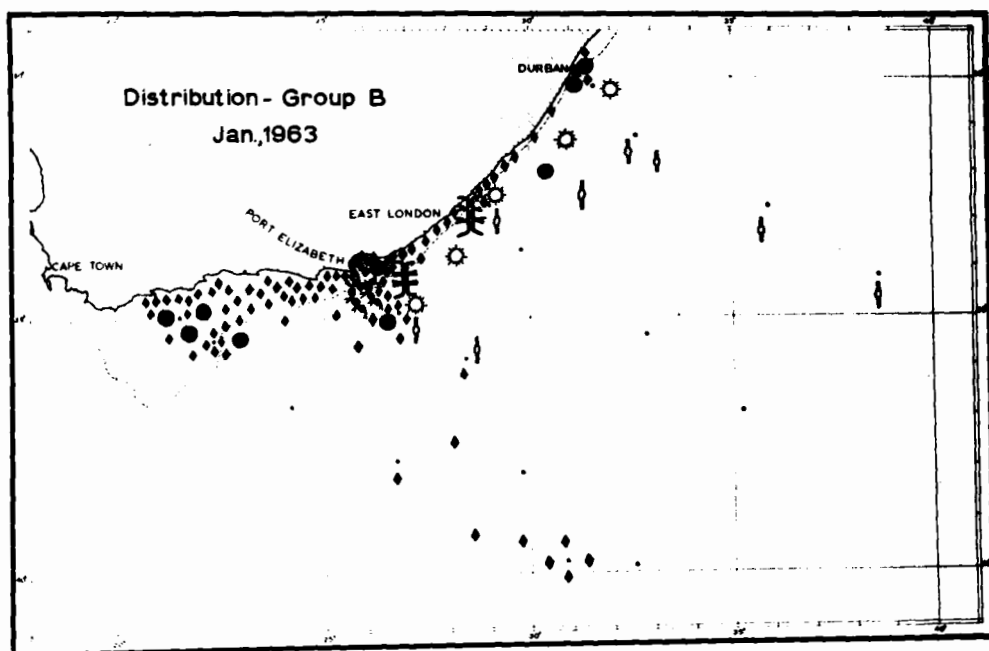


Chart 17



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 33.70‰, with a mean value of 35.71‰. Its absence from inshore waters is possibly attributable to the lower salinities commonly prevailing in coastal waters,

but is not fully understood. Hart & Currie (1960) considered the species to be indicative of intrusions of oceanic water into the Benguela Current region off the coast of South West Africa.

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 $37^{\circ}S$. 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.

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 $20^{\circ} - 30^{\circ}\text{C}$ 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 $21^{\circ} - 25^{\circ}\text{C}$ 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, Gossamerella tropica (also shown on

charts 14 - 17), Asterolamara narylandica, 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, Hemiasellus chinensis, Bacteriastrum comosum, Chaetoceros aquatorialis, Chaetoceros aurivillii, Chaetoceros denticulatus, Chaetoceros diversus, Chaetoceros imbricatus

and Chaetoceros pendulus.

(f) Thalassiothrix longissima (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 Red 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 replenishing 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 Pseudopenotia 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 Pg. 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 crionhilus, 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 around 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. curvicaetus in the S.W. Indian Ocean are Stephanopyxis turris, Chaetoceros borealis (also shown on charts 14 - 17), Chaetoceros difficilis, Chaetoceros tetras, Bacteriostrium 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 curvicaetus, 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) it 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 Sereas 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 Coscinodiscus compressum most of the dinoflagellates were oceanic or panthalassic 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 Bacteriastrium 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 from

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/m²/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 thiebautii 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, Mastagloia rostrata and Mastagloia 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 Gosslerella tropica and Asterolamara 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 Mastoglione 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

Ocean by them. Their determinations were made in summer, the season when phytoplankton in the net samples used in the present study was most sparse in the offshore waters. Kabanova (1961) concluded that the concentration of nitrogen compounds limited the production of phytoplankton in tropical Indian Ocean waters at some seasons.

(c) The Natal Shelf Zone.

This is the shelf water of the Natal coast extending southwards to a variable point usually in the vicinity of Port St. Johns. The zone is hydrographically very similar to the Agulhas Current which flows extremely close to the coast along the edge of the narrow continental shelf. Temperatures close inshore are usually only two or three degrees lower than in the current itself. Local counter currents flowing northwards close inshore may sometimes link up into a continuous system. Salinities are slightly lower than in the current possibly due to land drainage.

Phytoplankton populations at stations in this zone were dense for most of the year. Mitchell Innes (1964) in a monthly study of the productivity of a station situated near Durban found that it varied between 0.05 to more than 1.0 g.C/m²/day, generally being highest in spring and autumn.

From the point of view of species composition the dense concentrations off the Natal coast are interesting in

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 Bacteriastrium 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 roseleyana 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, Bacteriastrium minus, Asterionella japonica, Lauderia annulata, Rhizosolenia stouterfothii, 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 ^{being} Zone probably 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 rather 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 (++++^k) 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 (1980) 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/m²/day in the area (the highest productivity recorded during the Galathea cruise, 3.8 g.C/m²/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/m²/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/m²/day for station 155, an offshore station on line B, and the highest was 1.21 g.C/m²/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 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	zodiacus	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.). ^{in the present study} As the material 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 cruises. 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 Subrahmanyam (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).

V. 2. Main observations and conclusions.

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 Chaetoceros and Rhizosolenia, were predominant, although certain pennate species of the genera Nitzschia, Thalassionema and Thalassiothrix were also common and occasionally abundant in the material. An unusually large number of species of the centric genus Coscinodiscus 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 Ceratium and Peridinium. 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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PLATES.

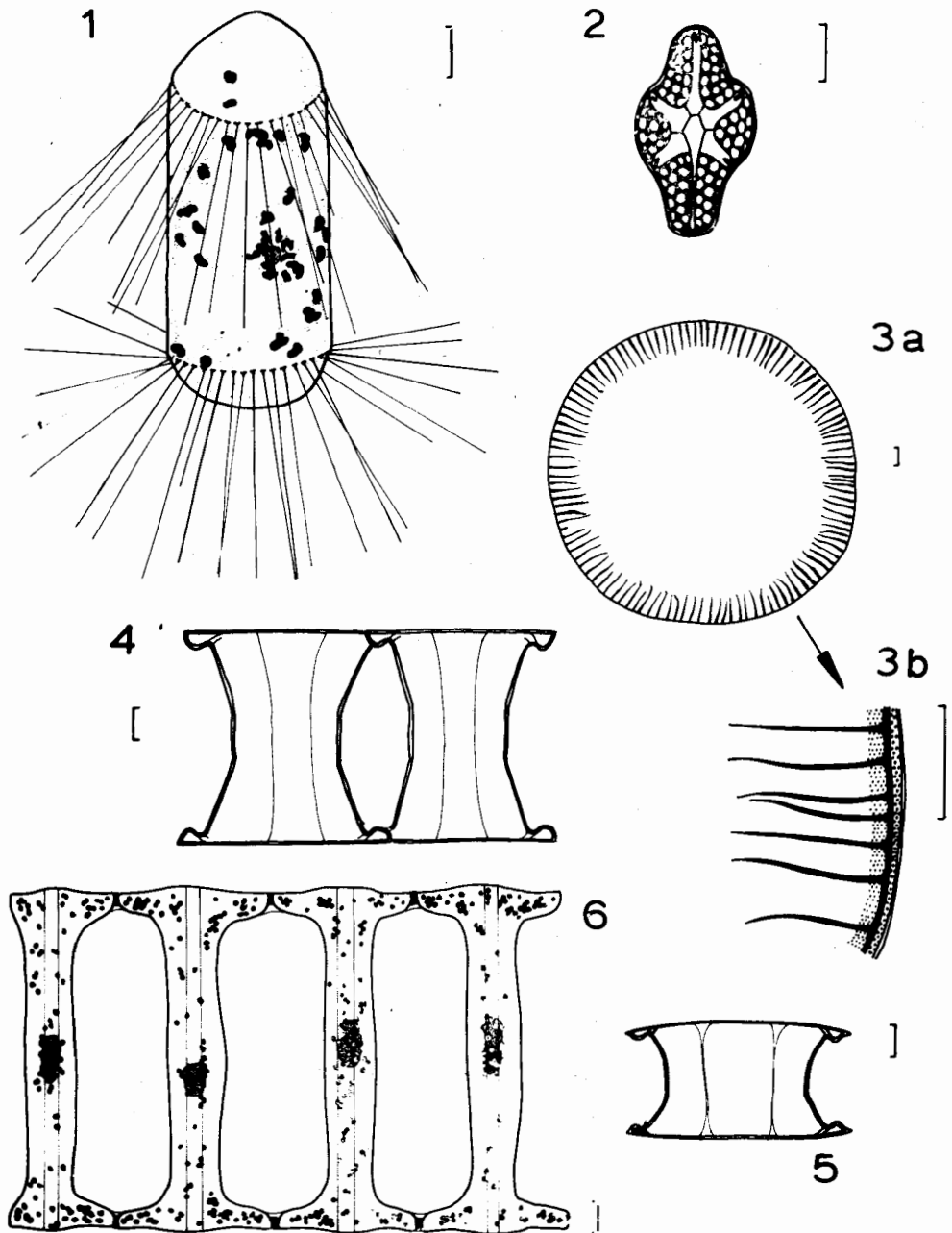
The scale - line represents 10u except where indicated to the contrary. The station numbers cited are those from which the specimens were collected. When figures are cited as -a, -b, -c they are features of the same specimen

All drawings and photomicrographs are by the author.

Bacillariophyceae	: plates 1 - 19
Chrysophyceae	: plate 20
Cyanophyceae	: plate 21
Xanthophyceae	: plate 22
Dinophyseae	: plates 23 - 27

Plate 1.

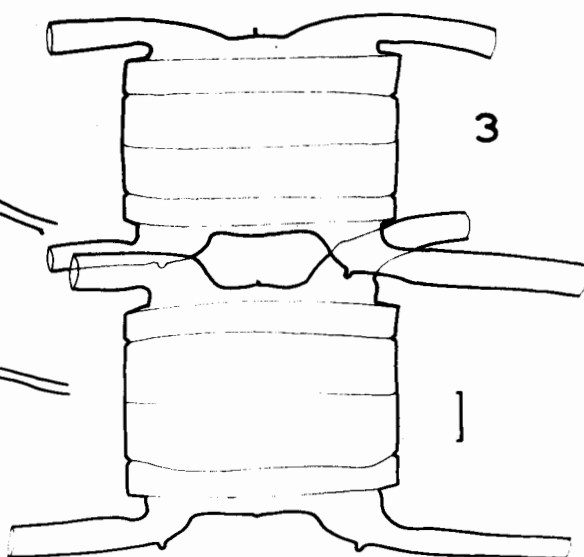
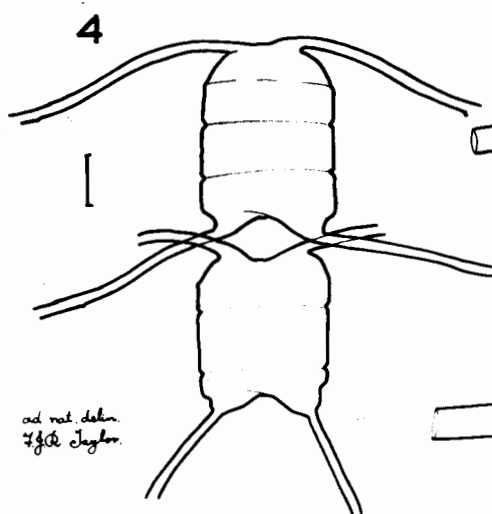
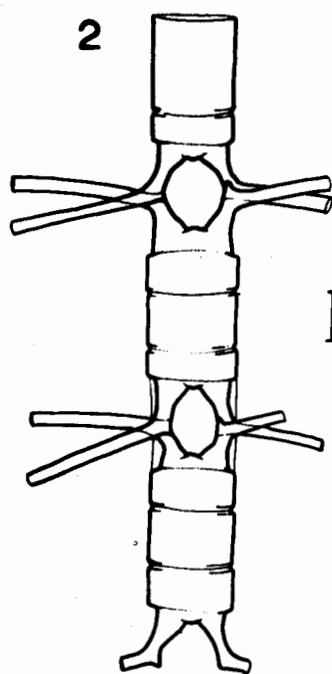
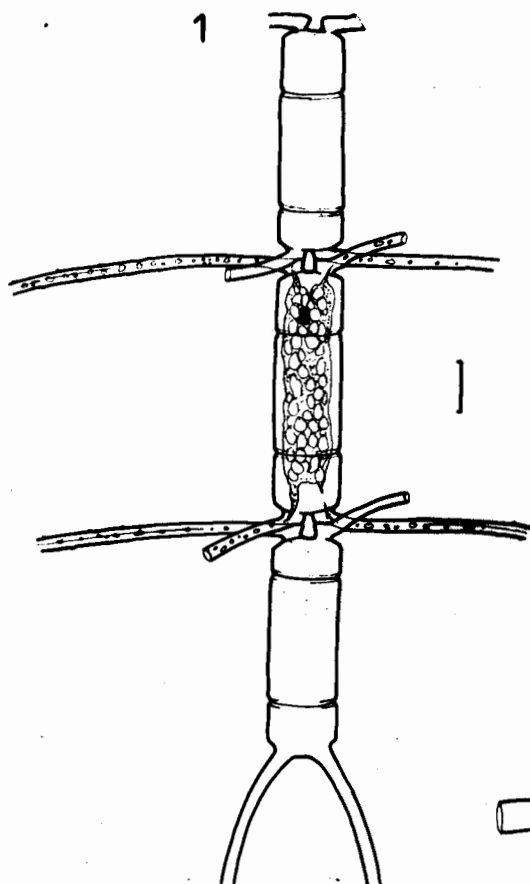
- Fig. 1. Corethron criophilum Castr. Water mount. NIOE 87.
2. Asteromphalus sarcophagus Wallich; a specimen with markedly concave sides. Water mount. NIOE 35.
3. Melissira^o sol (Ehrenb.) Kutz.; fig. a is an entire valve view, fig. b a detail of the margin. Myrax mount. NIOE 58.
4. Climacodium biconcavum Cleve; a pair of larger cells. Note the characteristic overlapping of the processes. Water mount. NIOE 18.
5. Climacodium biconcavum Cleve; a smaller cell more closely resembling the typical appearance than those in fig. 4. Water mount. NIOE 18.
6. Climacodium^o fraxenfeldianum Grun.; a portion of a chain showing the distinct end - cell (to the left) a feature not usually commented on or illustrated. Water mount. NIOE 80.



ad nat. delin.
J. G. Taylor

Plate 2.

- Fig.1. Chaetoceros aurivillii Cleve = Ch. Seychellarum
Karst.. Water mount. NIOE 78.
2. Chaetoceros denticulatus Laud. f. denticulatus.
Water mount. NIOE 78.
3. Chaetoceros denticulatus f. latus Hust.. Water
mount. NIOE 78.
4. Chaetoceros crionhilus f. okamurai (Ikari) Taylor,
stat. et comb. nov. = Ch. ^ookamurai Ikari. Water
mount. NIOE 78.



ad nat. delin.
J. H. Taylor.

Plate 3.

- Fig. 1. Chaetoceros imbricatus Mangin; a typical chain from the S.W. Indian Ocean. Note the partial fusion of adjacent setae, and the spirillations on the distal portions of the setae. Water mount. NIOE 9.
2. Chaetoceros paradoxus Cleve, showing the characteristic arrangement of the setae, the cell bodies of the rounded type figured by Allen & Cupp (1935). Water mount. NIOE 54.
3. Chaetoceros affinis f. inflatespinosus Taylor, stat. nov. = Ch. femur Schutt. Water mount. NIOE 5.
4. Bacteriastrum varians var. hispidum (Castr.) Schroder. Only two of the five pairs of the setae between adjacent cells are shown. Water mount. NIOE 74.

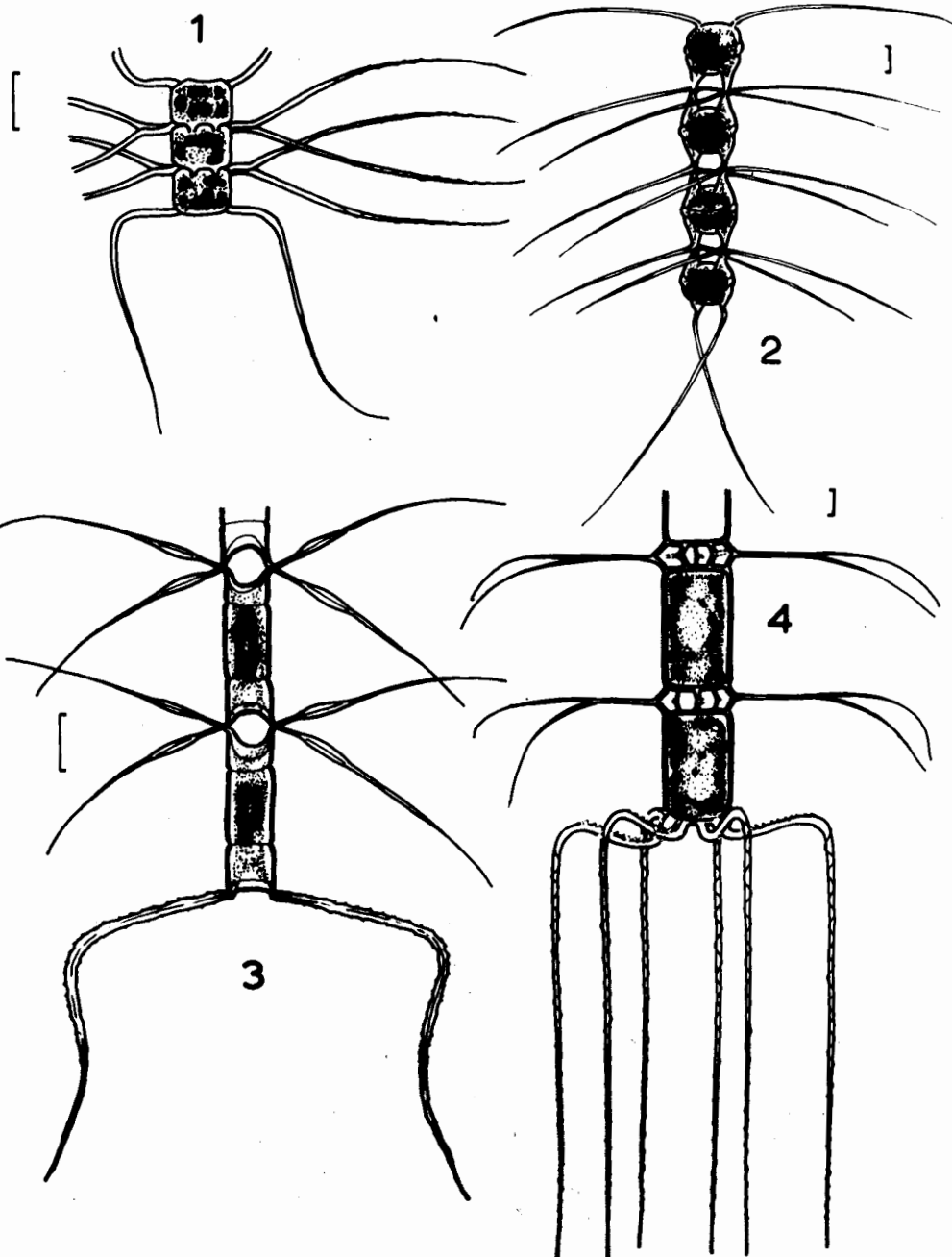
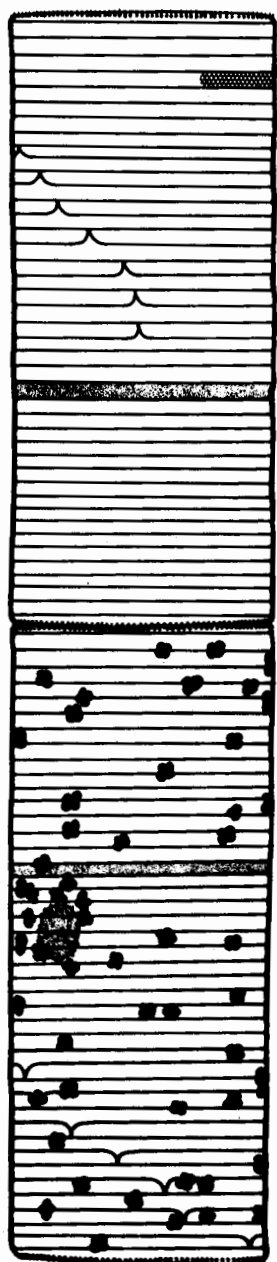


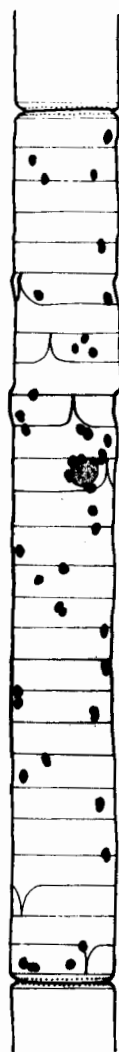
Plate 4.

- Fig. 1. Detonula moseleyana (Castr.) Gran; a pair of broad cells typical of the inshore population. The lower cell shows the marked parietal nucleus and the numerous chromatophores. The dark intercalary bands, one per cell, are also shown. *Arcolation* is partially indicated in the upper cell. Hyrax mount. N10E 73.
2. Detonula moseleyana (Castr.) Gran; The characteristic oceanic form of this species. The cells are narrow, elongated, lacking the dark intercalary bands, and the marginal spinulae are very fine (not visible in water mounts). Water mount. N10E 62. (iconotype).
3. Schroderella delicatula (Perag.) Pavill. f. delicatula; present in the warm water off the coast of Natal. *Arcolation* partially indicated. Hyrax mount. N10E 75.
4. Schroderella delicatula f. schroderii (Bergon) Taylor, stat. et comb. nov. = Schroderella schroderii (Berg.) Pavill.; the cold water form of S. delicatula. *Arcolation* not visible on the intercalary bands. What appears to be rows of fine punctae are partially indicated in the figure. Hyrax mount. N10E 94.

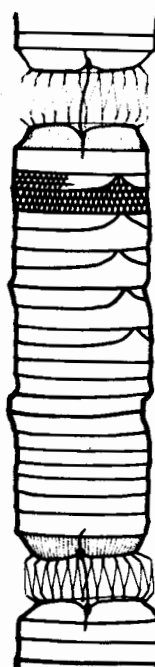


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7/8. Taylor.

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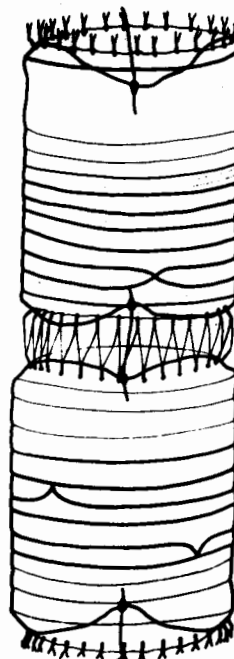


Plate 5.

- Figs. 1, 2 & 3. Synedra indica Taylor sp. nov. Three cells showing the range in size and shape of the species. Hyrax mount. NIOE 62 (a), 21 (b,c). (fig. 1, iconotype).
4. a, b & c. Synedra palagica Hendey? Whole cell and details of central terminal portions. Hyrax mount. NIOE 21.
5. a, b & c. Synedra regalis Taylor sp. nov. Whole cell and details of central and terminal portions. Hyrax mount. NIOE 62. (iconotype).
6. a & b. Synedra reinholdii Van Heurek. Whole cell and detail of central portion. Hyrax mount. NIOE 21.
7. Mastagloia capitata (Brun) Cleve. Hyrax mount. NIOE 101.
8. Chaetoceros myrianodus Mangin; complete chain showing distinctive end - cells. Water mount. NIOE 94.

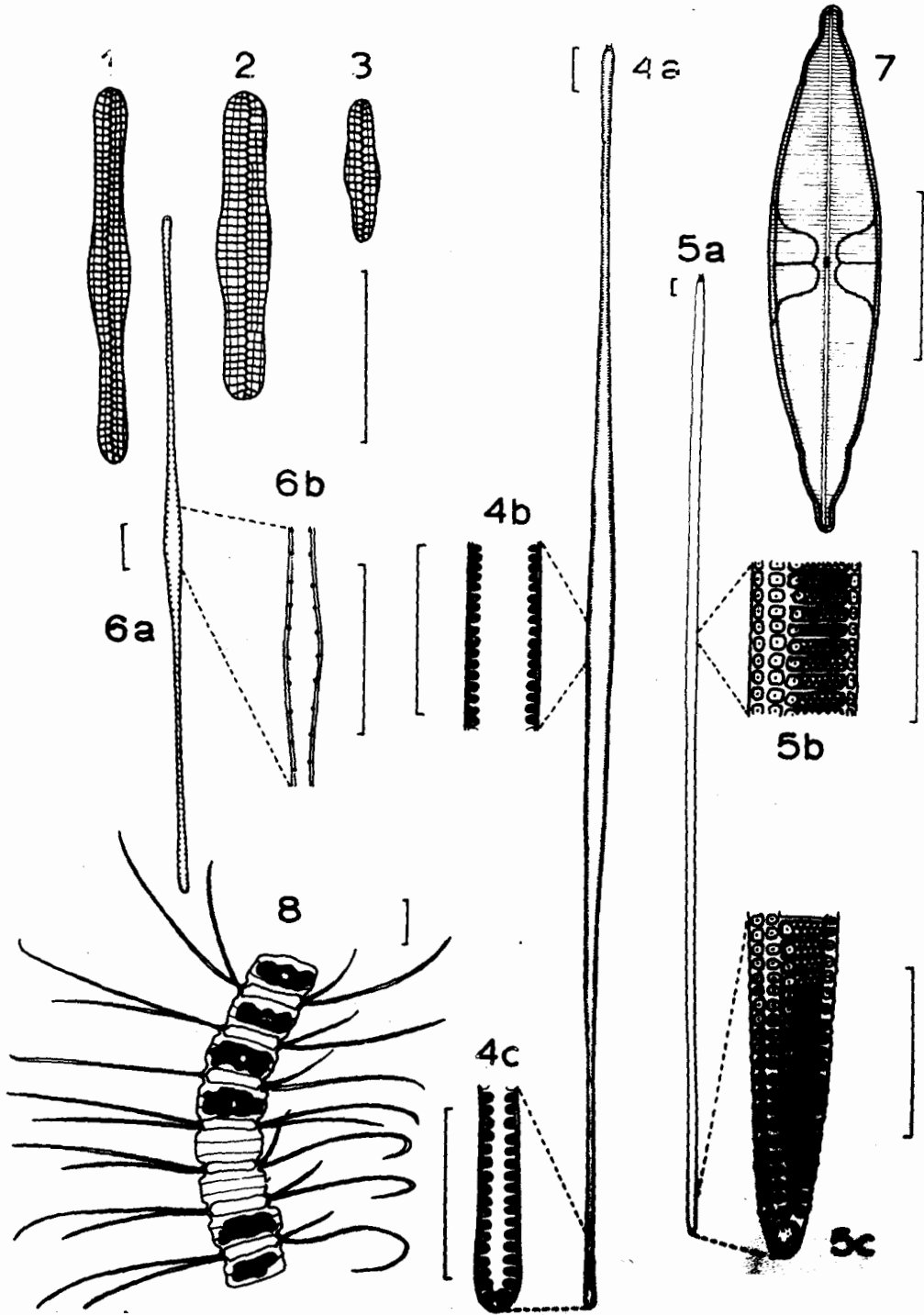
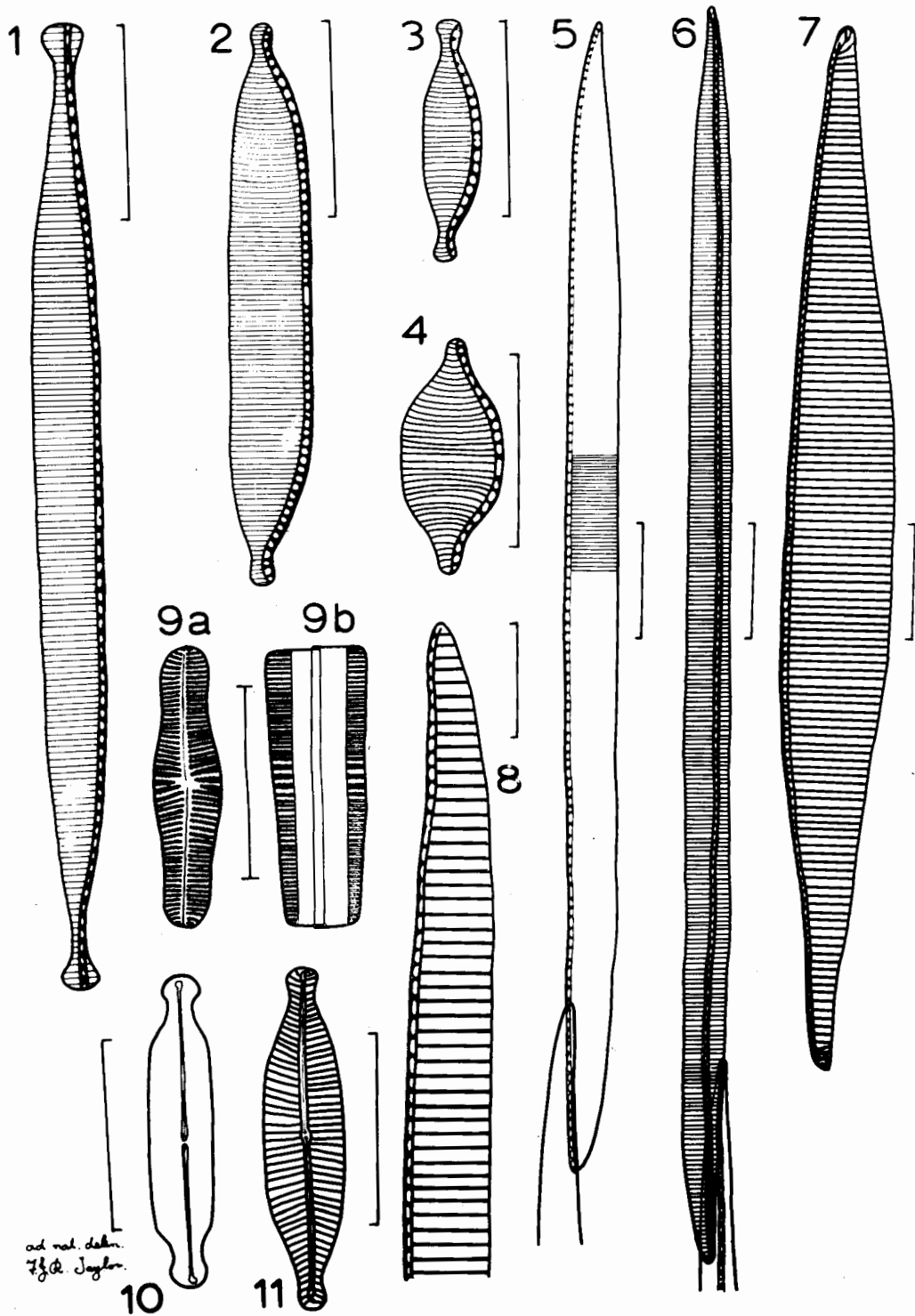


Plate 6.

- Figs. 1 - 4. Nitzschia bicapitata Cleve; Four cells indicating the range of variation in this species.
Hyrax mount. N10E 58 (2, 3), 178 (1, 4).
5. Nitzschia delicatissima Cleve; a large cell, striation partially indicated. Hyrax mount.
N10E 71.
6. Nitzschia pacifica Cupp. Hyrax mount. N10E 21.
7. Nitzschia seriata Cleve. Hyrax mount. N10E 30.
8. Nitzschia sicula var. bicuneata Grun. $\frac{2}{3}$ of cell, actual length 82u. Hyrax mount. N10E 60.
9. Navicula ^htendeyana Taylor sp. nov. Hyrax mount.
N10E 78. (iconotype).
10. Navicula sp. 1. Hyrax mount. N10E 21.
11. Navicula sp. 2. Hyrax mount. N10E 21.



- Fig. 1. Coscinodiscus centralis Ehrenb.. Water mount. NIOE 178.
2. Coscinodiscus africanus Jan. ex A. Schmidt. Water mount. NIOE 159.
3. Coscinodiscus nodulifer Jan. ex A. Schmidt. Central papilla indicated by the arrow. Water mount. NIOE 178.
4. Coscinodiscus lineatus Ehrenb.. Water mount. NIOE 97.
5. Coscinodiscus marginata^o - lineatus A. Schmidt. Water mount. NIOE 97.
6. Coscinodiscus stellaris Roper. Water mount. NIOE 178.

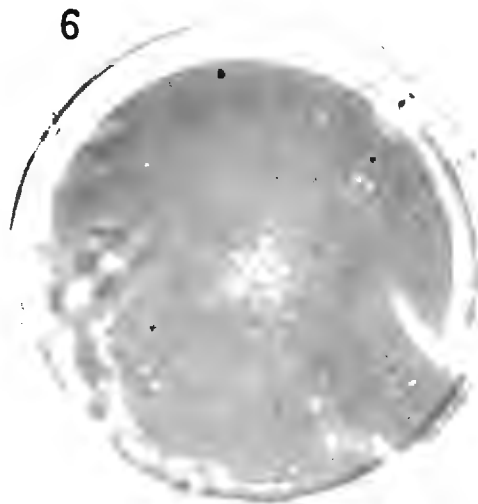
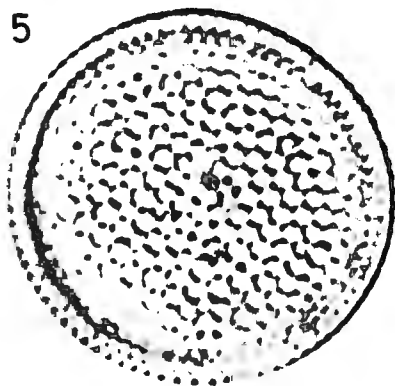
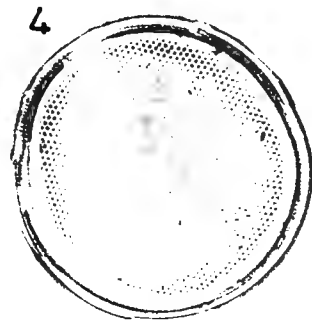
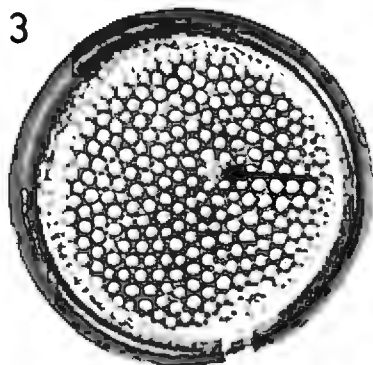
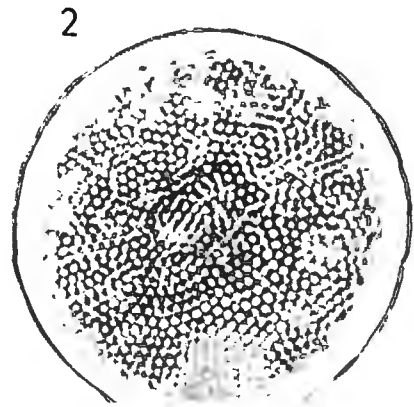
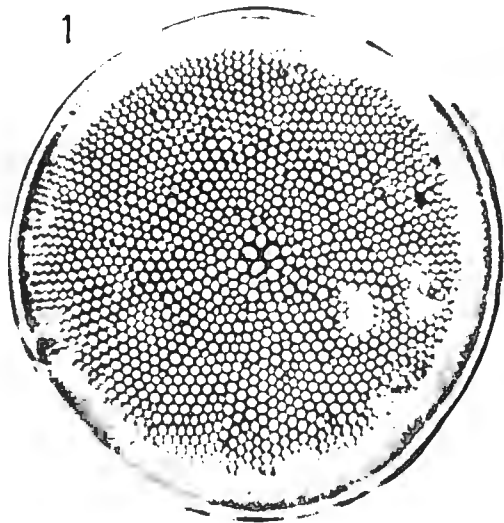


Plate 8.

- Fig 1. Coscinodiscus reniformis Castr.. Hyrax mount. NIOE 71.
2. Roperia tessellata (Roper) Grun. in V. H. . Water mount. NIOE 108.
3. Coscinodiscus gigas var. praetexta (Jan.) Hust.. whole cell. Water mount. NIOE 130.
4. The same. Girdle view of a larger individual than figured in 3. Note intercalary bands. Water mount. Specimen from additional material, locality : False Bay.

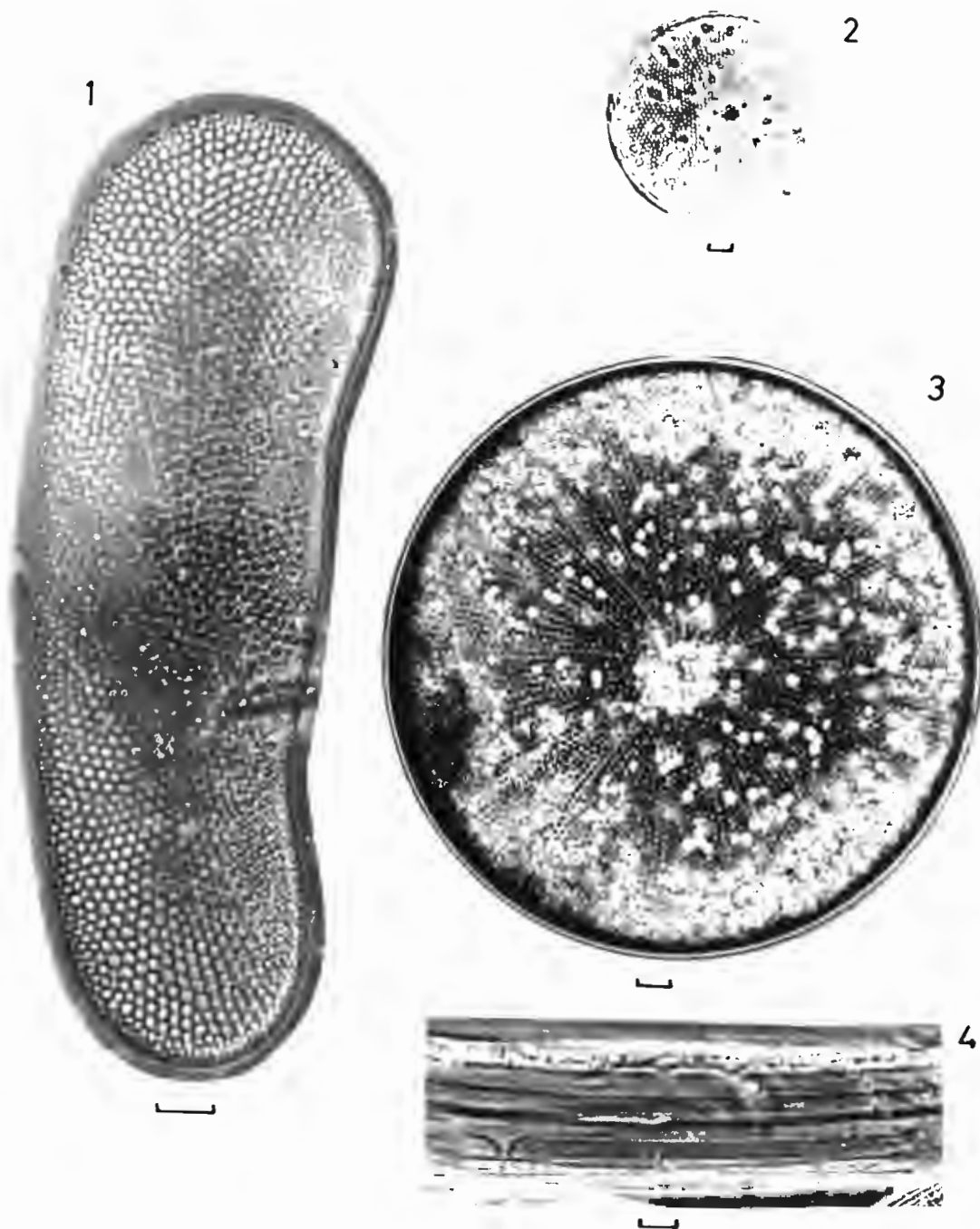
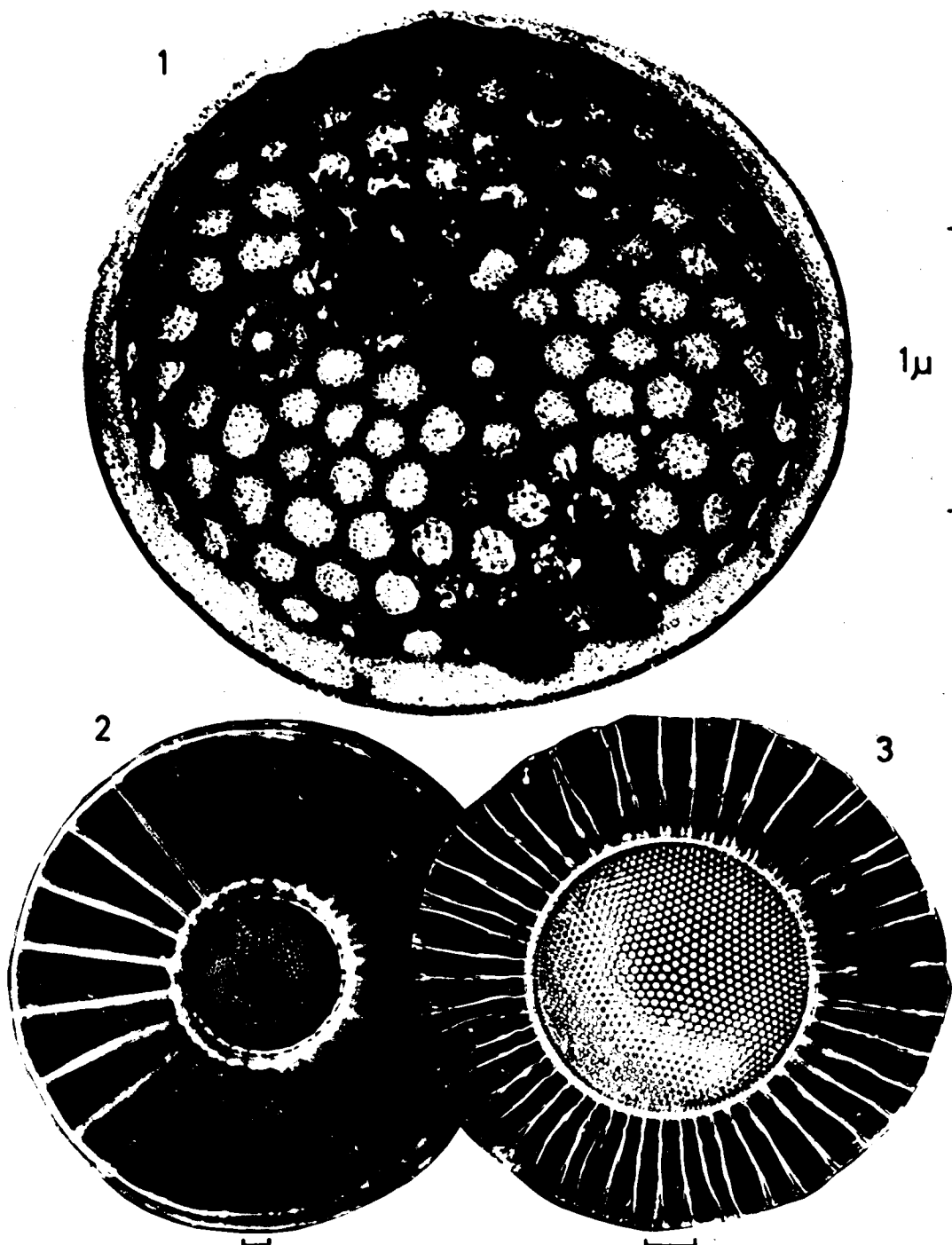


Plate 9.

- Fig. 1. Coscinodiscus trioculatus Taylor sp. nov. Electron - micrograph of detached valve. Preparation for electron micrography. NIOE 85.
2. Planktoniella sol (Wall.) Schütt; a large - winged specimen from the vicinity of the Subtropical Convergence region. Hyrax mount. NIOE 87.
3. The same. A specimen with a smaller wing in relation to the size of the valve. Hyrax mount. NIOE 71.



(This plate has been inverted)

Plate 10.

- Fig. 1. Skeletonema costatum (Grev.) Cleve; a chain of large cells in which the chromatophores are exceptionally stellate. Water mount. NIOE 114.
2. Stephanonxys turris (Grev.) Ralfs in Pritch.. Water mount. NIOE 94.
3. Thalassiosira ^oretula Neun.. Hyrax mount. NIOE 178.
4. Thalassiosira condensata Cleve. Hyrax mount. NIOE 94.

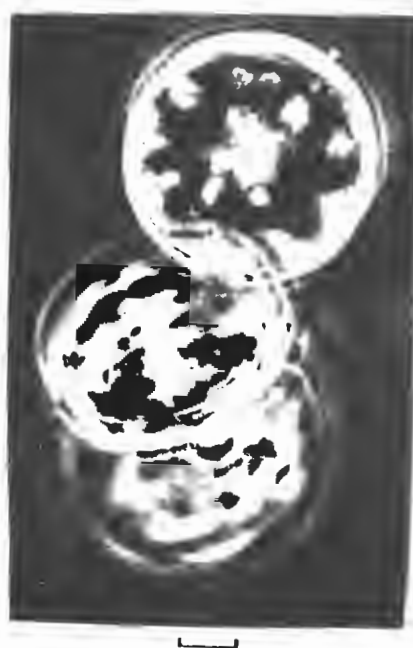


Plate 11.

1. Asteromphalus arachne (Breb.) Ralfs in Pritch..
Water mount. NIOE 150.
2. Asteromphalus sarcophagus Wall.; a variant in which
the sides show no concavity. Water mount. NIOE 178.
3. Asteromphalus robustus Castr.; a small specimen
(short diameter 28u) with 5 + 1 rays. This specimen
closely resembles A. antarcticus Castr. in all respects
except for the sharply angled umbilical lines
(straight in A. antarcticus). Water mount. NIOE 150.
4. Asteromphalus distinctus Mann. Due to the poor
reproducibility of the photomicrograph the central
area and ray margins have been inked in. Water mount.
NIOE 150.
5. Cassleriella tropica Schutt. Water mount. NIOE 110.

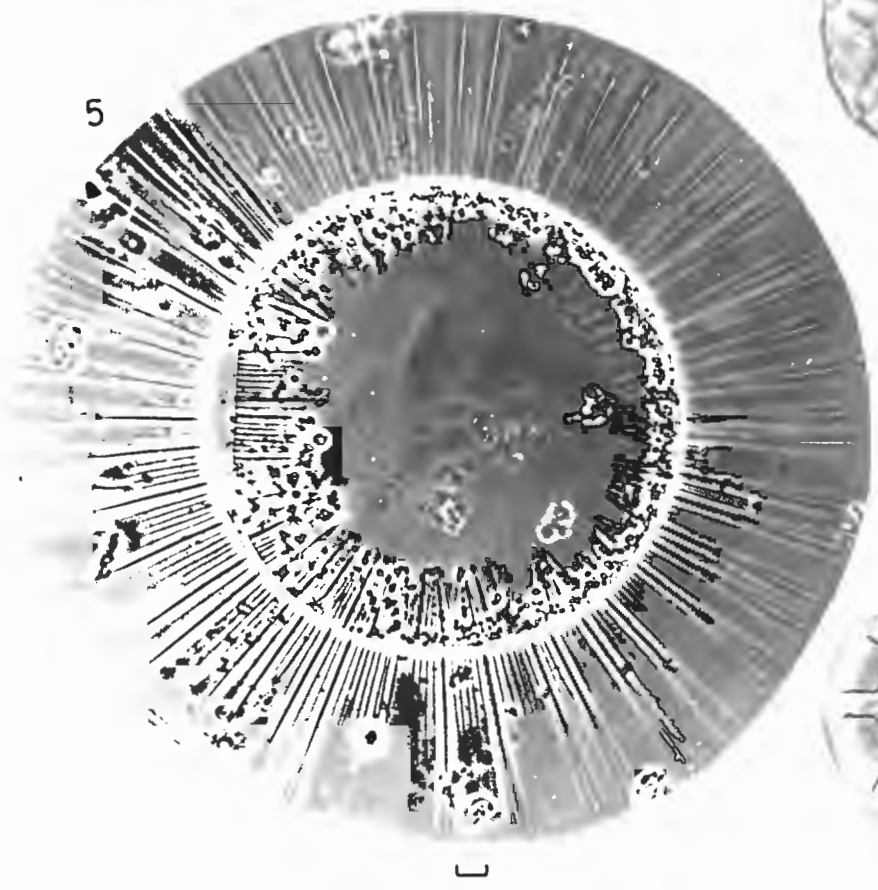
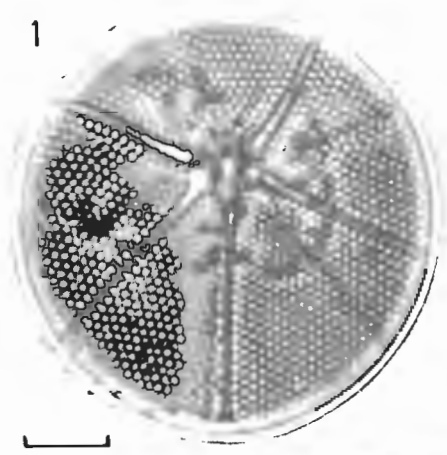


PLATE 12

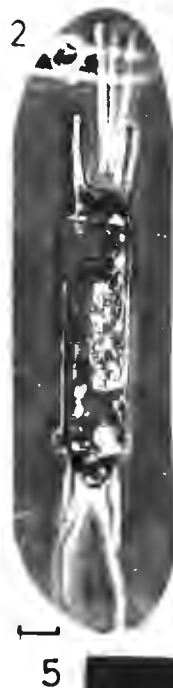
Fig. 1 Biddulphia chinensis Grev.. Internal division has taken place, the cell contents being disarranged due to treatment. Hyrax mount. NIOE 94.

2. Biddulphia longiaruria Grev.. Hyrax mount. NIOE 112.

3. Biddulphia mobilensis Bail.. Hyrax mount. NIOE 94.

4. Biddulphia tridens (Ehrenb.) Ehrenb. = B. tuomeyi (Bail.) Roper. Water mount. NIOE 111.

5. Triceratium alternans Bail.. Hyrax mount. NIOE 94.



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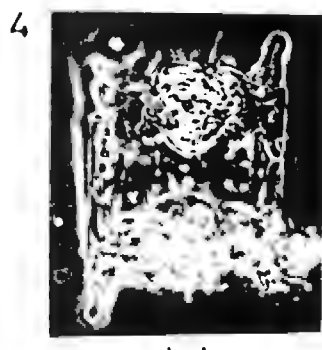


Plate 13.

- Fig. 1. Bacteriastrum minus Karsten. Water mount. NIOE 115.
2. Chaetoceros pendulus Karsten. Cell showing six curious objects, possibly unusual chromatophores, contained within it. Water mount. NIOE 153.
3. Chaetoceros rostratus f. glandazii (Mangin) Taylor, stat. et. comb. nov. = Ch. glandazi Mangin. Water mount. NIOE 103.

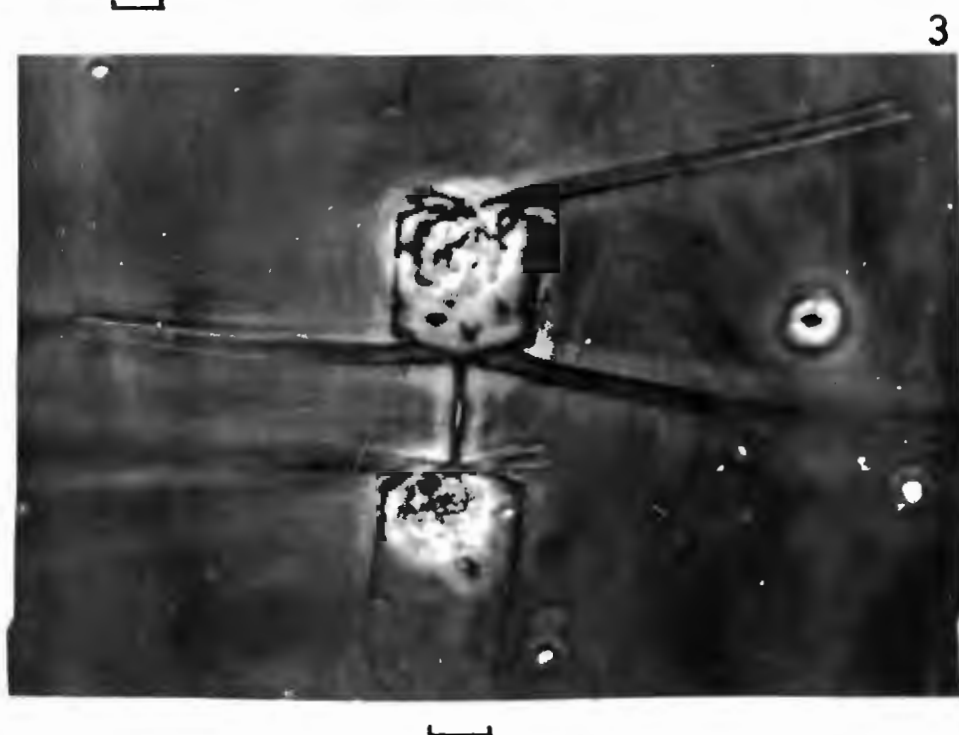
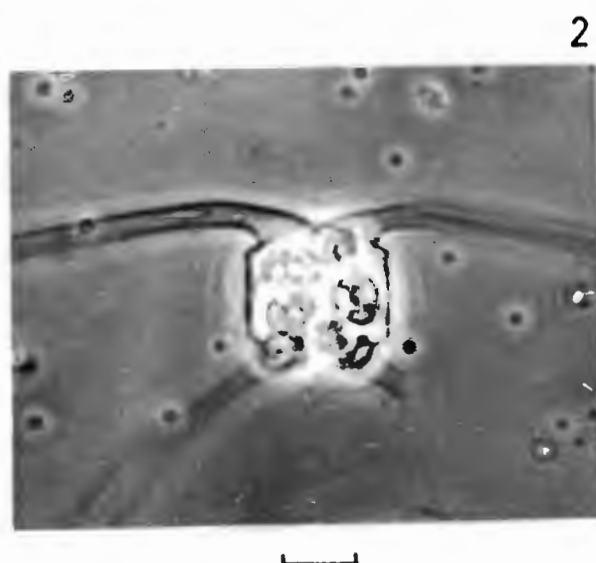
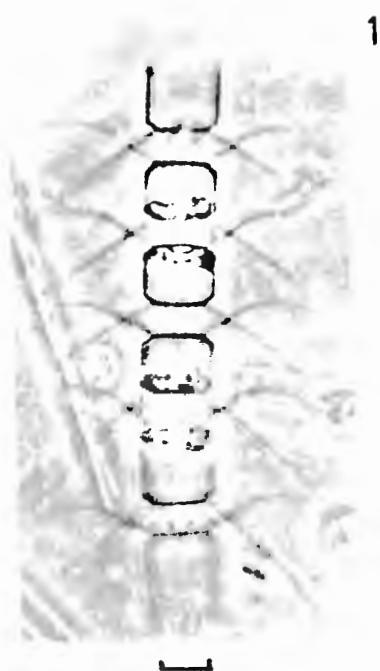
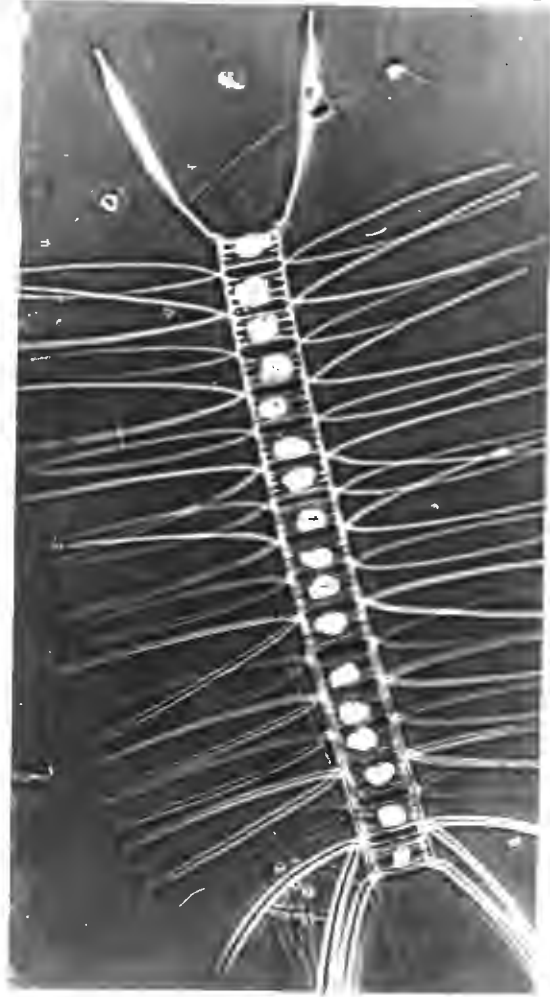


Plate 14.

- Fig. 1. Chaetoceros tetrastichon Cleve. Complete chain.
Water mount. NIOE 110.
2. Chaetoceros decipiens Cleve. Complete chain. Hyrax
mount. NIOE 94.
3. Chaetoceros compressus Laud.. Section of a chain
showing the distinctly differentiated setae. Water
mount. NIOE 114.



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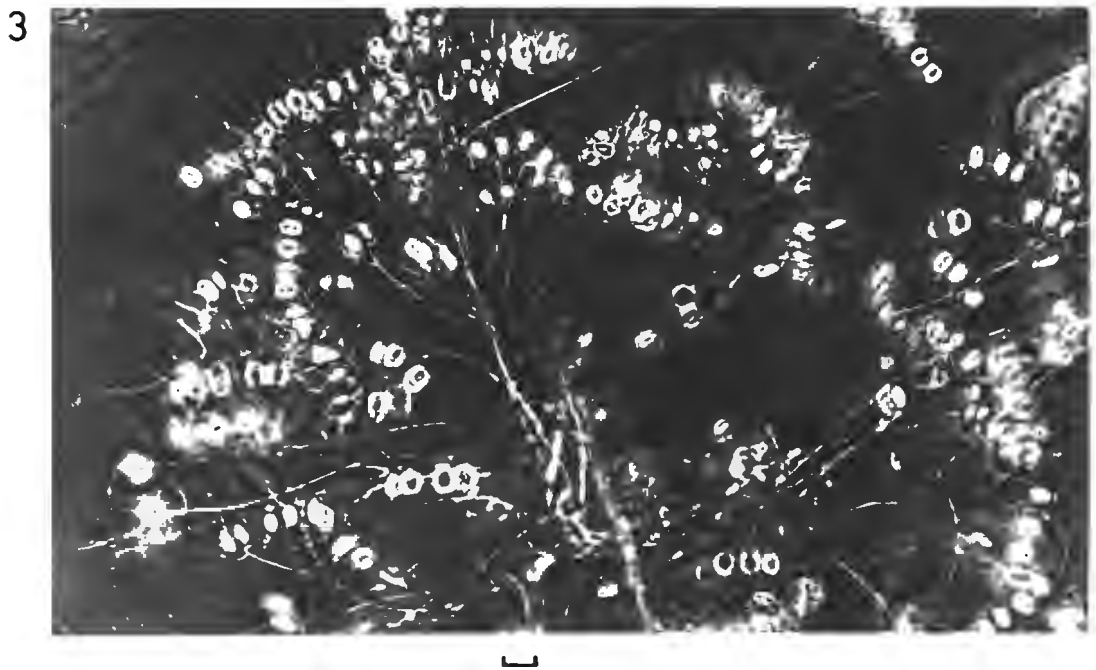
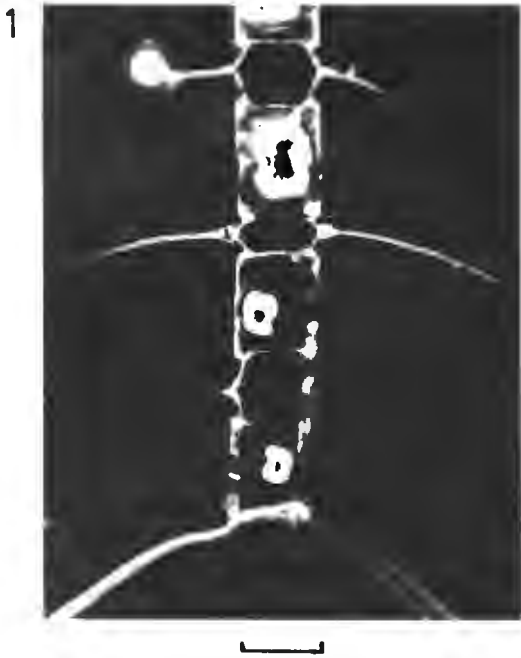
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Plate 15.

- Fig. 1. Chaetoceros pelagicus Cleve. Hyrax mount. NIOE 94.
2. Chaetoceros neglectus Karsten. Water mount. NIOE 115.
3. Chaetoceros socialis Lauder. Typical colony. Hyrax mount. NIOE 94.



, Plate 16.

Fig. 1. Dactyliosolen mediterraneus H. Perag. Hyrax mount.

NIOE 111.

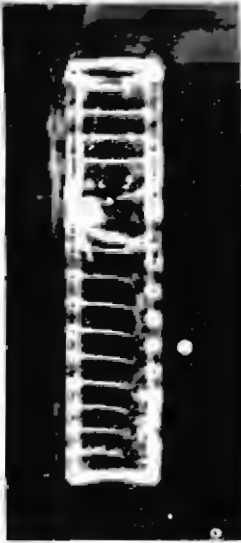
2. Schröderella delicatula f. schröderii (Berg.) Taylor,
stat. et comb. nov. Enlarged cells resulting from
the division of an auxospore. Water mount. NIOE 114.

3. Rhizosolenia cylindrus Cleve, Water mount. NIOE 117.

4. Rhizosolenia bergonii H. Perag. Pair of cells.
Water mount. NIOE 104.

5. Rhizosolenia imbricata Brightw. Terminal portion.
Hyrax mount. NIOE 58.

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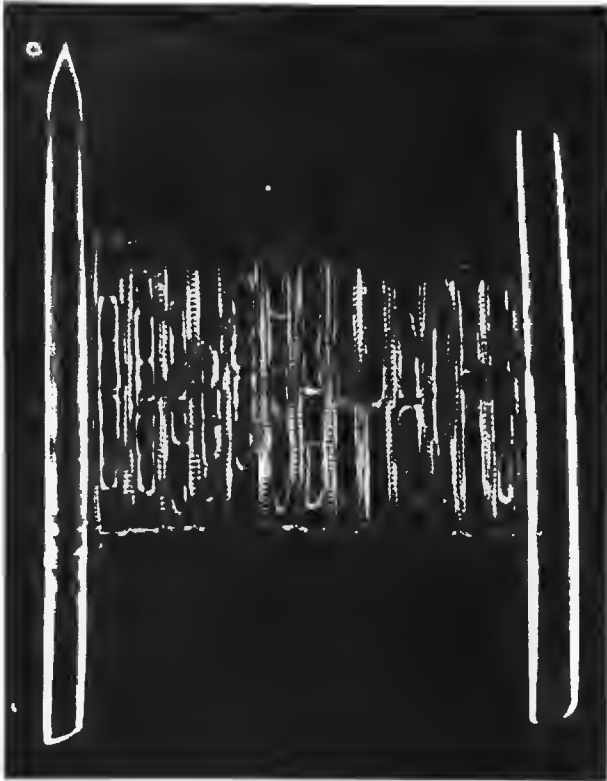
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Plate 17.

- Fig. 1. Fragilaria linearis Castracane. A chain of cells with sponge spicules on either end. Water mount. NIOE 94.
2. Fragilaria linearis Castr. Hyrax mount. NIOE 94.
3. Pseudocunetia doliolus (Wall.) Grun. in Van Heurck.
A typical short chain of cells. Water mount. NIOE 103.
4. Synedra ossiformis Taylor sp. nov. Water mount
(oil immersion). NIOE 87. (iconotype).

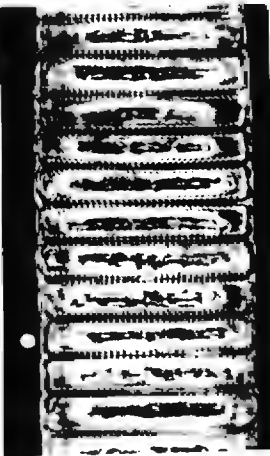
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Plate 18.

Fig. 1. Pleurosigma minutum Grun. ex Cleve. Water mount.

NIOE 111.

2. Thalassionema nitzschioides (Grun.) Hustedt. A typical chain of cells. Hyrax mount. NIOE 21.

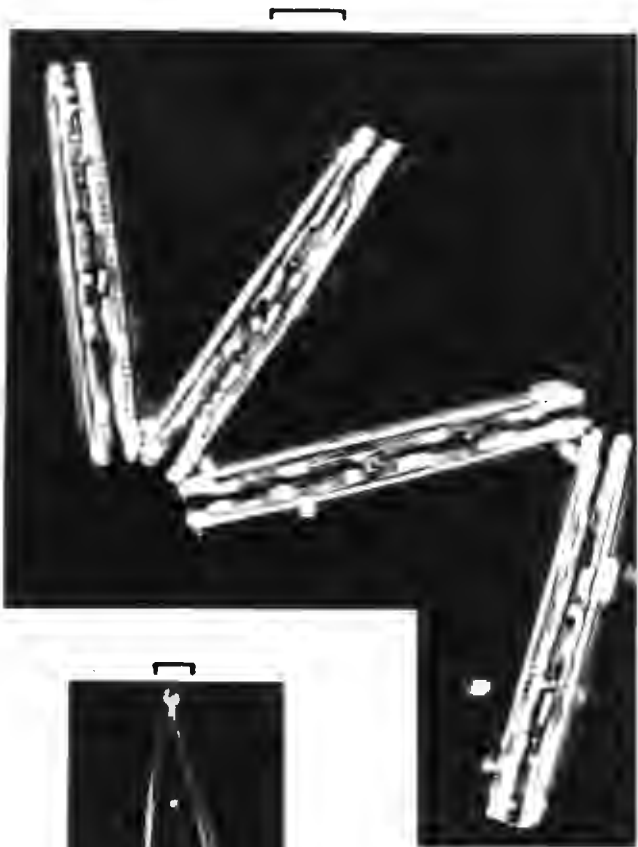
3. Tropidoneis lepidontera (Greg.) Cleve. Water mount.

NIOE 2.

4. Mastagloia rostrata (Wall.) Hust. A specimen with short processes and an angular valve. Water mount.

NIOE 101.

5. The same. A greatly elongated specimen. Water mount. NIOE 150.



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Plate 19.

- Fig. 1. Nitzschia spathulata var. hyalina (Greg.) Grun. in
V. Heurck. Hyrax mount. NIOE 178.
2. Nitzschia sigma var. rigida (Kütz.) Grunow. Water
mount. NIOE 114.
3. Nitzschia ? sp. Small cells epiphytic on an empty
frustule of Rhizosolenia styliformis. Water mount.
NIOE 108.
- 4 a, b Nitzschia lanceolata var. quincuncata Taylor var. nov.
Fig. a shows the characteristic striation on the valve.
Fig b is a deeper focus in which the keel punctae
are more easily discernable. Water mount. NIOE 103.

Plate 20.

1. Calcosolenia tenuis Bernard & Lecal. Water mount.
Oil immersion. NIOE 117.
2. Coccolithus leptoporus (Murray & Blackman) Schiller.
A particularly large coccolith, 12.5 u in diameter.
Water mount. Oil immersion. NIOE 117.
- 3, 4. Two coccoliths of Helicosphaera carterii (Wallich)
Kamptner. Fig. 3 shows a specimen viewed from below,
the lower shield with its two pores being uppermost.
Fig. 4 is of a specimen viewed from above. Water
mounts. NIOE 117.
5. Anthosphaera robusta (Lohmann) Kamptner. An incomplete
cell. Most of the coccoliths are viewed from above
but the arrow indicates one seen laterally. Water
mount. NIOE 117.
6. D Discosphaera tubifer (Murray & Blackman) Ostenfeld.
Fig. a is a poor photomicrograph of an entire cell.
Fig. b is a detail sketch of the cell body and one
coccolith. Water mount. NIOE 151.

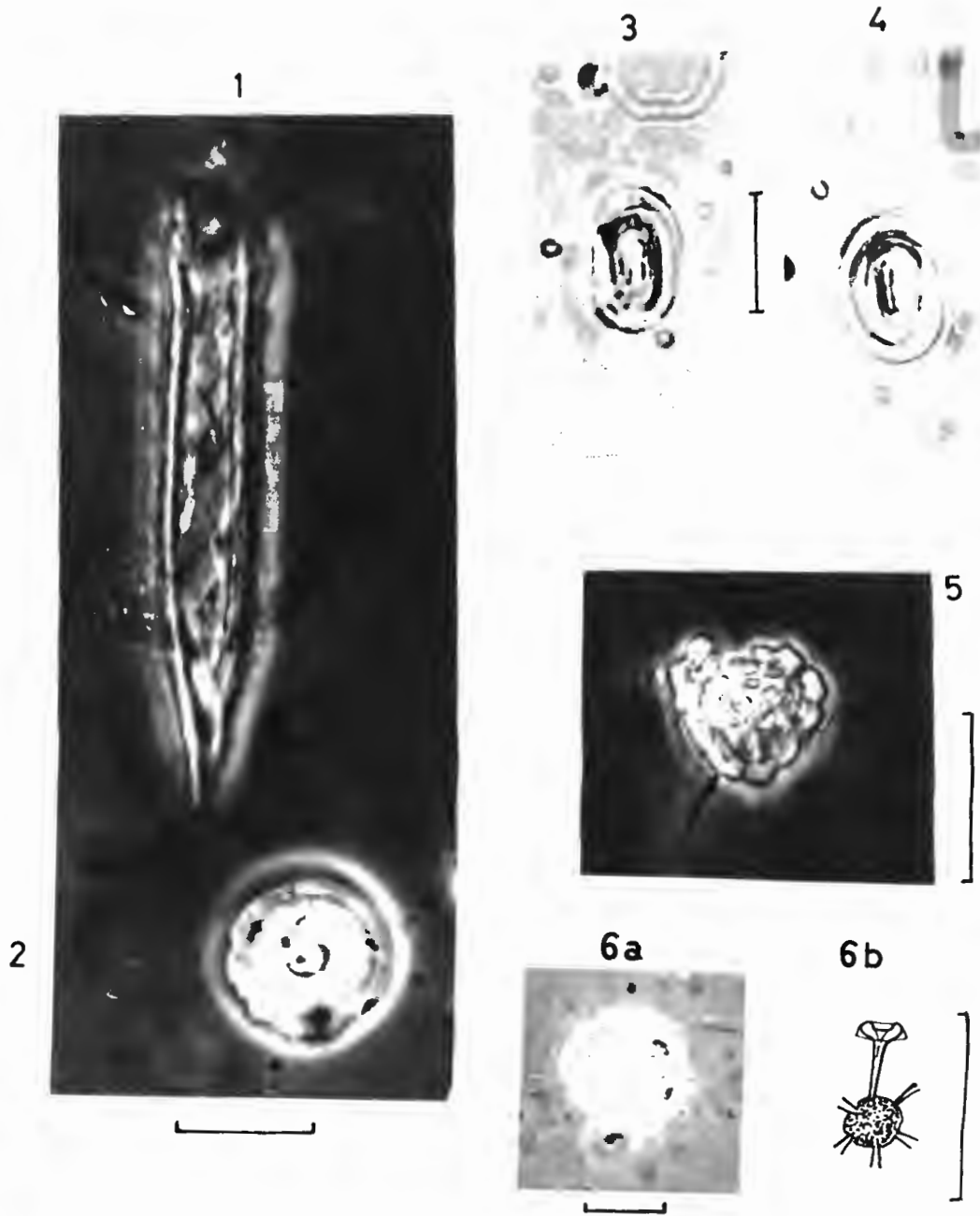


Plate 21.

- Fig. 1. Trichodesmium thiebaultii Gomont. A typical filament.
Water mount. NIOE 111.
2. Trichodesmium hildebrandtii Gomont. The characteristic
terminal cap is indicated by the arrow.
3. Nostoc sp. Water mount. NIOE 104.
4. Nostoc sp. An aggregation of cells in which a number
of cysts can be seen. Water mount. NIOE 153.

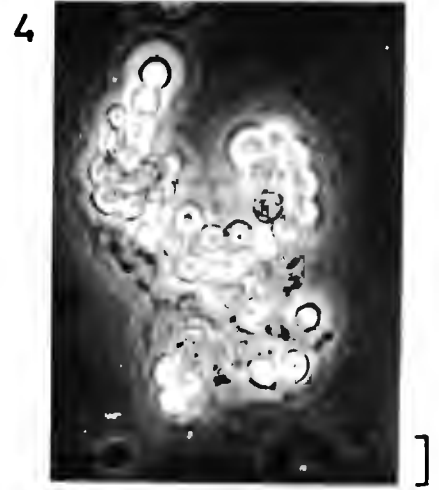
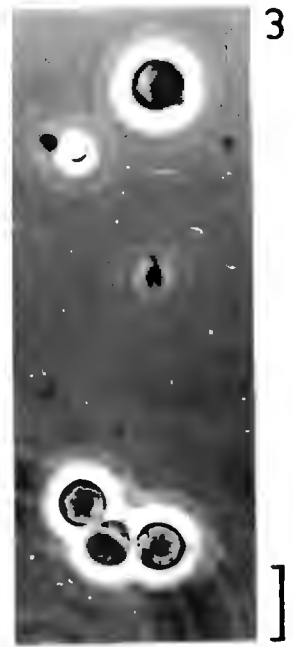
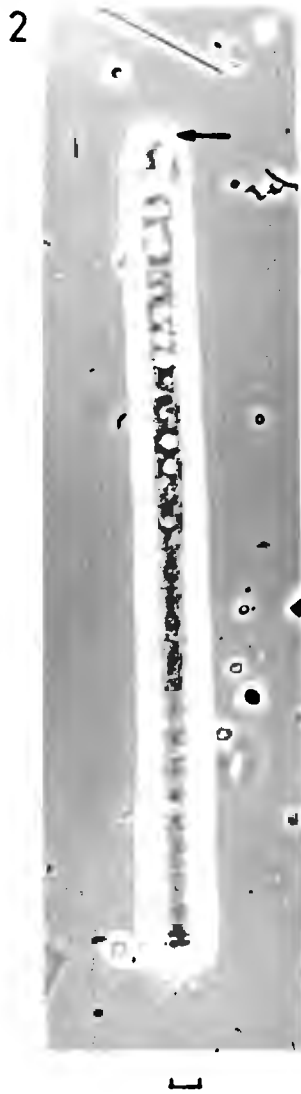
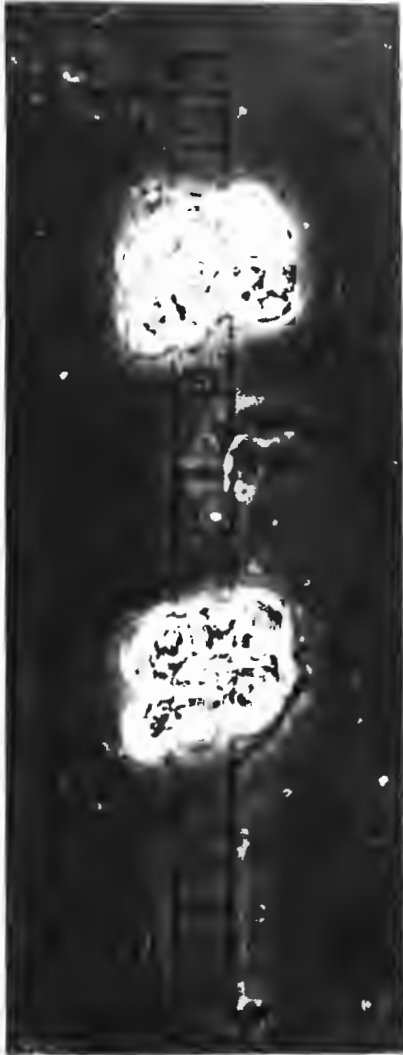


Plate 22.

- Fig. 1. Solenicola setigera Pavill. Two colonies on a cell
of Dactyliosolen mediterraneus. Water mount. NIOE 117.
- 2, 3. Halospheera viridis Schmitz. Water mounts. NIOE 97,
108.

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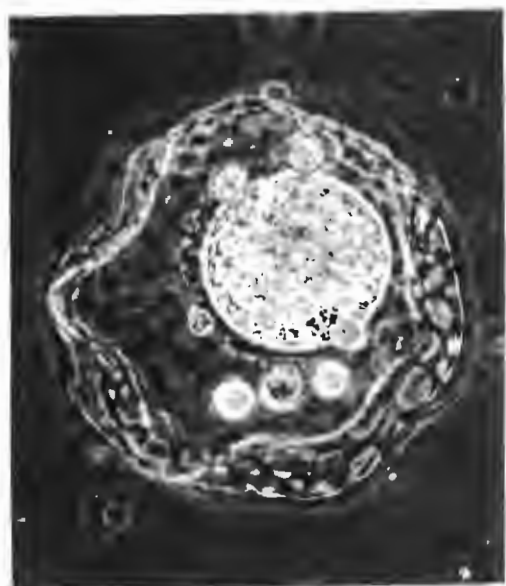
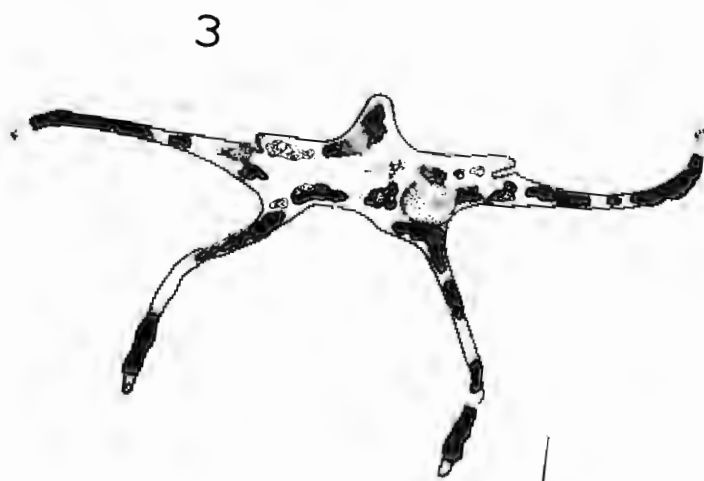
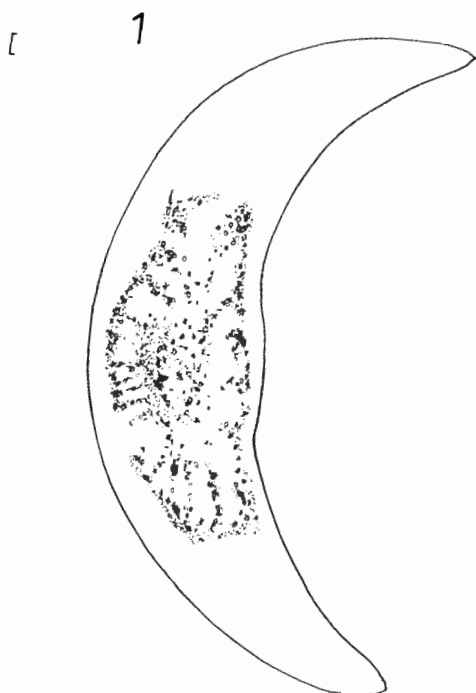


Plate 23.

- Fig. 1. Pyrocystis lunula Schütt. A secondary cyst prior to the formation of Gymnodinium-like zooids. Water mount. NIOE 155.
2. Pyrocystis fusiformis (Wyville Thompson) Murray. A stage corresponding to fig. 1. Water mount. NIOE 73.
3. Brachydinium capitatum F. Taylor. Cyst? Water mount. NIOE 71. (from Taylor, 1963).



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F. H. Taylor.

Plate 24.

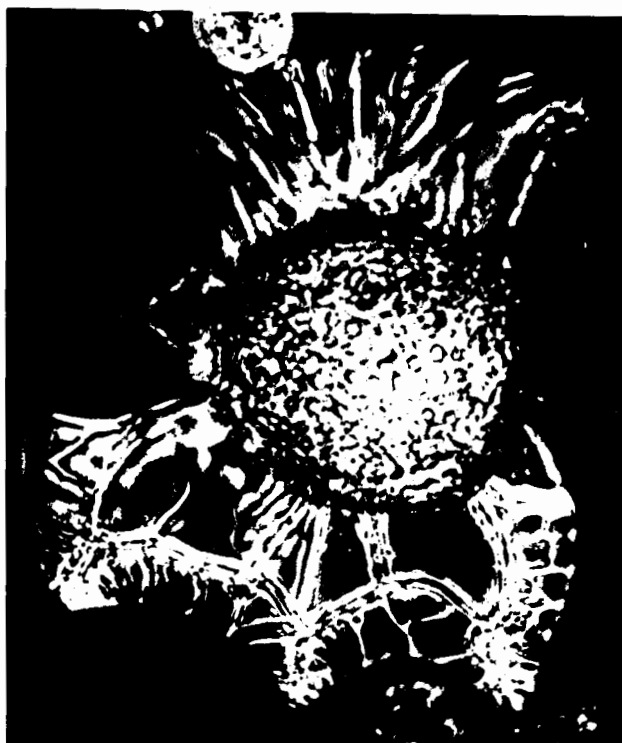
Fig. 1. Ornithocercus magnificus Stein. Water mount.

NIOE 104;

2. Ornithocercus quadratus Schutt. Water mount.

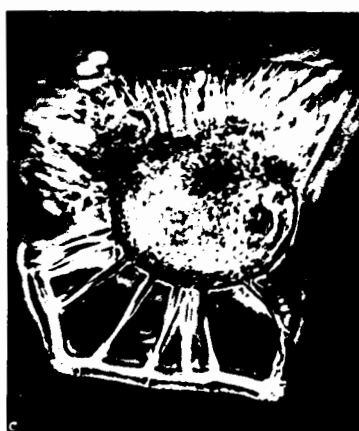
NIOE 110.

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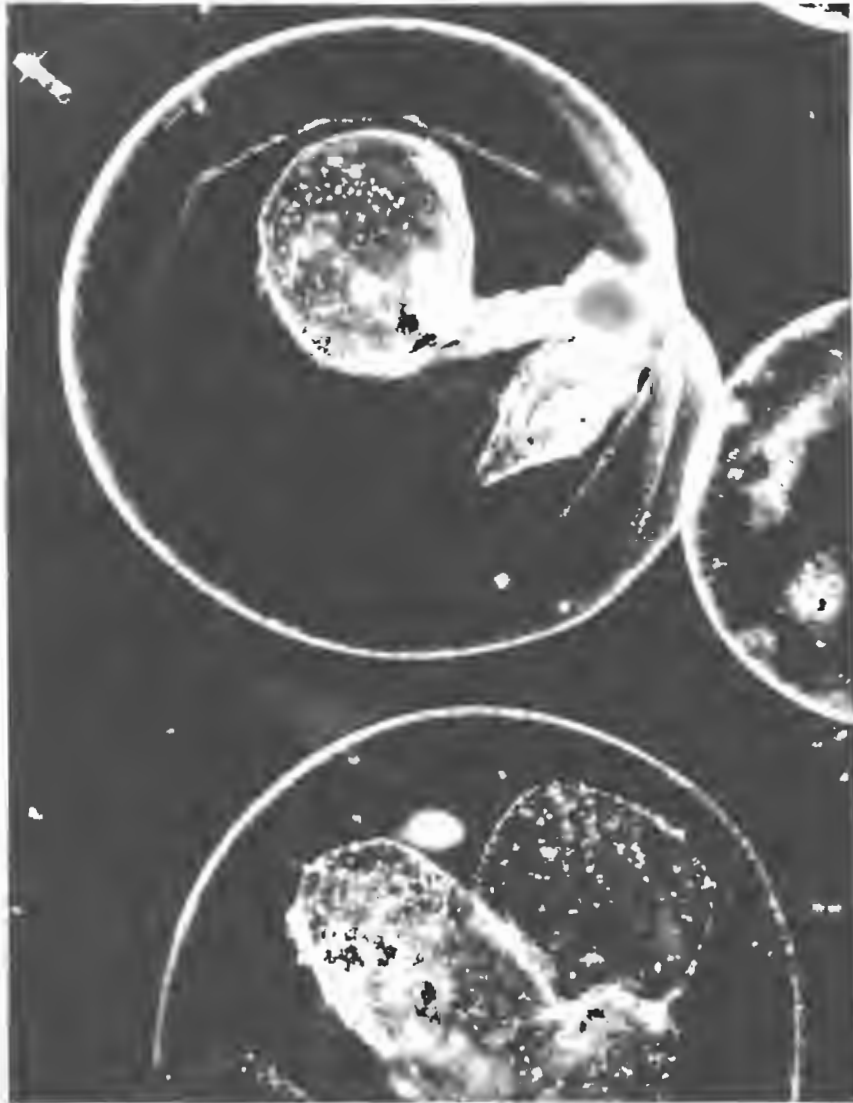
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Plate 25.

Fig. 1. Noctiluca scintillans (Macartney) Kof. & Swezy =
N. miliaris Suriray. Several individuals feeding
chiefly on Ch. socialis. Water mount. NIOE 94.



100μ

Plate 26.

Fig. 1 a & b. Two views of a specimen of Pronoctiluca spinifera
(Lohm) Schiller. Water mount. NIOE 177.

2, 3. Two specimens of Pronoctiluca pelagica Fabre-Dom.
The arrow in figure 3 indicates the formation of the
cyst-membrane (corresponding to Schiller's 'first
phase of encystment'). Water mounts. NIOE 177, 178.

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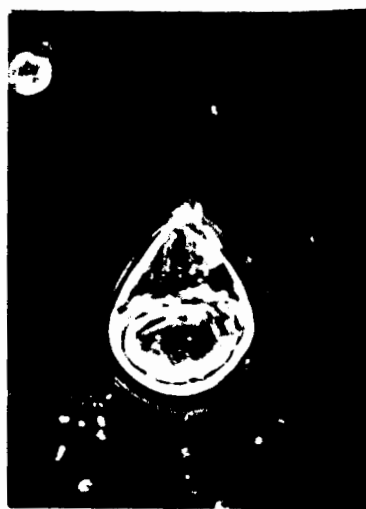
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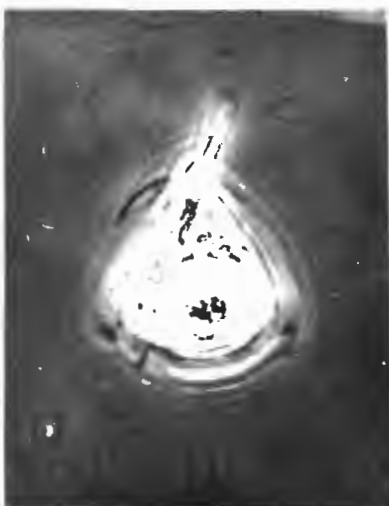


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Plate 27.

- Fig. 1. Exuviella marina Cienk.. Water mount. NIOE 110.
2. Ceratocorys horrida Stein. Water mount. NIOE 108.
3. Ceratium paradoxica Cleve. Water mount. NIOE 119.
4. Oxytoxum scolopax Stein. Water mount. NIOE 117.

