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PHYTOPLANKTON OF THE EGYPTIAN MEDITERRANEAN WATERS II-ECOLOGY AND DISTRIBUTION OF THE GENUS CERATIUM SCHRANK

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ABSTRACT

The distribution of Ceratia in the south-eastern Mediterranean waters along the Egyptian coast was studied from vertical plankton net hauls collected seasonally during 1966. The **Ceratium** population comprised about 40 species, all of them (except **C. egyptiacum**) are indigenous to the eastern Mediterranean. The population is composed of more or less tolerant tropical and cosmopolitan forms and is dominated by a limited number of species viz.: **C. contrarium, C. karsteni C. macroceros, C. massiliense, C. trichoceros, C. carriense, C. furca, C. fusus** and **C. extensum.**

On the average the population density was lowest in winter and highest in autumn. The region of El-Arish harboured the lowest density while that of the Gulf of Pelusium maintained the largest population. In general the population density was approximately 5 times higher in the inshore neritic zone than in the oceanic province. The results were discussed in relation to the prevailing environmental conditions.

The genus **Ceratium** is one of the important dinoflagellate genera in the south eastern Mediterranean waters. Members of this genus constitute a permanent and sometime common element of the phytoplankton community in the Egyptian Mediterranean waters. Some of them describe interesting seasonal and spatial distribution pattern.

Previous studies on this genus in the Mediterranean waters of Egypt are mostly of qualitative nature and almost exclussively confined to the inshore neritic waters of Alexandria region (Dowidar and Allem, 1963 and Halim, 1963). Information on the occurrence and abundance of these organisms in the oceanic waters of the south eastern Mediterranean waters are almost completely lacking.

The present paper deals with the ecology, abundance, seasonal and spatial distribution of **Ceratium** species recorded from the south eastern Mediterranean waters along the Egyptian coast from rab's Gulf in the west to El-Arish in the east.

MATERIAL AND METHODS

The results in this paper are mostly based on the examination and analysis of seasonal plankton samples collected by the R/V Ichthyolog during the Soviet-Egyptian Expedition to the south-eastern Mediterranean Sea in 1966. The area sampled lies betweenn 29° and 33° 30'E and extends latitudinally from near the coast to about 75 km seaward; thus covering both the neritic and oceanic provinces. In this area six sections more or less parallel and perpendicular to the coast were occupied in February, April, August and November 1966. The locations of these sections lied approximately at El-Arish (33°40'E), Tena Bay (Gulf of Pelusium, 32°40'E), Damietta (31°30'E), El-Borollus (30°50'E), Abu Kir (30°10'E) and Arabs Gulf (29°03'E) and are consecutively numbered A to F from East to West (Fig. 1). Each section comprised 5-6 stations situated approximately at 5, 10, 20, 30, 50 and 75km from the coast. The depth range varied between 7 and 10 m at the most inshore stations and more than 1000 m at the most oceanic stations. Vertical plankton hauls were produced from almost all stations by a Juday net of bolting cloth No. 38, mesh size 145µ and mouth diameter 37 cm. The filtration coefficient of the net was determined with the aid of a flow meter and varied between 1.0 and 0.96. In other words, approximately one cubic meter of sea water was filtered by the net every 10 m hauling distance. At stations with depth not exceeding 100 m, the whole water column was sampled; while in deeper stations the upper 100 m layer of the epipelagic zone was vertically hauled.

Plankton samples collected from each station were preserved in 4% neutralized fromalin. The samples were examined for the occurrence of zooplankton organisms (El-Maghraby and Dowidar, 1973) and were then concentrated to 100ml. From this volume, two aliquots, 5 ml each (i.e.1/10th of the sample) were examined for the occurrence of **Ceratia** and the numbers of each species were counted. The final numbers were expressed as /m^3. Altogerther 112 net samples shared almost equally between the four seasons were examined.

It is important to note that, with the type of net used, some specimens are liable to escape particularly those of small sized species, such as; **C. minutum, C. teres, C. fusus** and **C. furca**. The occurrence of **Ceratia** was also traced in 1 l water samples simultaneously collected by the expedition from standard depths at each station. Furthermore, reference is made to the occurrence of these organisms in fine-net plankton samples collected off Port Said and Abu Kir during 1969-1970 and examined by the author.

The quantitative data presented herein are not without limitations; they represent a semiquantitative aspect rather than an absolute quantitative assessment.

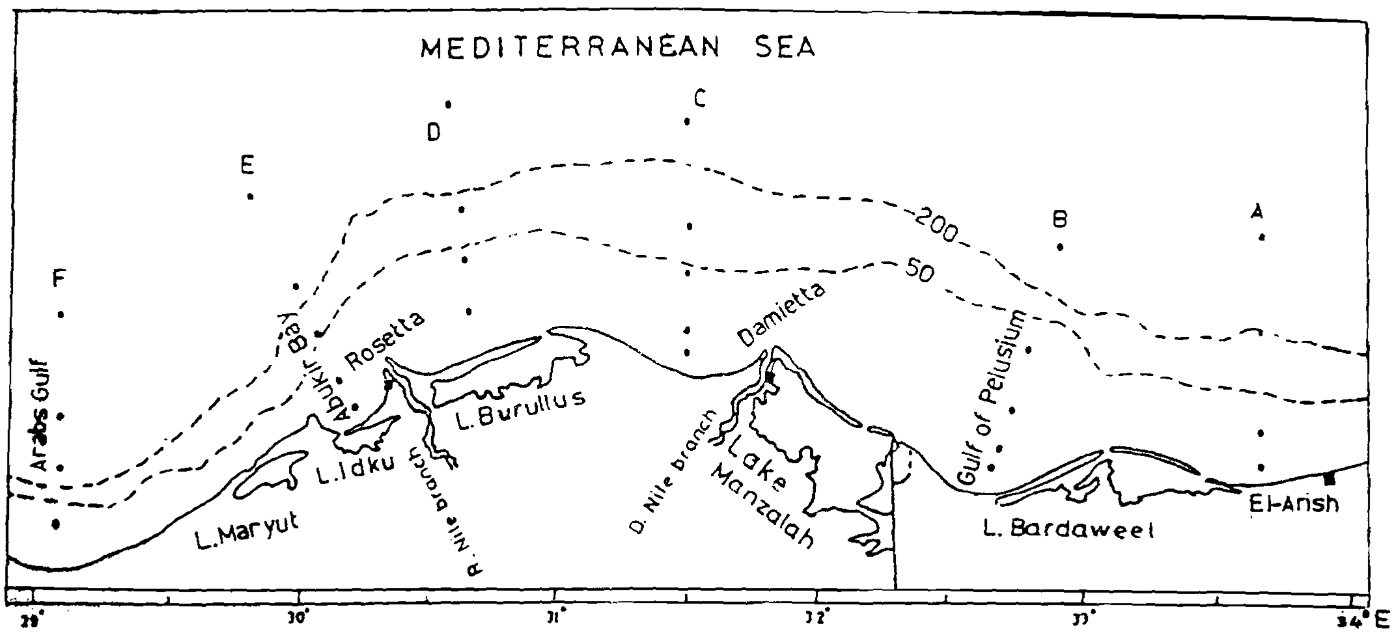

Fig. 1
Showing area investigated, section and stations sampled.

RESULTS

Seasonal and spatial variations of the total population.

Winter Season:

The distribution of Ceratia during this season is shown in Fif. 2. Relatively large concentrations were found in the coastal zone (<50 m depth) of sections B & E. The maximum density during this season (average, 2,435 cells/m^3) was recorded in section B, while the minimum (average 360 cells/m^3) occurred in section F. Apart from sections B & E the numerical density of Ceratia in the whole area was remarkably low. The average population density of all sections amounted to 960 cells/m^3. On the whole, the density in the oceanic waters was much lower than that in the coastal region; the average density being almost in the ratio 1:6.

Spring Season:

The average population density increased slightly during this season, reaching 1,060 cells/m^3. The population along section E showed the highest crop (average 2,065 cells/m^3), the maximum density, i.e. 5,210 cells/m^3 was recorded at station I (Fig. 3). The numerical density at section D showed also a remarkable increase. The lowest density occurred at sections C & F. As in the preceeding season, the inshore waters maintained the highest density. The average density at station I in all sections was about 4 times higher than the corresponding average at station V.

Summer Season:

The distribution of Ceratia during summer is shown in Fig. 4. The population density showed a further increase during this season, reaching on the average 1,180 cells/m^3. Except for remarkably low density in section A, variations in the average numbers in other sections were, on the whole, less pronounced. The population density in the water layer sample over the continental shelf ranged between 1,000 and 2,000 cells/m^3. Pockets of high concentration occurred at stations III & IV and not at stations I & II as usually found. The population density in the oceanic waters sampled beyond the continental shelf was also relatively high. The average density at station V in all sections amounted to 585 cells/m^3, the corresponding average at station I being 1,825 cells/m^3 i.e. nearly in the ratio of 1:3. The average density in the inshore neritic waters (50 m depth) was almost twice that in the more off shore waters sampled.

Autumn Season:

The progressive increase in the population density of Ceratia, commenced in spring, culminated in a pronounced autumn peak. The average density during this season (i.e. 2,450 cells/m^3) was more than twice the corresponding average in the preceding season. This increase was due to a flourishing population of Ceratia in the whole area (Fig. 5). The inshore neritic waters

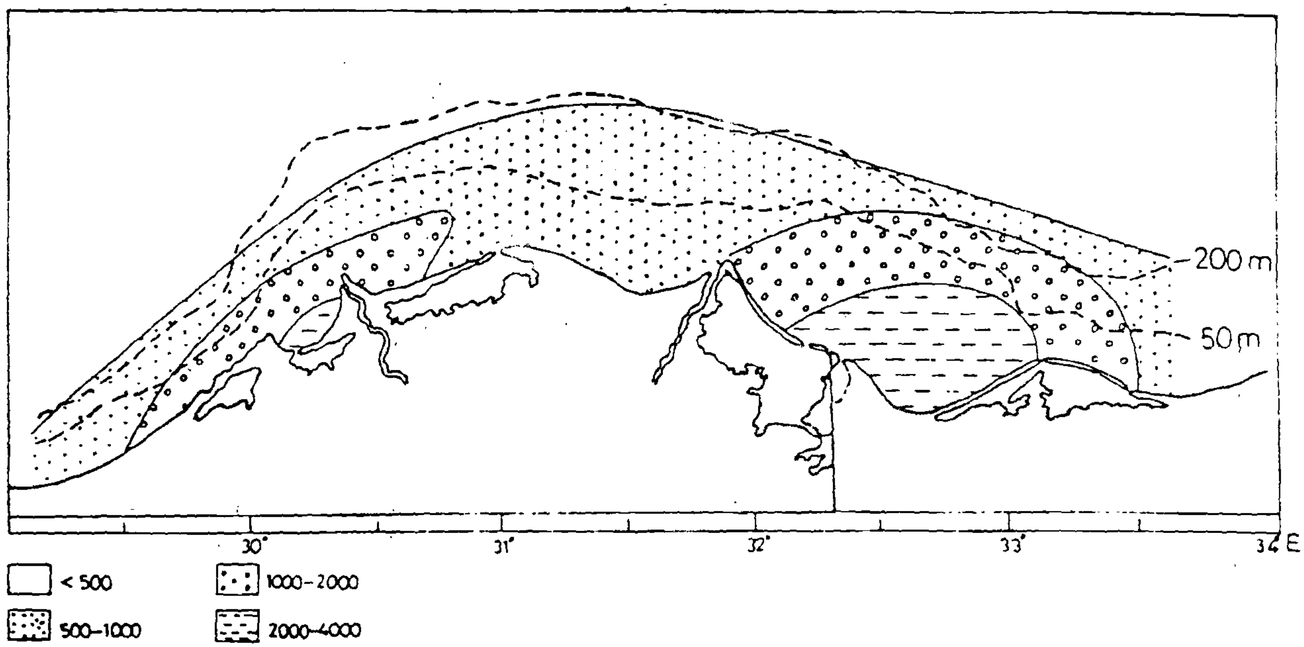

Fig. 2
Horizontal distribution of ceratia in winter (cells/m^3).

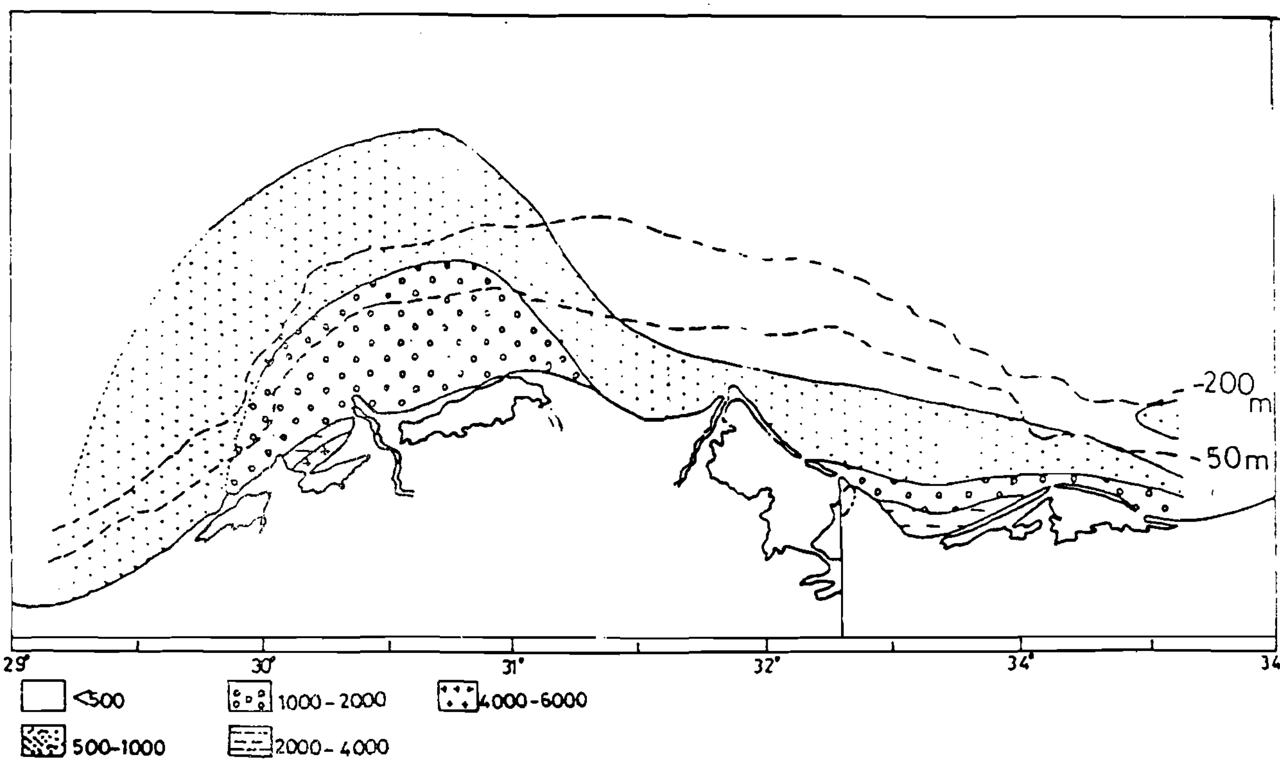

Fig. 3
Horizontal distribution of ceratia in spring (cells/m^3).

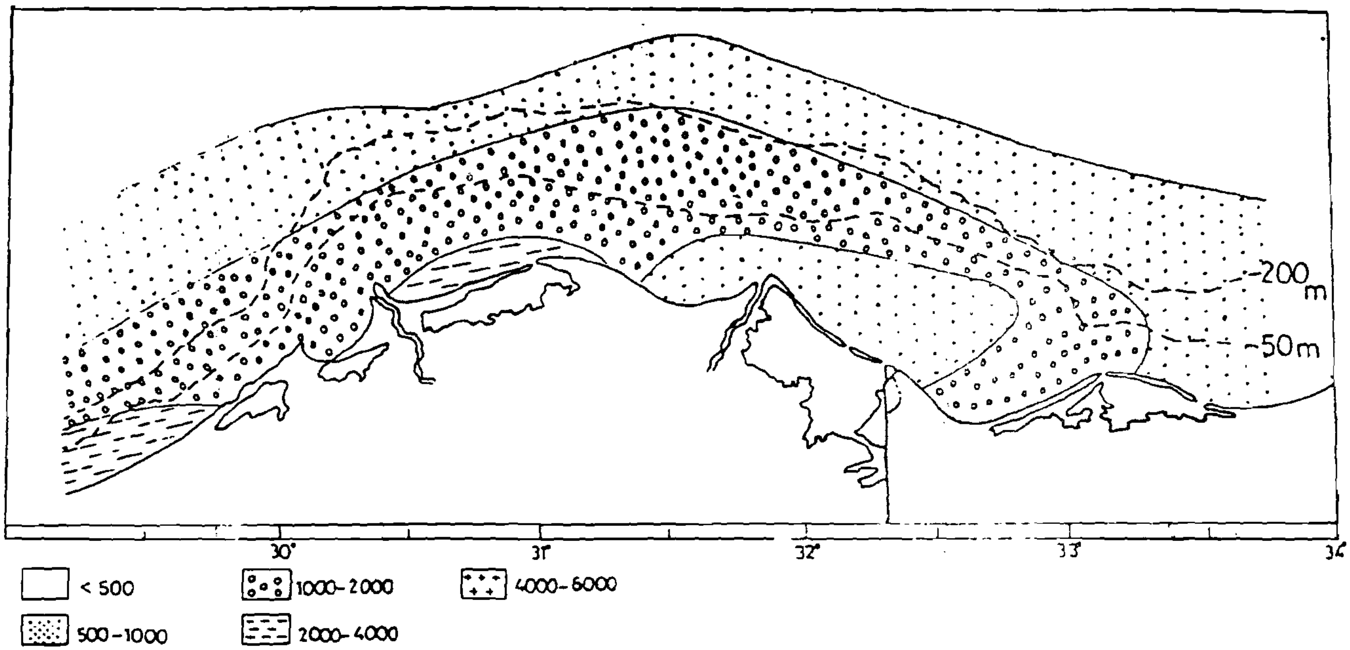

Fig. 4
Horizontal distribution of ceratia in summer (cells/m^3).

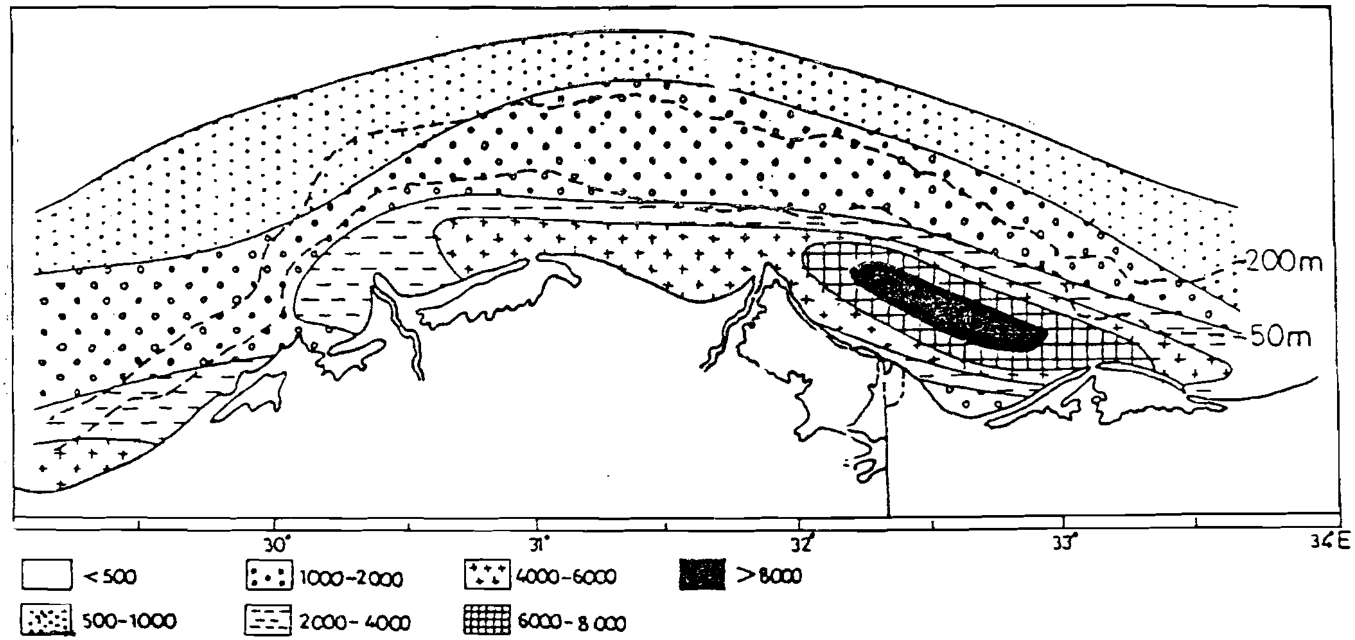

Fig. 5
Horizontal distribution of ceratia in autumn (cells/m^3).

bordered by the 50 m depth contour showed a pronounced blooming with an average density of 4,050 cells/m^3. The increase in the density of the more oceanic population (> 50 m depth) was rather limited (average density 850 cells/m^3); the ratio of the numerical density between the two regions being on the average 5:1. As shown in Fig. 5, the highest density occurred in the inshore neritic region of section B (Gulf of Pelusium) where the maximum concentration (i.e. 8,820 cells/m^3) was recorded at station 11. During this season an additional section comprising three stations was occupied in the neritic province off Lake Manzalah, the numerical density in these stations were respectively, 3,270, 8,600 and 7,100 cells/m^3 in an offshore direction. It is worth to mention that in this region (also in sections C, D & E) the highest concentration occurred at about 10-20 km from the shore and not in the very inshore waters as usually found in other seasons.

Species Density

The list of *Ceratium* species, so far, recorded from the south eastern Mediterranean waters off the Egyptian coast comprises about 40 species (Dowidar, 1974). Except for *C. minutum* all of them were recorded in the samples examined. The density of species in the net samples varied between a minimum of 3 and a maximum of 25 species/ sample (Table 1). The winter population was characterized by a high diversity in species as compared with the diversity in spring and summer seasons. On the other hand, the number of species of permanent occurrence in the sample of each season was remarkable low varying between 3 and 7 species/ sample, while those occurring in 50% of the samples varied between 8 and 11 species/ sample (Table. 1).

TABLE 1

Species [illegible] of Ceratia in the net-sample [illegible] different seasons.

	Winter	Spring	Summer	Autumn
Total number of species	35	[illegible]	27	29
No. of species/sample	7-25	3-21	6-24	5-22
No. of species occurring:				
in 10% of the samples	25	21	24	22
in 25% of the samples	19	11	12	15
in 50% of the samples	11	8	10	9
in 75% of the samples	10	4	8	8
in 90% of the samplees	9	4	7	8
in 100% of the samples	7	3	6	5

Occurrence of Ceratia in Water Samples:

As previously mentioned, water samples (1 l each) were simultaneously collected with the net samples at standard depths. Thr following 18 species were recorded in the sedimented volumes of these samples:

C. minutum	**C. inflatum**	**C. buceros**
C. teres	**C. longirostrum**	**C. contrarium**
C. fusus	**C. arietinum**	**C. trichoceros**
C. furca	**C. horridum**	**C. massiliense**
C. extensum	**C. candelabrum**	**C. macroceros**
C. pentagonum	**C. tripos**	**C. setaceum**

All of them were recorded in autumn particularly in section B (Gulf of Pelusium). In other seasons the number of species recorded in water samples varied betweenn 7 in winter and summer and 9 in spring. Many of them occurred in relatively large numbers exceeding their densities in the net samples. **Ceratium fusus** was by far the commonest species. Its numerical density varied between 3 cells/l and 270 cells/l. It was especially common in the eastern sections (A, B & C)during spring and autumn. Throughout, it was represented in surface samples. The numerical densities of the other species were much lower varying between 2 cells/l and 80 cells/l; the high concentrations were recorded in section B during autumn. The highest concentrations were found in the upper 10 m layer; below 50 m depth, Ceratia were rare in water samples. Furthermore the occurrence of **Ceratium** species in water samples was by no means consistent at the stations sampled in the different seasons.

Percentage Abundance of Important Species:

The percentage composition of the numerically important species in the net samples varied widely in the different seasons. Of the 35 species recorded during winter, only 7 species were common, forming on the average about 90% by number of the total population during this season (Fig. 6). Based on the average numbers, **C. contrarium** (26.4%), **C. karsteni** (21.6%), **C. massilience** (16%) and **C. macroceros** (15.2%) were the dominant species. As shown in Fig. 6, sections B and E harboured the largest densities of these species.

The spring population was dominated by almost the same species as in winter but with more or less different positions of abundance (Fig. 7). **C. contrarium** was still dominant forming on the average 28.0% of the total population in all sections, followed by **C. massiliense** (18.5%), **C. fusus** (13.8%) and **C. trichoceros** (12.0%). As shown in Fig. 7, the populations in sections A and B were dominated by **C. fusus**. However, on account of its small size, its density in the net samples was naturally low. During this season, the concentrations of this species in the surface water samples taken in both sections were exceedingly high varying between 200 cells/l in section A and 270 cells/l in section B.

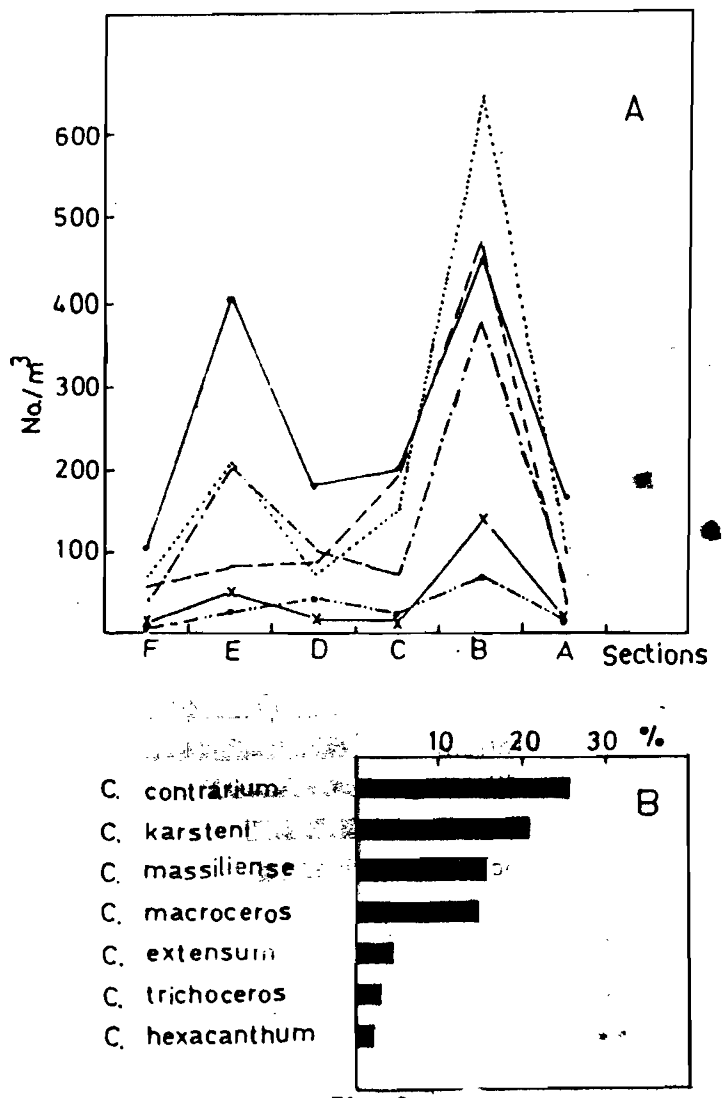

Fig. 6

Distribution of important Ceratium species in winter.

A : Spatial distrubution based on the average number (cells/m^3) in each section.

B : Average percentage abundance of important species in the whole area.

C. contrarium — C. massiliense — C. karasteni

C. extensum — C. macroceros

C. trichoceros

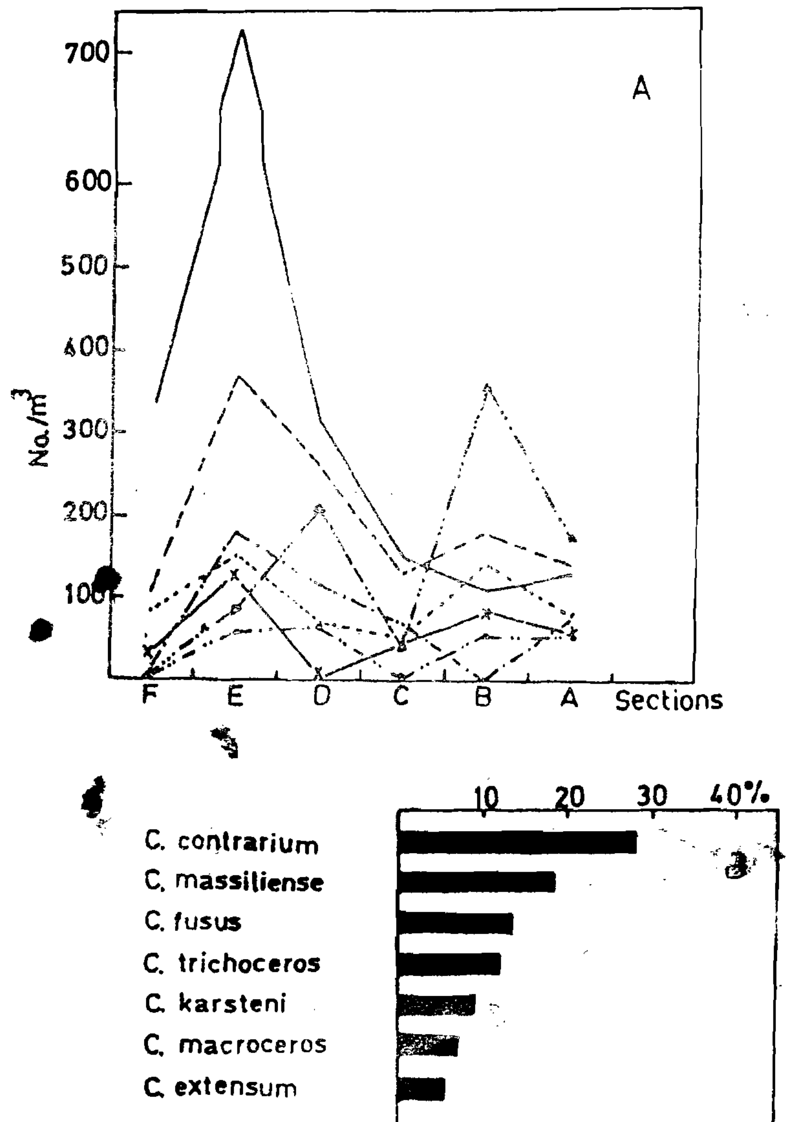

Fig. 7

Distribution of important **Ceratium** species in spring.

A : Spatial distribution based on the average number (cell/m^3) in each section.

B : Average percentage abundance of important species in the whole area.

— —— C. contrarium; —— - - — C. massiliense; - - - - - - C. karsteni

×——× C. extensum; —— · —— C. macroceros; △— ··· —△ C. fusus

•— ·· —• C. trichoceros

The summer population was dominated by C. **massiliense** (28.1%) and C. **contrarium** (24.8%). C. **extensum**, C. **karsteni** and C. **carriense v. volans** followed in order of abundance with 13.0%, 11.2% and 7.5%, respectively (Fig. 8). It is worth to note that C. **trichoceros** which is common in spring was now poorly represented (average 1.1%); furthermore, it was almost exclussively persent in section A where it formed 7.9% of the total population. The numerical density of C. **massiliense** increased more or less gradually from section A to F. C. **contrarium** was more numerous at sections D and F.

During autumn, about 94% of the numerical density of the population was formed up by 10 **Ceratium** species (Fig. 9). C. **trichoceros** was by far the leading species forming on the average 27.1% of the total population. It was the dominant species in all sections except sections E and F (Fig. 9). It was highly abundant in section B where it constituted 38.9% of the population. C. **macroceros** occupied the second position in order of abundance (15.2%) followed by C. **contrarium** (13.8%), C. **extensum** (8.9%) and C. **massiliense** (8.5%). The distribution of C. **egyptiacum** is of special interest. It occurred in the area only during this season and was throughout, confined to the eastern sections A and B. It was particularly common in section B where it formed 13.3% of the population and occupied the third position in order of abundance in that region (Fig. 9). This species is an erythraeun immigrant, newly introduced into the eastern Mediterranean (Dowidar, 1971). In 1970, it occurred in the plankton of Port Said Habour during winter, spring and autumn seasons.

DISCUSSION

The great majority of Ceratia recorded in the southeastern Mediterranean waters is more or less tolerant warm water species. Nearly all of them (except C. **digitatum**) occur in the Red Sea (Dowidar, 1983) and all (except C. **egyptiacum**) are widely distributed in the warm waters of all oceans (Jorgensen, 1920; Bohm, 1931; Peters, 1934; Steemann Nielsen, 1939; Graham and Bronikovsky, 1944; Wood, 1954, 1963; Halim, 1967 and Sournia, 1967 & 1970). Some of them are classified by Graham and Bronikovsky (loc. cit.) as intolerant tropical forms e.g. C. **digitatum**, C. **buceros**, C. **euarcuatum**, C. **falcatum**, C. **incisum**, C. **inflatum**, C. **limulus**, C. **longirostrum**, C. **longissimum**, C. **lunula** and C. **trichoceros**.

A fairly large number of the species recorded belongs to the so-called oligophotic or shade forms, e.g.

C. digitatum	**C. incisum**	**C. arietinum**	**C. longissium**
C. gravidum	**C. lunula**	**C. kofoidii**	**C. symmetricum**
C. limulus	**C. ranipes**	**C. euarcuatum**	

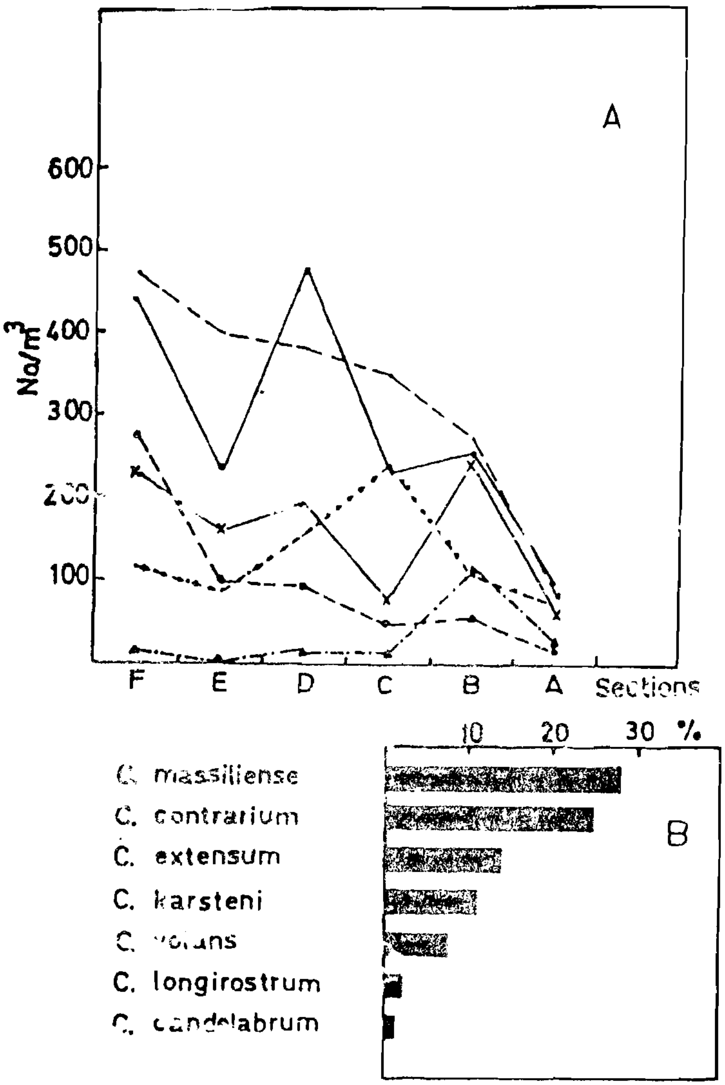

Fig. 8

Distribution of important *Ceratium* species in summer.

A : Spatial distribution based on the average number (cell/m^3) in each section.

B : Average percentage abundance of important species in the whole area.

——— C. contrarium — — — C. massiliense - - - - - C. karsteni
×———× C. extensum △— · —△ C. longirostrum •- - -• C. volans

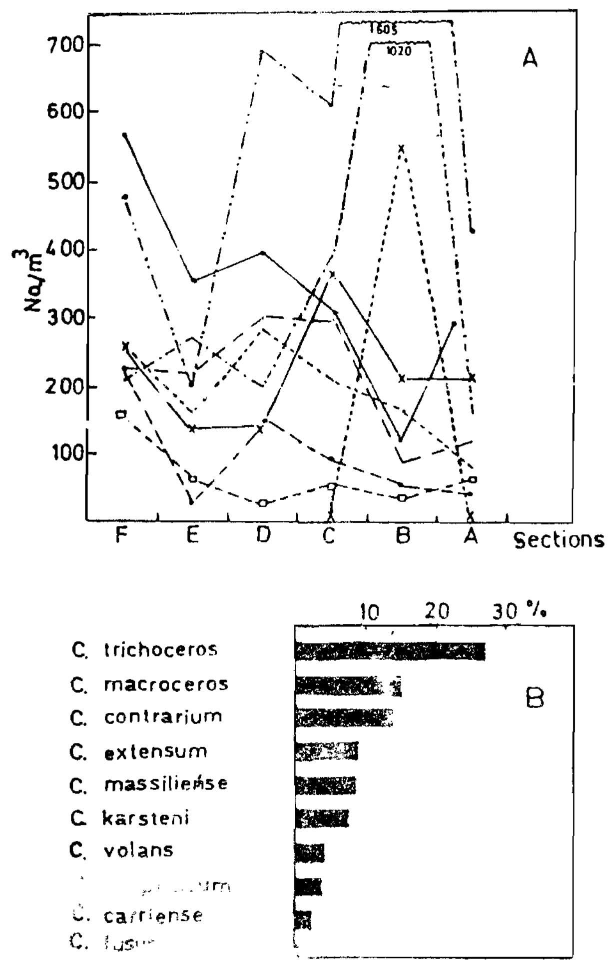

Fig. 5

Distribution of important **Ceratium** species in autumn.

A : Spatial distribution based on the average number (cell/m^3) in each section.

C : Average percentage abundance of important species in the whole area.

C. contrarium — C. massiliense — C. karsteni
C. extensum — C. macroceros — C. volans
C. trichoceros — C. egyptiacum
C. carriense.

These species are usually classified as rare tropical oceanic forms. Except for C. digitatum and C. limulus which were recorded in the area only in winter, all of them were occasionally recorded in other seasons as well but with lower frequency; furthermore, they were frequently recorded at shallow stations (depth 20-50 m) during this season. Their occurrence in the coastal waters of the area in winter is probably due to the influx of oceanic water under the influence of the rather strong northwesterly winds which blow frequently during this season. Unfortunately no fractional samples were taken during the present study. In the eastern Mediterranean, Kimor and Wood (1975) found that in summer most of the Ceratia were usually confined to the upper 80. m (i.e. euphotic zone), a few e.g. C. kofoidi, C. **carriense**, C. **massiliense** and C. **vultur** were recorded in the aphotic zone. Jorgensen (1920) who studied the vertical distribution of Ceratia in the Mediterranean, found that a great number of species which occurred at the surface in winter, inhabited the deeper levels in summer.

These observations may indicate that Ceratia are photorophic (Steemann Nielsen, 1939). Graham and Bronikovsky (1944) denied the concept that the vertical migration of Ceratia is a simple light reaction phenomenon, and suggested a trophotropism as well. They stated that in the summer time, the upper levels of the sea are depleted of nutrient salts while in winter the upper layers are comparatively rich in nutrients. It is thus possible that these forms have a positive trophic reaction to nutrient salts or some associated condition as well as phototrophic response. On the other hand, the phenomenon of phototactic vertical migration has been demonstrated by several authors in many species of Ceratia and other dinoflagellates (cf. Hasle, 1950 & 1954). The concept of phototropism proposed by Graham and Bronikovsky (loc. cit.) for the explanation of the vertical distribution of Ceratia is however, not far from crticism. The nutrient requirements of Ceratia in general and of the shade species in particular are usually small (cf. Wood, 1954). Many of them are even characteristic of oligotrophic waters. Peters (1934) suggested that relatively large concentrations of nitrate and phosphate inhibited the growth of certain **Ceratium** species. In the Pacific and North Atlantic Oceans, Graham and Bronikovsky (1944) found that regions of very low phosphate content are generally characterized by a large number of **Ceratium** species with low population density of each species. Their conclusion is in good agreement with the winter condition in the southeastern Mediterranean. Early in winter, vertical mixing is highly pronounced and increases the nutrient level in the upper layers. However, this limited supply of nutrients seems to be rapidly consumed by the winter diatom bloom which reaches its peak in January. The winter bloom of Ceratia follows in February when the phosphate concentrations in the upper 300 m were very low, while maximum phosphate concentrations occurred in summer both in the surface and subsurface layers (Table 2). It sppears therefore, that the relative abundance of shade species in the surface water in winter and their descendance to deeper layers in summer may be correlated with the phenomenon of phototropism.

TABLE 2

Seasonal variations of temperature, salinity and phosphate (ug.at.PO_4-P/l); average values of the water columu sampled in the inshore (<50 m depth) and offshore water during the period of study (partly after Emara, 1969; Hassan, 1969).

Season	Parameters	Zone	Average values in sections					
			A	B	C	D	E	F
Winter	Temp. C	Inshore	16.6	16.4	16.5	17.0	16.7	16.7
		Offshore	17.5	17.4	17.4	17.5	16.9	16.9
	Salinity‰	Inshore	39.1	38.6	38.9	39.2	39.1	39.2
		Offshore	39.3	39.3	39.3	39.3	39.2	39.2
	Phosphate	Inshore	0.06	0.06	0.08	0.06	0.04	[illegible]
		Offshore	0.05	0.05	0.08	0.04	0.04	0.04
Spring	Temp. C	Inshore	21.2	20.7	19.4	19.4	19.8	18.3
		Offshore	18.3	17.8	18.1	17.7	17.8	17.6
	Salinity‰	Inshore	39.1	39.1	38.6	39.0	38.6	38.9
		Offshore	39.1	39.1	38.9	[illegible]	38.9	[illegible]
	Phosphate	Inshore	0.13	0.13	0.09	0.04	0.04	0.04
		Offshore	0.12	0.08	0.04	0.04	0.04	0.04
Summer	Temp. C	Inshore	27.4	27.9	27.2	26.4	28.0	27.4
		Offshore	25.1	23.8	23.7	22.7	26.8	26.7
	Salinity‰	Inshore	38.7	38.6	38.9	38.9	38.2	39.0
		Offshore	[illegible]	[illegible]	39.0	39.2	38.9	38.9
	Phosphate	Inshore	0.05	0.11	0.12	0.22	0.14	0.03
		Offshore	0.09	0.11	0.12	0.15	0.12	0.10
Autumn	Temp. C	Inshore	24.0	23.7	23.4	23.4	23.1	23.4
		Offshore	24.2	24.0	24.0	24.2	23.3	22.2
	Salinity‰	Inshore	39.5	39.2	39.0	38.9	38.9	38.9
		Offshore	39.5	39.2	39.1	39.2	39.2	38.9
	Phosphate	Inshore	0.08	0.09	0.09	0.15	0.10	0.16
		Offshore	0.09	0.05	0.09	0.15	0.10	0.11

However, the depth of maximum concentration of such shade species varies widely in the different oceans (Jorgensen, 1920; Steemann Nielsen, 1934; Graham and Bronikovsky, 1944). Many of them were found in summer in the upper 50 m layer, in the Red Sea off Jeddah (Dowidar, 1983), a condition which throws doubt on the validity of the phototropic and trophotropic concepts discussed above. It seems that, in the different biogeographic regions, there might exist different physiological races of the same species with variable requirements of light, temperature, nutrients and other growth promoting conditions. Furthermore, the optimum requirements of a species from any parameter is probably modified by the interaction of these parameters in the different marine habitats.

Concerning the quantitative distribution of Ceratia in the study area, it was found that the inshore neritic region harboured the largest population density. On the average, the standing crop of the inshore stations I and II was about 5 times higher than that at the oceanic station V (Table 3). Furthermore, while the density of the inshore population varied widely in the different seasons, seasonal variations of the standing crop of the oceanic population were (except in winter) not significant. The rather constant and low density of Ceratia in the oceanic waters of the area may be attributed to the relative constancy of environmental conditions in that province (Table 2); being away from land, it is not affected by sources of land drainage; besides seasonal changes are usually not rapid. On the other hand, by virtue of the more effective and continuous mixing processes, and being subjected to various sources of land runoff, neritic waters are usually more fertile due to the abundance of nutrient salts and probably also of some growth promoting substances.

The seasonal and regional variations of the Ceratium population in the area are of species interest. On the average section A showed the lowest density while section B maintained the largest crop in all seasons; otherwise variations of the average denisty in other sections were less significant (Table 4). Furthermore, except on rare occasions the population density in all sections increased more or less gradually from its minimum in winter to a pronounced maximum in autumn. It is not easy to identify the factors affecting the size of the population of Ceratia in the study area. Peters (1934) concluded that water temperature between 15° and 27.5°C had no influence on the distribution of Ceratia in the south Atlantic. Steemann Nielsen (1934) considered that 15°C is too low for non effective temperature, but he did not find many cases of temperature correlation in the south Pacific. As previously mentioned the area investigated is populated by tropical-subtropical and cosmopolitan forms. Most of them are indigenous and perennial to the southeastern Mediterranean. The temperature range recorded in the area i.e. 16-29°C is well tolerated by all of them. The size of the population of each species is mostly contrtolled by its optimum temperature rather than the absolute range. At the optimum temperature, when other conditions are suitable, a species is able to build up large population. Within the temperature range of the area only a few species were able to from relatively large populations. The most suitable range of temperature recorded for the common species

TABLE 3

Horizontal distribution of Ceratia in the southeastern Mediterranean waters of Egypt; average numbers/m^3 of corresponding stations sampled in all sections.

	I	II	III	IV	V
Winter	1400	1485	945	640	250
Spring	2085	1265	950	980	525
Summer	1825	1400	1340	785	585
Autumn	3390	4600	2300	1465	500
Mean	2175	2190	1385	970	465

TABLE 4

Seasonal variation of the stanging crop of Ceratia; average numbers/m^3 of each section

Winter	490	2435	730	590	1140	360	956
Spring	825	1060	530	1250	2065	615	1056
Summer	565	1150	1020	1450	1190	1590	1180
Autumn	1730	4120	2150	2215	1490	2635	2450
Mean	900	2190	1200	1375	1470	1300	1410

(as judged from their numerical densities) is rather wide, as shown from the following data:

C. furca	16-28°C	C. massilience	21-28°C
C. contrarium	16-28°C	C. trichoceros	23-25°C
C. karsteni	16-25°C	C. carriense	23-25°C
C. macroceros	16-25°C	C. extensum	23-25°C

It seems, therefore, that temperature is not the only factor controlling the size of the **Ceratium** population in the area. However, the low standing crop recorded in the area during winter may, at least partly, be due to the low temperature during this season.

The effect of salinity on the population density of Ceratia in the oceanic waters of the area is not significant. During the present study the salinity of the offshore waters varied between 38.9%o and 39.5%o. Several authors (e.g. Peters, 1934; Steemann Nielsen, 1934 & 1939 and Graham and Bronikovsky, 1944) have shown that within the oceanic habitats, slight variations in salinity have no influence on the distribution of Ceratia. However, Sateemann Nielsen (1934) found that in the neritic waters of Panama region where the salinity is low, the number of species was considerably low. In the neritic waters of Alexandria Dowidar (1965) found that during the flood season (prior to 1965) only a few euryhaline species were able to tolerate the drop of salinity (ca. 30%o) viz.: **C. furca, C. fusus, C. massiliense, C. contrarium, C. karsteni, C. tripos** and **C. macroceros.** The first mentioned four species were able to build up large populations under these conditions. During the present studty a remarkable decrease in salinity was detected in the neritic waters of sections B, C and E. This lowering of salinity is due to the brackish water outflow from the northern Delta lakes viz: Lake Manzalah, Lake Burullos, and Lake Idku as well as from Rosetta Nile mouth through Idfena Barrages. The latter two sources affect the area of Abu Kir and adjacent regions. This outflow is however, not continuous and is controlled by the cycles of irrigation and drainage of agricultural lands. The outflowing brackish water is rich in nutrient salts and other growth promoting substances which favours the prosperity of phytoplankton. The relatively high population density observed in the inshore waters of section B in winter is probably due to its enrichment by the brackish water discharge from Lake Manzalah which spreads eastwards following the general circulation in the southeastern Mediterranean. The surface salinity of the inshore water of that section (i.e. 38.0%o) was the lowest in the whole area during this season and there is no other source for this dilution. The large population found in the neritic waters of section E in spring (salinity 38.0%o) is mostly due to the fertilizing effect by the brackish and fresh water discharge from Lake Idku and Rosetta Nile branch. On the other hand, the condition during summer is difficult to explain. During this season, the surface salinities of the inshore stations of sections A, B and E were remarkably low, being 38.5%o, 38.2%o and 37.7%o respectively; indicating brackish water invasion. Nevertheless, the standing crop in these regions was relatively low (Fig. 4). Attributing this to lack of nutrients is not probable since (except in section A) the phosphate content at these sections was comparatively high (Table 2); further the phosphate content of section F (salinity 38.9%o) was low and yet it harboured the largest population during this season. It is probable that the brackish water of the northern Delta lakes discharged into the sea during summer, may contain soluble residues of some stable pesticide compounds used extensively in controlling plant pests during this season. Further research on the toxicity, stability and fate of these compounds in the brackish water of the Delta lakes and its extension in the sea is greatly needed.

The condition during autumn is of special interest. During this season the **Ceratium** population in the whole area reached its maximum density indicating optimal conditions. This increase was more pronounced in the inshore neritic waters bordered by the 50 m depth contour particularly in the region of section B. Furthermore, the maximum crop occurred at stations II and III and not in the very inshore water. Other phytoplankton elements were also abundant. The standing crop of zooplankton in the Gulf of Pelusium (section B) during this season was much higher than in other sections (El-Maghraby and Dowidar, 1973). Furthermore, this area is considered one of the important fishery grounds for many commercial fishes. The high salinity of the eastern sections A and B i.e. 39.20‰-39.50‰ may indicate that the amount of brackish water reaching them is negligible, if at all. The bottom in that region is covered by huge amounts of Nile flood sediments yearly accumulated since time immemorial. These sediments may act as a reservoir for nutrient salts. It is most probable that the water circulation developed in that region during autumn plays a great role in bringing up these nutrients to the upper layers where phytoplankton blooms are developed. The circulation in that region is not precisely known, but direct current measurements (Gorgy, 1966 and Hassan, 1969) showed that beside the general eastward flow, local anticlockwise movements were observed. These may develop some sort of vortices which may help in regeneration of nutrients from the bottom. However, the satisfactory explanation in this regard must await further research. On the other hand, the blooming of Ceratia in the western sections during this season is probably due to the fertilizing effect caused by the brackish water discharge. The surface salinities of the inshore stations were 38.7‰, 38.2‰ and 38.9‰ at sections D, E and F respectively. The phosphate concentrations in these region were also high (Table 2). The low surface water salinity and high **Ceratium** density recorded in the inshore water of section F may indicate a westward flow of surface water probably from the region of Abu Kir. The distribution of zooplankton elements in that region (Dowidar, 1965) provides further biological evidence of the existence of this westward inshore surface current during autumn.

SUMMARY AND CONCLUSIONS

During the expedition of R/V Ichthyolog to the southeastern Mediterranean in 1966, six sections more or less parallel and perpendicular to the shore were occupied between Arab's Gulf (29°00' E) and El-Arish region (33°30' E). Each section comprised about five stations covering both the neritic and oceanic provinces. The quantitative distribution of Ceratia in the upper 100 m layer of the area sampled was studied seasonally from vertical net hauls as well as water samples (1 l each) collected at standard depths from each station during February, April, August and November 1966.

The **Ceratium** population inhabiting the southeastern Mediterranean is composed of more or less tolerant tropical-subtropical and cosmopolitan

forms. A fairly large number of the species recorded belongs to the oligophotic shade species. These are rare tropical oceanic forms, and were relatively more frequent in the upper layers of the area sampled in winter. The concepts of phototropism and trophotropism proposed by some authors for the explanation of the vertical migration of Ceratia were dicussed. It is concluded that in the different biogeographic regions, there might exist different physiological races of the same species with variable requirements of temperature, light and nutrients salts. It seems also that the optimum requirements of a species from any parameter is probably modified by the interaction of these and other environmental parameters in the different marine habitats.

The present study has shown that 1 l water samples are not adequate for the quantitative assessment of Ceratia; large volumes of water are required to obtain more representable results. Net samples are more suitable for qualitative studies. The number of species recorded in 1 l water samples (i.e. 18 species) was by far less than that recorded in the net samples (i.e. 40 species). Furthermore some of the species common in the net samples were either rare or absent from water samples. However, notwithstanding the small number of species recorded in water samples, it was found that in regions and/or periods of high **Ceratium** production. the average population density in water samples was at least 3 times greater than in the net samples. On the contrary, during periods of low production, the density in the net samples was significantly higher than that in water samples.

The great majority of the Ceratium species recorded is indigenous and perennial to the southeastern Mediterranean. However, only a few species are able to build up large population. viz.: **C. contrarium**, C. **karsteni**, C. **macroceros**, C. **massiliense**, C. **trichoceros**, C. **carriense**, C. **furca**, C. **fusus** and C. **extensum**; the first mentioned four species dominated the population in all seasons.

Concerning the seasonal and spatial variations, it was found that on the average the standing crop increased from its minimum in winter to a maximum in autumn. The region of El-Arish showed the lowest density while that of the Gulf of Pelusium maintained the largest crop; otherwise, variations of the average population density in other sections were less important.

The effect of temperature, salinity and nutrient salts (i.e. phosphate) on the seasonal and spatial distribution of Ceratia in the area has been discussed. It is concluded that, the low winter temperature (ca. 16°C) probably affected the size of the population during this season. The winter population is characterized by sparce populations of nearly all species but a large number of species. Otherwise, seasonal variations in temperature have probably a negligible effect on the population density of most **Ceratium** species in the area. The effect of salinity on the quantitative and qualitative distribution of Ceratia in the area is probably not significant. In this regard the effect of the neritic conditions is more important. The population density in the inshore neritic stations (bordered by the 50 m depth contour) was about 5 times higher than in the most oceanic stations. Furthermore, seasonal and spatial variations in the size of the oceanic population were rather limited. The rich population in the neritic waters of the area is attributed to its invasion, at times, by brackish water outflow from the northern Delta lakes. The brackish water of Lake Manzalah is directed eastwards and affects the region of the Gulf of Pelusium in winter and spring; that of Lake Idku and Rosetta mouth affects the area off Abu Kir and may extend further westward to variable distances during summer and autumn. It is most probable that the fertilizing effect of this brackish water is due, besides its high nutrient content, to the presence of some organic and inrogenic growth promoting substances necessary for the successful propagation of these organisims. However, the discharge of large amounts of brackish water into the sea during the summer had a negative effect on the population size of Ceratia. It is most probable that this water contained soluble residues of some stable pesticide compounds used extensively in controlling plant pests during the summer season.

The outstanding **Ceratium** crop observed in the region of the Gulf of Pelusium during autumn suggests that the local water circulation is set up in a manner which brings up nutrients and other growth promoting substances from the rich bottom sediments in that region.

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