SEASONAL CHANGES IN NET PHYTOPLANKTON OFF ERDEMLI, NORTHEASTERN MEDITERRANEAN

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SUMMARY: *The seasonal qualitative and quantitative fluctuations of net phytoplankton (> 55 μm) populations were investigated off Erdemli, northeastern Mediterranean coast, from November 1984 to October 1985. The samples were counted to obtain the relative proportions of each species rather than the absolute numbers. Changes in the species composition of net phytoplankton are described A total of 35 genera including 111 species and varieties (62 diatoms 47 dinoflagellates and 2 silicoflagellates) were identified throughout the sampling period. Diatoms were the predominant group of the phytoplankton and were represented mainly by centric diatoms, and of these the genera* Chaetoceros *and* Rhizisolenia *were found to be abundant for most of the year. Dinoflagellates were mostly presented by genus* Ceratium.

KUZEYDOĞU AKDENİZ'DE ERDEMLİ AÇIĞININ NET FİTOPLANKTONUNDAKİ MEVSİMSEL DEĞİŞİMLER

ÖZET: *Net fitoplankton populasyonlarındaki mevsimsel kalitatif ve kantitatif değişimler Kasım 1984 den Ekim 1985 e kadar Kuzeydoğu Akdeniz'de Erdemli açığında araştırıldı. Örnekler mutlak sayılardan ziyade her türün nisbi oranlarını tespit etmek amacıyla sayıldı. Net fitoplanktonunun tür kompozisyonundaki değişimler tanımlandı. Örnekleme süresince toplam 35 genusa ait 111 tür ve varyete (62 diatom, 47 dinoflagellat ve 2 silikoflagellat) tanımlandı. Diatomların fitoplanktonlar içerisinde baskın grubu oluşturduğu; başlıca sentrik diatomlar ile temsil edildiği ve bunlardan* Chaetoceros *ve* Rhizosolenia *genuslarının da yılın büyük bir kısmında bol olarak bulunduğu saptandı. Dinoflagellatlar ise çoğunlukla* Ceratium *genusu ile temsil edildiler.*

INTRODUCTION

Most studies of the phytoplankton of the eastern Mediterranean Sea are restricted to the coasts of Libya (1), Egypt (2-4), Israel (5-6), and of Lebanon (7). Little work has been published on the phytoplankton of the northeastern Mediterranean. Qualitative studies of the diatoms were carried out by Unsal (8-9) in Iskenderun and Mersin Bays and later, the plankton conditions were studied by Gokalp (10) in İskenderun Bay. None of these studies carried out in the northeastern Mediterranean has included a detailed qualitative and quantitative interpretation of the phytoplankton over a year. The main purpose of this study was to establih the seasonal variations in abundance and in species composition of the net phytoplankton of this area.

MATERAIL AND METHODS

Phytoplankton samples were collected at monthly intervals from November 1984 trough October 1985. A fixed station (Fig. 1) approximately 3.5 nautical miles from coast and with a total depth of 100 m was chosen off Erdemli-METU Campus in the western part of Mersin Bay (3631'N, 34° 18'E). At this distance from the coast, it was expected that the effects of the Lamas river (Fig. 1) would be avoided and the station chosen, would reflect the standard conditions of the eastern Mediterranean especially that of the northern part of the Cilician Basin.

The phytoplankton samples were collected with a standard net of 55 µm aperture. During each cruise, a vertical haul, from 75 m to surface, was carried out. All samples were fixed immediately with 5 % formaldehyde solution. References used to identify the species were Pavillard (11), Hendey (12, 13), Lebour (14), Heurck (15), Cleve-Euler (16), Rampi and Bernhard (17) for diatoms and Kofoid (18, 19) Jorgensen (20, 20), Lebour (22), Rampi and Bernhard (23) and Dodge (24) for dinoflagellates.

Quantitative examination was performed with the Palmer-Maloney chamber under the microscope and used to estimate the standing stock of phytoplankton (25). Net phytoplankton species diversity indices were computed by using the Shannon-Weaver Index (26). Correlation coefficients between phytoplankton and environmental factors were determined by using Spearman's rank correlation analysis (27).

RESULTS

Hydrographic Conditions

Hydrographic measurements included surface temperature and water transparency (Secchi disc visibility). Rainfall was provided from a local Meteorological Station. Lowest surface temperature was recorded in February (18°C) and the highest in August (31.3°C). The secchi disc depth ranged from

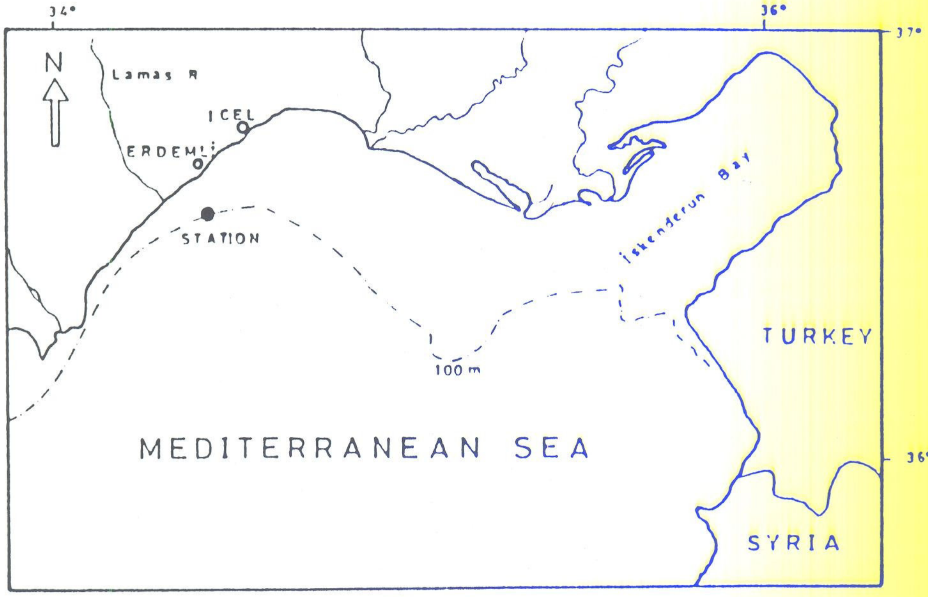

Figure 1.

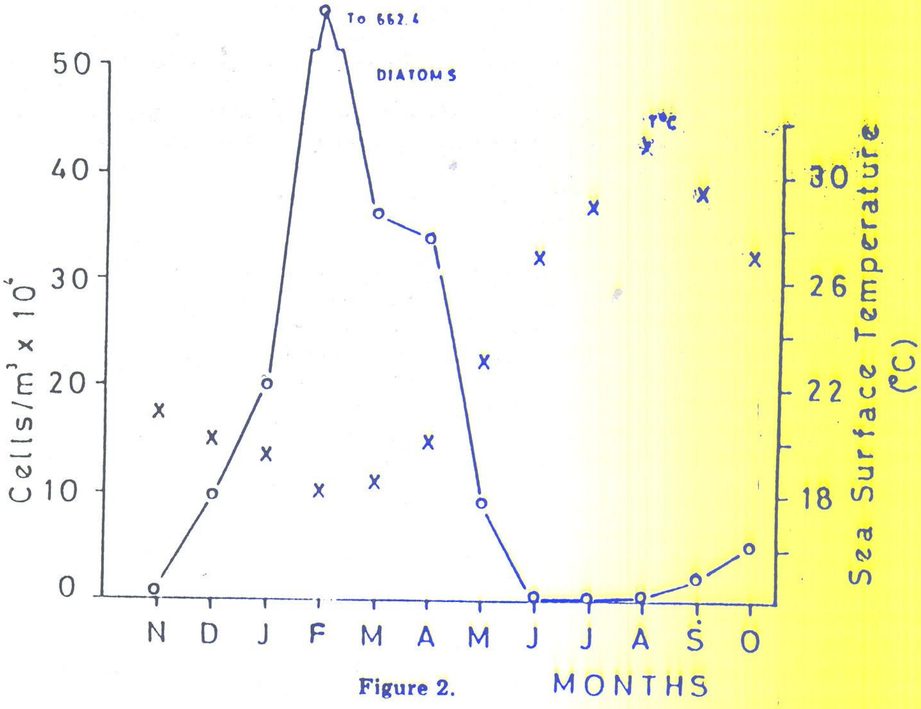

Figure 2.

7.2 m in February to 44.8 m and 44.7 m in May and July, respectively. With the expection of September, rainfall was recorded throughout the study period with a minimum of 0.7 kg/m^2 in August and a maximum of 146.5 kg/m^2 in November. Similar values (145.6) and 143.7 kg/m^2) were also found in January and October, respectively. Earlier hydrographic studies carried out by the Middle East Technical University, Institute of Marine Sciences (28) showed that the thermocline began to develop to wards the end of april, it was then well pronounced between May and october, being quite strong in August and destroyed by November. Thus, winter mixing seems to occur between December and April. The salinity was partly affected by fresh water inflow from different sources, i.e.rainfall and rivers, as well as by inflow into the Medirranean Atlantic waters. It fluctuated between 34.5 % in spring and 39.07 % in Autumn.

Seasonal Fluctuations:

Phytoplankton species found during each sampling period are shown in Table 1. A total of 35 genera including 111 species and varieties were identified. The phytoplankton abudance was composed mainly of diatoms (99.7 %) with a small portion of dinoflagelates (0.3 %). Silicoflagellates were represented only by 3 species and showed an abudance of 40-140 cells/m^3.

Diatoms

Diatoms were dominant both in abudance and species during each sampling period except in July, when the dinoflagellates were slightly more abundant. A total of 62 diatom species were identified. Of these, centric diatoms were dominant with 14 genera including 54 species. They constituted 96.7 % of the total diatoms and 96.4 % of the total phytoplankton (diatoms and dinoflagellates). This group was mainly represented by species of *Chaetoceros* and *Rhizosolenia. Chaetoceros* was represented by 19 species and constituted 92 % of all diatoms in abudance. *Rhizosolenia* was also important in species number being represented by 15 species. But it was less important in cell number and contributed only 1.3 % to diatom abudance.

Pennate diatoms consisting of 8 genera and 8 species, constituted 3.3 % in abudance of both the diatoms and the total phytoplankton. *Thalassiothrix* was the most abundant species of this group and comprised 73.1 % of pennate diatoms and 2.4 % of the total diatoms and of total phytoplankton. It was represented by two species: *T. frauenfeldii* and *T. mediterranea.*

Five of the most abundant diatom species (centric and pennate) were ranked monthly in order of numerical dominance (Table 2). Apart from the two pennate diatoms, *Thalassiothrix frauenfeldii* and *T. mediterranea,* the centric diatoms were always dominant throughout the sampling period. The dominant centric diatoms were chiefly represented by species of *Chaetoceros.* In order of dominance, they were, *C. curvisetus, C. decipiens, C. affinis* and *C. pseudocurvisetus*. *Chaetoceros curvisetus* especially appeared as a leading form among the most abundant species from November to April except in December where it was the second in abundance.

The main peak of abundance of the diatoms, which also represented the maximum peak of total phytoplankton, occured in February (Fig. 2). This peak was caused by *Chaetoceros,* namely *C. curvisetus* (2.6 million cells/m^3), *C. decipiens* (1.9 million cells/m^3) and coincided with the lowest seawater temperature of the year (18°C). A significant negative correlation ($r=0.84$, $P<0.01$) was found between sea surface temperature and the abundance of diatoms (Fig. 2).

Dinoflagellates

Dinoflagellates were numerically insignificant compared with diatoms. They were represented by 12 genera including 46 species and varieties, and composed0.3 % in abundance of total phytoplankton.

The dinoflagelates were dominated mainly by species of *Ceratium* (totaly 34 species) throughout the study period. Only the total abundance of four species exceeded 1000 cells/m^3. In order of numerical dominance, these are: *Ceratium horridum* var. *buceros, C. macroceros* var. *gallicum, C. fusus,* and *C. horridum* var. *buceros f. inclinatum.*

The main peak of dinoflagellates also appeared in February (Fig.3) dominated by two species *C. horridum* var. *buceros* and *Peridinium sp.* The peaks of December and May were mainly due to *Ceratium species.*

The diatom/dinoflagellate ratio was high in winter, and in spring, while it decreased in summer and in autumn (Fig. 3) which reflects a decrease in diatom abundance, as well as an increase in the cell density of dinoflagellates.

Species diversity:

The calculation of species diversity was based on the numbers of species and specimens. The species diversity of total phytoplankton (diatom and dinoflagellates) ranged from 2.16 in February to 4.34 in June. It was governed by diatoms from November to March and by Dinoflagellates from June to September (Fig. 4). The lowest diversity of diatoms was observed in July, when only four species belonging to three genera were present. Among these species, *Chaetoceros dadayii* was the most abundant accounting for 72.7 % of the total number of organisms recorded in this month. The highest diversity of diatoms in November resulted from low abundance and also from an even distribution of individuals among the species.

The diversity of dinoflagellates showed two minima values; one in February and another one in April. This was due to low number of species in these months. The highest diversity coincided with highest species number in October.

DISCUSSION

The hydrographic conditions are consistent with those found by other authors for the eastern Mediterranean Sea (3, 28, 29).

In the present study, the diatoms were found to dominate both in terms of absolute abundance and in number of species for most of the year, while the dinoflagellates were dominant in species in June and July (Table 1) and they were slightly more abundant only in June. In earlier studies, El-Maghraby and Halim (3) found similar results with the exception that the number of diatom species was lower than that of dinoflagellates only in June but higher during the rest of the year. Abboud-Abi Saab (7) observed that the diatoms predominated in cell density but the dinoflagellates were richer in number of species.

Diatoms were dominated by *Chaetoceros* and *Rhizosolenia* communities and dinoflagellates by *Ceratium* community. Similer results were found by El-Maghraby and Halin (3) in Alexandria waters, by Ignatiades (30) in Saronicos Bay, by Abboud-Abi Saab (7) on the Lebanon coast and by Azov (6) on the Israeli coast.

Chaetoceros and *Rhizosolenia* communities appeared to be abundant generally in the cold seasons, that is, from September to May. Abboud-Abi Saab (7) studied qualitatively and quantitatively the phytoplankton of the coastal waters of Lebanon and found that *Chaetoceros* and *Rhizosolenia* were the most important genera of diatoms being represented by 33 and 16 species, respectively. Azov (6) also pointed out that the diatoms were dominant species in the neritic region of the oligotrophic waters of the Levant Basin and that the most abundant diatoms belonged to genera *Chaetoceros, Coscinidiscus* and *Rhizosolenia.*

The main phytoplankton peak occurred in February. It was caused primarily by diatoms and especially by *Chaetoceros,* which constituted 96.7 % of total phytoplankton in this month. This peak coincided with the lowest seawater temperature (Fig. 2) which indicates that the diatoms develop well during the cold months in this area. Kimor and Golandsky (31) described the diatoms as preferring a lower seawater temperature. Ignatiades (30) observed a diatom bloom which lasted from October to May reaching to its maximum abundance in February and March in Saronicos Bay. According to Lalami-Taleb (32), the increase of diatoms during January and February is a general phenomenon in the Mediter-

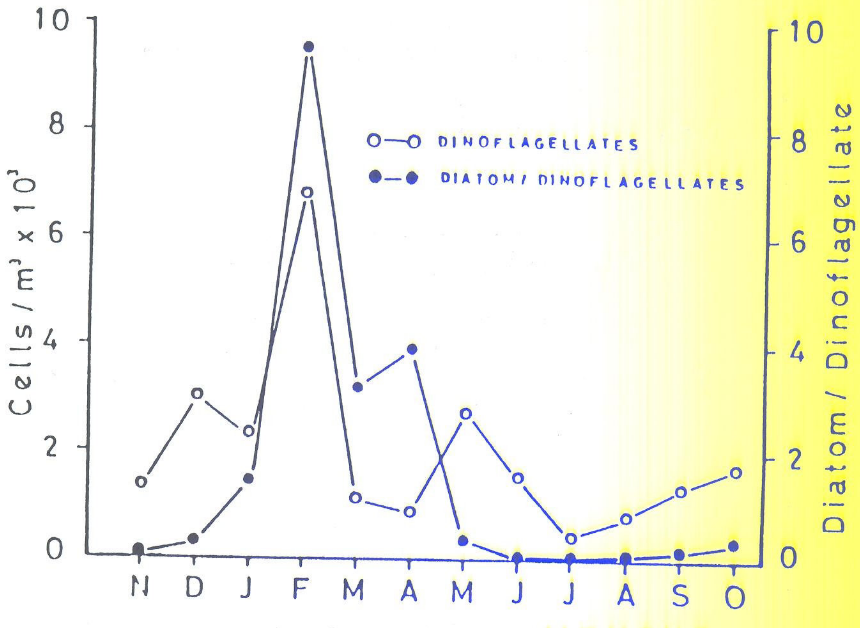

Figure 3.

ranean Sea, which coincides with a sudden rise of sunlight, without any modification of water temperature. Similar suggestion was made by Abboud-Abi Saab (7). According to this author, February is the time of vertical mixing of the water masses and hydrologic conditions become favorable for the development of cells and thus the phytoplankton starts to increase. Likewise, Azov (6) pointed out that among the large phytoplankton, the diatoms will respond faster to favorable growth conditions. A significant negative correlation ($r = -0.84$, $P < 0.01$) found in the present study between the temperature and the abundance of diatoms confirms these results.

Among the species of *Chaetoceros*, which occurred during the February peak, *Chaetoceros curvisetus* was the most abundant with 2.6 million cells/m^3 and this species was a leading form for most of the year (Table 2). It was followed by C. *decipiens* and *C. affinis* with 1.9 million and 1.2 million cells/m^3, respectively. El-Maghraby and Halim (3) indicated that the winter bloom was due to *C. curvisetus* (dominant) followed by *C. socialis*. Ignatiades (30) and Abbou-Abi Saab (7) reported the dominancy of *C. curvisetus* in early spring. So, our results are in agreement with those found by the earlier authors. Only two dinoflagellate species *(Ceratium horridum var. buceros* and *Peridinium sp.)* have been found to contribute, with similar cell numbers (3.500 cells/m^3) to the main phytoplankton peak in February. *Ceratium* was represented by 34 species constituting 66 % of total dinoflagellates. It occured throughout the study period. The dominancy of this genus among the dinoflagellates was also observed by Abboud-Abi Saab (7) and Azov (6) in the eastern Mediterranean and by Ignatiades (30) in Saronicos Bay. Although the outburst of dinoflagellates occured in the same month (February) as the diatoms, the diatom/dinoflagellate ratio reached to its highest level (1,000) in this month, and dropped to its lowest level (0.96) in July. This suggest that the diatoms predominate during cold seasons (autumn, winter and spring), but decrease in the warm summer months and this leads to low diatom/dinoflagellate ratios (Fig. 4).

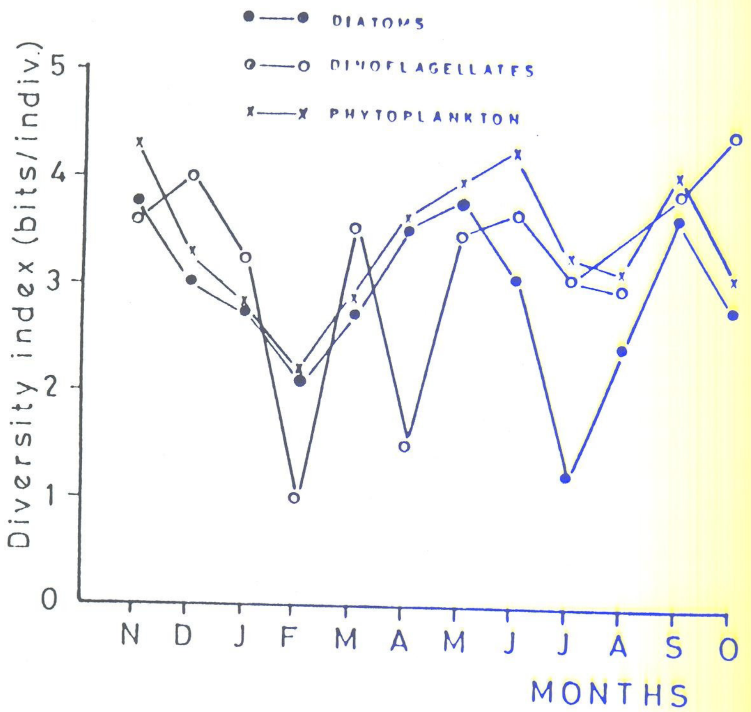

Figure 4.

Table 1. Qualitative Composition of net Phytoplankton From November 1984 to October 1985.

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Aug.	Sep.	Oct.	
DIATOMS												
Centrics												
Asterolampra marylandica EHRBG.						x						
Bacteriastrum biconicum PAV.	x	x	x									
B. delicatulum CLEVE		x	x	x	x	x	x					
B. elegans PAV.		x		x	x	x	x				x	x
B. hyalinum LAUD.		x										
B. mediterraneum PAV.	x		x		x							
Biddulphia mobiliensis (BAIL.) GRUN.				x	x							
Chaetoceros affinis LAUD.	x	x	x	x	x	x	x			x	x	x
C. atlanticus CLEVE var. neapolitana (SCHROD.) SCHUTT		x	x	x							x	
C. coarctatus LAUD.	x	x									x	x
C. costatus PAV.		x										
C. crinitus SCHUTT							x					
C. curvisetus CLEVE	x	x	x	x	x	x	x					
C. dadayi PAV.	x	x							x	x	x	
C. danicus CLEVE		x					x					
C. decipiens CLEVE	x	x	x	x	x	x	x					x
C. didymus EHRBG.	x		x							x	x	x
C. didymus var. protuberance (LAUD.) GRAN et JENDO					x	x					x	x
C. diversus CLEVE		x	x		x		x	x			x	
C. laciniosus SCHUTT	x	x	x		x						x	x
C. lauderi RALFS	x	x		x	x	x	x				x	
C. peruvianus BRIGHT.			x		x		x	x				x
C. pseudocurvisetus MANGIN	x	x	x	x	x	x						x
C. rostratus LAUD.	x	x	x		x	x	x					
C. tetrastichon CLEVE											x	
C. sp.			x				x			x	x	
Climacodinium biconvacum CLEVE	x	x			x					x		x
Coscinodiscus gigas EHRBG.			x									
C. granii GOUGA			x	x								
C. janishii A. SCHM.			x	x								
C. janishii A. SCHM.			x									
C. thorii PAV.			x	x								
C. sp.					x		x				x	x
Dactyliosolen mediterraneus PERAG.	x	x	x		x		x				x	x
Guinardia blavyana PERAG.	x	x	x			x	x			x	x	x
Hemialus hauckii GRUN.	x	x	x	x	x	x	x	x	x	x	x	x
H. sp.		x										
Leptocylindrus adriaticus SCHROD.					6							
L. danicus CLEVE		x	x		x	x	x	x			x	x
L. minimus GRAN.						x					x	
Lithodesmium undulatum EHRBG.		x		x								
Rhizosolenia alata BRIGHT.	x	x	x	x	x	x	x	x	x		x	x
R. alata f. gracillima (CLEVE) GRUN.	x	x	x		x	x	x	x		x	x	x
R. alata f. indica (PERAG.) OSTFL.		x				x	x	x		x	x	x
R. calcar-avis SCHUTT.	x	x	x	x	x	x	x	x	x		x	x
R. castracanei PERAG.					x							
R. delicatula CLEVE							x					
R. fragillissima BERG.			x			x						
R. firma KARSTEN			4									
R. imbricata BRIGHT.	x	x										
R. robusta NORM.					x						x	x
R. setigera BRIGHT.						7						
R. shrubsolei (CLEVE) SCHROD.		x	x		x	x	x	x			x	x
R. stolterfothii PERAG.				x	x	x	x	x			x	x
R. styliformis BRIGHT.					x						x	x
R. temperei PERAG.				x								
Schroederella delicatula PAV.			x		x	x					x	
Thalassiosira decipiens (GRUN.) JORG.			x	x								
Uniden. centric diatoms		x	x	x	x					x	x	x

Table 1. (Contn'd)

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sep.	Oct.
Pennates												
Asterionella japonica CLEVE		x	x	x								
Bacillaria paradoxa GMELIN		x	x	x	x							
Navicula sp.		x	x									
Nitzschia closterium (EHRBG.) W.SM.						x						
N. delicatissima CLEVE	x	x	x		x	x	x	x				x
N. seriata CLEVE			x									
Pleurosigma sp.		x	x	x	x						x	x
Stauroneis sp.					x						x	x
Thalassionema nitzschioides GRUN.								x				
Thalassiothrix frauenfeldii GRUN.	x	x	x	x	x	x	x	x				x
T. mediterranea PAV.	x	x	x	x	x	x	x	x			x	
Uniden. pennate diatoms			x	x	x					x		
SILICOFLAGELLATES												
Dictyocha fibula EHRBG.		x	x									
D. speculum EHRBG.		x										
Uniden. silicoflagellate sp.		x										
DINOFLAGELLATES												
Ceratium arietinum (JORG.) SOURNIA		x								x		
C. candelabrum var. depressum (POUCHET) JORG.	x	x			x		x					x
C. carriense GOUR.	x	x									x	
C. carriense var. volans (CLEVE) SOURNIA											x	
C. concilians JORG.			x									
C. contortum var. karsteni (PAV.) SOURNIA												x
C. contortum (GOUR.) CLEVE var. subcontortum	x	x			x							
C. contrarium GOUR.	x	x					x	x				x
C. extensum (GOUR.) CLEVE		x	x		x		x	x	x			x
C. falcatum (KOF.) JORG.					x							
C. furca (EHRBG.) CLAP. et LACH.					x	x	x	x				x
C. fusus (EHRBG.) DUJARD		x	x		x				x			x
C. fusus var. seta (EHRBG.) SOURNIA	x						x	x			x	
C. glibberum GOUR.											x	x
C. symmetricum PAV.		x										
C. symmetricum var. orthoceros (JORG.) graham											x	
C. symmetricum var. symmetricum SOURNIA	x		x				x					
C. hexacanthum GOUR.												x
C. horridum var. buceros (LACH.) SOURNIA		x	x	x			x	x		x	x	x
C. horridum var. buceros f. inclinatum (KOF.)	x	x	x		x				x	x	x	x
C. kofoidi (JORG.)		x										x
C. longirostrum GOUR.												x
C. macroceros var. gallicum (KOF.) SOURNIA	x	x	x			x	x	x			x	x
C. massiliense (GOUR.) JORG.		x						x			x	x
C. massiliense var. protuberance (KARSTEN) JORG.	x											x
C. paraxoides CLEVE		x										
C. pentagonum GOUR.		x										x
C. pentagonum var. tenerum JORG.					x		x	x				
C. pulchellum SCHROD.	x	x			x		x				x	
C. rapines CLEVE		x										
C. reticulatum f. spiralis KOF.								x				x
C. setaceum JORG.		x					x					
C. teres KOF.		x					x	x				x
C. trichoceros (EHRBG.) KOF.	x	x	x		x					x	x	x
C. tripos (HULL.) NITZSCH.	x										x	x
Cladophyxis branchiolata STEIN			x									x
Dinophysis caudata SAVILLE KENT								x				x
D. operculoides (STEIN) BALECH									x			
D. rapa (STEIN) ABE								x				
Mesoporus sp.?	x							x				
Oxytoxum spp.			x					x				x
Ornithocerrus quadratus SCHUTT		x							x	x	x	
Pavillardinium intermedium? (PAV.) DE TONI										x		x
Peridinium depressum (BAILEY BALECH					x		x	x	x	x		
P. murrayi (KOF.)												x
P. pentagonum? (GRAN.) BALECH		x	x									
P. spp.				x	x					x		
Prorocentrum spp.						x						
Protoceratium pepo KOF et MICH.									x		x	
P. sp		x									x	
Pyrocystis fussioformis TOMPSON												x
Pyrophacus horlongium var. stenii SCHILLER	x									x	x	x
Uniden. dinoflagellates	x	x			x		x	x	x	x		

Table 2. Most Abundant Diatom Species During each Sampling Time

Species	Nov. R N	Dec. R N	Jan. R N	Feb. R N	Mar. R N	Apr. R N	May N R	June N R	July N R	Aug. N R	Sep. N R	Oct. N R
Chaetoceros curvisetus	1 3.34	2 4.21	1 4.94	1 6.42	1 5.12	1 4.93						
Chaetoceros affinis	2 3.20	3 4.10	4 3.94	3 6.08	4 4.57	2 4.68	1 4.15			1 3.43	1 3.66	
Chaetoceros coarctatus	3 3.05											
Rhizosolenia calcaravis	4 2.99								2 1.60			
Thalassiothrix frauenfeldii	5 2.99	1 4.61			2 4.96			2 2.71				
Bacteriastrum delicatulum		4 3.70	5 4.15		5 4.09		4 4.04					
Chaetoceros decipiens		5 3.65	3 4.15	2 6.29	3 4.61		3 4.08					
Chaetoceros pseudocurvisetus			2 4.73	4 5.77		3 4.64						
Thalassiosira decipiens				5 4.82								
Chaetoceros rostratus						4 4.43	2 4.15					
Rhizosolenia stolterfothii						5 4.32						
Bacteriastrum elegans							5 3.92					
Rhizosolenia alata f. gracillima								1 2.81				
Thalassionema nitzschioides								3 2.51				
Rhizosolenia alata								4 2b34	2 1.60			4 3.42
Hemialus hauckii								5 2.26	2 1.60	4 2.63	5 3.16	5 3.11
Chaetoceros dadayii									1 2.51			
Chaetoceros sp.										2 3.21	3 3.46	
Chaetoceros didymus										3 2.84	2 3.66	1 4.35
Climacodinium biconvacum										5 2.56		
Chaetoceros laciniosus											4 3.22	3 3.45
Thalassiothrix mediterranea												2 4.13

R – Ranking, N – log number of diatom cells/m^3.

Lalami-Taleb (32) studied the vertical migration of phytoplankton off Algeria and observed that the diatoms sink from the surface layer which becomes very hot and descend to a depth of 350 m to the cool intermediate deep waters. However, the dinoflagellates prefer the strong light intensity and high water temperature. According to the same author, the excessive illumination associated with the absence of winds and water stratification prevents the development of phytoplankton during the summer season. The poor summer population of phytoplankton was also observed by El-Maghraby and Halim (3) in waters off Alexandria.

The species diversity reflected the seasonal change in the abundance of phytoplankton groups. It was low from January to March, with its lowest value (2.16 bits/indiv.) in February, and higher (3.22 to 4.34 bits/indiv.) during the rest of the year (Fig. 4). As was mentioned previously, February is the time of maximum abundance of phytoplankton. Ignatiades (30) indicated that the intense spring bloom resulted in a lower diversity index. The results of this author ranged between 1.53 to 4.08 and our results agree with these. According to the theory of Margalef (1967, cited in 30) the diversity index is expected to be always minimal in sudden blooms of phytoplankton accompained by intense dominance of one or a few species, and it decreases in later stages of succession. Consequently, the abundance of phytoplankton fluctuated seasonally depending on the environmental factors and so the diversity index.

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