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# SEASONAL VARIATIONS IN BIOMASS, ABUNDANCE AND SPECIES DIVERSITY OF PHYTOPLANKTON IN THE İSKENDERUN BAY (NORTHEASTERN MEDITERRANEAN)

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**Abstract**

Phytoplankton biomass, abundance, diversity and their relations with physico-chemical properties of water were determined in the northwestern part of the İskenderun Bay, northeastern Mediterranean coast of Turkey. Nine stations were sampled monthly from July 2000 to July 2001. Phytoplankton biomass, in terms of chlorophyll *a* values ranged from 0.05 to 2.7 $\mu g.L^{-1}$ during the study period. Phytoplankton abundance was lowest in summer ($2.64x10^2$ cells $L^{-1}$) and highest in spring ($127.25 x10^2$ cells $L^{-1}$). Diatoms were found to be present throughout the year. They were the dominant group in terms of both number of species and abundance (66%). Dinoflagellates constituted 31% of total abundance. Diversity decreased when phytoplankton abundance increased showing an inverse relationship. The mean values for species diversity and evenness indices during the study period were 2.96±0.45 and 0.80±0.12, respectively.

## Introduction

In marine environment, phytoplankton communities vary according to factors existing in an area. The surrounding factors have a determinative role for phytoplankton communities. Phytoplankton blooms may occur due to the seasonal changes of these environmental conditions. The blooms are also one of the response of phytoplankton to environmental perturbations such as pollution. Pollution pressure can change the equilibrium among the species and even cause excess of some species. Thus, changes in phytoplankton communities due to the effects of natural events or pollutants can be determined with the investigation of the species composition, cell numbers and biomass. Determination of diversity indices rather than the investigation of each species might give more information on the changes in community structure due to large number of species that exist in nature. Diversity has two components, species richness and equitability of abundance of species (Valiela, 1984). A detailed definition of equitability (evenness) is the difference between the actual diversity and the hypothetical diversity resulting from all species being equally frequent (Krebs, 1989). By using some indices, some information about the species number and the distribution of individuals among species can be obtained. It might also be useful in describing the trophic conditions of the related area.

Eastern Mediterranean is known as one of the most oligotrophic area in the world on the basis of biomass and primary production values (Azov, 1991). However, coastal areas show high productivity due to nutrient rich terrestrial inputs and anthropogenic effects. Iskenderun Bay, which is located in northeastern Mediterranean part of Turkey is one of the most productive area in this region. The bay has approximately $2275km^2$ surface area and one of the largest continental shelf in the east Mediterranean. The mean depth is

around 70 m in the bay. Ceyhan River which is one of the most important rivers in this region discharges its water into the bay. The area is heavily populated with several fertilizer factories and iron-steel industry etc. In addition to all these factors, marine traffic is also very important source of pollution in the bay because of petroleum pipeline and other industries.

The objective of the present study was to investigate the seasonal variations of phytoplankton abundance, biomass and diversity at nine station in the northwestern part of İskenderun Bay in relation to changes in environmental factors.

## Materials and Methods

Samples were collected at monthly interval during the period of July 2000 to July 2001 from nine stations located in northwestern part of İskenderun Bay (Fig.1). Water samples were collected from surface water of each station for the analysis of phytoplankton, chlorophyll *a* and nutrients. Surface water temperature and salinity were measured by using YSI model SCT (salinity, conductivity, temperature) meter. Nutrient analyses ($PO_4$-P, $NO_3$+$NO_2$-N and $[Si(OH)_4]$-Si) were performed by spectrophotometric methods according to Parsons *et al.*, (1984). For chlorophyll *a* measurements, 2 L of sea water was filtered through GF/F filters. The filters were kept in 90% acetone for one night and the suspension was cleared by centrifugation. Spectrophotometric method given by Parsons *et al.*, (1984) was used to measure chlorophyll *a* levels. For phytoplankton enumerations, 2 L seawater samples were fixed with neutralized formaldehyde until final concentration of 4% is obtained. The samples were sedimented for one week. Then, upper layers of sedimented samples were siphoned. Thus, samples were reduced to a final volume of 20 ml and 1 ml aliquot was used for the enumeration of phytoplankton cells by Sedgwick-Rafter counting chamber. A phase-contrast binocular microscope was used for counting of phytoplankton and the references used for the identification of species were Tregouboff & Rose (1957), Rampi & Bernhard (1980), Sournia (1986), Ricard (1987) and Tomas (1997).

After quantitative phytoplankton analyses, species and cell numbers were used for calculations of diversity and evenness index. Shannon-Wiener diversity and Pielou evenness index were used (Krebs, 1989; Omori & Ikeda, 1984).

Shannon –Wiener index is defined as:

$$H' = -\sum_{i=1}^{S} (pi \log_2 pi)$$

where **s** is the total number of species, ***pi*** is the proportional abundance of ith species and, ***H'*** is the Shannon-Wiener diversity.

Pielou evenness index is computed using species richness and the Shannon-Wiener index and this index is defined as:

$$J' = \frac{H'}{H'\max} = \frac{H'}{\log_2 S}$$

where, **S** is the number of species, ***J'*** is the evenness index.

Phytoplankton cell number and physico-chemical data were analysed statistically for detection of differences among stations and sampling periods. In addition, relationships between physico-chemical factors and phytoplankton cell number, chlorophyll *a* and diversity calculations were estimated by simple linear correlation analysis with SPSS 8.0 statistical package program.

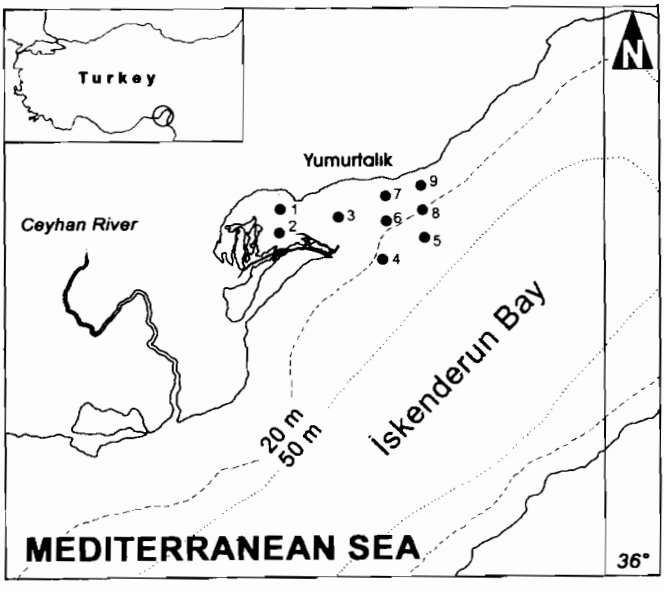


Fig. 1. Sampling area and location of sampling points.

## Results

The mean values of physico-chemical factors according to sampling periods are given in Fig. 2 and 3. The highest temperature values were recorded in August, and the lowest in January (Fig. 2) with minimum (16.2°C and maximum (30.5°C) surface water temperatures. Salinity decreased to the lowest levels (35.1%) in winter and reached the highest values (39.2%) in summer and autumn due to the lack of rain and high evaporation (Fig. 2).

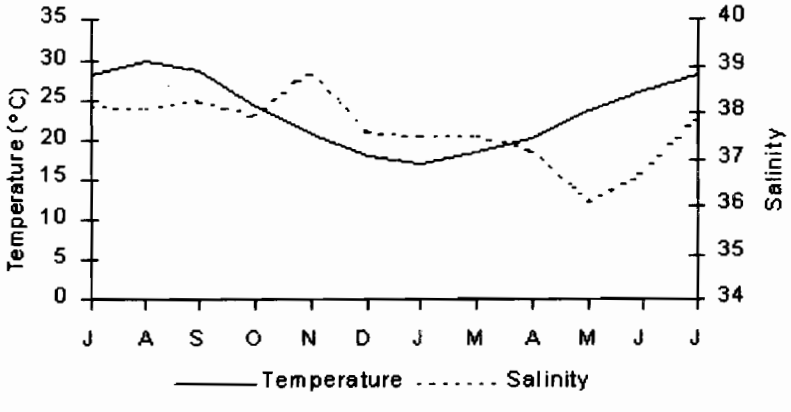


Fig. 2. Temporal variations of surface water temperature and salinity (means of nine stations)

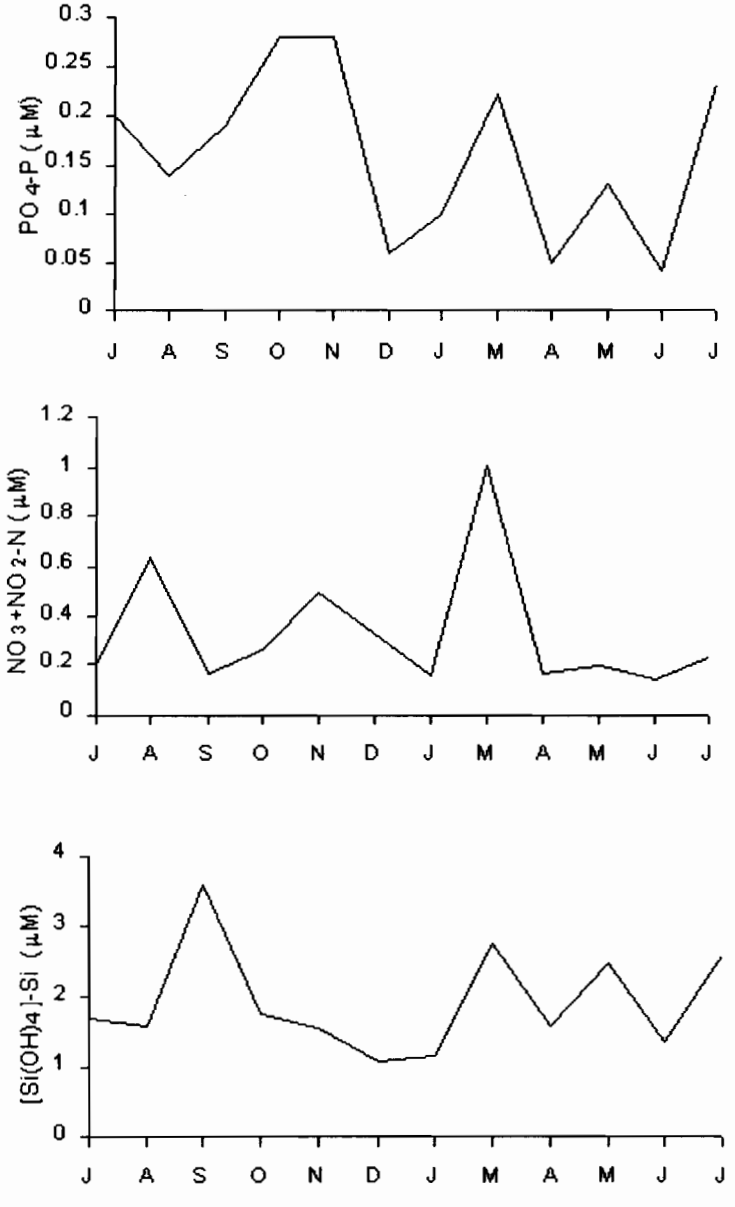


Fig. 3. Temporal variations of nutrient concentrations (means of nine stations).

Phosphate concentrations showed clear fluctuations during the research period. The mean phosphate concentrations ranged between 0.04±0.003 and 0.28±0.03 μM. The highest phosphate concentration detected was 0.73 μM in March (station 3). The highest mean value of nitrate+nitrite was in March (1.01±0.97 μM) and a small peak was recorded in August. It was in low level between April and June (~0.17 μM) (Fig.3). The lowest nitrate+nitrite concentration was found in July (0.06 μM, station 6). The most important peak of silicate was observed in September (3.6±0.56 μM) but smaller peaks were also recorded in spring and summer (Fig.3). The minimum and maximum silicate concentrations during the study were found in December (0.86 μM, station 9) and March (4.79 μM, station 3), respectively.

The difference between sampling periods in terms of nutrient concentrations were found statistically significant ($p<0.01$), however it was not significant among sampling stations ($p>0.05$).

Phytoplankton biomass, estimated as chlorophyll *a* showed mean values between 0.07±0.04 and 1.53±0.82 $\mu g.L^{-1}$ (Fig.4). Chlorophyll *a* values were found high in spring and the highest value was in March as 2.7 $\mu g.L^{-1}$ (station 3). The lowest recorded value was 0.05 $\mu g.L^{-1}$ in January (station 9). The difference in chlorophyll *a* values among months was found statistically significant ($p<0.01$), but the difference among stations was not significant ($p>0.05$). A significant negative correlation ($r=-0.259$, $p<0.01$) was found between chlorophyll *a* and temperature, whereas the correlation of chlorophyll *a* was positive with nutrients ($r=0.311$ for phosphate, $r=0.618$ for nitrate+nitrite and $r=0.440$ for silicate, $p<0.01$).

A total of 96 phytoplankton taxa were determined. These include 51 taxa belonging to diatoms and 41 to dinoflagellates. Coccolithophorids and Dictyochophyceans were represented with only 2 taxa each (Table 1).

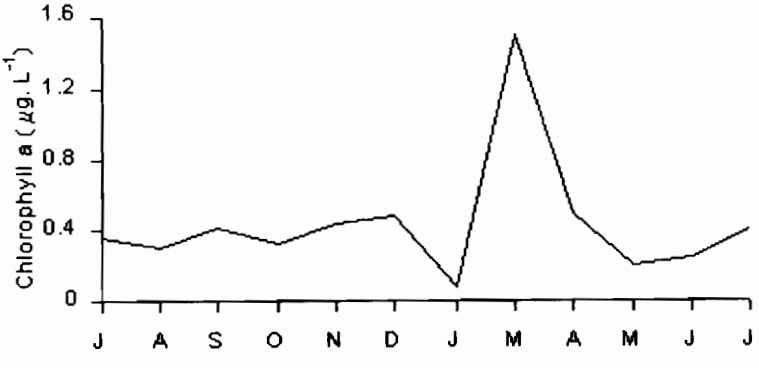


Fig. 4. Temporal variations of chlorophyll *a* concentrations (means of nine stations).

The total species numbers in autumn and winter months varied between 24 and 29. In late spring, total species number increased and were found between 43 and 45, respectively (Fig.5). Diatoms were dominant in terms of cell number with 66% of total abundance. Dinoflagellates were 31% of total abundance. The ratio of others (Coccolithophorids and Dictyochophyceans) was 2.9% of total abundance. Phytoplankton abundance (as mean values) were low between a minimum $4.89x10^2$ cells

$L^{-1}$ and a maximum 49.61 $x10^2$ cells $L^{-1}$ and showed two important peaks, in September and April (Fig.5). The increase of phytoplankton cell number in September was mainly due to increase of a diatom, *Thalassiothrix fraunfeldii* followed by *Guinardia flaccida*. In this period, diatoms reached 97% of total cell number (Fig.6). The recorded highest cell number was in April (127.25 $x10^2$ cells $L^{-1}$). The increase of phytoplankton in April was mainly due to a dinoflagellate, *Goniodoma polyedricum* (72.7$x10^2$ cells $L^{-1}$). Relatively high densities of *Prorocentrum micans* (max. 25.9$x10^2$ cells $L^{-1}$) was recorded in the same period and dinoflagellates comprised 78% of the total abundance. The recorded lowest cell number was found in July (2.64$x10^2$ cells $L^{-1}$, station 6). In summer, diatoms were abundant as compared to dinoflagellates but, they were represented with very low concentrations. The difference in phytoplankton cell numbers among sampling periods was found statistically significant ($p<0.01$), however it was not significant among stations ($p>0.05$). The correlations between phytoplankton cell numbers and nutrient concentrations were not statistically significant ($p>0.05$). Meanwhile, the correlation between cell numbers and chlorophyll *a* was also not significant ($p>0.05$).

Shannon-Wiener diversity and evenness indices were low in September as mean values 2.35±0.28 and 0.61±0.09 due to increase of two diatoms. These indices were found in high levels in November and December, whereas cell numbers were in low levels in that periods (Fig. 5). Shannon-Wiener diversity ranged from 1.59 (in January, station 7) to 3.57 (in December, station 9) with a mean value of 2.96±0.45. Evenness index ranged from 0.44 (in January, station 7) to 0.95 (in December, station 5) with a mean value of 0.80±0.12 through the study period. An important negative correlations between indices of Shannon-Wiener and evenness and cell numbers were found ($r=-0.272$, $p<0.01$ for Shannon-Wiener diversity, $r=-0.564$, $p<0.01$ for evenness index). This means, diversity decreased when phytoplankton abundance increased. Evenness index showed positive correlation with phosphate ($r=0.244$, $p<0.05$) and nitrate+nitrite ($r=0.234$, $p<0.05$), whereas Shannon diversity showed no important correlation with these two nutrients. However, both index values were negatively correlated with silicate ($p<0.01$).

## Discussion

The oligotrophy of Mediterranean has already been determined by previous workers on nutrients and primary production (Kimor *et al.*, 1987; Dugdale & Wilkerson, 1988; Ediger & Yılmaz, 1996). Primary production was recorded at quite low levels as 25 g $C/m^2$/year for east Mediterranean (Murdoch & Onuf, 1974) and 18 g $C/m^2$/year for northeastern Mediterranean (Berman *et al.*, 1984). This case is explained with quite narrow continental shelf, insufficient upwelling areas and limited external input (Murdoch & Onuf, 1974; Azov, 1991). In such oligotrophic waters, phytoplankton diversity is usually higher than eutrophic waters (Harris, 1986). However, coastal areas may show different specifications than open sea in terms of nutrient concentrations, phytoplankton biomass and primary production levels. Industrial complexes and agricultural efforts and increased human population surrounding the coastal zone induce nutrient rich input flow to the area. İskenderun Bay is under the influence of these factors explained above. Besides, the Ceyhan River which has an average discharge of 180 $m^2/s$, carries phosphorous and nitrogenous fertilizers from agricultural areas to the bay. The annual primary productivity level in İskenderun Bay is 115 g/$C/m^2$/year and this value is 2-4 times higher than those of the northeastern Mediterranean (Yılmaz *et al.*, 1992)

**Table 1. List of phytoplankton taxa found in the study area during 2000-2001.**

| | |
|---|---|
| **Diatoms** | |
| *Amphiprora* sp. | *Melosira sulcata* (Ehrenberg) Kützing |
| *Asterionella japonica* Cleve | *Navicula* sp. |
| *Bacillaria paxillifera* (O.F.Müller) Hendey | *Nitzschia longissima* Brebisson in Kützing |
| *Bacteriastrum delicatulum* Cleve | *Nitzschia* sp. |
| *Cerataulina pelagica* (Cleve) Hendey | *Odontella mobiliensis* (Bailey) Grunow |
| *Chaetoceros affinis* Lauder | *Pleurosigma elongatum* W.Smith |
| *C. atlanticus* Cleve | *P. normanii* Ralfs in Pritch. |
| *C. compressus* Lauder | *Podocystis perrinensis* |
| *C. curvisetus* Cleve | *Pseudonitzschia* sp. |
| *C. dadayi* Pavillard | *P. pungens* (Grun. ex Cleve) Hasle |
| *C. decipiens* Cleve | *Rhabdonema adriaticum* Kützing |
| *C. didymus* Ehrenberg | *Rhizosolenia alata* f. *gracillima* (Clev.)Gran |
| *C. laciniosus* Schütt | *R. alata* f. *indica* (H.Peragallo) Gran |
| *C. lorenzianus* Grunow | *R. calcar-avis* Schultze |
| *C. peruvianus* Brightwell | *R. fragilissima* Bergon |
| *C. tetrastichon* Cleve | *R. imbricata* var. *shrubsolei*(Clev.) Schröder |
| *Chaetoceros* sp. | *R. robusta* Norman in Pritchard |
| *Climotosphaenia moniligera* Ehrenberg | *R. stolterfothi* H. Peragallo |
| *Cylindrotheca closterium* (Ehr.)Lewin et Reim. | *R. sytliformis* Brightwell |
| *Eucampia zodiacus* Ehrenberg | *Surirella* sp. |
| *Guinardia flaccida* (Castracane) H.Peragallo | *Synedra ulna* (Nitzsch) Ehrenberg |
| *Hemiaulus hanckii* Grunow in Van heurck | *S. undulata* (Bailey) Gregory |
| *H. membranaceus* Cleve | *Thalassionema nitzschioides* Hustedt |
| *Leptocylindricus danicus* Cleve | *Thalassiothrix fraunfeldii* Grunow |
| *L. minimus* Gran | *T. mediterranea* Pavillard |
| *Licmophora abbreviata* Agardh | |
| **Dinoflagellates** | |
| *Ceratium arietinum* Cleve | *Gonyaulax polygramma* Stein |
| *C. candelabrum* (Ehrenberg) Stein | *G. spinifera* (Clap. et Lachmann) Diesing |
| *C. extensum* (Gourret) Cleve | *Ornithocercus magnificus* Stein |
| *C. furca* (Ehrenberg) Claparede et Lachmann | *Oxytoxum scolopax* Stein |
| *C. fusus* (Ehrenberg) Dujardin | *O. reticulatum* (Stein) Schütt |
| *C. hexacanthum* Gourret | *Podoplampas bipes* Stein |
| *C. horridum* (Cleve) Gran | *P. spinifera* Okamura |
| *C. inflatum* (Kofoid) Jörgensen | *Prorocentrum micans* Ehrenberg |
| *C. kofoidii* Jörgensen | *Protoperidinium conicum* (Gran)Balech |
| *C.macroceros* (Ehrenberg) Vanhöffen | *P. depressum* (Bailey) Balech |
| *C.massiliense* (Gourret) Jörgensen) | *P. divergens* (Ehrenberg) Balech |
| *C. teres* Kofoid | *P. globolus* (Stein) Balech |
| *C. trichoceros* (Ehrenberg) Kofoid | *P. mediterraneum* (Kofoid) Balech |
| *C. tripos* var. *atlanticum* (Ostenfeld) Paulsen | *P. oceanicum* (Vanhöffen) Balech |
| *C. tripos* var. *pulchellum* (Schröder) Paulsen | *P. steinii* (Jörgensen) Balech |
| *Ceratocorys horrida* Stein | *P. pedunculatum* (Schutt) Balech |
| *Dinophysis caudata* Saville-Kent | *P. pellucidum* (Bergh) Balech |
| *D. mitra* (Schütt) Abe | *Pyrophacus steinii* (Schiller) Wall Dale |
| *Dinophysis rotundata* Claparede et Lachmann. | *Scrippsiella trochoidea* (Stein) Loeblich |
| *Dinophysis* sp. | *Kofoidinium velelloides* Pavillard |
| *Goniodoma polyedricum* (Pouch.) Jörgensen | |
| **Coccolithophorids** | |
| *Anaplosolenia brasiliensis* (Lohmann) Deflandre | *Scyphosphaeria apsteinii* Lohmann |
| **Dictyochophyceans** | |
| *Dictyocha fibula* Ehrenberg | *D. speculum* Ehrenberg |

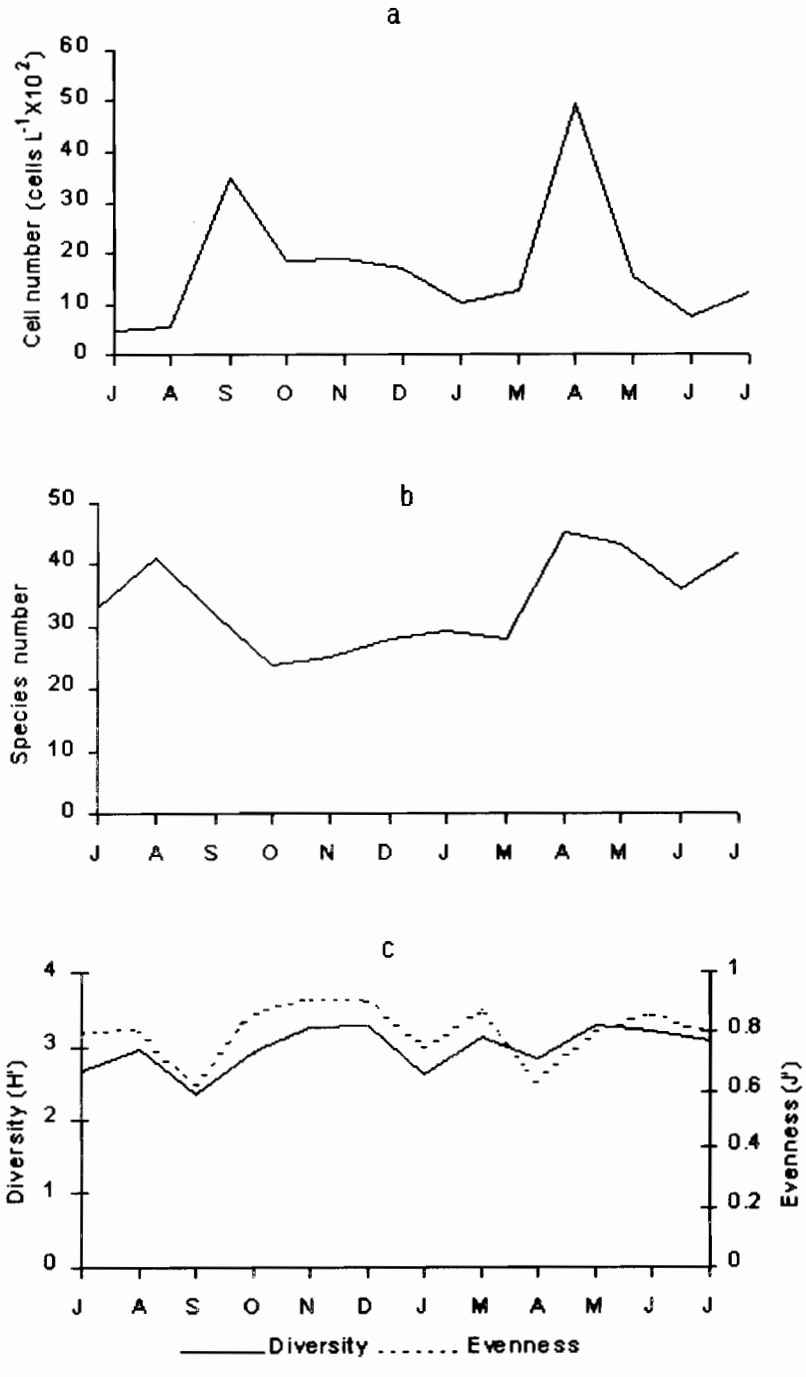


Fig. 5. Temporal variations of parameters belonging to phytoplankton, a) cell numbers, b) species numbers, c) diversity and evenness (cell numbers and diversity values are the means of nine stations).

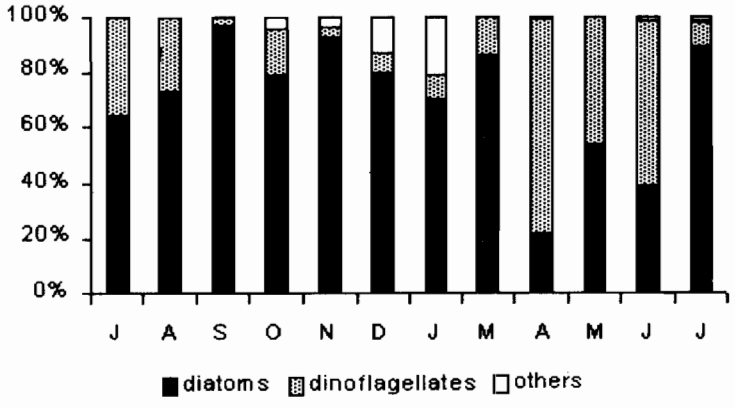


Fig. 6. Percentage abundance of the recorded phytoplankton groups.

The sampling area in the present study is located in northern part of the İskenderun Bay. Nutrients did not show clear seasonality due to the location of sampling points which were close to coast. However, nutrient concentrations were not in very high levels probably due to physically dynamic structure of the area as well as biological utilization. Phosphate, nitrate+nitrite and silicate concentrations recorded in this research were lower than those of previous records (0.1-1.5 for phosphate, 0.5-12 for nitrate+nitrite and 1-11 μM for silicate) of Yılmaz *et al.*, (1992) for İskenderun Bay. Higher nutrient concentrations in the study of Yılmaz *et al.*, (1992) may be due to source stations where the sewage outfall and the fertilizer industry waste is discharged. Ignatiades *et al.*, (1995) studied in southeast Aegean Sea and reported the nutrient concentrations to be 0.01-0.53, 0.02-0.79, 1.57-15.6 μM for phosphate, nitrate and silicate, respectively. They described the area as oligotrophic.

Chlorophyll *a* values ranged from 0.05 to 2.7 $\mu g.L^{-1}$ and made a peak in March. Chlorophyll *a* concentrations and phytoplankton cell numbers were in low levels in summer months. However, there were two peaks in terms of cell numbers in September and April. It was conspicuous that chlorophyll *a* and phytoplankton abundance made peaks in different months and as a result, the correlation between cell number and chlorophyll *a* was not found statistically significant. This situation can be explained that some part of chlorophyll *a* in March originated from small sized phytoplankton such as nano- or picoplankton which were not evaluated in the present study. In March, chlorophyll *a* values were high, but cell numbers were in low levels. In oligotrophic areas, small size fractions have very important role in total phytoplankton biomass and primary production (Azov, 1986; Berman *et al.*, 1986; Agawin *et al.*, 2000). Another reason of high chlorophyll *a* concentrations may be due to degradation products of chlorophyll *a* moved to surface layers by circulation events in early spring. The presence of these products may cause overestimation of chlorophyll *a* (Jeffrey & Welschmeyer, 1997). On the other hand, in April, high cell numbers in contrast to low chlorophyll *a* concentrations are probably due to a low contribution rate of counted phytoplankton fraction to total chlorophyll *a*. In addition, temporal changes in species composition and different pigment contents of species may affect chlorophyll *a* levels. The ranges of

chlorophyll *a* in this study were lower than records of Yılmaz *et al.*, (1992) for İskenderun Bay (0-6.5 $\mu g.L^{-1}$). However, the results of present study were higher than those previous reports of Yılmaz *et al.*, (1992) for northeastern Mediterranean (0.05-0.35 $\mu g.L^{-1}$) and Kimor *et al.*, (1987) for near surface waters of the east Mediterranean (0.03-0.07 $\mu g.L^{-1}$). Phytoplankton cell numbers in this study were also lower than the findings for northeastern Mediterranean by Polat *et al.*, (2000).

Phytoplankton diversity index usually tends to decrease when cell numbers increase. In the present study, there was a negative correlation between Shannon- Wiener diversity and phytoplankton abundance ($r = -0.272$, $p<0.01$). An important negative correlation ($r = -0.564$, $p<0.01$) was also found between evenness index and the phytoplankton abundance. The decrease of index value in September was due to the domination of two diatoms, *T. fraunfeldii* and *G. flaccida*. Similarly, Margalef (1978) reported that the domination of a single or few species may cause a fall in the diversity index. On the other hand, cell numbers were in highest levels in April but, there was a slight decrease in Shannon diversity index. Species numbers also increased at the same time and for this reason, there was no important decrease in diversity. The decrease in evenness index was more obvious in April. In June, evenness showed an increase whereas diversity decreased. These findings show that there are slight differences between both indices in terms of months. Therefore, the use of more than one index is suggested for the determination of the fractions of species richness and evenness (Omori & Ikeda, 1984). Moreover, the using of Shannon-Wiener index together with evenness was recommended by Parsons *et al.*, (1990). In the present study, high diversity values (3.2-3.3 bits) were found in November and December, and there were no dominancy in terms of cell numbers in this period. Ignatiades (1969) stated that under poor growth conditions and advanced stages of succession when no species was particularly successful, the index tended to have higher values. In other words, in mild or favourable environments the number of species is large but none of them is abundant (Michael, 1990). In polluted areas, on the contrary, diversity is low, since very large amounts of resources may lower diversity. In this case only opportunistic species proliferate (Valiela, 1984). The mean Shannon-Wiener diversity in the present study was found as $2.96\pm0.45$ bits. Caroppo *et al.*, (1999) reported that the mean diversity index ($H'$) in the Adriatic Sea is $2.79\pm0.73$ and this value was expressed as characteristic for temperate coastal areas. In coastal waters, phytoplankton diversity range between 1 and 2.5 bits. On the other hand, diversity may be close to 5 bits in oceanic areas having low and uniform population density but high species number (Margalef, 1978).

As can be seen from the results, there may be important changes in phytoplankton biomass and abundance during one year period. Although the research area is under the influence of land based input, no clear response of phytoplankton was detected in terms of biomass, abundance and diversity due to these effects. Nutrient concentrations in this coastal area did not reach high concentrations. Relatively low nutrient concentrations, mainly low levels of phosphate and characteristic dynamic structure of the area prevent the formation of eutrophic conditions. Besides, the results of phytoplankton community structure and abundance support this suggestion. It can be said that, phytoplankton periodicity and community structure can not be explained with only location but by multiple effects of many environmental factors which control phytoplankton dynamics in the area.

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