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DAILY VARIATIONS OF COASTAL PHYTOPLANKTON ASSEMBLAGES IN SUMMER CONDITIONS OF THE NORTHEASTERN MEDITERRANEAN (BAY OF İSKENDERUN)

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Abstract

Daily variations of coastal marine phytoplankton populations were studied over a 31-day period in the northeastern Mediterranean, Bay of İskenderun. Sampling was conducted between 21 June and 22 July 2002. In addition to phytoplankton sampling, chlorophyll a and nutrient analysis, seawater temperature and salinity measurements were done. Surface water temperature fluctuated between 25.2-30°C. Salinities were generally low and ranged from 35.4 ‰ to 36.1 ‰. A total of 120 phytoplankton taxa were detected during the study. Diatoms were the dominant group in terms of numerical abundance while dinoflagellates were dominant in terms of species diversity. Phytoplankton abundance varied between 10.8×10^2 and 112.2×10^2 cells l^{-1}. Temperature was one of the most important factor influencing the variations of phytoplankton and a positive significant correlation was found between temperature and phytoplankton abundance. Phytoplankton abundance and physico-chemical data showed fluctuations in this selected period. For this reason, it can be said that daily sampling provide important information on coastal phytoplankton succession and on the effects of related environmental parameters.

Introduction

Phytoplankton production is affected by many environmental factors of the surrounding area. The dominant physico-chemical factors controlling phytoplankton production in marine water are solar radiation and nutrient availability (Harris, 1986; Kennish, 2001). The generation times of phytoplankton vary from a few hours to a few days. So, they can reflect the effect of environmental changes in a short time.

Coastal areas have high contribution to the productivity due to high phytoplankton production. Coastal environments differ in their physical and hydrographic properties such as depth, tidal stirring or nutrient loadings and these differences can lead to complex phytoplankton dynamics (Cabrias & Valiela, 1999). In these areas, phytoplankton periodicity is affected by the different sources of land-derived nutrients and by their dilution patterns (Zingone *et al*., 1995).

The Eastern Mediterranean Sea has oligotrophic characteristics mainly due to phosphorus deficiency, which is one of the essential elements for primary producers (Krom *et al*.,1991; Yılmaz *et al*., 1992). The oligotrophy increases from the west to the east of the Mediterranean Sea (Ignatiades *et al*., 2002) and primary production is on average 3 times lower in the eastern Mediterranean Sea (Turley, 1999). İskenderun Bay is located in the northeast of the Eastern Mediterranean Sea. The Bay, along with and its opening, covers relatively the largest continental shelf area in the Eastern Mediterranean Sea (excluding Nile Delta). The average depth is 70 m and the depth of %1 light transmission ranges between 40-70m (Yılmaz *et al*., 1992).

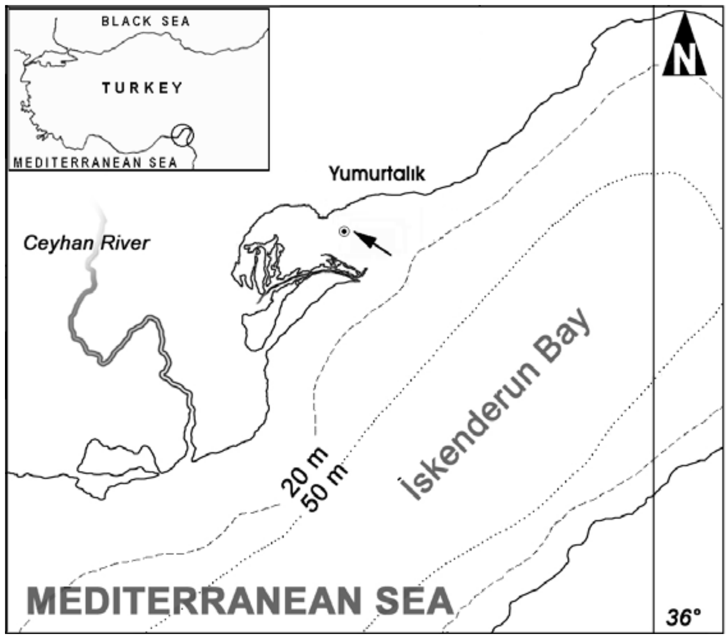

Fig. 1. Location of sampling area in İskenderun Bay, northeastern Mediterranean coast of Turkey.

The number and timing of peaks detected in the time series of phytoplankton biomass largely depend on the sampling frequency employed (Harris, 1984). However, previous studies on phytoplankton ecology in the Mediterranean coastal waters have been conducted at seasonal, monthly or weekly intervals (Lakkis & Lakkis, 1980; Koray, 1995; Polat *et al*., 2000; Eker & Kıdeyş, 2000; Polat & Piner, 2002). But, few studies have appeared on daily changes of phytoplankton (Abboud-AbiSaab, 1992). There are no studies conducted on a daily-interval basis in the Mediterranean coast of Turkey.

The aim of this study was to investigate the composition and the daily variations of phytoplankton abundance in the northeastern Mediterranean coast of Turkey. The environmental factors and the effects of environmental fluctuations on phytoplankton were also investigated.

Materials and Methods

Sampling was conducted at daily intervals at one station from 21 June to 22 July 2002. The station was selected in the Yumurtalık Bight which is located on the northwest side of İskenderun Bay (36° 45' N- 35°43' E) (Fig. 1). The depth of the station was 8-9 m. Samples were taken between 8.30-9.30 h every morning. Water samples for phytoplankton enumeration, chlorophyll a and nutrient analysis were collected at surface level. For phytoplankton enumerations, water samples were preserved in formaldehyde to a final concentration of 4%. Sedimentation was done for one week for each sample. After sedimentation, phytoplankton cells were enumerated by Sedgewick-Rafter counting cells from concentrated samples. For the enumeration and identification of phytoplankton, an Olympus Phase Contrast microscope was used. References referred to in the identification of phytoplankton were Tregouboff & Rose, 1957; Rampi & Bernhard, 1980; Delgado & Fortuno, 1991; Tomas, 1997).

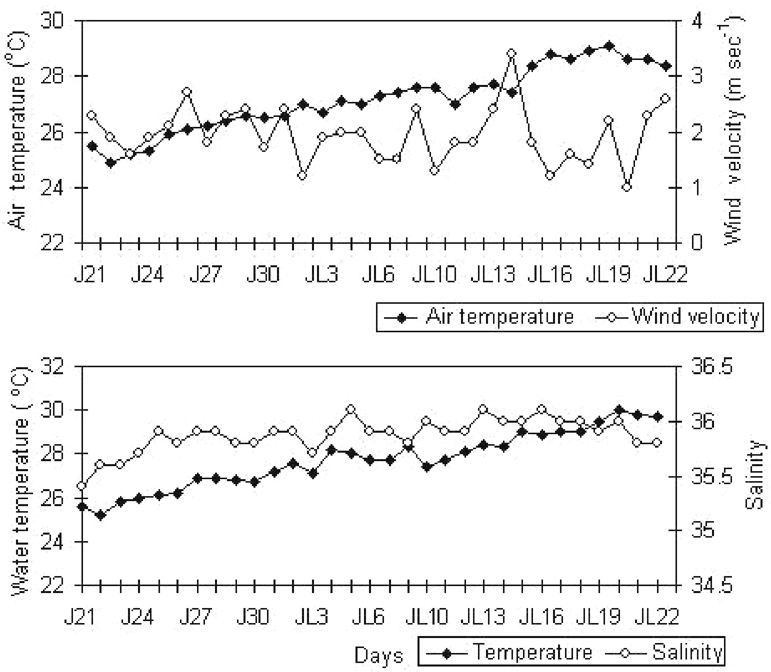

Fig. 2. Daily variations of meteorological and hydrographic factors between June 21 and July 22, 2002.

For chlorophyll a analyses, water samples (2 L) were filtered through glass fibre GF/F filters. The filters were stored at -20°C until the analysis. The filters were extracted in 90 % acetone for one night. Then, the samples were centrifuged and chlorophyll a readings were conducted spectrophotometrically according to the method presented by Parsons *et al*., (1984).

Inorganic nutrient concentrations of surface waters (phosphate, silicate, nitrate+ nitrite and ammonia) were determined spectrophotometrically using the methods presented by Strickland & Parsons (1972). Seawater salinity and temperature were measured by a YSI salinometer. Meteorological data (air temperature and wind velocity) belonging to the study area were provided by the Turkish State Meteorological Service.

Species diversity of phytoplankton was calculated using Shannon-Weaver (H') diversity index. The similarity matrix between days was estimated using Bray-Curtis similarity index after logaritmic transformation of phytoplankton count data. Cluster and nonmetric Multi Dimensional Scaling analyses were applied to transformed cell count data by using PRIMER software package (Clarke & Warwick, 1994). The results of these analyses are shown in diagrams.

Results

The mean daily air temperature and wind velocity ranged between 24.9- 29.1 °C and 1-3.5 m s^{-1}, respectively throughout the sampling period. Surface water temperature displayed summer conditions, characterized by a minimum of 25.2°C and a maximum of 30°C (Fig. 2). Temperature values gradually increased from the beginning to the end of the study. The surface water salinity was not notably high and ranged from 35.4 ‰ to 36.1‰. Relatively lower salinities were due to the closeness to the coast.

The nitrate+nitrite concentrations in the study period ranged from 0.29 to 1.68 µM. The highest value was recorded on July 5 (Fig. 3). Ammonia concentrations showed a 0.2-0.96 µM range. Phosphate ranged from 0.05-0.39 µM. Phosphate concentrations were lower than other nutrients. The highest values of phosphate and ammonia were recorded at the beginning of the study (June 22). Silica ranged from 1.2 µM to 4.1 µM. Silica values started to increase at the end of June and it showed clear fluctuations in July.

Surface chlorophyll a concentrations varied from 0.11 to 1.41 $\mu g l^{-1}$. Chlorophyll a concentrations between June 21 and July 1 showed generally low values. They started to increase from July 2 and reached their highest value on July 8 with a peak of 1.41 $\mu g\ l^{-1}$. It decreased in subsequent days and the lowest chlorophyll a values were obtained on July 20-21 at a rate of 0.11 $\mu g\ l^{-1}$(Fig. 4).

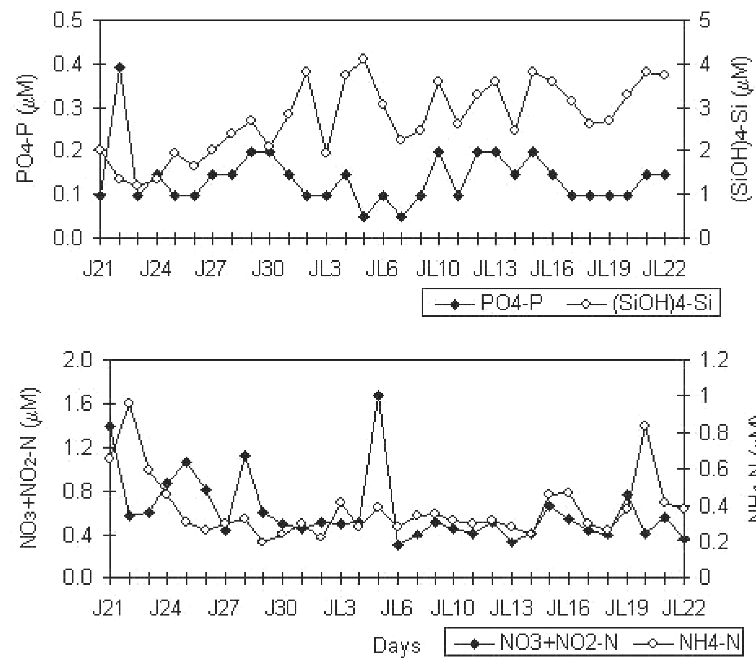

Fig. 3. Daily variations of surface water nutrient concentrations between June 21 and July 22, 2002.

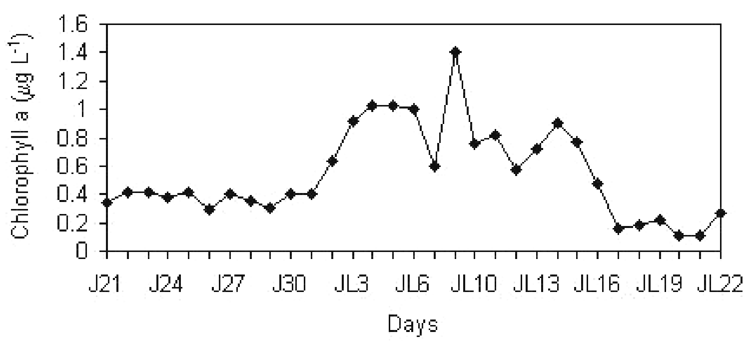

Fig. 4. Daily variations of chlorophyll a values between June 21 and July 22, 2002.

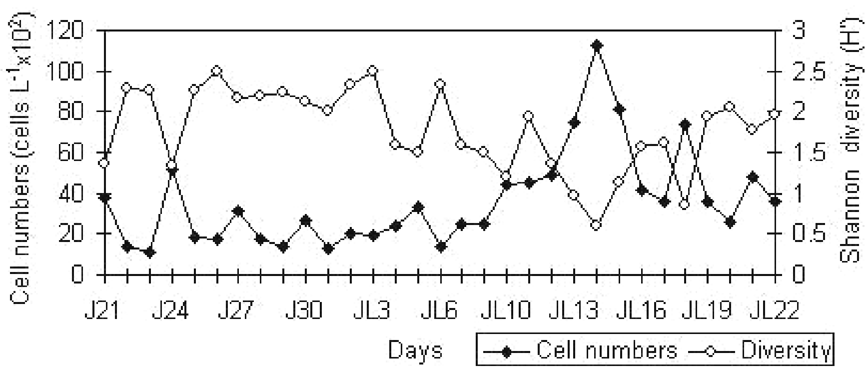

Fig. 5. Daily variations of phytoplankton cell numbers and diversity values between June 21 and July 22, 2002.

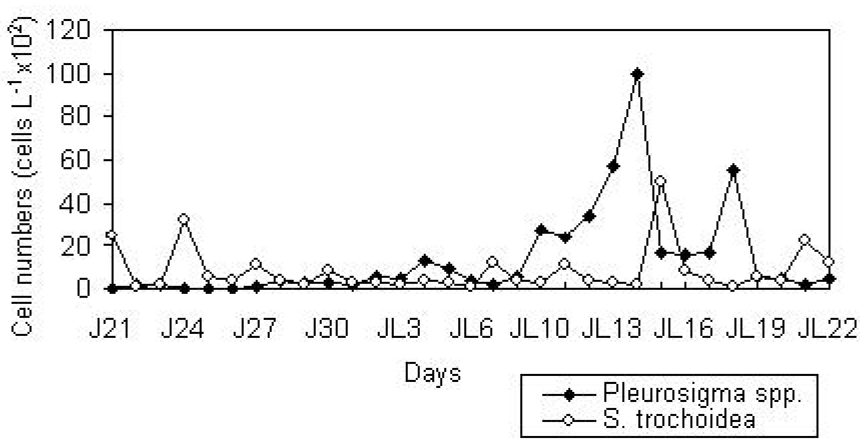

Fig. 6. Daily variations of the most important phytoplankton taxa.

Phytoplankton showed day to day variation in the study period. A total of 120 taxa were identified. These include 50 taxa belonging to Bacillariophyceae, and 68 taxa belonging to Dinophyceae. Cyanophyceae and Dictyochophyceae were represented by only one species each. Diatoms were dominant in terms of abundance whereas dinoflagellates were dominant in terms of species diversity. Phytoplankton cell numbers ranged from $10.8x10^2$ cells l^{-1} to $112.2x10^2$ cells l^{-1}. Phytoplankton abundance was low between June 25 and July 8 and it started to increase by July 10. The highest phytoplankton abundance was reached on July 14 with a peak of $112.2x10^2$ cells l^{-1}. Then, the number of cells decreased and found to be $41.4x10^2$ and $35.8x10^2$ cells l^{-1} on July 16 and July 17, recpectively (Fig. 5). Phytoplankton abundance displayed a second and small peak on July 18. The most important peak was caused by diatom species, *Pleurosigma* spp. The cell number of these species reached $99.6x10^2$ cells l^{-1} on July 14 (Fig. 6). Other diatom species such as *Thalassiothrix fraunfeldii, Guinardia flaccida* and *Hemiaulus hauckii* have minor importance in terms of abundance but they existed almost throughout the study period. Some diatom species were limited to the first half of the study, such as *Rhizosolenia alata* f. *gracillima, R. stolterfothi*. Dinoflagellates were much less abundant than diatoms. The most abundant dinoflagellate species was

Scrippsiella trochoidea. It reached 50.1x10^2 cells l^{-1} on July 15 (Fig. 6). The dominant dinoflagellates after *S. trochoidea* were *Protoperidinium steinii* and *Ceratium kofoidii*. Other well represented species were *Prorocentrum micans*, *Ceratium trichoceros, Ceratium extensum* during the study period.

The lowest and highest species diversity (H') was found to be 0.57 on July 14 and 2.49 on June 26, respectively (Fig. 5). It was the lowest when number of cells was the highest. Phytoplankton abundance was positively correlated with air temperature (r=0.412* $p<0.05$), water temperature (r =0.413* $p<0.05$) and salinity (r=0.389* $p<0.05$). But, the correlations of phytoplankton abundance with wind velocity and nutrients were not significant.

Daily phytoplankton samples from 31 days were compared through cluster analysis. This method served to indicate the groups that occur according to days. The results of hiercarchical clustering analysis are presented in Fig. 7a. At level of 60% similarity, mainly two major clusters formed. In other words two temporal periods were formed with respect to species composition and abundance of phytoplankton. The first cluster includes the days between June 23 and July 6 and the second cluster includes the days between July 13 and July 22. On the other hand, three days (June 22, July 19 and July 21) were not grouped and located as isolated days. It can be said that *Pleurosigma* spp., and *S. trochoidea* are the species which have the major effect on group formation due to their peak increase which occured after July 10. The results of multidimensional scaling analysis were plotted to obtain a better view of the phytoplankton daily variations (Fig. 7b). The stress value found in MDS was high. Nonetheless, the groups implied the pre increase period of phytoplankton as well as the peak increase time and subsequent days.

Discussion

The studies conducted at short intervals on phytoplankton ecology are very important for the successful explanation of phytoplankton dynamics and an investigation of the impact level of environmental factors on phytoplankton communities. In the present study which was performed at daily intervals, different stages were observed in terms of phytoplankton abundance during the sampling period (31 days). Phytoplankton are known to be under the effects of meteorological conditions in coastal zones (Azov,1986). However, water temperature is much more important than meteorological conditions when thermic stability exists because the increase in temperature favour the stability of surface water mass and this stability causes harmonic development of phytoplankton when there is not any nutrient limitations in the area (Abboud-AbiSaab, 1992). It can be said that temperature was one of the most effective factors in the present study since positive relationship were found between phytoplankton abundance and temperature.

Nitrate+nitrite, ammonium, phosphate and silicate concentrations were found to be 0.29-1.68μM, 0.2-0.96 μM, 0.05-0.39μM and 1.20-4.10 μM, respectively. There were no regular increases or decreases in nutrient concentrations towards the end of the sampling period. But, some small and repeating fluctuations occured. The correlations between phytoplankton abundance and nutrient concentrations were not found significant, probably due to these fluctuations. These findings showed that there is no nutrient limitation in this coastal area. It is generally accepted that nutrients are not limiting due to run off from land and lack of a permanent thermocline in coastal waters (Sze, 1998; Nybakken, 2001).

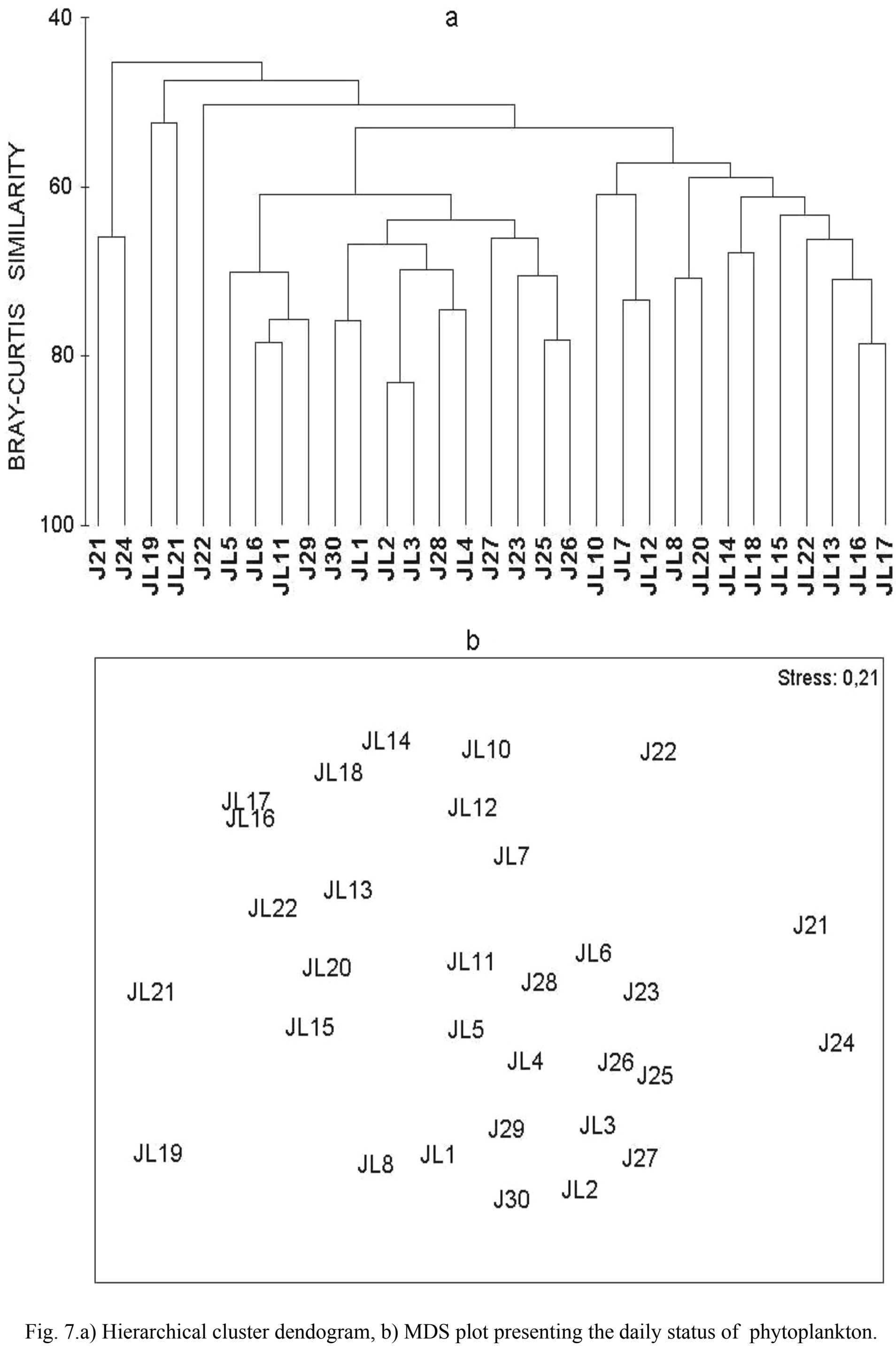

Fig. 7.a) Hierarchical cluster dendogram, b) MDS plot presenting the daily status of phytoplankton.

Results on chlorophyll a showed that the increase of chlorophyll a concentrations began before phytoplankton cell number increment (Fig. 4-5). Besides, the correlation was not significant between phytoplankton abundance and chlorophyll a ($p>0.05$). This may be explained with the contribution of benthic species to pelagic samples due to the shallowness of the area. On the other hand, small sized phytoplankton (picophytoplankton) which could not be evaluated in this study may also have been a source of high chlorophyll a when counted cell numbers were low. Because, in oligotrophic waters such as the eastern Mediterranean picophytoplankton community becomes dominant in summer months (Berman *et al*., 1986; Caroppo, 2000).

Dinoflagellates were dominant (with 68 taxa) in terms of diversity and diatoms were dominant (with 50 taxa) in numerical abundance. It is a known fact that bigger phytoplankton such as diatoms and dinoflagellates are the main groups in the food chain in nutrient rich waters (Caroppo, 2000). Diatoms in particular, are more abundant in nutrient rich coastal areas (Azov,1986; Zingone *et al*., 1995). The reason for this is that diatoms need high nutrient concentration and grow very fast in nutrient rich waters. These reasons account for the abundance of diatoms in this area. In contrast, dinoflagellates as a whole seem to be less favoured by the upwelling of nutrient rich water than diatoms (Taylor, 1987). On the other hand, dinoflagellates are more sensitive to fluctuations in salinity (Abboud-Abi Saab, 1992). For all these reasons, dinoflagellates could not reach high densities in the present study.

In the present study, phytoplankton abundance ranged between 10.8×10^2 and 112.2×10^2 cells l^{-1}. In the eastern Mediterranean, Lakkis & Lakkis (1980), Ignatiades *et.al*., (1995) and Polat & Piner (2002) recorded the summer phytoplankton abundace in the range of $69\text{-}130 \times 10^3$ cells l^{-1}, $1.8\text{-}63 \times 10^3$ cells l^{-1} and $3.36\text{-}37.4 \times 10^2$ cells l^{-1}, respectively. As can be seen, phytoplankton abundance was lower than that of Lakkis & Lakkis (1980), Ignatiades *et al*., (1995) but higher than that of Polat & Piner (2002). These low abundance values show not only the oligotrophic characteristic of the eastern Mediterranean but also the limiting effects caused by the summer conditions.

The daily changes of phytoplankton abundance were more clearly observed through Cluster and non metric Multi Dimensional Scaling Analysis. The groups reflected the temporal variations of phytoplankton. The increase in abundance of the species (especially *Pleurosigma* spp., and *Scrippsiella trochoidea*) after July 10 affected the formation of the day groups. In spite of a high stress value found in MDS, there is a gradient of the days from preincrease period towards the peak increase time (from right to left).

Finally, it can be said that clear daily fluctuations can occur in hydrologic and meterorological conditions of coastal environments. All these properties can lead complex phytoplankton dynamics. For this reason, short interval studies (such as daily) performed in different seasons are needed to determine the details of phytoplankton dynamics and the response of phytoplankton communities against environmental variables in coastal areas.

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