

CROSS-SHELF PHYTOPLANKTON DYNAMICS IN THE NORTHEASTERN LEVANTINE BASIN

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ABSTRACT: A time series sampling program at monthly intervals was carried out at three stations across the shelf in the northeastern Levantine basin to collect phytoplankton samples and associated physical (temperature, salinity, secchi disc depth) variables over a year. Quality and quantity of phytoplankton varied significantly across the shelf in time. Total 71 diatom, 40 dinoflagellate, 4 silicoflagellate and 17 coccolithophore species have been identified from the study area. Diatoms' contribution to total phytoplankton abundance was maximal during autumn and spring in the nearshore and only during spring in the mid shelf. Coccolithophores formed the dominant group almost throughout the year except May and June in the offshore. Dinoflagellates formed the least abundant group in the shelf over the year. Phytoplankton species have been found the most abundant and diverse during spring when the river runoff to the basin was maximal. In general, a decreasing trend in phytoplankton abundance towards offshore was prominent. Phytoplankton has been found most abundant in the entire shelf during spring and early summer reaching a peak level of 2.7×10^6 cells/l during May in the shallowest station. A huge difference in quantity was observed in phytoplankton contents of the nearshore and offshore waters during summer. Multivariate analyses have shown formation of distinct seasonal phytoplankton assemblages throughout the year. Based on Spearman's rank correlation analysis, a highly significant negative correlation ($n=35$, $r_s = -.587$, $P < 0.01$) was observed between phytoplankton abundance and surface salinity. Superimposed surface temperatures seemed to better illustrate seasonal clusters relative to surface salinity plots.

KEYWORDS: Phytoplankton; abundance; diversity; distribution; Levantine basin

INTRODUCTION

The coastal and the cyclonic areas of the northeastern Levantine basin differ from the open waters in their biology, chemistry and physics since cyclonic areas receive relatively high nutrients from the deep water compared to the open waters and the coastal waters are completely different ecosystems. The shelf ecosystem of the north-eastern Levantine basin has been subject to dramatic changes due to increasing anthropogenic loads during the last few decades. Dramatic increase in human population, intense marine traffic, pollutants of industrial and domestic origin in addition to agricultural and atmospheric loads makes the ecosystem of the region extremely vulnerable to the imposed environmental burdens. The most predominant anthropogenic impact is the severe eutrophication experienced in coastal sectors of Iskenderun and Mersin Bays fueled both by perennial river inputs and municipal outlets. Eutrophication is considered

to play a key role in the ecosystem by leading to substantial alterations in the structure and function of marine flora and fauna both qualitatively and quantitatively, which is the first target of the increased nutrient loads. Recent studies have indicated increasing basinwide expansion of the eutrophication phenomenon (Uysal *et al.*, 2008, 2014; Tuğrul *et al.*, 2011). A sharp contrast exists between the coastal area supplied by land-based nutrient sources and the nutrient limited open sea (Yılmaz & Tuğrul, 1998). In this environment, coastal / open sea interactions determine the changes in the coastal ecosystem, including eutrophication processes. Intrusion of vast amount of nutrients via waste discharges from domestic, industrial and agricultural sources lead for monospecific phytoplankton blooms in coastal areas and inner Mersin bay (Uysal *et al.*, 2003a).

Phytoplankton studies undertaken earlier in the area are few and have targeted only certain specific sub-areas (inner bays, coastal areas, harbours, etc.) of the Cilician basin (Kideyş *et al.*, 1989; Eker & Kideyş, 2000; Polat & Sarıhan, 2000; Polat *et al.*, 2000; Polat & Işık, 2002; Eker-Develi *et al.*, 2003; Yılmaz *et al.*, 2003; Uysal *et al.*, 2004). Majority of these studies have covered large sized cells composed mainly of diatoms, dinoflagellates and a few of smaller sizes like coccolithophores. Time series (weekly data off IMS-METU at three stations within the shelf) data is available only for the period April 1997 to November 1998 (Uysal *et al.*, 2003b). Observations are not regular and gaps do exist for this basin. Basinwide (mostly seasonal) as well as multibasin phytoplankton distributions are also available although they are very few (Uysal *et al.*, 2008, 2014).

Since this basin is well known of its highly oligotrophic open waters and highly eutrophic shallower shelf waters, it is critically important to know changes in time and space of its microscopic flora across the shelf. Major aim of this study is to provide preliminary information about changes in qualitative and quantitative properties of phytoplankton with respect to changing surface water temperature and salinity in the shelf.

MATERIALS AND METHOD

Phytoplankton sampling in connection with the project “*Picoplankton (heterotrophic bacteria and cyanobacteria) content and dynamics of the Levantine Basin shelf waters*” supported by the Turkish Scientific and Technical Research Council (TUBITAK-YDABAG Project no. 102Y037) was carried out in Mersin bay (northeastern Levantine basin), during the period September 2002 - August 2003 on board R/V *Erdemli* of the Institute of Marine Sciences, Middle East Technical University (IMS-METU). Monthly cruises were held at three stations (namely nearshore, middle and offshore stations with total depths of 20, 110 and 210 m, respectively) across the continental shelf to collect data on a number of biological, physical oceanographic variables (Fig. 1). Temperature, salinity and depth were measured using a Sea-Bird model CTD probe. Closing bottles were used to sample sea water and phytoplankton. Phytoplankton samples being collected into dark coloured glass bottles of 1 liter volume were then preserved with 4% buffered formalin (final concentration) on board. Phytoplankton were kept in Hydro-Bios made settling chambers of 25 ml volume for cell enumeration and identification. Qualitative and quantitative analyses of phytoplankton were performed under inverted microscope

(Utermohl, 1958) and later pooled data was utilized for the analysis of multispecies data via multivariate techniques, Multi-Dimensional Scaling (MDS). Each phytoplankton cell count involved as far as possible at least 400 cells (Venrick, 1978).

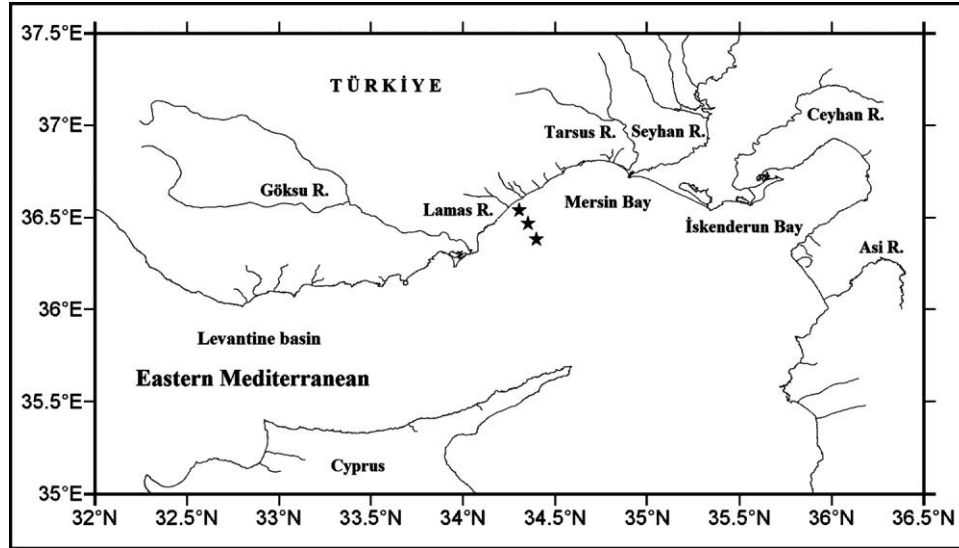


Fig. 1. Location of the sampling stations in the north-eastern Levantine basin.

Phytoplankton samples consisted mainly of diatoms, dinoflagellates, coccolithophores and silicoflagellates. To calculate similarities between samples Bray-Curtis Coefficient was used. Similarity matrix was formed between every pair of samples in a lower triangular array for clustering and ordination. For a graphic representation of relations among sites, dendrogram showing clustered groups at an arbitrary cut-off level was constructed. Among the various hierarchical sorting strategies the group-average sorting was preferred to produce a dendrogram from the similarity matrix. This joins 2 groups of samples together at the average level of similarity between all members of one group and all members of the other. In order to visualize relationships between samples, ordination was done by delineating dendrogram classes on the corresponding ordination via Multi-Dimensional Scaling (MDS).

To find out discriminating species responsible for groupings among the community, contribution to average dissimilarity ($\bar{\delta}$) or similarity (\bar{S}) from i 'th species was calculated. Higher $\bar{\delta}_i$ and high ratio of $\bar{\delta}_i/SD(\bar{\delta}_i)$ pointed out the discriminating species. Further, contribution of the i 'th species (\bar{S}_i) to the average similarity within a group (\bar{S}) was computed similarly (FAO/IOC/UNEP, 1992). This indicates that species concerned is consistently prominent in that group. Community diversity indices mainly included Shannon-Wiener Index (H') for species richness and the Pielou's Evenness Index (J') for proportional representation (Equitability). For the analysis of multispecies data and the associated environmental variables both STATGRAPHICS (Univariate Statistics Package) and PRIMER (Multivariate Analyses Package-Plymouth Routines in

Multivariate Ecological Research), a number of PC programs written at the Plymouth Marine Laboratory, UK were used.

RESULTS AND DISCUSSION

Changes in surface temperature and salinity over the year: Changes in surface temperature and salinity at all three stations with time throughout the sampling period are given in figures 2A, B. Over the year, temperature varied in the range 15.5 - 29.9 °C and

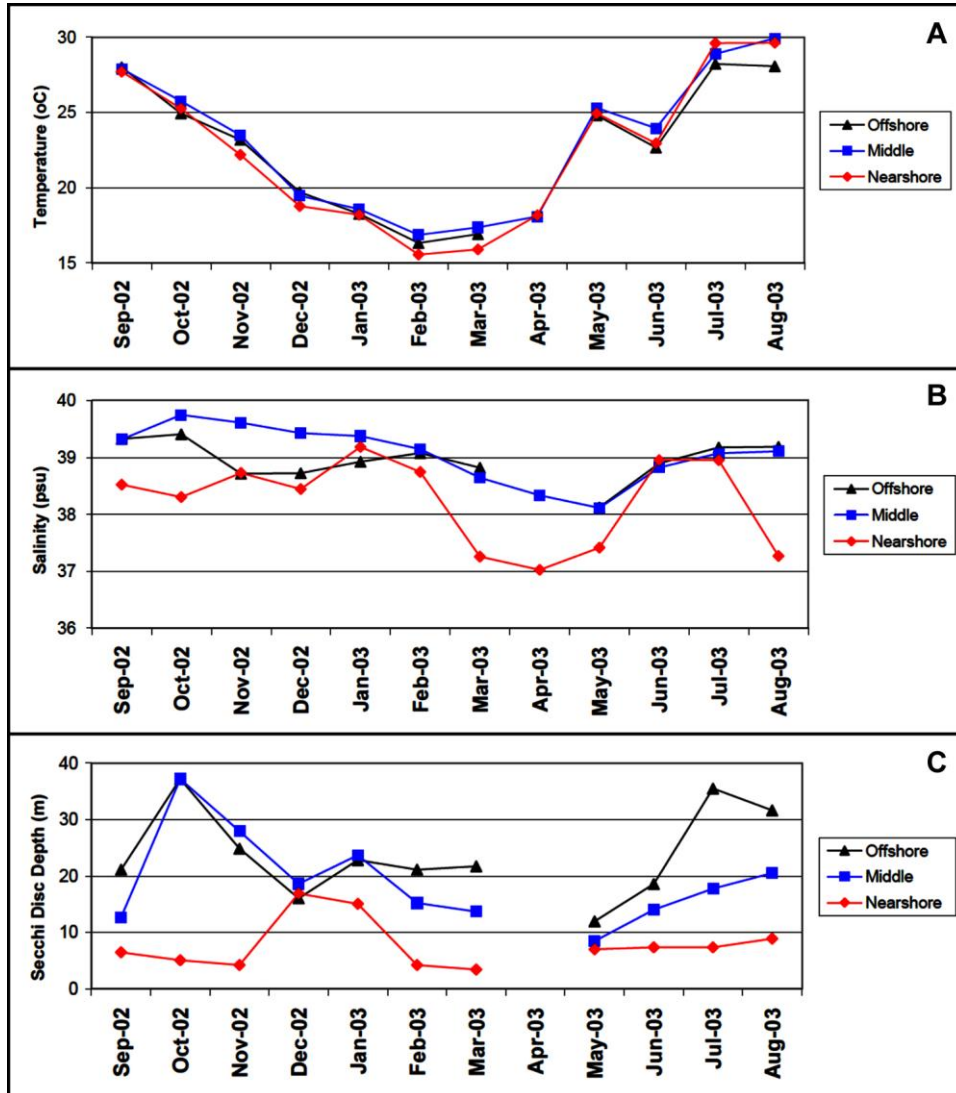


Fig. 2. Monthly changes in surface temperature: A, salinity; B & C, secchi disc depth in the shelf.

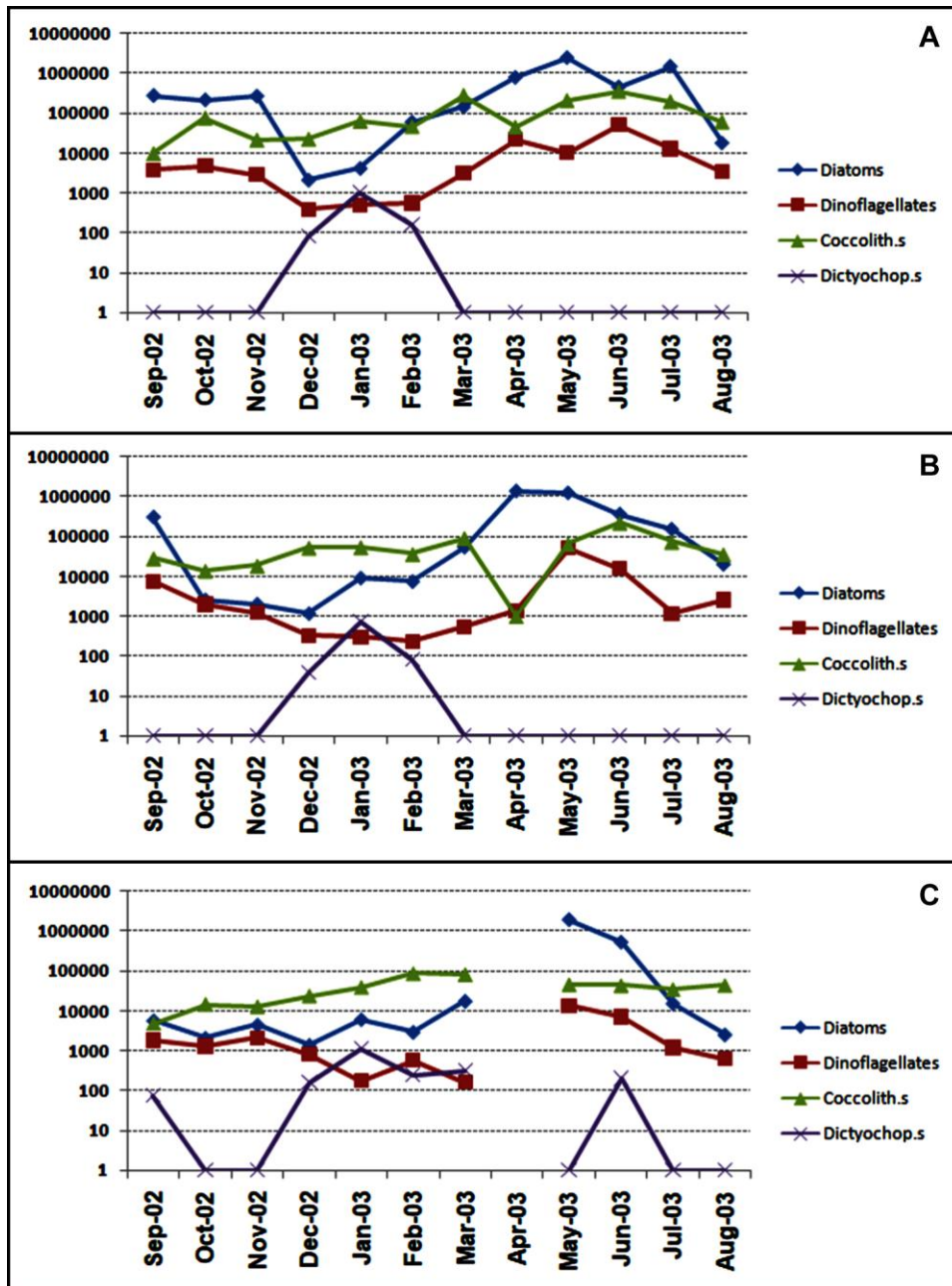


Fig. 3. Monthly changes in abundance of different taxons at nearshore: A, midshelf; B & C, offshore over a year period.

salinity in the range 37 - 39.7. Shelf surface water was coldest during February & March and warmest in August. With the onset of spring, a gradual warming of the surface waters was observed. With increasing irradiance, the surface waters continued to warm up from March to August. Perennial rivers (Asi, Ceyhan, Seyhan, Goksu) as well as the small Lamas creek nearby draining to the basin and the sampling site appeared to play a major role in the heat as well as the salinity budget of the surface waters of the shelf.

Changes in Secchi Disk Depth (SDD) over the year: The annual average SDD for the nearshore, middle and offshore stations were 7.8, 19.1 and 23.9 m, respectively. The minimum and maximum readings varied between 3.4-16.9, 8.5-37.2 and 12-37.2 m for the nearshore, middle and offshore stations, respectively (Fig. 2C). Low SDD in winter & spring followed high SDD in summer & autumn. Low SDD values observed during spring coincided with high phytoplankton abundance levels obtained in the meantime.

Changes in phytoplankton species composition and abundance over the year: Total number of 71 diatom, 40 dinoflagellate, 17 coccolithophore and 4 silicoflagellate species were identified throughout the study period. Phytoplankton species encountered from the shelf are listed in table 1. Diatoms' contribution to total phytoplankton abundance was maximal during autumn and spring in the nearshore and only during spring in the middle station (Fig. 3). Dinoflagellates formed the least abundant group throughout the year in the shelf. Other groups in which majority are composed of the coccolithophorid *Emiliana huxleyi* was only dominant during winter in the nearshore and during autumn & winter in the middle station. Coccolithophores formed the dominant group almost throughout the year except May and June in the offshore station.

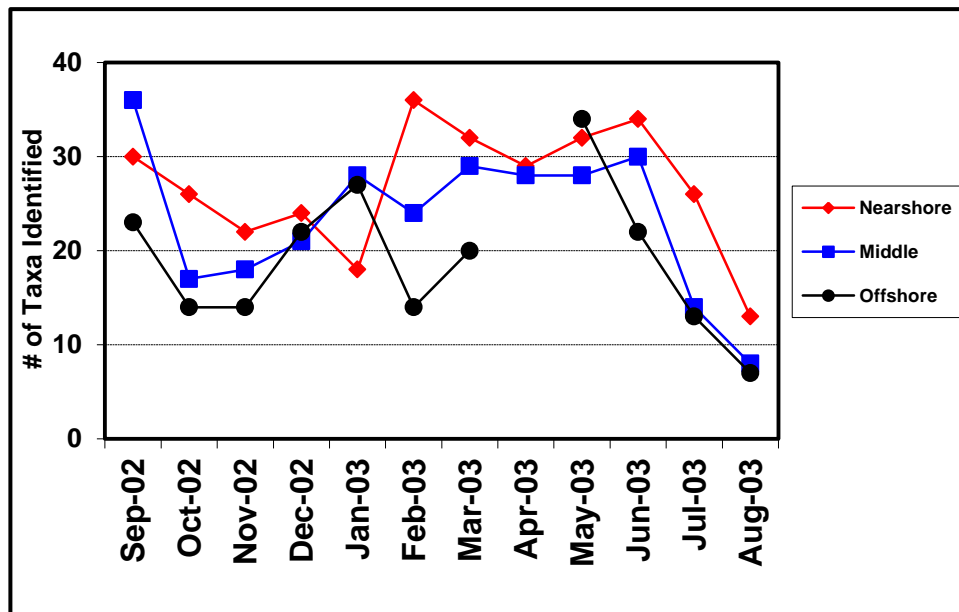


Fig. 4. Changes in total number of phytoplankton species identified in different sectors of the shelf.

Table 1. List of phytoplankton species encountered in the shelf.

<i>Bacillariophyceae</i>	<i>Pseudo-nitzschia delicatissima</i> (Cleve) Heiden	<i>Gyrodinium</i> sp.
<i>Achnanthes</i> sp.	<i>Nitzschia longissima</i> (Brebisson) Ralfs	<i>Heterocapsa niei</i> (Loeblich) Morrill & Loeblich III
<i>Asterionella japonica</i> Cleve & Möller	<i>Nitzschia</i> sp.	<i>Heterocapsa pygmaea</i> Loeblich III, Schmidt & Sherley
<i>Asteromphalus</i> sp.	<i>Nitzschia tenuirostris</i> Mer.	<i>Heterocapsa</i> sp.
<i>Bacillaria</i> sp.	Pennate diatom (unidentified)	<i>Kofooidinium velleoides</i> Pavillard
<i>Bacteriastrum delicatulum</i> Cleve	<i>Pleurosigma angulatum</i> (Quekett) W. Smith	<i>Oxytoxum areolatum</i> Rampi
<i>Bacteriastrum elegans</i> Pavillard	<i>Pleurosigma directum</i> Grunow	<i>Oxytoxum caudatum</i> Schiller
<i>Cerataulina pelagica</i> (Cleve) Hendey	<i>Pleurosigma normanii</i> Ralfs	<i>Oxytoxum gladiolus</i> Stein
<i>Chaetoceros affinis</i> Lauder	<i>Pleurosigma</i> sp.	<i>Oxytoxum ligusticum</i> Rampi
<i>Chaetoceros anastomosans</i> Grunow in Van Heurck	<i>Pyrophacus</i> sp.	<i>Oxytoxum longiceps</i> Schiller
<i>Chaetoceros brevis</i> Schütt	<i>Proboscia alata</i> f. <i>alata</i> (Brightwell) Sundström	<i>Oxytoxum longum</i> Schiller
<i>Chaetoceros curvisetus</i> Cleve	<i>Proboscia alata</i> f. <i>gracillima</i> (Brightwell) Sundström	<i>Oxytoxum scolopax</i> Stein
<i>Chaetoceros danicus</i> Cleve	<i>Pseudosolenia calcar-avis</i> (Schultze) Sundström	<i>Oxytoxum</i> sp.
<i>Chaetoceros decipiens</i> Cleve	<i>Rhizosolenia castracanei</i> H. Peragallo	<i>Oxytoxum variabilis</i> Schiller
<i>Chaetoceros densus</i> (Cleve) Cleve	<i>Rhizosolenia delicatula</i> Cleve	<i>Oxytoxum viride</i> Schiller
<i>Chaetoceros didymus</i> Ehrenberg	<i>Rhizosolenia imbricata</i> var. <i>shrubslei</i> (Cleve) Schröder	<i>Protoperidinium diabolus</i> (Cleve) Balech
<i>Chaetoceros didymus</i> var. <i>protuberans</i> (Lauder) Gran & Yendo	<i>Rhizosolenia pungens</i> Cleve - Euler	<i>Protoperidinium longipes</i> Balech
<i>Chaetoceros diversus</i> Cleve	<i>Rhizosolenia setigera</i> Brightwell	<i>Protoperidinium ovum</i> (Schiller) Balech
<i>Chaetoceros lauderi</i> Ralfs	<i>Rhizosolenia stouterfothii</i> H. Peragallo	<i>Protoperidinium pyriforme</i> (Paulsen) Balech

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<i>Chaetoceros lorenzianus</i> Grunow	<i>Rhizosolenia styliformis</i> Brightwell	<i>Protoperidinium steinii</i> (Jørgensen) Balech
<i>Chaetoceros lorenzianus</i> var. <i>forceps</i> Meunier	<i>Skeletonema costatum</i> (Greville) Cleve	<i>Scrippsiella trochoidea</i> (Stein) Loeblich III
<i>Chaetoceros neglectus</i> Karsten	Small diatom (Unidentified)	<i>Prorocentrum compressum</i> (Bailey) Abe
<i>Chaetoceros peruvianus</i> Brightwell	<i>Surirella</i> sp.	<i>Prorocentrum micans</i> Ehrenberg
<i>Chaetoceros rostratus</i> Lauder	<i>Synedra ulna</i> (Nitzsch) Ehrenberg	<u>Dictyochophyceae</u>
<i>Chaetoceros</i> sp.	<i>Thalassionema nitzschioides</i> (Grunow) Mereschkowsky	<i>Dictyocha</i> sp.
<i>Coscinodiscus</i> sp.	<i>Thalassiothrix mediterranea</i> Pavillard	<i>Dictyocha fibula</i> Ehrenberg
<i>Cosmarium</i> sp.	<i>Dinophyceae</i>	<i>Dictyocha fibula</i> var. <i>longispina</i> Ehrenberg
<i>Cymbella affinis</i> Kützing	<i>Cachonina niei</i> Loeblich	<i>Distephanus speculum</i> Ehrenberg
<i>Cymbella</i> sp.	<i>Ceratium candelabrum</i> f. <i>depressum</i> (Pouchet) Schiller	<u>Coccolithophyceae</u>
<i>Dactyliosolen antarcticus</i> Castracane	<i>Ceratium extensum</i> (Gourret) Cleve	<i>Anoplosolenia brasiliensis</i> (Lohmann) Deflandre
<i>Dactyliosolen fragilissimus</i> (Bergon) Hasle	<i>Ceratium furca</i> (Ehrenberg) Claperede & Lachmann	<i>Calcioconus vitreus</i> Schiller
<i>Detonula confervacea</i> (Cleve) Gran	<i>Ceratium fusus</i> (Ehrenberg) Dujard	<i>Calcioappus caudatus</i> Gaarder & Ramsfjell
<i>Diploneis</i> sp.	<i>Ceratium fusus</i> var. <i>fuscus</i> (Ehrenberg) Dujardin	<i>Calciosolenia murrayi</i> Gran
<i>Fragilaria</i> sp.	<i>Ceratium fusus</i> var. <i>seta</i> (Ehrenberg) Sournia	<i>Coronosphaera binodata</i> (Kamptner) Gaarder
<i>Guinardia blavyana</i> H. Peragallo	<i>Ceratium horridum</i> (Cleve) Gran	<i>Emiliana huxleyi</i> (Lohmann) Hay & Mohler III
<i>Guinardia flaccida</i> (Castracane) H. Peragallo	<i>Ceratium kofoidii</i> Jørgensen	<i>Helladosphaera richardii</i> Bernard
<i>Guinardia</i> sp.	<i>Ceratium teres</i> Kofoid	<i>Michaelsarsia elegans</i> Gran
<i>Gyrosigma</i> sp.	<i>Ceratium trichoceros</i> (Ehrenberg) Kofoid	<i>Ophiaster hydroideus</i> (Lohmann) Lohmann

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<i>Hemiaulus hauckii</i> Grunow	<i>Ceratium tripos</i> (O. F. Müller) Nitzsch	<i>Rhabdosphaera claviger</i> Murray & Blackman
<i>Hemiaulus sinensis</i> Greville	<i>Ceratium tripos</i> var. <i>atlanticum</i> (Ostenfeld) Paulsen	<i>Rhabdosphaera longistylis</i> Schiller
<i>Leptocylindrus danicus</i> Cleve	<i>Dinophysis parva</i> Schiller	<i>Rhabdosphaera</i> sp.
<i>Leptocylindrus mediterraneus</i> (H. Peragallo) Hasle	<i>Dinophysis rotundata</i> Claperede & Lachmann	<i>Rhabdosphaera stylifer</i> Lohmann
<i>Leptocylindrus minimus</i> Gran	<i>Exuviaella compressa</i> (Bailey) Ostenfeld	<i>Rhabdosphaera tignifer</i> Schiller
<i>Licmophora ehrenbergii</i> (Kützing) Grunow	<i>Gonyaulax</i> sp.	<i>Scyphosphaera apsteinii</i> Lohmann
<i>Navicula</i> sp.	<i>Gymnodinium</i> sp.	<i>Syracosphaera pulchra</i> Lohmann
<i>Nitzschia closterium</i> (Ehrenberg) W. Smith	<i>Gyrodinium fusiforme</i> Kofoid & Swezy	<i>Syracosphaera</i> sp.

Species diversity displayed an apparent decrease from nearshore to offshore (Fig. 4). Species diversity has been found high during the spring blooming period and in June and September. To a maximum of 36 species have been recorded during February at nearshore and in September at middle station, respectively. Community has been found most abundant and species diverse during May at all three stations, consecutively. Only in May the number of species observed in offshore station (total 34 species) has exceeded the middle (total 28 species) and the nearshore (total 32 species) stations. Total species observed at mid station has only exceeded the others only in September and January. Flora has been found less diverse at nearshore station compared to offshore ones only in January. Shelf flora has been represented with least number of species during August. Overall, the annual mean number of species present at nearshore (27) has exceed those observed at middle and offshore stations (23 and 19) respectively.

In general species of phytoplankton have been found more abundant and diverse during spring & early summer in the shelf (Fig. 5). Cell abundances varied in the range 2.5×10^4 cells/l in December and 2.75×10^6 cells/l in May at the nearshore station. Cell counts varied in the range 1.8×10^4 , 1.4×10^6 and 1.2×10^4 , 2.0×10^6 cells/l at the middle and offshore stations respectively. Annual mean cell counts were calculated as 6.5×10^5 , 3.6×10^5 and 2.7×10^5 cells/l for the nearshore, middle and offshore stations, respectively. Offshore phytoplankton abundances are mimiced much more by the middle station than the nearshore flora, both displaying an apparent increasing trend from autumn (excluding September) to spring. Nearshore flora has displayed higher population abundances during autumn compared to offshore ones. Phytoplankton abundances seemed to be distributed equally across the shelf during winter. The ratio between the minimal and maximal cell counts retained at nearshore and offshore stations was maximum (34) during July and relatively very high throughout autumn. Phytoplankton

content of the offshore station differed greatly only during September & July from that of the mid station.

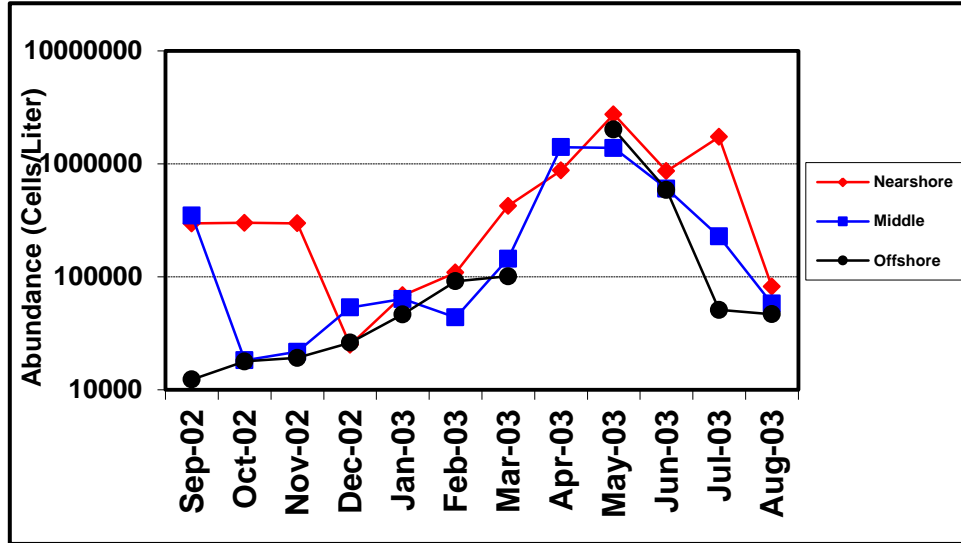


Fig. 5. Monthly changes in abundance (total cells/l) of phytoplankton in different sectors of the shelf.

Shannon Index H' decreased inshore to offshore with annual average values of 1.4, 1.3 and 1 for the nearshore, middle and offshore stations, respectively (Fig. 6). H' was found highest in September with a good apportionment among species and lowest in December in the shelf. Both H' & J values tend to decrease from September to December in the shelf. Based on annual mean values J was almost equal at both nearshore and middle stations (0.4) and slightly lower at offshore (0.35).

MDS (Multi-Dimensional Scaling) plots of gridded stations (Fig. 8) have distinguished 4 main clusters at an arbitrary similarity level of 35% (Fig. 7). Group I was represented mainly by the August shelf flora where group II displayed a much wider time span. Group III comprised almost mainly of the autumnal flora and lastly the Group IV of the winter flora. Shelf flora was most identical only in May and affinity among stations has been found greater during April, May and June. Conversely, similarity among the stations has been found least during August. Similarly the offshore flora separated clearly from the nearshore and mid-shelf flora during July. Superimposed surface temperatures (Fig. 9A) visually brought a better insight to groupings compared to surface salinity plots (Fig. 9B).

Among the major species that contributed much to average similarities during August (group I) were *E. huxleyi*, *L. minimus*, *C. brevis*, *Heterocapsa* sp. and *Navicula* sp., (table 2). However, in the largest group II, except the coccolithophorid *E. Huxleyi*, the diatom species *Pseudo-nitzschia delicatissima*, *Chaetoceros* sp., *Proboscia alata gracillima* and *L. minimus* were consistently prominent. *E. huxleyi* was the major

contributing species to average similarities in all groups. Species displaying a major role in discriminating the groups are listed in table 3. Diatom species of *Leptocylindrus minimus*, *Chaetoceros brevis*, *Heterocapsa* sp., dominating the first group and *Leptocylindrus danicus*, *Oxytoxum variabilis* dominating the group III were caused for such discrepancy between the late summer and autumn flora.

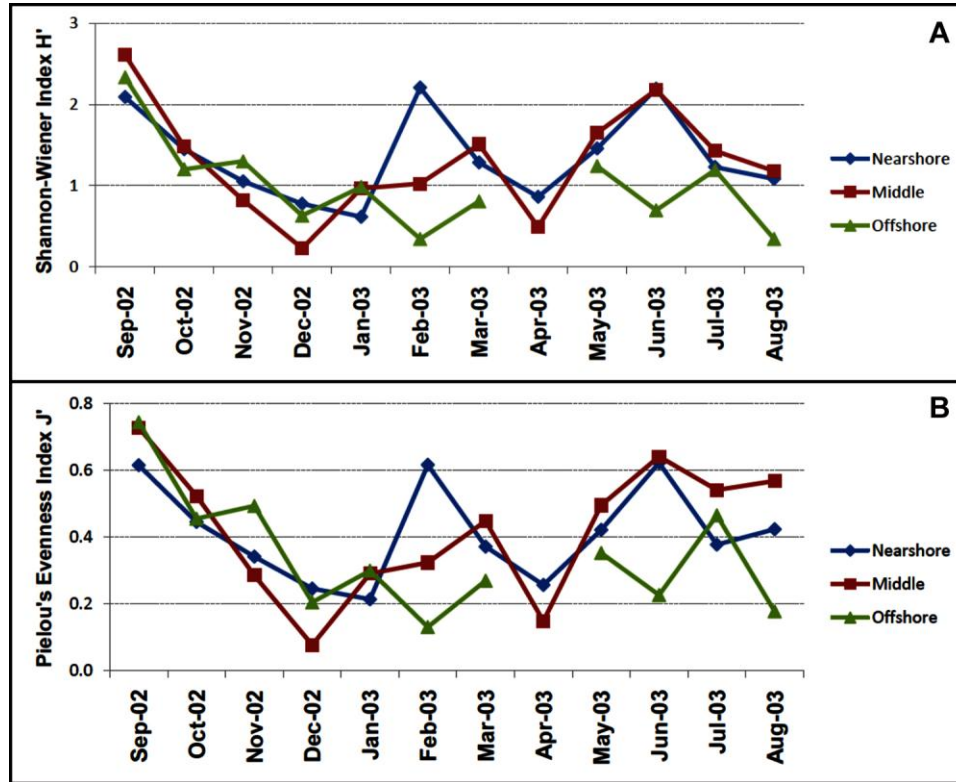


Fig. 6. Monthly changes in Shannon-Wiener: A & B, Pielou's Evenness measures within the shelf.

Discussion: The magnitude of change in surface temperature (15.5 – 29.9 °C) was much greater compared to change in surface salinity (37 - 39.7) over the year in the shelf. Surface shelf water was coldest during February & March and warmest during July & August. Middle station was relatively warmer and more saline compared to nearshore & offshore stations almost throughout the year. Surface salinity of the nearshore station differed greatly from the middle & offshore ones during spring due to increasing runoff from the local perennial rivers. Runoff is maximal during spring due to increasing melting of the snow in the Taurus mountain range in the meantime. The rivers Göksu, Tarsus, Seyhan, Ceyhan, Asi and some smaller rivers (Lamas river nearby) constitute a large proportion of all available fresh water inputs into the entire oligotrophic eastern Mediterranean, concentrated in relatively small area of the Cilician Basin. In the Levantine Basin of the eastern Mediterranean, the Cilician basin' rivers and the Nile are

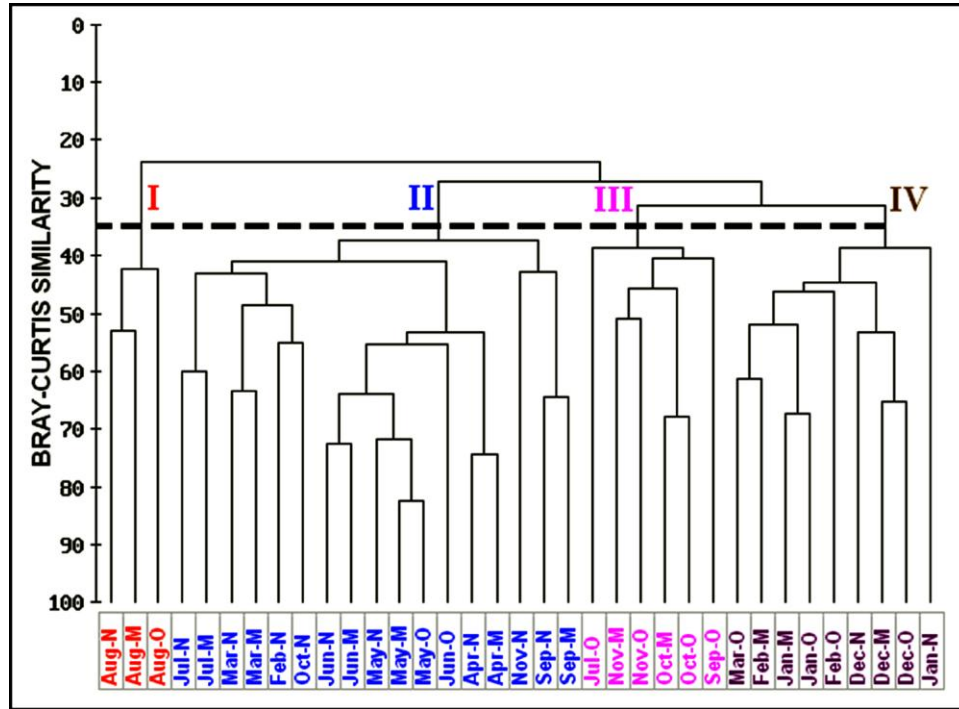


Fig.7. Dendrogram showing classification of total 35 samples with four major groups distinguished at an arbitrary similarity level of 35% (N, M, O stands for Nearshore, Middle and Offshore).

such exceptions providing fresh water to the region. Perennial rivers Göksu, Lamas, Tarsus, Seyhan, Ceyhan and Asi plus some smaller rivers draining an area of 80,000 km² connected to the Cilician basin account for a total fresh water flux of 27 km³/yr (870 m³/s), accounting for about half the river discharge along the Turkish Mediterranean - Aegean coasts, but much greater than the present discharge of the Nile in the eastern Mediterranean (Pinaridi *et al.*, 2006) (estimated to be 540 m³/s). In the nutrient poor eastern Mediterranean, these river inputs are extremely significant regional sources. Especially following the almost 90% reduction in the discharge of the river Nile in the 1960's, Turkish rivers concentrated in the Cilician basin presently seem to be the main fresh water and nutrient sources for the entire Levantine Basin of the oligotrophic eastern Mediterranean. Because of the significant inputs of these rivers, the Cilician Basin has all the characteristics of the ROFI (Regions of Freshwater Influence) but in the oligotrophic environment typical of the eastern Mediterranean. Increase in freshwater input during winter (via precipitation) and spring (via river inputs) have boosted phytoplankton growth in the shelf mainly during spring leading to low secchi depth readings in the meantime. Moreover, SDD readings were fluctuated significantly among the stations almost throughout the year. SDD reading were lowest in the nearshore station and the difference was greatest among stations only in summer. SDD readings were more stable

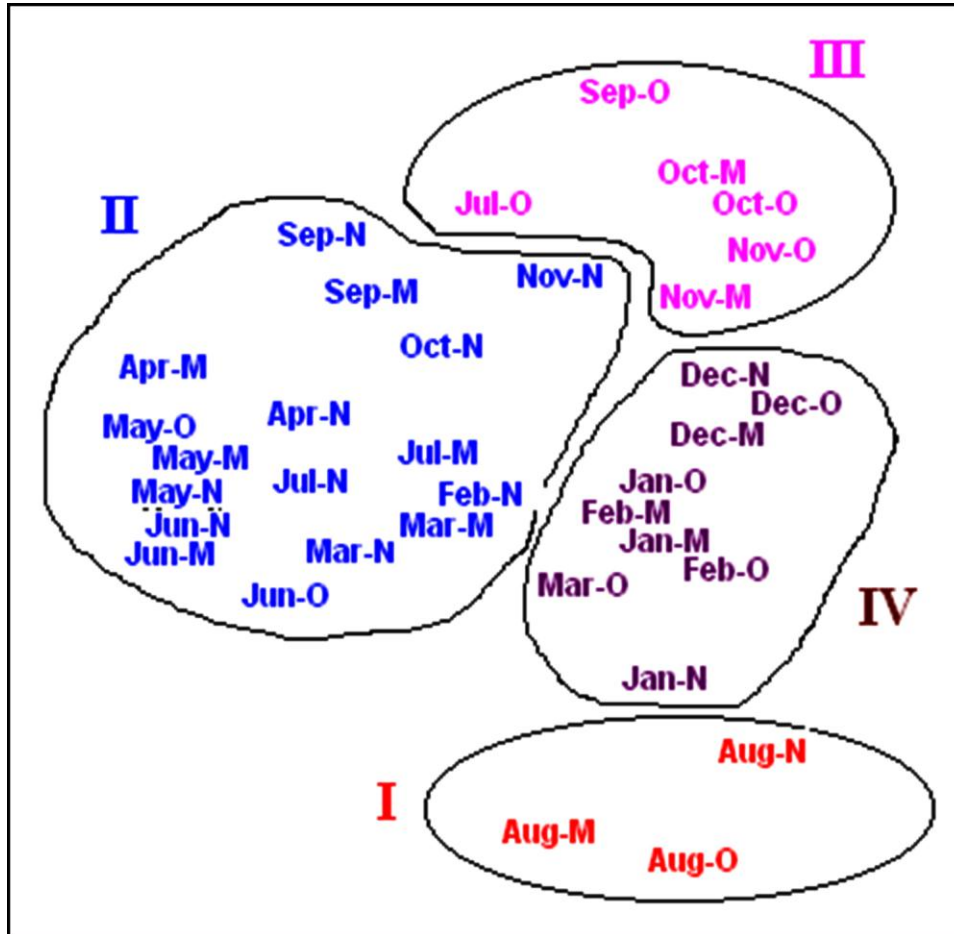


Fig. 8. Two-dimensional non-metric MDS (Multi-Dimensional Scaling) ordination of total 35 samples.

in the middle & offshore stations from October to January due to winter convective mixing. Low SDD values observed during spring coincided with high phytoplankton abundance levels obtained in the meantime.

Significant changes in number of phytoplankton species are observed cross-shelf over the year. Total number of diatom species (71) observed throughout the year has exceeded significantly the total number of dinoflagellates (40), coccolithophores (17) and the silicoflagellates (4). Overall, diversity displayed an apparent decrease from nearshore to offshore. Shelf flora has been found most species rich during the spring blooming period and in June and September. Minimum and maximum number of species ranged in between 13 - 36, 8 - 36 and 7 - 34 with annual averages of 27, 23 and 19 species observed in the nearshore, middle and offshore stations, respectively. Maximum number of species (36) has been recorded during February at nearshore and in September at middle station,

Table 2. Species contributions (\bar{S}_i) to average similarities (\bar{S}) within site groups.

Group	Species	\bar{S}_i	SD(S_i)	$\bar{S}_i / \text{SD}(S_i)$	$\Sigma \bar{S}_i$ %
*45.9 I	<i>Emiliana huxleyi</i>	23.1	4.1	5.7	50.4
	<i>Leptocylindrus minimus</i>	10.9	1.3	8.1	74.1
	<i>Chaetoceros brevis</i>	3.6	6.2	.6	81.9
	<i>Heterocapsa sp.</i>	2.5	4.3	.6	87.3
	<i>Navicula sp.</i>	2.1	3.6	.6	91.8
44.7 II	<i>Emiliana huxleyi</i>	5.7	2.7	2.1	12.8
	<i>Pseudo-nitzschia delicatissima</i>	3.6	2.7	1.6	20.8
	<i>Chaetoceros sp.</i>	3.6	2.9	1.2	28.8
	<i>Proboscia alata gracillima</i>	2.7	.9	2.8	34.7
	<i>Leptocylindrus minimus</i>	2.5	2.5	1.0	40.4
43.8 III	<i>Emiliana huxleyi</i>	13.3	2.6	5.1	30.4
	<i>Oxytoxum variabilis</i>	4.5	3.3	1.4	40.7
	<i>Heterocapsa pygmaea</i>	3.7	2.9	1.3	49.1
	<i>Leptocylindrus danicus</i>	3.6	2.7	1.3	57.3
	<i>Oxytoxum sp.</i>	3.2	2.4	1.3	64.5
46.5 IV	<i>Emiliana huxleyi</i>	14.6	2.3	6.2	31.4
	<i>Nitzschia tenuirostris</i>	2.9	1.8	1.6	37.7
	<i>Oxytoxum variabilis</i>	2.7	1.6	1.7	43.5
	<i>Chaetoceros sp.</i>	2.5	2.2	1.1	48.8
	<i>Anoplosolenia brasiliensis</i>	2.1	1.8	1.1	53.2

* Average similarity (\bar{S}) within the group.

respectively. Shelf flora has been represented with least number of species during August. Shannon Index H' decreased towards offshore with annual mean values of 1.4, 1.3 and 1 for the nearshore, middle and offshore stations, respectively. H' was found highest in September with a good apportionment among species and lowest in December during which few species (mainly the coccolithophorid *E. huxleyi*) dominated the community in the shelf. H' was found higher during September, February and June in the nearshore and in September and June in the middle station during which the proportional representation of species was well established. Both H' & J values tend to decrease from

Table 3. Species contribution ($\bar{\delta}_i$) to total average dissimilarity ($\bar{\delta} = \Sigma \bar{\delta}_i$) between all four site groups.

Group	Species	$\bar{\delta}_i$	SD(δ_i)	$\bar{\delta}_i / \text{SD}(\delta_i)$	$\Sigma \bar{\delta}_i$ %
*77.9 I&II	<i>Pseudo-nitzschia delicatissima</i>	4.0	2.9	1.4	5.1
	<i>Chaetoceros</i> sp.	3.7	2.8	1.3	9.9
	<i>Chaetoceros anastomosans</i>	3.3	4.1	.8	14.2
	<i>Proboscia alata gracillima</i>	3.0	1.2	2.5	17.9
	<i>Leptocylindrus danicus</i>	2.8	1.7	1.6	21.6
77.0 III&I	<i>Leptocylindrus minimus</i>	5.6	1.8	3.2	7.3
	<i>Chaetoceros brevis</i>	3.8	2.8	1.4	12.1
	<i>Leptocylindrus danicus</i>	3.3	2.1	1.5	16.4
	<i>Oxytoxum variabilis</i>	3.1	1.5	2.0	20.5
	<i>Heterocapsa</i> sp.	2.8	2.2	1.3	24.1
73.8 III&II	<i>Pseudo-nitzschia delicatissima</i>	3.9	2.8	1.4	5.3
	<i>Chaetoceros</i> sp.	3.5	2.2	1.6	10.0
	<i>Leptocylindrus minimus</i>	3.4	2.8	1.2	14.7
	<i>Chaetoceros anastomosans</i>	3.2	3.9	.8	19.0
	<i>Cerataulina bergonii</i>	2.3	1.5	1.6	22.1
72.4 IV&I	<i>Leptocylindrus minimus</i>	4.8	1.9	2.5	6.6
	<i>Chaetoceros brevis</i>	3.3	2.4	1.4	11.2
	<i>Chaetoceros</i> sp.	2.6	1.5	1.7	14.8
	<i>Heterocapsa</i> sp.	2.5	2.0	1.3	18.2
	<i>Nitzschia delicatissima</i>	2.2	2.1	1.0	21.2
71.9 IV&II	<i>Pseudo-nitzschia delicatissima</i>	3.5	2.6	1.4	4.9
	<i>Leptocylindrus minimus</i>	3.2	2.6	1.2	9.3
	<i>Chaetoceros</i> sp.	3.0	2.0	1.5	13.5
	<i>Chaetoceros anastomosans</i>	3.0	3.6	.8	17.7
	<i>Proboscia alata gracillima</i>	2.6	1.0	2.5	21.4
68.5 IV&III	<i>Emiliania huxleyi</i>	2.3	1.3	1.8	3.4
	<i>Nitzschia tenuirostris</i>	2.3	1.2	1.9	6.7
	<i>Heterocapsa pygmaea</i>	2.2	1.1	2.0	10.0
	<i>Leptocylindrus danicus</i>	2.2	1.7	1.2	13.2
	<i>Oxytoxum</i> sp.	2.1	1.0	2.0	16.2

* Average dissimilarity ($\bar{\delta}$) within the groups.

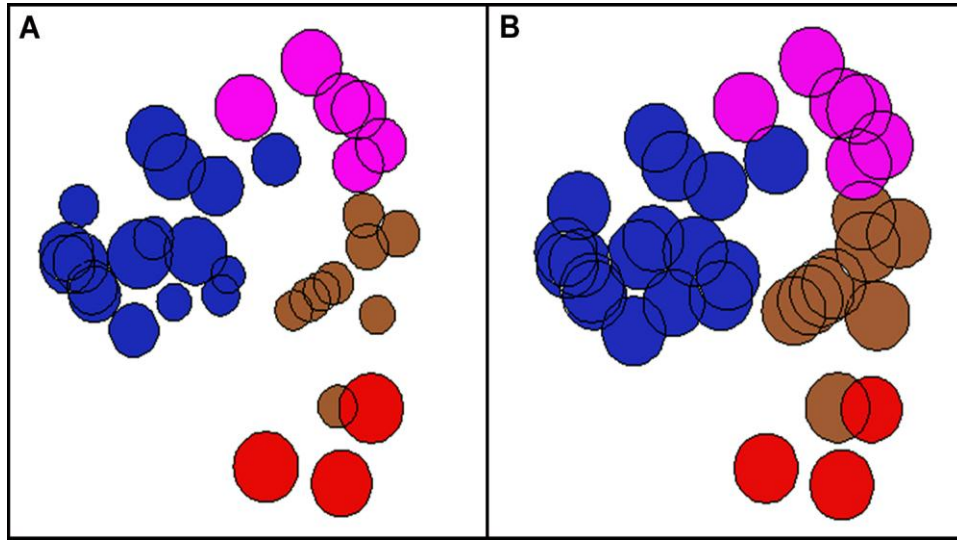


Fig. 9. MDS of 35 samples with values of surface temperature ranging between 15.5-29.9 °C: A & B, surface salinity ranging between 37-39.7 superimposed for each sampling event.

September to December in the shelf indicating dominance of certain few species within the flora. The lowest level was retained in December due to persisting dominance of coccolithophorid *E. Huxleyi* (formed almost 98% of the total cell counts) over the others. Same is true for the offshore station for the period February and end of June. This species has been found dominant from October to March and August in the shelf (Fig. 3). Having relatively greater surface to volume ratio enable this species to survive better under oligotrophic conditions compared to other large sized phytoplankters. Recent phytoplankton pigment studies conducted in the shelf also indicate significant contribution of coccolithophores to total chlorophyll in offshore waters¹⁹. Based on annual mean values J was almost equal at both nearshore and middle stations (0.4) and slightly lower at offshore (0.35).

Shelf phytoplankton species have been found much more abundant and rich during spring & early summer during which the river runoff to the basin was maximal. Over the year, total cell numbers varied between 2.5×10^4 and 2.75×10^6 cells/l at nearshore, in between 1.8×10^4 and 1.4×10^6 cells/l at middle and in between 1.2×10^4 and 2.0×10^6 cells/l at offshore station, respectively. Annual mean cell counts were calculated as 6.5×10^5 , 3.6×10^5 and 2.7×10^5 cells/l for the nearshore, middle and offshore stations, respectively. Offshore phytoplankton abundance exhibited similar patterns with the middle station both displaying an apparent increasing trend from autumn to spring. Nearshore flora has displayed higher population abundances during autumn compared to offshore ones. Thermocline starts to develop during September and deepens towards January with further cooling, so called, winter convectional mixing. Since the river runoff is minimal during autumn phytoplankton abundance displayed an apparent decrease

inshore to offshore. In addition formation of thermocline delimited upward entrainment of nutrients from lower depths in deeper shelf during autumn. However, nearshore waters are more prone to wind induced mixing and terrestrial freshwater inputs (as the major source of nutrients) which in turn favours excess phytoplankton growth nearshore compared to offshore. Phytoplankton abundances seemed to be distributed equally across the shelf during winter. The ratio between the minimal and maximal cell counts retained at nearshore and offshore stations was maximum (34) during July and relatively very high throughout autumn. Phytoplankton content of the offshore station differed greatly only during September & July from that of the mid station. Diatoms' contribution to total phytoplankton abundance peaked during autumn and spring in the nearshore and only during spring in the middle station. Dominancy of diatoms over the other groups has been also stated by others for the shelf (Kideys *et al.*, 1989; Eker & Kideys, 2000; Eker-Develi *et al.*, 2003; Uysal *et al.*, 2003b; Yücel *et al.*, 2017). It was also stated that the net plankton fraction increases in relative abundance in continental shelf and coastal upwelling waters where chain-forming diatoms and large, solitary diatoms and dinoflagellates dominate the phytoplankton (Malone, 1980). Other groups in which majority are composed of the coccolithophorid *Emiliania huxleyi* was dominant during winter in the nearshore, during autumn & winter in the middle station and almost throughout the year (except May & June) in the offshore station. Coccolithophores formed the dominant group almost throughout the year except May and June in the offshore station. Dinoflagellates formed the least scarce group throughout the year in the shelf. Similar nearshore to offshore phytoplankton dynamics has been reported from the Albanian coast where diatoms dominate the nearshore and coccolithophores the offshore waters (Vilicic *et al.*, 2011).

MDS analysis have distinguished 4 main groups at an arbitrary similarity level of 35%. Group I composed mainly of the August shelf flora where the larger group II involved part of the spring, summer and autumn flora. Group III comprised almost mainly of the autumnal offshore flora and lastly the Group IV of the majority of the winter flora. Compared to the dendrogram two dimensional MDS plots provided much better clear picture of the affinities among samples. It is clearly visible from the MDS plots that although a part of the autumn samples exist in the largest group III, they are indeed closely located to the main autumn group II (Fig's. 7, 8). This is also true for the winter group in which few winter samples present in the largest group II are located closer to the main winter group IV. Superimposed surface temperature values also clearly illustrate such close affinity within the samples (Fig. 9A). It is also interesting that the August flora is separated fully from the rest during which the number of species & abundance was found lowest. Shelf flora composition was most identical in May and affinity among stations has been found greater during April, May and June. This can be explained by the expansion of the excess amounts of nutrient rich freshwater towards offshore during spring. This phenomenon is also clearly visible from the low surface salinities observed across shelf during spring (Fig. 2B). Conversely, similarity among the stations has been found least during August during which exchange with offshore waters are limited. Similarly the offshore flora separated clearly from the nearshore and mid-shelf flora during July.

Among the major species that contributed much to average similarities during August (group I) were *E. huxleyi*, *L. minimus*, *C. brevis*, *Heterocapsa* sp. and *Navicula*

sp., (table 2). However, in the largest group II, except the coccolithophorid *E. Huxleyi*, the diatom species of *Pseudo-nitzschia delicatissima*, *Chaetoceros* sp., *Proboscia alata gracillima* and *Leptocylindrus minimus* were consistently prominent. In addition to *E. Huxleyi* dinoflagellate species *Oxytoxum variabilis* and *Heterocapsa pygmaea* have contributed much to similarity in this autumn group. Contribution of dinoflagellates to autumn flora was more significant compared to the rest of the year. Again in the fourth group coccolithophorid *Emiliania huxleyi* was followed by the diatom species *Nitzschia tenuirostris* and dinoflagellate *Oxytoxum variabilis*. *E. huxleyi* was the major contributing species to average similarities in all groups. Diatom species of *Leptocylindrus minimus*, *Chaetoceros brevis*, *Heterocapsa* sp., dominating the first group and *Leptocylindrus danicus*, *Oxytoxum variabilis* dominating the group III were caused for such discrepancy between the late summer and autumn flora. Winter and summer flora have separated from each other due to presence of *Leptocylindrus minimus*, *Chaetoceros brevis*, *Chaetoceros* sp., *Heterocapsa* sp. and *Pseudo-nitzschia delicatissima*. Among these *Leptocylindrus minimus*, *Chaetoceros brevis* and *Heterocapsa* sp. belong fully to the summer flora and the other two species *Chaetoceros* sp and *Pseudo-nitzschia delicatissima* are present rarely in the summer but consistently and more abundant in the winter flora. *Pseudo-nitzschia delicatissima* has been also reported as the major contributor to flora from the Aegean (Varkitzi *et al.*, 2018) and Black Sea (Moncheva *et al.*, 2001; Feyzioğlu & Şahin, 2017).

CONCLUSIONS

Changes in quality and quantity of shelf phytoplankton in the northeastern Levantine basin is affected much from the local river inputs and anthropogenic inputs. Nearshore shelf waters fed directly from such sources have displayed the highest phytoplankton abundances dominated by diatoms during autumn and spring-summer while the highest abundances were observed during spring in the deeper shelf waters. On the other hand, coccolithophores formed the dominant group almost throughout the year except May and June in the offshore, whereas dinoflagellates formed the least abundant group in the shelf throughout the year. Phytoplankton species have been found most abundant and diverse during spring when the river runoff to the basin was maximal. Multivariate analyses have shown formation of distinct seasonal phytoplankton assemblages throughout the year. Superimposed surface temperatures seemed to better illustrate seasonal clusters relative to surface salinity plots.

ACKNOWLEDGEMENTS

This work is part of a time series sampling program carried out in the northern Levantine Basin in connection with the project supported by the Turkish Scientific and Technical Research Council (TUBITAK - YDABAG 102Y037). We extend our sincere thanks to the academic and technical staff and the crew of R/V *Erdemli* of the Institute of Marine Sciences of Middle East Technical University for their assistance and help both at sea and in the laboratory.

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