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Investigation of the Seasonal Variation in the Phytoplankton in the Surface Waters of the Gulf of Edremit

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Abstract

The aim of this study was to determine the phytoplankton species existing in the Gulf of Edremit and some environmental conditions affecting them. Samples were collected in July and October 2003 and in January and April 2004 from 3 stations through horizontal tows using a plankton net. After the analysis of plankton samples, 123 species that belong to 5 classes were identified. It was determined that one species (*Phalacroma cuneus* Schütt, 1895) was a new record for Turkish waters. The species composition mostly consisted of dinoflagellates (53.7%) which were followed by diatoms (43.9%). Most of the species which were identified in this study were similar to those phytoplanktonic algal species which were reported from the Eastern Mediterranean Sea in previous studies. These are neritic, oceanic, temperate and subtropical climate species. It was detected that 10 out of 19 potentially harmful algal species identified in this study were toxic species; however, they did not show an extreme increase. Dinophyceae had the highest cell number in July (1100 cell/L, St.1) and Bacillariophyceae in April (2280 cell/L, St.2). The environmental variables of the seawater such as temperature (13.0-26.5 ºC), salinity (35.9-38.5‰) and dissolved oxygen (4.43-8.46 mg/L) were measured in every sampling period. Consequently, the phytoplankton species and their abundances in the Gulf of Edremit were firstly determined with this study, and phytoplankton composition representing oligotrophic sea water characteristic in the Aegean Sea was obtained.

Keywords: Phytoplankton, coastal waters, Gulf of Edremit.
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Edremit Körfezi'nin Yüzey Suyu Fitoplanktonundaki Mevsimsel Değişimlerin İncelenmesi

Özet

Edremit Körfezi'nde var olan fitoplankton türleri ile bunların üzerine etkili olan bazı ortam koşullarının saptanması amacıyla örnekler, 2003 yılının Temmuz ile Ekim aylarında ve 2004 yılının Ocak ile Nisan aylarında, 3 istasyondan plankton kepçesiyle, horizontal çekimler yapılarak elde edilmiştir. Plankton örneklerinin incelenmesi sonucunda, 5 sınıfa ait 123 tür saptanmıştır. Bir türün (*Phalacroma cuneus* Schütt, 1895) Türkiye denizleri için yeni kayıt olduğu belirlenmiştir. Tür kompozisyonunun büyük çoğunluğunu dinoflagellatlar oluşturmuş (%53,7) ve bunu diyatomlar izlemiştir (%43,9). Belirlenen türlerin büyük çoğunluğu, önceki çalışmalarda Doğu Akdeniz'den rapor edilen fitoplanktonik alg türleriyle benzerlik göstermiştir. Bu türler neritik, oseanik, ılıman ve subtropik iklim türleridir. Çalışmada belirlenen 19 potansiyel zararlı alg türünden 10'unun toksik türler olduğu saptanmıştır; ancak, bu türler aşırı artış göstermemiştir. En yüksek birey sayısına Dinophyceae Temmuz ayında (1100 h/L, ist.1), Bacillariophyceae ise Nisan ayında (2280 h/L, ist.2) ulaşmıştır. Deniz suyunun sıcaklık (13,0-26,5 ºC), tuzluluk (‰35,9-38,5) ve çözünmüş oksijen (4,43-8,46 mg/L) gibi fiziko-kimyasal özellikleri de her örnekleme döneminde ölçülmüştür. Sonuç olarak, Edremit Körfezi'nde yaşayan fitoplankton türleri ve bollukları ilk kez bu çalışmayla belirlenmiş ve Ege Denizinin tipik olarak oligotrofik su karakteristiğini temsil eden bir fitoplankton kompozisyonu elde edilmiştir.

Anahtar kelimeler: Fitoplankton, kıyısal sular, Edremit Körfezi.

Introduction

Phytoplankton play an important role in the carbon flow in aquatic environments thanks to their ability to photosynthesize. Although the phytoplankton biomass in seas form only 1-2% of vegetable carbon in the world, these organisms can absorb 40% of total carbon per year, which means 30-50x10^9 tons of carbon (Berger et al. 1989; Falkowski and Woodhead 1992). Further, the phytoplankton constitutes the basis of the marine food chain, and together with microzooplankton serve as a food source for many animal organisms (Löder et al. 2011).

Bays and gulfs are of considerable importance in terms of fishery since they provide habitats for the sheltering and reproduction for most living species. Due to the fact that they have a semi-closed and a more stagnant structure as compared to the open seas, the possibility of occurrence of such events as red-tide and eutrophication increases. The increasing amount of phytoplankton in the environment can have toxic and harmful effects. In order to study them and manage these events better, projects like EUROHAB (European Initiative on Harmful Algal Blooms) are conducted in such areas (EUROHAB, National European and International Programmes 2002). Additionally, Spatharis and Tsirtsis (2010) developed a scale which could determine the "ecological quality status" of seas within the "Water Framework Directive" using the previous ecological studies.

The level of effect of pollution on the living species is directly correlated with the species diversity, and the effects of pollution in a specific environment can be determined by monitoring the natural process. However, in order to achieve this, the most significant requisite is to determine the species diversity of the area that will be studied before pollution (Koray and Kesici 1994). Yet a comprehensive study has not been conducted to determine the phytoplankton species composition and the abundance status of the existing species in the Gulf of Edremit. Only Gökalp (1972) detected that dinoflagellates were the richest group in terms of species number in a study which he conducted in the Gulfs of Edremit, Bodrum and Iskenderun and reported that most of the dinoflagellate species belonged to the genus *Ceratium* (accepted name *Neoceratium*). He also determined that 70% of total phytoplankton consisted of dinoflagellates and 30% consisted of diatoms. In the area, there is only one study specifically on tintinnids which are included in the group of plankton (Balkıs and Wasik 2005).

Due to the reasons expressed above, the Gulf of Edremit, where there is no comprehensive study on the composition and abundance status of the phytoplankton species, was designated as study area, and the data obtained from the samples were evaluated together with ecological data (Balkıs and Balcı 2010) belonging to the period of sample collection.

Materials and methods

Study area

The Aegean Sea is located between the coasts of Turkey and Greece. It lies within 23°-27° east longitude and 35°-41° north latitude. Its total surface area is 241000 km^2, its volume is 74104 km^3, its length from north to south is 660 km and its width is 270 km in the north and 400 km in the south. It has a special place in the Mediterranean ecosystem in terms of its regional location, geomorphologic structure, and hydrographic and ecological properties (Kocataş and Bilecik 1992). While the Aegean Sea is linked to the Sea of Marmara by the Dardanelles, the Sea of Marmara is linked to the Black Sea by the Bosphorus. The salinity of the surface waters of the Aegean Sea ranges between 26‰ and 35‰ seasonally due to the influence of Black Sea water with low salinity (Yüce 1995). The salinity of surface water in summer is lower compared to winter. The reason is the fact that low salinity waters of Black Sea origin are effective in the north of Aegean Sea in the summer months (Yüce 1987).

The Gulf of Edremit is located south of the Biga Peninsula along the north-eastern part of the Aegean Sea, which is a significant basin of the Mediterranean Sea and an important gulf accommodating intensive touristic and fishing activities. In addition, the Gulf has domestic and industrial pollution, unprocessed disposal of municipal solid wastes, basin and coastal erosion (Irtem et al. 2005).

Sampling method and analysis

Sampling was performed using a fisher boat at 3 stations in the inner part of Gulf of Edremit in July and October 2003 and in January and April 2004 seasonally (Fig. 1). With qualitative purposes, samples were collected through horizontal tows using a plankton net having a pore size of 55 µm. The samples were preserved with borax buffered formaldehyde solution (final concentration 4%). Phase contrast inverted microscope with "Olympus CK2" digital camera attachment was used to observe the species. In addition, the resources stated at the study by Balkıs (2000) were used to identify species, and Hasle and Syvertsen (1997), Steidinger and Tangen (1997), Throndsen (1997) and MarBEF Data System (http//www.marbef.org/data/erms.php) were used to give current names to the species.

Figure 1. Sampling stations at the inner part of the Gulf of Edremit (http://www.google.com/earth).

In order to determine the quantitative distribution of the species, samples were collected from the surface of the same stations on the same dates using a "Ruttner" water sampler of 3 liters capacity. After the samples were preserved with Lugol's solution for one week (Throndsen 1978) in the laboratory, they were siphoned away to obtain a concentrated sample of 50 ml (Sukhanova 1978) and fixed in borax buffered formaldehyde solution which has a concentration of 4%. Cell counting was carried out under a phase contrast inverted microscope (Olympus CK2) in a Sedgwick-Rafter cell. The results of countings were summarized as cells per litre (Semina 1978).

In this study, physicochemical parameters such as seawater temperature, salinity, dissolved oxygen (DO) and nutrients were determined during the collection of plankton community samples (Balkıs and Balcı 2010) and the study by Balkıs and Balcı (2010) was used to show the correlation between those ecological parameters and species.

Species diversity was also estimated by using Shannon–Weaver diversity index ($H'_{\log 2}$) (Zar 1984);

$$H' = -\sum_{i=1}^{k} P_i \log P_i \qquad P_i = f_i / n$$

The correlation between the species and cell numbers of phytoplankton and ecological variables was evaluated using Spearman's rank correlation coefficient (Siegel 1956). In addition, the similarity between stations in terms of these parameters was calculated using Bray-Curtis similarity index [(log(x+1)] (Clarke and Warwick 2001) on "Primer v6 software".

Results

Phytoplankton composition, succession and abundance

In this study 123 species belonging to 5 classes were determined: 54 species of **Bacillariophyceae** (43.9%), one species of **Chlorophyceae** and one species of **Dictyochophyceae** (0.8%), 66 species of **Dinophyceae** (53.7%) and at genus level one species of **Euglenophyceae** (0.8%) were identified (Fig. 2). According to the literature review, one of these species (*Phalacroma cuneus* Schütt, 1895) is a new record for Turkish seas (Fig. 3). This species was observed at stations 1 and 2 in January 2014 and was found only in net samples. Epitheca of this species is relatively broad and cell surface has irregular reticulate ornamentation. This species has been reported previously from the Adriatic and Levantine Sea (Gomez 2003) and has a worldwide distribution. The list of all species and their frequencies at each station are presented at Table 1.

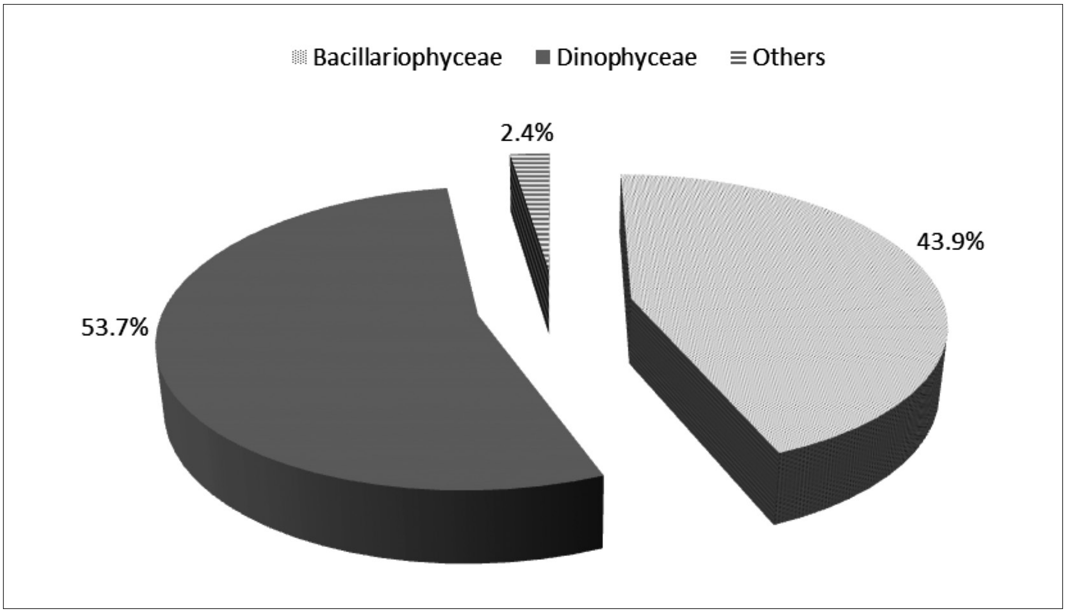

Figure 2. Percentage distributions of the classes according to the number of species they include.

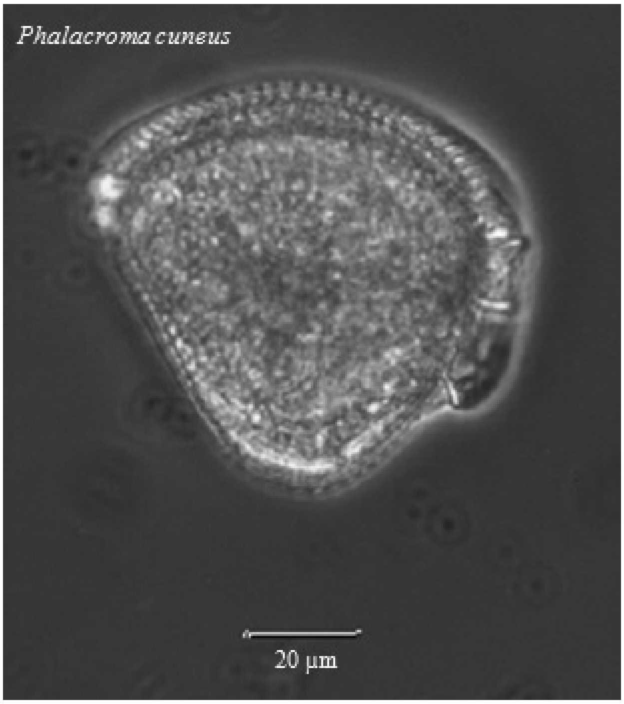

Figure 3. New record species (*Phalacroma cuneus* Schütt, 1895) in the Gulf of Edremit.

When we examine Table 1, we see that the highest number of species was recorded at Station 3 (72 species) in October 2003, which was subsequently followed by Station 3 (69 species) in January 2004. The highest species number of the classis Dinophyceae was obtained at Station 3 (44 species) in October 2003 while the highest species number of Bacillariophyceae was recorded at Station 2 (35 species) in April 2004. The highest species number of Dinoflagellates was obtained from the genera *Neoceratium* (25 species) and *Protoperidinium* (9 species) while the highest species number of Diatoms was obtained from the genus *Chaetoceros* (14 species).

Table 1. Phytoplankton species collected through horizontal tows in the Gulf of Edremit during the seasonal sampling period between July 2003 and April 2004 and their frequency percentages per station.

SPECIES	Sampling date and stations												
	July 2003			October 2003			January 2004			April 2004			
	St. 1	St. 2	St. 3	St. 1	St. 2	St. 3	St. 1	St. 2	St. 3	St. 1	St. 2	St. 3	%
Dinophyceae													
Amphisolenia bidentata		+		+	+	+		+	+				50
Neoceratium arietinum					+	+	+	+	+	+		+	58
Neoceratium candelabrum	+	+	+	+	+	+	+	+	+		+	+	92
Neoceratium carriense	+	+		+	+		+	+		+	+		67
Neoceratium compressum							+						8
Neoceratium concilians	+		+	+	+	+	+	+	+		+	+	83
Neoceratium contortum				+	+	+	+						33
Neoceratium declinatum	+	+	+	+	+	+	+	+	+				75
Neoceratium deflexum	+					+							17

Neoceratium extensum	+	+	+	+	+	+	+		+		+	+	83
Neoceratium falcatum			+	+		+	+		+		+	+	58
Neoceratium furca	+	+	+	+		+	+	+	+	+	+	+	92
Neoceratium fusus	+	+	+	+	+	+	+	+	+	+	+	+	100
Neoceratium gibberum	+						+		+				25
Neoceratium hexacanthum	+	+	+	+	+	+	+	+	+		+	+	92
Neoceratium kofoidii	+		+	+	+	+	+	+	+	+	+		83
Neoceratium macroceros	+	+	+	+	+	+	+	+	+	+	+		92
Neoceratium massiliense	+	+	+		+						+	+	50
Neoceratium paradoxides							+	+	+				25
Neoceratium pentagonum		+			+		+	+	+		+		50
Neoceratium ranipes					+		+	+	+				33
Neoceratium schroeteri				+	+	+							25
Neoceratium symmetricum	+				+	+	+	+	+	+	+	+	75
Neoceratium teres				+	+	+	+	+					42
Neoceratium trichoceros	+	+	+	+	+	+	+	+	+	+		+	92
Neoceratium tripos	+		+	+	+		+	+	+	+	+	+	83
Ceratocorys armata	+							+	+				25
Ceratocorys horrida	+	+	+	+	+	+	+	+	+		+		83
Dinophysis acuta						+							8
Dinophysis caudata	+	+	+	+	+	+	+	+	+		+		83
Dinophysis fortii					+			+	+				25
Dinophysis schuettii					+	+							17
Dinophysis tripos					+	+			+				25
Goniodoma polyedricum	+	+	+	+	+	+	+	+	+			+	83
Gonyaulax polygramma	+	+	+	+	+	+			+		+	+	75
Kofoidinium velleloides	+	+	+	+		+		+	+	+	+	+	83
Lingulodinium polyedrum			+					+					17
Ornithocercus francescae								+					8
Ornithocercus heteroporus					+	+			+				25
Ornithocercus magnificus	+	+	+	+	+	+	+	+	+				75
Ornithocercus quadratus	+			+	+	+		+	+				50
Phalacroma cuneus							+	+					17
Phalacroma doryphorum					+								8
Phalacroma favus		+	+	+		+	+						42
Phalacroma mitra						+		+					17
Phalacroma rapa	+		+		+								25
Phalacroma rotundatum		+	+	+	+	+		+					50
Podolampas bipes	+		+		+	+	+			+	+	+	67
Podolampas elegans							+	+	+				25
Podolompas palmipes			+		+								17
Podolompas spinifera		+	+			+							25
Prorocentrum micans	+	+	+	+		+		+	+				58
Prorocentrum scutellum	+	+		+									25
Protoperidinium divergens	+	+	+	+	+	+	+	+	+	+	+	+	100
Protoperidinium globulum					+	+	+	+	+		+	+	58
Protoperidinium grande									+			+	17
Protoperidinium mite	+						+					+	25

Protoperidinium oblongum	+	+		+	+	+					+		50
Protoperidinium oceanicum			+			+						+	25
Protoperidinium ovatum	+		+	+	+	+				+	+	+	67
Protoperidinium pentagonum					+			+	+		+	+	42
Protoperidinium steinii	+	+	+	+	+	+		+				+	67
Pyrocystis robusta				+									8
Pyrophacus horologicum	+					+				+	+	+	42
Pyrophacus steinii	+	+	+	+	+	+		+					58
Pyrophacus vancampoae		+	+	+	+	+							42
Total species number of Dinophyceae	**35**	**28**	**33**	**35**	**43**	**44**	**33**	**38**	**36**	**14**	**25**	**25**	
Bacillariophyceae													
Asterolampra grevillei						+							8
Asterolampra marylandica	+		+			+	+		+				42
Bacillaria paxillifera							+	+	+		+		33
Bacteriastrum delicatulum	+	+	+	+	+		+	+	+	+	+	+	92
Bacteriastrum elegans				+			+		+	+	+		42
Bacteriastrum hyalinum				+	+	+	+	+	+	+	+	+	75
Cerataulina pelagica						+		+		+	+	+	42
Chaetoceros costatus										+			8
Chaetoceros dadayi						+							8
Chaetoceros danicus	+			+	+	+			+				42
Chaetoceros decipiens	+	+		+	+	+	+	+	+	+	+	+	92
Chaetoceros diadema					+	+				+	+	+	42
Chaetocetos didymus										+	+	+	25
Chaetoceros eibenii										+			8
Chaetoceros holsaticus										+	+	+	25
Chaetoceros messanensis						+		+	+	+	+	+	50
Chaetoceros neapolitanus								+	+		+	+	33
Chaetoceros peruvianus	+				+		+		+	+	+	+	58
Chaetoceros pseudocurvisetus									+				8
Chaetoceros rostratus					+	+				+	+	+	42
Chaetoceros socialis											+		8
Coscinodiscus concinnus								+					8
Coscinodiscus perforatus							+						8
Coscinodiscus radiatus	+		+				+	+	+				42
Cylindrotheca closterium										+	+	+	25
Ditylum brightwellii							+		+				17
Entomoneis alata				+			+	+				+	33
Eucampia cornuta										+	+	+	25
Eucampia zodiacus			+	+	+	+							33
Guinardia delicatula						+		+	+	+	+	+	50
Guinardia flaccida	+		+	+	+	+	+	+	+	+	+	+	92
Guinardia striata	+	+	+	+	+	+	+		+	+	+	+	92
Hemialus hauckii	+	+	+	+	+	+	+	+	+	+	+	+	100
Hemiaulus sinensis						+	+	+	+	+	+	+	58
Leptocylindrus mediterraneus	+	+		+	+	+	+		+	+	+	+	83
Licmophora abbreviata	+	+	+								+		33

Lithodesmium undulatum							+		+				17
Odontella mobiliensis							+	+	+	+	+		42
Petrodictyon gemma	+												8
Pleurosigma normanii				+	+	+	+	+		+	+		58
Proboscia alata	+	+	+	+	+	+	+		+	+	+	+	92
Pseudo-nitzschia delicatissima	+								+	+			25
Pseudo-nitzschia pseudodelicatissima						+							8
Pseudo-nitzschia pungens							+	+			+		25
Pseudosolenia calcar-avis	+	+	+	+		+	+	+	+	+	+	+	92
Rhizosolenia castracanei						+	+	+	+				33
Rhizosolenia robusta		+	+	+	+	+	+	+	+	+	+	+	92
Rhizosolenia styliformis	+	+		+	+	+		+	+	+	+	+	83
Skeletonema costatum	+									+	+	+	33
Striatella unipunctata		+					+	+	+	+	+	+	58
Thalassionema frauenfeldii				+	+	+	+	+	+	+	+	+	75
Thalassionema nitzschioides	+			+	+	+	+	+	+	+	+		75
Thalassiosira rotula						+				+			17
Thalassiothrix mediterranea					+	+	+		+		+	+	50
Total species number of Bacillariophyceae	**18**	**11**	**11**	**18**	**19**	**28**	**28**	**24**	**31**	**33**	**35**	**28**	
Dictyochophyceae													
Dictyocha fibula			+		+		+	+	+				42
Total species number of Dictyochophyceae	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	
Chlorophyceae													
Pediastrum boryanum									+				8
Total species number of Chlorophyceae	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	
Euglenophyceae													
Eutreptiella sp.												+	8
Total species number of Euglenophyceae	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	
Total Species Number	**53**	**39**	**45**	**53**	**63**	**72**	**62**	**63**	**69**	**47**	**60**	**54**	

Of the 123 species collected during the sampling, 25 species were very abundant (20.3%), 11 were abundant (8.9%), 32 were common (26%), 28 were rare (22.8%) and 27 were present sporadically (22%). In addition, the abundances of phytoplankton species by season and station were also determined (Fig.4).

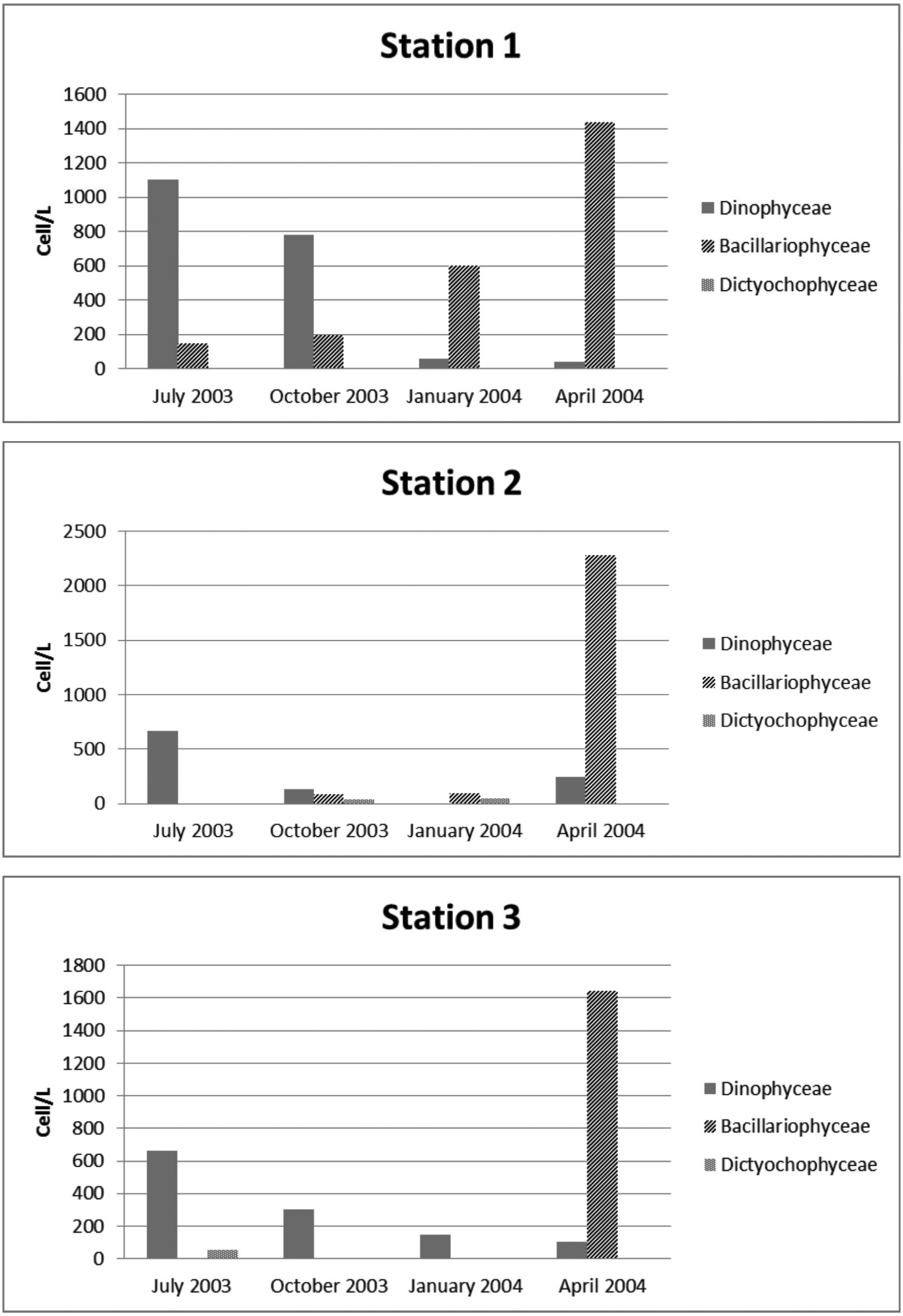

Figure 4. Seasonal variations in the abundance (cell/L) of phytoplankton at the stations.

During the four-season sampling period, Dinophyceae and Bacillariophyceae were dominant in terms of both species number and cell number compared to other groups. Additionally, Dinophyceae showed notable increases in summer and autumn and Bacillariophyceae in winter and especially spring. Dinophyceae reached the highest cell number in July at Station 1 (1100 cell/L) and showed gradual decreases from autumn to spring. Bacillariophyceae reached the highest cell number in April at Station 2 (2280 cell/L), showed the lowest abundance in the following summer and showed an increase in cell number towards the cold period.

In order to demonstrate the phytoplankton species diversity in the whole sampling period, the Shannon-Weaver diversity index (*H'*) was used to measure diversity among stations and seasons based on species and cell numbers, and the results are presented at Figure 5. During the sampling period, *H'* value ranged between 0.9 and 3.0. The highest *H'* value was recorded in October at Station 1 and in April at Station 2 while the lowest value was recorded in January at Station 3.

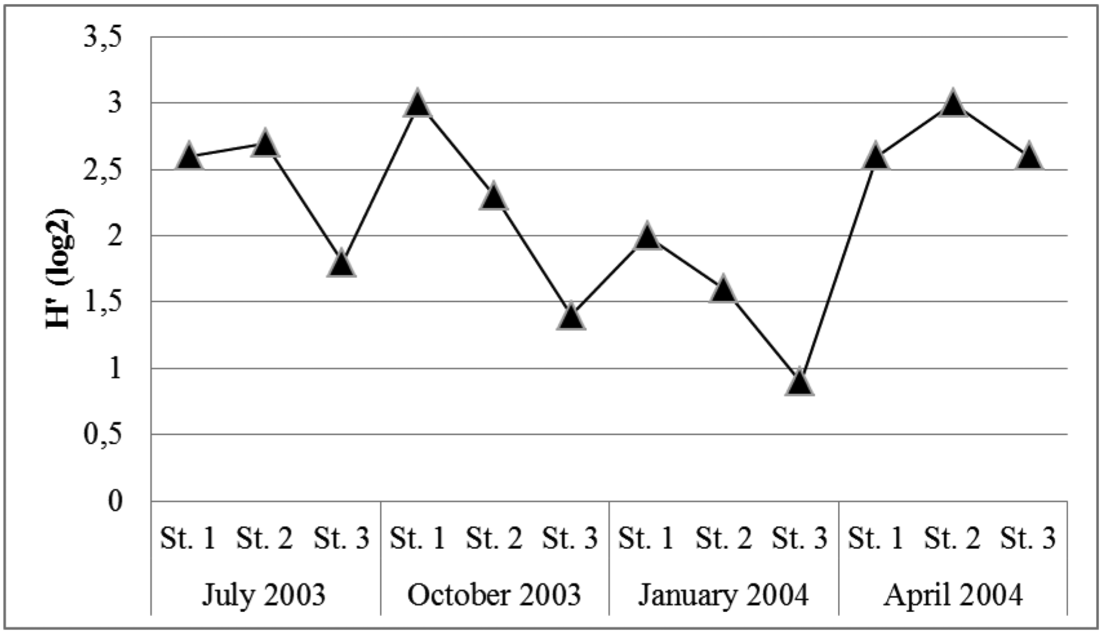

Figure 5. Seasonal variations of the Shannon-Weaver index (H'_{log2}) in the Gulf of Edremit.

Environmental variables

In order to determine the environmental variables of the seawater, surface water temperature (°C), salinity (‰), dissolved oxygen (DO) (mg/L), chlorophyll-a (chl *a*, µg/L), Nitrate+Nitrite-N (µg-at/L), Phosphate-P (µg-at/L) and Silicate-Si (µg-at/L) values were measured and the results are presented at Table 2.

Table 2. Ecological variables of the sampling stations in the Gulf of Edremit.

		Temperature (°C)	Salinity (‰)	DO (mg/L)	Chlorophyll *a* (µg/L)	Nitrate+Nitrite-N (µg-at/L)	Phosphate-P (µg-at/L)	Silicate-Si (µg-at/L)
St. 1	July 03	26.5	37.5	8.24	1.68	1.81	0.31	1.6
	October	21.2	38.5	5.64	0.54	0.96	0.34	1.69
	January 04	13.0	36.9	8.46	0.44	1.10	0.36	1.97
	April	15.6	36.8	4.44	0.22	0.43	0.24	0.96
St. 2	July 03	26.5	37.8	6.56	0.11	0.20	0.2	1.11
	October	21.2	38.3	5.3	0.32	0.85	0.31	1.65
	January 04	13.0	36.9	4.57	0.34	1.70	0.31	4.06
	April	15.6	35.9	5.68	0.10	0.36	0.26	0.83
St. 3	July 03	26	37.8	6.52	0.10	0.19	0.31	1.23
	October	21.2	38.2	4.43	0.10	0.38	0.26	1.44
	January 04	13.0	36.8	6.86	0.56	0.85	0.51	4.92
	April	15.8	36.1	5.49	0.10	0.33	0.21	0.91

According to Table 2, during the sampling period surface water temperature ranged between 13.0 and 26.5 °C, salinity between 35.9 ‰ and 38.5 ‰ and dissolved oxygen between 4.43 and 8.46 mg/L. The highest temperature was recorded in July 2003 (26.5 °C) while the lowest was recorded in January 2004 (13.0°C). The highest salinity was recorded in October 2003 (38.5‰) while the lowest was recorded in April 2004 (35.9‰). The lowest dissolved oxygen value was recorded in October 2003 (4.43 mg/L) at Station 3 and in April 2004 (4.44 mg/L) at Station 1 while the highest was recorded in January 2004 (8.46 mg/L) at Station 1. The highest chl a value was obtained in July 2003 at Station 1 (1.68 µg/L) while the lowest value was obtained in April 2004 at Station 2 and 3 and in July and October 2003 at Station 3 (0.10 µg/L).While in July 2003 nitrogen value was the lowest at Station 2 and 3 (0.19 µg-at/L), it is the highest at Station 1 (1.81 µg-at/L). The highest phosphorus and silica values were obtained in January 2004 at Station 3. The lowest silica value was recorded in April 2004 at Station 2 (0.83 µg-at/L) while the lowest phosphorus value was recorded in July 2003 at Station 2 (0.20 µg-at/L).

The correlation between the species and cell numbers of phytoplankton and ecological variables was evaluated using Spearman's rank correlation coefficient and the results are presented at Table 3.

Table 3. Spearman's rank correlation coefficient that shows the correlation between the species and cell numbers of phytoplankton and ecological variables.

	°C	‰	DO	Chl *a*	Nitrogen	Phosphorus	Silica	Cell numbers
Salinity	0.583*							
DO	0.082	-0.127						
Chl *a*	-0.154	0.166	0.459					
Nitrogen	-0.314	0.111	0.161	0.845**				
Phosphorus	-0.374	0.201	0.435	0.695*	0.613*			
Silica	-0.359	0.334	0.238	0.755**	0.701*	0.842**		
Cell numbers	0.260	-0.384	0.032	-0.353	-0.328	-0.502	-0.816**	
Species numbers	-0.513	-0.139	-0.312	0.004	0.223	0.254	0.354	-0.430

*$p<0.05$, **$p<0.01$, n=12.

When Table 3 is examined, it is seen that there is a positive correlation between salinity and temperature ($p<0.05$) and there is also a positive correlation between all nutrients and chl *a*. Of nutrients, nitrogen is in positive correlation with both phosphorus and silica ($p<0.05$) while phosphorus is in positive correlation with silica ($p<0.01$). In addition, silica is in negative correlation with phytoplankton cell number ($p<0.01$).

The results of the Bray-Curtis similarity index which was performed to determine similarity between stations in terms of ecological variables are presented in Figure 6.

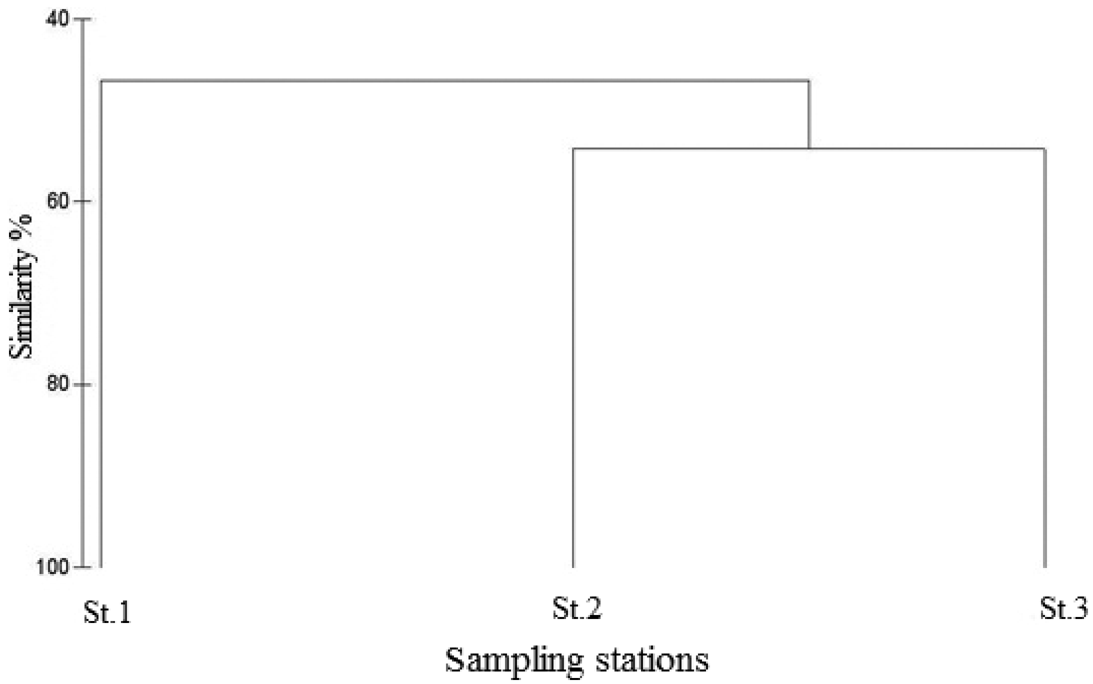

Figure 6. Similarity between stations in terms of ecological variables.

Discussion

Since the 1950s until today, the most comprehensive study of the phytoplankton studies, is that of Koray (2001). In the study which includes a phytoplankton species checklist, it was reported that 7 prokaryotic and 485 eukaryotic species were present in Turkish waters. In the first study which was conducted in the Gulf of Edremit (Gökalp 1972), a total of 27 species (2 at genus level) were reported. 123 species which were reported in our study showed similarity with the phytoplankton species recorded in Eastern Mediterranean Sea previously. Most of the species identified in the Gulf were neritic, temperate and subtropical climate species; however there were also oceanic species. Benthic species such as *Licmophora abbreviata* and *Pleurosigma normanii* which adapted to planktonic life, typical marine species such as *Proboscia alata*, *Thalassionema nitzschioides* and *Neoceratium fusus*, and brackish water species such as *Cylindrotheca closterium* and *Prorocentrum micans* were observed during the sampling periods. In addition, it is known that *Proboscia alata* which was observed at 11 out of 12 samplings is cosmopolitan and might also be present in oceanic and neritic areas (Marshall 1986).

It was observed that of the 5 classes determined in this study Dinophyceae and Bacillariophyceae were dominant in terms of species and cell numbers compared to other classes, and the species and cell numbers of Dinophyceae increased especially in summer and autumn and those of Bacillariophyceae in spring. A similar case was reported for the coastal waters of Bozcaada which is located close to the Gulf of Edremit (Balkıs 2009). *Pseudosolenia calcar-avis* and *Hemiaulus hauckii* are the notable species of oligotrophic waters, which are poor in nutrients (Kimor 1985) and are observed in all seasons. During the sampling period, *Neoceratium* and *Protoperidinium* from Dinophyceae and *Chaetoceros* from Bacillariophyceae were the richest genera.

While diatom species are dominant thanks to their populations, dinoflagellate species showed an extreme increase in the algal blooms occurring in phytoplankton communities in recent studies (Balkıs 2003, 2009). Compared to the other studies carried out in this area, lower phytoplankton abundance was observed in the surface water in the Gulf of Edremit. While the highest cell number recorded in spring (2520 cell/L, April 2004) in this study, Balkıs (2009) reported in the coastal waters of Bozcaada 46200 cell numbers at 0.5 m depth in spring (May 2000). In addition, *Ceratium furca*, *C. fusus*, *Prorocentrum micans* and *Thalassiosira rotula* which were reported to bloom by Koray (1985) did not form bloom in this study. During this study period, Bacillariophyceae showed a notable increase especially in April. In this period, the amount of silica was found to be lower compared to other sampling periods. As is known, silica is a necessary element for the growth of diatoms (Roberts et al. 2003).

The incidence of harmful algal blooms which can be defined as a sudden multiplication of one or more phytoplankton species has increased in recent years (Mann 2000). Generally such factors as domestic, agricultural and industrial activities, the increase in the input of nutrients into seas and seasonal changes cause excessive increase in algae. This results in mass deaths among fauna, and causes negative effects on fishery, tourism and water quality (Hallegraeff 1993; Vila and Masó 2005). Dinoflagellates and diatoms are two important toxin-producing groups. In our study, 10 of the 19 species that have the potential to bloom (*Dinophysis acuta*, *D. caudata*, *D. fortii*, *D. tripos*, *Lingulodinium polyedrum*, *Phalacroma mitra*, *P. rotundatum*, *Pseudo-nitzschia delicatissima*, *P. pseudodelicatissima* and *P. pungens*) were toxin-producing species. None of these species exhibited blooming.

It was determined that during the course of sampling surface water temperature ranged between 13.0 and 26.5 ºC, salinity between 35.9‰ and 38.5 ‰ and dissolved oxygen between 4.43 and 8.46 mg/L. Especially temperature and salinity values showed notable changes seasonally. It is known that seawater temperature causes changes in the cell concentrations of diatoms and dinoflagellates and there can be increases in the cell concentrations of species with the increase in temperature (Koray 1985). However, temperature showed positive correlation with only salinity and no correlation with species and cell numbers of phytoplankton. Dinoflagellates showed an increase in the summer in parallel with the temperature increase while diatoms showed an increase in winter in parallel with the decrease in temperature and reached the highest abundance in spring. It is also known that cell division in diatoms increases with the presence of high amounts of nutrients in the environment (Arin et al. 2002). In this study, we also observed that especially in the winter period the diatom abundance increased when the amount of nutrients was high and as the same time the sea water temperature was low. It is known that the daily temperature change in shallow waters of seas is a maximum of 2 ºC (Lalli and Parsons 1993). Similarly, no notable difference in surface water temperatures was observed in this study.

The oxygen content of water changes depending on the water circulations and biological events in the environment. In this study, the highest DO value was recorded in January 2004 at Station 1; however, DO values were variable among stations and seasons. It is known that the oxygen content of water decreases depending on an increase in temperature. However, in this study DO values were high in the summer (July 2003). The environmental parameters such as the interaction between atmosphere and surface waters and water circulations, and the abundance of nanoplankton which was not sampled in this study might have caused the increase in oxygen content in July. When DO values decrease below 5 mg/L some vulnerable fish species are affected negatively, and below 2.5 mg/L most fish species are affected negatively (Frodge et al. 1990). In this study, in only two periods (St. 3 in October 2003; St.1 in April 2004) DO values were measured just below 5 mg/L.

Friligos (1977) suggested that nutrient concentrations were high in surface waters and nitrogen was the limiting nutrient in winter. In this study, we also recorded that nutrient concentrations were higher in winter than other periods. Especially vertical mixtures and stream inputs might have caused the increase. In the Gulf of Izmir, Kontas et al. (2004) reported that in cold periods, the water column showed similar distribution patterns in nutrients due to the cooling of surface water and vertical mixing induced by winds. In addition, Friligos (1976) stated that in the periods when phytoplankton increased, especially in spring, the amount of nutrient decreased. In this study, similar findings were obtained. Especially in spring when the diatom abundance increased, and the concentration of silica decreased due to cellular use.

In seas, the distribution of chl *a* changes due to the hydrochemical conditions of water such as the presence of nutrients, temperature changes, light conditions and water mixtures (Lakkis et al. 2003; Nikolaidis et al. 2006a, b). Ignatiades (2005) proposed a trophic scaling for the Aegean Sea based on chl *a* concentrations: <0.5 µg/L oligotrophic, 0.5-1.0 µg/L mesotrophic and $>1,0$ µg/L eutrophic. In our study, chl *a* concentrations ranged between 0.10-1.68 µg/L. It was seen that the sea was sometimes eutrophic (July 2003, Station 1) and mostly oligotrophic. According to Ignatiades (2005), in general terms the Aegean Sea was oligotrophic. Also, in a previous study carried out in the Gulf of Edremit, Balkıs and Balcı (2010) stated that according to low chl *a*, nutrient and trophic index (TRIX) values the Gulf was in high quality status but at low trophic level.

Consequently, in this study the phytoplankton species distributed in the Gulf of Edremit and their abundances were firstly determined. A new record species was registered for Turkish seas. Therefore, this study can be used as a resource for future studies that will be conducted for the identification of species in the area. In addition, phytoplankton composition representing oligotrophic sea water characteristic in the Aegean Sea was obtained.

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