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Short Time Variations of Winter Phytoplankton, Nutrient and Chlorophyll a of Kepez Harbor in the Dardanelles (Çanakkale Strait, Turkey)

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Abstract

This study was carried out to determine the short time series of phytoplankton density and chlorophyll *a* in relation to nutrients and other environmental parameters in surface waters of Kepez Harbor in the Dardanelles in winter period of 02 December 2004 and 07 March 2005. Average temperature, salinity, pH, specific conductivity, TDS, DO, TSS, NO^-_2+NO^-_3, $PO^{-3}4$, SiO_4 and chlorophyll *a* were measured 9.47°C, 27.5 ppt, 8.12, 42.86 mS cm^{-1}, 27.86 g L^{-1}, 9.23 mg L^{-1}, 27.1 mg L^{-1}, 0.43 µM, 0.23 µM, 2.91 µM, 1.919 µg L^{-1}, respectively. Both N:P (1.78) and Si:P ratios (14.9) were significantly lower than the assimilatory optimal Redfield ratio. Total phytoplankton density varied between 8.25E+04 and 4.71E+06 Cell L^{-1}. Phytoplankton community structure was observed to be controlled by 3 dinoflagellates and 4 diatoms in the Dardanelles. However, also there were blooms of coccolithophoride *Emiliania huxleyi* in early December (2.36E+06 Cells L^{-1}) and late February (1.57E+06 Cells L^{-1}) and some silicoflagellates such as *Dictyocha* spp. in early February (2.36E+05 Cells L^{-1}). Contribution of diatoms to total phytoplankton density (48.8%) was higher than the contribution of dinoflagellates (30.9%) and other taxonomic groups (20.3%). Relationships between chlorophyll *a* and diatoms (r=0.726), between chlorophyll *a* and dinoflagellates (r=0.579) and between chlorophyll *a* and other taxonomic groups (r=0.514) showed that chlorophyll a was highly controlled by diatoms than dinoflagellates and other taxonomic groups. On the other hand, short time distribution of phytoplankton revealed that there was growing 7 phytoplankton populations in the winter period. High chlorophyll *a*, nutrient, phytoplankton density and rational differences between major taxonomic groups revealed that the Dardanelles was connected with the process of eutrophication due to high terrestrial discharges coming from Black Sea surface waters via straits system and international carrying activities by vessels.

Keywords: Dardanelles, phytoplankton, short time variations, winter, environmental parameters, eutrophication.

Çanakkale Boğazı Kepez Limanında Kış Dönemi Fitoplankton, Nütrient ve Klorofil a Düzeylerinde Kısa Zaman Serili Değişimler

Özet

Bu çalışma, Aralık 2004-Mart 2005 periyodunu içeren kış döneminde, Çanakkale Boğazı Kepez limanının yüzey sularında besin tuzu ve diğer çevresel parametrelerle ilişkili olarak fitoplankton yoğunluğu ve klorofil a'nın kısa zaman serili değişimlerini incelemek amacıyla yapıldı. Ortalama sıcaklık, tuzluluk, pH, spesifik iletkenlik, TDS, DO, TSS, NO^-_2+NO^-_3, PO^{-3}_4, SiO_4 ve klorofil *a* düzeyleri sırasıyla 9.47°C, 27.5 ppt, 8,12, 42,86 mS cm^{-1}, 27,86 g L^{-1}, 9,23 mg L^{-1}, 27,1 mg L^{-1}, 0,43 µM, 0,23 µM, 2,91 µM, 1,919 µg L^{-1} olarak ölçüldü. Hem N:P (1,78) ve hem Si:P oranları (14,9) optimum Redfield asimilasyon oranından oldukça düşüktü. Toplam fitoplankton yoğunluğu 8,25E+04 ve 4,71E+06 hücre L^{-1} arasında değişim gösterdi. Çanakkale Boğazında fitoplankton kommunite yapısı 3 dinoflagellat ve 4 diatom türü tarafından kontrol edildiği gözlendi. Bununla birlikte, Aralık ayı başında (2,36E+06 hücre L^{-1}) ve Şubat ayı sonunda (1,57E+06 hücre L^{-1}) kokkolitoforid *Emiliania huxleyi* türünün ve Şubat ayı başında ise *Dictyocha* spp. gibi bazı silikoflagellat türlerinin önemli üremeleri (2,36E+05 Cells L^{-1}) görüldü. Diatomların toplam fitoplankton yoğunluğuna olan katkısı (%48,8) dinoflagellatların (%30,9) ve diğer taksonomik grupların katkısından (%20,3) çok daha yüksekdi. Klorofil a ve diatomlar (r=0,726), klorofil a ve dinoflagellatlar (r=0,579), klorofil a ve diğer taksonomik gruplar (r=0,514) arasındaki korelasyon ilişkileri, klorofil a'nın dinoflagellatlar ve diğer taksonomik gruplardan daha ziyade diyatomlar tarafından kontrol edildiğini göstermiştir. Diğer taraftan, fitoplanktonun kısa zaman serili değişimleri, kış döneminde 7 farklı fitoplankton populasyon eğrisinin geliştiğini göstermiştir. Türk Boğazlar Sistemi yoluyla Karadeniz'den gelen yüksek karasal girdiler ve uluslar arası gemi taşımacılık aktiviteleri nedeniyle, yüksek klorofil a, yüksek besin tuzu konsantrasyonu, yüksek fitoplankton yoğunluğu ve büyük taksonomik gruplar arasındaki değişen oransal farklılıklar Çanakkale Boğazı'nın ötrofik bir yapıya sahip olduğunu göstermiştir.

Anahtar Kelimeler: Çanakkale Boğazı, fitoplankton, kısa zaman serisi, kış dönemi, çevresel parametreler, ötrofikasyon.

Introduction

The Turkish Straits System including the Bosphorus, the Sea of Marmara and the Dardanelles (Canakkale Strait) connects the Mediterranean and the Black Sea (Besiktepe *et al*., 1994; Polat and Tugrul, 1996). Sea of Marmara is a semi-enclosed basin with an 11500 km^2 area and a 3378 km^3 total volume (Polat and Tugrul, 1996). The Dardanelles (Canakkale Strait) which is a part of the Turkish Strait System is located between the Aegean Sea and the Sea of Marmara and has a 50 m mean depth (Polat and Tugrul, 1996).

The Dardanelles is a very important water passage connecting the Aegean Sea and the Marmara Sea. The Dardanelles has two current systems. One of the currents is derived from the Aegean Sea, where the water density is high. The other comes from the Sea of Marmara that characteristically is of low density. Aegean water is typically flowing from the southwest to northeast below Marmara Sea water (Polat and Tugrul, 1996; Unsal *et al*., 2003; Turkoglu *et al*., 2004a, 2006; Baba *et al*., 2005).

Due to large salinity differences between the Aegean Sea (38-39 ppt) and the Sea of Marmara (24-26 ppt), it is likely to observe intense vertical mixing of the counter-flows in the Dardanelles, especially near the southern exits. This way, before reaching to the Aegean basin, the salinity of the Dardanelles surface flow increases at least 4-8 ppt. The Dardanelles surface water is more saline in the spring and winter compared to other seasons in the south east of the Dardanelles. When the salinity in the surface water is low, values of total dissolved solids (TDS) in the Dardanelles are lower (Unsal *et al*., 2003; Turkoglu *et al*., 2004a, 2006; Turkoglu, 2008) than those in other marine systems ($\geq$35.0 mg L^{-1}) (Xie *et al*., 2003). Temporal cycle of pH in the Dardanelles reveals fluctuations throughout the year, winter values were significantly lower (mean 8.20) than the spring (mean 8.36) and fall values (mean 8.28). DO concentrations vary generally from 6.00 to 10.0 mg L^{-1} during the year, being higher in the spring and winter compared to summer (Turkoglu *et al*., 2004b; Turkoglu, 2008).

Phytoplankton succession in the region shows similarities to the Black Sea (Turkoglu and Koray, 2000, 2002, 2004). It is controlled by blooms of coccolithophorid *Emiliania huxleyi* (Lohmann) Hay and Mohler, 1967, dinoflagellates such as *Ceratium* spp. ve *Prorocentrum* spp. and diatoms such as *Dactyliosolen fragilissimus* (Bergon) G.R. Hasle, 1991, *Proboscia alata* (Brightwell) Sundström, 1986, *Pseudo-nitzschia pungens* (Grunow ex P.T. Cleve) Hasle, 1993 (Unsal *et al*., 2003; Turkoglu *et al*., 2004a, 2004b, 2004c). These species and some others which are opportunistic suppress other phytoplankton species due to fluctuations in the nutrients. Researchers had reported previous harmful and toxic algal blooms, especially *Dinophysis* spp. and *Gonyaulax* spp. is being a potential threat in the region (Unsal *et al*., 2003; Turkoglu *et al*., 2004a, 2004b, 2004c). Furthermore, some researchers revealed that life cycles of phytoplankton species have been completed between 3 and 4 days in an average manner (Eker and Kideys, 2000; Turkoglu and Erdogan, 2007, 2010).

This study has been planned for short time series (once a five day) to uncover excessive algal successions of only winter period due to the fact that this period contains an important community structure of phytoplankton species and their various algal blooms in this period in the Dardanelles which is a part of the Turkish straits system. Until now, such studies have been planned for monthly and even seasonally from various stations in an aquatic system. But, studies on phytoplankton must be planned in detail in short time series (once a day or at least once a week) related to one or a few station anymore, since phytoplankton populations complete their successions in 3-4 days in an average manner. Therefore, this study stipulates to exhibit more evolution of the winter time period in view of phytoplankton, chlorophyll *a*, nutrients and the other environmental parameters in this system. We also tried to explore interactions between phytoplankton and environmental parameters in the system in the period of 02 December 2004 and 07 March 2005.

Materials and Methods

For this study, environmental parameters, phytoplankton, nutrient and chlorophyll *a* data were analyzed from station (D-KH) located in Kepez Harbor at 40°06'20" N latitude and 26°22'41" E longitude (Figure 1). The sampling period and frequency were planned in 4-5 day intervals in winter period of 02 December 2004 and 07 March 2005.

Since the sampling station is an open harbor, it is generally affected by two flow systems of the Dardanelles. Moreover, it is also affected by Kepez and Sarıçay Rivers from time to time, especially in just after the periods of heavy precipitations.

Temperature (T), salinity (S), pH, dissolved oxygen (DO) and total dissolved solids (TDS) were measured in surface water (0.5 m). Environmental parameters were measured using an "YSI 556 Model Multiple Water Analysis Probe" *in situ*. Nutrient, TSS, chlorophyll *a* and phytoplankton samples were collected from the surface with a 5 liter Water Sampler.

Water samples collected for TSS determination were filtered through a pre-weighed GF/F glass fiber filters after the filters were dried for 4 h at 105°C in an oven. The residues retained on the GF/F glass fiber filters were dried again for 1 h at 105°C in an oven. Then, the samples were cooled in a desiccator to balance temperature and weighed by *a* sensitive balance (APHA, 1998). TSS was accepted as an increase in weight of the filter and calculated using by following formula,

$$\text{TSS (mg L}^{-1}\text{)} = (\text{A-B}) * 1000 / \text{Sample Volume, ml}$$

where: A=weight of filter + dried residue, mg; B =weight of filter, mg

Nutrient samples collected from the surface were transferred to 100 ml polyethylene bottles and kept frozen until analysis. Nutrient analyses including nitrate (NO^-_3), nitrite (NO^-_2), soluble reactive phosphorus (PO^{-3}_4) and silicate (SiO_4) were conducted using a Technicon model two-channel Auto-Analyzer according to Strickland and Parsons (1972).

Samples for chlorophyll *a* determination were collected immediately after the water samples were collected. The samples were filtered through GF/F glass fiber filters. Chlorophyll *a* concentration was analyzed spectrophotometrically after extraction by 90% acetone (Strickland and Parsons, 1972). Filters used for filtration of surface water were wrapped in aluminum foil and kept frozen until analysis.

Whole water phytoplankton samples collected from the surface were preserved with acidic Lugol 2-4% v/v and kept at 2-4°C pending microscopic analysis. For enumeration of the phytoplankton species, Uterhmöhl Sedimentation Chambers, Neubauer and Sedgwick-Rafter counting slides were used in combination according to the dimensions of the organisms (Guillard, 1978; Hassle, 1978; Venrick, 1978). The phytoplankton was identified under phase-contrast microscopy to the taxonomic level of species (Tregouboff and Rose, 1957; Cupp, 1977). Depending on the density, sample volumes of 2-8 ml were used.

Descriptive statistics and correlations of data groups were conducted using BioDiversity Pro/BD2.bdp (McAleece *et al*., 1999) and SPSS 11.5 for windows (SPSS, 2003).

Results

Environmental Parameters and Statistical Analysis Results

Descriptive statistics and temporal distribution of the short time series for environmental parameters and total suspended solids (TSS) in the surface water of the Dardanelles in the winter period of 02 December 2004 and 07 March 2005 are displayed in Table 1 and Figures 2 and 3. Moreover, Pearson correlation coefficients among different bio-physicochemical data groups in surface waters of Kepez Harbor in the Dardanelles in the winter period are listed in Table 2.

Temperature and salinity varied between 7.01 and 13.72°C (mean 9.47±1.90°C) and between 26.43 and 29.22 ppt (mean 27.5±0.60 ppt), respectively (Table 1). Due to vertical mixing between two-layer flows in the Dardanelles, salinity was variable like in the temporal temperature variations during the winter sampling period (Figure 2). Additionally, December and February-March salinity values were higher than the January values (Figure 2). Although temporal cycle of pH showed some fluctuations throughout the year (min-max: 7.36-8.77; mean: 8.12±0.40) like in the salinity and TDS; Pearson correlation results between salinity with pH (r=0.618) and TDS with pH (r=0.579) was supported with the correlation coefficient results (Table 2).

Dissolved oxygen (DO) concentrations varied from 6.64 to 12.35 mg L^{-1} (mean: 9.23±1.23) during

Figure 1. Satellite image of the Dardanelles and sampling station (D-KH: 40°06'20" N - 26°22'41" E).

Table 1. Descriptive statistics of some physicochemical parameters in short time intervals (4-5 days) in surface waters of Kepez harbor in the Dardanelles in the winter period of 02 December 2004 and 07 March 2005

Physicochemical Parameters	N	Min	Max	Mean	SD
Temperature (°C)	21	7.010	13.72	9.466	1.901
Salinity	21	26.43	29.22	27.51	0.596
pH	21	7.360	8.770	8.124	0.397
TDS (g L^{-1})	21	27.20	29.37	27.86	0.496
DO (mg L^{-1})	21	6.640	12.35	9.229	1.225
PO^{-3}_4 (µM)	21	0.070	0.570	0.233	0.129
NO^-_2+NO^-_3 (µM)	21	0.100	1.970	0.427	0.420
SiO_4 (µM)	21	0.860	11.24	2.905	2.576
Chlorophyll a (µg L^{-1})	21	0.480	2.600	1.919	0.472
TSS (mg L^{-1})	21	9.400	140.1	27.13	36.61
N:P Ratios	21	0.620	3.590	1.780	1.000
Si:P Ratios	21	4.110	53.94	14.92	12.83

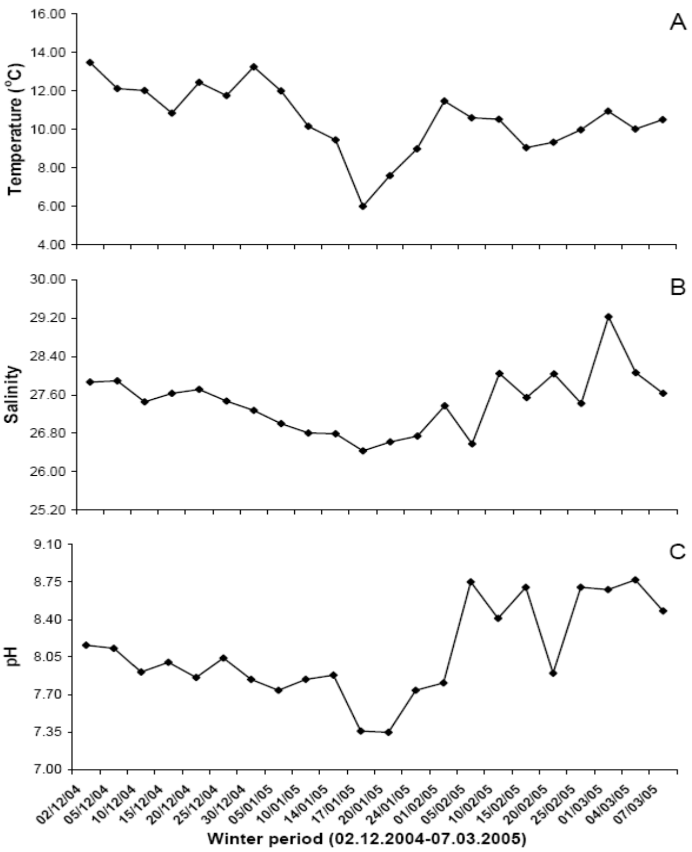

Figure 2. Short time variations of temperature (A), salinity (B) and pH (C) in surface waters of Kepez Harbor in the Dardanelles in the winter period of 02 December 2004 and 07 March 2005.

the year (Table 2), being lower on 25 December and 24 January compared to other sampling dates (Figure 3). However, DO was super saturated at 02 December 2004 (Figure 3) due to powerful vertical mixture effected by two counter flow systems from time to time in the study area. Total temporal dissolved solids (TDS) variations were similar to the temporal salinity variations (Figure 2) and this similarity was supported by the correlation coefficient between TDS and salinity (r=0.989) (Table 2). The December and January TDS values were lower than the February and March values like in the salinity values in the same period (Figure 3).

Total suspended solid (TSS) varied between 9.40 and 140.1 mg L^{-1} (mean: 27.13±36.61 mg L^{-1}) during the winter period (Table 2). Due to high terrestrial inputs by Kepez Stream in the period of heavy precipitation, TDS values were higher (95.7-140.1 mg L^{-1}) in early winter times between 10 and 20 December 2004 than other winter time (9.40-18.7 mg

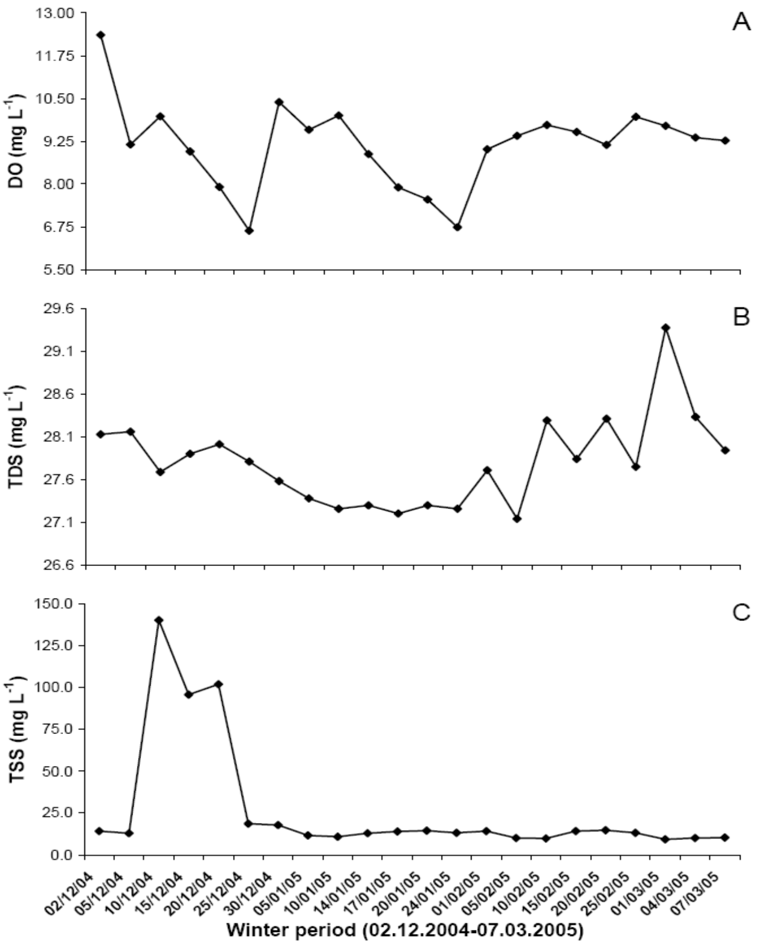

Figure 3. Short time variations of dissolved oxygen (DO) (A), total dissolved solids (TDS) (B) and total suspended solids (TSS) (C) in surface waters of Kepez Harbor in the Dardanelles in the winter period of 02 December 2004 and 07 March 2005.

Table 2. Pearson correlation coefficients between different bio-physicochemical data groups in short time intervals (4-5 days) in surface waters of Kepez harbor in the Dardanelles in the winter period of 02 December 2004 and 07 March 2005 (N: 21, Sig. 2-tailed)

	Temp.	Salin.	pH	TDS	DO	PO^{-3}_4	NO^-_2 $+NO^-_3$	SiO_4	Chl-a	TSS	Dinop	Bacil.	Other Groups	Tot. Phyto
Temp.	1													
Salin.	-0.037	1												
pH	-0.458*	0.618**	1											
TDS	-0.053	0.989**	0.579**	1										
DO	0.230	0.291	0.317	0.236	1									
PO^{-3}_4	-0.372	0.260	0.288	0.295	0.142	1								
$NO^-_2+NO^-_3$	-0.465*	-0.064	0.025	-0.051	-0.124	0.752**	1							
SiO_4	0.476*	0.279	0.092	0.310	0.405	0.098	-0.123	1						
Chl-a	0.082	0.305	0.040	0.312	0.073	-0.019	-0.070	0.196	1					
TSS	0.413	0.026	-0.239	0.006	-0.063	-0.252	-0.273	0.110	-0.405	1				
Dinoph	0.234	-0.104	-0.149	-0.130	0.317	0.078	0.102	0.010	0.579**	-0.201	1			
Bacil.	-0.317	-0.408	-0.116	-0.389	0.014	0.523*	0.528*	-0.256	0.726**	-0.373	0.369	1		
Other Groups	0.312	0.303	0.011	0.286	0.187	0.073	0.069	0.317	0.514**	-0.218	0.150	-0.060	1	
Total Phyto	-0.028	-0.165	-0.111	-0.164	0.173	0.453*	0.459*	-0.020	0.942**	-0.440*	0.551**	0.798**	0.529*	1

* Correlations are significant at 0.05 level (2-tailed).
** Correlations are significant at 0.01 level (2-tailed).

L^{-1}) (Figure 3). Due to the high terrestrial inputs, there was not any positive correlation between TSS and total phytoplankton. Moreover, this relationship was negative (r=-0.440). This situation was slightly supported by positive correlation between silicate and TSS (r=0.110) (Table 2).

Temporal Distribution of Nutrients

Results of descriptive statistics of N:P and Si:P ratios and distribution of nutrients (PO^{-3}_4, NO^-_2+NO^-_3 and SiO_4) and chlorophyll *a* in short time intervals in the Dardanelles in the winter period are shown in Table 2 and Figure 4, respectively.

Due to winter phytoplankton blooms, both N:P (min-max: 0.62-3.59; mean: 1.78±1.00) and Si:P ratios (min-max: 4.11-53.94; mean: 14.92±12.83) were significantly lower (Table 2) than both the assimilatory optimal Redfield ratios and previous N:P and Si:P values in the Dardanelles (Turkoglu *et al.*, 2004a). Naturally, the study system is nitrogen limited and low N:P ratios in this study confirmed previously reported values of Polat *et al.* (1998) and Turkoglu *et al.* (2004a).

Concentrations of PO^{-3}_4, NO^-_2+NO^-_3 and SiO_4 varied between 0.07 and 0.57 (mean: 0.23±0.13 µM), 0.10 and 1.97 (mean: 0.43±0.42 µM) and 0.86 and 11.24 µM (mean: 2.91±2.58 µM), respectively, in the surface waters of the Dardanelles (Table 2). PO^{-3}_4 showed more fluctuations than those in NO^-_2+NO^-_3 and SiO_4 during the winter sampling period (Figure 4). Additionally, the time of peak in PO^{-3}_4 was similar to NO^-_2+NO^-_3. High correlation between PO^{-3}_4 and NO^-_2+NO^-_3 (r=0.752) (Table 2) revealed that both are roughly effected by similar nutrient sources. Contrary to NO^-_2+NO^-_3 and PO^{-3}_4, SiO_4 showed a regular distribution, except in the period of 02-20 December 2004. Nevertheless, SiO_4 concentrations revealed high variations like in other nutrients due to high bio-physicochemical fluctuations in the system (Figure 4).

Temporal Distribution of Winter Phytoplankton

Descriptive statistics in cell density of different taxonomic groups of phytoplankton are revealed in Table 3. Temporal distributions in density of different phytoplankton groups in surface waters of Kepez Harbor in the Dardanelles in the winter period are also shown in Figure 5.

Although there were dramatic changes due to various algal blooms during the winter period, phytoplankton abundance in January (5.03E+05-

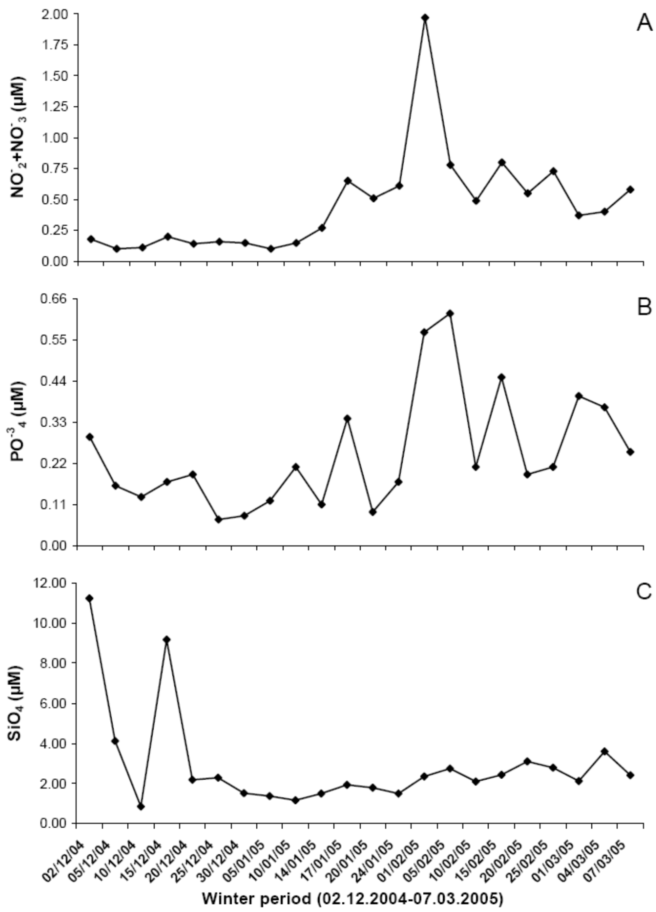

Figure 4. Short time variations of NO^-_2+NO^-_3 (A), PO^{-3}_4 (B) and SiO_4 (C) in surface waters of Kepez harbor in the Dardanelles in the winter period of 02 December 2004 and 07 March 2005.

Table 3. Descriptive statistics of cell density of different phytoplankton taxonomic groups in short time intervals (4-5 days) in surface waters of Kepez Harbor in the Dardanelles in the winter period of 02 December 2004 and 07 March 2005

	Phytoplankton Cell Density (Cells L^{-1})				
Taxonomic Groups	N	Min	Max	Mean	SD
Cyanophyceae	21	0.00E+00	6.88E+05	8.93E+04	1.95E+05
Dinophyceae	21	4.71E+04	7.54E+05	3.62E+05	2.33E+05
Prynesiophyceae	21	0.00E+00	2.36E+06	2.38E+05	6.25E+05
Dictyochophyceae	21	0.00E+00	2.36E+05	8.89E+04	8.47E+04
Bacillariophyceae	21	0.00E+00	3.06E+06	8.92E+05	9.45E+05
Euglenophyceae	21	0.00E+00	5.89E+04	1.30E+04	1.48 E+04
Total Phytoplankton	21	8.25E+04	4.71E+06	1.68E+06	1.24E+06

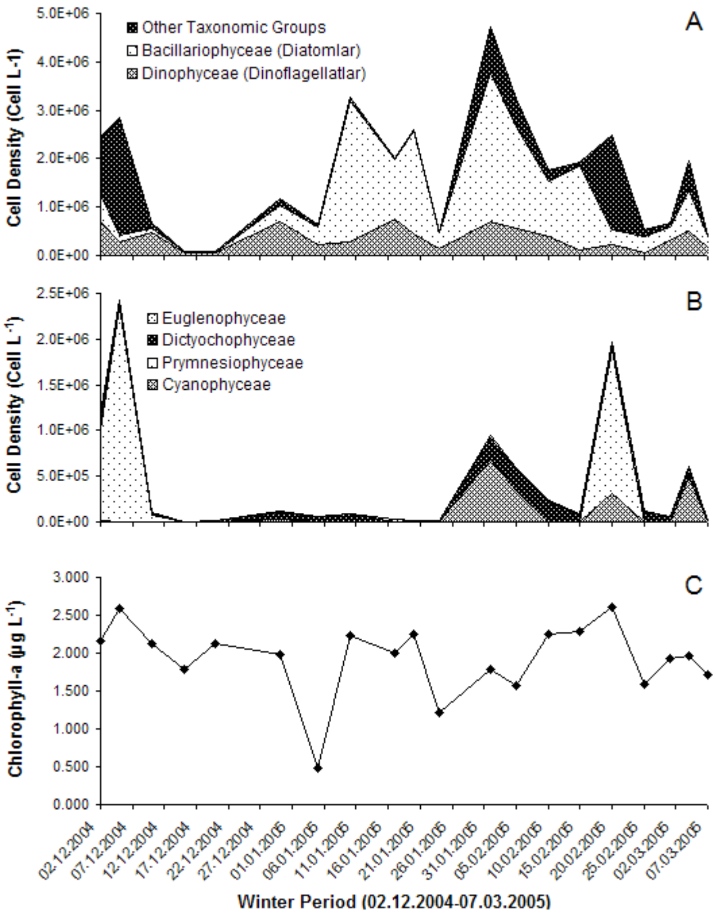

Figure 5. Short time variations of percent contributions of Bacillariophyceae, Dinophyceae and other taxonomic groups (Cyanophyceae, Prymnesiophyceae, Dictyochophyceae and Euglenophyceae) to total phytoplankton (A), Cyanophyceae, Prymnesiophyceae, Dictyochophyceae and Euglenophyceae to total other taxonomic groups (B) and chlorophyll a (C) in surface waters of Kepez harbor in the Dardanelles in the winter period of 02 December 2004 and 07 March 2005.

3.26E+06 Cells L^{-1}) and February (5.19E+05-4.71E+06 Cells L^{-1}) was higher than in December (8.25E+04-2.84E+06 Cells L^{-1}) and in March (4.09E+05-1.96E+06 Cells L^{-1}) (Figure 5). These dramatic fluctuations of different taxonomic groups were confirmed that relationships between PO^{-3}_4 and diatoms (r=0.523), between PO^{-3}_4 and total phytoplankton (r=0.453), between NO^-_2+NO^-_3 and diatoms (r=0.528) and between NO^-_2+NO^-_3 and total phytoplankton (r=0.459) were important (Table 2). Although the largest contribution to total phytoplankton abundance was by diatoms (Bacillariophyceae) during January (3.61E+05-2.90E+06 Cells L^{-1}) and February (3.14E+05-3.06E+06 Cells L^{-1}), contribution of diatoms decreased in other period (4.71E+04-8.49E+05 Cells L^{-1}). However, dinoflagellates (Dinophyceae) showed regular fluctuations at 15 day intervals and varied between 4.71E+04 and 7.54E+05 Cells L^{-1} during the winter period (Figure 5).

Of other taxonomic groups, although Prymnesiophyceae (i.e., coccolithophore *Emiliania* *huxleyi* (Lohmann) Hay and Mohler, 1967) showed two peaks in early December (02 Dec.04; 2.36E+06 Cells L^{-1}) and late February (20 Feb.05; 1.57E+06 Cells L^{-1}), there was not any coccolithophore production in other periods. Although Cyanophyceae (coccoid cyanobacteria) varied between 0.00E+00 and 2.36E+04 Cells L^{-1} during December 2004-January 2005, they showed three peaks in different importance in early February (01 Feb.05; 6.88E+05 Cells L^{-1}), late February (20 Feb.05; 3.14E+05 Cells l^{-1}) and early March (04 March 05; 4.87E+05 Cells L^{-1}), respectively (Figure 5). Except a period of no production in samplings of 15 December 2004 and 16 January 2005; Dictiyochophyceae (silicoflagellates) varied between 7.86E+03 and 2.36E+05 Cells L^{-1} (mean: 8.89E+04 ± 8.47E+04 Cells L^{-1}) during the winter period. Another taxonomic group, Euglenophyceae varied between 0.00E+00 and 5.89E+04 Cells L^{-1} (mean: 1.30E+04 ± 1.48E+04 Cells L^{-1}) (Table 3 and Figure 5).

Contributions of Dinophyceae, Bacillariophyceae and other taxonomic groups to total phytoplankton have varied between 6.10 and 76.19% (mean 30.91±20.69%), between 0.00 and 89.02% (mean 48.76±26.74%), between 0.00 and 82.99% (mean 5.08±9.52%), respectively (Table 4). Furthermore, contributions of other taxonomic groups such as Cyanophyceae, Prymnesiophyceae, Dictyochophyceae and Euglenophyceae to the total phytoplankton have particularly been presented in Table 4 and 5. These contribution levels of different taxonomic groups to total phytoplankton have also been confirmed by relationships between dinoflagellates and total phytoplankton (r=0.551), diatoms and total phytoplankton (r=0.798), other taxonomic groups and total phytoplankton (r=0.529).

Phytoplankton Chlorophyll *a*

Phytoplankton chlorophyll *a* values varied between 0.480 and 2.600 µg L^{-1} (mean 1.919±0.472 µg L^{-1}) in the surface waters of the Dardanelles during the winter period (Table 2). The temporal distribution of chlorophyll *a* is shown in Figure 5-C. High winter chlorophyll *a* values ranged from 1.792 to 2.588 µg L^{-1} in December, from 0.480 to 2.253 µg L^{-1} in January, from 1.568 to 2.600 µg L^{-1} in February, and from 1.706 and 1.959 µg L^{-1} in early March (Figure 5). Chlorophyll *a* was highly correlated with Bacillariophyceae (r=0.726) than Dinophyceae (r=0.579) and the other taxonomic groups (r=0.514) (Figure 5 and Table 2). However, relationship between chlorophyll *a* and total phytoplankton was more important (r=0.942) than relationships between chlorophyll *a* and different phytoplankton taxonomic groups (Table 2). However, although there was important positive correlation between chlorophyll *a* and phytoplankton, there was negative correlation between chlorophyll *a* and PO^{-3}_4 (r=-0.019), that is, while PO^{-3}_4 was decreasing, chlorophyll *a* was increasing (Table 2).

Contributions of Taxonomic Groups to Total Phytoplankton and of Some Species to Their Taxonomic Groups

Contributions of taxonomic groups to total phytoplankton and of some species to their taxonomic groups are presented in Table 5.

Table 5 revealed that the major contributions to total phytoplankton were from dinoflagellates *Heterocapsa triquetra* (Ehrenberg, 1840) Stein, 1883, *Prorocentrum* spp. (*Prorocentrum micans* Ehrenberg, 1834, *Prorocentrum minimum* (Pavillard, 1916) Schiller, 1931, *Prorocentrum scutellum* Schröder, 1900, *Prorocentrum triestinum* Schiller, 1918), *Ceratium* spp. (*Ceratium furca* (Ehrenberg, 1834) Claparède et Lachmann, 1859, *Ceratium fusus* (Ehrenberg, 1834) Dujardin, 1841), *Scrippsiella trochoidea* (Stein, 1883) Loeblich III, 1976, *Protoperidinium* spp. (*Protoperidinium longipes* (Jørgensen, 1899) Balech, 1974), *Podolampas elegans* Schütt, 1895, *Dinophysis* spp. (*Dinophysis caudata* Saville-Kent, 1881 and *Dinophysis acuminata* Claparède & Lachmann, 1859), *Protoceratium reticulatum* (Claparède et Lachmann, 1859) Bütschli, 1885, diatoms *Chaetoceros* spp., *Climacosphenia* spp., *Coscinodiscus* spp., *Cylindrotheca closterium* (Ehrenberg) Reiman and Lewin, 1964, *Grammatophora marina* (Lyngbye) Kützing, 1844, *Hemiaulus hauckii* Grunow in Van Heurck, 1882, *Leptocylindrus danicus* P.T. Cleve,

Table 4. Descriptive statistics of contributions of different taxonomic groups to total phytoplankton cell density in short time intervals (4-5 days) in surface waters of Kepez Harbor in the Dardanelles in the winter period of 02 December 2004 and 07 March 2005

Taxonomic Groups	Ratios (%)				
	N	Min	Max	Mean	SD
Cyanophyceae	21	0.00	24.80	3.110	6.710
Dinophyceae	21	6.10	76.19	30.91	20.69
Prynesiophyceae	21	0.00	82.99	9.410	23.15
Dictyochophyceae	21	0.00	24.24	7.130	7.390
Bacillariophyceae	21	0.00	89.02	48.76	26.74
Euglenophyceae	21	0.00	2.400	0.680	0.810

Table 5. Contributions of different taxonomic groups to total phytoplankton and of some important species to related taxonomic groups in short time intervals (4-5 days) in surface waters of Kepez Harbor in the Dardanelles in the winter period of 02 December 2004 and 07 March 2005

Date D/M/Y	Dinop %	Important Species in Dinophyceae (%)	Bacil. (%)	Important Species in Bacillariophyceae (%)	Other (%)	Important Species in Other Taxonomic Groups (%)
02.12.04	28.80	*H. triquetra* (11.5%), *P. micans* (6.2%)	22.40	*D. fragilissimus* (15.4%)	48.80	*E. huxleyi* (38.5%), *Dictyocha* spp. (5.4%)
05.12.04	9.96	*H. triquedra* (5.5%), *P. micans* (2.7%)	4.43	*D. fragilissimus* (2.2%)	85.62	*E. huxleyi* (81.9%)
10.12.04	72.09	*H. triquetra* (14.9%), *P. micans* (38.3%)	11.63	*Coscinodiscus* spp., *Navicula* spp., *D. fragilissimus*, *T.nitzschioides* (11.6%)	16.28	*E. huxleyi* (10.9%), Euglenaphyceae (2.2%)
15.12.04	50.00	*P. minimum*, *Protoperidinium* spp., *S. trochoidea* (50.0%)	50.00	*G. marina*, *D. fragilissimus*, *T. longissima* (50.0%)	0.00	
20.12.04	76.19	*Prorocentrum* spp. (38.09%), *P. elegans* (19.05%), S. *trochoidea* (19.05%)	0.00		23.81	*D. fibula* var. *messanensis* (23.81%)
25.12.05	34.73	*P. micans* (23.95%)	44.31	*C. closterium*, *L. danicus*, *Hemiaulus* spp., *P. pungens* (40.7%)	20.96	*Dictyocha* spp. (20.96%)
30.12.04	60.81	*P. micans* (38.5%), *P. minimum*, *P. triestinum* (12.2%)	28.38	*Pseudonitzschia* spp.(12.2%), *C.closterium*, *Coscinodiscus* spp., *Synedra* spp. (14.2%)	10.81	*D. fibula* var. *messanensis* (3.38%), *D. speculum* (3.38%)
05.01.05	33.33	*P. micans* (15.2%), *P. scutellum*, *P. triestinum* (9.1%)	57.58	*Pseudonitzschia pungens* (45.5%)	9.09	*Dictyocha* spp. (9.09%)
10.01.05	8.66	*C. fusus*, *D. caudata* (1.4%), *Prorocentrum* spp. (6.5%)	88.81	*Pseudonitzschia pungens* (54.2%), *C. closterium* (8.7%), *Climachosphenia* spp. 11.6%)	2.53	*Dictyocha* spp. (2.53%)
14.01.05	37.65	*C. furca* (4.7%), *P. micans* (20.0%), *P. triestinum* (7.1%)	61.18	*Leptocylindrus* spp. (10.6%), *Licmophora* spp. (5.9%), *P. pungens* (29.4%)	1.18	Euglenaphyceae (1.18%)
17.01.05	17.48	*Ceratium* spp. (2.3%), *Prorocentrum* spp. (12.6%), *Prt.longipes* (2.1%)	81.80	*Cheatoceros* spp. (35.5%), *P. pungens* (35.6%), *Climachosphenia* spp.(6.4%)	0.71	*D. speculum* (0.71%)
24.01.05	25.00	*Ceratium* spp. (6.3%), *Prorocentrum* spp. (15.6%), *Prt.longipes* (3.1%)	71.88	*Cheatoceros* spp. (37.5%), *P. pungens* (15.6%), *Climachosphenia* spp.(6.3%)	3.13	*D. speculum* (3.13%)
01.02.05	15.00	*C. furca* (1.3%), *P. micans* (9.2%), *P. triestinum* (7.1%)	65.00	*T. nitzschioides* (20.8%), *L. abbreviata* (11.7%), *T. frauenfeldii* (6.3%)	20.00	Cyanobacteria (14.6%), *D. polyactis* (5.0%), Euglenaphyceae (0.4%)
05.02.05	16.99	*C. furca* (2.4%), *P. micans* (7.2%), *P. triestinum* (4.4%)	64.81	*T. nitzschioides* (24.6%), *L.abbreviata* (10.5%), *T. frauenfeldii* (7.7%)	18.20	*D. polyactis* (17.8%), Euglenaphyceae (0.4%)
10.02.05	22.32	*Prorocentrum* spp. (14.3%), *C. fusus* (4.5%)	64.29	*T.nitzschioides* (28.6%), *Pseudonitzschia spp.* (8.0%)	13.39	Dictyocha polyactis (9.8%)
15.02.05	6.10	*Prorocentrum spp.* (3.66%), *Ceratium spp.* (1.2%), *S.trochoidea* (1.2%)	89.02	*Pseudonitzschia* spp. (37.8%), *T. nitzschioides* (18.3%), *Chaetoceros* spp. (8.5%), *N. longissima* (6.1%)	4.88	*Dictyocha polyactis* (3.7%), Euglenophyceae (1.2%)
20.02.05	8.81	*Prorocentrum* spp.(5.04%), *Ceratium* spp. (1.3%)	12.58	*Leptocylindrus* spp. (6.29%), *Licmophora* spp. (2.52%)	78.62	Cyanophyceae (12.6%), *E. huxleyi* (62.9%)
25.02.05	12.12	*D. acuminata*, *P. micans*, *P. reticulatum*, *S. trochoidea* (12.12%)	63.64	*Leptocylindrus* spp. (33.3%), *Licmophora* spp. (15.2%)	24.24	*Dictyocha* spp.(24.24%)
01.03.05	45.24	*P. micans* (16.7%), *S.trochoidea* (4.76%)	45.24	*Licmophora* spp. (19.0%), *C. closterium* (%7.14)	9.52	Dictyocha spp.(9.52%)
04.03.05	25.60	*Prorocentrum* spp. (13.9%), *Ceratium* spp. (3.1%), *Protoperidinium* spp. (3.1%)	43.20	*Leptocylindrus* spp. (17.7%), *Licmophora* spp. (11.5%), *Chaetoceros* spp. (3.1%)	31.20	Cyanophyceae (23.9%), Dictyochophyceae (4.6%), Euglenaphyceae (1.5%)
07.03.05	42.31	*Prorocentrum* spp. (30.8%), *Protoperidinium* spp. (7.7%),	53.85	*Licmophora* spp. (15.4%), *Leptocylindirus* spp. (11.5%),	3.85	*D. polyactis* (3.85%)

1889, *Licmophora* spp., *Navicula* spp., *Nitzschia longissima* (Brébisson in Kützing) Ralfs in Pritchard, 1861, *Pseudo-nitzschia pungens* (Grunow ex P.T. Cleve) Hasle, 1993, *Dactyliosolen fragilissimus* (Bergon) G. R. Hasle, 1991, *Synedra* spp., *Thalassionema nitzschioides* (Grunow, 1862) Van Heurck, 1896, *Thalassiothrix longissima* P.T. Cleve & Grunow, 1880, *Thalassionema frauenfeldii* (Grunow) Hallegraeff, 1986, coccolitophore *Emiliania huxleyi* (Lohmann) Hay & Mohler, 1967, coccoid cyanobacteria and silicoflagellate *Dictyocha* spp. (*Dictyocha polyactis* Ehrenberg, *Dictyocha fibula* var. *messanensis* (Haeckel in Peters) Lemmermann, 1908, *Dictyocha speculum* Ehrenberg, 1839) in surface waters of Kepez Harbor in the Dardanelles (Table 5).

Discussion

In this study, we tried to explore nutrient, phytoplankton interactions with respect to environmental parameters in the Dardanelles during the winter period (02 December 2004 -07 March 2005).

Temperature and salinity results showed that there were some fluctuations in their temporal variations, especially in period of late January and early March, due to intense vertical mixing of the two counter flows in the Dardanelles (Figures 2 and 3). In a previous study by Turkoglu *et al*. (2006), temperature and salinity measurements showed high variability at the southern part of the Kilitbahir in the Dardanelles. The narrowing of the Dardanelles leads to different temperature and salinity values to the northeast and southwest of the Narrows between Kilitbahir and Canakkale. Temperature along the southeast coasts of the Narrows (between Kilitbahir and Canakkale) is also lower than the other coasts of the Dardanelles due to upwelling and especially fresh water discharges from the rivers such as Saricay, Kalabakli and Karamenderes to surface layer (0-10 m) in early spring period. The surface waters in the southern part of the Dardanelles are also more saline especially in the spring and winter seasons compared to other seasons (Turkoglu *et al*., 2006; Turkoglu, 2008). Additionally, salinity variations effect behavior characters of the other bio-physicochemical variations due to different character of the lower layer waters. For instance, correlations between salinity and other physicochemical parameters indicated that TDS (r=0.989) and pH (r=0.618) were strongly affected by salinity variations (Table 2). It is known that TDS comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and some small amounts of organic matter that are dissolved in water. In other words, TDS concentration is the sum of the cations (positively charged) and anions (negatively charged), and ions in the water. Therefore, there is a high positive correlation between salinity and TDS due to the high NaCl in marine systems. pH can also be affected by higher salinity which tends to buffer pH in the 7-8 range and extensive algal blooms which can raise the pH over 8 in low-salinity waters (MD DNR, 2006) like in surface waters of the Dardanelles (Turkoglu *et al*., 2006; Turkoglu, 2008).

Besides the temporal variations in the nutrient concentrations, especially the southern part of the Dardanelles receives notable nutrient inputs due to domestic wastes from the city of Canakkale and from the rivers such as Saricay and Kalabakli (Polat and Tugrul, 1996; Polat *et al*., 1998; Turkoglu *et al*., 2004b, 2004c, 2006; Turkoglu, 2008). Therefore, in some periods of this study, extra accumulation of inorganic nutrients was highly pronounced. Additionally, the observed maximum values in different periods were principally due to entrainment of the inorganic nutrient-enriched salty Mediterranean waters from the lower layer by intense vertical mixing with the western basin surface layer. In fact, it has been shown that nutrient concentrations encountered in the Mediterranean waters are controlled by the exchanges at the straits (Besiktepe *et al*., 1994). On the other hand, during its passage through the Dardanelles, the Black Sea surface water outflow loses much of its nutrients via utilization and vertical loss (Polat and Tugrul, 1996). Additionally, the salty Mediterranean inflow to the Marmara deep basin via the Dardanelles contains low nutrient concentrations (Polat and Tugrul, 1996).

Correlations between PO^{-3}_4 and Bacillariophyceae (r=0.523), between PO^{-3}_4 and total phytoplankton (r=0.453) were similar to correlations between NO^-_2+NO^-_3 and Bacillariophyceae (r=0.528), NO^-_2+NO^-_3 and total phytoplankton (r=0.459) in the system. Additionally, there was an important positive correlation between PO^{-3}_4 and NO^-_2+NO^-_3 (r=0.752). This may indicate that both PO^{-3}_4 and NO^-_2+NO^-_3 come from same sources such as lower layer waters of the Aegean Sea rich in nutrient and terrestial sources which affected by human activity.

The chlorophyll *a* concentrations ranged from 0.480 to 2.600 µg L^{-1} (1.919±0.472 µg L^{-1}) during low and high productive periods, respectively. The observed early January (10 Jan. 05) and early February (01 Feb. 05) maxima were principally due to diatoms *P. pungens*, *T. nitzschioides* and *Chaetoceros* spp. blooms in the study area. Despite minimum values of 0.480 at 05 January 2005, average chlorophyll *a* concentration was very close to the 2.00 µg L^{-1} (1.919 µg L^{-1}) during the winter period. High chlorophyll *a* and phytoplankton showed that the Dardanelles had high eutrophication structure in the winter period. Chlorophyll *a* values in this study were higher than winter 2002 chlorophyll *a* values in the southern area of the Dardanelles (Turkoglu *et al*., 2004b), in the Aegean Sea (Kucuksezgin *et al*., 1995) and in other parts of the Mediterranean Sea (Salihoglu *et al*., 1990). However, the values were lower than winter values in northern area of the Dardanelles (Turkoglu *et al*., 2004c) and winter values in Sea of Marmara (Tugrul *et al*., 1986; Polat *et al*., 1998). Similar to the variations in the physicochemical conditions and the nutrients, chlorophyll *a* concentrations were also affected by the counter flows in the Dardanelles.

High phytoplankton cell density and high nutrient concentrations especially phosphate in the winter period in January and February showed that Dardanelles can be eutrophicated from time to time, comparable to the levels found in the Black Sea (Turkoglu, 1999; Turkoglu and Koray, 2000, 2002, 2004; Turkoglu, 2005; Demircan and Turkoglu, 2006) and Sea of Marmara (Polat and Tugrul, 1995, 1996). Phytoplankton community structure in the winter period was observed to be controlled by 4 diatoms (*P. pungens*, *T. nitzschioides* and *Chaetoceros* spp., *L.* danicus) and 3 dinoflagellate species (especially *C. fusus*, *C. furca*, *P. micans*) in the Dardanelles, as was shown in eutrophicated ecosystems such as the Sinop

Bay in the Black Sea (Turkoglu and Koray, 2000, 2002, 2004; Turkoglu, 2005) and Iskenderun Bay in the eastern Mediterranean (Polat *et al*., 2000). Other species can be considered as accessory species that do not cause significant fluctuations in the phytoplankton production as shown by many researchers (Pielou, 1975; Lukatelich and McComb, 1986; Turkoglu, 1999). This study showed that the relationship between Bacillariophyceae and chlorophyll *a* (r=0.726) was more important than the relationship between chlorophyll *a* and Dinophyceae cell density (r=0.579) and between chlorophyll *a* and other taxonomic groups (r=0.514). These relationships showed that chlorophyll *a* was highly controlled by cell density of Bacillariophyceae species than those of Dinophyceae and other taxonomic groups in the winter period.

Due to coastal structure of study area and high terrestrial inputs by Kalabakli, Kepez and Sarıçay stream, high TSS values (9.40 and 140.1 mg L^{-1}; mean 27.13±36.61 mg L^{-1}) were found in the Dardanelles during the winter period. Therefore, these high TSS values were not related with phytoplankton and this was supported by a negative correlation coefficient between TSS and phytoplankton (r=-0.440).

Conclusion

In result of this study, this short time series data allowed us to understand short time variations in phytoplankton and chlorophyll *a* in relation to nutrients and other environmental parameters in surface waters of the Dardanelles and gave us a synopsis of the coastal ecosystem. Additionally, we revealed that contributions of dinoflagellates (30.9%) and diatoms (48.76%) to total phytoplankton cell density in the Dardanelles in the winter period were similar to other eutrophic coastal ecosystems of Turkish seas such as the southern Black Sea (Uysal and Sur, 1995; Turkoglu, 1999; Turkoglu and Koray, 2002), Izmir Bay (Koray, 1995) and Sea of Marmara (Uysal, 1995). It is known that while contributions of Bacillariophyceae to total phytoplankton were gradually decreasing, contributions of other taxonomic groups to total phytoplankton were gradually increasing in marine systems due to terrestial inputs. We revealed that this situation was connected with the process of eutrophication in reason of a shift in the rational differences between major taxonomic groups due to high terrestrial discharges coming from the Black Sea surface waters via strait systems and international carrying activities by vessels in the Dardanelles.

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References

APHA, 2005. Standard Methods for the Examination of Water and Wastewater. American Public Health Association (APHA) Press, Washington D.C., 1368 pp.

Baba, A., Türkoğlu, M., Özcan, H. and Deniz, O. 2005. Investigation of discharge of fresh water in the Çanakkale Strait (Dardanelles, Turkey). Environmental Security in Harbour and Coastal Areas: Managent Using Comparative Risk Assesment and Multi-criteria Decision Analysis, NATO Advance Research Workshop, Thessaloniki, Greece.

Besiktepe, S., Sur, H.I., Ozsoy, E., Latif, M.A., Oguz, T. and Unluata, U. 1994. The circulation and hydrography of the Marmara Sea. Progress in Oceanography, 34: 285-334.

Cupp, E.E. 1977. Marine Plankton Diatoms of the West Coast of North America. University of California Press, Berkeley and Los Angeles, 237 pp.

Demircan, N.T. and Turkoglu, M. 2006. Diurnal Variations in Phytoplankton Density in Winter in the Southern Black Sea (Sinop Bay). E.U. Journal of Fisheries and Aquatic Sciences, 23: 57-60.

Eker, E. and Kıdeys, A.E. 2000. Weekly Variations in Phytoplankton Structure of a Harbour in Mersin Bay (north-eastern Mediterranean). Turkish Journal of Botany, 24: 13-24.

Guillard, R.R.L. 1978. Counting slides. A. Sournia (Ed.), Phytoplankton Manual, Unesco, Paris: 182-189.

Hasle, G.R. 1978. Using the inverted microscope. In: A. Sournia (Ed.), Phytoplankton Manual, Unesco, Paris: 191-196.

Koray, T. 1995. Phytoplankton species succession, diversity and nutrients in neritic waters of the Aegean Sea (Bay of Izmir), Turkish Journal of Botany, 19: 531-544.

Kuçuksezgin, F., Balci, A., Kontas, A. and Altay, O. 1995. Distribution of nutrients and chlorophyll a in the Aegean Sea, Oceanologica Acta, 18: 343-352.

Lukatelich, R.J. and McComb, A.J. 1986. Nutrient levels and the development of diatom and blue-green algal blooms in a shallow Australian estuary. Journal of Plankton Research, 8: 597-618.

McAleece, N., Lambshead, P.J.D., Paterson, G.L.J. and Gage, J.D. 1999. Biodiversity Pro. A program research for ecological data. [Accessed March 09, 2005], http://www.nrmc.demonco.uk

MD, DNR, 2006. "Continuous Monitoring," Maryland Department of Natural Resources [Accessed March 09, 2010], http://mddnr.chesapeakebay.net/newmontech/contmon/index. cfm.

Pielou, E.C. 1975. Ecological Diversity. Wiley and Sons, New York, 165 pp.

Polat, S.C. and Tugrul, S. 1995. Nutrient and organic carbon exchanges between the Black and Marmara seas through the Bosphorus strait, Continental Shelf Research, 15: 1115-1132.

Polat, S.C. and Tugrul, S. 1996. Chemical exchange between the Mediterranean and Black Sea via the Turkish strait. Bulletin Institute Oceanograhy, 17: 167-186.

Polat, S.C., Tugrul, S., Coban, Y., Basturk, O. and Salihoglu, I. 1998. Elemental composition of seston and nutrient dynamics in the Sea of Marmara. Hydrobiologia, 363: 157-167.

Polat, S., Sarihan, E. and Koray, T. 2000. Seasonal Changes in the Phytoplankton of the Northeastern Mediterranean (Bay of Iskenderun). Turkish Journal of Botany, 24: 1–12.

Salihoglu, I., Saydam, C., Bastürk, O., Yilmaz, K., Gocmen, D., Hatipoglu, E. and Yilmaz, A. 1990. Transport and distribution of nutrients and chlorophyll a by mesoscale eddies in the Northeastern Mediterranean. Marine Chemistry, 29: 375-390.

SPSS Advanced statistics™ 11.5., 2003. SPS Inc. Chicago, IL.

Strickland, J.D.H. and Parsons, T.R. 1972. A Practical handbook of seawater analysis. Fisheries Research Board of Canada Bulletin, Canada, 310 pp.

Tregouboff, G. and Rose, M. 1957. Manuel de Planctonologie Mediterraneenne: Texte et Illustrationes. Centre National De la Resherche Scientifique I-II, Paris, 587 pp.

Tugrul, S., Sunay, M., Basturk, O. and Balkas, T.I. 1986. The Izmit Bay Case Study. In: G. Kullenberg (Ed.), The role of the oceans as a waste disposal option, NATO ASI Series, Boston: 243-274.

Turkoglu, M. 1999. Some fluctuations in phytoplankton community structures of the Black Sea. E.U. Journal of Fisheries and Aquatic Sciences, 16(1-2): 201-217.

Turkoglu, M. and Koray, T. 2000. Ecological and geographical distribution of the planktonic protista in the southern parts of the Black Sea (neritic waters of Sinop peninsula, Turkiye). E.U. Journal of Fisheries and Aquatic Sciences, 17(1-2): 161-178.

Turkoglu, M. and Koray, T. 2002. Phytoplankton species succession and nutrients in the Southern Black Sea (Bay of Sinop). Turkis Journal of Botany, 26 (4): 235-252.

Turkoglu, M., Unsal, M., Işmen, A., Mavili, S., Sever, T.M., Yenici, E., Kaya, S. and Çoker, T. 2004a. Dinamic of lower and high food chain of the Dardanelles and Saros Bay (North Aegean Sea). TUBITAK-ÇAYDAG Technical Final Report, No: 101Y081, Çanakkale, Turkey, 313 pp.

Turkoglu, M., Yenici, E., Ismen, A. and Kaya, S. 2004b. Variations of Nutrient and Chlorophyll a in the Canakkale Strait (Dardanelles). E.U. Journal of Fisheries and Aquatic Sciences, 21(1-2): 93-98.

Turkoglu, M., Erdoğan, Y., Kaya, S. and Unsal, M. 2004c. Daily Changes in Phytoplankton Biomas in the Dardanelles. Canakkale Onsekiz Mart Univ., Scientific Research Project (BAP), No: 2002/02, Çanakkale, 198 pp.

Turkoglu, M. and Koray, T. 2004. Algal Blooms in Surface Waters of the Sinop Bay in the Black Sea, Turkey. Pakistan Journal of Biological Science, 7(9): 1577-1585.

Turkoglu, M. 2005. Succession of picoplankton (coccoid cyanobacteria) in the Southern Black Sea (Sinop Bay, Turkey). Pakistan Journal of Biological Science, 8(9): 1318-1326.

Turkoglu, M., Baba, A. and Ozcan, H. 2006. Determination and Evaluation of Some Physicochemical Parameters in the Dardanelles (Canakkale Strait -Turkey) Using Multiple Probe System and Geographic Information System. Nordic Hydrology, 37(3): 293-301.

Turkoglu, M. and Erdogan, Y. 2007. Daily and diurnal fluctuations of summer phytoplankton, nutrient and chlorophyll a in the Dardanelles (Çanakkale Strait, Turkey). AfPR Plankton Symposium IV, BDUA-Journal of Biology, 2: 62.

Turkoglu, M. 2008. Synchronous blooms of the coccolithophore *Emiliania huxleyi* (Lohmann) Hay & Mohler and three dinoflagellates in the Dardanelles (Turkish Straits System). Journal of the Marine and Biological Association of the United Kingdom, 88(3): 433-441.

Turkoglu, M. and Erdogan, Y. 2010. Diurnal variations of summer phytoplankton and interactions with some physicochemical characteristics under eutrophication of surface water in the Dardanelles (Çanakkale Strait, Turkey). Turkish Journal of Biology, 34(2): 211-225.

Unsal, M., Turkoglu, M. and Yenici, E. 2003. Biological and physicochemical researches in the Dardanelles (Canakkale Strait). TUBITAKTechnical Final Report, No: 101Y075 Çanakkale, Turkey, 131 pp.

Uysal, Z. 1995. A net plankton study in the Bosphorus juction of the Sea of Marmara. Turkish Journal of Botany, 20(5): 321-327.

Uysal, Z., Sur, H. I. 1995. Net plankton discriminating patches along the southern Black Sea coast in winter 1990. Oceanologica Acta, 18(6): 639-647.

Venrick, E. L. 1978. How many cells to count? A. Sournia (Ed.), Phytoplankton Manual, UNESCO, Paris: 167-180.

Xie, X.N., Jiao, J.J. and Cheng, J.M. 2003. Regional variations of formation water chemistry and diagenesis reaction in underpressured system: example from Shiwu depression of Songliao basin, NE China. Journal of Geochemistry Exploration, 78-79: 585-590.