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Phytoplankton composition and abundance in the coastal waters of the Datça and Bozburun Peninsulas, south-eastern Aegean Sea (Turkey)

S. TAŞ

Institute of Marine Sciences and Management, Istanbul University, Müşküle Sok. 34116, Vefa-Istanbul, Turkey

Corresponding author: stas@istanbul.edu.tr

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Abstract

A study on the abundance and composition of some groups of phytoplankton (diatoms, dinoflagellates and silicoflagellates) was carried out in the marine areas of the Datça and Bozburun Peninsulas between 2002 and 2004. Simultaneously, measured physical (salinity, temperature, secchi disc) and chemical parameters (nutrients, chlorophyll *a*, dissolved oxygen) were assessed together with phytoplankton data. Seawater and plankton net samples were taken from 63 stations during 6 sampling periods. A total of 132 taxa (genus, species and infraspecies level) belonging to 3 taxonomic classes were reported and a checklist of phytoplankton was prepared for this study area. Average nutrient values in surface water ranged from 0.01 to 1.19 μM for NO_3+NO_2–N, from 0.01 to 0.69 μM for PO_4–P and from 0.50 to 5.31 μM for SiO_2–Si and chl–*a* values were between 0.19 and 0.68 μg l^{-1} throughout the study area. The highest number of phytoplankton cells reached 5400 cells l^{-1} and dinoflagellate *Prorocentrum micans* reached 1500 cells l^{-1} while diatom *Thalassionema nitzschioides* reached 700 cells l^{-1}. Dinoflagellates showed a more homogeneous distribution in a wider area than diatoms. Dinoflagellate abundance increased in areas close to the fish farms due to the amount of nutrients originating from the farms. Spatial changes in phytoplankton composition observed in this marine area revealed that phytoplankton is very sensitive to ecosystem changes. The study area could generally be defined as oligotrophic in terms of trophic status, depending on the nutrient and chl–*a* concentrations. Moreover, very low cell abundance and the high number of species observed in this area also reflect the typical characteristics of oligotrophic waters.

Keywords: Aegean Sea, Datça–Bozburun, diatoms, dinoflagellates, phytoplankton.

Introduction

Phytoplankters are the basic food in the sea for all consumers such as zooplankton and fish. In recent years, applied aspects of phytoplankton research have become increasingly important (Zeitzschel, 1978). The life cycle of phytoplankton varies from a few hours to a few days. So, they reflect the effect of environmental, changes in a short time (Polat *et al.,* 2005). The Aegean Sea is one of the Eastern Mediterranean basins displaying a complicated hydrographic and ecological structure due to its geographical position between the Black Sea and the Ionian and Levantine Seas (Siokou-Frangou *et al.*, 2002; Zervakis *et al*., 2000). The Aegean Sea is separated by the Cyclades plateau into two subbasins, the North Aegean and the South Aegean, with significantly different hydrographic characteristics due to the influence of Black Sea waters and Levantine Sea waters, respectively (Ignatiades *et al*., 2002). Several studies on the temporal variations in biomass, primary production and species composition of phytoplankton communities have been carried out in the Southern Aegean (Becacos-Kontos, 1977; Ignatiades, 1976; Ignatiades *et al*., 1995; Gotsis-Skretas *et al*., 1996; Psarra *et al*., 2000). The results demonstrate the extremely oligotrophic status of waters (Ignatiades *et al*., 2002; Ignatiades, 2005).

The Mediterranean is considered to be one of the least productive seas in the world. Concentrations of nutrients decrease from the west to the east of the Mediterranean Sea (Azov, 1991; Krom *et al*., 1991). The north-eastern Mediterranean is the most oligotrophic part of the Mediterranean Sea. Low terrestrial input, nutrient poor waters, and the hot and dry climate are responsible for very limited plankton biomass and primary production (Turley *et al*., 2000). Also, phosphorus is considered to be a limited nutrient in the eastern Mediterranean (Krom *et al*., 1991). Phytoplankton production and nutrient concentration in the eastern Mediterranean is dependent on the duration and the intensity of deep water mixing, which allows transport of nutrients from a deeper layer to the surface (Yilmaz & Tugrul, 1998).

A number of studies on phytoplankton communities, dealing mainly with taxonomy, ecology and biomass distribution, have been carried out in the north-eastern Mediterranean Sea (Kideyş *et al*., 1989; Eker & Kideyş, 2000, Polat *et al*., 2000; Polat & Işik, 2002; Polat, 2002;

Polat & Piner, 2002a; Polat & Piner, 2002b; Polat *et al*., 2005; Eker-Develi *et al*., 2006; Polat, 2007; Polat & Koray, 2007; Balkis, 2009; Ozman-Say & Balkis, 2012). The Datça-Bozburun Specially Protected Area is one of thirteen specially protected areas in Turkey. The aim of this study is to investigate the taxonomic composition and abundance of the phytoplankton community in the coastal waters of the Datça and Bozburun Peninsulas, south-eastern Aegean Sea. The main environmental factors recorded during this study were also investigated and evaluated together with phytoplankton data.

Materials and Methods

Study area

The Datça Peninsula extends in an East–to–West direction and is located between the Gökova Gulf in the north and the Hisarönü Gulf in the south, while the Bozburun Peninsula lies to the South of the Datça Peninsula and extends towards the Island of Rhodes in the South (Okus *et al*., 2007). The study area was surveyed in six cruises and during each cruise a different region was studied. Cruise names and periods are as follows; DAT1: May 2002, DAT2: September 2002, DAT3: May 2003, DAT4: June 2003, DAT5: September 2003 and DAT6: April 2004 (Fig. 1). Station codes indicate the cruise number and the sampling station within that cruise; for example DAT1/01indicates Station 1 of Cruise-1 (May 2002). The water samples were taken from 11, 11, 13, 11, 10, and 7 stations from DAT1 to DAT6, respectively. Seawater samples were collected from 63 stations between May 2002 and April 2004 and oceanographic measurements were performed during the entire study period. All the sampling stations, except for DAT6/2, were inshore and only DAT6/2 was an offshore station.

Seawater analysis

Water salinity and temperature measurements were recorded by a SBE–Sea Logger 25 CTD probe system during the study period except in May 2003 (DAT3), when the physical data could not be measured due to a fault in the pressure sensor of the CTD probe system. A deep station in each sampling area was selected in order to draw the temperature and salinity profiles. Light transparency of water column was measured using a Secchi disc. Water samples were collected using 5 L Niskin bottles from 0.5, 5, 10 m and bottom water depending on the water depth at the sampling station. Samples for nutrients (NO_2+NO_3–N, PO_4–P and SiO_2–Si) analysis were deep–frozen at −20°C until they were analyzed. Nutrient analyses were performed by a Bran+Luebbe AA3 auto analyzer (Grasshoff *et al*., 1983). Chlorophyll a analyses were carried out using the acetone extraction method according to Parsons *et al*. (1984). Dissolved oxygen (DO) was measured according to the Winkler titration method (APHA, 1999). A suitable station representing each sampling area was selected in order to show the vertical distribution of chemical analysis.

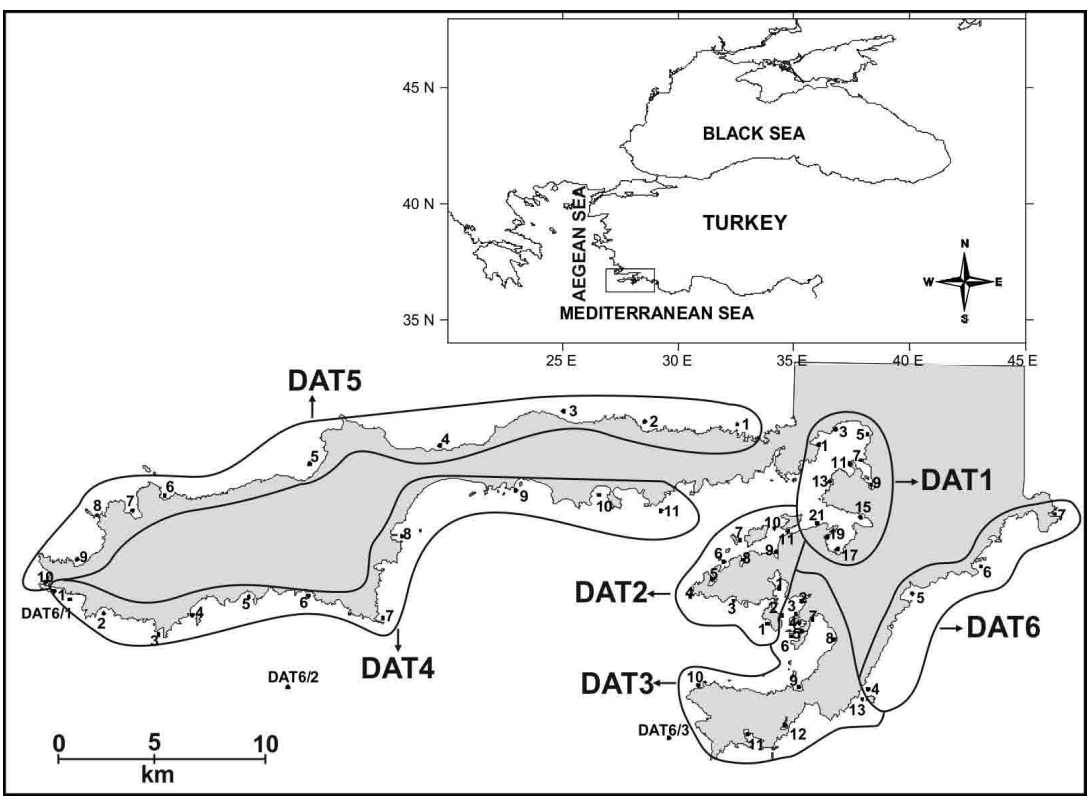

Fig. 1: Study area and sampling stations.

Phytoplankton analysis

Microphytoplankton ranges between 20 and 200 µm in the classification of phytoplankton according to the scaling nomenclature of Sieburth *et al*. (1978). In this study, three groups belonging to this classification such as diatoms (Bacillariophyceae), dinoflagellates (Dinophyceae) and silicoflagellates (Dictyochophyceae) were analyzed and evaluated in the phytoplankton community.

For the enumeration of phytoplankton, seawater samples were taken using 5 lt Niskin bottles. Water samples were immediately preserved with a neutralized formaldehyde solution at a final concentration of 0.4% (Throndsen, 1978). In the laboratory, samples were left to settle for a week according to the Utermöhl method (Utermöhl, 1958). After sample sedimentation, excess water in the upper part was removed and concentrated to 100 ml (Sukhanova, 1978). Then, these sub–samples were stored in dark coloured glass bottles until microscopic examination. Enumerations were carried out using an Olympus CH–2 light microscope (10×, 20× or 40×) on a Sedgewick–Rafter counting chamber (Guillard, 1978). Species identification were also carried out using a Nikon–Diaphot 300 inverted microscope with camera and phase–contrast equipment, and images of some species were taken for biometric measurements.

Plankton net sampling was used to investigate the species richness of phytoplankton. A plankton net (0.57 m diameter, 55 µm mesh) was vertically towed from 15 m to the surface. The following references were used for the identification of species: Cupp, 1943; Delgado & Fortuna, 1991; Dodge, 1985; Drebes, 1974; Hendey, 1964; Ricard & Dorst, 1987; Hasle *et al*., 1997. The recent revisions of dinoflagellate species were presented according to Gómez (2005, 2012).

Data analysis

Total microphytoplankton, dinoflagellate and diatom abundances, number of species (*S*), and Shannon index of diversity (*H'*, bits) were used as univariate descriptors. The relationship among total phytoplankton, dinoflagellate and diatom abundances, number of species, Shannon index of diversity and environmental parameters were analyzed by the Spearman rank correlation, following transformations to natural logarithms.

Results

Hydrobiological data

The data was collected during sampling periods that typically took place in spring and autumn. Surface water temperature ranged from 16.8ºC (April 2004) to 25.4ºC (September 2002) during the study period and was higher in the sheltered bays than offshore. The increased water temperature of the upper layer leads to the formation of a seasonal thermocline from April to June. A layer of thermocline formed due to the increased temperature of surface water in May 2002 and June 2003. In September 2002, a well–defined thermocline and a thicker upper layer were observed. Salinity values were measured within the range of 38.6 to 39.4 psu in the whole study area. The salinity values of the upper layer increased vertically from 0.2 to 0.4. Salinity values in the sampling area varied slightly between 38.6–39.4 psu (Fig. 2). The highest secchi depth was measured as 30 m at station DAT2/4 (Sept. 2002, St.4). Secchi disc value, which was about 20 m in the study area, decreased to 9 m at station DAT1/08 (May 2002, St.8) due to the long flushing time in the inner parts of the Gulf, settlements and tourism. Secchi disc values were generally less than 20 m in the DAT3 sampling area where shipyard activities and fish farms exist.

Inorganic nutrients exhibited very low concentrations in the study area, which has an oligotrophic character. Average nutrient values in surface water ranged from 0.01 to 1.19 µM for NO_3+NO_2–N, from 0.01 to 0.69 µM for PO_4–P and from 0.50 to 5.31 µM for SiO_2–Si. Nutrient concentrations were higher in regions of increased freshwater input and also of high tourism activities. The highest P–PO_4 value was measured as 0.69 µM at station DAT4/11 (June 2003, St.11) and this is 10–fold higher than the value obtained for the Aegean Sea prior to this

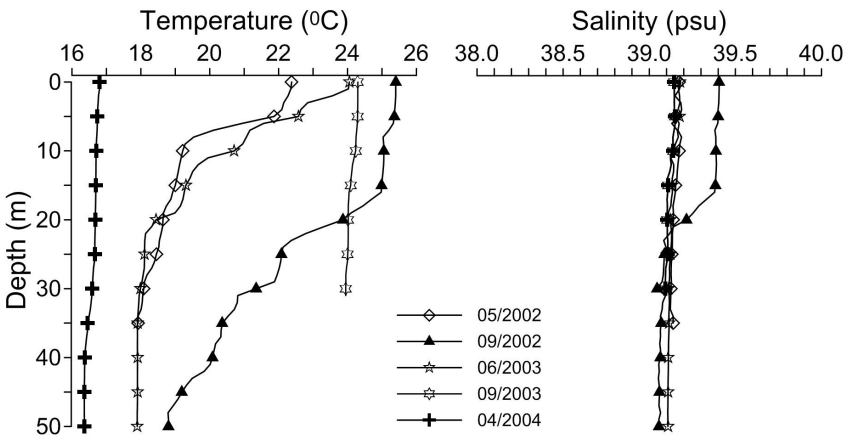

Fig. 2: Temperature and salinity profiles in the sampling periods.

Table 1. Spearman rank correlation coefficients (rho) between environmental parameters and total microphytoplankton, dinoflagellate and diatom abundances; number of species (*S*), Shannon index of diversity (*H'*).

	Rho						
	Temperature	**Salinity**	**DO**	**Chl-*a***	**NO_3+NO_2**	**PO_4**	**SiO_2**
Total phytoplankton	-0.081	-0.252*	-0.171	0.513***	-0.073	0.158	0.095
Dinoflagellate	0.040	-0.088	-0.192	0.459***	-0.073	0.178	0.161
Diatom	-0.172	-0.178	-0.078	0.314**	-0.099	-0.107	0.035
Number of species	-0.099	-0.298*	-0.122	0.556***	-0.065	0.150	0.136
Shannon index	-0.091	-0.262*	-0.116	0.543***	-0.061	0.143	0.190

*p<0.05; **p<0.01; ***p<0.001

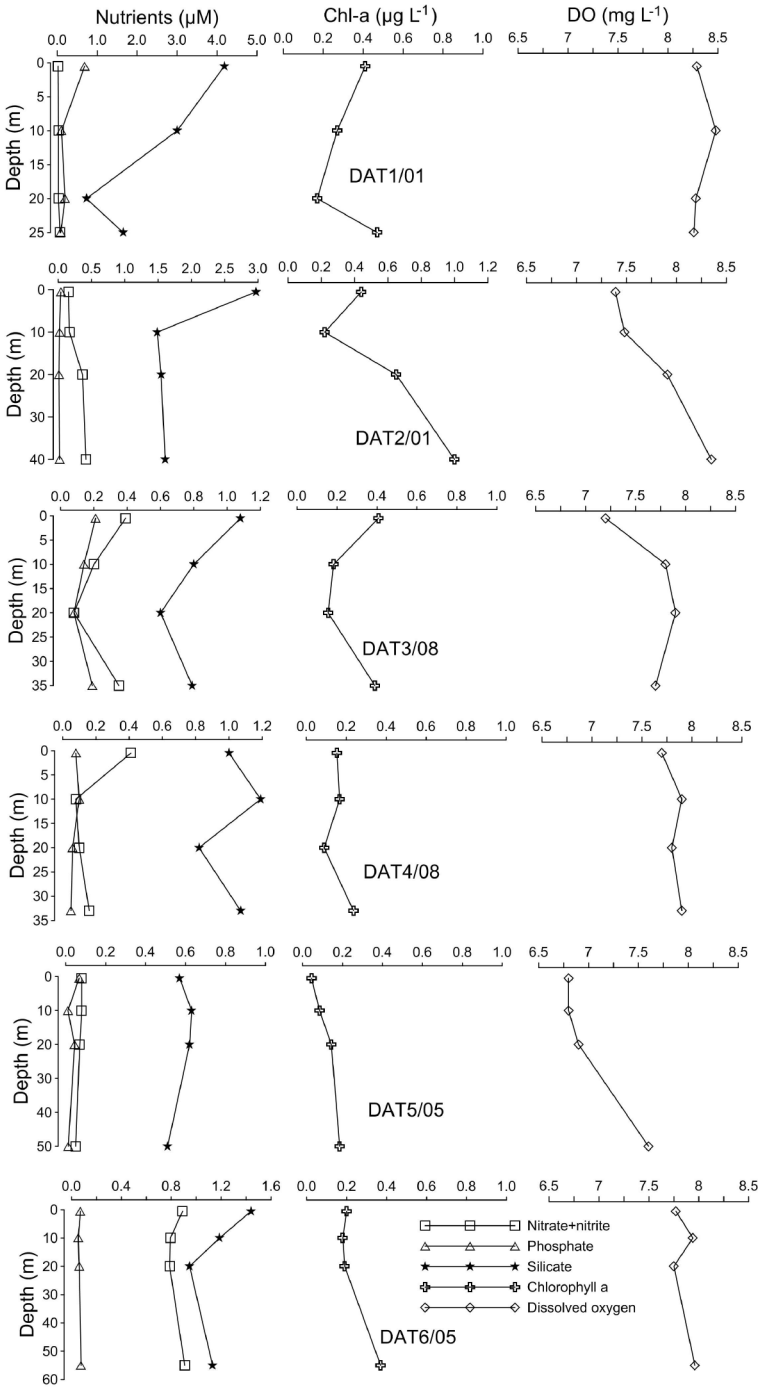

Fig. 3: Fluctuations in chl-*a*, dissolved oxygen and nutrient concentrations.

study. High domestic pollution in this area could be a reason for this increase (Fig. 3).

The spatial distribution of chl–*a* showed some differences depending on physical and chemical characteristics. The average values of chl–*a* in surface water were 0.34, 0.19, 0.68, 0.15, 0.17 and 0.22 µg l^{-1} for DAT1, DAT2, DAT3, DAT4, DAT5 and DAT6, respectively. Chl–*a* concentrations were relatively higher for DAT3 than other areas depending on phytoplankton productivity, because this area is affected by tourism activities and fish farms. Throughout the sampling area, the majority of chl–*a* values (87%) were less than 0.5 µg l^{-1} and 9% of the values were between 0.5 and 1µg l^{-1}. Only 4% of the values exceeded 1 µg l^{-1}. Vertical distribution of chl–*a* values was almost homogeneous in the whole study area except the DAT3 region (Fig. 3). A significant positive correlation was detected between cell abundance, number of species, Shannon index values, and chl–*a* values (Table 1).

High dissolved oxygen (DO) concentrations were measured in the whole study area and showed a homogeneous distribution from surface to the bottom. DO values varied between 6.7 and 8.3 mg l^{-1} at the surface and between 6 and 8.7 mg l^{-1} in deeper waters (Fig. 3).

Phytoplankton composition and abundance

A total of 132 taxa (genus, species and infraspecies level) belonging to 3 taxonomic classes were observed in both plankton net and water samples, 119 of which were identified to species level (Table 1). Diatoms and dinoflagellates were two major groups in the whole study area. Diatoms were the most diverse algal group with 71 (53.7%) taxa, followed by dinoflagellates with 60 taxa (45.4%) and silicoflagellate was only one taxa. Most genera were *Neoceratium* (21 taxa) and *Protoperidinium* (14 taxa) from dinoflagellates and *Chaetoceros* Ehrenberg (23 taxa) from diatoms. A checklist of phytoplankton species in water and net samples are presented in Table 2.

Plankton net samples show that the coastal area of Datça and Bozburun Peninsulas is rich in species composition. 86% of the reported phytoplankton species were observed in net samples (Table 2). Spatial distribution of phytoplankton composition showed some differences. The DAT1 sampling area was the most abundant in terms of species richness with 58 taxa, while DAT3 was much less abundant with 26 taxa. Diatoms were dominant in the DAT1 and DAT6 areas; dinoflagellates were dominant in the other areas in terms of the number of species. Dinoflagellates were more common and dominant than diatoms in some parts of DAT3, which means that the risk of pollution might be higher than in other areas due to the fish farms. The species encountered most frequently in net samples were *Neoceratium arietinum, N. candelabrum, N. furca, N. fusus, N. massiliense, N. tripos, Lingulodinium polyedrum, Protoperidinium depressum, P. divergens* and *P. oceanicum* from dinoflagellates; *Bacteriastrum delicatulum, Detonula confervacea, Hemialus hauckii, Pseudosolenia calcar–avis, Striatella unipunctata* and *Thalassionema nitzschioides* from diatoms. Fewer species were detected in the water samples than in the net samples.

Water samples comprised 54% of all phytoplankton species observed in this study, and the species encountered most frequently in water samples were *Neoceratium fusus, P. micans, P. scutellum, Protoperidinium mediterraneum* and *S. trochoidea* from dinoflagellates; *H. hauckii, Streptotheca thamensis and T. nitzschioides* from diatoms (Table 2). Images of light microscopy of some dinoflagellate species are given in Figure 4.

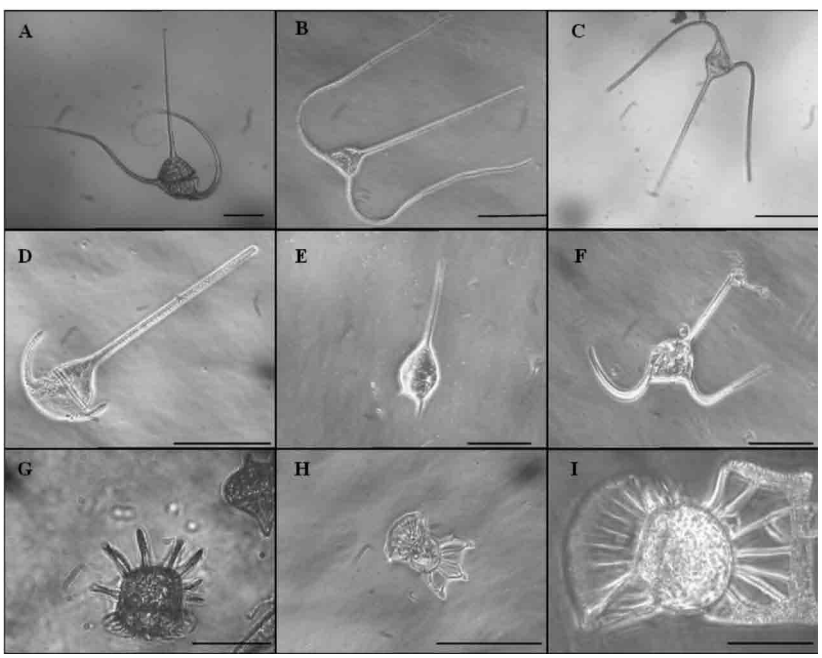

Fig. 4: Light micrographs of some dinoflagellate species identified in the study area. (A) *Neoceratium hexacanthum*, (B) *N. trichoceros*, (C) *N. massiliense*, (D) *N. pulchellum*, (E) *N. teres*, (F) *N. macroceros*, (G) *Ceratocorys horrida*, (H) *Ornithocercus magnificus* (Scale bars= 100 µm), (I) *O. quadratus* (Scale bar= 50 µm).

Table 2. Checklist of species identified in the net and water samples and local distribution of phytoplankton in the Datça and Bozburun Peninsulas (N: Net samples, W: Water samples).

			Sampling area					
Species	**N**	**W**	**DAT1**	**DAT2**	**DAT3**	**DAT4**	**DAT5**	**DAT6**
Bacillariophyceae								
Achnantes longipes C.Agardh	+	+	+	-	-	-	-	-
Achnantes sp.	+	-	+	-	-	-	-	-
Asterionellopsis glacialis (Castracane) Round	+	-	-	-	-	-	-	+
Asterolampra grevillei (Wallich) Greville	+	-	-	+	-	-	-	-
Asterolampra marylandica Ehrenberg	+	+	-	-	-	+	-	-
Asteromphalus flabellatus (Brébison) Greville	-	+	-	-	-	+	-	-
Asteromphalus heptactis (Brébison) Ralfs	+	-	-	+	-	-	-	-
Asteromphalus sp.	+	-	-	-	-	+	-	-
Bacteriastrum delicatulum Cleve	+	+	+	-	+	+	-	+
Bacteriastrum elongatum Cleve	+	+	+	-	-	+	-	-
Chaetoceros affinis Lauder	+	+	+	-	-	-	-	+
Chaetoceros affinis var. *willei* (Gran) Hustedt	+	-	+	-	-	-	-	+
Chaetoceros borealis Bailey	+	-	+	-	-	-	-	-
Chaetoceros compressus Lauder	+	-	+	-	-	+	-	+
Chaetoceros costatus Pavillard	+	-	+	-	-	-	-	-
Chaetoceros curvisetus Cleve	+	+	+	-	-	-	-	+
Chaetoceros danicus Cleve	+	-	-	-	-	-	-	+
Chaetoceros decipiens Cleve	+	-	+	-	-	-	-	+
Chaetoceros diadema (Ehrenberg) Gran	+	-	-	-	-	-	-	+
Chaetoceros diversus Cleve	+	+	+	-	-	-	-	+
Chaetoceros eibenii Grunow	-	+	+	-	-	-	-	-
Chaetoceros gracilis Schütt	+	-	-	-	-	-	-	+
Chaetoceros holsaticus Schütt	+	-	+	-	-	-	-	+
Chaetoceros laciniosus Schütt	+	+	+	-	-	-	-	+
Chaetoceros lauderi Ralfs	+	+	+	-	-	-	-	+
Chaetoceros lorenzianus Grunow	+	-	+	-	-	-	-	+
Chaetoceros messanensis Castracane	+	-	+	-	-	-	+	+
Chaetoceros peruvianus Brightwell	+	-	+	-	-	-	-	+
Chaetoceros simplex Ostenfeld	+	-	+	-	-	-	-	-
Chaetoceros teres Cleve,	+	-	-	-	-	-	-	+
Chaetoceros tortissimus Gra	+	-	-	-	-	-	-	+
Chaetoceros wighamii Brightwell	+	+	-	-	+	-	-	+
Chaetoceros sp.	+	+	+	-	+	-	-	+
Climacosphenia moniligera Ehrenberg	+	+	+	-	-	+	+	-
Coscinodiscus sp.	+	+	+	+	-	-	-	+
Cylindrotheca closterium (Ehrenberg) Reimann & Lewin	+	-	+	-	-	-	-	-
Dactyliosolen fragilissimus (Bergon) Hasle	+	-	+	-	-	-	-	+
Dactyliosolen mediterraneus H. Peragallo	+	-	+	-	-	-	-	-
Detonula confervacea (Cleve) Gran	+	+	+	+	-	+	-	+
Grammatophora marina (Lyngbye) Kützing	+	-	-	+	-	-	-	-
Guinardia delicatula (Cleve) Hasle	+	+	+	-	+	-	-	+
Guinardia flaccida (Castacane) Peragallo	+	-	+	+	-	-	-	-
Guinardia striata (Stolterfoth) Hasle	+	+	+	-	+	_	+	+
Gyrosigma sp.	-	+	-	-	-	-	+	-
Hemiaulus hauckii Grunow *ex* Van Heurck	+	+	+	+	+	+	+	+
Leptocylindrus danicus Cleve	+	-	-	-	-	-	-	+
Licmophora abbreviata Agardh	-	+	+	-	+	-	-	-
Licmophora sp.	+	-	-	+	-	-	-	-
Navicula sp.	+	+	+	+	-	+	+	+
Nitzschia longissima (Brébisson) Ralfs	+	-	+	-	-	+	-	-
Nitzschia sp.	+	-	-	-	-	+	-	+
Odontella mobiliensis (J.W.Bailey) Grunow	+	-	-	-	-	-	-	+

(continued)

(continued) **Table 2.**

			Sampling area					
Species	**N**	**W**	**DAT1**	**DAT2**	**DAT3**	**DAT4**	**DAT5**	**DAT6**
Pleurosigma normanii Ralfs	-	+	+	-	-	-	-	-
Pleurosigma sp.	+	+	+	-	-	-	+	-
Proboscia alata f. *alata* (Brightwell) Sundström	+	-	-	-	-	-	+	-
Proboscia alata f. *gracillima* (Brightwell) Sundström	+	-	+	+	-	-	-	-
Proboscia alata f. *indica* (H. Peragallo) Gran	+	-	-	-	-	+	+	+
Pseudo-nitzschia delicatissima (Cleve) Heiden	+	+	+	+	+	-	-	+
Pseudo-nitzschia pungens (Grunow *ex* P.T.Cleve) G.R.Hasle	+	+	-	-	+	-	-	+
Pseudosolenia calcar-avis (Schultze) Sundström	+	+	+	+	-	-	+	+
Rhabdonema adriaticum Kützing	+	-	-	-	-	+	-	-
Rhizosolenia hebetata var. *semispina* (Hensen) Gran	+	-	-	+	-	-	+	-
Rhizosolenia imbricata var. *shrubsolei* (Cleve) Schröder	+	-	+	+	-	-	-	-
Rhizosolenia styliformis Brightwell	+	-	+	+	-	-	+	-
Skeletonema costatum (Greville) Cleve	+	-	+	-	-	-	-	-
Streptotheca thamensis Shrubsole	-	+	-	-	+	+	+	+
Striatella unipunctata (Lyngbye) Agardh	+	+	+	+	-	+	+	+
Synedra undulata (Bailey) Gregory	+	+	+	+	-	+	-	-
Thalassionema nitzschioides (Grunow) Mereschkowsky	+	+	+	+	+	+	-	+
Thalassiothrix frauenfeldii Grunow	+	+	+	+	+	+	-	+
Thalassiothrix mediterranea Pavillard	-	+	+	-	-	-	-	-
Dinophyceae								
Alexandrium sp.	+	-	+	-	-	-	-	-
Ceratocorys gourretii Paulsen	+	-	-	-	+	-	-	-
Ceratocorys horrida Stein	+	-	-	-	+	-	-	-
Corythodinium tesselatum (Stein)Loeblich Jr. & Loeblich III	+	+	-	-	+	-	-	-
Dinophysis acuta Ehrenberg	-	+	+	+	+	-	-	-
Dinophysis caudata Saville-Kent	+	+	-	+	+	-	-	-
Dinophysis hastata Stein	+	-	-	-	-	+	-	-
Dinophysis tripos Gourret	+	+	+	+	+	+	-	-
Diplopsalis lenticula Bergh	+	+	+	-	-	+	-	-
Gonyaulax grindleyi Reinecke	-	+	-	-	+	-	-	-
Gonyaulax sp.	+	+	+	+	-	+	-	+
Gyrodinium sp.	-	+	+	-	+	+	-	+
Heterocapsa triquetra (Ehrenberg) Stein	-	+	+	+	-	-	+	-
Lingulodinium polyedrum (Stein) Dodge	+	+	+	+	+	+	+	+
Neoceratium arietinum (Cleve) F. Gómez, D. Moreira & P. López-García	+	-	+	+	+	+	+	+
Neoceratium candelabrum (Ehrenb.) F. Gómez, D. Moreira & P. López-García	+	+	+	+	+	+	+	-
Neoceratium carriense (Gourret) F. Gómez, D. Moreira & P. López-García	+	-	-	+	-	-	+	+
Neoceratium contortum (Gourret) F. Gómez, D. Moreira & P. López-García	+	-	-	-	-	-	+	-
Neoceratium declinatum (G. Karst.) F. Gómez, D. Moreira & P. López-García	+	-	-	-	+	-	+	-
Neoceratium euarcuatum (Jørgen.) F. Gómez, D. Moreira & P. López-García	+	-	-	-	-	+	-	-
Neoceratium furca (Ehrenberg) F. Gómez, D. Moreira & P. López-García	+	+	+	+	+	-	+	+
Neoceratium fusus (Ehrenberg) F. Gómez, D. Moreira & P. López-García	+	+	+	+	+	+	+	+
Neoceratium hexacanthum (Gourret) F. Gómez, D. Moreira & P. López-García	+	-	-	-	-	-	-	+
Neoceratium horridum (Gran) F. Gómez, D. Moreira & P. López-García	+	-	+	-	-	+	+	+
Neoceratium kofoidii (Jørgensen) F. Gómez, D. Moreira & P. López-García	-	+	-	+	+	-	-	-
Neoceratium lineatum (Ehrenberg) F. Gómez, D. Moreira & P. López-García	+	+	-	+	+	-	-	+
Neoceratium macroceros (Ehrenb.) F. Gómez, D. Moreira & P. López-García	+	+	-	+	+	+	+	+
Neoceratium massiliense (Gourret) F. Gómez, D. Moreira & P. López-García	+	+	+	+	+	+	+	+
Neoceratium minutum (Jørgensen) F. Gómez, D. Moreira & P. López-García	+	-	-	+	+	-	-	-
Neoceratium pentagonum (Gourret) F. Gómez, D. Moreira & P. López-García	+	-	+	-	-	-	+	-
Neoceratium symmetricum (Pavill.) F. Gómez, D. Moreira & P. López-García	+	+	-	+	+	-	-	-
Neoceratium teres (Kofoid) F. Gómez, D. Moreira & P. López-García	+	+	+	+	-	+	+	-
Neoceratium trichoceros (Ehrenb.) F. Gómez, D. Moreira & P. López-García	+	+	+	+	+	+	+	+
Neoceratium tripos (O.F.Müller) F. Gómez, D. Moreira & P. López-García	+	+	+	+	+	+	+	+
Neoceratium pulchellum (Schröder) F. Gómez, D. Moreira & P. López-García	+	-	+	+	+	+	+	-
Ornithocercus magnificus Stein	+	-	-	+	-	+	+	-
Ornithocercus quadratus Schütt	+	-	-	+	-	+	-	-
Oxytoxum scolopax Stein	+	-	-	+	-	-	-	-

(continued)

(continued) **Table 2.**

			Sampling area					
Species	**N**	**W**	**DAT1**	**DAT2**	**DAT3**	**DAT4**	**DAT5**	**DAT6**
Phalacroma rotundatum (Clap.&J. Lachm.) Kofoid & J.R. Michener	+	+	+	-	+	+	-	-
Podolampas palmipes Stein	+	-	-	+	-	-	-	+
Podolampas spinifera Okamura	+	-	-	-	-	+	-	-
Prorocentrum micans Ehrenberg	+	+	+	+	+	+	+	+
Prorocentrum scutellum Schröder	-	+	+	+	+	+	-	-
Prorocentrum triestinum Schiller	-	+	-	-	+	-	-	-
Protoperidinium claudicans (Paulsen) Balech	-	+	+	-	+	-	-	-
Protoperidinium conicum (Gran) Balech	+	+	+	-	+	-	-	-
Protoperidinium crassipes (Kofoid) Balech	+	-	-	+	+	-	-	+
Protoperidinium depressum (Bailey) Balech,	+	+	+	+	+	+	+	+
Protoperidinium diabolus (Cleve) Balech	+	+	-	-	-	+	-	+
Protoperidinium divergens (Ehrenberg) Balech	+	+	+	+	+	+	+	+
Protoperidinium grande (Kofoid) Balech,	+	-	-	-	-	+	-	-
Protoperidinium leonis (Pavillard) Balech	+	+	-	-	+	-	-	-
Protoperidinium mediterraneum (Kofoid) Balech	+	+	+	+	+	+	-	+
Protoperidinium oceanicum (Vanhöffen) Balech	+	+	+	+	+	+	+	+
Protoperidinium pellucidum Bergh	-	+	+	-	-	-	-	-
Protoperidinium pyriforme (Paulsen) Balech	-	+	-	-	+	-	-	-
Protoperidinium steinii (Jørgensen) Balech	+	+	+	+	+	-	-	-
Protoperidinium sp.	+	+	+	-	+	+	+	+
Scrippsiella trochoidea (Stein) Balech *ex* Loeblich III	+	+	+	+	+	+	-	+
Dictyochophyceae								
Dictyocha speculum Ehrenberg	+	-	-	-	-	-	-	+
Total number of species	**114**	**71**	**79**	**53**	**51**	**50**	**37**	**64**

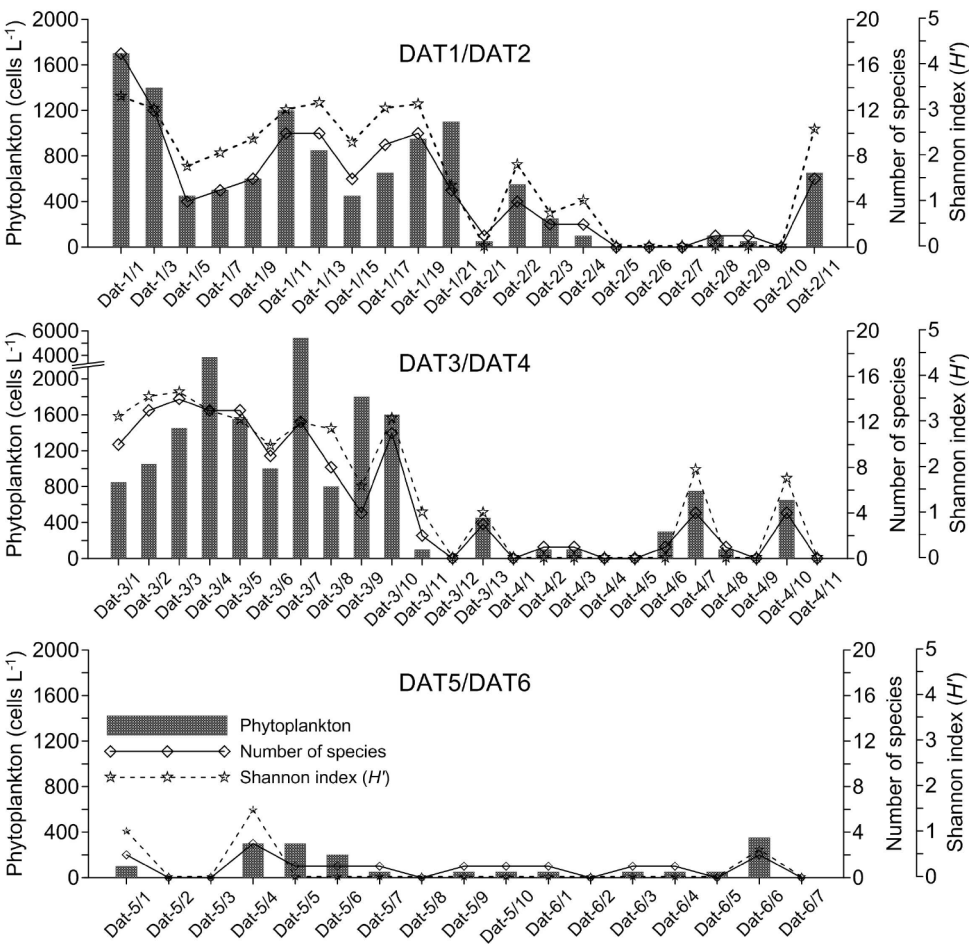

Fig. 5: Abundance of phytoplankton, number of species and diversity index during the study period.

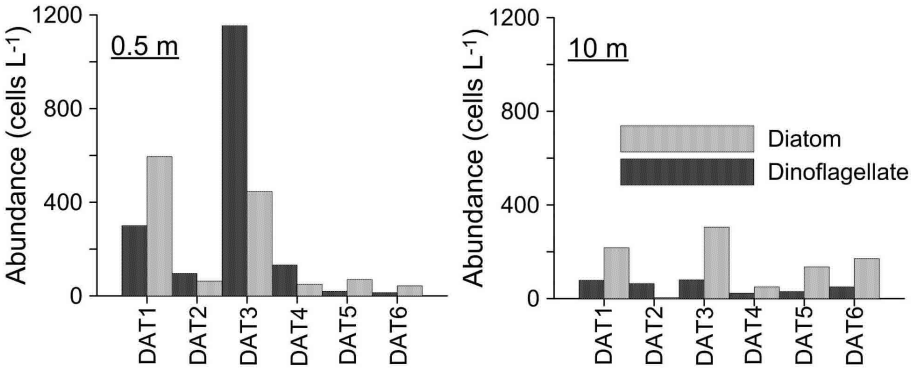

Fig. 6: Average abundances of the two major groups of phytoplankton.

Shannon index of diversity (*H'*) values generally increased in parallel to the number of species (*S*) throughout the study period. The highest diversity (*H'*=3.63 bits) was observed in DAT3/3 and the lowest value (*H'*=0.59 bits) was detected in DAT6/6 (Fig. 5). According to the Spearman rank correlation coefficients (rho), there was a low negative correlation between abundance of total phytoplankton, number of species, Shannon index and salinity values (Table 1). In general, number of species increased in parallel to increasing phytoplankton abundance.

Due to the oligotrophic structure of the region, phytoplankton abundance was very low and the highest cell density (5400 cells l^{-1}) was detected in the surface water of station DAT3/07 (May 2003, St.7). Phytoplankton abundance at DAT1 and DAT3 was relatively higher than in the other areas. This situation was supported by the chl–*a* values measured for DAT3. The average densities were 1600 cells l^{-1} and 895 cells l^{-1} in DAT1 and DAT3, respectively and the other areas had much less density (<200 cells l^{-1}). It is noteworthy that diatoms were more dominant in the surface water of DAT1 while dinoflagellates were more dominant in the surface water of DAT3 (Fig. 6). Cell density was higher at DAT1 and DAT3 and decreased from surface to bottom. Highest dinoflagellate density was 5400 cells l^{-1} and highest diatom density was 1800 cells l^{-1} throughout the study period. Diatoms were more frequently dominant than dinoflagellates at the depth of 10 m (Fig. 6). *P. micans* from dinoflagellates and *T. nitzschioides* from diatoms were the most abundant species, with 1500 cells l^{-1} and 700 cells l^{-1}, respectively.

Discussion

The hydrological data obtained in this study carried out in the marine environment of the Datça and Bozburun Peninsulas was determined within the limit values given for the southern Aegean and the eastern Mediterranean (Okuş *et al*., 2007). Some previous studies carried out in the eastern Mediterranean and Aegean Seas have shown that this region has oligotrophic characteristics (Azov 1991; Krom *et al*., 1991; Ignatiades *et al*., 2002; Turley *et al*., 2000; Balkis, 2009).

The results of this study revealed that this marine environment has oligotrophic characteristics with some exceptions related to nutrient and chl–*a* concentrations. This feature is similar to the previous studies carried out in the Aegean Sea (Lykousis *et al*., 2002; Ignatiades *et al*., 2002). The low chl–*a* concentrations (<0.5 µg l^{-1}), excluding some parts of the DAT3 region, showed an oligotrophic character according to the trophic status scaling of the Aegean Sea defined by Ignatiades (2005). Some parts of the DAT3 region, which is affected by fish farms can be characterized as mesotrophic according to the chl–*a* results. Even small increases in nutrient concentration, especially in areas with poor water renewal, lead to an increase in phytoplankton and chl-*a* values. The highest chl-*a* value was measured as 1.71 µg l^{-1} in the surface water of DAT3/07 depending on the increasing primary production caused by the nutrient inputs of tourism activities and fish farms. Low chl-*a* is similar to the result of the previous study (0.05–1.10 µgl^{-1}) carried out by Psarra *et al*., (2000) in the southern Aegean Sea. However, the increase in anthropogenic impacts in this marine environment can cause ecosystem damage. Ignatiades (2005) suggested that there was an overlap between the upper limits of oligotrophic waters and the lower limits of mesotrophic waters. However, the extreme upper values in oligotrophic waters had a low probability of occurrence (13.6–2.1%). Chl–*a* values, which exceed the criteria for oligotrophic water remained a low probability (13%) in this study area. Therefore, it is possible to say that this study area has generally oligotrophic waters. Nutrients and chlorophyll *a* values were relatively higher than the average values in some parts of the study area located close to fish farms. This may cause a negative effect on the ecosystem.

The oligotrophic conditions result in a high diversity of dinoflagellates in the Mediterranean (Gómez, 2003), which contains nearly 43% of the world's known marine dinoflagellate species (Gómez, 2005). The phytoplankton community observed in this study can also be characterized with high diversity and low abundance as a characteristic of the Mediterranean. The rich phytoplankton composition observed in this study area is similar when compared with the previous studies carried out in adjacent areas. The percentage of diatom and dinoflagellate calculated in this study (%52–%46) is almost similar to other studies carried out in adjacent seas

(Kideys *et al*., 1989; Eker and Kideys, 2000; Polat *et al*., 2000; Polat and Isik, 2002; Balkis, 2009). Among the species identified in this study, a dinoflagellate *Corythodinium tesselatum* was recorded for the first time in Turkish seas (Taş *et al*., 2006). Furthermore, the species list formed in this study is similar in content to the check-list prepared for Turkish seas by Koray (2001), in which 485 eukaryotes taxa were listedLow phytoplankton abundance in this study area relates to physical and chemical conditions and reflects the general characteristics of oligotrophic waters. Thus, very low nutrient concentrations limit phytoplankton growth. DAT5 and DAT6 had the lowest cell densities among stations, while DAT3 had the highest. Dinoflagellate and diatoms, which are two major groups of phytoplankton, constitute the dominant groups in this region. Dinoflagellate species showed a more homogeneous distribution in a wider area than diatoms. This situation could be associated with the fact that dinoflagellates have a higher tolerance of the existing ecological conditions than diatoms. Eker and Kideyş (2000) suggest that there is a positive relationship between dinoflagellates and water temperature; thus, dinoflagellates may be better adapted to the high temperatures. Most dinoflagellates are found in temperate waters, are most prevalent in summer months (Taylor, 1987) and dominate the phytoplankton in warm seasons (Tait, 1981).

As stated by some researchers, dinoflagellates are more common in eutrophic areas and may cause dense blooms (Taş & Okuş, 2004; Aktan *et al*., 2005; Taş *et al*., 2009). This study revealed that dinoflagellate abundance increases in areas close to fish farms due to the high load of organic materials originating from the farms. For instance, dinoflagellate *P. micans* was the most abundant species at station DAT3/07 (May 2003, St.7), which is close to the fish farms. However, no red tide event was recorded for the phytoplankton species observed in this study. The results of this work show that the physical and chemical structure of the water has a considerable effect on phytoplankton composition and that these results are in agreement with previous studies performed in oligotrophic waters.

Conclusions

Although this study area is oligotrophic, part of sampling area DAT3 displayed a transition from oligotrophic to mesotrophic conditions according to the trophic status scaling for the Aegean Sea described by Ignatiades (2005). This situation reflects some anthropogenic impacts such as intensive tourism activities and fish farms operating in this area. The phytoplankton community was dominated by dinoflagellates, particularly in the area of DAT3, while diatoms were more common in the other areas. At this point, the changes in phytoplankton composition in any marine area should be taken into consideration because phytoplankton is very sensitive to ecosystem changes. Therefore, more efforts should be made to protect this marine environment.

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