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Research Article

A Study on the Occurrence of *Merismopedia* Meyen (*Cyanobacteria*) Populations on the Littoral Sediments of İzmit Bay (Turkey)*

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Abstract: In a previous study of epipelic diatoms on the littoral sediments of İzmit Bay (Marmara Sea, Turkey), which was carried out from March 1999 to September 2000, it was found that two *Merismopedia* Meyen species (*Cyanobacteria*) occurred frequently. In the present study, the seasonal variations of density and biomass of the *Merismopedia* species, which were dominant at certain times in the epipelic algal flora on the littoral sediments of İzmit Bay, were investigated. In addition, some physical and chemical parameters were measured. One of the species, *Merismopedia glauca* (Ehrenb.) Nägeli, was dominant in terms of cell numbers and frequency while *M. tenuissima* Lemmerm. was found to be rare and was present in very low numbers. *M. glauca* was recorded at all seven stations and at certain times reached quite high numbers. The highest numbers were obtained from Station 4, which is characterised by being an area protected from wave action where the sediment is quite stable.

Key Words: *Merismopedia*, density, biomass, İzmit Bay, littoral sediment

İzmit Körfezi'nin (Türkiye) Littoral Sedimanlarındaki *Merismopedia* Meyen (*Cyanobacteria*) Popülasyonlarının Mevcudiyeti Üzerine Bir Çalışma

Özet: Mart 1999 – Eylül 2000 tarihleri arasında Marmara Denizi' nin İzmit Körfezinde littoral sedimanlar üzerinde epipelik diyatome toplulukları üzerinde yapılan çalışma sırasında iki *Merismopedia* Meyen türünün mevcudiyeti dikkat çekmiştir. Yapılan bu çalışmada, epipelik algal flora içinde bazı dönemlerde dominant olan *Merismopedia* türlerinin birey sayısı ve biyomasında ki mevsimsel değişim incelenmiştir. Ek olarak bazı fiziksel ve kimyasal parametreler ölçülmüştür. Araştırma süresi boyunca *Merismopedia tenuissima* Lemmerm. nadiren ve düşük birey sayılarında bulunurken, *Merismopedia glauca* (Ehrenb.) Nägeli tüm istasyonlarda kaydedilmiş ve bazı dönemlerde oldukça yüksek sayılara ulaşmıştır. En yüksek değerler, dalgalara karşı daha korunaklı ve daha durgun bir sedimana sahip olan 4. istasyonda kaydedilmiştir.

Anahtar Sözcükler: *Merismopedia*, densite, biyomas, İzmit Körfezi, littoral sediment

Introduction

Benthic microalgae play a significant role in the total primary productivity of estuarine and inshore ecosystems (Matheke & Horner, 1974). Epipelic algae mostly consist of species living on the sediment of the littoral zone capable of vertical migration; moreover, there are non-migratory species which occur in colonies or in mucilaginous or filamentous forms. *Cyanobacteria* form a major component of the benthic microalgae of soft-bottom sediments, and they are often seen as the predominant algae.

There have been few studies on benthic microalgae including epipelics, although many studies have been carried out on the composition and distribution of macroalgae and macrophytes in the benthic area of the Turkish coast. In the Marmara Sea, some previous studies on this subject were reported by Güner (1978), Güner & Aysel (1978b, 1979), Aysel & Güner (1979, 1980, 1982), and Aysel et al. (1991, 1993, 2000). In addition to these studies, additional research was carried out on the oceanographic characteristics of İzmit Bay and the characterization and treatment alternatives for waste

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effluents by the TÜBİTAK Research Centre. In addition, some physical and chemical parameters related particularly to pollution studies have been measured.

In the present study, we report for the first time the distribution and bloom of *Merismopedia* Meyen in the epipelic algal flora of Turkish waters. The aim was to investigate the seasonal variations of density and biomass of the *Merismopedia* populations, which were dominant at certain times in the epipelic algal flora on the littoral sediments of İzmit Bay, and some physical and chemical characteristics of the area.

Materials and Methods

İzmit Bay, located in the north-eastern part of the Marmara Sea, is surrounded by a rapidly growing industrial area (Figure 1). In addition to untreated or partly treated domestic waste originating from the increasing population, substantial industrial development, heavy maritime traffic and agricultural activity in the surrounding areas have caused considerable pollution in the bay. After a number of factories and urban sewage systems were damaged by earthquake in August of 1999, the bay area today faces with even more problems.

In terms of its oceanographic and geographic characteristics, İzmit Bay can be divided into three distinct regions connected to each other through narrow openings. It has a surface area of approximately 310 km^2. The main morphometric characteristics of İzmit Bay were determined by the TÜBİTAK Research Centre and are given in Table 1.

In terms of flow and stratification characteristics, İzmit Bay has a permanent two layer stratification throughout the year. The degree of stratification and water mass characteristics show considerable seasonal variations, particularly in the upper layer as a part of the

Table 1. Main morphometric characteristics of İzmit Bay.

	Eastern	Central	Western
Length (km)	16	20	17
Width (km)	2-5	3-10	3-5.5
Max depth (m)	35	180	200
Surface area (km^2)	44	166	100

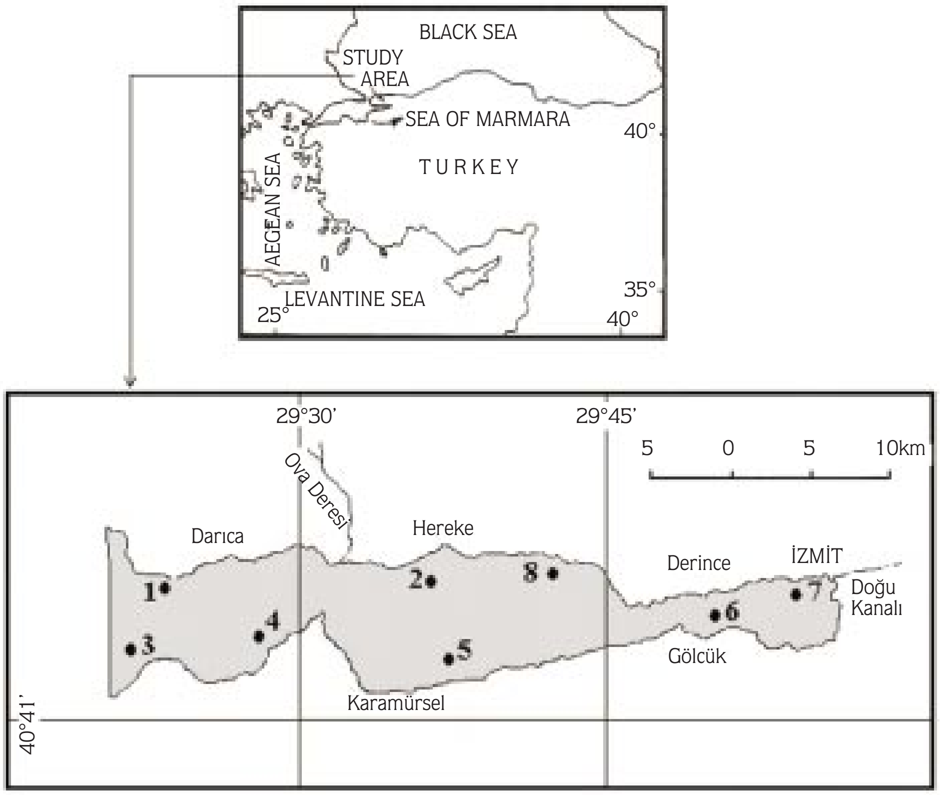

Figure 1. Experimental stations.

Turkish Straits (Dardanelles) and Marmara Sea. In general, the bay is characterised by the existence of less saline (20-22‰) waters (Black Sea origin) over a more saline (37-38.5‰) bottom layer (Mediterranean origin).

Samples were taken monthly from eight experimental stations around İzmit Bay between March 1999 and September 2000. The sample stations had different types of sediments and were under the influence of different environmental conditions. Samples were collected by drawing a glass tube (1 m long) across the surface of the sediment (Round, 1953). Sampling was not possible at Station 6 since it was covered by gravel and rocks after the earthquake.

The densities of *Merismopedia* populations were calculated in numbers of cells; biomass was estimated by calculating biovolumes. The cell volumes of *Merismopedia* were determined according to geometrical shape by measuring 10 organisms in each sample (Findenegg, 1974; Hillebrand, 1999). The results were analysed in the SPSS program in MS Windows 5.0 and were compared using the Student-Newman-Keuls (SNK) test. Relations between the temperature and *Merismopedia* abundance were found using correlation analysis (Spearman's correlation coefficient). Temperature, dissolved oxygen, salinity and pH were measured with a thermometer, by the Winkler method, with a refractometer, and with a pH meter, respectively.

Results

Some physical and chemical parameters

Seasonal temperature, dissolved oxygen, salinity and pH variations measured during the study period at the stations are given in Table 2. The highest temperature (30 °C) was measured in June 1999, while the lowest (3.5 °C) was measured in January 2000 (Figure 2). In the annual cycle of dissolved oxygen, the highest value (16.6 mg l^{-1}) was obtained from Station 8 (October 1999), while the lowest value (0 mg l^{-1}) was measured from Station 7 (April and May 1999). The mean dissolved oxygen value was quite high (10.5 mg l^{-1}) and this is explained by high wave action and extensive macroalgae growth in the area. The salinity was quite variable in the littoral zone due to the existence of fresh water in some areas, and it ranged between 13‰ (Station 1) and 28‰ (Station 5). pH ranged between 7.2 and 9.5, with a mean value of 8.3.

The results of the other chemical analyses are summarised in Table 3. NO^-_3-N, PO^-_4-P, SiO_2 and suspended solids were measured by the TÜBİTAK Research Centre (unpublished data).

Phytological parameters

During the research period, the members of four algal classes, *Bacillariophyceae, Cyanophyceae, Chlorophyceae* and *Dinophyceae*, were recorded on the littoral sediments of İzmit Bay. *Merismopedia* was recorded as being the most common epipelic *cyanobacteria* encountered in the slides and the most significant genus in terms of density and biomass. While *Merismopedia glauca* (Ehrenb.) Nägeli was constantly present (81%, n = 16) in the samples. *Merismopedia tenuissima* Lemmerm. was rarely present (6%, n = 16) in the samples, and was found to be not significant in terms of density and biomass as it was only recorded at Station 7 at a rate of 3179 cells cm^{-2} and 0.1 x 10^{-3} mg cm^{-2}, respectively (May 1999). The frequencies of epipelic *Cyanobacteria* taxa recorded in the study period in İzmit Bay are given in Table 4, which includes the colonial, filamentous non–heterocystous and flamentous heterocystous forms of *Cyanobacteria*.

Bacillariophyceae was the dominant class in terms of species number and biomass according to Aktan (PhD Thesis, unpublished data). However, during our study period, in some months on the sediments of İzmit Bay, biomass increases were noted for *Cyanobacteria*. *Merismopedia* populations, which were as the most common genus, did not show a regular growth pattern in particular. The bloom of *Merismopedia* occurred at different times at different stations. The bloom consisted mainly of *M. glauca*. The maximum density and biomass values (2,300,000 cells cm^{-2} and 86 x 10^{-3} mg cm^{-2}, respectively) were found at Station 4 on May 1999 (Fig. 2). A positive correlation was found between temperature and *Merismopedia* abundance ($r = 0.82$, $p < 0.01$, $n = 17$).

ANOVA showed differences between the groups in *Merismopedia* cell numbers. The result of SNK tests showed significant differences in the cell numbers of *Merismopedia* at Station 4, while there were no significant differences between the other areas ($p < 0.05$).

Table 2. The seasonal changes of dissolved oxygen, temperature, pH and salinity measured at sampling stations in İzmit Bay.

	STATION 1				STATION 2				STATION 3				STATION 4			
	D.Oxygen mg l^{-1}	Temperature °C	pH	Salinity ‰	D.Oxygen mg l^{-1}	Temperature °C	pH	Salinity ‰	D.Oxygen mg l^{-1}	Temperature °C	pH	Salinity ‰	D.Oxygen mg l^{-1}	Temperature °C	pH	Salinity ‰
Mar 99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apr 99	13	16	8.2	-	16	18	8.5	-	12	19	8.2	-	16	20	9.4	-
May 99	12	22	8.2	-	15	22	8.5	-	14	17	8.4	-	10	26	8.0	-
Jun 99	13	27	8.1	-	11	27	8.5	-	7.6	28	7.2	-	11	28	8.0	-
Jul 99	8.8	23	8.0	-	8.8	22	7.8	-	9.6	23	8.1	-	7.6	25	8.1	-
Sep 99	13	22	8.2	-	11	22	8.1	-	8	23	8.1	-	5.2	23	7.9	-
Oct 99	7.6	20	8.3	-	14	21	8.4	-	8.8	22	7.9	-	16	23	8.4	-
Nov 99	12	11	8.0	-	4.8	10	8.1	-	6.4	12	8.1	-	12	12	8.4	-
Dec 99	8	10	8.2	-	8	9	8.4	-	9.2	11	8.3	-	6.4	11	8.2	-
Jan 00	11	6	8.5	25	10	5	8.5	24	10	7	8.4	26	9.6	7	8.3	-
Feb 00	11	6	8.5	23	10	6	8.6	24	11	8	8.4	20	12	10	8.2	16
Mar 00	13	8.5	8.6	18	13	10	8.7	17	12	11	8.4	17	15	11	8.7	22
Apr 00	9.6	14	8.6	20	10	15	8.8	20	10	17	8.6	17	12	18	8.7	18
May 00	10	16	8.5	17	11	16	8.4	20	12	18	8.6	21	13	24	8.3	19
Jun 00	8.9	19	8.9	13	12	20	8.2	24	10	22	7.4	24	16	27	8.1	18
Jul 00	10	21	8.1	22	10	23	8.1	22	10	22	7.3	25	11	24	7.4	25
Aug 00	13	22	8.5	21	11	22	8.5	21	9.6	22	8.2	23	8.6	23	8.5	23
Sep 00	13	21	8.9	22	11	21	9.3	22	9.6	20	9.4	21	8.8	22	9.5	23

	STATION 5				STATION 6				STATION 7				STATION 8			
	D.Oxygen mg l^{-1}	Temperature °C	pH	Salinity ‰	D.Oxygen mg l^{-1}	Temperature °C	pH	Salinity ‰	D.Oxygen mg l^{-1}	Temperature °C	pH	Salinity ‰	D.Oxygen mg l^{-1}	Temperature °C	pH	Salinity ‰
Mar 99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apr 99	16	19	8.3	-	-	18	8.4	-	0	18	8.3	-	11	18	8.4	-
May 99	12	21	8.3	-	8.4	21	8.1	-	0	22	8.3	-	-	22	8.3	-
Jun 99	12	30	8.4	-	7.6	28	7.9	-	-	28	8.1	-	14	26	8.3	-
Jul 99	7.2	24	8.1	-	7.2	23	7.8	-	6.8	20	7.8	-	12	22	8.0	-
Sep 99	9.6	22	8.2	-	-	23	8.0	-	15	24	8.6	-	14	23	8.4	-
Oct 99	10	21	8.3	-	-	-	-	-	8	21	8.1	-	16.6	21	8.7	-
Nov 99	6.4	12	8.1	-	-	-	-	-	11	11	8.1	-	12	11	8.1	-
Dec 99	6.4	12	8.2	-	-	-	-	-	8.4	8	7.7	-	9.6	9	8.4	-
Jan 00	12	6	8.4	20	-	-	-	-	9.6	3.5	8.1	-	11	5.5	8.5	22
Feb 00	10	7	8.5	24	-	-	-	-	11	7	8.5	22	14	6	8.2	24
Mar 00	14	11	8.6	20	-	-	-	-	13	11	8.4	22	15	10	8.5	22
Apr 00	14	16	9.0	20	-	-	-	-	14	15	9.0	16	12	16	8.3	17
May 00	11	18	8.5	21	-	-	-	-	11	18	8.5	20	12	18	-	21
Jun 00	10	21	8.5	24	-	-	-	-	-	21	8.5	22	-	21	9.1	23
Jul 00	11	24	8.3	28	-	-	-	-	9.2	23	8.1	23	-	23	8.7	22
Aug 00	9.6	22	8.4	22	-	-	-	-	10	22	8.2	21	-	23	8.6	21
Sep 00	-	20	9.3	23	-	-	-	-	11	20	9.1	22	13	21	9.2	22

(-) not determined

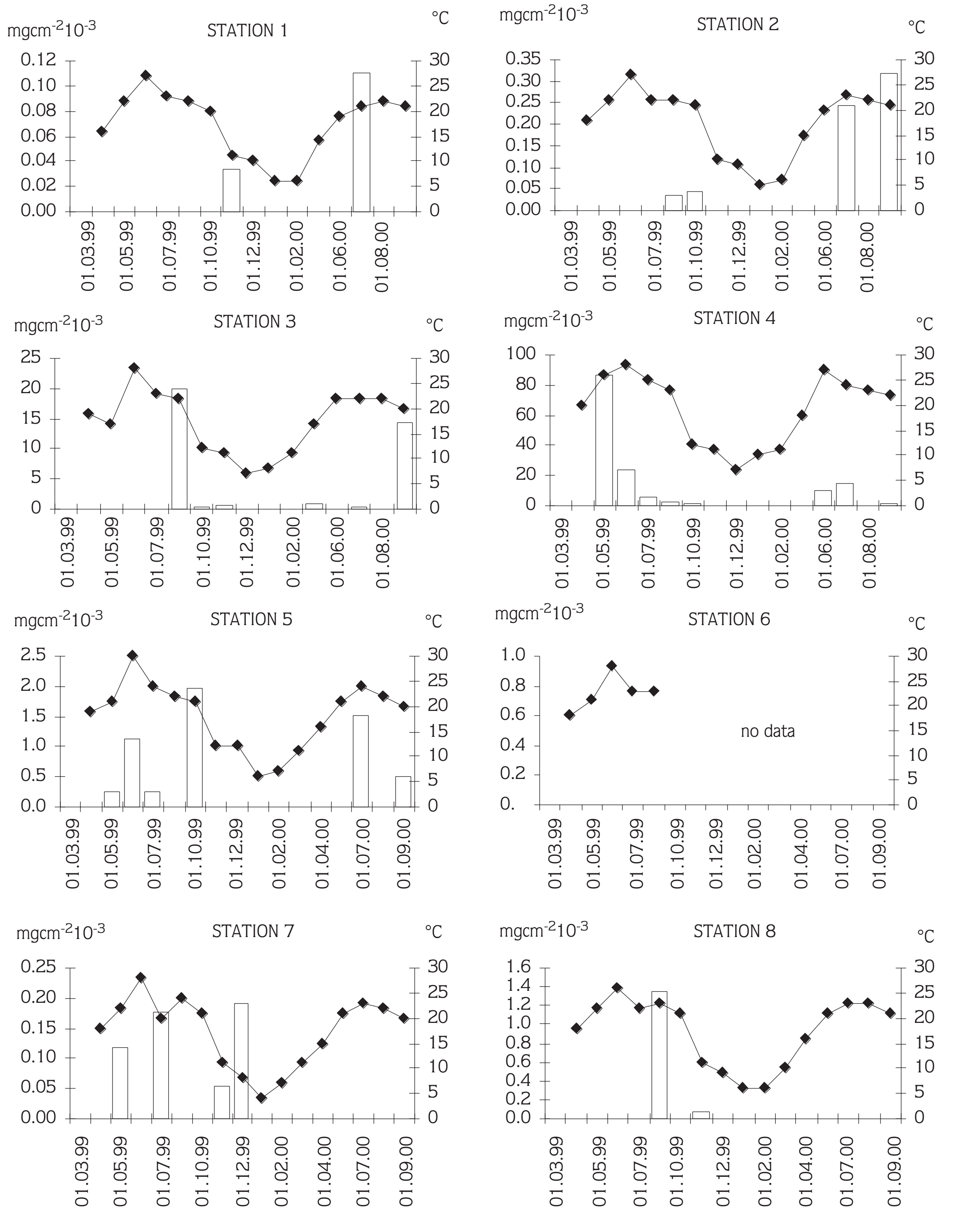

Figure 2. The seasonal changes of *Merismopedia* biomass and water temperature. The bars show the *Merismopedia* biomass; the lines show the temperature values.

Table 3. The results of the some physical and chemical parameters.

	min	max	average
Temperature (°C)	3.5	30	18.4
Dissolved oxygen (mg l^{-1})	0	16.6	10.5
pH	7.2	9.5	8.3
Salinity (‰S)	13	28	21.3
NO^{-}_{3}-N (µg l^{-1})	2 (Dec 99)	40.9 (Mar 99)	13
PO^{-}_{4}-P (µg l^{-1})	2 (Dec 99, Mar 00)	38 (May 99)	8.2
SiO_2 (µmol l^{-1})	0.12 (Dec 99)	7.17 (Mar 00)	5.5
Suspended solids (mg l^{-1})	17.8 (Sep 99)	32.4 (May 99)	22.6

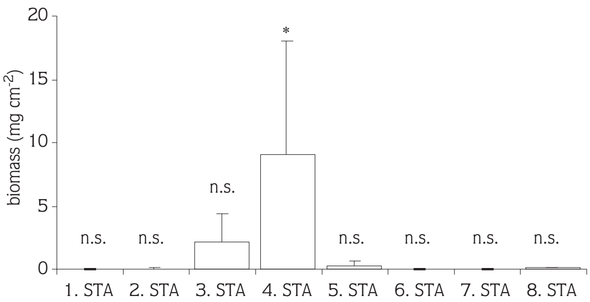

Figure 3. Means of seasonal *Merismopedia* biomass values for the stations in homogeneous subsets are displayed (uses harmonic mean sample size = 17). n.s: not significant; *: $p < 0.05$.

Table 4. List of *cyanobacteria* taxa recorded in İzmit Bay and their frequencies (f) n = 22 (1-20% rarely present, 21-40% occasionally present, 41-60% generally present, 61-80% mostly present, 81-100% constantly present).

Cyanobacterial taxa	f (%)
Colonial	
Merismopedia glauca (Ehrenberg) Nägeli	81
M. tenuissima Lemmermann	6
Aphanocapsa sp.	13
Flamentous non-heterocystous	
Lyngbya spp.	13
Planktotrix sp.	31
Oscillatoria calybea Mertens	19
O. limosa (Roth) C.A.Agardh	38
O. tenuis C.A.Agardh	38
Pseudanabaena sp.	25
Spirulina spp.	38
Flamentous heterocystous	
Anabaena cf. *constricta*	31

Discussion

The sediment flora is very rich in the littoral zones, where suitable substrata exist. The two major microscopic algal groups colonised in the marine sediment are blue-green algae and diatoms (Round, 1981). In the present study, increasing numbers of *Cyanobacteria*, particularly *Merismopedia*, were observed on the littoral sediments of İzmit Bay. As mentioned in previous research and also in this study, *Merismopedia* was found to be attached to marine sand grains (Meadows & Anderson, 1968) and to benthic habitats (Silva & Pienaar, 1999, 2000). Although the presence of *M. glauca* was mentioned in Turkish waters (Dural, 1995), there was no previous record for the density or biomass of this species. Many interactions between environmental and physical factors can lead to the development and persistence of blooms of algae and *Cyanobacteria*. Common factors that often lead to such blooms include warm weather conditions, high incident light levels, enhanced nutrient loading and the availability of essential metals supplied by terrestrial inputs (Dennison et al., 1999). Since İzmit Bay receives large quantities of wastewater, it had been evaluated as an eutrophic area. In our study, nutrient analyses and light intensity measurements were not possible in the sediment. However, the well-known effects of sediment structure and disturbance are reflected in the occurrence and abundance of the *Merismopedia*. The composition of epipelic flora changes according to sediment structure and disturbance in addition to the physical and chemical parameters of the sediment and water column (Round, 1981; Watermann et al., 1999). It was reported that high light intensity and optimum temperature levels probably cause *Cyanobacteria* development during autumn and spring (Round, 1961; Tsujimura et al., 2000). In İzmit Bay, the temperature dynamics were driven by the changing seasons, with increasing temperature values from spring to summer and a progressive decrease from autumn to winter. The annual *Merismopedia* growth peak occurred in late spring, which is a period of increasing light and temperature. *Merismopedia* started to grow in May (especially at Station 4) when the temperature was on the rise, and the decline in biomass occurred after spring.

While the peak for *Merismopedia* occurred at certain times for all stations, significant differences were recorded in cell number and biomass levels. This result was explained by the sediment disturbance. Underwood and Paterson (1993) determined that changes in the sediment bed and the erosion of sediment during periods of strong winds were reflected by changes in the abundance of algal populations. The density and biomass of *Merismopedia* were found to be lowest at Stations 1 and 3 because of the less stable sediments and extensive cover of macroalgae, (particularly *Ulva* L.), which covered the sediment, reducing the growth of epipelic flora at these sites.

The highest *Merismopedia* density and biomass values were recorded at Station 4, which is a partly sheltered area with more stable sediment. In addition, particularly after the earthquake, extensive nutrient loading, determined by Morkoc (unpublished data), stimulated the growth of *Merismopedia*. In contrast, growth was limited at Station 2, which had coarse and less stable sediment, and at Stations 5 and 7, where wave action and unstable sediment did not allow the development of *Merismopedia* colonies; only small increases and decreases in density and biomass were recorded at these sites. At Station 8 the seasonal growth of *Merismopedia* was not significant; only a small increase was recorded and the biomass remained quite low in September 1999.

High microalgal biomass is an important indicator that shows changes in water quality (Leskinen, 1993). The data represented in this study demonstrates considerably high *cyanobacteria*l density and biomass in some parts of İzmit Bay. As a result of this study, the density and biomass variations of *Merismopedia* species have been recorded for the first time on the littoral marine sediments of Turkey. More detailed investigations are required before any conclusions can be reached regarding the possible ecological and physical mechanisms involved.

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