Turk J Bot
29 (2005) 83-94

Research Article

Colonisation of Epipelic Diatoms on the Littoral Sediments of İzmit Bay*

Yelda AKTAN, Güler AYKULU
İstanbul University, Fisheries Faculty, Ordu Cad. No: 200, 34470, Laleli, İstanbul - TURKEY

Received: 02.04.2004
Accepted: 06.12.2004

Abstract: Seasonal variations in the composition, density and diversity of the epipelic diatom assemblages were investigated monthly from March, 1999, to September, 2000, at 8 sampling sites chosen in the littoral of İzmit Bay. The main physical and chemical parameters, which affected species composition and density, were also measured on every sampling date. During the study period, 3 centric and 41 pennate diatoms were recorded in the epipelic diatom flora of the bay. *Achnanthes* Bory spp., *Amphora exigua* W.Greg. and *Navicula tripunctata* (O.Müll.) Bory were dominant in terms of frequency and density. In general, the bay showed a small species diversity in epipelic diatoms (annual mean 1.46 ± 0.44 bits ind^{-1}). In addition to marine diatoms, freshwater species were also recorded in the epipelic diatom assemblages.

Key Words: Epipelic diatom, density, species diversity, İzmit Bay

İzmit Körfezi'nin Littoral Sedimanlarındaki Epipelik Diyatomelerin Kolonizasyonu

Özet: Mart 1999 - Eylül 2000 tarihleri arasında yapılan bu çalışmada Marmara Denizi'nin İzmit Körfezi'nde seçilen sekiz örnekleme istasyonunda kıyı bölgesi sedimanları üzerinde yaşayan diyatome topluluklarının kompozisyon ve yoğunluklarında ki mevsimsel değişimler incelenmiştir. Ayrıca her örnek alım tarihinde tür kompozisyonu ve yoğunluğunu etkileyen başlıca fiziksel ve kimyasal parametreler ölçülmüştür. Araştırma süresi boyunca, epipelik florada 3 sentrik ve 41 pennat diyatome kaydedilmiştir. Özellikle, *Achnanthes* Bory spp., *Amphora exigua* W.Greg. ve *Navicula tripunctata* (O.Müll.) Bory diğerlerine göre sıklık ve birey sayısı bakımından baskın türler olmuşlardır. Körfez bölgesinde epipelik diyatome topluluğunda tür çeşitliliği düşük (yıllık ortalama H'=1.46 ± 0.44 bits birey^{-1}) olarak belirlenmiştir. Epipelik florada denizel diyatomelerin yanı sıra tatlı su türleride bulunmuştur.

Anahtar Sözcükler: Epipelik diyatome, yoğunluk, tür çeşitliliği, İzmit Körfezi

Introduction

Benthic diatoms are important contributors to primary production in estuarine and marine coastal ecosystems (Matheke & Horner, 1974). Diatoms are the dominant group in marine epipelic communities (Round, 1981; Underwood & Paterson, 1993) and are the main food source for fauna such as molluscs and amphipod crustaceans (Mazzella & Spinoccia, 1992; Scipione & Mazzella, 1992).

Many studies have been carried out on the systematics and distribution of benthic macroalgae and seagrasses in Turkish seas (Güner & Aysel, 1978; Aysel & Güner, 1979, Güner & Aysel, 1979; Aysel & Güner, 1980 and 1982; Dural, 1988; Aysel et al., 1991, 1993 and 1996; Erdugan et al., 1996; Aysel, 1997a; Aysel, 1997b; Aysel et al., 2000; Aktan & Aykulu, 2003). However, despite the importance of the benthic microalgal flora in marine littoral zones there is no information about the colonisation and diversity of epipelic diatoms among these studies.

In İzmit Bay, previous studies have focused on physical and chemical parameters of water with particular reference to pollution. The aims of this study are to characterise the epipelic diatom flora in İzmit Bay among the benthic algal flora and at the same time to contribute insights into the factors controlling the seasonal changes in the species diversity and density of epipelic diatoms.

Study Area

İzmit Bay, located on the north-east part Marmara Sea, is one of the most polluted areas in Turkey (Figure 1). Several industries have been developing rather rapidly around the bay. In addition to untreated or partly treated

---

* This work was supported by the Research Fund of İstanbul University, project number: T-670/190299, and is part of a PhD thesis.

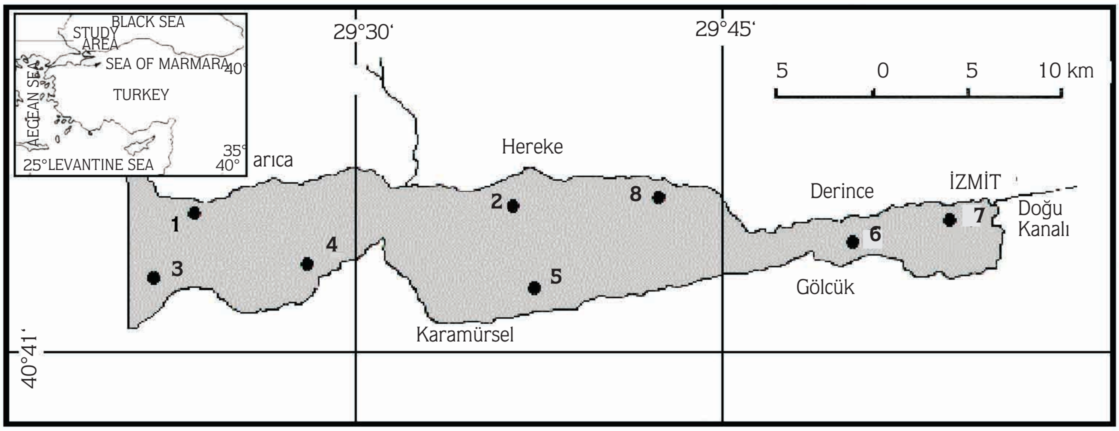


Figure 1. Sampling stations in İzmit Bay.

domestic wastes originating from the increasing population, the substantial industrial development, the heavy maritime traffic and the agricultural activities in the surrounding areas have caused a considerable pollution burden. Furthermore, some factory and urban sewage systems were damaged by the earthquake of August, 1999. The bay ecosystem was strongly affected by the quake and subsequent refinery fire, as were the settlements and industrial regions.

İzmit Bay, a semi-enclosed sea, is about 45 km long and varies in width from 1.8 to 9 km (Morkoç et al., 2001). In terms of its oceanographic characteristics, İzmit Bay may be separated into 3 distinct regions, western, central and eastern, which are connected to each other through narrow openings. It has a surface area of approximately 261 km^2. The main morphometric characteristics of İzmit Bay are given in Table 1. In terms of the flow and stratification characteristics of İzmit Bay, there are 2 layer current systems associated with 2 stratification layers persisting throughout the whole year as a part of the Turkish Strait system and Marmara Sea. The upper layer is occupied by the less saline (20 - 22 psu) waters of Black Sea origin, while the lower layer contains saline (37 - 38.5 psu) Mediterranean waters.

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

Materials and Methods

A total of 18 collections were conducted, with samples taken every month at 8 sampling stations on the littoral sediments of İzmit Bay between March, 1999, and September, 2000. The sampling stations were influenced by different environmental conditions. Sampling was not possible at Station 6, which was covered with gravel and rocks after the earthquake (August, 1999).

Station 1 was at the western part of the bay which, being open to waves, had disturbed sediments consisting of sand and gravel. A stream carried snowmelt and rain water to the site in the spring, autumn and winter. Station 2, in the middle part of the bay, was also open to waves. The bottom consisted of fine sand and gravel. The site was affected by industrial wastes in the north-eastern part of the bay and wastewater entering from small towns. Station 3 was located at the western part of the bay. Sediment consisted of sand and gravel. The shores had dense growth of macroalgae: macroalgal remains, especially of *Ulva* L. species covered the sediments and shores under the effect of strong winds from the north. Station 4, a somewhat more sheltered site, was in the western part of the bay. The annual water temperature was higher than those at the other sampling stations. The bottom consisted of fine sand and mud. This station was surrounded by agricultural areas and by houses used in the summer. Station 5, in the middle part of the bay, was significantly affected by waste water. The shore was affected by wave action and had rocky areas, and the bottom had fine sand. Station 6 was exposed to wave actions and Station 7 (somewhat more sheltered) was in the eastern part of the bay. Sampling was not possible at

Station 6, which was covered with gravel and rocks after the earthquake (August, 1999). Station 7 was near the refinery at the north-eastern coast of the bay. The bottom consisted of fine sand and mud. Station 8, in the middle part of the bay, had soft and fine sand. The site was affected by the untreated domestic wastewaters from the small cities and also from İzmit, which is the most populous city in the region.

Physical and chemical parameters

Physical and chemical parameters were measured from surface waters on all 18 collection dates. Temperature was determined with a thermometer, salinity with a hand refractometer (508-I, Salinometer, NaCl) and pH with a standard laboratory pH meter. Nutrient analyses were performed bimonthly at the TÜBİTAK Research Centre. Samples for the analysis of silicate were stored at 4 °C, whereas the other nutrient samples (nitrate + nitrite and ortho-phosphate) were deep-frozen to -20 °C and stored for not longer than 2 weeks. Nutrient analyses were performed by a Technicon Autoanalyzer II System. Total suspended solids were analysed gravimetrically as described in the standard methods. Standard methods (APHA, 1985) modified for continuous analysis (Technicon Industrial Method, 1977a, 1977b) were used.

Sampling and identification of epipelic diatoms

For sampling, isolating and counting the diatoms Round's method (1953) was used. The samples were obtained by drawing a glass tube (0.7 cm in diameter and 1 m long) along the sediment. This sample method collected a sample from the surface–growing algae. The samples were placed into a petri dish (10 cm in diameter) to a depth of 1 cm. Cover slips were placed on the mud in the petri dishes and left for 24 h. During this time the positively phototactic algae moved upwards through the sediments and came to rest on the under surface of the coverslips. The latter were then removed at the 10 o'clock position, and placed on a glass slide, and transects were taken across them using a light microscope (10 x 40), counting 3 slides for each species. Density was calculated with the following formula: organisms in count (organism/cm^2) = A / Fd x L, where A is the individual number of organisms, Fd is the diameter of the counting area (cm), and L is the length (cm) of the counting area (cover-glass). Identification of diatoms was made with light and scanning electron microscopy. Permanent slides were made. An appropriate volume of each sample was boiled with H_2SO_4 and HNO_3, and then washed in distilled water. After drying, they were mounted in Entellan for light microscopy. For scanning electron microscopy (SEM), concentrated samples were cleaned from organic material by burning with acetic acid and hydrogen peroxide, and were then photographed. Hustedt (1930), Cupp (1943), Hustedt (1959, 1961), Hendey (1964), Hustedt (1966), Patrick & Reimer (1966, 1975), Hustedt (1985), Krammer & Lange-Bertalot (1986), Poulin (1986), Tomas (1995), and Hartley (1996) were used for the identification of diatoms. Shannon-Weiner (H') diversity indices were used to describe the diatom assemblage structure. The formula is $H' = -\Sigma P_i \, (\log_2 P_i)$, where p_i is the proportion of the *i* th taxon in the sample, and k is the number of phytoplankton species (Zar, 1984). Relationships between the epipelic abundance and diversity and main parameters were found using correlation analysis (Spearman's correlation coefficient).

Results

The physical and chemical factors

Seasonal variations in surface water temperature, pH and salinity measured during the research period at the 8 stations are given in Figure 2. The water temperature showed appropriate seasonal changes. The lowest temperature measured was 3.5 °C at Station 7 in winter (January, 2000) while the highest temperature measured was 30 °C at Station 5 in summer (June, 1999). There were no important differences between stations, with the exception of Station 4, which is a sheltered area. The pH of the surface water in İzmit Bay varied between 7.2 and 9.5, with an annual mean of 8.3. Changes in salinity at the surface water showed considerable differences between stations. Average salinity was determined as 21.3 psu while the highest and lowest values were 28 psu (at Station 5, in July, 2000) and 13 psu (at Station 1, with freshwater input in June, 2000), respectively. The highest average values were recorded in July (23.9 psu), while the lowest value was recorded in April (18.3 psu). Salinity showed a negative correlation with abundance and diversity of epipelic diatoms, but this was not statistically significant ($r = -0.30$ and $r = -0.19$, $P < 0.01$). Some physical and chemical parameters are summarised in Table 2.

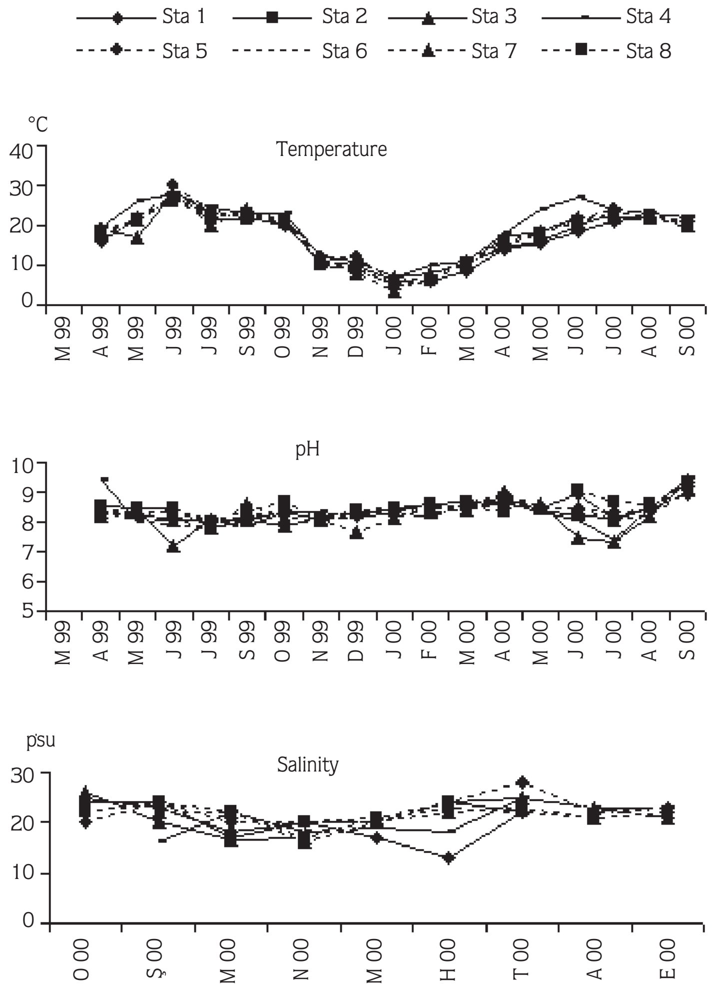


Figure 2. Seasonal variations of temperature, pH and salinity from surface water in İzmit Bay.

Table 2. The results of the physical and chemical parameters (March, 1999-September, 2000).

	min.	max.	average
Temperature (°C)	3.5	30.0	18.4
pH	7.2	9.5	8.3
Salinity (psu)	13.0	28.0	21.3
NO_2+NO_3-N (µg l^{-1})	2.0 (Dec. 99)	40.9 (Mar. 99)	13.0
PO_4-P (µg l^{-1})	2.0 (Dec. 99, Mar. 00)	38.0 (May 99)	8.2
SiO_2 (µg l^{-1})	7.0 (Dec. 99)	430.0 (Mar. 00)	5.5
Suspended solids (mg l^{-1})	17.8 (Sep. 99)	32.4 (May 99)	22.6

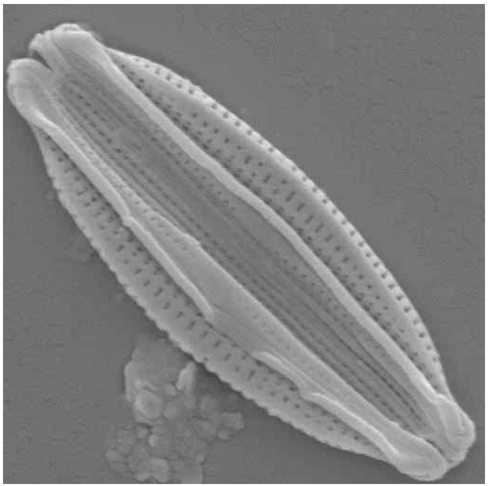
Epipelic diatoms

Species composition and seasonal changes in density

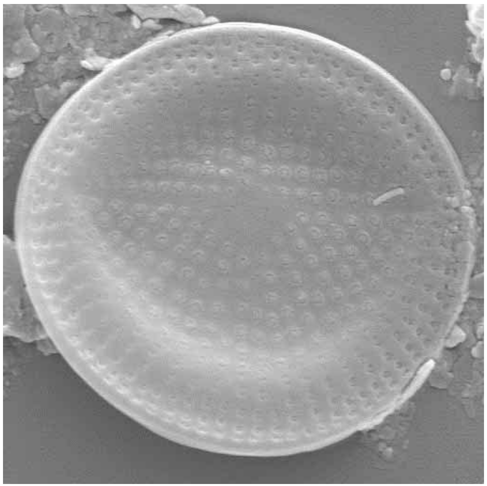
A total of 44 epipelic diatom taxa, consisting of 3 centrics and 41 pennates, were identified during the research period. Of these, there were 9 freshwater species. The epipelic diatom taxa and their habitats are listed in Table 3, and some SEM photos of epipelic diatoms are given in Figure 3. Epiphytic and planktonic species were also found in the epipelic diatom assemblages.

Table 3. List of epipelic diatoms found in İzmit Bay and their habitats. (B = Brackish Water; M = Marine; F = Freshwater).

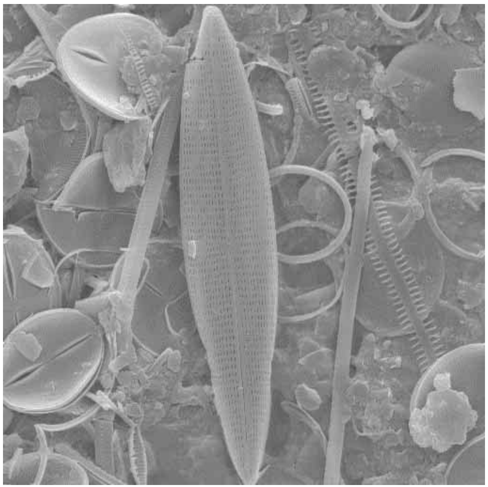
Taxon	Habitat
Centrales	
Melosira moniliformis (O.F.Müll.) C.Agardh	B M
Melosira nummuloides C.Agardh	B
Skeletonema costatum (Grev.) Cleve	M
Pennales	
Achnanthes brevipes C.Agardh	B
Achnanthes sp. Bory	
Amphiprora alata (Ehrenb.) Kütz.	M
Amphora coffeaeformis (C.Agardh) Kütz.	B M
Amphora costata W.Sm.	M
Amphora delicatissima Krasske ex Hust.	F
Amphora exigua Greg.	B M
Amphora ovalis (Kütz.) Kütz.	F
Anorthoneis excentrica (Donkin) Grunow	M
Caloneis sp. Cleve	
Cocconeis scutellum Ehrenb.	M
Cylindrotecha closterium (Ehrenb.) Reinmann & Lewin	M
Fragilaria oceanica Cleve	M
Gyrosigma fasciola (Ehrenb.) J.W.Griff. & Henfr.	B M
Hantzschia amphyroxys (Ehrenb.) Grunow	B F
Lichmophora abbreviata C.Agardh	M
Lichmophora paradoxa (Lyngb.) C.Agardh	M
Navicula cryptocephala Kütz.	F
Navicula directa W.Sm.	M
Navicula lyra Ehrenb.	M
Navicula menisculus Schum.	B
Navicula palpebralis Bréb. ex W.Sm.	M
Navicula radiosa var. *tenella* (Bréb. ex Kütz.) Grunow ex Van Heurck	B M
Navicula ramosissima var. *mucosa* (Aleem) Hendey	M
Navicula rostellata Kütz.	M
Navicula tripunctata (O.Müll.) Bory	F
Navicula tuscula Ehrenb.	B F
Navicula sp. Bory	
Nitzschia apiculata (Greg.) Grunow	M
Nitzschia frustulum (Kütz.) Grunow	B F
Nitzschia frustulum var. *perpusilla* (Rabenh.) Grunow	B F
Nitzschia longissima (Bréb.) Grunow	M
Nitzschia palea (Kütz.) W.Sm.	F
Psammodictyon panduriforme (Greg.) D.G.Mann	M
Petroneis humerosa (Bréb.) Stickle & D.G.Mann	M
Pleurosigma angulatum (Quekett) W.Sm.	B
Pleurosigma salinarum (Grunow) Grunow in Cleve ex Grunow	B
Pleurosigma sp. W.Sm.	
Synedra tabulata var. *fasciculata* (Kütz.) Grunow	B M
Synedra tabulata var. *parva* (Kütz.) Grunow	B M
Toxonidea insignis Donkin	M



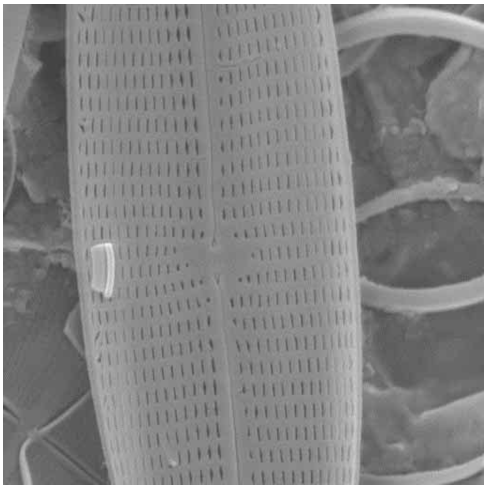
Amphora delicatissima (x 6750)



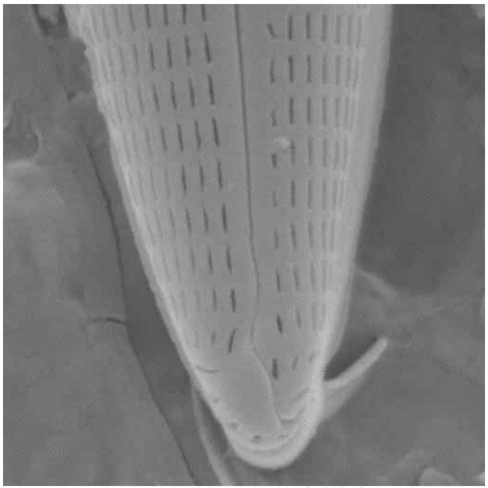
Anorthoneis excentrica (x 4000)



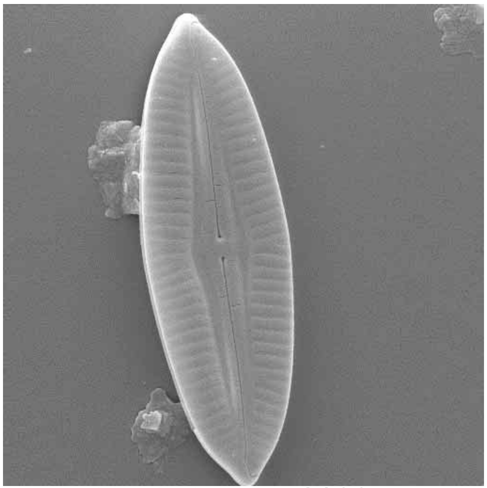
Navicula meniscuIus (x 1650)



Navicula meniscuIus (x 5000)

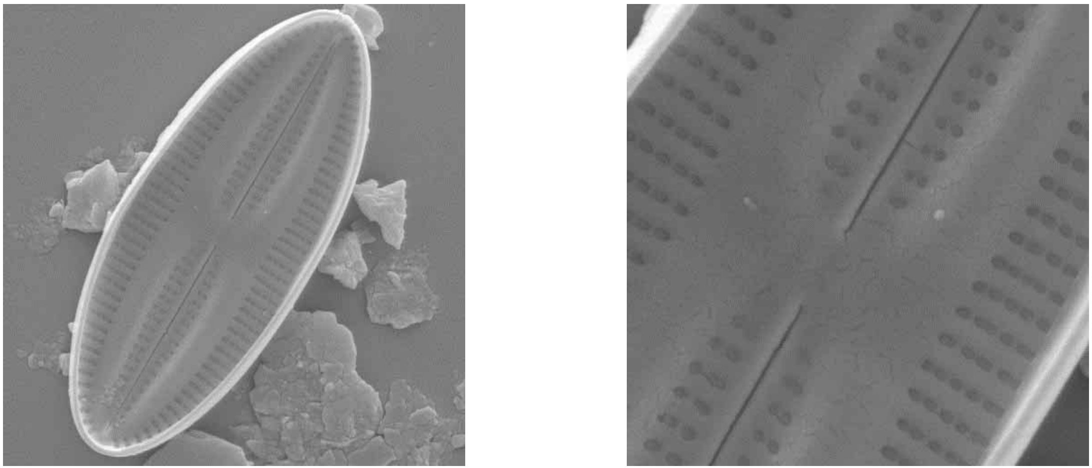


Navicula meniscuIus (x 10000)

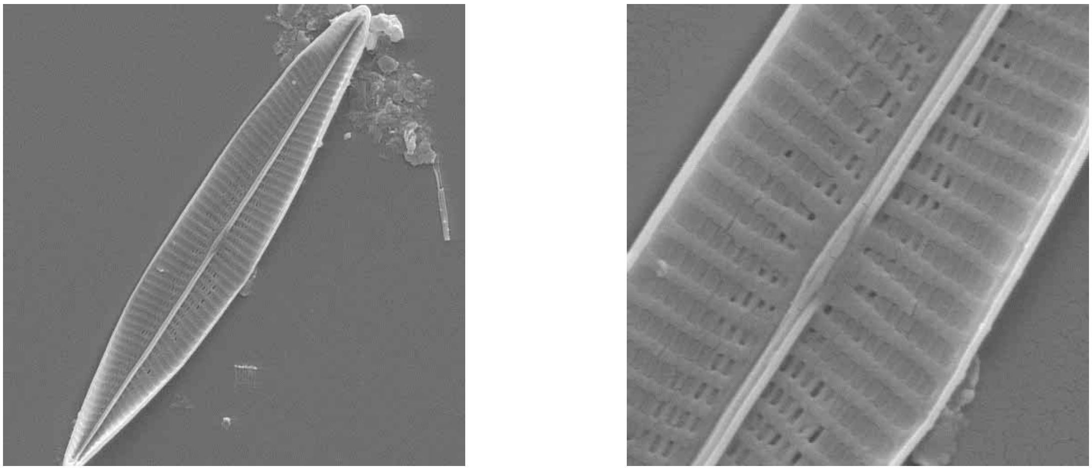


Navicula palpebralis (x 2100)

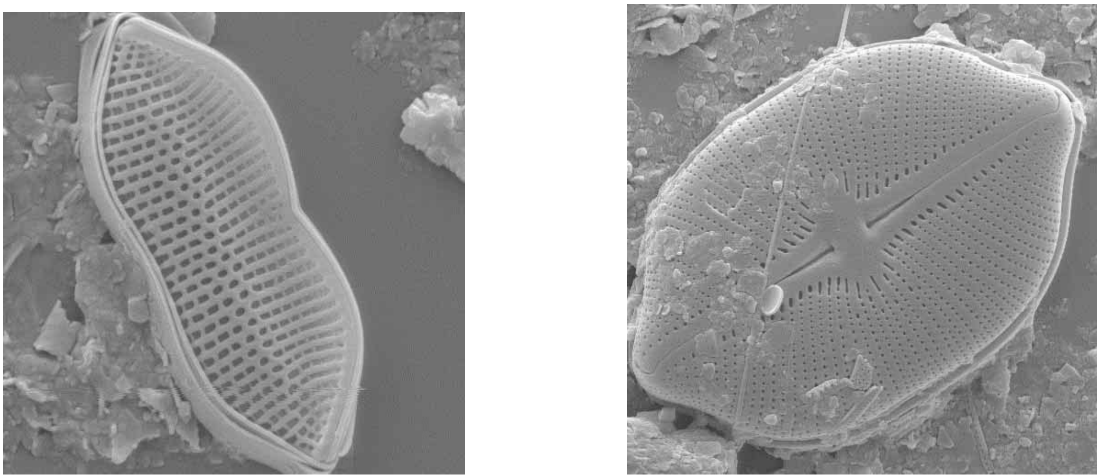
Figure 3. Some epipelic diatoms (with magnification) recorded on the littoral sediments of İzmit Bay.



Navicula lyra (x 3500) *Navicula lyra* (x 9500)

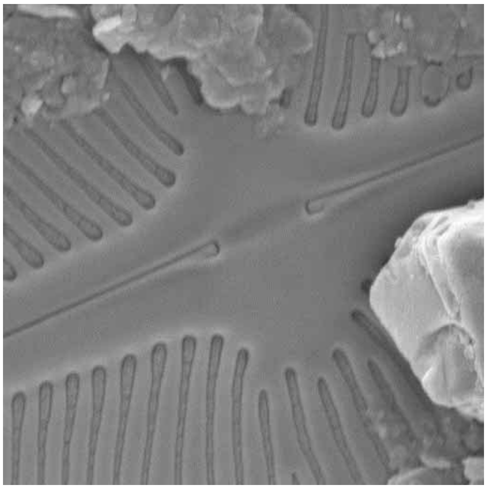


Navicula rostellata (x 1900) *Navicula rostellata* (x 7250)

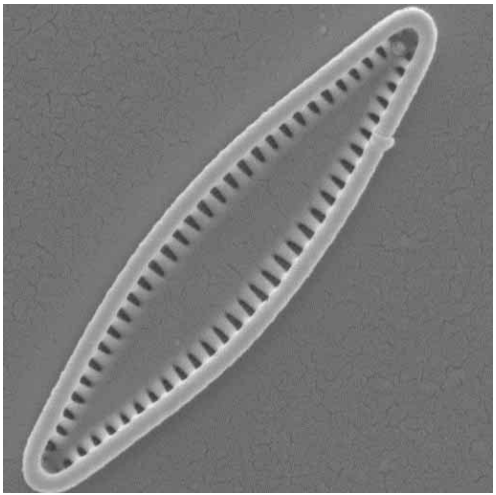


Psammodictyon panduriforme (x 4500) *Petroneis humerosa* (x 1150)

Figure 3. (Contunued) Some epipelic diatoms (with magnification) recorded on the littoral sediments of İzmit Bay.



Petroneis humerosa (x 5000)



Synedra tabulata var. *parva* (x 5750)

Figure 3. (Contunued) Some epipelic diatoms (with magnification) recorded on the littoral sediments of İzmit Bay.

Achnanthes Bory spp., *Amphora exigua* W.Greg. and *Navicula tripunctata* (O.Müll.) Bory were the dominant species in these assemblages in terms of density and relative abundance. In addition to these species, *Amphora delicatissima* Krasske and *Navicula menisculus* Schum. reached high densities during the study period. However, these 2 species did not show a regular seasonal variation, with peaks on a few dates. The maximum number of species was recorded at Station 4. In terms of total epipelic diatom density, considerable differences were recorded among the stations. The highest total numbers were recorded in July, 2000, (352778 cells cm^{-2}) at Station 4 and in February, 2000 (416319 cells cm^{-2}) at Station 7 due to a sharp increase in cell numbers of *Achnanthes* spp. and *N. tripunctata*, respectively.

Figure 4 shows the seasonal changes in the density of the epipelic diatoms and the Shannon-Weiner index (H'), and Figure 5 shows the seasonal changes in relative abundance in epipelic diatoms.

Species diversity

The Shannon-Weiner diversity index (Figure 4), using the monthly estimation of species and cell numbers, showed that littoral sediments of İzmit Bay had a small species diversity of epipelic diatoms (with an annual mean of 1.46 ± 0.44 bits ind^{-1}). A significant positive correlation was found between species numbers and the Shannon diversity index ($r = 0.63$, $P < 0.01$). The maximum value was recorded in April, 1999, at Station 3 ($H' = 2.94$ bits ind^{-1}) and the lowest in April to September, 1999. A negative correlation was found between the Shannon diversity index and temperature ($r = -0.23$, $P < 0.05$).

Discussion

Epipelic, mainly mobile, diatoms on the littoral sediments are important in the algal flora and primary productivity of the benthic zone. The composition of epipelic flora is influenced by the physical-chemical properties of water, and by waves that alter the structure of sediments (Round, 1981).

There are various environmental factors which affect the increase and decrease in the biomass of benthic diatoms. While nutrients, light and temperature conditions influence biomass increase, the mobility or instability of the environment, strong waves, large amounts of precipitation of the suspended material and consumption by animals reduce it. In measurements taken from the surface waters of the littoral zone in İzmit Bay, changes in temperature were recorded at different sites and in various seasons, related to wind and wave movements. Salinity measurements showed changes parallel to evaporation and rainfall. While these changes were very small in open waters, they were more evident in the shore region of İzmit Bay. Freshwater species were also recorded in some seasons related to changes in salinity.

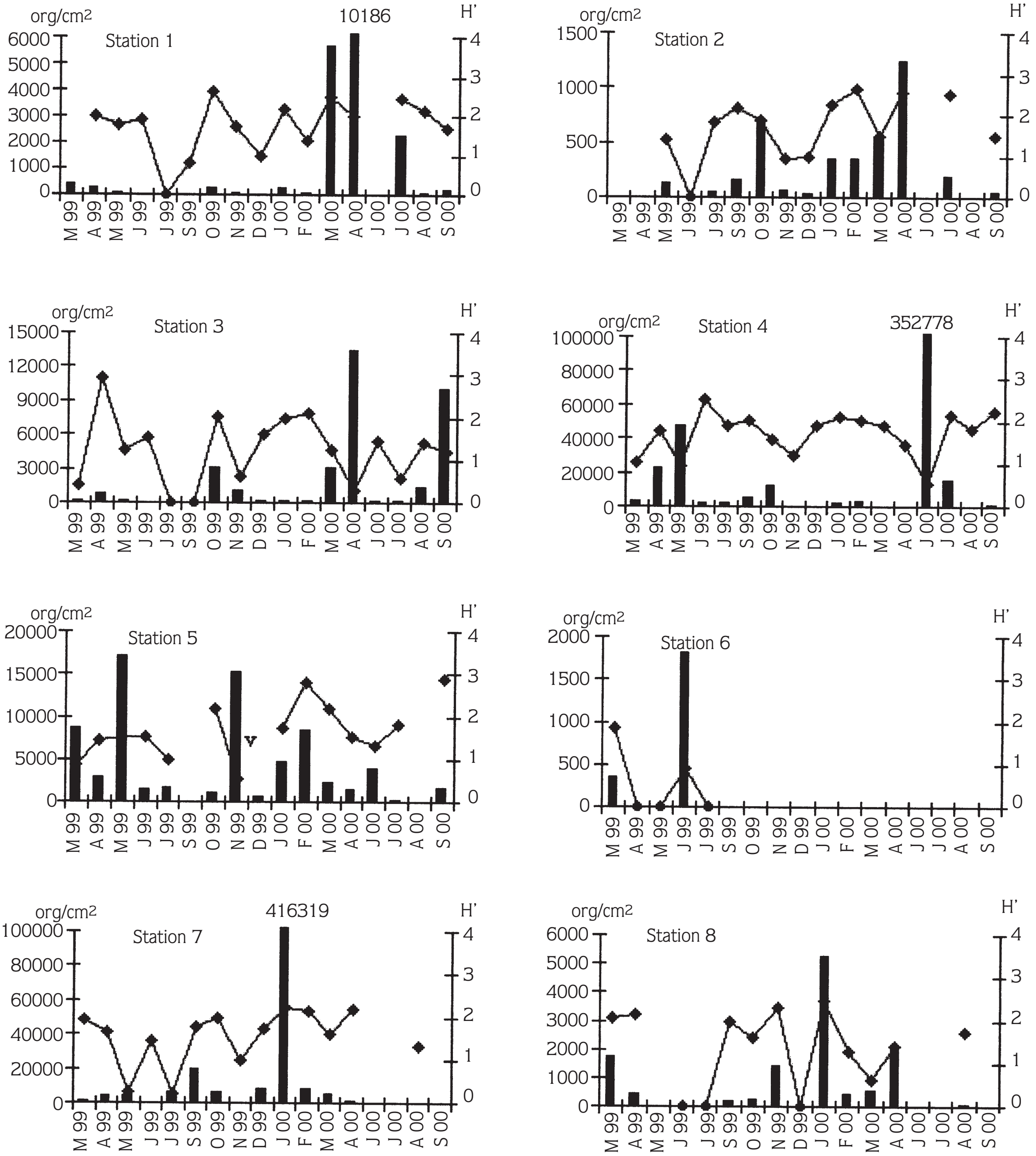


Figure 4. Seasonal changes in the density of epipelic diatoms and the Shannon-Weiner index (H') according to all stations. The bars show the density of epipelic diatoms and the lines show the Shannon-Weiner index.

Pennates were the dominant epipelic diatoms in İzmit Bay. Two common centric diatoms, *Melosira moniliformis* (O.Müll.) C.Agardh and *Melosira nummuloides* C.Agardh, were recorded as “seldom present” and “rarely present” in the epipelic flora, and were not numerically important. In studies of epiphytic algae in İzmit Bay (Aktan & Aykulu, 2003), these species were recorded on host macroalgae and were denser in the epipelic flora. This study shows that the main habitat of these species is the epiphyton, and that they mix with the epipelic flora from time to time. The high number reached at Station 7, in February, 2000, of *Skeletonema costatum* (Grev.) Cleve, a very

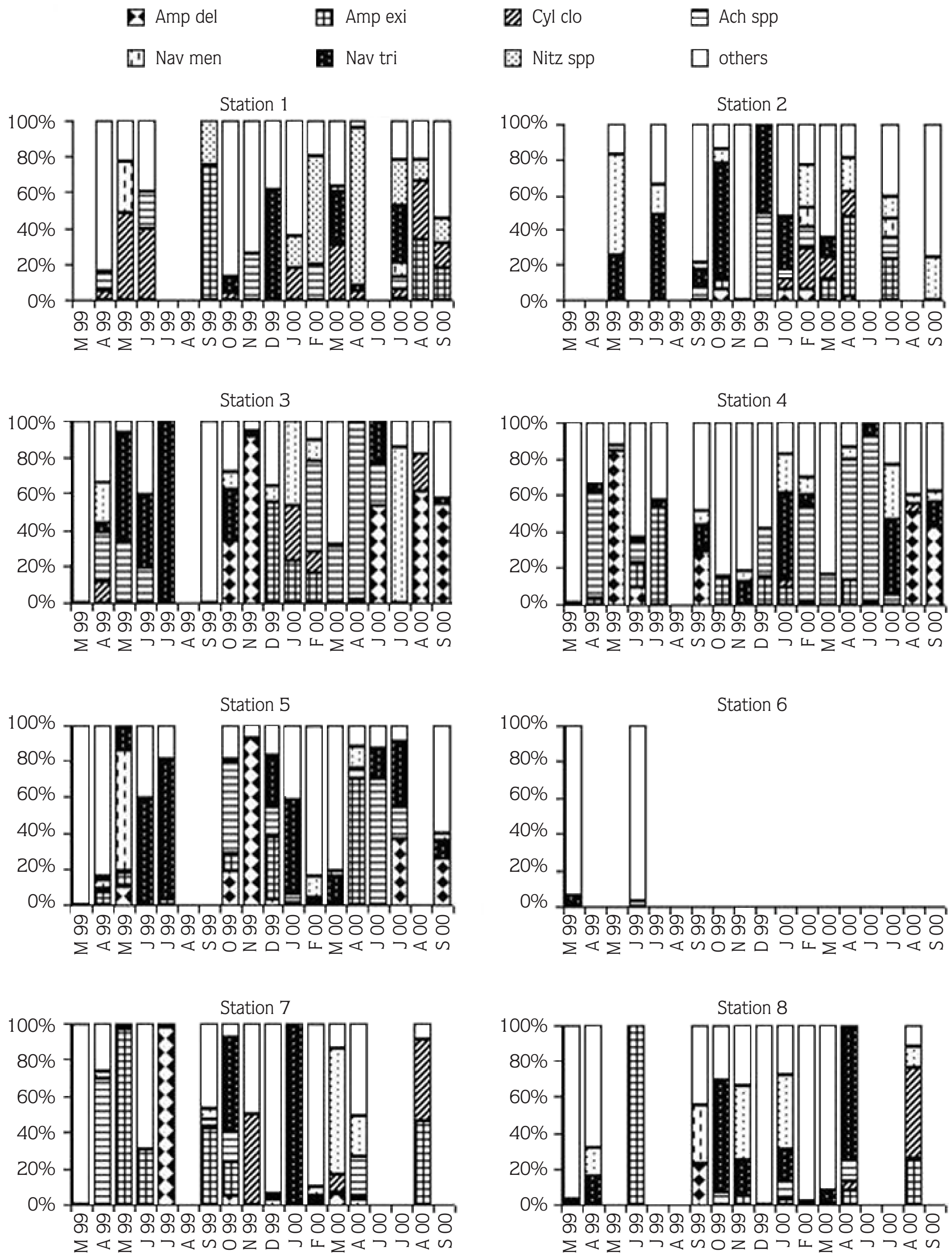


Figure 5. Seasonal changes in relative abundance of epipelic diatoms according to all stations.

common pelagic diatom (Hendey, 1964), can be explained by the large increase in phytoplankton (unpublished data). Although *Anorthoneis excentrica* (Donkin) Grunow was recorded as “common” in the marine phytoplankton and epipelon (Round et al., 1990), it was “rarely” recorded in İzmit Bay.

The pennate diatoms *Amphora exigua* Greg., *Navicula tripunctata* (O.Müll.) Bory and *Achnanthes* Bory spp.

were recorded in high numbers on sediments. *Cylindrotecha closterium* (Ehrenb.) Lewin & Reimann and *Amphora coffeaeformis* (C.Agardh) Kützing were recorded as “commonly present” in İzmit Bay, but were not numerically important. In Riga Bay, *C. closterium* and *A. coffeaeformis* were recorded in the epipelic, and in both the epipelic and epiphytic flora, respectively (Vilbaste et al., 2000). *A. exigua*, reported as reaching high numbers in the summer in the Severn Inlet, U.K. (Oppenheim, 1991), was found very abundantly at 14074 cells/cm^2 in İzmit Bay in November, 1999.

Characterised as “common” species in epipelic diatom communities by Round et al. (1990), *Hantzschia amphioxys* (Ehrenb.) Grunow, *Navicula lyra* Ehrenb., *Petroneis humerosa* (Bréb.) Stickle & D.G.Mann, *Pleurosigma angulatum* (E.J.Quekett) W.Sm., *Psammodictyon panduriforme* (W.Greg.) D.G.Mann, *Rhabhoneis* Ehrenb. sp. and *Toxonidea insignis* Donkin were also recorded on sediments of İzmit Bay.

İzmit Bay is affected by industrial and domestic water, and the epipelic flora showed differences in physical and chemical effects, sediment structure and the presence of macroalgae. The dense growth of macroalgae and seagrasses on these shores affected the epipelic algal growth on the sediments. Macroalgal remains, especially of *Ulva* L. species covering the sediments and shores under the effect of strong winds from the north in Stations 1 and 3 in İzmit Bay, also block the sunlight, reducing the epipelic flora.

Hopkins (1963) observed the movements of diatoms in inlets related to their physical and chemical changes, and recorded a greater growth on thin sand than on thick sand. Round & Eaton (1966) and Happey-Wood & Jones (1988) reported that waves and water movement moved the sediments, and affected the growth of epipelic diatoms and their daily vertical migration. In our study, the sediment structure was thick sand in Station 2 with decreased growth at diatom flora. The maximum number was reached on April, 2000, with 1243 cells cm^{-2}, and *A. exigua* was the dominant species in diatoms. Station 4, being partially sheltered and having thinner and less mobile sediment, was the best region for the development of epipelic diatom flora. For the increase observed in the spring and autumn of 1999 and the beginning of summer, 2000, *Amphora* spp. Ehrenb., *N. tripunctata* and *Achnanthes* spp. were recorded as the dominant species. The structure of the sediments and the nutrients entering the region caused increases in the epipelic diatoms.

At Station 5, which is open to waves, the total numbers of epipelic diatoms were smaller than those at the other stations, and numbers showed sudden increases and decreases. At this station, *Amphora* spp., *Navicula menisculus* Schum., *Navicula palpebralis* (Bréb.) W.Sm. and *Achnanthes* spp. were recorded as dominant species in some months.

Species diversity is analysed to explain the structure of communities. Species diversity is considered higher in communities in stable environments than in disturbed ones. Communities with high diversity are usually composed of many species and no great difference in population size is observed among them (Odum, 1971). The low diversity in İzmit Bay (with an annual mean of 1.46 ± 0.44 bits ind^{-1}) can be explained in this way. In some seasons, the effect of nutrients carried by wastewater has caused certain species to increase substantially, thus reducing the species diversity.

References

Aktan Y & Aykulu G (2003). Epiphytic diatoms of different host plants in the İzmit Bay (Marmara Sea, Turkey). In: Oray IK, Çelikkale MS & Özdemir G (eds.) *International Symposium of Fisheries and Zoology*, pp. 201-218. Istanbul: Istanbul University Press.

APHA (1985). *Standard methods for examination of water and wastewater*. Washington: American Public Health Association.

Aysel V & Guner H (1979). Ege ve Marmara Denizindeki alg toplulukları üzerinde kalitatif ve kantitatif çalışmalar. 3. *Gracilaria verrucosa* (Hudson) Papenfuss topluluğu. *Ege Univ Fen Fak Derg Ser B* 3: 111-118.

Aysel V & Güner H (1980). Ege ve Marmara Denizindeki alg toplulukları üzerinde kalitatif ve kantitatif çalışmalar. 4. *Gelidium capillaseum* (Gmelin) Kütz. topluluğu. *Ege Univ Fen Fak Derg Ser B* 4: 141-153.

Aysel V & Güner H (1982). Ege ve Marmara Denizindeki alg toplulukları üzerinde kalitatif ve kantitatif çalışmalar. 6. *Laurencia obtusa* (Hudson) Lamour var. *obtusa* topluluğu (*Rhodomeleceae, Ceramiales, Rhodophyta*). *Do?a Bilim Derg Temel Bilimler* 3: 97-103.

Aysel V, Guner H & Dural B (1991). Türkiye Marmara denizi florası I. *Cyanophyta* ve *Chlorophyta*. *Ege Univ Su Ürünleri Semp*, pp. 74-112. Izmir: Ege University, Fisheries Faculty Press.

Aysel V & Guner H, Dural B (1993). Türkiye Marmara denizi florası II. *Phaeophyta* ve *Rhodophyta*. *Ege Univ Su Ürünleri Fak Derg* 10: 115-168.

Aysel V, Erdoğan H, Sukatar A & Güner H (1996). Bartın deniz algleri, Karadeniz, Türkiye. *Turk J Bot* 20: 251-258.

Aysel V (1997a). Türkiye'nin Akdeniz kıyılarının deniz florası, 1. Kırmızı Algler (=*Rhodophyta*). *Turk J Bot* 21: 329-334.

Aysel V (1997b). Türkiye'nin Akdeniz kıyılarının deniz florası, 2. Kahverengi Algler (*Fucophyceae=Phaeophyceae*). *Turk J Bot* 21: 329-334.

Aysel V, Şenkardeşler A, Aysel F & Alpaslan M. (2000). Çanakkale Boğazı (Marmara denizi, Türkiye) deniz florası. In: Öztürk B, Kadıo?lu M & Öztürk H (eds.) *Marmara Denizi 2000 Sempozyumu Bildiriler Kitabı*. TÜDAV, Yayın No.5: 436-449, İstanbul: Ofis Grafik Mat.

Cupp EE (1943). *Marine plankton diatoms of the west coast of north America*. California: University of California Press.

Dural B (1988). Çandarlı Körfezi, *Ulvales* ordosu üzerinde taksonomik çalışmalar. *Doğa TU Biyol. Derg* 12: 176-182.

Erduğan H, Aysel V & Güner H (1996). Rize-Sarp arası deniz algleri, Karadeniz-Türkiye. *Turk J Bot* 20: 103-108.

Guner H & Aysel V (1978). Ege ve Marmara Denizindeki alg toplulukları üzerinde kalitatif ve kantitatif çalışmalar. 1. *Ulva lactuca* Linnaeus topluluğu (*Chlorophyta*). *Ege Univ Fen Fak Derg Ser B* 2: 55-71.

Guner H & Aysel V (1979). Ege ve Marmara Denizindeki alg toplulukları üzerinde kalitatif ve kantitatif çalışmalar. 2. *Dictyopteris membranacea* (Stackhous) Batters topluluğu. *Ege Univ Fen Fak Derg Ser B* 3: 85-93.

Happey-Wood CM & Jones P (1988). Rhythms of vertical migration and motility in intertidal benthic diatoms with particular reference to *Pleurosigma angulatum*. *Diatom Research* 3: 83-93.

Hartley B, Barber HG & Carter JR (1996). *An atlas of British diatoms.* England: Biopress Ltd.

Hendey NI. (1964). *An introductory account of the smaller algae of British coastal waters.* Part 5: *Bacillariophyceae*. London: Her Majesty's Stationery Office.

Hopkins TJ (1963). A study of the diatoms of the Ouse Estuary, Sussex, I. The movement of the mud-flat diatoms in response to some chemical and physical changes. *J Mar Bio Ass* 43: 653-663.

Hustedt F (1930). *Rabenhorst's kryptogamen flora, die kieselalgen.* 1. Teil, Reprint 1991. USA: Koeltz Scientific Books.

Hustedt F (1959). *Rabenhorst's kryptogamen flora, die kieselalgen.* 2. Teil, Reprint 1991. USA: Koeltz Scientific Books.

Hustedt F (1961-1966). *Rabenhorst's kryptogamen flora, die kieselalgen.* 3. Teil, Reprint 1977. USA: Koeltz Science Publishers.

Hustedt F (1985). *The pennate diatoms.* Koenigstein, Germany: Koeltz Scientific Books.

Kramer K & Lange-Bertalot H (1986). *Süsswasserflora von Mitteleuropa, Bacillariophyceae*, Band 2/3. 3. Teil. Stuttgart: Gustav Fisher Verlag.

Matheke GEM & Horner R (1974). Primary productivity of the benthic microalgae in the Chukchi Sea near Barrow, Alaska. *J Fish Res Board Can* 31: 1779-1786.

Mazzella L & Spinoccia L (1992). Epiphytic diatoms of leaf blades of the Mediterranean Seagrass *Posidonia oceanica* (L.) Delile. *Giornale Botanico Italiano* 126: 752-754.

Morkoç E, Okay, O. S., Tolun, L, Tüfekçi V., Tüfekçi H & Legoviç T (2001). Towards a clean İzmit Bay. *Environment International* 26: 157-161.

Odum P (1971). *Fundamentals of ecology*. Philadelphia: WB Saunders Co.

Oppenheim DR (1991). Seasonal changes in epipelic diatoms along an intertidal shore, Berrow Flats, Somerset. *J Mar Biol Ass* 71: 579-596.

Patrick R & Reimer CW (1966, 1975). *The diatoms of the United States*. Volume 1-2. Philadelphia: The Academy of Natural Sciences of Philadelphia.

Poulin M, Berard-Therriault L & Cardinal A (1986). *Fragilaria* and *Synedra* (*Bacillariophyceae*), a morphological and ultrastructural approach. *Diatom Research* 1: 99-112.

Round FE (1953). Two benthic algal communities in Malham Tarn, Yorkshire. *J Ecol* 41: 174-197.

Round FE & Eaton JW (1966). Persistent vertical-migration rhythms in benthic microflora, III. The rhythm of epipelic algae in a freshwater pond. *J Ecol* 54: 609-615.

Round FE (1981) The ecology of algae. Cambridge: Cambridge University Press.

Round FE, Crawford RM & Mann DG (1990). *The diatoms: Biology and morphology of the genera*. Cambridge: Cambridge University Press.

Scipione MB & Mazzella L (1992). Epiphytic diatoms in the diet of crustacean amphipods of *Posidonia oceanica* leaf stratum. *Oebalia* suppl. XVII: 409-412.

Technicon Industrial Method (1977a). *Nitrate and nitrite in water and wastewater*. No. 158-71 W/A. Tarrytown, NY: Technicon Industrial Systems.

Technicon Industrial Method (1977b). *Phosphate analyses in water and seawater*. No. 253-80. Tarrytown, NY: Technicon Industrial Systems.

Tomas C (1995). *Identifying marine diatoms and dinoflagellates.* London: Academic Press Inc.

Underwood GJC & Paterson D (1993). Seasonal changes in diatom biomass, sediment stability and biogenic stabilisation in the Severn Estuary. *J Mar Biol Ass* 73: 871-887.

Vilbaste S, Sundback K, Nilsson C & Truu J (2000). Distribution of benthic diatoms in the littoral zone of the Gulf of Riga in the Baltic Sea. *Eur J Phycol* 35: 373-385.

Zar JH (1984). *Biostatistical analysis*. Second edition, Englewood Cliffs: Prentice-Hall Inc.