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Effects of Sewage Outfall on Phytoplankton Community Structure in Izmir Bay (Aegean Sea)

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Özet: ***İzmir Körfezi'nde kirliliğin fitoplankton komunite yapısı üzerine etkisi.*** Aşırı kirletilmiş İzmir Körfezinde evsel atıkların fitoplankton gelişimi ve süksesyonu üzerine etkilerini belirlemek için aylık çalışma yapıldı. Plankton örnekleri periyodik olarak Ocak 1992 ve Şubat 1993 ayları arasında evsel atık suları alan Karşıyaka Yat Limanından alındı. NO^{-}_{3}-N, NO^{-}_{2}-N, NH^{+}_{4}-N, $Si(OH)^{-}_{4}$-Si ve PO^{-3}_{4}-P, klorofil-*a*, partikül organik karbon, feopigment konsantrasyonları ölçüldü. Nütrient konsantrasyonları yüksek olarak tespit edildi. Silikat konsantrasyonu 41.10 µg-at Si l^{-1} ve amonyum düzeyi 73.80 µg-at NH_4-N l^{-1}'ye erişti. Araştırma süresince silikatın ortama temininden dolayı diatom türleri baskın olarak belirlendi. *Cylindrotheca closterium* (Ehrenberg) Reimann&Lewin, *Thalassiosira allenii* Takano, *Pseudonizcshia* spp. türlerinin hücre konsantrasyonları yüksek sayılarda saptandı. Dinoflagellat türleri ilkbahar ve yaz aylarında düşük silikat, yüksek azot ve fosfat konsantrasyonları nedeniyle baskın rekabetçi türlerdir.

Anahtar Kelimeler: Fitoplankton, Ege Denizi, İzmir Körfezi, nutrient, kirlilik

Abstract: A monthly study was carried out to determine the effects of sewage outfall on the phytoplankton growth and succession in the highly eutrophic Izmir Bay. Phytoplankton samples were collected monthly between January 1992 and February 1993 at station near the sewage outfall in Karsiyaka Yacht port. Additionally NO^{-}_{3}-N, NO^{-}_{2}-N, NH^{+}_{4}-N, Si $(OH)_4$-Si and PO^{-3}_{4}-P, chlorophyll-*a*, pheopigment and particulate organic carbon concentrations were determined. Concentration of nutrients was high. Silicate and ammonium concentrations were found as high as 41.10 µg-at Si l^{-1} and 73.80µg-at NH_4-N l^{-1} respectively. Diatoms were dominant due to continuous supply of silicate to ambient waters throughout the year. *Cylindrotheca closterium* (Ehrenberg) Reimann&Lewin, *Thalassiosira allenii* Takano, *Pseudonitzschia* spp. were represented by large numbers. Dinoflagellates were dominant competitors due to the temperature, high N, P and low silicate values throughout the spring and summer months.

Key Words: Phytoplankton, Aegean Sea, Izmir Bay, nutrients, pollution

Introduction

Izmir Bay, with an area of 410.3 km^2 is located in the eastern part of Aegean Sea, between latitude 38° 20 N and 38° 40 N and longitude 26° 30 E and 27° 10 E is known to have been polluted over the past three decades by domestic and industrial waste inputs. For this reason the bay waters were regarded highly eutrophic (Buyukisik & Erbil, 1987; Koray and Buyukisik, 1992; Koray *et al*., 1992).

Red–tide events due to high nutrient levels have been documented since 1955 (Numann, 1955; Acara&Nalbantoğlu, 1960) in the bay. Phytoplankton species that caused red tides have been identified earlier by Koray (1988). There are few studies reporting on pollution effects on the phytoplankton distribution and community structure in the Bay area (Koray *et al.*, 1999; Sabancı and Koray, 2001). Studies on nutrient limitation on phytoplankton growth near the sewage outfall were initiated by Aydin&Buyukisik (1994). The aim of this study is to determine the effects of sewage outfall on the phytoplankton composition and phytoplankton succession in Izmir Bay (Aegean Sea).

Materials and Methods

This study was carried out between January 1992 and February 1993 in Izmir Bay (Aegean Sea). The sampling area is shown in Figure 1.

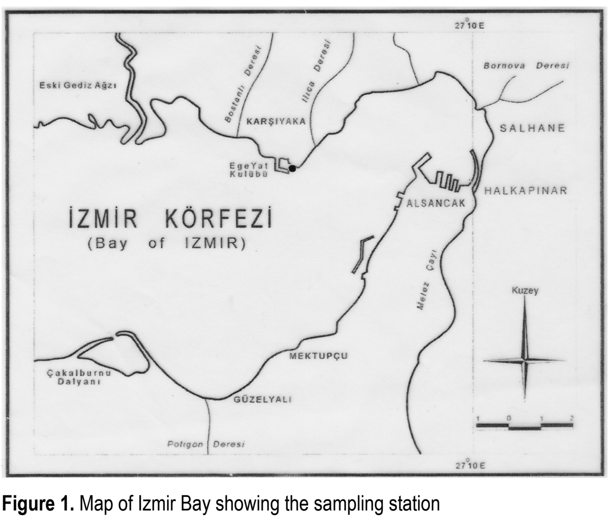

Figure 1. Map of Izmir Bay showing the sampling station

Monthly surface seawater samples were collected at a station near sewage outfall at Karsiyaka Yacht Port. Samples were brought to the laboratory shortly after for immediate analysis of nitrite, nitrate, ammonium, silicate and phosphate concentrations (according to Strickland and Parsons, 1972, Wood, 1975) pH of the seawater was measured using pHep-pH Electronic Papier and dissolved oxygen was measured by Winkler Method. Salinity was measured according to Mohr Knudsen. Particulate organic carbon and chlorophyll-*a* were measured as described in Strickland and Parsons (1972).

Phytoplankton cell counts were performed in samples preserved with 4% formalin and the cells were enumerated using Improved–Neubauer counting chamber, under a phase–contrast microscope.

Results

Changes in surface seawater temperature, salinity, dissolved oxygen, and pH throughout the year is shown in Figure 2.

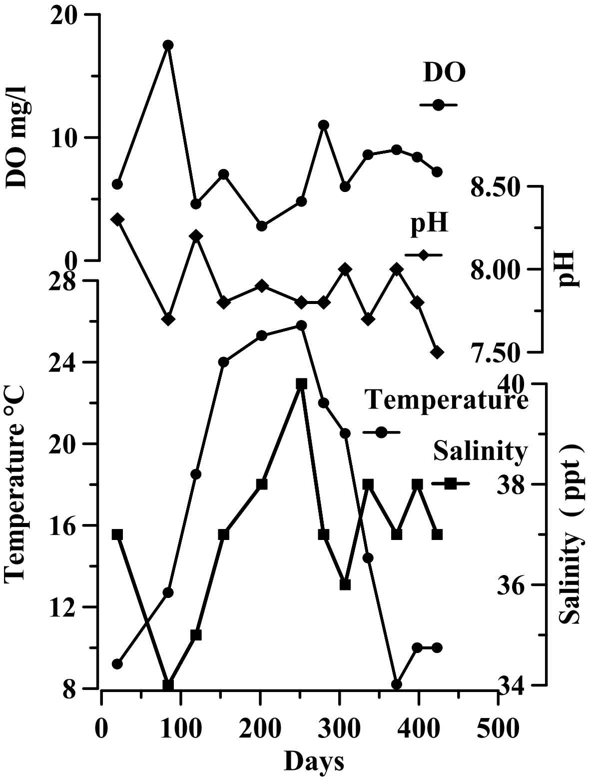

Figure 2. Seasonal variations of temperature, salinitiy, DO., Ph concentrations.

Surface seawater temperatures ranged from 8.2°C to 10°C at midday during winter, while average summer temperatures were over 25°C (Figure 2).

There were no marked monthly changes in salinity except the apparent increase between July and August. In these months, with the increase in evaporation, the salinity reached 40 psu whereas with the beginning of heavy rains this percentage decreased as low as 34 psu. A gradual increase in salinity from spring toward summer is evident Figure 2.

Two major peaks of pH are observed in January and one in April (8.3, 8.2 respectively). Both the pH and chlorophyll-*a* values were fluctuated proportionally throughout the year (Figure 2).

Dissolved oxygen concentrations varied monthly during the year. Maximum levels were attained in March (17.5 mg l^{-1}) and September (11 mg l^{-1}). Increase in DO is considered to be as a function of the photosynthetic activity of diatoms in March and October (Figure 2).

Changes in concentration of nutrients, such as nitrate, nitrite, ammonium, phosphate, silicate as well as chlorophyll-*a*, pheopigment and particulate organic carbon throughout the year are shown in (Figure 3).

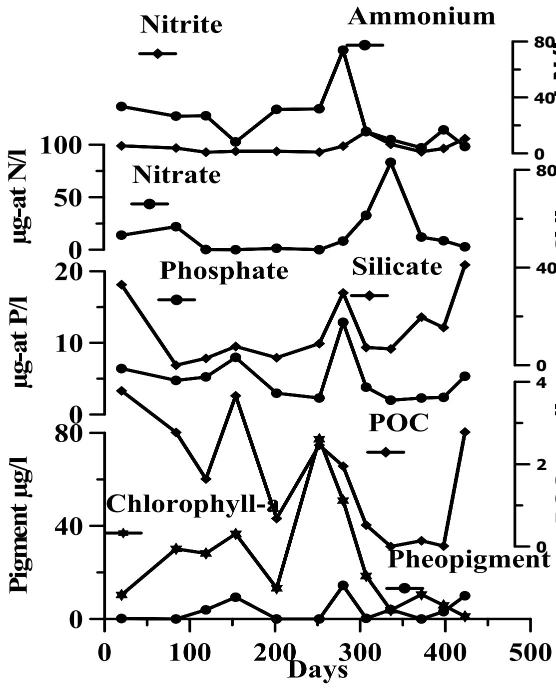

Figure 3. Seasonal variations of nutrients, POC, Chlorophyll-*a* and Phaeopigment

Significant seasonal changes in nutrient levels are observed in Izmir Bay (Figure 3). Nitrate concentrations were measured 13.84 µg- at NO_3- N l^{-1} in January 1992 and 21.96 µg- at NO_3- N l^{-1} in March, respectively. Throughout the spring a gradual decrease in these values was observed. Following an insignificant increase in July, the nitrate level dramatically dropped to undetectable levels and again reached a maximum level of 83.12 µg- at NO_3- N l^{-1} in December 1992 It is highly probable due to sewage outfall near the station.

Nitrate levels fluctuated significantly throughout the year. In summer months several peaks were observed ranging between 31.38 and 73.80µg-at NH_4^+-N l^{-1}. Since ammonium is present in the environment in great quantities throughout the year this makes the small sized species possible to compete with the big sized species. In addition, the fluctuations observed in NO_3-N also support the presence of the big species (Stolte *et al.*, 1994).

The concentration of nitrite was found 5.33 µg- at NO_2-N l^{-1} in January. A gradual decreases in nitrite levels is observed during the spring and summer months. Two peaks are observed in November and February, with the nitrite concentrations reaching 15.46 µg- at NO_2- N $l^{-1}$and 10.48 µg- at NO_2- N l^{-1}, respectively.

Ammonium, nitrite and nitrate peaks followed one another in an alternating manner throughout the year. This fact proves that there is a nitrification process in the water column.

Two peaks in phosphate values were observed in June and in October (7.95 and 12.86 µg- at PO_4^{-3}-P l^{-1} respectively). As phosphate was released frequently from the sewage outfall the phosphate levels did not decrease enough with the consumption of phytoplankton. Sharp *et al.*, (1984) and Lebo (1991) claimed that large phytoplankton blooms could lower the phosphate concentrations below detection limits of 1-to 2 µg l^{-1}.

However in our study because of the above-mentioned reasons, the phosphate limitation was not observed. Although phosphate and ammonium showed a similar trend to silicate, a high enough level of phytoplankton was present in the surface seawater.

Fluctuations in silicate concentrations were recorded during the study. In March it was below the detection limit due to late winter bloom and during the spring and summer the concentrations were significantly low compared to the winter levels. Silicate concentration was found highest with level of 41.10 µg- at Si l^{-1} in surface seawater in February 1993. As a result, diatom species were present throughout the year in the surface seawater.

Chlorophyll-*a*, Pheopigment and Particulate organic carbon values are shown in Figure 3. Increases in chlorophyll-*a* were significant especially in spring and summer months and in early autumn. Eventually higher nutrient pheopigment levels were attained in the following months. This situation proves the existence of microzooplankton grazing as it is also pointed out by other researchers (Yentch, 1965; Daley, 1973; Welschmeyer, 1985). The increase in chlorophyll-*a* together with the decrease in silicate concentrations denotes the presence of a diatom bloom and silicate uptake. In another study carried out in the same area, Aydin and Buyukisik (1994) reported the effect of silicate limitation for the growth of *Pseudonitzschia* spp. Since the dinoflagellate cyst were dominant in the samples in January 1992, it is possible that between these two successive samplings a dinoflagellate bloom could have occurred. The chlorophyll-*a* concentration was around 10 mg l^{-1}, which might be caused by the presence of nano&picoplankton. Particulate organic carbon showed a similar trend as chlorophyll-*a* thorougout the year except in January.

Two diatom species *Chaetoceros affinis* Lauder and *Chaetoceros decipiens* Cleve were determined to be dominated in the surface waters in January (Figure 4 a). These two species most presumably disappeared due either to the increase in surface temperature or to silicate limitation in March. These species were replaced by *Thalassiosira anguste–lineata* (A. Schmidt) G. Fryxell&Hasle and *Scrippsiella trochoidea* (J. R. Stein) A. R Loebl (Figure 4 b). There must be a role of the consumption of silicate in the previous diatom bloom for such a result. The peak in chlorophyll-*a* observed in the study was greatly because of these two species (Figure 4 a). In April *Skeletonema costatum* (Grev.) Cleve, *Gonyaulax* sp. and ciliates were dominant (Figure 4 b, c) and the presence of pheopigment (3.92µgl^{-1}) supported ciliates grazing. The decrease in chlorophyll- a concentration proved the occurrence of such a process (Figure 4 b). During the early June the increase in silicate concentration favored diatoms. *C. closterium* and *Pseudonitzschia* spp. dominated the surface waters (Figure 4 c). Meanwhile the increase in cholorophyll-*a* was highly significant (36.56 µg Chl-*a* l^{-1}). In July, the species composition changed and Hemiaulus sp. and *Gonyaulax* sp. became dominant (Figure 4 b, c). The absence of ciliate grazing supported the blooming of *Gonyaulax* sp. The low silicate concentration was in concordance with the low *Hemiaulus* sp. abundance. Chlorophyll- a concentration also dropped significantly with the influence of stratification of seawater column (Figure 4 a). The peak in chlorophyll-*a* observed in September (77.27 µg Chl-*a* l^{-1}) can be explained with the increase in numbers *Pseudonitzschia* spp., *Oxytoxum scolopax* Stein and with unidentified flagellates. The dominant species recorded in October were *Prorocentrum micans* Ehrenb., Unidentified chain-forming dinoflagellate and *Pseudonitzschia* spp. (Figure 4 b, c).

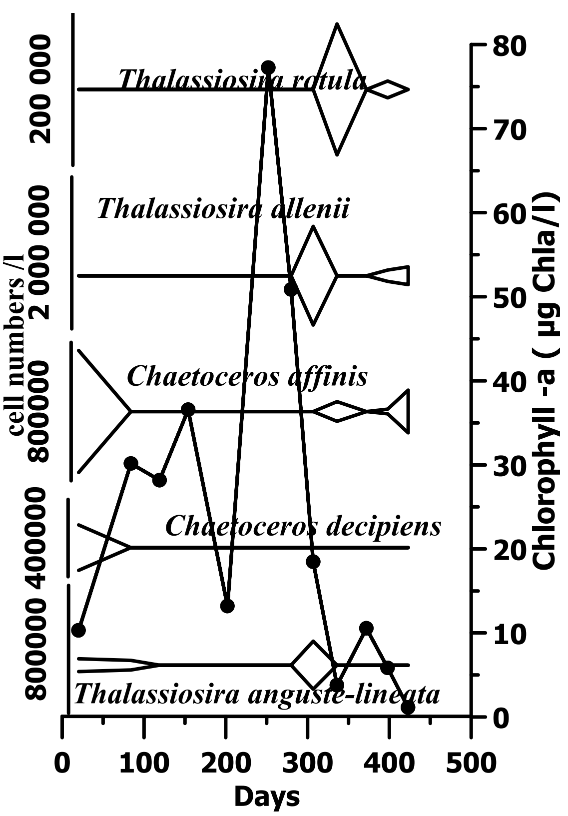

Figure 4a. Succession of phytoplanktonic species in the Bay of Izmir.

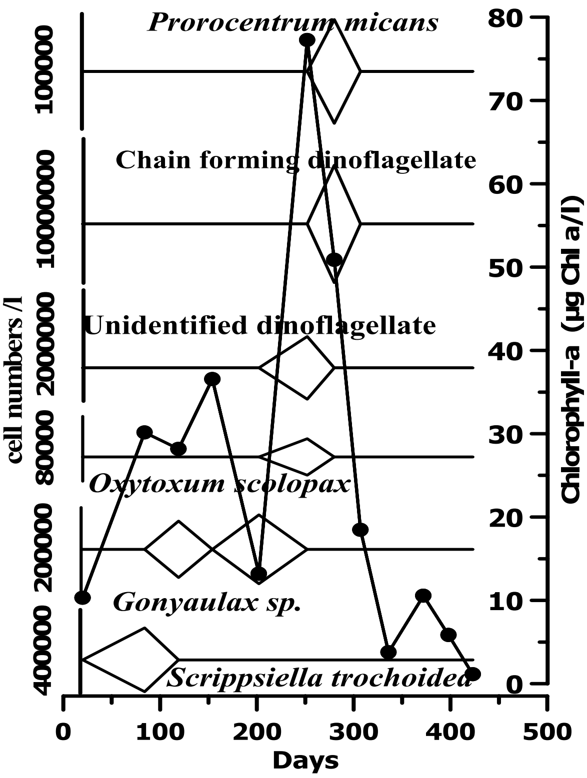

Figure 4b. Succession of phytoplanktonic species in the Bay of Izmir.

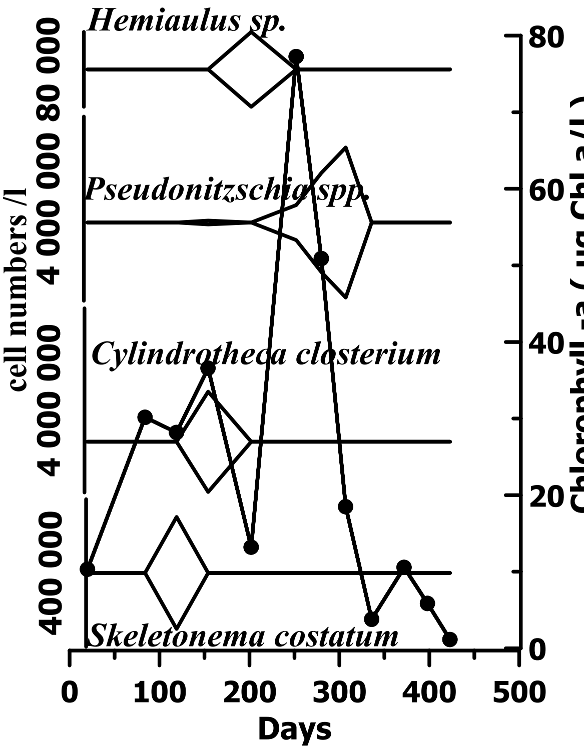

Figure 4c. Succession of phytoplanktonic species in the Bay of Izmir.

The noteworthy decrease in chlorophyll-*a* can be attributed to grazing activity. Furthermore, the apperent increase in pheopigment concentration seems to confirm this supposition. In November with decreasing temperature, diatom species *T. allenii*, *T. anguste-lineata* and *Pseudonitzschia* spp. were became dominant species (Figure 4 a, c). In December *Thalassiosira rotula* Meunier and *C. affinis* were dominant species with much lower contributions in the surface sea water (Figure 4 a). When the seawater temperature dropped to its lowest level in the same month (8.2°C) the unidentified dinoflagelllate cyst became dominant in the surface water (Figure 4 b). The presence of dinoflagellate cyst in the surface waters may probably due to the cyst was conveyed from the benthic region with the help of water movements. A simultaneous but insignificant increase in chlorophyll-*a* (3.77 µg l^{-1}) is most probably due to the presence of picoplankton or nanoplankton. The nanoplankton can at times account for up to 90% of the phytoplankton chlorophyll in coastal and open ocean waters (Jeffrey & Hallegraff, 1990).

In February *C. affinis* and *T. allenii* were observed as dominant species (Figure 4 a).

Discussions and Conclusions

Diatoms and dinoflagellates exhibited their own characteristic succession throughout the sampling period. Abundance of diatoms and dinoflagellates were generally high in the surface seawater throughout the year (Figure 4 a, b, c). Diatoms species *C. affinis*, *T. anguste- lineata*, *T. rotula* dominated the early- winter- mid- winter phytoplankton populations. These findings agree well with other studies conducting in Izmir Bay (Koray, 1994). In contrast to the diatoms dinoflagellates bloomed during late spring and late summer. During the summer and autumn blooms, a microzooplankton as well accompanied to the blooms. Changes in silicate concentrations have directly influenced the bloom dynamics. Since phosphate and ammonium concentrations were high throughout the year, they are regarded to have no limiting role in phytoplankton growth (Aydin&Buyukisik, 1994). The dramatic increase in nitrate levels in the sea showed the influence of deep sea water and seemed to have occurred as a result of nitrification in the bay of Izmir (Buyukisik&Erbil 1987). Similarly, as a result of the differences in salinity and temperatures phytoplankton bloom was reported to have occurred in August and October (Koray, 1994). During the summer months the significant decrease in nitrate levels in surface seawaters showed that nitrate was used by blooming species. Stolte and Riegman (1995) stated that $N0_3$ pulse cultures (fluctuating NO_3 concentrations) result in domination of large sized species. Large species were present during spring and summer when extreme decreases were observed in nitrate levels in this study. Moreover, the continuous supply of high levels of ammonium resulted in the preservation of the small species in turn. Buyukisik (1984) as well, pointed out the same fact. Changes in nitrate, ammonium, silicate and phosphate levels in time, regulated phytoplankton diversity greatly (Figure 3). Blooming species recorded near sewage outfall in this study differed from those obtained in the outer and middle parts of Izmir Bay (Koray, 1988; Koray *et al.*, 1999; Sabancı and Koray, 2001). In our study, the diatom species were persistent throughout the year. The primary reason of this is continuous supply to the area from the sewage outfall. Smayda (1989) as well states the role of silica in regulating the responses to coastal nutrient enrichment.

Further research is necessary to understand the effects of the treated water on the water quality, phytoplankton species composition and phytoplankton succession in the Bay area.

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