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The effect of environmental factors on the growth and size structure of two dominant phytoplankton species in Büyükçekmece Reservoir (İstanbul, Turkey)*

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Abstract: The aim of this study was to investigate seasonal variability in the growth and size structure of dominant phytoplankton species in Büyükçekmece Reservoir, and to determine the environmental factors that affect morphological plasticity in those dominant species. In total, 78 taxa from 8 algal divisions were identified. Bacillariophyta and Chlorophyta were the most important divisions with respect to species number, but cryptomonads *Plagioselmis nannoplanctica* (Skuja) Novarino, Lucas, and Morrall, and a *Cryptomonas* sp. were dominant in terms of density and biomass. *P. nannoplanctica* was the major contributor of biomass in the reservoir. A significant difference in *Plagioselmis* species biovolume was observed between winter-early spring and summer. A significant negative correlation was observed between its seasonal size structure and abundance. During winter (December 2004-April 2005) nutrient values were higher than during autumn (October-Novermber 2005) and *P. nannoplanctica* had maximum cell size (17.5 µm x 10 µm; biovolume: 589.5 μm^3), but its abundance was very low (< 6 cells × 10^3 l^{-1}). The minimum surface:volume ratio (SA/V: 0.87) was recorded in this period. Among the measured environmental factors, water temperature was the only parameter that had a statistically significant negative relationship (R^2: 0.635; $P < 0.01$) with *P. nannoplanctica* cell size. The results indicate that seasonal changes in cryptomonad size structure were controlled by water temperature.

Key words: Cryptomonads, surface-volume ratio, environmental factors, Büyükçekmece Reservoir

Büyükçekmece Gölü'nde (İstanbul, Türkiye) baskın olarak kaydedilen iki fitoplankton türünün gelişimi ve boyutları üzerine çevresel faktörlerin etkisi

Özet: Bu çalışmanın amacı Büyükçekmece Gölü'nde kaydedilen dominant fitoplankton türlerinin yoğunluk ve boyutlarında meydana gelen mevsimsel değişimi görmek ve bu değişimde etkili olan çevresel faktörleri ortaya koymaktır. Araştırma süresi boyunca gölde sekiz farklı algal divizyoya ait toplam 78 taxa teşhis edilmiştir. Bacillariophyta ve Chlorophyta en çok tür sayısına sahip divizyolar olarak bulunurken, Cryptophyta divizyosundan *Plagioselmis nannoplanctica* (Skuja) Novarino, Lucas et Morrall ve *Cryptomonas* sp. yoğunluk ve biyokütle bakımından oldukça yüksek sayılara ulaşmışlardır. *P. nannoplanctica* toplam fitoplankton biyokütlesine katkıda bulunan başlıca tür olarak kaydedilmiştir. Kış döneminden ilkbahar başına kadar ve yaz dönemi arasında ölçülen *Plagioselmis* türünün hacimleri arasında belirgin farklılık kaydedilmiştir. Türün yapısal büyüklük ve bolluk derecesinin mevsimsel değişimi arasında önemli negatif ilişki bulunmuştur. Çalışma süresi boyunca besin tuzu değerlerinin yüksek olarak kaydedildiği kış döneminde *P. nannoplanctica* en yüksek (boy: 17,5 µm and çap: 10 µm; biyohacim: 589,5 μm^3) hücre boyutuna sahip olurken, birey sayısı bakımından çok düşük (< 6 cells × 10^3 l^{-1}) değerler bulunmuştur. Bu dönemde, en düşük yüzey-hacim oranı (SA/V: 0,87) bulunmuştur. Ölçülen çevresel faktörler arasında yalnızca su sıcaklığının istatistiksel olarak *P. nannoplanctica* hücre boyutu ile önemli negatif ilişkisi (R^2: 0,635; $P < 0,01$) kaydedilmiştir. Çalışma sonucunda elde edilen bulgular cryptomonadların yapısal büyüklüğünde meydana gelen değişimin su sıcaklığı tarafından kontrol edildiğini göstermiştir.

Anahtar sözcükler: Cryptophyta, yüzey-hacim oranı, çevresel faktörler, Büyükçekmece Gölü

Introduction

One of the main goals of studying phytoplankton ecology is to determine the factors that regulate phytoplankton production and their seasonal succession in aquatic ecosystems (1). Several factors are linked to phytoplankton growth limitation and size structure, e.g. light, temperature, and nutrient availability (2,3). The morphology of each species is further modified by physical factors, the availability of nutrients, grazing, competition, and parasitism (4-6).

During the 14th Workshop of the International Association of Phytoplankton Taxonomy and Ecology (IAP), environmental factors affecting both phytoplankton composition and morphological variation (cell shape, size structure, metabolic self-regulation such as buoyancy, formation of colony or mucilage, and spines), as well as physical (mixing, light availability, and temperature), chemical (nutrients), and biological (food web, grazing, and competition) pressures were presented by Reynolds (7), Dokulil et al. (8), Kamenir (9), Naselli-Flores and Barone (10), Morabito et al. (11), O'Farrel et al. (12), Stoyneva et al. (13), and Salmaso and Padisak (14).

The aim of the present study was to contribute to the understanding of the morphological responses of phytoplanktonic algae to their environment by considering seasonal variability in the growth and size structure of the 2 dominant cryptomonads (*Plagioselmis nannoplanctica* (Skuja) Novarino, Lucas, and Morrall, and a *Cryptomonas* sp.) in Büyükçekmece Reservoir, and by determining the environmental factors that affect the morphological plasticity of those species.

Materials and methods

Study site

Büyükçekmece Reservoir was constructed by ISKI (Water and Sewerage Administrative Center of İstanbul) on the mouth of the Karasu River in 1985, separating the river from the Marmara Sea (Figure 1). Since its construction, the reservoir has progressively lost its saline characteristics; during the study period its salinity was 2‰-3‰. The reservoir is an important source of water for İstanbul. Mean depth is 6 m and this shallow reservoir has regular mixing throughout the year. Maximum surface area and volume are 28.5 km^2 and 160×10^6 m^3, respectively (15).

Sampling

Between June 2004 and June 2005 samples were collected at the surface above the deepest part of the reservoir, and from depths of 1 m, 3 m, and 5 m with a Nansen bottle. Samples were collected monthly between October 2004 and April 2005, and biweekly for the remainder of the study. Water temperature, dissolved oxygen, pH, conductivity, and salinity were measured in situ with a multiparameter probe. Transparency was measured with a Secchi disc. For chlorophyll *a* analysis, water was filtered through a glass fiber filter (Whatman GF/C). Chlorophyll *a* concentrations were determined spectrophotometrically with phaeopigment

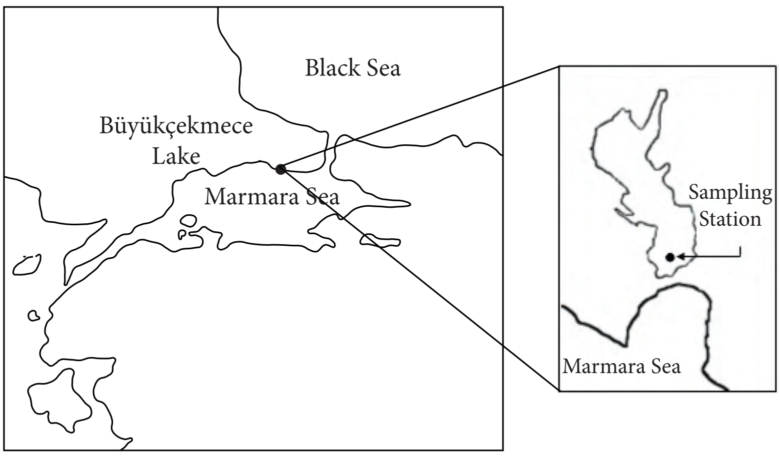

Figure 1. Sampling station in Büyükçekmece Reservoir.

correction; adjustments were made before and after acidification, following 24-h extraction in ethanol Nusch, 1980 E.A. Nusch, Comparison of different methods for chlorophyll and phaeopigment determination, *Ergeb. Limnol.* (1980), pp. 14–36. (16). Nutrients (e.g. reactive phosphorus, nitrate and nitrite nitrogen, and silicate) were analyzed in the laboratory according to standard analytical techniques (17). Phytoplankton species were identified via light microscopy from samples both living and fixed in Lugol's solution. Identification of the dominant phytoplankton species, *Plagioselmis nannoplanctica* (Skuja) Novarino, Lucas, and Morrall, and a *Cryptomonas* sp., was carried out according to Huber-Pestalozzi (18) and Novarino (19,20).

Phytoplankton density and biomass were determined in subsamples fixed in Lugol's solution, according to Utermöhl (21), and estimation of cell surface area (S) and volume (V) was performed according to Hillebrand et al. (22). Data were analyzed using one-way ANOVA to test vertical differences. Correlation coefficients ($P < 0.01$ and $P < 0.05$) between phytoplankton abundance and variation in environmental factors were computed.

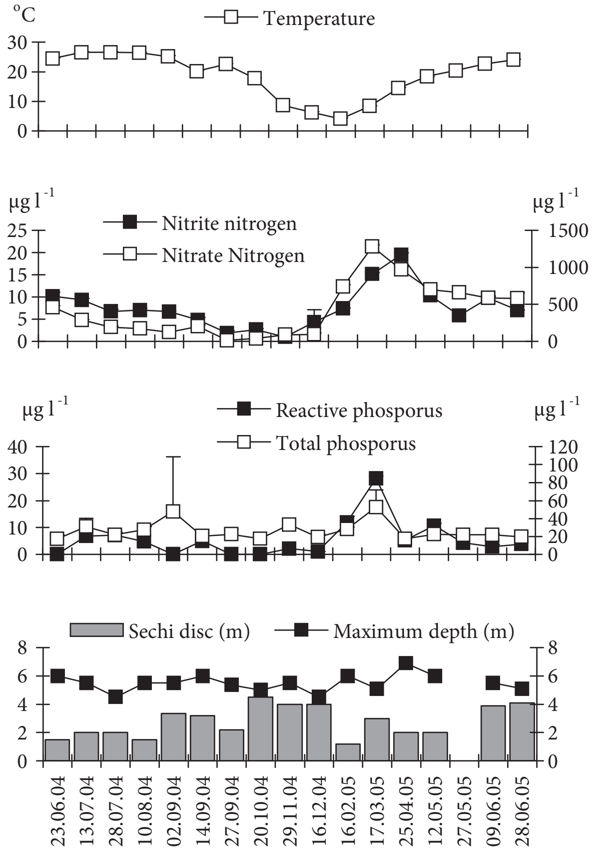

Figure 2. Seasonal variation in some environmental factors, with standard deviations.

Results

In all, 78 species belonging to 8 algal divisions—Bacillariophyta (46%), Chlorophyta (27%), Chrysophyta (3%), Cryptophyta (4%), Cyanophyta (13%), Dinophyta (3%), Euglenophyta (3%), and Xanthophyta (1%)—were identified. Diatoms and chlorophytes were the most important groups in terms of species number, but cryptomonads were dominant in terms of density and biomass throughout the study period. This finding agrees with some previous reports (3,23,24). *Plagioselmis nannoplanctica* and a *Cryptomonas* sp. were the most abundant and common species.

During the study period the euphotic depth generally reached the reservoir's bottom, with the exception of summer 2004, and late April and early May 2005. Seasonal changes in environmental factors in the reservoir are shown in Figure 2. Water temperature increased sharply from spring to summer, reaching a maximum of 26.6 °C in July. Dissolved oxygen concentration in surface water was high due to exchange with the atmosphere and phytoplankton productivity. Higher values (maximum 13.9 mg l^{-1} in surface) were noted in April 2005. Significant differences were recorded in seasonal variation (ANOVA, $P < 0.05$). The lowest pH value (7.53 ± 0.1) was recorded November 2004. The pH value was high (maximum 8.53 ± 0.04 in August) in summer and autumn due to intensive phytoplankton development. Higher concentrations of dissolved nutrients were recorded between February and May 2005. Mean annual dissolved nutrient values were 7.6 ± 4.6 µg l^{-1} for nitrite, 423 ± 364 µg l^{-1} for nitrate, 5.5 ± 6.9 µg l^{-1} for reactive phosphorus, and 2216 ± 748 µg l^{-1} for silicate. Total phosphorus was 26.9 ± 10.2 µg l^{-1}.

Seasonal distribution of total phytoplankton abundance and biomass were similar to that of chlorophyll *a* (Figure 3). Our analysis shows that there

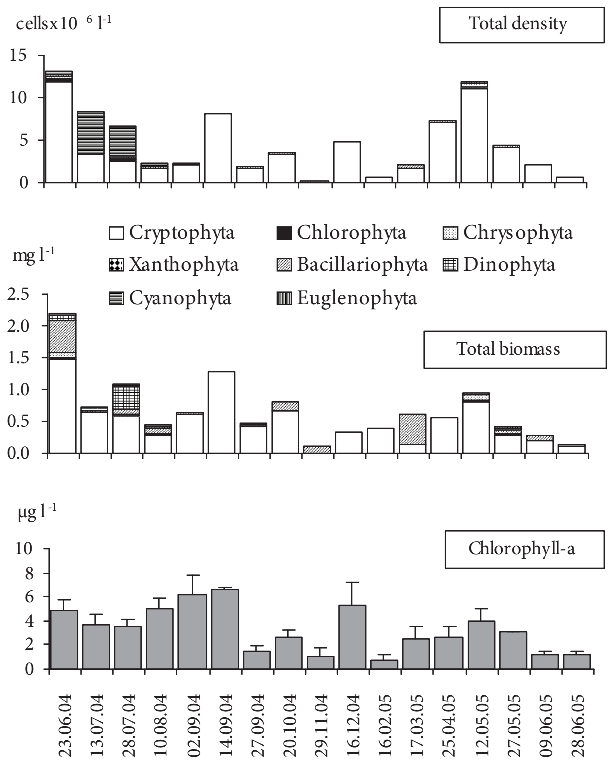

Figure 3. Seasonal variation in total phytoplankton density and biovolume, with the contribution of classes and chlorophyll *a* (error bars indicate + standard deviation).

was a significant relationship between phytoplankton abundance and biomass, and chlorophyll *a* ($P < 0.01$). The correlation between total phytoplankton biomass and total cryptomonad biomass was also significant ($P < 0.01$). Accordingly, *Plagioselmis nannoplanctica* was the major contributor to total biomass in the reservoir. On the other hand, increases in phytoplankton density and chlorophyll *a* concentration were to the result of reduced water transparency. Low Secchi disc depth values were recorded in June and August 2004 (1.5 m) and in February 2005 (1.2 m) (Figure 2). A negative correlation between water transparency and total phytoplankton density was noted ($R^2 = 0.17$).

Surface area:volume (S/V) ratios of *Plagioselmis nannoplanctica* and the *Cryptomonas* sp. were 1.41 ± 0.26 and 0.62 ± 0.07, respectively. The *Cryptomonas* sp. cell size variation could not be followed due to its fluctuating abundance. Marked seasonal differences, however, were observed in the S/V ratio of *P. nannoplanctica* (Figure 4). The minimum S/V ratio, which indicates increasing size, was recorded in the winter-early spring. There was a negative correlation ($R^2 = 0.89$) between the *P. nannoplanctica* S/V ratio and cell volume (Figure 5), and cell size was negatively correlated with both total phytoplankton density and biomass ($P < 0.01$).

Water temperature was an important factor in controlling variation in cell size. Decreases in cell size were observed to follow the growth of phytoplankton in March 2005, when the water temperature began to

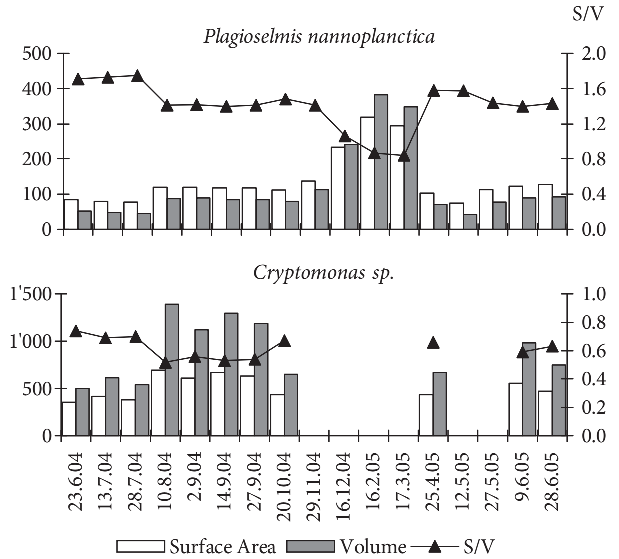

Figure 4. Seasonal variation in size structure (surface area as μm^2 and volume as μm^3) in *Plagioselmis nannoplanctica* and the *Cryptomonas* sp.

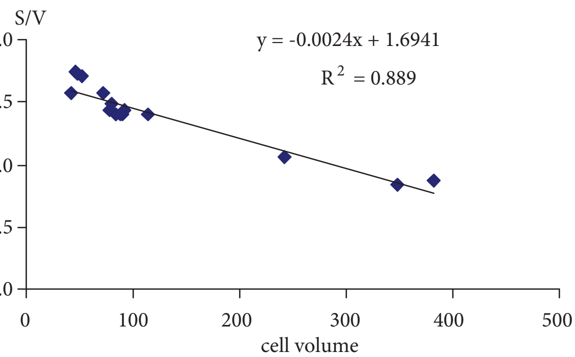

Figure 5. The relationship between the S/V ratio and cell volume in *Plagioselmis nannoplanctica*.

increase. *Plagioselmis* cell size was positively correlated with nutrient concentrations, but the correlation was not statistically significant ($P < 0.05$). Temperature and nutrients affected not only size variability, but also the structure and dynamics of the reservoir's phytoplankton. There were no significant differences (ANOVA, $P < 0.05$) in vertical distribution of temperature (mean: 18.6 ± 0.06 °C), nutrients (mean 426 ± 23 $\mu g\ l^{-1}$ for nitrite + nitrate, 5.7 ± 0.4 $\mu g\ l^{-1}$ for reactive phosphate, and 2228 ± 42 $\mu g\ l^{-1}$ for silicate), or size structure of *Plagioselmis* (biovolume: 119 ± 4 μm^3) and *Cryptomonas* (biovolume: 585 ± 30 μm^3) due to the hydrodynamics of this shallow regularly mixing reservoir.

Discussion and conclusion

In terms of the factors that limit phytoplankton size (25), morphological variability is related to ecosystem variability. In natural environments, size selection is perhaps the strongest driving force shaping phytoplankton assemblage under variable environmental conditions (8,11,26). Morabito (11) reported significant seasonal changes in phytoplankton size, which were mainly dependent on nutrient and temperature variability. On the other hand, Naselli-Flores and Barone (26) reported that environments with different mixing regimes and underwater light conditions might contain the same phytoplankton taxa, but generally with differing morphologies. Büyükçekmece Reservoir is a shallow regularly mixing reservoir. Underwater light was not a limiting factor for phytoplankton growth and did not affect size structure. Among the measured environmental factors in Büyükçekmece Reservoir, the only parameter that had a statistically significant negative correlation with *Plagioselmis nannoplanctica* cell size was water temperature ($P < 0.01$).

The results of the present study show that large cell size and low density was due to a decrease in the rate of cell division in response to low water temperature. Change in *P. nannoplanctica* size structure was reflected in the S/V ratio, as well as in the percentage of chlorophyll *a*'s contribution to biomass as biovolume. Similar results have been reported in a study on a shallow urban lake in Austria; chlorophyll *a* content and the S/V ratio drastically increased during the early recovery phase due to the development of small-celled species (8).

Another factor affecting the dynamics and size structure of this species might have been the grazing activity of herbivores. According to a review by Van Donk, numerous studies have documented the grazing pressure applied by herbivorous zooplankton on phytoplankton, their defense mechanisms against grazing, such as size and shape of the cells, (27) and the importance of size-selective grazing in regulating the average morphological dimension of a phytoplankton assemblage (8,11,24). In Büyükçekmece Reservoir, larger *Plagioselmis* individuals (low S/V ratio) were abundant in winter (December 2004-February 2995) and in March 2005 when zooplankton biomass was low (15). Grazing may have a significant effect on their dynamics and population ecology (25). Grazers might influence phytoplankton biomass and species composition. Barone and Naselli-Flores' (24) study of Sicilian reservoirs confirmed that the presence of filter feeding crustaceans was a major factor affecting the population dynamics of these small edible cryptomonads.

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