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Seasonal variation in the diversity, species richness and composition of the phytoplankton assemblages in a shallow lake

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Résumé – Variation saisonnière de la diversité, de la richesse spécifique et de la composition du phytoplancton dans un lac peu profond. La variation saisonnière de la flore algale planctonique et la richesse spécifique du phytoplancton a été étudiée de janvier 2000 à avril 2001, dans un lac peu profond de Turquie, le lac Gıcı. Des échantillonnages à la surface et à un mètre de profondeur, ainsi que la mesure mensuelle de la richesse spécifique et de la diversité (indices de Shannon-Wiener, $H^{'}$) ont été effectuées. Les indices ont été calculés en utilisant le biovolume. Les changements climatiques, spécialement les précipitations, les conditions de mélange et la stabilité relative de la colonne d'eau, sont considérés comme des facteurs importants pour expliquer la variation saisonnière observée.
Au total, on a identifié 109 espèces dont la plupart appartiennent aux Bacillariophytes et aux Chlorophytes. On observe des Cyanophytes, des Euglenophytes et des Xantophytes parmi les autres groupes taxinomiques. La biomasse phytoplanctonique est dominée par les diatomées (développant une stratégie R). En dehors de certains changements numériques, la variation saisonnière de la densité phytoplanctonique est semblable à la surface et à un mètre de profondeur. Les associations estivales se développent durant des périodes de forte stabilité thermale de la colonne d'eau et de faible disponibilité des nutriments (favorisant les organismes développant une stratégie S).

Assemblage / diversité Shannon / groupes fonctionnels / Phytoplankton / richesse spécifique / variation saisonnière

Abstract – The seasonal variations in the diversity, composition and species richness of phytoplankton in a shallow lake (Gıcı Lake, Turkey) were studied between January 2000 and April 2001. Samples were collected monthly from surface water and deeper (1m depth) stations and species richness and diversity (Shannon-Wiener, $H^{'}$) were measured. Indices were calculated using biovolume. Climatic changes, especially rainfall, mixing conditions, and relative water column stability were found to be important factors affecting the seasonal variation observed.
A total of 109 species, mostly belonging to the Bacillariophyta and Chlorophyta, were identifed. Among the other taxonomic groups were Cyanoprokaryota, Euglenophyta and Xantophyta. Phytoplankton biomass was dominated by diatoms (R-strategists). The summer assemblages develop during strong thermal stability of the water column and low availability of nutrients (S-strategists).

Phytoplankton / Shannon diversity / functional groups / assemblage / species richness / seasonal variation

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INTRODUCTION

Phytoplankton research on small lakes has been controversial. While they have been preferred targets for taxonomic and floristic work, the bulk of our knowledge on ecology of phytoplankton originates from middle-sized or large lakes (Padisák *et al*., 2003a). Maitland (1978) states that shallow lakes are globally more important than deep lakes; they are much more numerous on a global scale than deep lakes. They possess a more complex ecological structure and have a higher productivity. As a consequence of their small water volume and often unstable hydrological balance, small lakes react quickly to human impacts like N and P loadings, acidification or climatic changes even at small scales. Their common feature is that historical data are largely absent. Interest towards understanding driving forces that govern their spatial and temporal phytoplankton patterns has just started to increase (O'Farrel *et al*., 2003; Ortega-Mayagoita *et al*., 2003; Stoyneva, 2003).

In temperate lakes, an autogenic sequence of different phytoplankton associations or functional groups as a temporal model has been described (Reynolds 1997, 2001; Reynolds *et al*., 2002). In a temporal scale, phytoplankton shows patterns of a strong relationship between physical changes in the environment and biological processes. These interactions usually prevent equilibrium conditions (Sousa, 1984), affecting the growth and persistance of phytoplankton population and setting its communities far away from a steady-state (Reynolds 1994, 1997).

Species richness, or the number of species, is currently the most widely used diversity measure. Relative species abundance in a community is another factor that affects diversity (Whittaker, 1965; Hurlbert, 1971). It is measured with a standardized index of species abundance (evenness) that is typically on a scale ranging from near 0, which indicates low evenness or high-single species dominance, to 1, which indicates equal abundance of all species or maximum evenness (Routledge, 1980). Because of the large number of species, the comparative analysis of phytoplankton communities is simplified by the use of indices that summarize the community structure (Sommer *et al*., 1993; Figueredo & Giani, 2001). Diversity estimates, for example, can help to describe ecological systems (Magurran, 1988) and are a measure of the community stability and its resistance to disturbances (Barnese & Schelske, 1994).

The shallow Gıcı Lake, situated in the Kızılırmak Delta, can be considered as a representative of many lakes at sea level in this area. The knowledge of the composition and abundance of phytoplanktonic organisms constitutes an essential feature for the assessment of the trophic status in lakes and for the evaluation of the possible or optimal utilization of different water resources. The aim of this study was to observe seasonal variations in the phytoplankton density, richness, and diversity of a shallow lake and to contribute to the knowledge of the phytoplankton assemblages at the Gıcı Lake, considering the relative water column stability and the climatic seasonality in terms of the rainfall quantity along the year. Species richness and diversity (Shannon-Wiener, H') were measured monthly from the selected stations.

MATERIAL AND METHODS

Study Site

Kızılırmak Delta is situated along the Blacksea coast of Turkey (latitude: 41° 30’ to 41° 45’ N; longitude: 35° 43’ to 36° 08’ E). The larger part of the delta is composed of alluvial sediment supplied by the River Kızılırmak during the holocene. The age of these sediments increases in inland direction, those of sediments of pleistocene age and older surface (Hollis & Thompson, 1992). Bafra Balık Lakes in the Kızılırmak Delta are lagoons that are closed and separated from the sea by the coast cordons. These lakes are in the east of the River Kızılırmak and include Liman Lake, Cernek Lake, Gıcı Lake, Tatlı Lake, Balık Lake and Uzun Lake (Fig. 1).

Lake Gıcı is 20 km away from Bafra located on the east side of the River Kızılırmak and Bafra city. Most channels were constructed in order to drain water from agricultural land in the delta plain (Hustings & Van Dijk, 1994) and for irrigation purposes. There are many drainage canals connected to the lake. The lake show a great seasonal variation in water depth. All lakes in this area are shallow and their surface water levels are approximately at sea level. At the end of the dry season their water levels regularly fall below Blacksea level (Dijksen & Kasparek, 1985).

The area is characterized by the coastal Black Sea climate regime. The weather is hot in summer, mild and rainy in winter. The amount of rainfall increases in February (102.4 mm) and December (68.0 mm) (Anonymous, 2000) (Fig. 2A). According to Emberger (1952), the rain regime type of Bafra is the west Mediterrean.

The lakes of the Kızılırmak Delta are subjected to the impact of agricultural activities. The most important stresses on lakes in this area are organic

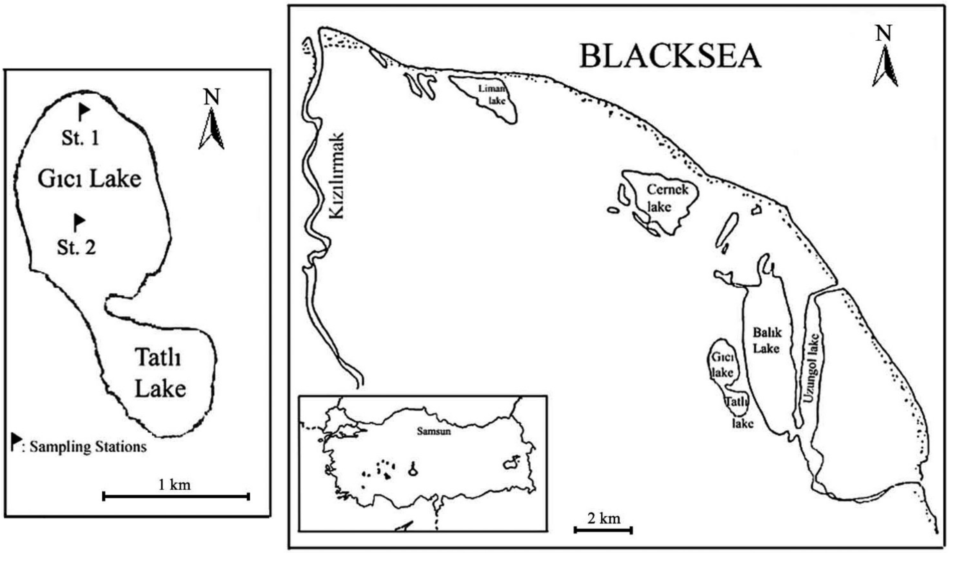

Fig. 1. Map of the Gıcı Lake and location of the sampling stations.

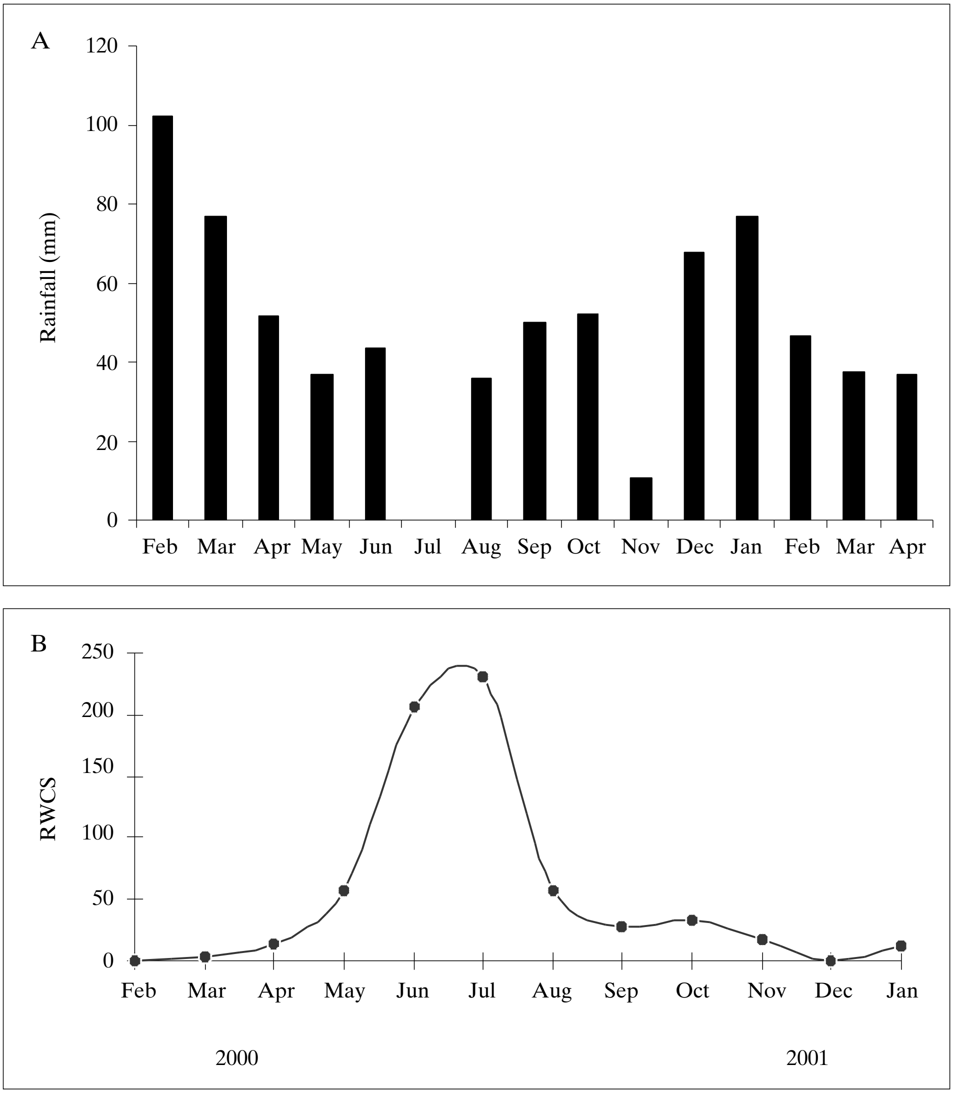

Fig. 2. Seasonal variation of (A) total monthly rainfall (mm), (B) relative water column stability (RWCS) in the Kızılırmak Delta.

enrichments (discharge of untreated sewage), nutrients, pesticides, herbicides and physical changes produced by canalisation. The pastures around the lake are the feeding zones for approximately 10,000 cattle and water buffalo, sheep and horses. Since the vicinity of the Gıcı Lake is under protection, it hosts many species of birds.

The Gıcı Lake is surrounded by treeless marshes that are considered to be important ecosystems and add significantly to the high biodiversity of the delta. The lake's surface area is 125 ha. The two sites sampled are shown on Fig. 1. St. 1

is situated near the north edge of the Lake. St. 2 is situated in the south of the lake. The Gıcı Lake is connected to the Tatlı Lake in the south edge. The depth varied from 1.0 to 1.5 m. in the sampling stations. St. 1 and St. 2 are covered with sandy sediments.

Typha angustifolia L. and *T. lalifolia* L. are the emergent plants, *Chara vulgaris* L., *Ceratophylum demersum* L., *Potamageton panorminatus* L. are the submerged aquatic macrophytes of the Gıcı Lake. Macrophytes cover the lake bottom especially in summer.

Samples were collected monthly from January 2000 to April 2001 with a 2 litre capacity Hydro-Bios water sampler to determine the density of the algae at two stations and two different depths: water surface, 1 m. Phytoplankton determinations were carried out on subsamples preserved in acetic Lugol's solution; a constant volume of 10 ml was sedimented in the counting chambers. Algal cells were counted on a Prior inverted microscope at 400 × magnification, following Lund *et al.* (1958). At least 200 individuals were counted. In the evaluations the average of three countings from each stations was used. The remaining part of the water sample was filtered using Whatman GF/A fibre filter paper to identify the algae except Bacillariophyta. Bacillariophyta were identified in permanent slides prepared according to Round (1953), under oil immersion at 1000 × magnification. Biovolume was estimated by geometrical approximations according to Hillebrand *et al.* (1999).

Taxonomic identifications were undertaken following John *et al.*, 2003; Krammer & Lange-Bertalot, 1986; 1991a, b; 1999; Komárek & Anagnostidis, 1986, 1989, 1999; Anagnostidis & Komárek, 1988; Komárek *et al.*, 1998.

At the time of sampling, the water temperature, pH, dissolved O_2 and conductivity were measured using Consort oxygen meter. Surface water samples were collected for chemical anlyses and transfered to DSI laboratory. Other chemical analyses data were obtained from DSI quality control and laboratory in Samsun (Anonymous, 2001).

The diversity ($\log_2$ base) calculated by the Shannon-Wiener index (Shannon & Weaver, 1949) and dissimilarity matrix were computed with BioDiversity Professional 2.0. The species richness was represented as the total number of taxa presented within the samples.

Realtive water column stability (RWCS) was calculated, according to Padisák *et al.* (2003b), by comparing the diversity difference between (D_b) and surface (D_s) water to the density difference between 4°C (D_4) and 5°C (D_5) of pure water, using the formula:

$$RWCS = \frac{D_b - D_s}{D_4 - D_5}$$

Water density was calculated from temperature values using a Water Density Calculator, available on the Internet, which calculates water density at a given temperature using 5-point Langrange interpolation (Senese, 2003).

RESULTS

A total of 109 planktonic algae was found: 39 Bacillariophyta, 39 Chlorophyta, 15 Cyanoprokaryota, 13 Euglenophyta, 3 Dinophyta and 2 Xantophyta (Table 1). Bacillariophyta and Chlorophyta were generally dominant, and

Table 1. List of algae present in phytoplankton and their occurrence in the stations.

Taxons	*Station 1*		*Station 2*	
	0 m	*1 m*	*0 m*	*1 m*
Bacillariophyta				
Centrales				
Cyclotella ocellata Pantocsek	+	+	+	+
Melosira varians C. Agardh				
Pennales				
Amphora arenaria Donkin		+		+
Amphora ovalis Kütz.	+	+	+	+
Amphora pediculus Kütz.		+		
Cocconeis pediculus Ehr.	+	+	+	+
Cocconeis placentula Ehr.	+	+	+	+
Cymbella affinis Kütz.	+	+	+	+
Cymbella cistula (Ehr.) Kirchner				+
Cymbella minuta Hilse	+	+	+	+
Cymbella parva W. Smith			+	
Epithemia sorex Kütz.	+	+	+	+
Fragilaria ulna (Nitz.) Lange-Bertalot	+	+	+	+
Gomphonema constrictum Ehr.			+	
Gomphonema affine Kütz.			+	
Gomphonema olivaceum (Horn.) Bréb. var. *olivaceum*		+	+	+
Gomphonema parvulum (Kütz.) Grun.		+		+
Gyrosigma acuminatum (Kütz.) Rabenh.	+	+	+	
Gyrosigma attenuatum (Kütz.) Rabenh.	+	+		+
Gyrosigma scalproides (Rabh.) Cleve	+			
Hantzschia amphioxys (Ehr.) Grunow			+	
Meridion circulare (Grev.) Agardh	+	+		
Navicula amphibola Cleve		+	+	
Navicula cincta (Ehr.) Kütz.	+	+	+	+
Navicula cuspidata Kütz. var. *cuspidata*	+	+		
Navicula cryptocephala Kütz.	+	+	+	+
Navicula elginensis (Gregory) Ralfs	+	+		
Navicula radiosa Kütz.	+	+	+	+
Navicula rhyncocephala Kütz.	+	+	+	+
Navicula veneta Kütz.	+	+		+
Nitzschia acicularis (Kütz.) W. Smith	+	+	+	+
Nitzschia angustata (W. Smith) Grunow	+	+		+
Nitzschia constricta (Nitz.) W. Smith	+	+	+	+
*Nitzschia longissima (*Breb.) Ralfs	+	+	+	+
Nitzschia palea (Kütz.) W. Smith	+	+	+	+
Nitzschia sigmoidea (Ehr.) W. Smith	+	+		+
Nitzschia tryblionella Hantzsch			+	
Nitzschia vermicularis (Kütz.) Hantzsch.	+	+		
Rhoicosphaenia abbreviata (C. Agardh) Lange-Bertalot	+	+	+	+
Surirella ovalis Bréb.	+			+
Surirella linearis W. Smith		+		
Chlorophyta				
Chlorococcales				
Ankistrodesmus falcatus (Corda) Ralfs	+	+	+	+
Ankistrodesmus spiralis (W.B. Turner) Lemmerm.	+	+	+	+
Botryococcus braunii Kütz.		+		
Chlorella vulgaris Beijerinck		+		
Crucigeniella rectangularis (Nägeli) Komárek	+			

Taxons	*Station 1*		*Station 2*	
	0 m	*1 m*	*0 m*	*1 m*
Kirchneriella elongata G.M. Smith			+	
Kirchneriella lunaris (Kirchner) K. Möbius	+	+	+	
Kirchneriella irregularis (G.M. Smith) Korshikov			+	
Kirchneriella obesa (West) Schmidle	+	+	+	+
Monoraphidium griffithii (Berkeley) Komárková-Legnerová		+	+	
Pediastrum tetras (Ehr.) Ralfs		+		
Scenedesmus communis Hegewald	+	+	+	+
Scenedesmus arcuatus var. *platydiscus* G.M. Smith		+		+
Scenedesmus obtusus Meyen		+	+	
Scenedesmus sp.	+	+		+
Tetraedron minimum (A. Braun) Hansgirg				+
Tetrastrum komarekii Hindák			+	+
Chaetophorales				
Desmococcus olivaceus (Persoon ex Acherson) J. R. Laundon		+	+	
Klebsormidiales				
Klebsormidium subtile (Kütz.) Tracanna ex Tell				+
Volvocales				
Chlamydomonas globosa J. Snow	+	+	+	+
Pandorina morum (O.F. Müller) Bory		+		+
Oedogoniales				
Oedogonium calvum Wittrock		+		+
Desmidiales				
Closterium dianae Ehr. ex Ralfs	+	+	+	+
Closterium kuetzingii Bréb.	+	+	+	
Closterium praelongum Bréb.		+		
Cosmarium blyttii Wille	+	+	+	+
Cosmarium denticulatum Borge	+	+	+	+
Cosmarium laeve Rabenh.	+	+	+	+
Cosmarium granatum Bréb. in Ralfs		+		
Cosmarium tinctum Ralfs		+		
Cosmarium sp.	+			
Eastrum dubium Nägeli var. *dubium*		+		+
Staurastrum gracile Ralfs	+	+	+	+
Zygnematales				
Spirogyra ellipsospora Transeau			+	+
Dinophyta				
Peridinium sp.		+		
Glenodinium pulvisculus (Ehr.) F. Stein			+	
Cryptomonas ovata Ehr.	+	+	+	+
Cyanoprokaryota				
Chroococcales				
Chroococcus pallidus (Nägeli) Nägeli			+	+
Chroococcus turgidus (Kütz.) Nägeli				+
Microcystis aeruginosa (Kütz.) Kütz.	+	+	+	+
Synechocystis endobiotica (Elenkin & Hollerbach) Elenkin		+		
Nostocales				
Anabaena spiroides Klebahn	+			
Anabaena sp.	+	+	+	
Cylindrospermum stagnale (Kütz.) Born. & Flah.	+			+
Geitlerinema lemmermanni (Woloszynska) Anognostidis				+
Leptolyngbya tenuis (Gomont) Anognostidis & Komárek		+	+	+
Limnothrix guttulata (Van Goor) I. Umezaki & M. Watanabe		+		
Limnothrix planctonica (Wolosz.) Meffert		+		
Lyngbya sp.	+			

Taxons	*Station 1*		*Station 2*	
	0 m	*1 m*	*0 m*	*1 m*
Oscillatoria limosa (C. Agardh) Gomont	+		+	+
Phormidium konstantinosum I. Umezaki & M. Watanabe		+	+	+
Pseudanabaena limnetica (Lemmerm.) Komárek	+	+	+	+
Euglenophyta				
Euglena gracilis G. A. Klebs		+	+	+
Euglena minuta Prescott	+	+	+	+
Phacus acuminatus A. Stokes		+	+	+
Phacus arnoldii Swirenko	+	+	+	
Trachelomonas armata (Ehr.) F. Stein ex Deflandre				+
Trachelomonas dybowski Drezepolski	+	+	+	+
Trachelomonas hispida (Perty) F. Stein	+	+	+	+
Trachelomonas lacustris Drezelpolski		+		
Trachelomonas oblonga Lemmerm.	+	+	+	+
Trachelomonas scabra Playfair		+		
Trachelomonas superba Svirenko emend. Deflandre		+		+
Trachelomonas volvocina Ehr.	+		+	
Trachelomonas sp.			+	
Xantophyta				
Goniochloris fallax Fott	+			+
Goniochloris mutica (A. Braun) Fott		+		+

Cyanoprokaryota and Euglenophyta were subdominant among the planktic algae in terms of number of species. The succession during 2000 began with diatoms (R-strategists, with a high surface to volume ratio). Phytoplankton were dominated by fast-growing and disturbance tolerant species (R-strategists) of cryptophytes (*Cryptomonas ovata*), which reached a high biomass in the lake (0.17 mg l^{-1}). This group was followed by chlorophytes (C-strategists, small phytoplankton that grow quickly), euglenophyes and cyanophytes (S-strategists, slowly growing large unicells or colonies with low suface to volume ratio). C- species are thought to be selected by conditions of both high nutrient and high light. These conditions may occur seasonally in temperate lakes immediately after stratification begins.

Water temperature ranged between 4ºC in February and 25°C in August and no significant differences were found between sites. Values of pH and dissolved O_2 oscillated throughout the year, with with no clear seasonal pattern. NO_2^- and NO_3^- presented similar seasonal changes. The variation of the most important environmental characteristics in the Gıcı Lake is shown in Table 2. The sampling sites were considered as a whole and the minimum, maximum and average values are listed.

Relative stability of the water column stratification increases in May and reaches a maximum of 207 to 231 RWCS during the summer. The temperature difference between the surface and the bottom increased constantly up to 9°C at the end of the June. And relative stability of the water column stratification (Fig. 2B) reached its maximum of 231 at the end of June. Since the beginning of July an increasing tendency to mixing could be observed in the water column.

The seasonal variations in the density of the phytoplankton at 0 m and 1 m depth were similar except some quantitative changes. Peaks of phytoplankton were recorded during autumn and early spring in the surface water samples (October 2000, December 2000 and March 2001). The density reached its lowest

Table 2. Variation of the most important environmental characteristics in the Gıcı Lake.

Variable	*Minimum*	*Maximum*	*Average*
Dissolved O_2 (mg l^{-1})	3.3	8.5	6.7
PH	8.0	8.6	8.2
Conductivity (µS cm^{-1})	1060	1349	1227
Alkalinity (mg l^{-1} $CaCO_3$)	197.5	235	213
Total hardness (mg l^{-1} $CaCO_3$)	305	320	313
Ca^{2+} (mg l^{-1})	58	61	60
Mg^{2+} (mg l^{-1})	37	41.3	39.6
PO_4^{3} (mg l^{-1})	0	0.14	0.07
SO_4^{2-} (mg l^{-1})	66.7	99.8	85.8
NH_3-N (mg l^{-1})	0.05	0.3	0.16
NO_2^--N (mg l^{-1})	0	0.15	0.03
NO_3^--N (mg l^{-1})	0.07	0.95	0.38

level at St. 1 with 136 ind ml^{-1} in March 2000, its highest level at St. 2 with 5145 ind ml^{-1} in March 2001. Chlorophytes were dominant, comprising 97% of the overall assemblage (5145 ind ml^{-1}). Euglenophytes were most numerous (1945 ind ml^{-1}) in September. In January, at each sampling site, Euglenophytes were replaced by Chlorophytes in terms of total contribution to the assemblage (Fig. 3).

The investigation carried out from February 2000 to April 2001 showed that the assemblage was strongly dominated by a few species, one by one. Diatoms comprised up to 100% of the phytoplankton biomass, especially in winter and spring. Among the diatoms, *Fragilaria ulna* and *Melosira varians* were responsible for the highest peak registered in the entire study period. The contribution of *Fragilaria ulna* to the biomass was 26-92% at both stations. This species was dominant for 6-11 months of the study period. In the short stratification period, at the end of June when the relative water column stability reached a maximum of 231, the dominant species changed completely. Chlorophytes were replaced by diatoms, which became important in terms of biomass in early summer and March 2002 at 1 m in St. 1. *Cosmarium denticulatum* became dominant, making up 97% of the phytoplankton biomass with 2.2 mg l^{-1} in June, 66% of the biomass with 0.34 mg l^{-1} in July. *Cryptomonas ovata* comprised 76% of the biomass with 0.17 mg l^{-1} at 0 m in June. *Trachelomonas hispida* was dominant forming 66% of the phytoplankton biomass in July in the same station. *Trachelomonas hispida* and *Nitzschia acicularis* were dominant in June and July and contributed, respectively, 48 and 80% to the biomass at 0 m in St. 2. Smaller peaks observed were mainly a result of increases in the occurence of *Cocconeis pediculus, Cymbella ventricosa* and *Navicula cryptocephala* (Fig. 4).

Relative species abundance (evenness) around 0 indicated a high single-species dominance (i.e. *Fragilaria ulna*) that formed 97% of the biovolume with 34 mm^3 m^{-3} in the surface samples of St. 1 in April 2001. The bloom pattern of this species resulted in decrease of *H'*, indicating low evenness. In March and July 2000, evenness value increased to nearly 1, indicating maximum evenness in the same station. In the surface samples of St. 2, *Nitzschia acicularis* comprised 80% of the biovolume and showed high dominance values, low richness and diversity in July. Also the bloom pattern of *Melosira varians* with 1321 mm^3 m^{-3} showed low evenness, diversity and species richness in February 2000 at 1m depth in St. 1.

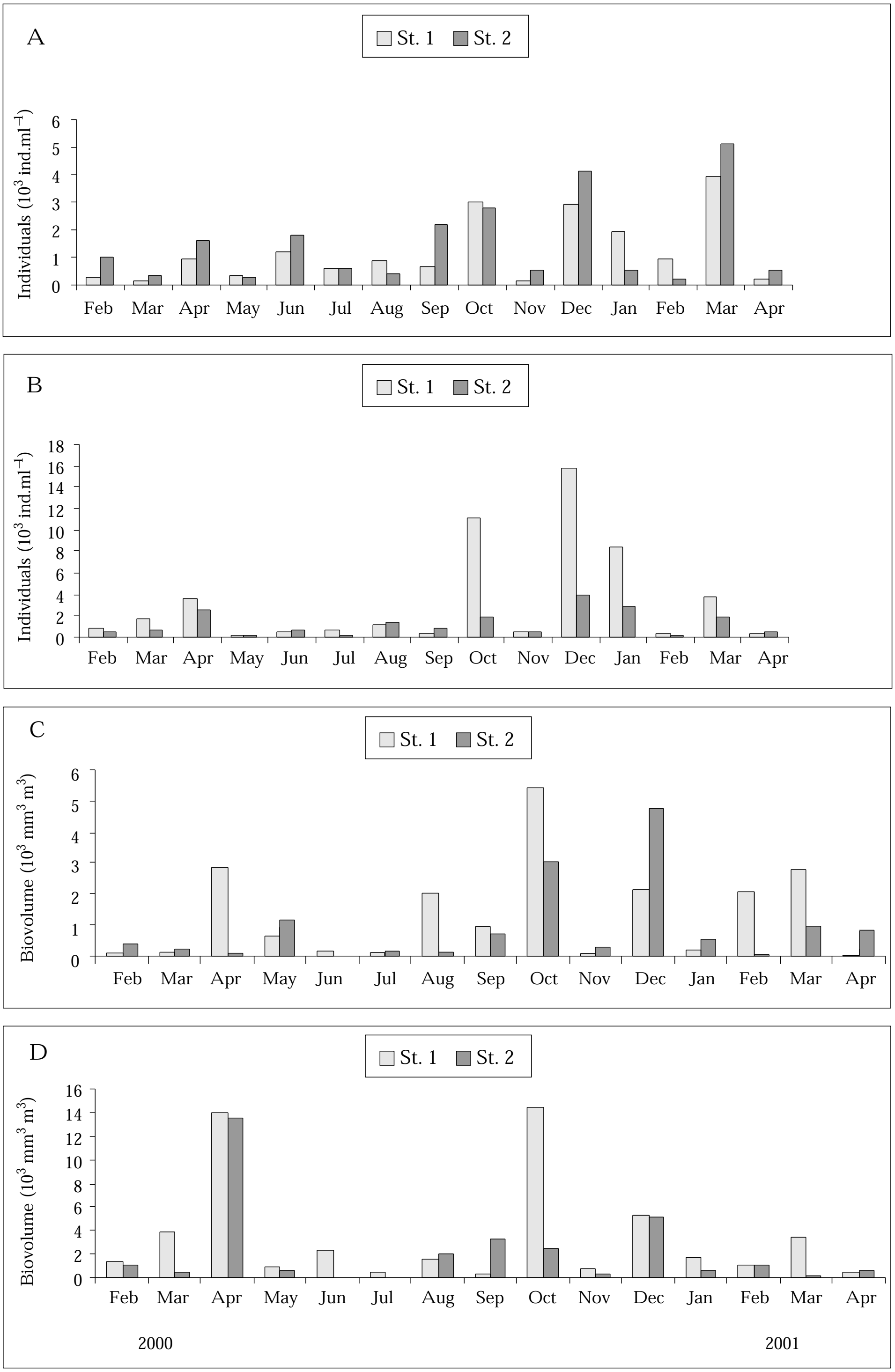

Fig. 3. Seasonal variation of the phytoplankton density (ind. ml^{-1}) (A) at 0 m, (B) 1 m and biovolume (mm^3 m^{-3}) (C) at 0 m, (D) 1 m in Gıcı Lake.

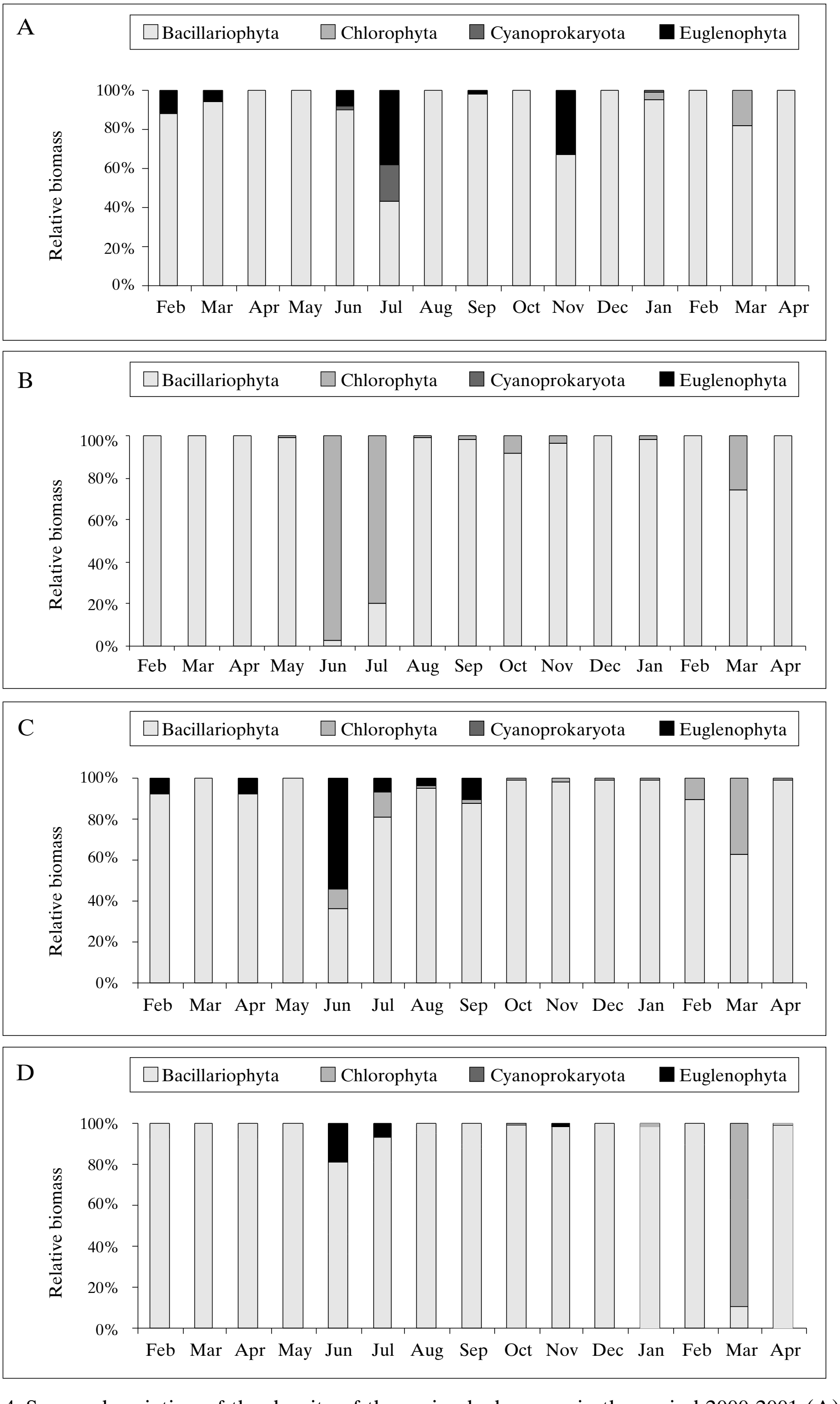

Fig. 4. Seasonal variation of the density of the main algal groups in the period 2000-2001 (A) at 0 m, (B)1 m in St. 1 and (C) at 0 m and (D) 1m in St. 2.

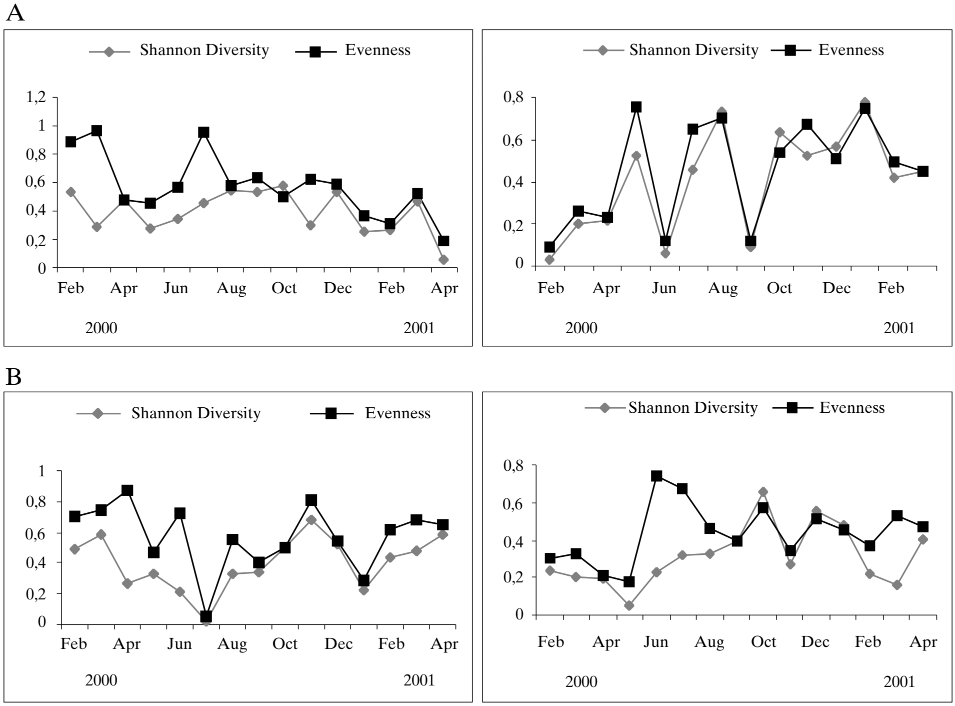

Fig. 5. Shannon Diversity index and evenness in (A) St. 1, (B) St. 2 at 0 m (left) and 1 m (right).

In May, evenness was about 0, indicating high single-species dominance of *Melosira varians* (607 $mm^3\ m^{-3}$) at 1 m depth in St. 2 (Fig. 5).

Species richness values for Gıcı Lake were generally low and showed only small variations during almost the entire study period (Fig. 6). However, in the surface samples of St.1, the highest and lowest values were recorded within a short period of time. The lowest values for both stations were detected in October.

DISCUSSION

Shallow lakes represent variable environments, where the limiting constraints frequently vary and the identity of the best adapted species changes. Meteorological events like heavy rainfall, hot weather periods and stormy days can have a pronounced impact on hydrodynamics, water temperature, and nutrient supply. Such short-term variability can retard succession, thus preventing one species from outcompeting the rest (Scheffer, 1998). Heavy rainfalls and turbulence effects enhance the distribution of diatoms during their peak appearance (Sep., Dec., Mar.) since their decline is also due to the sedimentation that occurs when these phenomena are absent.

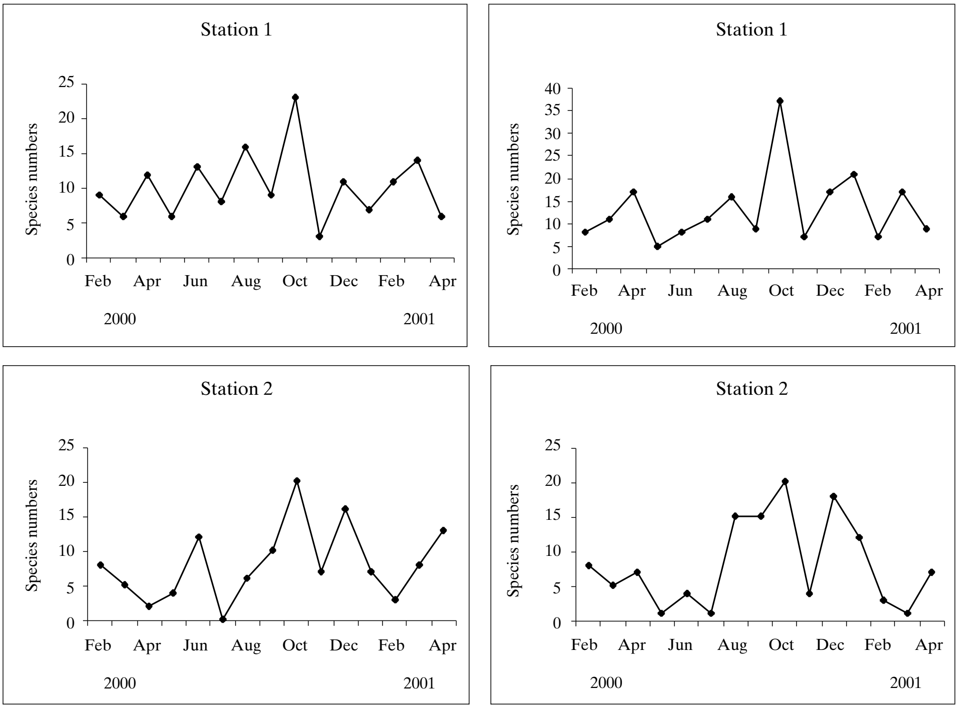

Fig. 6. Species richness of the phytoplankton at 0 m (left) and 1 m (right) in the sampling stations.

Pennate diatoms were the most widespread and dominant algal group in Gıcı Lake, forming 36% of the assemblage. The increased importance of diatoms in the phytoplankton community could be explained by the change in the physical structure of the lake, with the extent of vertical mixing and thermal stability of the water column being crucial factors controlling the development of diatoms (Reynolds, 1997). In agreement with Reynolds *et al.* (2002), large diatoms are considered very sensitive to water column stratification and they should decline when the environmental stability increases. However, some opposite evidence exists: Agbeti *et al.* (1997) described the development of lightly silicified and spindle-shaped diatoms during a period of high water column stability in Lake Upper Rock in Ontorio.

As the depth varied from 1.0 to 1.5 metre in the sampling stations, the waters of the windexposed shallow Gıcı Lake were mixed and showed no evidence of strafication except during the summer period. The intense sediment-water interaction and potentially large impact of aquatic vegetation makes the functioning of a shallow lake different from that of their deep counterparts in many aspects (Scheffer, 1998). Clear-water periods are usually short in eutrophic shallow lakes (Deneke & Nikdorf, 1999), but in Lake Gıcı phytoplanktonic biomass remained below potential values throughout the summer. It has been shown that macrophytes promote and stabilize clear water conditions, keeping the biomass low by (i) offering refuge to zooplankton species, (ii) competing with algae for resources, (iii) releasing allopathic substances (Scheffer, 1998; Bertolo *et al.,* 1999; Strand & Weisner, 2001, Burks *et al.,* 2001).

According to the concept of adaptive strategists (Grime, 1979; Reynolds, 1988), the summer assemblages develop during strong thermal stability of the water column and low avilability of nutrients (high stress), i.e under conditions favoring stress-tolerant algae (S-strategists, e.g. *Trachelomonas* and *Microcystis*). In the classification of trait-separated phytoplankton groups (Reynolds *et al*., 2002) some characteristics of the **D**, **P** and **N** Reynolds associations describe the Gıcı Lake assemblages, but they don't strictly match with them. The **D** assemblage, which was the first dominant group recorded in February 2000, includes diatoms (*Nitzschia palea*), mostly found in shallow, nutrient-enriched waters that are prone to be turbid. The **P** assemblage includes diatoms (*Fragilaria ulna*), which are dependent on physical mixing, requiring a continuous or semi-continuous mixed layer of, at least, 2-3 m in thickness (Reynolds *et al*., 2002). The **N** (*Cosmarium denticulatum*) and $\mathbf{W_2}$ assemblages (*Trachelomonas hispida*) were dominant during the short stratification period. **B** (*Melosira varians*) and **C** assemblages (*Nitzschia acicularis*), which can develop in mixed conditions, tolerant to low light and carbon deficiency, but sensitive to stratification, form larger units and were dominant after the stratification period.

The onset of stratification occurred at the end of May when the temperature difference between the surface and the bottom was 2°C. This value increased constantly up to 9°C at the end of the June. From the beginning of July an increasing tendency to mixing could be observed in the water column due to the decrease in depth (Kennedy *et al*., 2002). The pattern observed in Gıcı Lake was similar to the finding by Elliott *et al.* (2000), who also recorded a diversity decrease in stable conditions. Those authors attributed this result to the vertical segregation of the water column, which makes the environment more selective with reduced mixing depth. In contrast, Tilman (1994) regarded that the thermal stratification during summer should create environmental heterogeneity, giving rise to a niche diversification and to an increase of diversity (Salmoso, 2003).

In aquatic environments, the stability of the water column is considered a factor in the control of the structure of phytoplankton assemblages (Morabito *et al.*, 2003). The influence of water stability on the composition and diversity of the algal community was also found by Figueredo & Giani (2001) and Calijuri & Dos Santos (1996) in Brazil. Higher species diversity index (H') were registered in October and August, coinciding with the higher rainfall values, which, probably, caused the algal suspension of the sediment and the periphyton removal, increasing the specific richness as well as the possibility of collecting a higher number of species than during the dry season. Rain is possibly the main reason for the observed seasonal variation (Huszar & Reynolds, 1997). The instability of the water surface during the rainy season induces changes in species dominance and in H' values. Later, several successional stages follow until the moment when the stability of the water column permits the dominance of *Fragilaria ulna* and *Trachelomonas hispida.* Thus, the calculation of diversity indices and water column stability were important to demonstrate the instability of this system, which for the most part of the year does not allow the dominance of a single species and shows rather high H' values. The diversity and periodicity of dominant species observed in the shallow lake and the small pond may be explained by frequent allogenic disturbances such as postulated in the Intermediate Disturbance Hypothesis (Sommer *et al.*, 1993).

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