Turk J Biol
35 (2011) 485-501
© TÜBİTAK
doi:10.3906/biy-0904-5

Seasonal variations in phytoplankton composition and biomass in a small lowland river-lake system (Melen River, Turkey)

Tülay BAYKAL[1], İlkay AÇIKGÖZ[2], Abel U. UDOH[2], Kazım YILDIZ[2]

[1]Department of Biology, Faculty of Arts and Science, Ahi Evran University, 40100 Kırşehir - TURKEY

[2]Department of Biology Education, Faculty of Education, Gazi University, 06500 Teknik Okullar, Ankara - TURKEY

Received: 08.04.2009

Abstract: A series of studies were carried out to determine the succession and phytoplankton community of the Melen River in the Western Black Sea region of Turkey. The study was conducted at 6 stations at monthly intervals between May 2003 and April 2004. It was observed that the abundance and biovolume of phytoplankton were low in winter, though higher values were recorded in late spring and summer. Among the values noted, the spring peak was 534.38 × 10^5 ind. L^{-1} and 7384.8 mm^3 L^{-1} belonging to *Peridinium* sp. The most common diatom, *Cyclostephanos dubius,* was favoured by low discharge at stations 1 and 2 in the early summer (214.29 × 10^5 ind. L^{-1} and 9.84 × 10^5 ind. L^{-1}), respectively. Chlorophyll-a concentrations were between 0.86 and 64.2 µg L^{-1}. A total of 135 taxa belonging to Cyanophyta, Bacillariophyta, Chlorophyta, Dinophyta, Euglenophyta, Heterokontophyta, Streptophyta, and Xanthophyta were identified. The total biomass of the stations 1 and 2 was mainly characterised by Dinophyta and at other stations by Bacillariophyta. Five major genera (*Peridinium*, *Ceratium*, *Phacus*, *Cyclostephanos*, and *Melosira*) accounted for over 70% of the total phytoplankton abundance. Phytoplankton abundance was significant and positively correlated with Chl-a and temperature ($r = 0.57$ and $r = 0.78$, respectively $P < 0.05$). Species richness and diversity indices increased gradually throughout the course of the river.

Key words: Phytoplankton, abundance, biomass, diversity, seasonal changes, Melen River

Küçük bir nehir - göl sisteminin fitoplankton kompozisyonu ve biyomasındaki mevsimsel değişimler (Melen nehri, Türkiye)

Özet: Melen Nehrindeki araştırmalar fitoplankton topluluğu ve mevsimsel değişimini ortaya koymak için yapılmıştır. Bu çalışma Mayıs 2003 ve Nisan 2004'te altı istasyonda aylık olarak sürdürülmüştür. Fitoplankton bolluğu ve biyoması kış aylarında düşük, ilkbahar sonu ve yaz aylarında yüksek değerlerde kaydedilmiştir. *Peridinium* sp.'ye ait ilkbahar pik değerleri 534,38 × 10^5 birey L^{-1} ve 7384,8 mm^3 L^{-1}'dir. En yaygın diyatom türü olan *Cyclostephanos dubius*, birinci ve ikinci istasyonlarda debinin düşük olduğu erken yaz aylarında iyi gelişim göstermiştir (214,29 × 10^5 birey L^{-1} ve 9,84 × 10^5 birey L^{-1}). Chlorophyll-a konsantrasyonları 0,86-64,2 µg L^{-1} arasında kaydedilmiştir. Cyanophyta Bacillariophyta, Chlorophyta, Dinophyta, Euglenophyta, Heterokontophyta, Streptophyta ve Xanthophyta' ya ait toplam 135 takson teşhis edilmiştir. Birinci ve ikinci istasyonların toplam biyoması Dinophyta, diğer istasyonlar ise Bacillariophyta tarafından karakterize edilmiştir. *Peridinium*, *Ceratium*, *Phacus*, *Cyclostephanos* ve *Melosira* cinsleri toplam fitoplankton bolluğunun %70'ini oluşturmuştur. Fitoplankton bolluğu, klorofil a ve sıcaklık ile önemli pozitif korelasyon göstermiştir (sırasıyla, $r = 0,57$ and $r = 0,78$, $P < 0,05$). Tür zenginliği ve diversity indisleri nehir boyunca giderek artmıştır.

Anahtar sözcükler: Fitoplankton, yoğunluk, biyomas, çeşitlilik, mevsimsel değişimler, Melen Nehri

Introduction

Algae are one of the most important primary producers in almost every water ecosystem. These organisms are, at the same time, very sensitive to changes in their environments. In rivers, phytoplankton succession is mainly determined by changes in hydrological and abiotic parameters both in space and time (1). Biotic and hydrochemical factors have rarely been reported to affect the development of the phytoplankton community (2), and numerous studies have been conducted on the seasonal dynamics of the phytoplankton community in aquatic ecosystems (2-11). However, in comparison to large lowland rivers, less is known about phytoplankton succession from small lowland rivers. Studies into phytoplankton periodicity in lotic ecosystems are limited compared to those covering Turkey's lentic ecosystems. However, research into the ecology of phytoplankton in lowland rivers has become more and more popular in recent times (12-16).

The Melen River is one of the largest rivers in the Western Black Sea region of Turkey. The 2 main branches of the river are the Big and Small Melen, and they are of great importance in many aspects. Hasanlar Dam Lake, used for irrigation and energy generation, was built on the Small Melen River. Efteni Lake, a wildlife protection area, is located at the point where the 2 branches converge. In addition, the Melen watershed should be regarded as a 'sensitive area' in accordance with the European Union (EU) Urban Wastewater Treatment Directive, since the Big Melen River will be used as a potable water source in the near future. After the completion of a water supply project organised by Turkey's General Directorate of State Hydraulic Works (DSI), İstanbul will receive an additional 8.5 m^3/s of water from the river (17,18).

There has been no study done on the phytoplankton population of the Melen River. Therefore, we think that this study will contribute greatly to the Turkish freshwater algal database. In this regard, the study aimed to describe the phytoplankton community and to observe temporal changes in the composition, biomass and, diversity of phytoplankton in the river. Moreover, it should be taken into consideration that phytoplankton might respond in different ways according to the different hydrological and morphological characteristics in the longitudinal gradient. For this reason, the assumption that stations would exhibit differences from each other was tested.

Materials and methods

Study site

The Melen watershed is located in the western part of the Black Sea region of Turkey (latitudes 41°50′N to 40°40′N and longitudes 30°50′E to 31°40′E) and covers a total area of 2317 km^2. This river basin is surrounded by high mountains and is affected by flooding, especially between November and May (19). The Düzce Plain is located in the middle of the basin, and extends over a 360 km^2 area. The winter, spring, and autumn months are rainy but warm in the basin, while the summer months are hot and dry (20). The highest and lowest rates of precipitation occur in autumn and summer, respectively, and the annual average precipitation varies between 700 and 1000 mm. In addition, the geology, soil structure, climate, hydrology, and land uses are diversified and vary widely throughout the basin (21).

The Melen River is separated into 2 courses in this area, namely the Big Melen and the Small Melen. The Big Melen River is an evacuation channel for the basin. The river discharges 178,284 t of sediment annually into the Black Sea. The Small Melen, Asar, Uğur, and Aksu streams converge with the Big Melen in Efteni Lake. The mean water discharges of these streams over long periods are 13.3 m^3/s, 4.5 m^3/s, 4 m^3/s, and 2.5 m^3/s respectively (20). The water discharge of the Big Melen River reaches its maximum value of 204 m^3/s in April, and minimum of 5.0 m^3/s in August (average 49 m^3/s) (21). A 20-year period of water discharge measured at stations 1 and 2 localised on the Small Melen revealed a minimum of 1.43 m^3/s and 3.37 m^3/s, and a maximum of 13.32 m^3/s and 18.45 m^3/s, respectively (17). Efteni Lake, located 118 m above sea level between the Big and Small Melen rivers, has tectonic features, and its area is reduced to 5 km^2 when the waters retreat, and increases to 25 km^2 during flood periods. Its deepest part is 8 m, and there are hydromorphic alluvial and riverbed soils in the surrounding areas (20). Hasanlar Dam on the Small Melen River is the largest lake in Düzce Province. Its area reaches up to 42.5 km^2. Six stations (Figure 1) were chosen along the course of

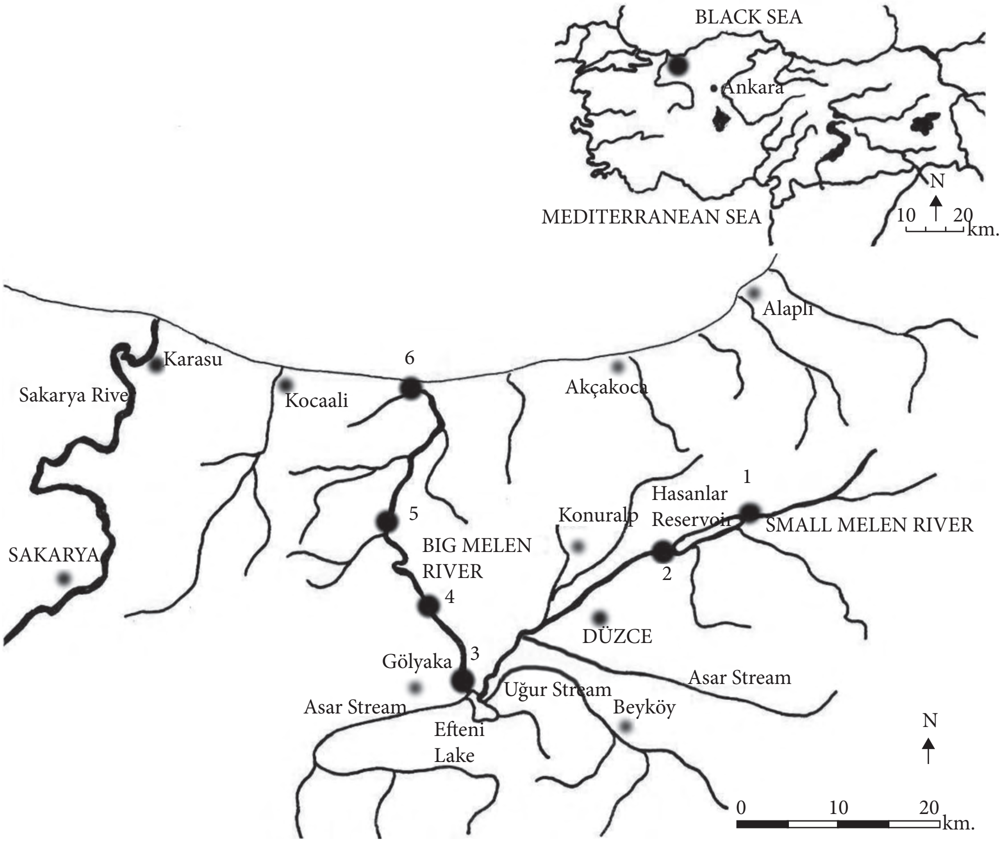

Figure 1. Map of the Melen River and its branches showing the location of sampling stations.

the river starting from its source (Station 1 at the 18th km, station 2 at the 26th km, station 3 at the 51st km, station 4 at the 57th km, station 5 at the 69th km, and station 6 at the 87th km). There are several branches that flow into the Melen River from both banks, thus forming a large watershed.

Sampling and counting

Phytoplankton samples were collected from 6 stations on a monthly basis along the river between May 2003 and April 2004, except for during 2 winter months (January and February). For the taxonomic analysis of phytoplankton, samples were taken with a 25-µm mesh size plankton net and fixed by formalin with a final concentration of 4%. For quantitative analysis, 1 L of water surface samples was taken and preserved in PVC flasks and fixed with 10 mL of Lugol's iodine solution. The density and biomass were estimated by employing an inverted microscope according to Utermohl (22). In order to calculate biomass, individual numbers were converted to biovolumes using geometric or combined forms formulae according to Standard Operating Procedure for Phytoplankton Analysis (23). Algae species were identified with a Nikon microscope (magnification 15 × 40). For the identification of diatoms, frustules were cleaned with concentrated HCl and H_2SO_4. Different sources were used for species identification (24-32). The arrangement of the phyla follows that of the AlgaeBase (33). Genera are in alphabetical order, and species are the same within the genus. Phytoplankton biomass was measured in terms of Chlorophyll-a (Chl-a). Water samples (1 L) were filtered with GF/C. The filtrate was removed and placed in a flask with 14 mL of methanol and boiled in a water bath for 5 min and then cooled for 5 min in a dark medium. The filtrate was removed and 10 mL of a supernatant was transferred to the spectrophotometer (Shimadzu brand) cuvette. Extract absorbance was measured at 665 and 750 nm (34).

During sampling, temperature, dissolved oxygen, salinity, conductivity, and pH were measured in situ using YSI model (55/25 FT, 30/25 FT) and Thermo/Orion (210 model) portable probes, respectively. Daily collected discharge values belonging to station 1 (inflow to the reservoir) and station 5 were obtained from the DSI. To analyse the other variables, samples were stored at 4 °C in a dark medium and transported to the DSI laboratory in Ankara. Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD_5), and major nutrients such as ammonium, nitrate, nitrite, and phosphate were measured by the DSI in accordance with Standard Methods (35). Abiotic variables were correlated with main phytoplankton attributes using non-parametric Spearman's correlation coefficients. Differences in all variables were tested using a non-parametric Kruskal-Wallis ANOVA median test (KW). Differences at the <0.05 level were accepted as significant. Also, to compare stations, non-parametric statistics (the Mann-Whitney *U* test) were used (36). Species richness was considered to be the number of taxa present in each sample. Biological diversity (*H´*) was calculated by the following formula (37):

$$H' = -\sum_{i=1}^{S} Pi \log_2 Pi \qquad (Pi = Ni / N)$$

Calculations were performed on the different units, where *Ni* is the quantity of individuals and biovolume of species, *N* is the total amount of units, and S is the total number of species in the sample.

Results and discussion

Abiotic factors

Seasonal variations in surface water temperature, pH, and oxygen were measured at the 6 stations during the research period, and these are given in Figure 2. Water temperature varied parallel with seasonal atmospheric changes. The lowest temperature was measured at 5.8 °C at station 4 in January 2004, while the highest temperature was 27 °C at station 1 in July 2003. There were no significant differences between the stations as regards the following parameters: pH varied between 7 and 8, and oxygen concentration ranged from 6.5 mg L^{-1} in July 2003 to 14.6 mg L^{-1} in February 2004. Oxygen, pH, and temperature values showed similar fluctuations, and salinity ranged between 0.1 and 0.6 ppt. The lowest salinity was measured at stations 1 and 2 and the highest was at station 6. The mean values of the other seasonal environmental parameters in the Melen River are given in Table 1.

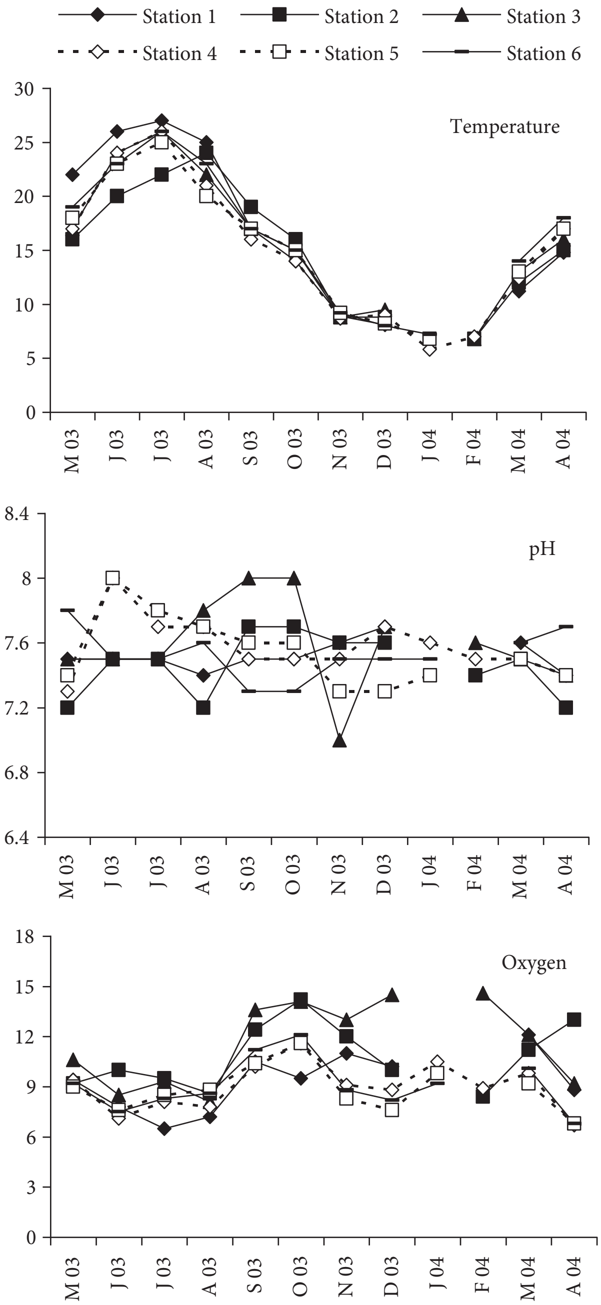

Figure 2. Environmental parameter variations in the Melen River.

Table 1. Mean values (±S.D.) of some environmental variables in the Melen River (n = number of data).

Parameters	Summer n = 11	Autumn n = 11	Winter n = 10	Spring n = 11
Turbidity (NTU)	92.209 (90.84)	39.95 (42.83)	210.2 (110.58)	76.65 (32.73)
Suspended solids	115.63 (116.98)	46.54 (51.61)	281.4 (155.21)	79.72 (29.87)
Total dissolved Solids	240.72 (50.04)	284.09 (57.63)	198.9 (25.33)	197.45 (16.63)
Electrical conductivity (µS cm^{-1})	399.45 (102.6)	467.36 (86.01)	318.7 (42.58)	328.09 (18.70)
Salinity (ppt)	0.277 (0.151)	0.25 (0.115)	0.241 (0.124)	0.222 (0.153)
Ammonia-N (mg L^{-1})	0.66 (0.448)	0.804 (0.487)	0.241 (0.124)	0.453 (0.163)
Nitrite-N (mg L^{-1})	0.137 (0.104)	0.095 (0.043)	0.018 (0.009)	0.038 (0.033)
Nitrate-N (mg L^{-1})	1.4 (0.87)	2.038 (1.187)	0.785 (0.224)	0.616 (0.116)
Phosphate (mg L^{-1})	0.482 (0.298)	0.60 (0.259)	0.421 (0.184)	0.139 (0.068)
Sulphate (mg L^{-1})	22.254 (5.778)	27.882 (4.371)	21.905 (5.760)	17.445 (3.84)
Biological Oxygen Demand (mgO_2 L^{-1})	3.550 (1.225)	3.999 (1.229)	6.07 (2.088)	3.933 (1.336)
Chemical Oxygen Demand (mgO L^{-1})	17.245 (5.658)	17.174 (4.934)	28.641 (19.425)	18.361 (4.783)
Sodium (mg L^{-1})	13.804 (7.414)	17.239 (6.083)	8.734 (1.357)	7.95 (1.979)
Potassium (mg L^{-1})	7.131 (6.912)	7.621 (5.789)	4.854 (2.966)	3.028 (1.906)
Calcium (mg L^{-1})	59.30 (10.265)	65.309 (7.752)	46.22 (7.703)	52.763 (2.123)
Magnesium (mg L^{-1})	7.12 (3.258)	11.421 (2.421)	7.228 (1.199)	6.009 (1.454)

Discharge variations at station 1 on the Small Melen River and station 5 on the Big Melen River are given in Figure 3. Discharges were found to decrease in the summer months and increased in the rainy periods (November to April). Mean momentary water discharge was measured by the DSI as 9.047

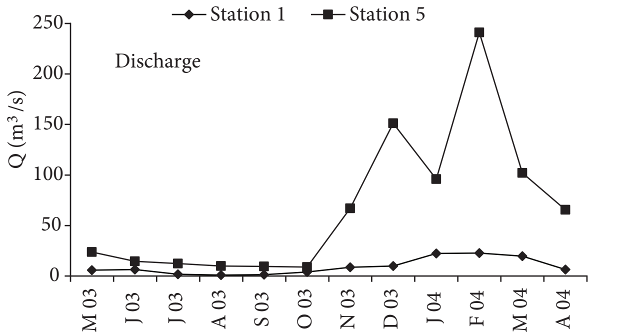

Figure 3. Monthly average discharge of the Melen River (data obtained from the DSI).

m^3/s for station 1 (minimum 0.56 m^3/s in August and maximum 136 m^3/s in February) and 49.9 m^3/s for station 5 (minimum 4.75 m^3/s in October and maximum 224 m^3/s in February). While turbidity was negatively correlated with total dissolved solids ($r = -0.75$; $P < 0.05$), it was positive for suspended solids ($r = 0.94$; $P < 0.01$). However, there was no clear relation between other physico-chemical variables.

When the stations were compared according to abiotic factors, stations 2 and 3 were found to be different from stations 4, 5, and 6 in terms of dissolved oxygen (DO). There were significant differences between stations 2 and 5 as well as 3 and 5 because of the DO levels of stations 2 and 3 (M-W *U* test = 24.5 $P < 0.05$, M-W *U* test = 22 $P < 0.01$ respectively). In addition, there was a highly significant difference between station 6 and the others in terms of salinity ($P < 0.01$).

Phytoplankton community

The community consisted of 136 taxa, distributed among 50 genera. Most species belong to Cyanophyta (10), Bacillariophyta (83), Chlorophyta (20), Dinophyta (4), Euglenophyta (9), Heterokontophyta (1), Streptophyta (8), and Xanthophyta (1). Relevant results are given in Table 2. The results indicated that Bacillariophyta was qualitatively dominant, while Chlorophyta was subdominant in the river.

The preponderance among different groups was quite common. Dinophyta was dominant at stations 1 and 2 in late spring, summer and early autumn. Except at station 2, Euglenophyta was intermittently dominant at the other stations (Figure 5). Streptophyta showed significant growth

Table 2. Floristic list of phytoplankton taxa found in the Melen River.

Stations	**1**	**2**	**3**	**4**	**5**	**6**
Phylum: CYANOPHYTA						
Class: CYANOPHYCEAE						
Order: Chroococcales						
Chroococcus turgidus (Kutzing) Nägeli					+	
Cyanodictyon endophyticum Pascher					+	
Order: Oscillatoriales						
Jaaginema minimum (Gicklhorn) Anagnostidis & Komárek				+		
Leptothrix ochraceae (Leiblein) Kützing					+	
Limnothrix planctonica (Wolozynska) Mefferet			+	+		
Oscillatoria lauterbornii Schmidle					+	
O. subbrevis Schmidle			+			
Pseudanabaena limnetica (Lemmermann) Komárek	+	+	+	+	+	+
Phormidium limosum (Dillwyn) P.C. Silva			+	+	+	
Phormidium mucicola Huber Pestalozzi et Naumann					+	
Phylum: BACILLARIOPHYTA						
Class: BACILLARIOPHYCEAE						
Order: Cymbellales						
Cymbella affinis Kützing					+	+
C. caespitosa (Kützing) Brun			+		+	
C. cistula (Hemprich & Ehrenberg) Kirchner			+			+
C. cymbiformis Agardh		+				
C. lanceolata (Ehrenberg) Kirchner				+		
C. leptoceros (Ehrenberg) Kützing			+		+	
C. tumida (Brebisson in Kützing) Van Heurck				+		
C. turgidula Grunow				+	+	
Didymosphenia geminata (Lyngbye) M.Schmidt				+		
Encyonopsis microcephala (Grunow) Krammer					+	
Encyonema minutum (Hilse in Rabenhorst) D.G.Mann	+	+	+	+	+	
E. prostratum (Berkeley) Kützing					+	+
E. silesiacum (Bleisch) D.G.Mann	+		+			
Gomphonema acuminatum Ehrenberg				+	+	+
G.vibrio Ehrenberg var. *intricatum* (Kützing) Playfair			+			
G. augur Ehrenberg var. *augur*			+			
G. minutum (C. Agardh) C.Agardh						+
G. olivaceum (Hornemann) Kützing	+			+	+	+
G. parvulum (Kützing) Kützing		+			+	
Gomphonema sp.	+				+	
G. truncatum Ehrenberg				+		
Reimeria sinuata (Gregory) Kocioleck & Stoermer		+			+	
Order: Achnanthales						
Achnanthes minutissima Kützing var. *minutissima*	+	+	+	+	+	+

Table 2. (Continued).

Stations	**1**	**2**	**3**	**4**	**5**	**6**
Cocconeis placentula Ehrenberg var. *euglypta* (Ehrenberg) Grunow	+	+	+	+	+	
C. placentula var. *lineata* (Ehrenberg) Van Heurck						+
Cocconeis sp.		+	+			
Order: Fragilariales						
Ctenophora pulchella (Ralfs ex Kützing) D.M.Williams & Round						+
Diatoma vulgare Bory de Saint-Vincent		+		+	+	+
Fragilaria capucina Desmazieres				+		
F. capucina var. *vaucheriae* (Kützing) Lange-Bertalot				+		
Fragilaria sp.					+	+
Ulnaria acus (Kützing) M.Aboal	+		+	+	+	
U. ulna (Nitzsch) P.Compére	+	+	+	+	+	+
Order: Naviculales						
Craticula cuspidata (Kützing) D.G.Mann	+					
Diploneis pseudovalis Hustedt					+	
Fallacia pygmaea (Kützing) A.J.Stickle & D.G.Mann				+		
Gyrosigma acuminatum (Kützing) Rabenhorst		+	+	+		+
Navicula bacilloides Hustedt		+				
N. clementis Grunow				+		
N. cryptocephala Kützing	+		+	+	+	+
N. festiva Krasske			+		+	+
N. menisculus Schumann var. *menisculus*			+	+		
N. pseudotuscula Hustedt					+	+
N. radiosa Kützing			+	+	+	
N. rostellata Kützing					+	
Sellaphora bacillum (Ehrenberg) D.G.Mann						+
S. pupula (Kützing) Mereschkovsky			+		+	
Order: Thalassiophysales						
Amphora ovalis (Kützing) Kützing	+				+	
A. veneta Kützing					+	
Order: Bacillariales						
Denticula elegans Kützing					+	
Nitzschia acicularis (Kützing) W.Smith	+		+	+	+	+
N. amphibia Grunow var. *amphibian*						+
N. dissipata (Kützing) Grunow var. dissipata			+	+	+	
N. fonticola (Grunow) Grunow	+	+	+	+	+	+
N. hantzschiana Rabenhorst			+	+		
N. incerta (Grunow) M.Peragallo				+		
N. linearis (Agardh) W.Smith var. *linearis*	+	+	+	+	+	+
N. palea (Kützing) W.Smith		+	+	+	+	+
N. sigmoidea (Nitzsch) W.Smith				+	+	+

Table 2. (Continued).

Stations	1	2	3	4	5	6
Nitzschia sp.	+	+	+	+	+	
N. umbonata (Ehrenberg) Lange-Bertalot				+	+	
N. vermicularis (Kützing) Hantzsch in Rabenhorst			+	+		
Tryblionella apiculata Gregory			+			
T. hungarica (Grunow) Frenguelli			+		+	
Order: Rhopalodiales						
Epithemia adnata (Kützing) Brebisson			+		+	
Rhopalodia gibba (Ehrenberg) O.Müller	+					
Order: Surirellales						
Cymatopleura elliptica (Brebisson) W.Smith					+	+
C. solea (Brebisson) W.Smith					+	+
Surirella linearis W.Smith						+
S. ovalis Brebisson				+	+	
Surirella sp.					+	
S. splendida (Ehrenberg) Kützing				+		
Class: COSCINODISCOPHYCEAE						
Order: Melosirales						
Melosira varians Agardh	+	+	+	+	+	+
Order: Aulacoseirales						
Aulacoseira granulata (Ehrenberg) Simonsen		+	+	+	+	+
A. granulata var. *angustissima* (O.F.Müller) Simonsen						+
Aulacoseira sp.	+					
Order: Coscinodiscales						
Actinoptychus pulchellus (Grunow) Wolle var. *pulchellus*						+
Class: MEDIOPHYCEAE						
Order: Thalassiosirales						
Cyclostephanos dubius (Fricke) Round	+	+	+	+	+	+
Cyclotella atomus Hustedt			+			
C. meneghiniana Kützing	+	+	+	+	+	+
C. ocellata Pantocsek	+	+	+	+		
C. radiosa (Grunow in Van Heurck) Lemmermann					+	
Cyclotella sp.	+	+			+	+
Phylum: CHLOROPHYTA						
Class: CHLOROPHYCEAE						
Order: Volvocales						
Chlamydomonas incurva A.A.Pascher	+					+
Pandorina morum (O.F.Müller) Bory	+					
Order: Chlorococcales						
Actinastrum fluviatile (J.L.B.Schröder) B.Fott			+			
A. hantzschii Lagerheim var. *gracile* V.K.Tschernov				+		

Table 2. (Continued).

Stations	**1**	**2**	**3**	**4**	**5**	**6**
Closteriopsis longissima (Lemmermann) Lemmermann	+					
C. acicularis (Chodat) J.H.Belcher et Swale	+		+	+		+
Chlorella vulgaris Beijerinck	+	+			+	+
Coelastrum microporum Nägeli			+			
Golenkiniopsis longispina (Korshikov) Korshikov	+					
G. solitaria (Korshikov) Korshikov			+			+
Pediastrum dublex Meyen var. *cohaerens* (Bohlin) Ergashev						+
Order: Tetrasporales						
Sphaerocystis planctonica (Korshikov) Bourrelly	+					
Stauridium tetras (Ehrenberg) E.Hegewald						+
Order: Sphaeropleales						
Hyaloraphidium contortum Pascher & Korshikov						+
H. moinae Korshikov				+		+
H. rectum Korshikov			+			+
Scenedesmus platydiscus (G.M.Smith) Chodat			+			
S. communis E.H.Hegewald	+					
S. obliguus (Turpin) Kützing f. *alternans* (Reinsch) Compére				+		
S. protuberans F.E.Fritsch & M.F.Rich			+			
Phylum: DINOPHYTA						
Class: DINOPHYCEAE						
Order: Gymnodiniales						
Gymnodinium sp.	+					
Order: Gonyaulacales						
Ceratium hirundinella (O.F.Müller) Dujardin	+	+				
Order: Peridiniales						
Peridinium cinctum (O.F.Müller) Ehrenberg var. *tuberosum* (A.F.Meunier) E.Lindeman	+	+		+		
Peridinium sp.	+	+		+		
Phylum: EUGLENOPHYTA						
Class: EUGLENOPHYCEAE						
Order: Euglenales						
Euglena gracilis G.A.Klebs			+	+	+	+
E. minima France			+			
Euglena. sp.				+		
Lepocinclis fusiformis (H.J.Carter) Lemmermann			+			
Phacus caudatus var. *ovalis* Drezepolski	+					
P. circulatus Pochmann	+		+			
P. elegans Pochmann		+				
Trachelomonas bernardinensis W.Vischer emend. Deflandre				+		
T. hispida (Perty) F.Stein						+
Trachelomonas sp.	+			+		+

Table 2. (Continued).

Stations	1	2	3	4	5	6
Phylum: HETEROKONTOPHYTA						
Class: CHRYSOPHYCEAE						
Order: Chromulinales						
Epipyxis tabellaria (Lemmermann) G.M.Smith		+	+			
Phylum: STREPTOPHYTA						
Class: ZYGNEMATOPHYCEAE						
Order: Zygnematales						
Closterium lunula (O.F.Müller) Nitzsch ex Ralfs			+			
Cosmarium granatum Brebisson in Ralfs var. *granatum*					+	
C. pyramidatum Brebisson in Ralfs				+		
C. subcrenatum Hantzsch in Rabenhorst				+		
Spirogyra circumlineata Transeau				+		
S. gratiana Transeau				+		
S. rhizobrachialis Jao			+			
Staurastrum sebaldi Reinsch var. *ornatum* fo. *elongata* W.Krieger & P.Bourrelly			+			
Phylum: XANTHOPYTA						
Class: XANTHOPHYCEAE						
Order: Mischococcales						
Monallanthus brevicylindrus Pascher	+					

at stations 2, 3, and 4 in the spring and summer months. Bacillariophyta had the highest dominance effect, whereas Chlorophyta and Cyanophyta had the lowest. In early spring and autumn (especially in October and November), Bacillariophyta made a highly significant contribution to heterogeneity. No single species was dominant in this period. In other periods, particularly when precipitation was low, the dominance of a single species was more common.

With a bloom caused by *Peridinium* sp., phytoplankton in the Melen River witnessed both maximum abundance (534.38 ind. 10^5 $L^{-1)}$ and biovolume (7384.8 mm^3 L^{-1}) at station 1 in May, recording its peak in spring (Figures 4 and 5). The lowest organism abundance was recorded as 0.41 ind. 10^5 L^{-1} at station 4 in April. Except for the spring peaks, the highest organism abundance were recorded as *Cyclostephanos dubius* (214.29 ind. 10^5 L^{-1}) at station 1 in June, *Peridinium* sp. (2.87 ind. 10^5 L^{-1}) at station 2 in the same month, *Nitzschia palea* (10.58 ind. 10^5 L^{-1}) at station 3 in July, *N. fonticola* (31.7 ind. 10^5 L^{-1}) at station 4 in July, *Navicula* sp. (5.49 ind. 10^5 L^{-1}) at station 5 in June, and *Chlamydomonas* sp. (18.2 ind. 10^5 L^{-1}) at station 6 in July. Species of *C. dubius*, *Ceratium hirundinella, Phacus caudatus* var. *ovalis* (station 1), *Closterium lunula* (stations 2, 3, and 4), *Euglena gracilis* (stations 3 and 4), and *Melosira varians* (stations 2 and 6) contributed significantly to the biovolume. There was generally an inverse dominance effect in terms of organism number and biovolume. For example, *N. fonticola* accounted for 87% of the total organisms at station 4 in July, while *C. lunula* made up 46% of the biovolume (Table 3).

Phytoplankton assemblage and abundance showed similar fluctuations in the Big Melen River. Maximum densities were observed in May and July. Summer periods with low phytoplankton abundance (compared to spring peaks) have been reported from many river systems (38). This situation was valid only for station 1 in the Melen River. Considering abundance and biomass, high algae development was observed mostly in June and July at the other

Table 3. Percentage of the most abundant species at sampling stations on the Melen River.

	Abundance		Station	Biomass		Station
May 2003	*Peridinium* sp.	(99.7%)	1	*Peridinium* sp.	(99.9%)	1
June	*Cyclostephanos dubius*	(97%)	1	*Peridinium* sp.	(98%)	2
July	*Nitzschia fonticola*	(87%)	4	*Closterium lunula*	(88%)	3
August	*Nitzschia palea*	(20%)	5	*Ceratium hirundinella*	(94%)	1
September	*Monallanthus brevicylindrus*	(29%)	1	*C. hirundinella*	(89%)	1
October	*Melosira varians*	(59%)	6	*C. hirundinella*	(85%)	1
November	*Phacus caudatus* var. *ovalis*	(96%)	1	*P. caudatus* var. *ovalis*	(99.9%)	1
December	*Pseudoanabaena limnetica*	(31%)	4	*C. hirundinella*	(77%)	1
Jan. 2004	*N. palea*	(50%)	5	*Cyclotella ocellata*	(35%)	5
February	*Hyaloraphidium rectum*	(43%)	3	*Diatoma vulgare*	(85%)	2
March	*M. varians*	(70%)	6	*M. varians*	(92%)	1
April	*P. limnetica*	(17%)	6	*Peridinium* sp.	(71%)	2

stations. The estuarine site (station 6), especially, had a greater proportion of diatom biomass compared to the other stations. A reduction in algal biomass occurred in winter and early spring (March and April) throughout the study period.

The abundance of phytoplankton was significant, and was positively correlated with Chl-a and temperature ($r = 0.57$ and $r = 0.78$, respectively $P < 0.01$). The biovolume of Bacillariophyta was positively correlated with species number ($r = 0.77$ $P < 0.01$). The 2 estimates of algal biomass did not show any correlation with nutrients.

Some water quality parameters were found to show a significant relationship with the dominant taxa. For example, DO concentration was correlated with the mean total number of *C. hirundinella* and *M. varians* Agardh ($r = 0.62$ and $r = 0.67$, respectively $P < 0.05$). In addition, an abundance of Cyanophyta and *M. varians* had a significant negative correlation with salinity ($r = -0.694$ and $r = -0.609$, respectively $P < 0.05$).

The highest Chl-a value was measured as 64.2 µg L^{-1} at station 5 in October, and the lowest was 0.86 µg L^{-1} at stations 1 and 2 (Figure 4). In terms of individual number and biovolume, Chlorophyta, Streptophyta, and Cyanophyta, which constituted a small portion, as well as the occasionally dominant Euglenophyta, had more of an influence on Chl-a. For example, though Dinophyta was dominant at station 2 in May, *Spirogyra* sp. showed more significant and effective growth. The region from stations 1 and 2 until Efteni Lake is a small stream. In smaller streams benthic organisms and periphytons act as important sources of potamoplankton (10). This situation could be explained as having been the result of the effect *Spirogyra* sp. on Chl-a. Although Bacillariophyta was more dominant at station 5 in September and October, the development of Chlorophyta, Cyanophyta, and Euglenophyta groups caused the Chl-a value to reach its maximum. Similarly, Reynolds (39) reported that green algae and cryptophytes contain proportionally more chlorophyll than diatoms.

Differences in the biovolumes of Dinophyta and Cyanophyta were significant (KW). There were highly significant differences between stations 1 and 5 as well as stations 1 and 6 considering the biovolume of Dinophyta at station 1 (M-W U test = 27.5 $P < 0.01$ for both of them). There was a significant difference between stations 3 and 5 considering the biovolume of Cyanophyta at station 3 (M-W U test = 29 $P < 0.05$).

The maximum Shannon diversity index (H') value was recorded as 2.9 bits ind.$^{-1}$ at station 5 in October 2003 and the lowest as 0.02 bits ind.$^{-1}$ at station 1 in May 2003 (Figure 4). The lowest diversity index values were recorded in the spring and summer months for all stations, while the maximum values were in the autumn months. A similar situation was observed at the Miyatoko Mire Pools (40). As in this study, the

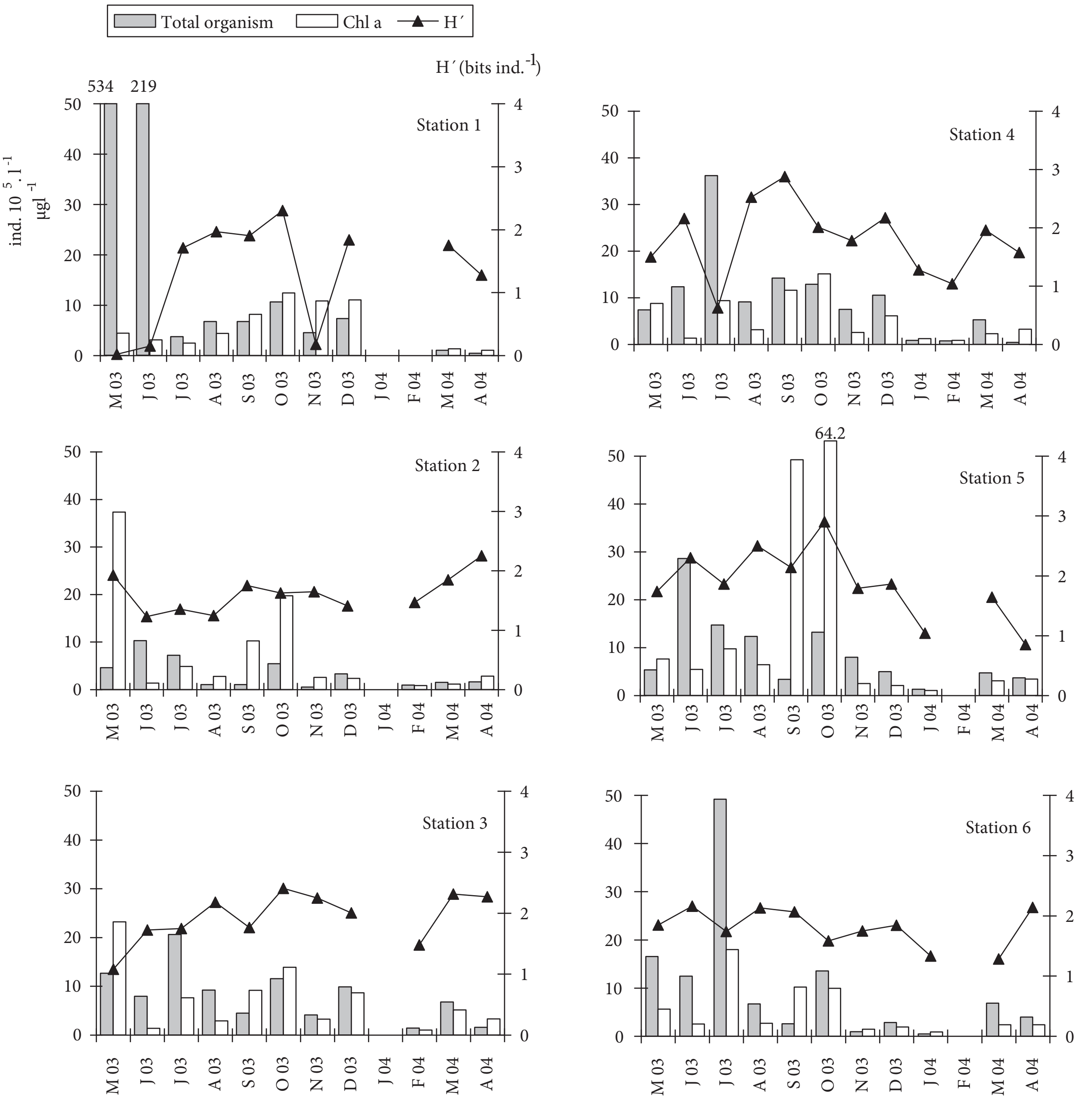

Figure 4. Monthly variations in phytoplanktonic abundance, Chl-a and Shannon diversity for the Melen River.

bloom patterns of a few species such as *Peridinium* sp., *C. hirundinella*, and *P. caudatus* var. *ovalis* have been frequently mentioned in the literature to be a consequence of a decrease in H´ (41).

Species richness increased in the early autumn months, while it fell over the winter months, caused by the decreasing water temperature. During the study, the Melen River generally showed low species richness and limited variation (Figure 6). One of the lowest levels of richness was recorded during the bloom of *Peridinium* sp. in May at station 1. The values estimated for species richness and diversity indices increased gradually from station 1 to 6 in all seasons.

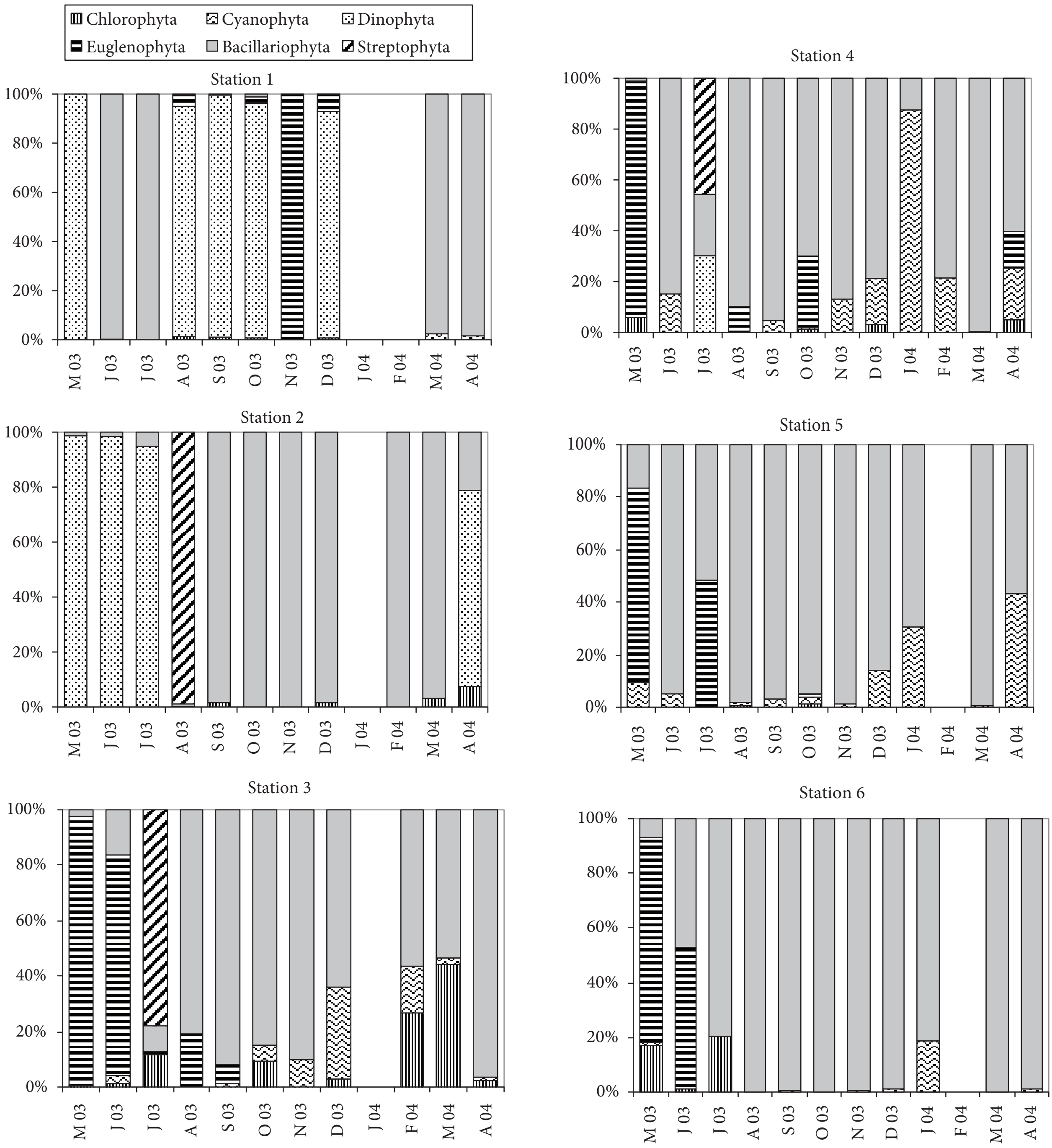

Figure 5. The percentages of phytoplankton composition for the Melen River.

When algal structure and development were compared, a higher level of variability was determined between stations 1 and 2 than the other stations. While these stations were only characterised by the predominance of dinoflagellates and diatoms, others were dominated by diatoms (Figure 5). *C. hirundinella* are known to be abundant and widespread in reservoir systems (42). After Efteni Lake, with its convergence with the other streams, the river hydrology and phytoplankton community appear to change significantly. In the Melen River, pinnate diatom species were also a heterogeneous

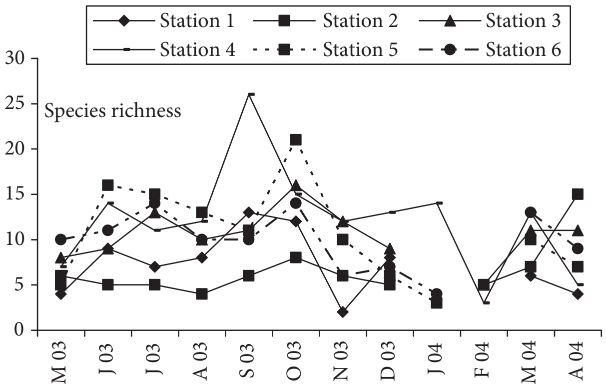

Figure 6. Species richness of phytoplankton in the Melen River at each station.

group of species, but these showed a steady prolonged decline as discharge volumes increased. A complete unimodal response to discharge is predicted for the centric diatom *Melosira varians* over a range of discharge values. At discharges of up to 72 $m^3 s^{-1}$, increasing numbers of frustules will break free and enter the phytoplankton, but at higher discharge levels there is expected to be a net decline of planktonic *M. varians* owing to wash-out (43). At stations 5 and 6, when water discharge was still low, *M. varians* constituted 40% and 60% respectively and disappeared in the following months. It was recorded in high quantities when water discharge was high again (50% and 70% respectively).

Discharge and sediment supply are the main important variables in the Melen River. Discharge increases along a stream and appears to be more stable in the lower reaches (44). The values for water discharge at station 2 are higher than those for station 1 as a result of the waterflow from Hasanlar Dam (17). The lowest plankton biomass was observed at station 2 with its sandy/pebble bank sediment. In this sense, the stability of water discharge towards the mouth of the river after Efteni Lake may lead to an increase in sediment. As the surrounding land dries up in spring, discharge declines and the amount of suspended detritus in the river diminishes, enabling large phytoplankton populations to develop (45). Especially after the spring peaks, summer conditions (e.g. low discharge, abundant nutrients and high temperature) contributed to increased phytoplankton abundance, and biomass and species richness in the Melen River. Sedimentation may well be higher in mid-summer as discharge drops, and may be an important factor (46). Due to floods in the rainy seasons, alluvium that was carried downstream increased the suspended sediment loads such as silt, mud and pebbles. Also, the presence of exposed tree roots, clumps of grass, and collapsed river banks and the brown colour of the river water showed the effect of erosion as an important external force on phytoplankton development. Since all the river sites showed similar patterns of turbidity during autumn and winter, it is reasonable to assume that they had similar underwater light conditions. In this case, the decrease in light permeability and sediment mixture in plankton are inevitable. *Euglena*, many Bacillariophyta and Cyanophyta species were abundant at the stations along the Big Melen, which supports this view. Light limitation derived from higher water turbidity may limit photosynthesis and prevent phytoplankton development (47). Algal abundance and biomass were very low at all stations in these seasons (Figure 4). Also, periods of high discharge can result in reduced chlorophyll concentration, but are often accompanied by very turbid conditions and restricted light penetration. High chlorophyll values occurred during October originating from 1975 when discharge was exceptionally low in the River Nene (48). For the Melen River, high levels of Chl-a concentration were measured at station 5 in October and November, when the discharge was lower. In the Big Melen River, Chl-a concentration was significantly negatively correlated with total dissolved solids, suspended solids and water discharge ($r = -0.87$, $r = -0.90$ and $r = -0.78$, respectively $P < 0.01$). Also, water discharge was negatively correlated with species richness ($r = -0.65$, $P < 0.05$).

Bacillariophyta showed significant growth only in early summer phytoplankton at station 1. Typically, the diatom community remains the dominant group most of the time in large lowland river systems around the world, except in hot summers (49). The phytoplankton taxa observed in this study were dominated by the species *C. dubius*, *C. ocellata*, and *M. varians*. While *C. ocellata* and *M. varians* recorded maximum abundance in winter at stations 5 and 6, *C. dubius* showed maximum abundance in June at station 1 on the river (Table 3).

Contrary to large lowland rivers, the Melen River has a shallow river-reservoir-type system. *Stephanodiscus* bloom has been increasingly observed in eutrophic and shallow river-reservoir systems (50). The presence of *Cyclostephanos* growth could probably be attributed to an excessive concentration of nutrients (NO_3-N: 0.71 mg L^{-1} and PO_4: 0.55 mg L^{-1}) and decreased water discharge in this month. However, lowland rivers are often rich in nitrogen and phosphorous compounds, but these nutrients seldom limit phytoplankton productivity (2). In addition, centric diatoms are one of the best adapted algal groups to turbulent and turbid systems with high nutrient concentrations (51). According to Turkish Water Quality Control Regulations (52), the Melen River is of first-degree quality in terms of pH, DO and nitrogen (ammonia and nitrate) values, but of third-degree quality from a nitrite point of view. The high concentration of nitrite in the Big Melen, caused by sewage discharge from settlements, agricultural activities and proximity to animal farms, is an indication of the serious pollution threat the river faces. Urban, industrial, and agricultural pollution reduce water quality, and the river-channel ecosystem is altered in so many ways that it may be difficult to link cause and effect (50). COD, TDS, PO_4, and inorganic N values at stations 5 and 6 were substantially different from others except for BOD_5. In terms of eutrophication, Chl-a, inorganic nitrogen, and phosphate values were so conspicuous that there were similarities in pollution properties at all stations, while they increased towards stations 5 and 6.

Throughout the river mouth, the planktonic algae ratio within the biomass was between 0.69% and 0.78%, which was mainly contributed by organisms such as *Navicula cryptocephala*, *Nitzschia palea, N. acicularis N. fonticola*, and *N. amphibia*. As in the Ebro and San Joaquin rivers, it was observed that tychoplanktonic species did not contribute much to the biomass and diversity of the plankton (54). Garnier et al. (55) emphasised that tychoplanktonic diatoms are more abundant in the phytoplankton of shallow lowland rivers than in deep rivers.

When algal developments at all the stations were examined, it was occasionally observed that, except for Dinophyta, Bacillariophyta was dominant. This was greatly affected by the mixture of sediment with plankton. Moreover, sudden changes in physical and chemical limits may play more important roles in the dominance of diatoms in small lowland rivers compared to large lowland river systems. However, a major portion of the Melen River is an alluvial valley. The Big Melen consists of the combination of materials from different origins (the presence of a reservoir system, a lake, other joint streams, and brackish water). Therefore, the phytoplankton of a river may also indicate different responses to different hydrological properties in these habitats. Water depth, velocity and discharge are fundamental hydrological properties contributing to spatial variation in the structure of planktonic algal assemblages in rivers (54). Hydrological fluctuation also affects solid and organic matter concentrations (56).

This condition was more obvious in the Big Melen. Though the flow rate is clearly an important factor for rivers, the effect of increasing flow rate is often seen only as a decrease in the population density (57). In the present study, phytoplankton abundance and biomass were rather low at stations 1 and 5 during periods of high discharge. In addition, since the river bottom structure is composed of sand, silt and mud, the river environment is very sensitive to erosion and sediment transportation. Since İstanbul's water needs are starting to be met from the Melen River, this will eventually cause rapid changes in the physico-chemical and biological properties of the river, thereby requiring detailed monitoring.

Acknowledgements

We would like to thank Gazi University, Scientific Projects Research Management for financing this research and also the General Directorate of State Hydraulic Works (DSI) for analysing the physical and chemical parameters of the Melen River.

Corresponding author:

Tülay BAYKAL

Department of Biology,

Faculty of Arts and Science,

Ahi Evran University,

40100 Kırşehir - TURKEY

E-mail: tubaykal@gazi.edu.tr

References

1. Reynolds CS, Descry JP. The production, biomass and structure of phytoplankton in large rivers. Archiv für Hydrobiologie Supplementband. Large rivers 10 1-4: 161-187, 1996.
2. Piirsoo K, Pall P, Tuvikene A et al. Temporal and spatial patterns of phytoplankton in a temperate lowland river (Emajõgi, Estonia). Journal of Plankton Research 30: 1285-1295, 2008.
3. Aktan Y, Gürevin C, Dorak Z. The effect of environmental factors on the growth and size structure of two dominant phytoplankton species in the Büyükçekmece Reservoir (İstanbul, Turkey). Turk J Biol 33: 335-340, 2009.
4. Türkoğlu M. Temporal variations of surface phytoplankton, nutrients and chlorophyll a in the Dardanelles (Turkish Straits System): a coastal station sample in weekly time intervals. Turk J Biol 34: 319-333, 2010.
5. Zaim E. Planktonic Diatom (Bacillariophyta) Composition of Lake Kaz (Pazar, Tokat). Turk J Biol 31: 203-224, 2007.
6. Descy JP. Ecology of the phytoplankton of the River Moselle: effects of disturbances on community structure and diversity. Hydrobiologia 249: 111-116, 1993.
7. Chan TU, Hamilton DP, Robson BJ et al. Impacts of hydrological changes on phytoplankton succession in the Swan River, Western Australia. Estuaries 25: 1406-1415, 2002.
8. Barinova S, Tavassi M, Glassman H. Diversity and ecology of algae from the Lower Jordan River, Israel. Plant Biosystems 143: 340-360, 2009.
9. Leland HV. The influence of water depth and flow regime on phytoplankton biomass and community structure in a shallow, lowland river. Hydrobiologia 506-509: 247-255, 2003.
10. Salmaso N, Braioni MG. Factors controlling the seasonal development and distribution of the phytoplankton community in the lowland course of a large river in Northern Italy (River Adige). Aquatic Ecology 42: 533-545, 2008.
11. Kyong H, Hyun-Woo K, Gea-Jae J. The phytoplankton succession in the lower part of hypertrophic Nakdong River (Mulgum), South Korea. Hydrobiologia 369/370: 217-227, 1998.
12. Soylu EN, Gönülol A. Phytoplankton and seasonal variations of the River Yeşilırmak, Amasya, Turkey. Turkish Journal of Fisheries and Aquatic Sciences 3: 17-24, 2003.
13. Yıldız K, Şen B, Baykal T. Abundant and wide-spread diatoms found in some waters of the Central Anatolian region. Firat University Journal of Science and Engineering 12: 37-49, 2000.
14. Baykal T, Udoh UA, Yıldız K. The algal flora and seasonal variations of species abundance in Kilicözü Stream (Kirşehir) TURKEY. Journal of Phytological Research 14: 43-54, 2001.
15. Atıcı T, Obalı O. Çoruh River's (Bayburt-Turkey) Algae (Excluding Bacillariophyta). The Herb Journal of Systematic Botany 7: 231-247, 2000.
16. Ertan OÖ, Morkoyunlu A. The algae flora of Aksu Stream (Isparta-Turkey). Tr. J. of Botany 22: 239-255, 1998.
17. Ertürk A, Gürel M, Şeker DZ et al. Design of decision support system tools for integrated protection and water quality management in Melen watershed. International Congress on River Basin Management, Antalya 2007.
18. Mantaş EP, Aydın E, İnsel G. Conceptual approach for the determination of point sources in Melen watershed. International Congress on River Basin Management, Antalya 2007.
19. Düzce Valiliği İl Çevre Ve Orman Müdürlüğü. Düzce İl Çevre Durum Raporu. Düzce; 2004.
20. Sümer B, İleri R, Şamandar A et al. Water quality in the River Büyük Melen and its branches. Çevre Koruma 10 (39): 13-18, 2001.
21. Karakaya N, Gönenç İE. A decision support system proposal for interbasin water transfer in Turkey. İTÜ dergisi 16(1-3): 79-90, 2006.
22. Utermohl H. Zur vervollkommung der quantitativen phytoplankton methodik. Mitteilung Internationale Vereinigung, Limnoogie 9: 1-38, 1958.
23. GLNPO's WQS. LG 401 Standard Operating for Phytoplankton Analysis. Revisions 04, 8-42, 2007.
24. Huber-Pestalozzi G. Das Phytoplankton Des Süβwassers 8. Teil Conjugatophyceae, Zygnematales and Desmidiales. E. Schweizerbart'sche Verlagsbuchhandlung. Germany; 1982.
25. Korshikov OA. The fresh water algae of the Ukrainian SSR. Bishen Singh Mahendra al Singh and Koletz. India; 1987.
26. Krammer K, Lange-Bertalot, H. Süβwasserflora von Mitteleuropa, Bacillariophyceae Band 2/1, 1. Teil: Naviculaceae. Gustav Fischer Verlag. Stuttgart; 1986.
27. Krammer K, Lange-Bertalot H. Süβwasserflora von Mitteleuropa, Bacillariophyceae Band 2/2, 2. Teil: Bacillariaceae, Epithemiaceae, Surirellaceae. Gustav Fischer Verlag. Stuttgart; 1988.
28. Krammer K, Lange-Bertalot H. Süβwassers von Mitteleuropa, Bacillariophyceae Band 2/4, 4. Teil: Achnanthaceae, Kritische Ergönzungen zu Navicula (Lineolatatae) ubnd Gomphonema Gesamtliteraturverzeichnis. Gustav Fischer Verlag. Stuttgart; 1991.
29. Krammer K, Lange–Bertalot H. Süβwasserflora von Mitteleuropa, Bacillariophyceae Band 2/3,3.Teil: Centrales, Fragilariaceae. Gustav Fischer Verlag. Stuttgart; 1991.
30. John DM, Whitton BA, Brook. AJ. The Freshwater Algal Flora of the British Isles. Cambridge University Press. Cambridge; 2002.
31. Round FE, Crawford RM, Mann DG. The Diatoms. Biology, Morphology of the genera. Cambridge University Press. Cambridge; 1990.
32. Sims PA. Atlas of British Diatoms. Biopress Ltd. Dorchester, UK; 1996.

33. Guiry MD, Guiry M. AlgaeBase. World-wide electronic publication. National University of Ireland, Galway. - http://www.algaebase.org; searched on 28 May, 1996-2010.

34. Hipkins MF, Baker NR. Spectroscopy. In photosynthesis energy transduction. A practical approach. MF Hipkins and NR Baker eds Oxford: IRL Press; 51-101, 1986.

35. APHA, AWWA, WPCF. Standard methods for the examination of water and waste water. 18th ed., Washington D.C.; 1992.

36. Albayrak AS, Eroğlu A, Kalaycı Ş et al. SPSS uygulamalı çok değişkenli istatistik teknikleri. Asil Yayın. Ankara; 2008.

37. Shannon CE, Weaver W. The mathematical theory of communication. Illinois University Press. Urbana; 1963.

38. Köhler J. Production and losses of phytoplankton in lowland River Spree. I. Pollution dynamics. J. Plankton Res 15: 335-349, 1993.

39. Reynolds CS. The ecology of freshwater phytoplankton. Cambridge University Press, Cambridge; 1993.

40. Watanable MM, Mayama S, Hiroki M et al. Biomass, species composition and diversity of epipelic algae in mire pools. Hydrobiologia 421: 91-102, 2000.

41. Figueredo CC, Giani A. Seasonal variation in the diversity and species richness of phytoplankton in a tropical reservoir. Hydrobiologia 445: 165-174, 2001.

42. Naselli-Flores, L. Barone R. Phytoplankton dynamics and structure; a comperative analysis in natural and man-made water bodies of different trophic state. Hydrobiologia 438: 65-74, 2000.

43. Ruse L, Love A. Predicting phytoplankton composition in the river Thames, England. Regulated rivers: Research & Management 13: 171-183, 1997.

44. Vilbaste S, Truu J. Distribution of benthic distoms in relation to environmental variables in lowland streams. Hydrobiologyia 493: 81-93, 2003.

45. Marker AFH, Collett GD. Spatial and temporal characteristics of algae in the river Great Ouse. 1. Phytoplankton. Regulated rivers: Research & Management 13: 219-233, 1997.

46. Reynolds CS, White ML, Clarke RT, Marker AFH. Suspension and settlement of particles in flowing water: comparison of the effects of varying water depth and velocity in circulating channels. Freshwater Biol 24: 23-34, 1990.

47. Reynolds CS. Ecology of phytoplankton. Cambridge Univ. Press; Cambridge 2006.

48. Balbi DM. Suspended chlorophyll in the River Nene, a small nutrient-rich river in eastern England: long-term and spatial trends. The Science of the Total Environment 251: 401-421, 2000.

49. Ha K, Jang MH, Joo GJ. Winter *Stephanodiscus* bloom development in the Nakdong River regulated by estuary dam and tributaries. Hydrobiologia 506- 509: 221- 227, 2003.

50. Wehr JD, Descy JP. Use of phytoplankton in large river management. Journal of Phycologia 34: 741-749, 1998.

51. Reynolds CS. The long, the short and the stalled: on the attributes of phytoplankton selected by physical mixing in lakes and river. Hydrobiologia 289: 9-21, 1994.

52. Anonymous. Kıta içi Su Kaynaklarının Sınıflarına Göre Kalite Kriterleri. Çevre ve Orman Bakanlığı Su Kirliliği Kontrol Yönetmeliği. Resmi Gazete 31 Aralık 2004 Sayı: 25687, 2004.

53. Moss B. Ecology of Freshwaters. Blackwell Science, USA; 170-171, 2001.

54. Leland HV, Brown LR, Mueller DK. Distribution of algae in the San Joaquin River, California, in relation to nutrient supply, salinity and other environmental factors. Freshwater Biology 46: 1139-1167, 2001.

55. Garnier J, Bilen G, Coste M. Seasonal succession of diatoms and Chlorophyceae in the drainage network of the Seine River; Observations and modeling. Limnology and Oceanography 40: 750-765, 1995.

56. Neiff JJ. Large rivers of South America; toward the new approach. Verhandlungen Internationale Vereinigung Limnologie 26: 167-180, 1996.

57. Round FE. The ecology of algae. Cambridge University Press. Cambridge; 1981.