



Diversity and Ecology of Algae from Melen River (Western Black Sea River Catchment) in Turkey

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Received 27 January 2017
Accepted 18 December 2017

Abstract

Algae are among the key organisms of aquatic ecosystems. While there have been a large number of important ecological studies on different river basins in Turkey, the use of algae in biomonitoring is a new approach. Epiphytic and epilithic algae in the Melen River were studied between May 2003 and April 2004. A total of 148 taxa, with 101 belonging to Bacillariophyta, 18 to Chlorophyta, 9 to Charophyta, 13 to Cyanobacteria, 5 to Euglenophyta, and 2 to Miozoa, were identified in this study. Members of Bacillariophyta were the dominant taxa at all sites, with oligohalobious-indifferents and alkaliphiles being the most common. Among the non-diatom taxa, there were more species with oligohalobious-indifferent and indifferent properties. The river water was alkaline and temperate, with low salinity characters. Bio-indications (autecology) of the river were studied. From the results, organic pollution indicators of Watanabe's classification (46 species, 31.1%) constituted three groups (saproxen, eurysaprobe and saprophile). Based on the classification (according to Watanabe's system) and RPI (River Polluted Index), the ecological conditions of Melen River were assessed as low, with a moderate level of organic pollution, and lightly to moderately polluted, respectively.

Keywords: Biomonitoring, diatom, ecological indices, Melen River.

Introduction

Bio-monitoring assessment relies on the variations seen in indicator species and aquatic communities in response to environmental changes, particularly those caused by the polluting agents to which they are exposed. Species that have predictable responses to changes in a selected variable can serve as bio-indicators, reflecting the reactions of aquatic ecosystems to eutrophication, pH levels (acidification), salinity, and organic pollution (Barinova & Krassilov, 2012). Many algal species are indicative of environmental conditions that reflect the effect of hydrochemical variables on aquatic populations.

Diatom and non-diatom communities in similar climatic conditions were studied according to the seasonal influences of environmental factors governing the riverine systems in Greece (Ziller & Montesanto, 2004), Lebanon (Squires & Saoud, 1986), Iran (Atazadeh, Sharifi & Kelly, 2007), Israel (Barinova, Medvedeva & Anissimova, 2006; Barinova, Tavassi & Nevo, 2010a), Georgia (Barinova, Kukhaleishvili, Nevo & Janelidze, 2011a), Italy (Dell'Uomo & Torrisi, 2009), Portugal

(Resende, Resende, Pardal, Almeida & Azeiteiro, 2009), and Spain (Blanco, Becares, Cauchie, Hoffmann, & Ector, 2007; Urrea & Sabater, 2009). Bio-indication approaches for river monitoring using algal communities were developed in Israel during the last decade (Barinova, Tavassi & Nevo, 2006a; Barinova, Tavassi, Glassman & Nevo, 2010b; Barinova & Krassilov, 2012; Barinova *et al.* 2016). In bio-monitoring assessments conducted on river ecosystems, the use of algal bio-indicators is becoming more widespread due to changing environmental conditions. Though numerous phycological investigations have been performed in different Turkish river basins, the use of diatoms in biomonitoring (according to diatom indices by OMNIDIA and autecological indices, such as Watanabe's or Van Dam's systems) is relatively new in Turkey (Solak, Ector, Wojtal, Acs & Morales, 2012). We believe that the correct use of bio-indication approaches will contribute significantly to bio-monitoring trials that are still inadequate in the Turkish river systems. The aim of the present study was to establish the diversity of algae in the Melen River by examining the compositions of epilithic and epiphytic algae, their number of species and major

environmental variables, and revealing autecological status of the river.

Materials and Methods

Melen River runs within Düzce Province, with 80% of its basin of 2317 km² confined within the Province (Figure 1). The river rises within Yigilca district boundaries and is fed by Efteni Lake, which has Ugur, Sigirlik, Samandere and Torkul as tributaries from the South and the Asar stream from the east. Melen River takes water from the Aksu Stream and flows through Adapazari Akyazi. It empties into the sea at Akcakoca village, where the mouth of the river is located. Between Düzce and Yigilca lies Hasanlar Dam, initially constructed for irrigation purposes but later converted for hydroelectricity generation. The river has got a complex river system that supports a variety of uses, including irrigation systems in agricultural lands.

drinking water and several different industries' wastewater. The return flow from all these users is directly discharged into the river (Doğan, Sengörür & Koklu, 2009). Melen River is named the Small Melen until Lake Efteni, and the Big Melen after Lake Efteni. Descriptions of the Melen River stations are given in Table 1.

Seventy-two samples were collected monthly from 6 stations along the Melen River between May 2003 and April 2004. In parallel with the sampling for epilithic and epiphytic algae, we also collected water samples for the assessment of hydrochemical analysis with phytoplanktonic algae in Melen River as published (Baykal, Açıkgoz, Udoh & Yıldız, 2011). Epiphytic and epilithic samples were collected by scraping the submerged aquatic plants and stones. All samples were fixed by 4% formalin. For the identification of diatoms, frustules were cleaned of subjected to the organic matter with hot concentrated HCl and KMnO₄ method described by Taylor, de la

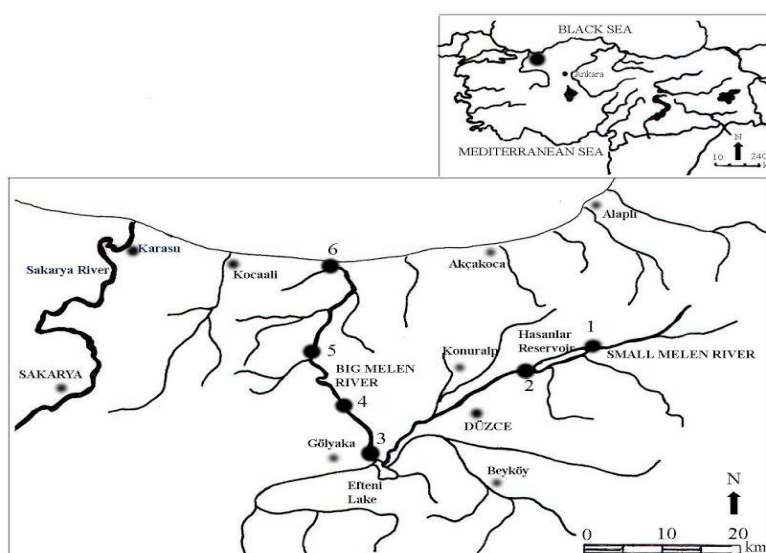


Figure 1. Melen River and sampling stations.

Table 1. Descriptions of Melen River sampling stations

Stations	Descriptions	Coordinate
1	At Aydın village (Düzce-Yığılca), entrance into the dam, with slow water flow.	40°56'24.3"N 31°20'26.2"E
2	Hasanlar dam regulator exit. Region rich in vegetation along the river.	40°54'53.6"N 31°16'41.9"E
3	Exit in Efteni Lake near Gölyaka (Düzce). qualitatively, the river water here was more turbid than the other stations, probably as a result of the intensive farming and live stock activities in the area.	40°46'25.6"N 31°02'12.7"E
4	Region nearest the settlement area.	40°49'38.6"N 31°01'18.1"E
5	Named Big Melen after exit from Efteni Lake.	40°54'34.2"N 30°56'54.0"E
6*	100 m of Big Melen, where it empties into the Black Sea at Adapazari (Melen mouth) as the last station.	41°04'19.4"N 30°57'58.6"E

*This station possesses special characteristics due to its brackish nature. Throughout the studies, the highest level of salinity was recorded at this station.

Rey & Van Rensburg (2005) before being mounted in Canada balsam for microscopic observation. Temporary slides for non-diatom taxa and permanent slides for diatoms were examined under microscope (Nikon brand) at a magnification of 400-1000. Different studies from the relevant literature were consulted for species identification (Huber-Pestalozzi, 1982; John, Whitton & Brook, 2002; John & Sheat 2003; Korshikov, 1987; Krammer & Lange-Bertalot, 1991a,b; Krammer & Lange-Bertalot, 1999a,b). There is no specific method for the taxonomical process. After identification, current nomenclature of species was checked on relevant websites like AlgaeBase (Guiry & Guiry, 2017). The ecological data analysis performed for algal species diversity revealed the grouping of freshwater algae in respect to variables that were taken from the database compiled for freshwater algae (Barinova et al., 2006). Each group was separately assessed according to its bio-indication significance. Saprobity was investigated according to Watanabe's system, which describes 3 indicator groups: "saproxenes (unpolluted water)", "eurysaprobies (moderately polluted water)", and "polysaprobies (polluted water)" (Watanabe, Asai & Houki, 1986). Pollution index (RPI), (Sumita, 1986) which is currently used by the EPA to conduct river quality assessments (<http://wq.epa.gov.tw>), was calculated based on dissolved oxygen (DO), biological oxygen demand (BOD), suspended solid (SS) and ammonia-nitrogen. The values of DO, BOD, SS and ammonia-nitrogen were taken from previous publications (Baykal et al., 2011).

Results and Discussion

A total of 148 taxa were identified in the Melen River, with *Nitzschia* (16) constituting the highest number in the community, followed by the *Navicula* (13) and *Gomphonema* genus (10) (Table 2).

There were 69 (46.6%) indicator species for streaming and oxygenation, as shown in the diagram, where the species are arranged along the gradient of water flow. Most of the species preferred moderate rates of low water flow (44) as opposed to standing water (13). A majority of the diatom varieties in the Melen River were species typically found in low water flow. A total of six groups of acidophilic indicators constituted 74 (50%) of the species (Figure 2e). In the diagram, these groups are arranged along the pH gradient. The ratio of the groups reflected the influence of carbonate substrates (Barinova et al., 2006c; Sládeček, 1986). Alkaliphiles predominated, with 48 species (32.4%). *Achnanthisidium minutissimum*, *Cocconeis pediculus*, *Cymbella affinis*, *Diatoma vulgare*, *Nitzschia palea* and *Ulnaria ulna* were the most prominent among the other species. *C. pediculus*, the most abundant species in the river, was extensively present in the summer months of 2003 at the 2nd and 3rd sites, constituting more than 50% of the species. This species is an epiphytic and cosmopolitan

diatom that is found in inland waters with a medium-to-high content of electrolytes and in coastal salt waters (Cox, 1996; Noga et al., 2016). Another alkaliphile dominant species, *U. ulna*, is tolerant to water pollution, and its presence in Melen River (>30% of the number at site 1 in July 2004) showed a eutrophic character. It can be found in oligo- to polytrophic and oligo-saprobic to α -mesosaprobic waters (Hofmann, Werum & Lange-Bertalot, 2011). The "indifferents", which usually exist over silicate substrates, were subordinate here, with 19 species. From these species, only *D. vulgare* was recorded, with 25% relative abundance in epiphyton at site 6 in July 2004. *D. vulgare* is common in slow-flowing rivers and can often be found in moderately nutrient-rich water conditions (Cox, 1996). Alkalibiontes, which are tolerant to excessive alkalinity, were represented by 2 species (Figure 2a-f). Most of the rivers and streams in Turkey, Europe and nearby phytogeographic realms have an alkaline character (Barinova et al., 2006a; Barinova, et al., 2010b; Noga et al., 2016; Sládeček, 1986). Indicators of salinity (79 species, 53.4%) were assigned to 4 ecological groups and arranged along the gradient of salinity. Mesohalobe and halophilous species (15 species) were recorded at low relative density, while only *Rhoicosphenia abbreviata* was recorded at station 6 (brackish water) at 15% in May 2003. Remarkably, the algal communities of Melen River also contain oligohalobious-indifferents, which prefer temperate, low alkaline, moderately oxygenated freshwater with low-to-middle organic pollution. *Oscillatoria tenuis* and *Oscillatoria limosa* tended to be found more frequently at the lower section with brackish or slightly saline character, and these species have been reported a wide range of salinity (Barinova et al., 2016). Furthermore, *R. abbreviata* and *O. limosa* are recognized as being pollution-tolerant species of algae such as *U. ulna* (Das & Chakrabarty, 2007). Among the non-diatom taxa serving as indicators of streaming and oxygenation, species preferring slightly turbulent waters and moderate oxygenation were more prevalent during the sample period. These species included *Cladophora fracta*, *Oedogonium* sp., *Scenedesmus arcuatus* (Chlorophyta), *Cosmarium crenatum*, *Closterium lunula*, *C. moniliferum*, *Spirogyra subsalsa* (Charophyta), *O. tenuis* (Cyanobacteria), *Euglena* sp. and *Phacus cudatus* (Euglenophyta). Many species of the mentioned genus have standing-stream characteristics and wide saprobic tolerance, from oligo-saprobic to meso-saprobic (Barinova et al., 2010a; 2010b; 2011a; Barinova, Nevo & Bragina, 2011b). In fact, most of the species in Table 2 are oligohalobious-indifferent and serve as the indicator species of these ecological conditions.

On the basis of four parameters (DO, BOD, SS and ammonia-nitrogen), the river pollution index (RPI) was calculated according to the data published on the Melen River (Baykal et al. 2011). The RPI

Table 2. Ecological classification of studied species

Divizyo: BACILLARIOPHYTA	Hab	T	Reo	D	Hal	pH	Geo
<i>Achnanthydium minutissima</i> var. <i>gracillima</i> (Meister) Lange-Bertalot							
<i>Achnanthydium minutissimum</i> (Kützing) Czamecki	B	eterm	st-str	es	i	alf	k
<i>Amphora ovalis</i> (Kützing) Kützing	P-B	warm	st-str	--	hl	alb	k
<i>Amphora pediculus</i> (Kützing) Grunow ex A.Schmidt	P	--	--	sx	i	alf	k
<i>Asterionella formosa</i> Hassall							
<i>Aulacoseira granulata</i> (Ehrenberg) Simonsen							
<i>Caloneis amphisbaena</i> (Bory) Cleve	B	--	st	sp	i	alf	k
<i>Caloneis ventricosa</i> (Ehrenberg) Meister							
<i>Cocconeis pediculus</i> Ehrenberg	B	--	st-str	sx	i	alf	--
<i>Cocconeis placentula</i> var. <i>euglypta</i> (Ehrenberg) Grunow	P-B	temp	st-str	sx	i	alf	--
<i>Cocconeis placentula</i> var. <i>lineata</i> (Ehrenberg) Van Heurck	--	--	--	--	hl	alf	k
<i>Craticula cuspidata</i> (Kützing) D.G.Mann	B	temp	st	es	i	alf	--
<i>Craticula halophila</i> (Grunow) D.G.Mann	B	--	st-str	es	mh	alf	--
<i>Cyclostephanos dubius</i> (Fricke in A. Schmidt) Round	P-B	--	st-str	--	i	alf	k
<i>Cyclotella meneghiniana</i> Kützing	B	--	--	--	--	--	k
<i>Cymatopleura elliptica</i> (Brébisson) W.Smith	P-B	--	st-str	--	i	alf	--
<i>Cymatopleura solea</i> (Brébisson) W.Smith	P-B	--	st-str	--	i	alf	--
<i>Cymbella affinis</i> Kützing	B	temp	st-str	sx	i	alf	--
<i>Cymbella cistula</i> (Ehrenberg) Kirchner							
<i>Cymbella helvetica</i> Kützing	B	--	str	sx	i	ind	B
<i>Cymbella lanceolata</i> (Ehrenberg) Kirchner							
<i>Cymbella tumida</i> (Brébisson) V.Heurck							
<i>Cymbopyleura amphicephala</i> Nägeli in Kützing	B	--	str	sx	i	ind	--
<i>Denticula elegans</i> Kützing	B	--	--	--	i	alf	--
<i>Diatoma moniliformis</i> (Kützing) D.M.Williams							
<i>Diatoma vulgaris</i> Bory de Saint-Vincent	P-B	--	st-str	sx	i	ind	--
<i>Didymosphenia geminata</i> (Lyngbye) M. Schmidt							
<i>Encyonema caespitosum</i> Kützing							
<i>Encyonema prostratum</i> (Berkeley) Kützing	B	--	st	sx	i	alf	k
<i>Encyonema silesiacum</i> (Bleisch. in Rabenh.) D. G. Mann in Round et al.	B	--	st	sx	i	alf	k
<i>Encyonopsis microcephala</i> (Grunow) Krammer	B	--	--	es	--	alf	k
<i>Encyonopsis minuta</i> Krammer & Reichardt	B	--	--	--	i	ind	--
<i>Epithemia adnata</i> (Kützing) Brébisson	Ep	--	--	--	hl	acf	k
<i>Epithemia sorex</i> Kützing							
<i>Fallacia pygmaea</i> (Kütz.) Stikle et Mann							
<i>Fragilaria capucina</i> var. <i>vaucheria</i> (Kützing) Lange-Bertalot							
<i>Fragilaria pulchella</i> (Ralfs ex Kützing) Lange-Bertalot	B	--	str	es	i	alf	b
<i>Frustulia vulgaris</i> (Thwaites) De Toni	P-B	--	st	es	i	alf	--
<i>Gomphonema angustatum</i> (Kützing) Rabenhorst							
<i>Gomphonema acuminatum</i> Ehrenberg							
<i>Gomphonema affine</i> Kützing	P-B	--	st	es	--	--	--
<i>Gomphonema angustum</i> Agardh							
<i>Gomphonema augur</i> Ehrenberg	B	--	aer	--	i	alf	k
<i>Gomphonema clavatum</i> Ehrenberg							
<i>Gomphonema minutum</i> (C.Agardh) C.Agardh	B	--	str	es	i	alf	a-a
<i>Gomphonema olivaceum</i> (Hornemann) Brébisson	B	temp	st-str	es	i	neu	k
<i>Gomphonema parvulum</i> (Kützing) Kützing	B	temp	str	es	i	ind	--
<i>Gomphonema truncatum</i> Ehrenberg	P-B	--	st-str	es	i	alf	--
<i>Gyrosigma acuminatum</i> (Kützing) Rabenhorst	B	cool	st-str	--	i	alf	--
<i>Gyrosigma attenuatum</i> (Kützing) Rabenhorst	P-B	--	st	--	i	alf	--
<i>Gyrosigma scalproides</i> (Rabenhorst) Cleve							
<i>Gyrosigma spencerii</i> (W. Smith) Cleve	B	--	--	es	mh	alf	--
<i>Halamphora veneta</i> (Kützing) Levkov	B	temp	st	sx	i	alf	--
<i>Hippodonta capitata</i> (Ehrenberg) Lange-Bertalot, Metzeltin et Witkowski	B	--	str	es	i	alf	k
<i>Lemnicola hungarica</i> (Grunow) F.E.Round & P.W.Basson	B	--	st	es	--	alf	--
<i>Melosira varians</i> Agardh							
<i>Navicula capitatoradiata</i> Germain							
<i>Navicula cryptocephala</i> Kützing							
<i>Navicula cryptotenella</i> Lange-Bertalot							
<i>Navicula lanceolata</i> Ehrenberg	B	--	st-str	es	i	alf	--
<i>Navicula menisculus</i> Schumann	B	--	st-str	es	i	alf	--
<i>Navicula phyllepta</i> Kützing	P-B, S	temp	st-str	sp	i	alf	k
<i>Navicula pseudonivalis</i> Bock							
<i>Navicula radiosa</i> Kützing	B	temp	st-str	es	i	ind	--
<i>Navicula rhyncocephala</i> Kützing							
<i>Navicula tripunctata</i> (O.F.Müller) Bory de Saint-Vincent	P-B	--	st-str	--	mh	acb	k
<i>Navicula trivialis</i> Lange-Bertalot							
<i>Navicula viridula</i> (Kützing) Ehrenberg	B	--	st-str	--	oh	alf	k
<i>Navicula viridula</i> var. <i>rostellata</i> (Kützing) Cleve	B	temp	st-str	sp	hl	alf	k
<i>Neidium dubium</i> (Ehrenberg) Cleve	B	--	str	--	i	alf	--
<i>Nitzschia acicularis</i> (Kützing) W. Smith	P-B	temp	--	es	i	alf	--

Table 2. Continued.

	Hab	T	Reo	D	Hal	pH	Geo
<i>Nitzschia capitellata</i> Hust. in A. Schmidt	B	--	--	--	i	ind	b
<i>Nitzschia clausii</i> Hantzsch							
<i>Nitzschia consricta</i> (Kützing) Ralfs in Pritchard							
<i>Nitzschia dissipata</i> (Kützing) Grunow	P-B	temp	st-str	es	mh	ind	k
<i>Nitzschia dissipata</i> var. <i>media</i> (Hantzsch) Grunow	--	--	--	sx	i	alf	--
<i>Nitzschia filiformis</i> (Smith) Van Heurck							
<i>Nitzschia fonticola</i> (Grunow) Grunow in Van Heurck	B	--	aer	es	i	ind	k
<i>Nitzschia gracilis</i> Hantzsch	P-B	temp	st-str	sp	i	ind	--
<i>Nitzschia hantzschiana</i> Rabenhorst							
<i>Nitzschia linearis</i> (Agardh) W. Smith	B	temp	st-str	es	i	alf	--
<i>Nitzschia palea</i> (Kützing) W. Smith	P-B	--	--	es	i	alf	k
<i>Nitzschia sigmoidea</i> (Nitzsch) W. Smith	P-B	--	st-str	--	i	alf	--
<i>Nitzschia solita</i> Hustedt							
<i>Nitzschia vermicularis</i> (Kützing) Hantzsch	B	--	str	--	i	alf	--
<i>Pantocsekiella ocellata</i> Pantocsek							
<i>Planothidium lanceolatum</i> (Brébisson ex Kützing) Lange-Bertalot	B	--	--	--	i	alf	k
<i>Reimeria sinuata</i> (Gregory) Kociolek et Stoermer							
<i>Rhoicosphenia abbreviata</i> (C.Agardh) Lange-Bertalot	B	--	st	sx	hl	alf	k
<i>Rhopalodia gibberula</i> (Ehrenberg) O. Müller	B	temp	str	es	mh	ind	--
<i>Sellaphora bacilloides</i> (Hustedt) Z.Levkov, S.Krstic & T.Nakov	B	--	--	--	--	--	k
<i>Sellaphora pupula</i> (Kützing) Mereschkovsky	P-B	--	--	sp	mh	alf	k
<i>Stauroneis smithii</i> Grunow	P-B	--	st-str	--	i	alf	--
<i>Surirella angusta</i> Kützing							
<i>Surirella linearis</i> W. Smith	P-B	--	--	es	i	ind	--
<i>Surirella ovalis</i> Brébisson	P-B	--	st-str	es	mh	alf	--
<i>Tryblionella calida</i> (Grunow) D.G.Mann							
<i>Tryblionella hungarica</i> (Grunow) Frenguelli	P-B	--	--	sp	mh	alf	--
<i>Ulnaria acus</i> (Nitzsch) P.Compère	P	--	st-str	es	i	alb	--
<i>Ulnaria ulna</i> (Kützing) P.Compère	B	temp	st-str	es	i	alf	--
Divizyo: CHLOROPHYTA							
<i>Schizomeris leibleinii</i> Kützing							
<i>Ulothrix</i> sp.							
<i>Stigeoclonium tenue</i> (C.Agardh) Kützing	B	--	st-str	--	--	--	k
<i>Cladophora fracta</i> (O.F.Müller ex Vahl) Kützing	P-B	--	st-str	--	--	--	k
<i>Oedogonium</i> sp.							
<i>Closteriopsis longissima</i> (Lemmermann) Lemmermann							
<i>Characium</i> sp.							
<i>Coelastrum microporum</i> Nägeli	P-B	--	st-str	--	i	ind	k
<i>Oocystis borgei</i> J.W.Snow	P-B	--	st-str	--	i	ind	--
<i>Oocystis solitaria</i> Wittrock							
<i>Tetradasmus lagerheimii</i> M.J.Wynne & Guiry	P-B	--	st-str	--	i	ind	k
<i>Scenedesmus arcuatus</i> (Lemmermann) Lemmermann	P-B	--	st-str	--	i	--	k
<i>Comasiella arcuata</i> var. <i>platydisca</i> (G.M.Smith) E.Hegewald & M.Wolf							
<i>Tetradasmus obliquus</i> (Turpin) M.J.Wynne	P	--	--	--	i	ind	k
<i>Desmodesmus communis</i> (E.Hegewald) E.Hegewald	P	--	--	--	i	ind	k
<i>Schroederia setigera</i> (Schröder) Lemmermann	P	--	st-str	--	i	--	--
<i>Tetraedron minimum</i> ((A.Braun) Hansgirg	P-B	--	st-str	--	i	--	k
<i>Tetrastrum elegans</i> Playfair	P	--	st-str	--	i	--	k
Phylum: CHAROPHYTA							
<i>Spirogyra dubia</i> Kützing							
<i>Spirogyra subsalsa</i> Kützing							
<i>Closterium closterioides</i> (Ralfs) A.Louis & Peeters							
<i>Closterium lunula</i> Ehrenberg & Hemprich ex Ralfs							
<i>Penium margaritaceum</i> Brébisson							
<i>Closterium moniliferum</i> Ehrenberg ex. Ralfs	P-B	--	st-str	--	i	--	--
<i>Closterium tumidum</i> L.N.Johnson							
<i>Cosmarium crenatum</i> Ralfs ex Ralfs	B	--	aer	--	--	--	--
<i>Cosmarium laeve</i> Rabenhorst	B	--	st-str	--	--	ind	--
Phylum: CYANOBACTERIA							
<i>Cyanophanon minus</i> Geitler							
<i>Merismopedia punctata</i> Meyen	P-B	--	--	--	i	ind	k
<i>Dolichospermum affine</i> (Lemmermann) Wacklin, L.Hoffmann & Komárek							
<i>Leibleinia willei</i> (Setchell & N.L.Gardner) P.C.Silva							
<i>Limnorphis hieronymusii</i> (Lemmermann) J.Komárek et al.							
<i>Lyngbya martensiana</i> Meneghini ex Gomont							
<i>Porphyrosiphon versicolor</i> (Gomont) Anagnostidis & Komárek							
<i>Kamptonema formosum</i> (Bory ex Gomont) Strunecký, Komárek & J.Smarda	P-B	--	st	--	--	--	--
<i>Pseudanabaena limnetica</i> (Lemmermann) Komárek							
<i>Oscillatoria limosa</i> C.Agardh ex Gomont	P-B	--	st-str	--	hl	--	--
<i>Oscillatoria planktonica</i> Woloszyńska							
<i>Oscillatoria tenuis</i> C.Agardh ex Gomont	P-B	--	st-str	--	hl	--	--
<i>Phormidium tergestinum</i> (Rabenhorst ex Gomont) Anagnostidis & Komárek	B,S	--	st-str	--	i	--	--

Table 2. Continued.

	Hab	T	Reo	D	Hal	pH	Geo
Phylum: EUGLENOPHYTA							
<i>Lepocinclis acus</i> (O.F.Müller) B.Marin & Melkonian	P	eterm	st	--	i	ind	k
<i>Euglena granulata</i> (G.A.Klebs) F.Schmitz							
<i>Euglena</i> sp.							
<i>Phacus caudatus</i> Hübner	P-B	eterm	st-str	--	i	alf	--
<i>Phacus curvicauda</i> Svireenko	P-B	--	st	--	i	ind	--
Phylum: MIOZOA							
<i>Peridiniopsis quadridens</i> (Stein) Bourrelly	P	--	--	--	--	--	k
<i>Peridinium cinctum</i> (O.F.Müller) Ehrenberg							

Abbreviations: Hab: Habitat, (B: benthic, P: planktic, P-B: planktonic-benthic, S: aerophytic, Ep: epiphytic); T: temperature, (temp: temperate water, eterm: eurythermic water, warm: warm water, cool: cool water); Reo: streaming and oxygenation, (st: standing water, str: stream, st-str: standing-streaming, aer: aerophile); D: saprobity, (es: eury saprobe, sx: saproxen, sp: saprophile); Hal: salinity, (mh: mesohalobe, oh: oligohalobe, i: oligohalobious-indifferent, hl: oligohalobious-halophilous); pH: Acidity, (ind: indifferent, alf: alkaliphile, acf: acidophil, alb: alkalibiont); Geo: Geography, k: cosmopolit. **Note:** For saprobity, 'D' according to Watanabe *et al.* (1986).

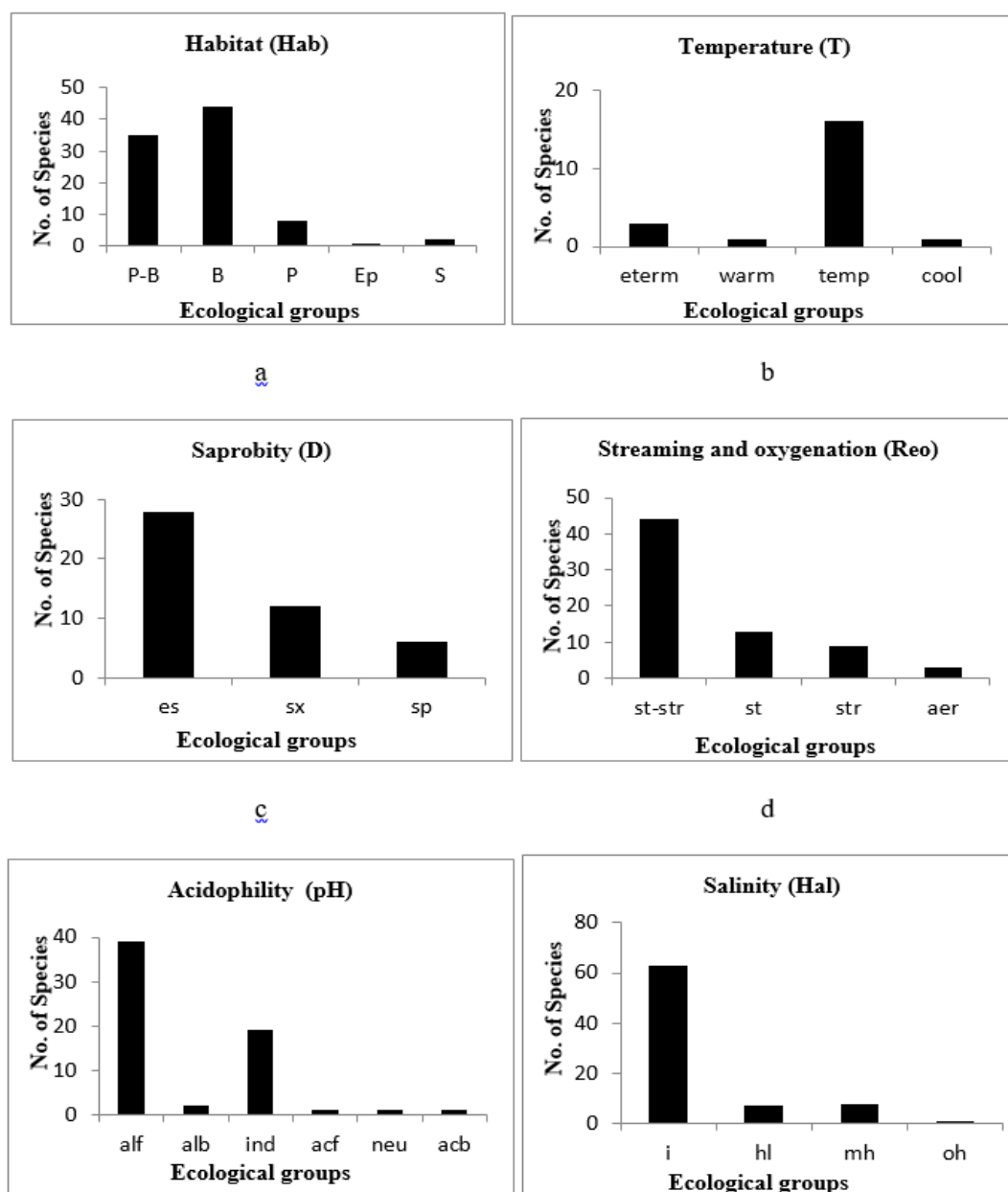


Figure 2. Ratios of the ecological groups according to the water quality parameters and habitats during the study period.

scores belonging to DO (=1), NH_4^+ (=2) and BOD (=3.75) indicated that the Melen River water had a good chemical status, while the value of suspended solids (=7.25) showed severely polluted water. Since the river bottom structure is composed of sand, silt and mud, the river environment is very sensitive to erosion and sediment transportation. In addition, agricultural inputs and anthropogenic impacts on the river bed have increased the amounts of suspended solids. Therefore, in the anthropogenically transformed river, diatoms will, in particular, indicate inferior water quality, compared to the indications derived from chemical parameters (Noga et al., 2016).

Conclusion

A total of 88 of the 148 taxa identified in the epiphytic and epilithic samples from 6 stations along the Melen River were determined as indicator taxa. Most of the indicator Bacillariophyta species preferred alkaline environments, while the other groups were indifferent. Ecological analysis showed that the algal community of Melen River preferred low salinity, as demonstrated by the prevalence of “oligohalobes-indifferent” groups. Most of the species (especially the diatoms) are common in waters with different hydrological conditions. They prefer oligo- to-eutrophic and β -mesosabrobic waters. Indicators of saprobity, according to Watanabe's methods, showed a low to moderate level of organic pollution.

Acknowledgements

We would like to thank Gazi University, Scientific Projects Research Management for financing this research.

References

- Atazadeh, I., Sharifi, M. & Kelly, M.G. (2007). Evaluation of the Trophic Diatom Index for assessing water quality in River Gharasou, Western Iran. *Hydrobiologia*, 589, 165-173.
- Barinova, S.S., Medvedeva, L.A., & Anissimova, O.V. (2006). Diversity of algal indicators in environmental assessment: Pilies Studio, Tel Aviv (in Russian).
- Barinova, S.S., Tavassi, M., & Nevo, E. (2006a). Diversity and ecology of algae from the Alexander River (Central Israel). *Flora Mediterranea*, 16, 111-132.
- Barinova S.S., Tavassi, M., & Nevo, E. (2010a). Algal communities of the Hadera River (Israel) under dramatic niche changes. *Central European Journal of Biology*, 5(4), 507-521. <http://dx.doi.org/10.2478/s11535-010-0033-1>
- Barinova, S., Tavassi, M., Glassman, H., & Nevo, E. (2010b). Algal indication of pollution in the Lower Jordan River, Israel, *Applied Ecology and Environmental Research*, 8(1), 19-38.
- Barinova, S.S., Kukhaleishvili, L., Nevo, E., & Janelidze, Z. (2011a). Diversity and ecology of algae in the Algeti National Park as a part of the Georgian system of protected areas. *Turkish Journal of Botany*, 35, 729-774. <http://dx.doi.org/10.3906/bot-1009-83>
- Barinova, S.S., Nevo, E., & Bragina, T.M. (2011b). Ecological assessment of wetland ecosystems of northern Kazakhstan on the basis of hydrochemistry and algal biodiversity. *Acta Bot. Croat.* 70(2), 215–244.
- Barinova, S., & Krassilov, V.A. (2012). Algal diversity and bio-indication of water resources in Israel. *International Journal of Environment and Resource*, 1(2), 62-72.
- Barinova, S., Khuram, I., Asadullah, Ahmad, N., Jan, S. & Shin, D.H. (2016). How Water Quality in the Kabul River, Pakistan, can be Determined with Algal Bio-indication, *Advanced Studies in Biology*, 8(4), 151-171.
- Baykal, T., Açıkgöz, İ., UdoUdoh, A., & Yıldız, K. (2011). Seasonal variations in phytoplankton composition and biomass in a small lowland river-lake system (Melen River, Turkey). *Turkish Journal of Biology*, 35, 485-501. <http://dx.doi.org/10.3906/biy-0904-5>
- Blanco, S., Becares, A., Cauchie, H.M., Hoffmann, L., & Ector, L. (2007). Comparison of biotic indices for water quality diagnosis in the Duero Basin (Spain). *Archiv für Hydrobiologie (suppl. Large Rivers)*, 17(3-4), 267-286. <http://dx.doi.org/10.1007/978-3-784-07016-1>
- Cox, E. J. (1996). Identification of Freshwater Diatoms From Live Material, Chapman & Hall, London, 158 pp.
- Das, S.K., & Chakrabarty, D. (2007). Limnological survey of three tropical water reservoirs in Eastern India, *Acta Botanica Malaciatia*, 32, 5-16.
- Dell'Uomo, A., & Torrisi, M. (2009). Freshwater algae and their usefulness in safeguarding the Mediterranean basin. *Boccone*, 23, 93-105.
- Doğan, E., Sengörür, B., & Koklu, R. (2009). Modeling biological oxygen demand of the Melen River in Turkey using an artificial neural network technique, *Journal of Environmental Management*, 90(2), 1229-1235.
- Guiry, M.D., & Guiry, G.M. (2017). *AlgaeBase*. World-wide electronic publication, National University of Ireland, Galway. Retrieved from <http://www.algaebase.org>
- Hofmann G., Werum M., Lange-Bertalot H. 2011. Diatomeen im Süßwasser – Benthos vom Mitteleuropa. Bestimmungsflora Kieselalgen für die ökologische Praxis. Über 700 der häufigsten Arten und ihre Ökologie. [In:] H. Lange-Bertalot. (ed.), A.R.G. Gantner Verlag K.G., pp. 908.
- Huber-Pestalozzi, G. (1982). Das Phytoplankton Des Süßwassers 8. Teil Conjugatophyceae, Zygnematales and Desmidiaceae, E. Schweizerbart'sche Verlagsbuchhandlung, Germany, 542 pp.
- John, D.M., Whitton, B.A., & Brook, A.J. (2002). The Freshwater Algal Flora of the British Isles. Cambridge University Press. Cambridge, 702 pp.
- John, D.W., & Sheat R.G. (2003). Freshwater algae of North America. Academic Press USA 918 pp.
- Korshikov OA (1987) The Freshwater Algae of the Ukrainian SSR. V. Sub-Class Protococcineae Vacuolales and Protococcales. Dehra Dun, Bishen Singh Mahendra Pal Singh & Koeltz Scientific Books. 412 pp.
- Krammer, K., & Lange-Bertalot, H. (1999a). Süßwasserflora von Mitteleuropa, Bacillariophyceae Band 2/1, 1. Teil: Naviculaceae, Gustav Fischer

- Verlag, Stuttgart, 876 pp.
- Krammer, K., & Lange-Bertalot, H. (1999b). Süßwasserflora von Mitteleuropa, Bacillariophyceae Band 2/2, 2. Teil: Bacillariaceae, Epithemiaceae, Surirellaceae, Gustav Fischer Verlag, Stuttgart, 584 pp.
- Krammer, K., & Lange-Bertalot, H. (1991a). Süßwasserflora von Mitteleuropa, Bacillariophyceae Band /3, 3. Teil: Centrales, Fragilariaceae, Gustav Fischer Verlag, Stuttgart, 576 pp.
- Krammer, K., & Lange-Bertalot, H. (1991b). Süßwassers von Mitteleuropa, Bacillariophyceae Band 2/4, 4. Teil: Achnanthaceae, Kritische Ergänzungen zu Navicula (Lineolatatae) ubnd Gomphonema Gesamtliteraturverzeichnis, Gustav Fischer Verlag, Stuttgart, 436 pp.
- Margarita A., & Benavides, S. (1996). The use of water chemistry and benthic diatom communities for qualification of a polluted tropical river in Costa Rica, *Rev. BioI. Trop.* 44(2), 395-416.
- Noga, T., Stanek-Tarkowska, J., Kloc, U., Kochman-Kędziora, N., Rybak, M., Peszek, L. & Pajęczek, A. (2016). Diatom diversity and water quality of a suburban stream: a case study of the Rzeszów city in SE Poland. *Biodiversity: Research and Conservation* 41, 19-34. <http://dx.doi.org/10.1515/biorc-2016-0004>
- Resende, P.C., Resende, P., Pardal, M., Almeida, S., & Azeiteiro, U. (2010). Use of biological indicators to assess water quality of the Ul River (Portugal). *Environmental Monitoring and Assessment*, 170(1), 535-544. <http://dx.doi.org/0.1007/s10661-009-1255-4>
- Sládeček, V. (1986). Diatoms as indicators of organic pollution. *Acta Hydrochimica et Hydrobiologica*, 14(5), 555-566.
- <http://dx.doi.org/10.1002/ahch.19860140519>
- Solak, C.N., Ector, L., Wojtal, A.Z., Acs, E., & Morales, E.A. (2012). A review of investigations on diatoms (Bacillariophyta) in Turkish inland waters. *Nova Hedwigia Beiheft*, 141, 431-462. <http://dx.doi.org/1438-9134/2012/0141-0431>
- Squires, L.E., & Saoud, N.S. (1986). Effects of water quality and season on diatom community structure in the Damour River, Lebanon. *Hydrobiologia*, 133, 127-141. <http://dx.doi.org/10.1007/BF00031862>
- Taylor, J.C, de la Rey, P.A. & Van Rensburg L. (2005). Recommendations for the collection, preparation and Enumeration of Diatom from Riverine Habitats for water Quality Monitoring in South Africa. *African Journal of Aquatic Sciences*, 3(1), 65-75.
- Urrea, G., & Sabater, S. (2009). Epilithic diatom assemblages and their relationship to environmental characteristics in an agricultural watershed (Gadiana River, SW Spain). *Ecological Indicators*, 9, 693-703.
- Van Dam, H., Mertens, A., & Sinkeldam, S. (1994). A coded checklist and ecological indicator values of freshwater diatoms from The Netherlands. *Netherland Journal of Aquatic Ecology*, 28, 117-133.
- Watanabe, T., Asai, K., & Houki, A. (1986). Numerical estimation to organic pollution of flowing water by using the epilithic diatom assemblage-Diatom Assemblage Index (DAIpo). *Science Total Environment*, 55, 209-218.
- Ziller, S., & Montesanto, B. (2004). Phytobenthos (diatoms) and water framework directive implementation: The case of two Mediterranean rivers in Greece. *Fresenius Environmental Bulletin*, 13, 128-138.