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**RESEARCH PAPER** 

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

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### Abstract

Algae are among the key organisms of aquatic ecosystems. While there have been a large number of important algological 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, pН 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 bioindication 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

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environmental variables, and revealing autecological status of the river.

### **Materials and Methods**

Melen River runs within Duzce Province, with 80% of its basin of 2317 km<sup>2</sup> 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, Sengorur & 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, Açıkgöz, 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 KMnO<sub>4</sub> method described by Taylor, de la

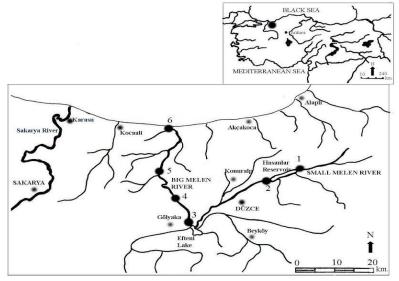


Figure 1. Melen River and sampling stations.

Table 1. Descriptions of Melen River sampling stations

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

\*This station posseses 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)", "eurysaprobes (moderately polluted water)", and "polysaprobes (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%). Achnanthidium minutissimum, Cocconeis pediculus, Cymbella affinis, Diatoma vulgaris, 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  $2^{nd}$  and  $3^{rd}$  sites, constituting more than 50% of the species. This species is an epiphytic and cosmopolitan

diatom that is found in inland waters with a mediumto-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. vulgaris was recorded, with 25% relative abundance in epiphyton at site 6 in July 2004. D. vulgaris is common in slow-flowing rivers and can often be found in moderately nutrientrich 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), О. 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 mesosaprobic (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

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Navioula pseudoninalia Pook		Р-В, S	temp	st-str	sp	1	alf	k
Navicula pseudonivalis Bock		в	tome	of of	0.2	:	ind	
Navicula radiosa Kützing         B         temp         st-str         es         i         ind           Navicula rhyncocephala Kützing         B         temp         st-str         es         i         ind		В	temp	st-str	es	1	ma	
		DR		st_st+		mb	ach	k
Navicula tripunctata (O.F.Müller) Bory de Saint-Vincent P-B st-str mh acb Navicula trivialis Lange-Bertalot		г-р		51-511		11111	act	ĸ
Navicula viridula (Kützing) Ehrenberg B st-str oh alf		R		st-str		oh	alf	k
Navicula viridula var. rostellata (Kützing) Cleve B temp st-str sp hl alf								k
Neidium dubium (Ehenberg) Cleve B str i alf			1		-			
Nitzschia acicularis (Kützing) W. SmithP-Btempesialf								

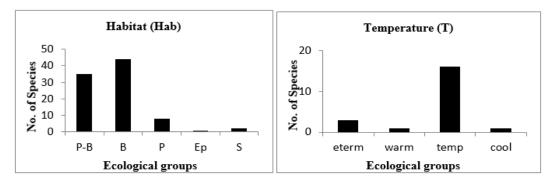
### Table 2. Continued.

	Hab	Т	Reo	D	Hal	pН	Geo
Nitzschia capitellata Hust. in A. Schmidt	В				i	ind	b
Nitzschia clausii Hantzsch							
Nitzschia consricta (Kützing) Ralfs in Pritchard Nitzschia dissipata (Kützing) Grunow	P-B	tomn	ot otr	00	mh	ind	k
<i>Nitzschia dissipata</i> (Kutzing) Grunow	г-D 	temp	st-str	es sx	i	alf	к 
Nitzschia filiformis (Smith) Van Heurck				574	•	un	
Vitzschia fonticola (Grunow) Grunow in Van Heurck	В		aer	es	i	ind	k
Nitzschia gracilis Hantzsch	P-B	temp	st-str	sp	i	ind	
Nitzschia hantzschiana Rabenhorst		-		-			
Nitzschia linearis (Agardh) W. Smith	В	temp	st-str	es	i	alf	
Nitzschia palea (Kützing) W. Smith	P-B			es	i	alf	k
Nitzschia sigmoidea (Nitzsch) W. Smith	P-B		st-str		i	alf	
Nitzschia solita Hustedt Nitzschia vermicularis (Kützing) Hantzsch	р		ata		;	alf	
Pantocsekiella ocellata Pantocsek	В		str		i	an	
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot	В				i	alf	k
Reimeria sinuata (Gregory) Kociolek et Stoermer	Б				1	an	ĸ
Rhoicosphenia abbreviata (C.Agardh) Lange-Bertalot	В		st	sx	hl	alf	k
Rhopalodia gibberula (Ehrenberg) O. Müler	B	temp	str	es	mh	ind	
Sellaphora bacilloides (Hustedt) Z.Levkov, S.Krstic & T.Nakov	В						k
Sellaphora pupula (Kützing) Mereschkovsky	P-B			sp	mh	alf	k
Stauroneis smithii Grunow	P-B		st-str		i	alf	
Surirella angusta Kützing							
Surirella linearis W. Smith	P-B			es	i	ind	
Surirella ovalis Brebisson	P-B		st-str	es	mh	alf	
Tryblionella calida (Grunow) D.G.Mann							
Tryblionella hungarica (Grunow) Frenguelli	P-B			sp	mh	alf	
Ulnaria acus (Nitzsch) P.Compère	Р		st-str	es	i	alb	
Ulnaria ulna (Kützing) P.Compère	В	temp	st-str	es	i	alf	
Divizyo: CHLOROPHYTA Schizomeris leibleinii Kützing							
Ulothrix sp.							
Stigeoclonium tenue (C.Agardh) Kützing	В		st-str				k
Cladophora fracta (O.F.Müller ex Vahl) Kützing	P-B		st-str				k
Oedogonium sp.							
Closteriopsis longissima (Lemmermann) Lemmermann							
Characium sp.							
Coelastrum microporumNägeli	P-B		st-str		i	ind	k
Oocystis borgei J.W.Snow	P-B		st-str		i	ind	
Oocystis solitaria Wittrock							
Tetradesmus lagerheimiiM.J.Wynne& Guiry	P-B		st-str		i	ind	k
Scenedesmus arcuatus (Lemmermann) Lemmermann	P-B		st-str		i		k
Comasiella arcuata var. platydisca (G.M.Smith) E.Hegewald & M.Wolf	Р					:	1-
Tetradesmus obliquus (Turpin) M.J.Wynne Desmodesmus communis (E.Hegewald) E.Hegewald	P P				i i	ind ind	k k
Schroederia setigera (Schröder) Lemmermann	r P		 st-str		i		к 
Tetraedron minimum ((A.Braun) Hansgirg	P-B		st-str		i		k
Tetrastrum elegans Playfair	P		st-str		i		k
Phylum:CHAROPHYTA	-		50 50		•		
Spirogyra dubia Kützing							
Spirogyra subsalsa Kützing							
Closterium closterioides (Ralfs) A.Louis & Peeters							
Closterium lunula Ehrenberg & Hemprich ex Ralfs							
Penium margaritaceum Brébisson							
Closterium moniliferum Ehrenberg ex. Ralfs	P-B		st-str		i		
Closterium tumidum L.N.Johnson							
Cosmarium crenatum Ralfs ex Ralfs	В		aer				
Cosmarium laeve Rabenhorst	В		st-str			ind	
Phylum: CYANOBACTERIA							
Cyanophanon minus Geitler	D D					• •	1
Merismopedia punctata Meyen	P-B				i	ind	k
Dolichospermum affine (Lemmermann) Wacklin, L.Hoffmann & Komárek Leibleinia willei (Setchell & N.L.Gardner) P.C.Silva							
Limnoraphis hieronymusii (Lemmermann) J.Komárek et al.							
Lyngbya martensiana Meneghini ex Gomont							
Porphyrosiphon versicolor (Gomont) Anagnostidis & Komárek							
Kamptonema formosum (Bory ex Gomont) Strunecký, Komárek & J.Smarda	P-B		st				
Pseudanabaena limnetica (Lemmermann) Komárek	1.0		51				
Oscillatoria limosa C.Agardh ex Gomont	P-B		st-str		hl		
Oscillatoria planktonicaWoloszynska							
Oscillatoria tenuis C.Agardh ex Gomont	P-B		st-str		hl		
	B,S				i		

#### Table 2. Continued.

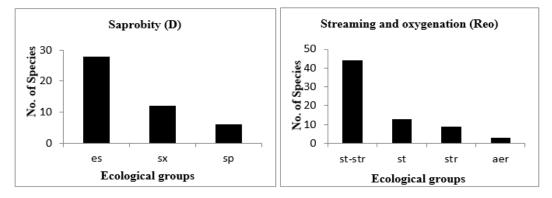
	Hab	Т	Reo	D	Hal	pН	Geo
Phylum: EUGLENOPHYTA							
Lepocinclis acus (O.F.Müller) B.Marin & Melkonian	Р	eterm	st		i	ind	k
Euglena granulata (G.A.Klebs) F.Schmitz							
Euglena sp.							
Phacus caudatus Hübner	P-B	eterm	st-str		i	alf	
Phacus curvicauda Svirenko	P-B		st		i	ind	
Phylum: MIOZOA							
Peridiniopsis quadridens (Stein) Bourrelly	Р						k
Peridinium cinctum (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: eurysaprobe, 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).





b





d

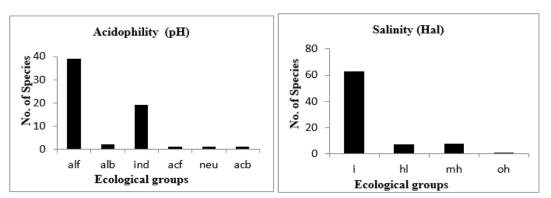


Figure 2. Ratios of the ecological groups according to the water quality parameters and habitats during the study period.

scores belonging to DO (=1), NH4+ (=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  $\beta$ -mesosabrobic waters. Indicators of saprobity, according to Watanabe's methods, showed a low to moderate level of organic pollution.

### Acknowledgements

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