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Evaluating Benthic Macroinvertebrate Fauna and Water Quality of Suleymanli Lake (Buldan-Denizli) in Turkey

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Abstract: Benthic macroinvertebrate samples were taken seasonally from October 2006 to April 2008 except winter seasons with the aim of evaluate macroinvertebrate fauna and water quality of Suleymanli Lake. In total, 61 benthic macroinvertebrate taxa were found and 40 of them are new records for the lake. Chandler Score and Shannon-Weiner Diversity Index provided more compatible data than Revised Biological Monitoring Working Party, Extended Trent Biotic Index and Belgian Biotic Index with physical-chemical results. Also, Principle Component Analysis was carried out to establish associations between benthic macroinvertebrates and environment variables. In our study, the lake water quality was determined as moderately polluted. Obtained environmental variables from water samples showed that the temperature, dissolved oxygen, pH, total dissolved solids and electrical conductivity are the most important parameters in explaining the macroinvertebrate community variation in the lake.

Key words: Benthic fauna, Principal Component Analysis, biotic indices, biomonitoring

Introduction

Water Framework Directive requires (WFD) all member states to protect, enhance and restore, and prevent deterioration of aquatic ecosystems. All water bodies need to achieve good ecological status or potential under the Directive (Council European Comm. 2000). Consequently, all water bodies should be classified according to their ecological status by using some of the quality elements such as benthic macroinvertebrates. In this process, to assign water body types, to set objectives, and to select implemented parameters are the most important steps.

Eventually, monitoring schemes should be prepared as soon as possible. The ecological reference conditions and assessment systems must be valid scientifically and relevant to the situation in Turkey. Therefore, to understand natural variation of the ecological communities is of vital importance to biomonitoring studies. One of the easiest ways to get this information is monitoring of shallow lakes and ponds.

In many regions of Anatolia, the biological richness of macroinvertebrate fauna has not been discovered yet (Duran, Suicmez 2007). So, information on fauna of Anatolia region is very limited, especially concerning macroinvertebrates. No reliable estimates for the number of invertebrates are available, although it is assumed that not to be less than 30 000 species (Eea 2002) in Turkey. Anatolia, a land bridge between Asia and Europe, has an important position as zoogeographically, ecologically and geologically (Boyaci, Ozkan 2004). Anatolia has also noticeably much different kinds of microhabitats. Therefore, all microhabitats must be taken under record urgently before their disappearance cause of pollution, ur-

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banization and climate change. In recent years, macroinvertebrates have received considerable attention in water ecosystem studies. Especially relationship between macroinvertebrate community structure and environmental variables has been used as subject of numerous studies in Turkey (Kazanci, Dugel 2000, Barlas *et al*. 2002, Duran *et al*. 2003, Dugel, Kazanci 2004, Capraz, Arslan 2005, Yildiz *et al*. 2005, Arslan, Sahin 2006, Duran 2006).

Benthic macroinvertebrates are also the most widely group of organisms used for assessment of water resources (Mebane 2001, Zweig, Rabeni 2001).

In Turkey, biomonitoring of macroinvertebrate communities in shallow lakes has not been examined sufficiently. The main aim of this study is to evaluate macroinvertebrate fauna and water quality of Suleymanli Lake and also to determine particular emphasis on the relationship between the structure of macroinvertebrate community and the physical-chemical features. This lake was chosen for this study due to very little human impact and there is not enough research has been done on the lake yet.

Materials and Methods

Study area

Suleymanli Lake, located on the plateau of Suleymanli on mount of Sazak is 8 km west of Buldan township of Denizli (Fig. 1). The lake trophy level is based on chironomid communities (Saether 1979). It is a shallow and eutrophic lake at an elevation of 1154 m. The maximum depth of the lake is quite variable through the annual precipitation. The mean annual precipitation is 604.4 mm in 2005, 462.2 mm in 2006, 482.2 mm in 2007 and 372.6 mm in 2008. The most of the area is less than 50 cm and measured the maximum depth of the lake is about 120 cm between the years 2006 to 2008. It covers an area of 1.05 sq km and feeds by snow and rain water. The lake area has Mediterranean climate which is characterised by hot dry summer and cool rainy winter.

A very large portion of the lake is dominated by reeds (*Typha spp.*). The longest distance between the shore and the reeds is about 400 m while the shortest distance is 5 m. The average distance from shore to reeds for the most portion of the lake is about 30 m. Its bottom is mostly composed of peat, clay and silt and largely covered by submerged vegetation with water milfoils (*Myriophyllum spp*.) and sedge (*Carex* spp.) as the dominant species. According to Ayaz *et al*. (2007) the other dominant plant species such as Common Spike Rush (*Eleocharis palustris*), Tufted Sedge (*Carex elata*), Pondweed (*Potamogeton* spp.), Tropical Hornwort (*Ceratophyllum submersum*) and Waterlily (*Nymphaea alba*) might be numerically considerable.

Sampling

Six sampling sites that offered the best representation for each parameter were determined on the lake (Fig. 1). Macroinvertebrate samples were taken seasonally from October 2006 to June 2008 except winter seasons, by using a bottom kick net with 500 µm mesh size. The samples were collected from an area of nearly 100 m^2 in order to include all possible microhabitats in each sampling site. Moreover, the macroinvertebrate samples on macrophytes and in the sediment were collected by using sieves with 250 µm mesh size. All collected samples were immediately fixed in 4% formaldehyde in the field and then transferred to 70% ethyl alcohol. In the laboratory, collected macroinvertebrates were sorted and counted by using a stereomicroscope and then identified to the possible lowest taxon (species, genus or families) by using a binocular microscope. The samples that collected in June 2006, July 2007 and June 2008 were also used to assess interannual variability changes of macroinvertebrate assemblages over the three years of this study.

Water temperature, dissolved oxygen (dO_2) (by using Lovibond oxi 200), electrical conductivity (EC) (Wtw 330i/set), total dissolved solid (TDS) (Wtw 330i/set), salinity (Wtw 330i/set), oxidation reduction potential (ORP) (Wtw 330i/set) and pH (Wtw 330i) were measured in the field using portable instruments. Nitrite (NO_2^-), phosphate (PO_4-P), ferrous (Fe), copper (Cu^{2+}), ammonium (NH_4^+), sulphate (SO_4^-) and potassium (K^+) levels in the lake water were measured in the laboratory using the Filterphotometer PF-11 (Macherey-Nagel GmbH&G Kg Neumann-Neander-Str. 6-8 D-52355 Duren Deutschland). Results of the physical-chemical analysis were also classified according to Turkish standards (Turkish Standards 1998) to demonstrate water quality.

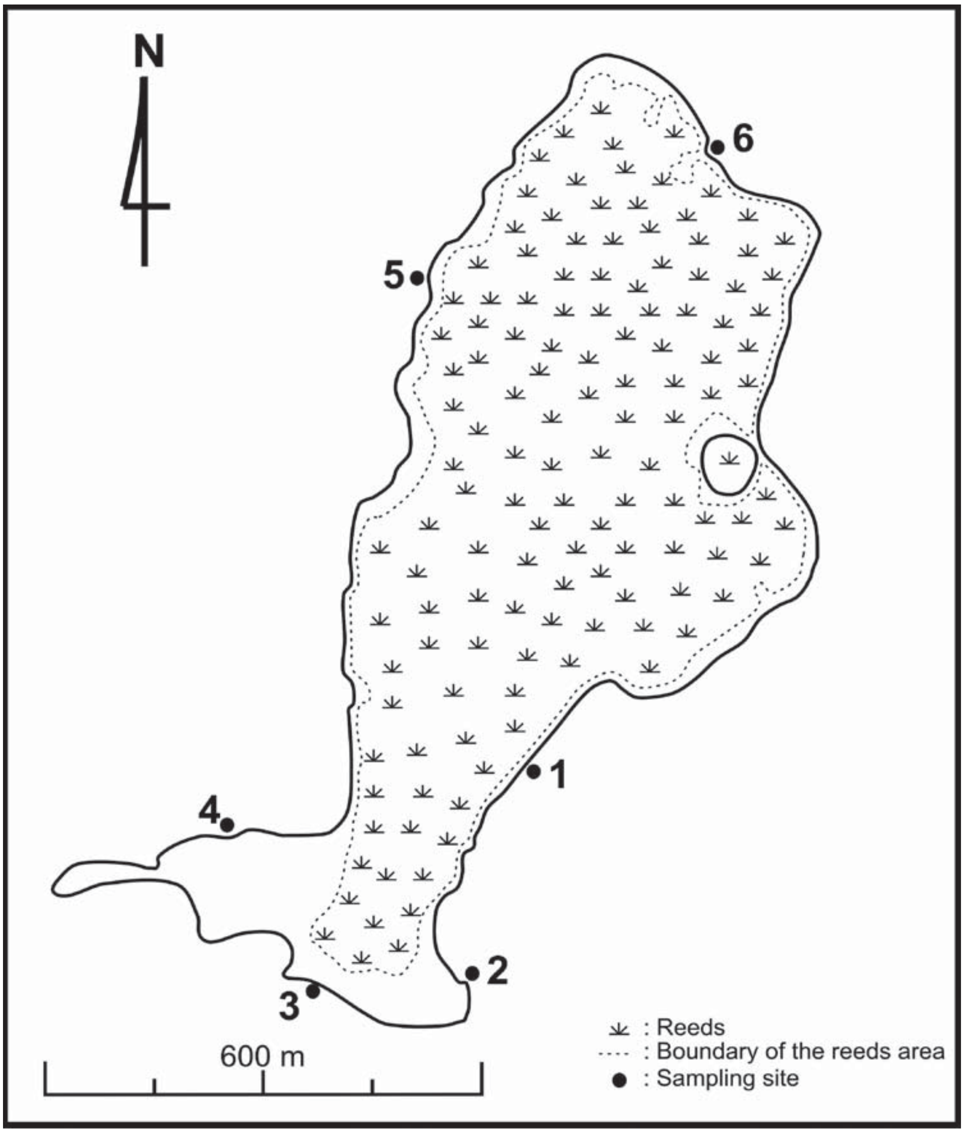

Fig. 1. Geographical distribution and co-ordinates of sampling sites: (1) 38° 3´14.78´´N - 28°46´34.89´´E, (2) 38° 3´0.89´´N - 28°46´29.14´´E ; (3) 38° 3´2.29´´N - 28°46´21.73´´E, (4) 38° 3´6.97´´N - 28°46´12.83´´E, (5) 38° 3´25.81´´N - 28°46´24.40´´E, (6) 38° 3´46.22´´N - 28°46´36.28´´E.

Biotic indices

From among the great variety of indices and scores available, we selected five for our study which are shown in Table 1. The Chandler Score (Chandler 1970) was used because it has been claimed to discriminate well for small changes in water quality; Revised Biological Monitoring Working Party (Hellawell 1978) – Rev. BMWP score (Walley, Hawkes 1997), Extended Trent Biotic Index – ETBI (Woodiwiss 1978) and Belgian Biotic Index – BBI (De Pauw,Vanhooren 1983) were chosen because they are easy to use and have been used widely in the past. Shannon – Weiner Diversity Index (Wilhm, Dorris 1968) ratio was also used to evaluate the biological assessment of water quality.

Statistical Analyses

Multivariate analysis was performed with CANOCO 4.5 (Ter Braak and Šmilauer 2002). Principle Component Analysis (PCA), (as provided in Canoco; Ter Braak 1998) was carried out as a linear method to establish associations between benthic macroinvertebrates and environment variables. Deciding whether to use linear or unimodal type of ordination method, lengths of gradient were used. The largest value of lengths of gradient was 2.358 which is less than 4.00. An indirect analysis of the species data

Table 1. Classification of lake water quality according to biotic indices, Chandler Score (CS), Revised British Monitoring Working Party (rev. BMWP), Extended Trent Biotic Index (ETBI), Belgian Biotic Index (BBI) and Shannon Weiner Diversity Index (S-W).

Biotic Index	Year	Score	Class	Significance
CS	2006	330	III	Doubtful
	2007	410	II	Fairly clean
	2008	220	III	Doubtful
Rev. BMWP	2006	52	III	Doubtful
	2007	94	III	Doubtful
	2008	43	IV	Polluted
ETBI	2006	5.55	III	Doubtful
	2007	7.2	II	Fairly clean
	2008	3.66	IV	Polluted
BBI	2006	7.42	III	Doubtful
	2007	8.4	II	Fairly clean
	2008	4.28	IV	Polluted
S-W	2006	2.23	-	Over average
	2007	3.07	-	Moderately high diversity
	2008	1,8	-	Moderately low diversity

was applied to summarize the community variation. We are more interested in the correlation among the counts of individual species and between the species and environmental variables (temperature, dissolved oxygen, total dissolved solid, salinity, conductivity, oxidation reduction potential, pH), rather than in precise positioning of sample points in the ordination space. The inorganic parameters such as nitrite, ammonium, ferrous, potassium and sulphate were not included in the analysis because the all measured values of them were very stable. We leaved none option for the samples and centre by species option for the species to portray both the differences in the proportions taken by individual species and the difference in their absolute counts.

Results

So far, totally 61 macroinvertebrate taxa were found and 40 of them are new record for the lake fauna (Table 2). Insecta was the most abundant group with a total of 49 taxa recorded including Ephemeroptera (9 taxa), Odanata (10), Hemiptera (6), Trichoptera (3), Diptera (15) and Coleoptera (5). Total taxa richness estimate showed a seasonal trend that the maximum and minimum values have been determined respectively as 43 taxa in summer 2007 and 24 in spring 2008 (Fig. 2a). Taxonomic richness also indicates a fluctuation among the years 2006 (39), 2007 (52 taxa) and 2008 (29) (Fig. 2b). The dipteran chironomids were highly represented in the samples over the three years as 11% in 2006, 19% in 2007 and 9% in 2008 (Fig. 2c). Ephemeroptera and Odonata were numerically important from years 2006 to 2008 as well (Fig. 1c). The previous data on the composition and the distribution of benthic macrofauna of Suleymanli Lake was rare and 31 taxa were determined (TASDEMIR *et al*. 2004).

The results of applied biotic indices are shown in Table 1. According to these results, the best water quality level was determined as fairly clean (Class II) while the poor water quality level was determined as polluted (Class IV). All applied biotic indices were especially doubtful (Class III) for the year 2006. Diptera and Ephemeroptera were the most dominant groups in the biotic indices. Also the results of physical-chemical analyses of water samples have been classified in by Turkish Standards (1988) (Table 3). And water quality was determined as between clean (Class I) and fairly clean (Class II) as a result of these standards.

According to PCA results the first canonical axis (axis 1) explained 41.8% of the total variability in the species data and the following axes decreased gradually (17.1% for axis 2, 14.5% for axis 3). The species-environment correlations were 0.904,

Table 2. Taxonomic list of collected benthic macroinvertebrates. * mark shows new record species for the lake.

Phylum: Annelida
Classis: Clitellata
Subclassis: Oligochaeta
Family: Naididae
Nais sp.
Dero sp.
Family: Megascolecidae
Enchytraeus sp.
Family: Tubificidae
Tubifex tubifex (Müller, 1774)
Limnodrilus profundicola (Verril, 1871)
Limnodrilus hoffmeisteri Claparede, 1862
Potamothrix moldaviensis Vejdovský et Mrázek, 1903
Subclassis: Hirudinea
Family: Glossiphoniidae
**Helobdella stagnalis* (Linnaeus, 1758)
Hirudo medicinalis (Linnaeus, 1758)
Phylum: Mollusca
Classis: Gastropoda
Family: Planorbidae
**Planorbarius corneus* (Linnaeus, 1758)
Planorbis (Gyraulus) albus (Müller, 1774)
Family: Neritidae
Theodoxus sp.
Phylum: Crustacea
Classis: Malacostraca
Ordo: Decapoda
Family: Potamidae
Potamon sp.
Phylum: Arthropoda
Subphylum: Hexapoda
Order: Ephemeroptera
Family: Ecdyonuridae
**Ecdyonurus dispar* (Curtis, 1834)
Family: Baetidae
**Baetis atrebatinus* (Eaton, 1870)
**Baetis buceratus* (Eaton, 1870)
**Baetis rhodani* (Pictet, 1843)
**Baetis scambus* (Eaton, 1870)
**Baetis vernus* (Curtis, 1834)
**Centroptilum pennulatum* (Eaton, 1870)
Cloeon dipterum (Linnaeus, 1761)
**Cloeon simile* (Eaton, 1870)
Order: Odanata
Family: Gomphidae
Gomphus sp.
Family: Aeshnidae
**Anax imperator* Leach, 1815
Family: Corduliidae
Cordulia sp.
Family: Libellulidae
**Libellula depressa* (Linnaeus, 1758)
Family: Calopterygidae
Calopteryx sp.
Family: Coenagrionidae
**Coenagrion ornatum* (Selys, 1850)
**Coenagrion pulchellum* (Van der Linden, 1825)
**Ischnura elegans* (van der Linden, 1820)
**Pyrrhosoma nymphula* (Sulzer, 1776)
**Enallagma cyathigerum* (Charpentier, 1840)
Order: Hemiptera
Family: Naucoridae
**Ilyocoris (Naucoris) cimicoides* (Linnaeus, 1758)
Family: Notonectidae
Notonecta sp.
Family: Pleidae
Plea leachi (MacGregor & Kirkaldy, 1899)
Family: Corixidae
**Corixa geoffroyi* (Leach, 1815)
Subfamily: Micronectinae
Micronecta sp.
Subfamily: Corixinae
**Sigara lateralis* (Leach, 1817)
Order: Trichoptera
Family: Hydropsychidae
**Hydropsyche fulvipes* (Curtis 1834)
**Hydropsyche pellucidula* (Curtis, 1834)
**Metalype fragilis* (Pictet, 1834)
Order: Diptera
Family: Chironomidae
Subfamily: Chironominae
**Chironomus defectus* (Kieffer, 1913)
**Chironomus nuditarsis* (Keyl, 1961)
Chironomus plumosus (Linnaeus, 1758)
Chironomus tentans (Linnaeus, 1758)
**Chironomus riparius* (Meigen, 1804)
**Chironomus nuditarsis* (Keyl, 1961)
**Dicrotendipes nervosus* (Staeger, 1839)
**Dicrotendipes tritomus* (Kieffer, 1916)
**Polypedilum nubeculosum* (Meigen, 1804)
**Polypedilum pedestre* (Meigen 1830)
**Potthastia alternis* (Şahin 1987)
Subfamily: Tanypodinae
**Ablabesmyia monilis* (Linnaeus, 1758)
**Tanypus punctipennis* (Meigen, 1818)
**Tanypus stellatus* (Coquillett, 1902)
**Trissopelopia flavida* (Kieffer, 1923)
Order: Coleoptera
Family: Gyrinidae
Gyrinus sp.
Family: Hydrophilidae
Berosus sp.
Family: Dytiscidae
**Dytiscus latissimus* (Linnaeus, 1758)
Family: Hydrophiliidae
**Hydrobius fuscipes* (Linnaeus, 1758)
**Hydrophilus piceus* (Linnaeus, 1758)

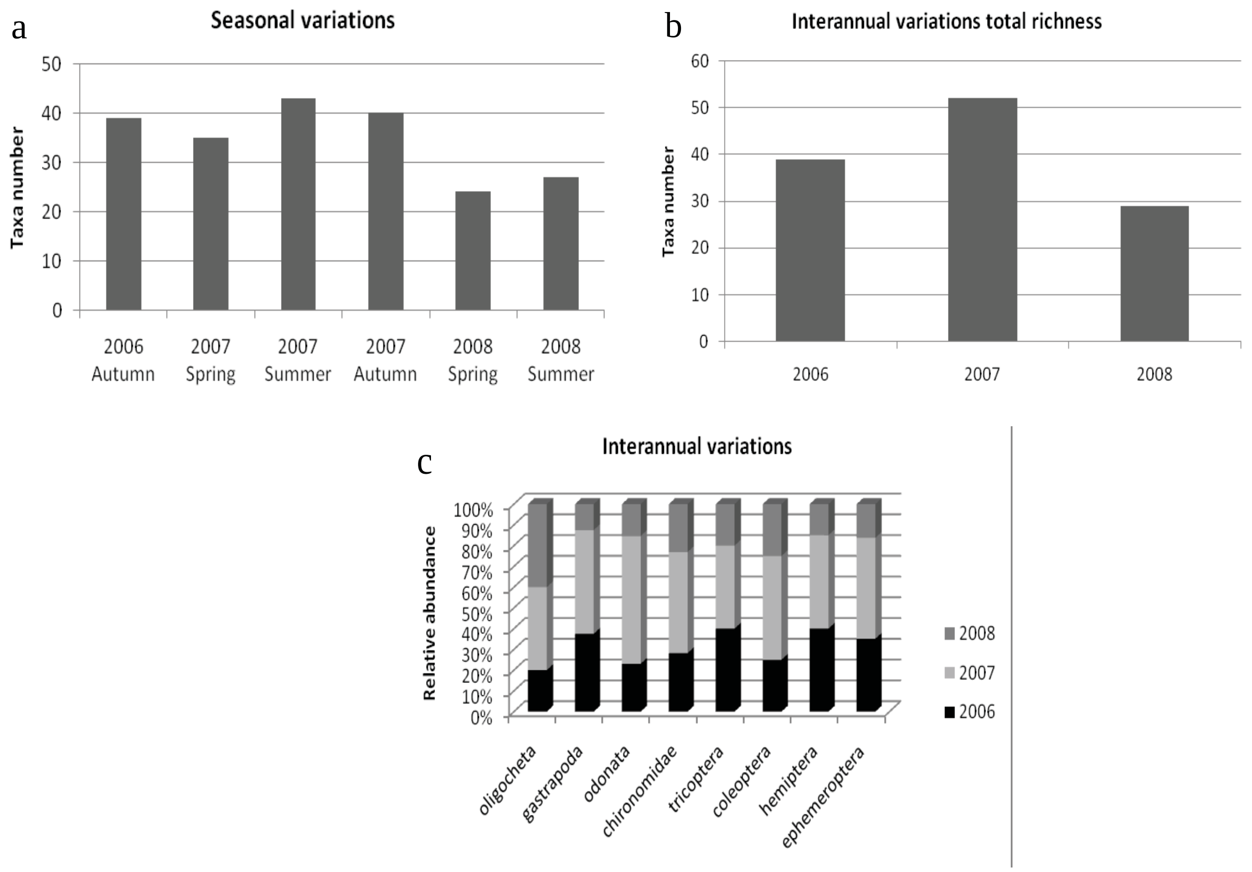

Fig. 2. Seasonal and interannual variations of taxa richness (a, b). Interannual variations of the relative abundances of macroinvertebrate taxa collected from Suleymanli Lake (c).

Table 3. Means of measured physical-chemical parameters and water quality classes according to the Turkish Standards. I: high quality water, II: weakly polluted water, III: polluted water, IV: high polluted water

Parameters	Mean value	Class
Temperature (ºC)	18.9	I
Conductivity (µs/cm)	272.4	-
Salinity (mg/l)	0	-
pH	8.13	I
TDS (mg/l)	121.6	I
dO_2 (mg/l)	7.87	I
NO_2^- (mg/l)	<0.05	I
PO_4 (mg/l)	<0.1	II
NH_4 (mg/l)	<0.13	II
Fe (mg/l)	<0.97	II
Cu^{2+} (mg/l)	<0.1	II
SO_4^- (mg/l)	<20	I
K^+(mg/l)	<5	II

0.685, 0.801 and 0.690 respectively from axis 1 to axis 4. Cumulative percentage variances of species-environment relation were 55.6, 68.6, 83.8 and 91.1 respectively. Sum of all canonical eigenvalues was 0.615. The pH and the temperature were positively correlated with the axis two (respective correlation factors were 0.772 and 0.532); while EC, dO_2, TDS and ORP were negatively correlated (respective correlation factors were -0.626, -0.634, -0.790 and -0.902). Species-environment biplot diagram from the PCA is shown in Fig. 3.

Discussion

The BBI, Rev. BMWP and ETBI were not very sensitive to slight changes between the sampling sites because samples were taken from relatively small stagnant water and sampling sites had also nearly the same characteristics. This situation was true for inorganic parameters too. However CS and Shannon–Weiner Diversity index differentiated

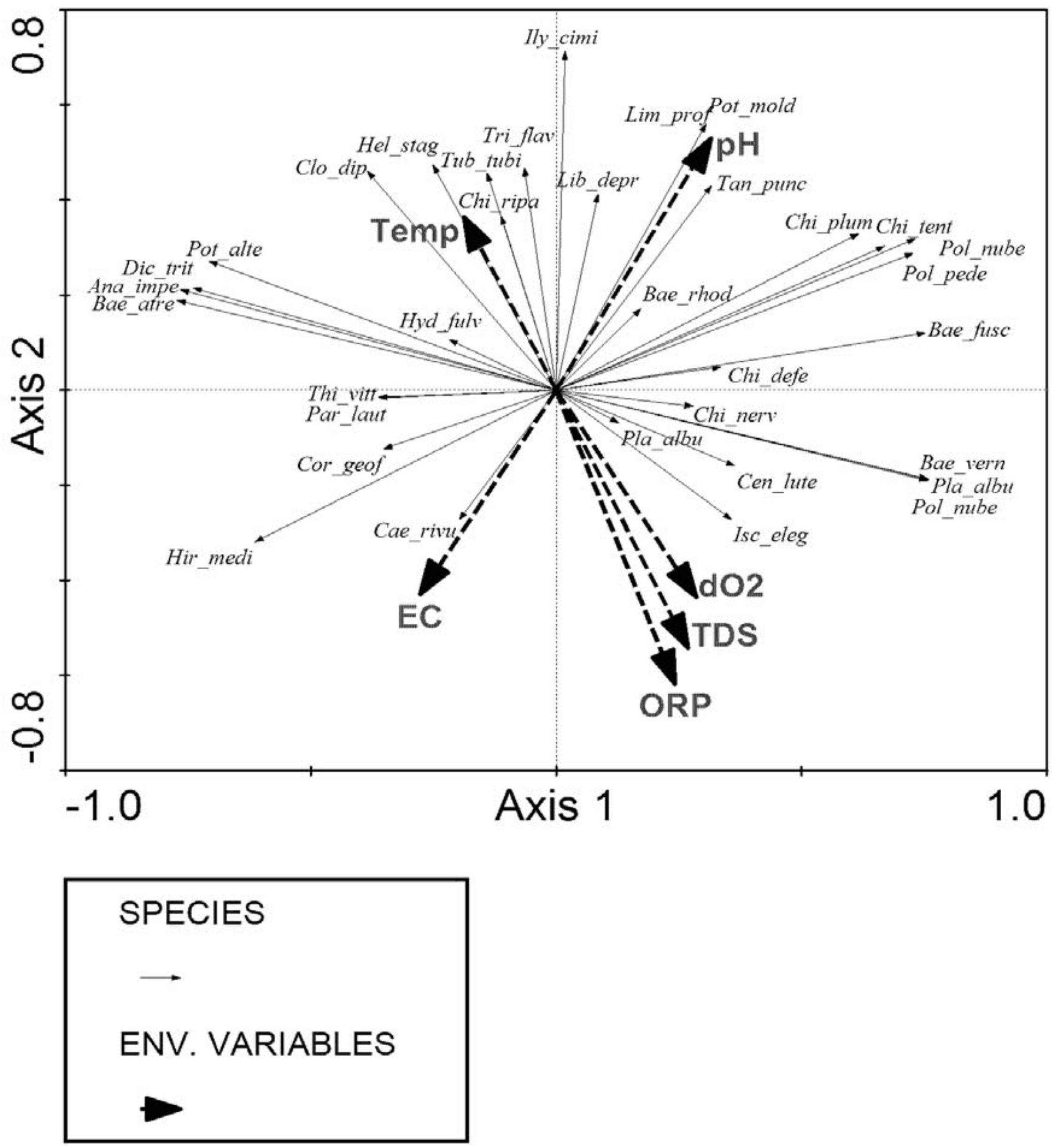

Fig. 3: Species-environment biplot diagram from Principal Component Analysis. Genus and species names are abbreviated.

very slightly between the stations. Besides, CS and Shannon-Weiner Diversity index, according to Rev. BMWP, BBI and ETBI index gave results compatible with physical-chemical results (Georgudaki *et al*. 2003, Duran 2006). Indeed, Suleymanli Lake is a mountain lake and it is absent from the effects of human impacts and urbanisation. Therefore, we were surprised while expecting the results of the applied biotic indices to be class I (clean). However, the water quality of the lake determined as between class II (fairly clear) and class IV (polluted). Probably, the most important factors for that result: the lake is shallow and eutrophic. Also, less precipitation ratios since the end of 2005 could be attributed to these conditions. Ayaz *et al*. (2007) in the same way emphasized that 'a decline in the amount of water carried by sources feeding the lake and a decrease in the rate of annual rainfall both cause the water level to drop considerably, especially in the summer months'. Besides, the reedy areas in the lake began to rise steadily and this increase in reeds might be caused by the formation of peat deposits.

Our PCA results confirm the important role of physicochemical conditions of water for the community composition of macroinvertebrates. Especially, *Tubifex tubifex*, *Limnodrilus profundico-*

la, *Potamothrix moldaviensis, Chironomus riparius* and *Tanypus punctipennis* which are tolerant to organic pollution (Hynes 1970, Hellawell 1986) was positively correlated with the temperature, while *Ischnura elegans*, *Caenis rivulorum*, *Baetis vernus* and *Centroptilum luteolum* which are intolerant to pollution (Rosenberg and Resh 1993) was positively correlated with the dissolved oxygen. The PCA results of our study also agree with the results of Haidekker, Hering (2008) that quantitative differences in benthic macroinvertebrate community can be partly explained by water temperature parameters. Most of the oligochaeta species were found during the summer period. Increasing temperatures might support eurythermic species and generalists, resulting in less specialised communities among lake types. Some certain taxa relates to general nutrient state, denoted by the terms oligotrophic, mesotrophic and eutrophic. Lang (1985) proposed a list of oligochaeta species identified as indicator species, also Sæther (1979) developed a lake trophic classification identifying 15 lake types using profundal chironomid assemblages from Nearctic and Palaearctic lakes. Furthermore, increasing water temperatures should be an ultimate threat to cold stenothermic aquatic insect species. Thermally specialized species, e.g. species with temperature-dependent life cycles for resource partitioning, might also be endangered by changing water temperatures. For example, Ephemeroptera taxa were reduced in 2008.

There was significant difference between water quality classifications of the applied biotic indices and Turkish Standards. According to our results water quality of Suleymanli Lake is determined between Class II (fairly clean) and Class IV (polluted) for biological parameters and determined as Class I (clean) for physicochemical data except in terms of phosphate, ammonia nitrogen, potassium, ferrous, copper and nitrite. Probably, drought and loss of water of the lake have been affected to fauna structure and reduced to water quality.

Climatic change will likely increase unintended or intended fluctuations of lake water levels, in particular in sub-arid regions of Europe. Further, the intensity of shoreline development is expected to increase in the future (Walz *et al.* 2002; Schmieder 2004). Both hydrological and morphological alterations clearly affect littoral and sub-littoral benthic invertebrate assemblages. The littoral zone of lakes plays a crucial and dynamic role in regulating the flows of nutrients and materials from the watershed. In this lake zone, benthic invertebrates take an intermediary position between primary producers and microbial decomposers. The results of the present study indicated that benthic invertebrates richness and diversity of Suleymanli Lake were moderate but the number of individual was high. Because water level fluctuations were also shown to reduce the diversity, or alter the composition of littoral habitats (Hellsten *et al.* 1996; Hill & Keddy 1992), and affect the littoral food chain through the loss of macrophytes as a food resource (Hill *et al.* 1998; Wilcox & Meeker 1992). Benthic invertebrates are biotic component of lake shores that are affected most severely by these alterations, since their low mobility restricts their ability to follow the receding water.

Current knowledge of benthic macroinvertebrates ecology and population dynamics is mostly based on data gathered from lakes in northern and central areas of Europe, and further studies need to be carried out to understand macroinvertebrate communities in Southern European lakes. Moreover, there is a general need to understand/determine benthic macroinvertebrate communities at lake reference conditions (Eur 22347 2006). Attention should be given to Mediterranean lakes that depart considerable from the contemporary limnological paradigm and of which there is still a limited knowledge of their flora, fauna and little understanding of biologically mediated ecological processes (Alvarez Cobelas *et al.* 2005). This study might be the most comprehensive work on benthic macroinvertebrate for Suleymanli Lake. In general it is indicated that it was not polluted by urbanisation yet. In particular, the drought effect in 2008 has shown itself in the form of a reduction taxa number. Therefore, the decrease of water quality in the lake might be caused by drought and it might revise again in a rainy period.

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