

Determination of influence of heavy metals on structure of benthic macroinvertebrate assemblages in low order Mediterranean streams by using canonical correspondence analysis

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ABSTRACT

1. The Köyceğiz-Dalyan Nature Reserve is an important wetland area in Eastern Mediterranean Region with wide variety of aquatic habitats. Its status was established as a Natural Reserve in the framework of the Barcelona Convention for the protection of the Mediterranean Sea in 1990.
2. The first and second order Mediterranean streams have cold karstic and associated waters, fed by karstic aquifers in study area. Some of them are dry in summer period.
3. The 10 collecting sites are characterised by small-sized (Kocaöz, Hamitköy and Çamlıdere Streams with 10-100 km² catchment areas) and medium-sized (Yuvarlakçay and Namnam Streams with 100-1000 km² catchment areas), calcareous with very low altitudes (< 200 m) according to System A of the EU Water Framework Directive (WFD).
4. Seventy-five species of benthic macroinvertebrates were identified. Relationships between benthic macroinvertebrate assemblages and the metal Zn, Cd, Ni, Cu, Fe, Mn and electrical conductivity, pH, Ca, dissolved oxygen and nitrate were explored by using canonical correspondence analysis.
5. While Fe, Cu, Mn, Zn and nitrate concentrations were low in all stations, Cd (between 0.217 and 0.24 mg/l), Ni (between 0.156 and 0.54 mg/l) and Ca concentrations were high in all stations.
6. According to canonical correspondence analysis, many species closely related with Cd and Ni and appear to be tolerant of high concentration of these metals because of high Ca concentrations and of high pH values of collecting sites.
7. These results emphasize the need for monitoring of heavy metals with other water quality variables in relation to conservation of the habitat quality of whole aquatic ecosystem.

KEY WORDS: Benthic macroinvertebrate, cadmium, canonical correspondence analysis, heavy metal, Köyceğiz Lake, Köyceğiz-Dalyan, nature reserve, Mediterranean stream, meromictic lake, Namnam Stream, nickel, stream order, Turkey, Water Framework Directive, water quality, Yuvarlakçay Stream.

Kanonik uyum analizi kullanılarak düşük nehir sıralı Akdeniz akarsularındaki taban büyük omurgasız toplulukları üzerine ağır metallerin etkilerinin belirlenmesi

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ÖZ

1. Köyceğiz-Dalyan Doğal Koruma Alanı, Doğu Akdeniz bölgesinde yer alan ve çeşitli sucul habitatları bünyesinde barındıran önemli bir sulak alandır. Bu bölge 1990 yılında, Akdeniz'in Korunması için Barcelona Sözleşmesi çerçevesinde doğal koruma alanı olarak kabul edilmiştir.
2. Çalışma alanındaki birinci ve ikinci nehir sırasındaki Akdeniz akarsuları soğuk, karstik sular olup karstik akiferlerden beslenmektedir. Bazıları yaz döneminde kurur.
3. On örnekleme istasyonu, Avrupa Topluluğu Su Çerçeve Direktifi (SÇD)'nin belirlediği A sistemine göre düşük irtifalarda (< 200 m) bulunan kalkerli, küçük boyutlu (10-100 km² havza alanlı Kocaöz, Hamitköy ve Çamlıdere Çayları) ve orta boyutlu (100-1000 km² havza alanlı Yuvarlakçay ve Namnam Çayları) akarsular üzerindedir.
4. Taban büyük omurgasızlarından 75 tür teşhis edilmiştir. Tür topluluklarının Zn, Cd, Ni, Cu, Fe, Mn, elektriksel iletkenlik, pH, Ca, çözünmüş oksijen ve nitrat ile olan ilişkileri kanonik uyum analizi kullanılarak belirlenmiştir.
5. Fe, Cu, Mn, Zn ve nitrat konsantrasyonları tüm istasyonlarda düşük çıkarken, Cd (0.217 - 0.24 mg/l), Ni (0.156 - 0.54 mg/l), ve Ca konsantrasyonları tüm istasyonlarda yüksek çıkmıştır.
6. Kanonik uyum analizine göre, birçok tür Cd ve Ni ile yakın ilişkilidir ve istasyonlardaki yüksek Ca konsantrasyonu ve yüksek pH değerlerinden dolayı bu metallerin yüksek konsantrasyonlarına karşı dayanıklıdırlar.
7. Bu sonuçlar, tüm sucul ekosistemin habitat kalitesinin korunmasıyla ilişkili olarak diğer su kalite değişkenleriyle birlikte ağır metallerin de izleme çalışmalarında yer alması gerektiğini vurgulamaktadır.

ANAHTAR KELİMELER: Ağır metal, Akdeniz akarsuları, kadmiyum, kanonik uyum analizi, Köyceğiz Gölü, Köyceğiz-Dalyan koruma alanı, meromiktik göl, Namnam Çayı, nehir sırası, nikel, Su Çerçeve Direktifi, su kalitesi, taban büyük omurgasızları, Türkiye, Yuvarlakçay.

INTRODUCTION

Macroinvertebrates are ideal indicator organisms as various taxa are associated with different levels of water quality. Macroinvertebrates also inhabit a vital position in the food chain of aquatic systems and therefore can be used to make estimates of ecosystem health (Bode and Novak 1995). Analysis of macroinvertebrate assemblages is also time and cost efficient compared to chemical and physical assessments of water quality which provide little insight into temporal variation in conditions (Bode *et al.* 1996).

The distribution of benthic macroinvertebrates and their relation to environmental variables are not well known in Turkey (Kazancı 1993, Kazancı and Dügel 2000), but various researchers have been applied various water quality indices based on benthic macroinvertebrates and multivariate technics recently (Kazancı and Dügel 2000, Kazancı *et al.* 2003, Duran *et al.* 2003, Dügel and Kazancı 2004, Girgin, Kazancı and Dügel 2003, Kazancı, Dügel and Girgin 2008, Kazancı and Türkmen 2008, Kazancı *et al.* 2008a, Kazancı *et al.* 2008b, Kazancı and Dügel 2008, Kazancı *et al.* 2009, Kazancı and Türkmen 2010, Girgin 2010).

The benthic macroinvertebrate community structure, physical and chemical properties of running waters especially of low-order streams in Mediterranean Region are seriously influenced by drought and flood.

The Köyceğiz-Dalyan Nature Reserve is an important wetland area in eastern Mediterranean Region. From the hydrobiological point of view, the importance of the region is due to the existence of a wide variety of aquatic habitats (four lagoon lakes, sulphuric thermal springs around and bottom of the Köyceğiz Lake, the labyrinth-like channel system between Köyceğiz Lake and Mediterranean Sea and six streams inflowing to Köyceğiz Lake) and to the presence of valuable aquatic plant and animal communities. Centre of this system is the meromictic Köyceğiz Lake. The lake fed by six streams belong to first and second order and by groundwater sources. Some of them are dry in summer period (Kazancı 1993, Kazancı and Dügel 2000).

Due to the complicated structure of the aquatic ecosystem, this region is one of the most important and sensitive Mediterranean limnosystem in Turkey. Its status was established as a Natural Reserve in the framework of the Barcelona Convention for protection of Mediterranean Sea in 1990 (Kazancı 1993).

The present study was carried out to determine composition of benthic macroinvertebrates and the relationships between their distribution and the metal Zn, Cd, Ni, Cu, Fe, Mn and electrical conductivity, pH, Ca, dissolved oxygen and nitrate at various locations of streams by using canonical correspondence analysis.

MATERIAL AND METHODS

Site description

The streams have cold karstic and associated waters, located around Köyceğiz Lake, fed by karstic aquifers in Köyceğiz-Dalyan Nature Reserve. Their chemical compositions indicate a typical rock-water interaction observed in carbonate aquifers. These streams discharge from limestone, dolomite and along the contact between limestone and ophiolite or alluvium (Bayarı *et al.* 1995). Some of these streams are dry during summer period. The 10 collecting sites are characterised (based on catchment area) by small-sized (Kocaöz, Hamitköy and Çamlıdere Streams with 10-100 km² catchment areas) and medium-sized (Yuvarlakçay and Namnam Streams with 100-1000 km² catchment areas), calcareous with very low altitudes (< 200 m) according to System A of the EU Water Framework Directive (WFD).

Typical Mediterranean climate with hot, dry summers and mild, wet winters prevails in the area. Based on the long term average data, the mean annual precipitation over the basin is 1202 mm. The mean annual temperature is about 18°C (Bayarı *et al.* 1995). The streams in the basin draining various geologic units discharge into the meromictic Köyceğiz Lake.

Physical and chemical analyses

The experimental design included collection of the water samples and macroinvertebrates from 10 sites. Dissolved oxygen (oxygen meter, OXI 96/B Set, WTW), temperature, pH (pH meter 91/Set WTW) and conductivity (LF 95/ Set WTW) were determined immediately after sample collection.

A suite of chemical variables, including Zn, Cd, Ni, Cu, Fe, Mn was assayed by DSI (State Water and Hydraulic Works). Nitrate and Ca were determined according to Merck (1986). A Hach DR 2000 photometer was used for spectrophotometric measurements.

Benthic macroinvertebrate sampling

The 10 sites were sampled between April 1992 and April 1993 (number of samples were given in Table 1). Each benthic macroinvertebrate sample was a fifteen minute collection with a standard pond net, obtained by both kicking and sweeping all available biotopes. Animals were sorted in the laboratory, preserved in alcohol, and identified to the lowest possible taxonomic level (Table 2).

Data analysis

Relationships between macroinvertebrate taxa and environmental variables were explored by canonical correspondence analysis (CCA; Ter Braak 1988).

RESULTS AND DISCUSSION

Many trace elements are important for terrestrial or aquatic ecosystem and some of them are required micro nutrients for plant, human or animal life such as Cu, Zn, Fe, Mn only becoming toxic at high concentrations. But Cd, Hg, Pb, U are non-essential and their physiological or biochemical functions are unknown and are toxic at very low concentrations (Bashkin 2002).

The heavy metals can be found in many forms in aquatic habitats. Increased contamination of the running water ecosystems by heavy metals from industrial, agricultural and domestic wastes requires detailed analysis of community structure of various organisms like benthic macroinvertebrates. The bioavailability of heavy metals in aquatic ecosystems is related to a wide variety of physical and chemical factors such as the pH, hardness, temperature, dissolved oxygen, electrical conductivity and nutrient concentrations (Mance 1987).

According to criterion values of “Regulation on Water Pollution Control” (Ministry of Environment and Forestry 2004) while Fe, Cu, Mn and Zn concentrations were low in all stations, Cd and Ni were high in all stations (Table. 1).

The Zn concentrations in the water samples were between 0.001 and 0.019 mg/l (0,2 mg/l is in class I in Turkish Standart), Cu between 0.006 and 0.071 mg/l (0.02 mg/l is in class I and 0.1 mg/l in class III in Turkish Standart), Mn between 0 and 0.13 mg/l (0,1 mg/l is in class I in Turkish Standart), Cd between 0.217 and 0.24 mg/l (0.01 mg/l is in class IV in Turkish Standart), Ni between 0.156 and 0.54 mg/l (0.02 mg/l is in class IV in Turkish Standart), Fe between 0.004 and 0.116 mg/l (3 mg/l is in class I in Turkish Standart).

Dissolved oxygen values were near saturation at all times at all sites except for the site 15 and site 16 which were impacted by domestic waste water discharge into these streams (Table 1). The higher levels of electrical conductivity and Ca at all sites is a reflection of the geological structure of Köyceğiz-Dalyan Nature Area and effects of the meromictic Köyceğiz Lake in the study area. The reason of high values of electrical conductivity were also water pollution. The physicochemical characteristics and heavy metal levels of streams were affected by water discharge from groundwater sources (karstic aquifers), surface water input from surrounding farmland and settlements in studied area.

Table 1. Mean, minimum (min.), maximum (max.) values of physical and chemical variables.

Site and no	<i>n</i>		EC	pH	DO	Ca	N-NO ₃	Cu*	Fe*	Mn*	Zn*	Ni*	Cd*
			(mS/cm)		(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Yuvarlakçay After	7	min.	0.23	7.98	7.4	120.2	0						
Fishfarm		max.	0.43	8.31	11.6	160.3	0.096						
(4)		mean	0.32	8.07	9.5	138.5	0.04	0.022	0.032	0.009	0.0045	0.138	0.166
Nasıfdede	7	min.	0.33	7.75	6.3	152.3	0.025						
(6)		max.	0.63	8.3	11.1	320.6	0.412						
		mean	0.46	7.9	8.6	191	0.16	0.026	0.016	0	0.0008	0.064	0.079
Yuvarlakçay After	7	min.	0.3	7.81	6.6	128.3	0.12						
Nasıfdede		max.	0.57	8.8	11.2	192.4	0.39						
(7)		mean	0.4	8.1	8.5	175.2	0.23	0.026	0.006	0	0.0008	0.111	0.102
Mouth of Yuvarlakçay	7	min.	0.31	8.13	8.6	136.3	0.14						
(8)		max.	0.51	8.64	14.4	192.4	0.31						
		mean	0.4	8.32	12.1	159.2	0.2	0.037	0.096	0.006	0.0193	0.025	0.052
Namnam Old Bridge	3	min.	0.29	8.25	9.5	64.1	0						
(9)		max.	0.44	8.7	12.2	160.3	0.14						
		mean	0.38	8.4	10.6	92.6	0.05	0.014	0.028	0.001	0.0013	0.156	0.217
Namnam New Bridge	7	min.	0.29	7.73	5.9	64.13	0						
(10)		max.	0.51	8.68	14	120.2	0.15						
		mean	0.4	8.4	11.8	85.8	0.06	0.022	0.032	0.009	0.0045	0.138	0.166
Kocaöz	6	min.	0.25	7.56	6.3	64.13	0						
(13)		max.	0.5	8.8	12.9	192.4	0.35						
		mean	0.36	8.2	8.5	91.6	0.11	0.026	0.005	0.013	0.016	0.093	0.197
Hamitköy	6	min.	0.36	7.61	6.2	48.1	0						
(14)		max.	0.66	8.52	18.1	192.4	0.15						
		mean	0.48	8.24	12.3	106.5	0.05	0.071	0.092	0.007	0	0.142	0.185
Sarıöz	7	min.	0.29	7.67	1.8	56.11	0						
(15)		max.	0.62	8.5	13.8	160.3	0.25						
		mean	0.42	8.03	7.9	103.1	0.08	0.058	0.116	0	0.0001	0.125	0.125
Çamlıdere	7	min.	0.3	7.9	5	80.16	0						
(16)		max.	0.65	8.23	9.9	176.4	0.35						
		mean	0.38	8.05	6.9	115	0.13	0.006	0.004	0.009	0.0019	0.054	0.24

n = number of samples; * = one sample, dissolved oxygen (DO), electrical conductivity (EC)

Mn and Zn

Aeschna sp., *Acroloxus lacustris*, *Sericostoma* sp., *Rhyacophyla* sp., *Erpobdella octoculata*, Elmidae gen. sp. 1, Elmidae gen. sp.2, *Elmis* sp., *Dina lineata concolor*, Empididae gen. sp., *Oxyethira* sp., *Heliopsis* sp., Naididae gen. sp., Ostracoda, Tabanidae gen. sp., *Lepidostoma* sp., *Gammarus* sp., *Atherix ibis* were positively related to Mn and Zn but negatively Fe, Cu and electrical conductivity (Figure 1). According to Mance (1987) aquatic insects, annelids, gastropods, crustaceans are tolerant of Zn. It has been established that Oligochaeta accumulate intensely Zn and Mn (Mance 1987). Naididae gen. sp. was also associated with Zn (0-0.325 mg/l) and Mn (0-0.820 mg/l) in Ankara Stream in Turkey (Kazancı and Girgin 1998). According to Armitage (1980) Ephemeroptera species were particularly sensitive to Zn. In this study, Ephemeroptera species were not related to Zn. Roline (1988) reported that *Rhyacophyla* was intolerant to heavy metal pollution. In our study *Rhyacophyla* was closely related to Mn.

The species richness was not high in this quadrant. Thorp and Lake (1973) reported that the species richness and abundances were negatively affected by zinc and cadmium in a Tasmanian Stream exposed to mine wastes. Armitage (1980) reported that zinc negatively impacts richness and abundance of benthic macroinvertebrate fauna of an English river.

Nitrate and Ca

Ecdyonurus sp., *Gerris najas*, *Gomphus flavipes*, *Aphelocheirus aestivalis*, *Pisidium casertanum casertanum*, *Theodoxus fluviatilis*, *Melanopsis praemorsa*, *Calopteryx splendens*, *Peltodytes* sp., *Psychoda* sp., *Dugesia* sp., *Culicoides* sp., *Gyraulus piscinarum*, *Limnephilus* sp. were positively related to nitrate and Ca and was negatively correlated with Cd, pH, Ni and dissolved oxygen (Figure 1). These species appear to be tolerant of organic pollution. The soft bodied forms like mollusks, flatworms are less tolerant of heavy metal ions (Brinkhurst and Cook 1974).

According to Streble and Krauter (1988) genus *Ecdyonurus*, *Aphelocheirus aestivalis* are oligosaprobic and betamesosaprobic; *Pisidium casertanum casertanum* is oligosaprobic betamesosaprobic and alphamesosaprobic (Nesemann and Reischütz 1995); *Theodoxus fluviatilis*, *Calopteryx splendens*, *Gerris najas*, *Limnephilus* are betamesosaprobic; *Psychoda* sp. is alphamesosaprobic. According to Rosenberg and Resh (1993) genus *Dugesia* is betamesosaprobic and oligosaprobic; *Gyraulus piscinarum* is betamesosaprobic. Saprobic level of *Melanopsis praemorsa* is not clear. But they appear to be tolerant of slight and moderate organic pollution. Kazancı *et al.* (2008a) reported that genus *Melanopsis* was positively related to temperature.

Genus *Peltodytes* is alphamesosaprobic (Sporka 2003). Genus *Culicoides* is alphamesosaprobic and betamesosaprobic (CSN 75 (7716)1998).

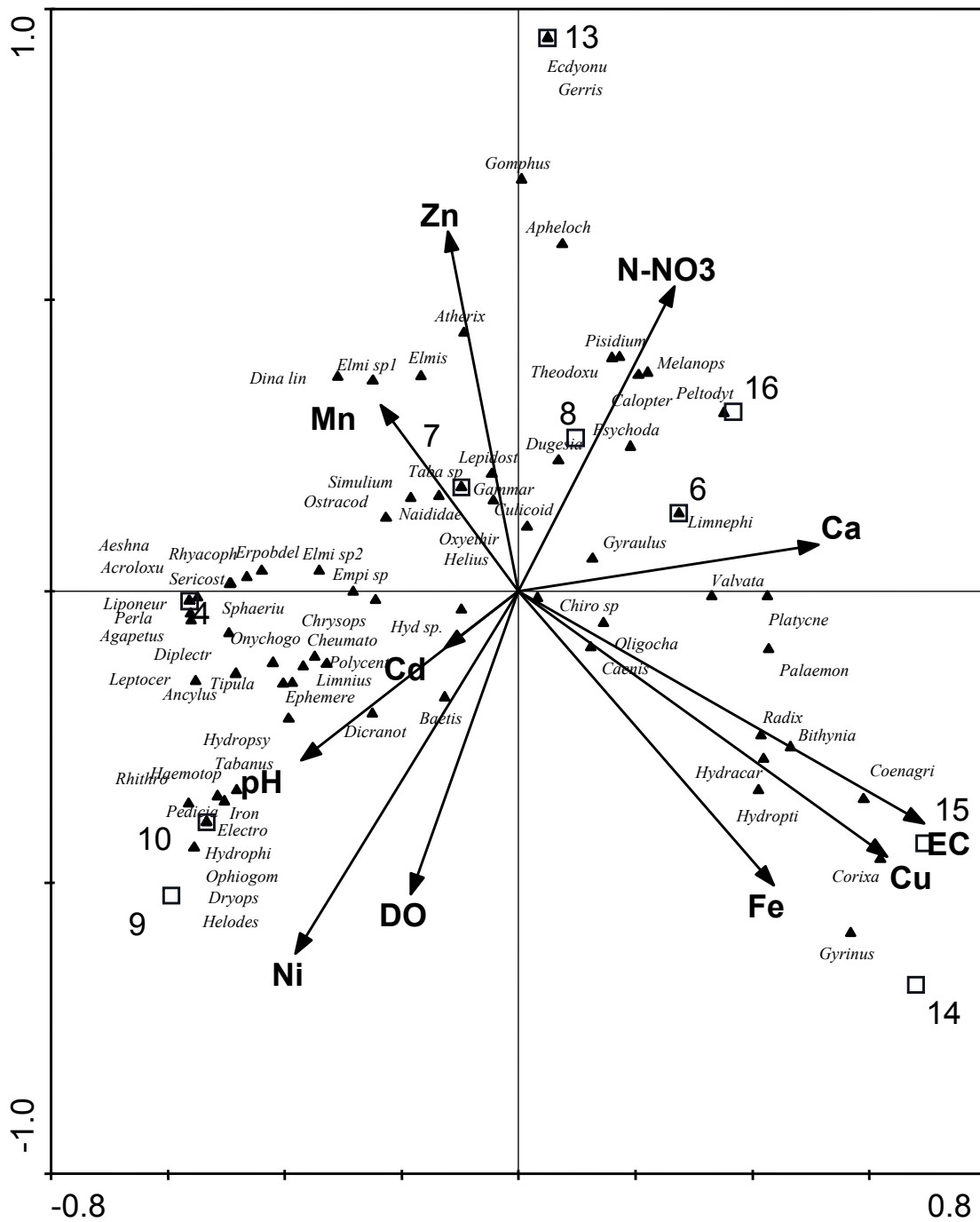


Figure 1. Canonical correspondence diagram for 10 sites for streams in Köyceğiz-Dalyan Nature Reserve. Sites are indicated by squares; species are indicated by triangles. For environmental variable and site codes see Table 1, whereas for species codes Table 2.

Table 2. Taxa list of benthic macroinvertebrates and their abbreviations in the CCA.

<i>Dugesia</i> sp.	Dugesia	<i>Peltodytes</i> sp.	Peltodyt
<i>Theodoxus fluviatilis</i>	Theodoxu	<i>Dryops</i> sp.	Dryops
<i>Valvata piscinalis</i>	Valvata	<i>Gyrinus caspius</i>	Gyrinus
<i>Bithynia tentaculata</i>	Bithynia	<i>Hydrophilus</i> sp.	Hydrophi
<i>Melanopsis praemorsa</i>	Melanops	<i>Elmidae</i> gen. sp. 1	Elmi sp1
<i>Radix peregra</i>	Radix	<i>Elmidae</i> gen. sp. 2	Elmi sp2
<i>Gyraulus piscinarum</i>	Gyraulus	<i>Elmis maugetii</i>	Elmis
<i>Acroloxus lacustris</i>	Acroloxu	<i>Limnius</i> sp.	Limnius
<i>Ancylus fluviatilis</i>	Ancylus	<i>Helodes elongata</i>	Helodes
<i>Pisidium</i> sp.	Pisidium	<i>Rhyacophila</i> sp.	Rhyacoph
<i>Sphaerium</i> sp.	Sphaeriu	<i>Agapetus</i> sp.	Agapetus
<i>Dina lineata concolor</i>	Hirudine	<i>Hydroptilidae</i> gen. sp.	Hyd sp.
<i>Erpobdella octoculata</i>	Erpobdel	<i>Hydroptila aegypta</i>	Hydropti
<i>Oligochaeta</i> gen. sp.	Oligocha	<i>Oxyethira</i> sp.	Oxyethir
<i>Naididae</i> gen. sp.	Naididae	<i>Diplectrona</i> sp.	Diplectr
<i>Hydracarina</i> sp.	Hydracar	<i>Hydropsyche</i> sp.	Hydropsy
<i>Ostracoda</i>	Ostracod	<i>Cheumatopsyche</i> sp.	Cheumato
<i>Palaemonetes antennarius</i>	Palaemon	<i>Polycentropus</i> sp.	Polycent
<i>Gammarus</i> sp.	Gammar	<i>Limnephilus</i> sp.	Limnephi
<i>Baetis</i> sp.	Baetis	<i>Lepidostoma</i> sp.	Lepidost
<i>Iron</i> sp.	Iron	<i>Leptocerus</i> sp.	Leptocer
<i>Rhithrogena</i> sp.	Rhithro	<i>Sericostoma</i> sp.	Sericost
<i>Ecdyonurus</i> sp.	Ecdyonu	<i>Liponeura</i> sp.	Liponeur
<i>Electrogena</i> sp.	Electro	<i>Tipula maxima</i>	Tipula
<i>Ephemerella</i> sp.	Ephemere	<i>Pedicia</i> sp.	Pedicia
<i>Caenis luctuosa</i>	Caenis	<i>Dicranota</i> sp.	Dicranot
<i>Perla caucasica</i>	Perla	<i>Helius longirostris</i>	Helius
<i>Calopteryx splendens</i>	Calopter	<i>Psychoda</i> sp.	Psychoda
<i>Platycnemis pennipes</i>	Platycne	<i>Simulium variegatum</i>	Simulium
<i>Coenagrion</i> sp.	Coenagri	<i>Chironomidae</i> gen. sp.	Chiro sp
<i>Aeshna</i> sp.	Aeshna	<i>Culicoides</i> sp.	Culicoid
<i>Gomphus</i> sp.	Gomphus	<i>Empididae</i> gen. sp.	Empi sp
<i>Onychogomphus forcipatus</i>	Onychogo	<i>Chrysops</i> sp.	Chrysops
<i>Ophiogomphus cecilia</i>	Ophiogom	<i>Haemotopota puluviatilis</i>	Haemotop
<i>Corixa affinis</i>	Corixa	<i>Tabanidae</i> gen. sp.	Taba sp
<i>Aphelocheirus aestivalis</i>	Apheloch	<i>Haemotopota puluviatilis</i>	Haemotop
<i>Gerris najas</i>	Gerris	<i>Tabanus</i> sp.	Tabanus
		<i>Atherix ibis</i>	Atherix

Cd, Ni, pH, dissolved oxygen

Iron caucasica, *Electrogena* sp., *Ephemerella ignita*, *Rhithrogena* sp., *Baetis* sp., *Liponeura* sp., *Perla caucasica*, *Agapetus* sp., *Diplectrona* sp., *Polycentropus* sp., *Leptocerus* sp., Hydroptilidae gen. sp., *Cheumatopsyche* sp., *Hydropsyche* sp., *Onychogomphus forcipatus*, *Ophiogomphus cecilia*, *Tipula maxima*, *Pedicia* sp., *Dicranota* sp., *Haemotopota puluviatilis*, *Tabanus* sp., *Dryops* sp., *Hydrophilus* sp., *Helodes elongata*, *Limnius* sp., *Chrysops* sp., *Ancylus fluviatilis* were related to Cd, Ni, dissolved oxygen and pH but negatively with nitrate nitrogen and Ca (Figure 1). These taxa tended to tolerate high concentrations of Cd and Ni and preferred alkaline, organically unpolluted habitat with low Ca concentration. According to Mance (1987) water hardness may have an ameliorating effect on Ni and Cd toxicity. The response of benthic macroinvertebrates to heavy metal toxicity at low oxygen concentrations is unclear. But the impacts of Cd on insects decreased at lower oxygen concentrations because of lower metabolism and consequently lower Cd uptake (Clubb *et al.* 1975). Many insect taxa were appear to be tolerant Cd and Ni at high oxygen concentrations in this study (Fig. 1).

Some species of Trichoptera and Ephemeroptera are highly tolerant of heavy metal pollution (Rosenberg and Resh 1993). According to Sjobakk *et al.* (1997) Ephemeroptera was more tolerant of Cd and Ni than Trichoptera and Plecoptera. Sumi *et al.* (1991) reported that selective induction of metal-binding proteins in the gut of a *Baetis* species is the most likely explanation for the high tolerance of mayfly larvae to heavy metals.

Onychogomphus sp. was also closely related to Cd in Ankara Stream (Girgin *et al.* 2003). *Perla*, *Limnius volckmari*, *Rhyacophyla dorsalis*, *Polycentropus flavomaculatus*, *Hydropsyche pellucidula*, *Tipula* spp., *Dicranota* sp. tended to accumulate Cd to lower concentrations than *Baetis* spp., *Rhithrogena* sp., *Ephemerella ignita* (Burrows and Whitton 1983). These genera were also related to Cd in this study.

Baetis and *Hydropsyche* are tolerant of heavy metal pollution (Roline 1988). *Baetis* and *Hydropsyche* were closely related to Cd and Ni in this study. But according to Roline (1988) *Rhyacophyla* is intolerant to heavy metal pollution. In this study *Rhyacophyla* was also closely related to Mn in very low concentration.

Fe, Cu, Electrical conductivity

Gyrinus caspius, *Corixa affinis*, *Hydroptila aegyptia*, *Hydracarina* sp., *Coenagrion* sp., *Bithynia tentaculata*, *Radix peregra*, *Paleomonetes antennarium*, *Valvata piscinalis*, *Platynemis pennipes*, *Caenis luctuosa*, Oligochaeta gen. sp. associated with Fe, Cu and electrical conductivity and were negatively related to Mn and Zn. Chironomidae gen. sp. was in the center of the CCA diagram because of weak correlation with variables (Figure 1).

The effect of Fe in aquatic animals are mainly indirect by disturbing metabolism and osmoregulation and by deteriorating quality of habitats and food resources. The direct and indirect impacts of Fe contamination decrease the species diversity of periphyton, benthic macroinvertebrates and fishes (Vuori 1995). The Fe concentrations of collecting sites were low in this study (Table 1).

Fe is of practically significant in the distribution of Trichoptera larvae. Most of the Trichoptera genera occur over a wide range of Fe concentrations (Roback 1965). Only *Hydroptila aegyptia* associated with Fe in this study. Hydroptilidae gen. sp., *Hydropsyche*, *Cheumatopsyche*, *Polycentropus*, *Sericostoma*, *Diplectrona*, *Agapetus* were closely related to Cd and Ni. *Rhyacophyla* closely related to Mn.

The negative effects of low concentrations (as low as 5µg/l) of Cu on benthic macroinvertebrate species richness were reported (Leland *et al.* 1986). The number of taxa in this quadrant was lower than other quadrants. There were one Ephemeroptera species (*Caenis luctuosa*) related to Cu. Gower *et al.* (1994) found that mayfly larvae were absent from streams with the highest Cu concentrations.

As a result of this study, Cd and Ni concentrations were high in the study area. Benthic macroinvertebrates demonstrate individual level responses as well as community level responses to metals. Community level responses often are used to evaluate the effects of metals on benthic macroinvertebrates. Invertebrate taxa richness is reduced by exposure of metals, as metal sensitive species are eliminated (Clements and Kiffney 1995). But in this study, many of the species closely related with cadmium and nickel and appear to be tolerant of high concentration of these metals because of high Ca concentrations and of high pH values of collecting sites (Table).

The results of the present study emphasize that the basic necessity for monitoring of heavy metals with other water quality variables in Köyceğiz-Dalyan Nature Reserve, as part of the efforts to conservation of the habitat quality of whole aquatic ecosystem.

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