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Discovering the Hidden Biodiversity of Crustacea (Branchiopoda, Maxillopoda and Ostracoda) Assemblages in the High Mountain Lakes of Kackar Mountains (Turkey)

Cem Aygen, Didem Ozdemir Mis and M. Rusen Ustaoglu
Department of Marine-Inland Water Sciences and Technology, Faculty of Fisheries,
Ege University, 35100 Bornova, Izmir, Turkey

Abstract: The Branchiopoda, Maxillopoda and Ostracoda fauna of 59 high mountain lakes of Kackar mountains was investigated for the first time. During the study, six expeditions were carried out in the Summers of 2005-2007. All lakes are located at altitudes between 2530 and 3370 m except Uzungol (1100 m). Beside the biological samplings, major environmental variables of the lakes were measured. A total of 21 Branchiopoda, 9 Maxillopoda and 3 Ostracod taxa were identified. All the taxa identified are new records for their localities except *C. ponticus*. The investigated ecosystems support a high micro-crustacean diversity that must be adequately preserved due to the increasing direct and indirect impacts on high mountain lakes.

Key words: Branchiopoda, maxillopoda, ostracoda, Kackar mountains, biodivesity, Eastern Black sea, Turkey

INTRODUCTION

High mountain lakes are extreme ecosystems and at first glance, appear inappropriate environments. Nutrient deficiency, low temperatures intensive UV radiation or darkness for months make high mountain lakes extraordinary aquatic habitats.

Because high mountain lakes are small and their trophic webs are less complex than those of lowland lakes they are suitable for measuring and understanding ecological processes.

Often located in remote areas, high mountain lakes are also studied to investigate community structure and flow in isolation from human influence, subject only to natural forcing (Such as climate variability) or to long-range human impact such as the impact of atmospheric pollutants.

In the late 19th and early 20th centuries many high-altitude lakes in the European Alps were inventoried and their plankton fauna and flora were described in detail. There are number of recent studies on the micro-crustaceans of Turkey but almost all of these were carried out in lowland lakes. Only a few studies of high mountain lakes are available.

A recent study of the zooplankton species diversity is very high (Ustaoglu *et al*., 2005; Aygen *et al*., 2009). Additionally, some rare species such as *Hemidiaptomus kummerloewei* Mann, 1940 included in the IUCN red list of threatened species, only occurs in those sheltered areas. The lack of previous studies dealing with high mountain lakes limits the ability to adequately conserve these unique environments. This study therefore, presents results of a study on the composition of crustaceans in the high mountain lakes of Eastern Black sea coast of Turkey.

Study area: The Pontic mountain range (Eastern Black sea coast) is one of the three major glacier regions of Turkey. The highest peak of the Pontic range is Mount Kackar (3932 m) where five glaciers are formed. Some of the lakes studied located within the Kackar Mountains National park.

The National park is situated in the East Black sea region in the North-Eastern corner of Turkey. The park was created in 1994 and covers 51,500 ha.

Results of this study also will contribute to biodiversity of the Kackar Mountains National park. The locations of the 59 lakes studied as well as the characteristics of the sampling sites are shown in Fig. 1 and Table 1.

The lakes in Kackar mountains are small in size (From 0.03-8.9 ha) and shallow (Maximum depths ranging from <1 m up to 49 m). They remain frozen from October or November until May or June and their small size brings about rapid gains and loss in heat. When the altitudes of the lakes take into account, all lakes situated between 2530 and 3370 m except Uzungol (1100 m).

Corresponding Author: Cem Aygen, Department of Marine-Inland Water Sciences and Technology, Faculty of Fisheries, Ege University, 35100 Bornova, Izmir, Turkey

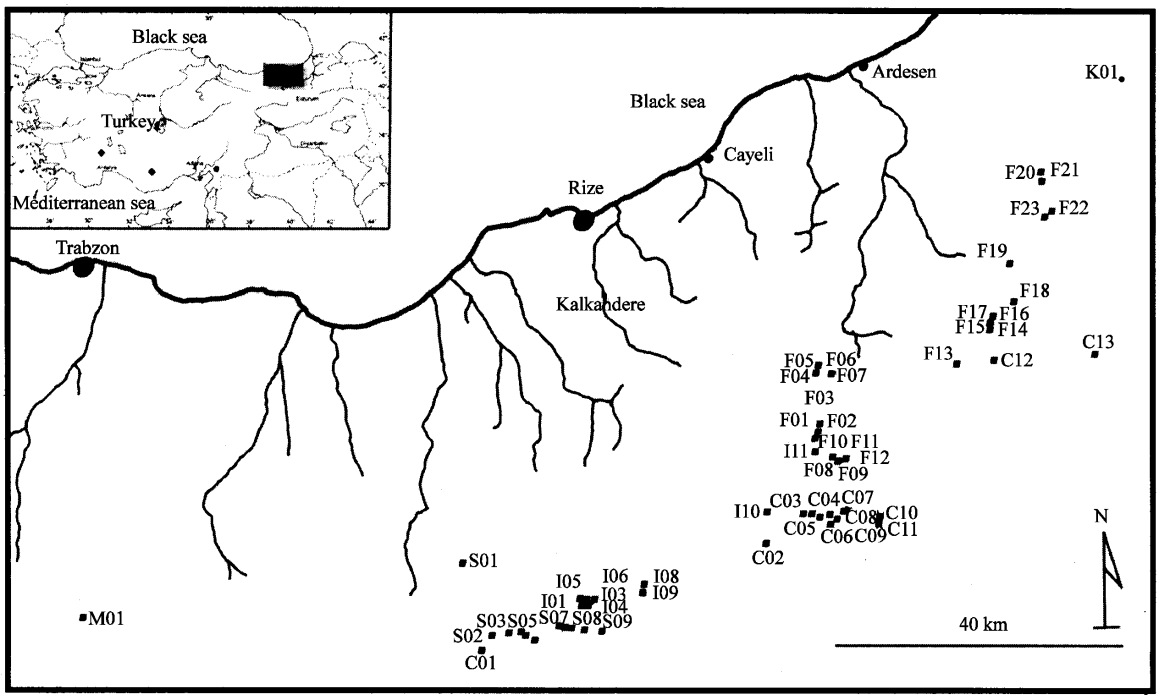

Fig. 1: Map of Eastern Black sea range in Turkey

Table 1: Investigated localities and sampling dates

Basin code	Date	Locality	Basin	Altitude	Coordinates
C01	30.07.2007	Goloba lake (Valley of Goloba)	Coruh river	2540	40°30'36"N 40°19'12"E
C02	19.08.2005	Dagbasi lake (Valley of Ovit)	Coruh river	2710	40°37'02"N 40°46'47"E
C03	04.08.2006	Batiaksu lake (Valley of Aksu)	Coruh river	3050	40°39'13"N 40°50'39"E
C04	04.08.2006	Kuzeyaksu lake (Valley of Aksu)	Coruh river	3070	40°39'19"N 40°50'57"E
C05	04.08.2006	Doguaksu lake (Valley of Aksu)	Coruh river	3120	40°39'09"N 40°51'06"E
C06	26.07.2007	Ortagol lake (Ovit Yedigoller)	Coruh river	2960	40°38'51"N 40°52'09"E
C07	19.08.2005	Ustgol lake (Mor yayla Yedigoller)	Coruh river	3030	40°38'51"N 40°52'54"E
C08	06.07.2005 19.08.2005	Adaligol lake (Mor yayla Yedigoller)	Coruh river	3020	40°38'43"N 40°53'10"E
C09	06.07.2005 19.08.2005	Ortagol lake (Mor yayla Yedigoller)	Coruh river	3010	40°38'53"N 40°53'18"E
C10	06.07.2005 19.08.2005	Buyukgol lake (Mor yayla Yedigoller)	Coruh river	2980	40°38'45"N 40°53'36"E
C11	19.08.2005	Altgol lake (Mor yayla Yedigoller)	Coruh river	2950	40°38'53"N 40°53'40"E
C12	23.08.2006	Deniz lake (Valley of Bahral)	Coruh river	3370	40°49'07"N 41°09'39"E
C13	24.08.2006	Kartal lake (Valley of Bahral)	Coruh river	2940	40°50'20"N 41°18'04"E
C14	24.08.2006	Devise lake (Valley of Bahral)	Coruh river	2935	40°50'22"N 41°18'12"E
F01	22.08.2005	Keci lake (Valley of Cermes)	Firtina stream	3070	40°44'25"N 40°51'50"E
F02	22.08.2005	Cermes Karagol lake (Valley of Cermes)	Firtina stream	2990	40°44'37"N 40°52'04"E
F03	09.07.2005 22.08.2005	Cermes lake (Valley of Cermes)	Firtina stream	2780	40°44'58"N 40°52'09"E

Table 1: Continued

Basin code	Date	Locality	Basin	Altitude	Coordinates
F04	25.08.2007	Kayakaynak lake (Valley of Ambarlik)	Firtina stream	3080	40°49'17"N 40°52'43"E
F05	25.08.2007	Buyuk Balikli lake (Valley of Ambarlik)	Firtina stream	2990	40°49'28"N 40°52'51"E
F06	01.08.2006	Sirpal lake (Valley of Cahberik)	Firtina stream	2940	40°49'21"N 40°53'40"E
F07	01.08.2006	Cahberik lake (Valley of Cahberik)	Firtina stream	2810	40°49'17"N 40°54'09"E
F08	08.07.2005 21.08.2005	Atmeydani lake (Valley of Vercenik)	Firtina stream	2910	40°43'11"N 40°54'01"E
F09	08.07.2005 21.08.2005	Kumlugol lake (Valley of Vercenik)	Firtina stream	2860	40°43'22"N 40°54'17"E
F10	08.07.2005 21.08.2005	Incegol lake (Valley of Vercenik)	Firtina stream	2915	40°43'06"N 40°54'23"E
F11	21.08.2005	Buyuk Kapili lake (Valley of Vercenik)	Firtina stream	3000	40°43'00"N 40°54'54"E
F12	21.08.2005	Altkapili lake (Valley of Vercenik)	Firtina stream	3000	40°43'11"N 40°54'57"E
F13	31.07.2006	Kiblekaya lake (Valley of Apivanak)	Firtina stream	2870	40°49'24"N 41°06'06"E
F14	11.07.2005 24.08.2005	Buyukdeniz lake (Valley of Kavron)	Firtina stream	2900	40°52'09"N 41°09'42"E
F15	24.08.2005	Meterez lake (Valley of Kavron)	Firtina stream	2990	40°51'49"N 41°09'45"E
F16	11.07.2005 24.08.2005	Isimsiz lake (Valley of Kavron)	Firtina stream	2890	40°52'28"N 41°09'46"E
F17	24.08.2005	Karadeniz lake (Valley of Ceymakcur)	Firtina stream	2770	40°52'42"N 41°10'03"E
F18	29.07.2006	Ceymakcur lake (Valley of Ceymakcur)	Firtina stream	2650	40°53'44"N 41°11'30"E
F19	30.07.2006	Buyukgol lake (Valley of Avusor)	Firtina stream	2670	40°56'13"N 41°12'02"E
F20	22.08.2007	Tobamizga lake (Valley of Tunca)	Firtina stream	2620	41°02'19"N 41°15'37"E
F21	22.08.2007	Kucuk Tobamizga lake (Valley of Tunca)	Firtina stream	2630	41°02'08"N 41°15'39"E
F22	23.08.2007	Buyuk Ciftegol lake (Valley of Tunca)	Firtina stream	2600	40°59'24"N 41°15'41"E
F23	23.08.2007	Kucuk Ciftegol lake (Valley of Tunca)	Firtina stream	2550	40°59'36"N 41°15'49"E
I01	20.08.2006	Dipsiz lake (Valley of Anzer)	Iyidere	2670	40°33'28"N 40°28'25"E
I02	25.07.2007	Koyun lake (Valley of Anzer)	Iyidere	3010	40°31'34"N 40°28'58"E
I03	20.08.2006	Kucukhatalan lake (Valley of Anzer)	Iyidere	2800	40°33'16"N 40°29'22"E
I04	20.08.2006	Hatalan lake (Valley of Anzer)	Iyidere	2810	40°33'11"N 40°29'24"E
I05	20.08.2006	Kucuksivri lake (Valley of Anzer)	Iyidere	2710	40°33'36"N 40°29'50"E
I06	20.08.2006	Sivrinin lake (Valley of Anzer)	Iyidere	2700	40°33'39"N 40°29'52"E
I07	02.08.2006	Akcaagil lake (Valley of Anzer)	Iyidere	2940	40°31'19"N 40°30'40"E
I08	21.08.2006	Katrec lake (Valley of Arzayan)	Iyidere	2700	40°34'06"N 40°34'51"E
I09	21.08.2006	Kucukkatrec Lake (Valley of Arzayan)	Iyidere	2690	40°34'13"N 40°34'58"E
I10	03.08.2006	Citrik lake (Valley of Cimil)	Iyidere	2850	40°39'31"N 40°46'59"E
I11	03.08.2006	Salar lake (Valley of Cimil)	Iyidere	2820	40°43'28"N 40°52'09"E
K01	25.08.2006	Arhavi Karagol lake (Valley of Kabisra)	Kabisra stream	2660	41°09'28"N 41°24'19"E
M01	26.08.2007	Cakir Lake (Valley of Altindere)	Macka stream	2530	40°34'34"N 39°41'26"E
S01	26.08.2006	Uzungol lake (Valley of Uzungol)	Solakli stream	1100	40°37'14"N 40°17'44"E

Table 1: Continued

Basin code	Date	Locality	Basin	Altitude	Coordinates
S02	30.07.2007	Kirklarcami lake (Valley of Uzungol)	Solakli stream	2740	40°31'46"N 40°20'06"E
S03	29.07.2007	Multat Karagol lake (Valley of Uzungol)	Solakli stream	2800	40°31'30"N 40°21'46"E
S04	27.07.2007	Balik lake (Valley of Uzungol)	Solakli stream	2570	40°31'54"N 40°23'01"E
S05	27.07.2007	Aygir lake (Valley of Uzungol)	Solakli stream	2710	40°31'39"N 40°23'28"E
S06	29.07.2007	Saricicek lake (Valley of Uzungol)	Solakli stream	2880	40°31'15"N 40°24'21"E
S07	28.07.2007	Demirkapi Karagol lake (Valley of Uzungol)	Solakli stream	2930	40°31'41"N 40°27'03"E
S08	28.07.2007	Piromer lake (Valley of Uzungol)	Solakli stream	2870	40°32'00"N 40°27'09"E
S09	28.07.2007	Buz lake (Valley of Uzungol)	Solakli stream	3040	40°31'58"N 40°27'36"E

MATERIALS AND METHODS

In order to study the micro-crustacean fauna of 59 mountain lakes in the Eastern Black sea range, six excursions were conducted in 2005-2007. Due to the high altitude most of the sites studied are generally covered by snow and ice during 8-9 months of the year and ice-free periods occurs only in warm months i.e., June-August. Qualitative samples were collected by horizontally and vertical hauls, using standart plankton net (Mesh size 60 μm). For the quantitative analyses, a 10 L. sampling container was filled and the samples pass through a 50 μm mesh. The zooplankton were washed from the filter into a jar. Also, samples taken from the littoral zone were collected with a plankton hand net (Mesh size 250 μm). All samples were kept in 330 mL PVC jars and fixed in 4% formaldehyde. Water samples were taken from the littoral of each lake. Six environmental variables, namely water temperature (Temp., °C), dissolved oxygen (DO, mg L^{-1}), pH, Electrical Conductivity (EC, μs cm^{-1}) and Secchi depths were measured *in situ* by using a WTW pH-meter (model 330), a WTW oxygen-meter (model 330) and an YSI 30 model SCT-meter and a secchi disc. Other variables (NO_2^--N, NO_3^--N, NH_4^--N, PO_4^{-3}-P, HCO_3^-, Ca^{+2}, Mg^{+2}, SiO_2^-, Chl.-a, etc.) were measured in the laboratory after following the standard methods of APHA (1989). For taxonomical identification of the specimens, the keys by Smirnov (1992, 1996), Benzie (2005), Korovchinski (1992), Beladjal and Mertens (1997), Reddy (1994), Bronstein (1947), Hendreson (1990) and Meisch (2000) were used.

RESULTS AND DISCUSSION

Environmental variables: Minimum and maximum values of the environmental variables of studied lakes are shown in the Table 2. In terms of water quality, all of the lakes can be classified as 1st class because in terms of their ammonium, nitrite, nitrate nitrogen levels and total phosphorus level. Similarly, the quality classes of the lakes were changed between I-III according to levels of dissolved oxygen. When the Total Nitrogen (TN) and Total Phosphourus (TP) are taking into consideration, all the lakes show oligotrophic character. Chlorophyll-a concentration of the lakes were generally low and this character also support the result is given above.

Table 2: Minimum and maximum values of the environmental variables

Variables	Min.	Max.
Secchi depth (cm)	50.00	1100.00
Temperature (°C)	2.50	21.00
pH	6.75	9.71
DO (mg L^{-1})	5.30	10.10
EC (μS 25°C cm^{-1})	12.00	121.80
d°H	0.80	3.40
HCO_3^- (mg L^{-1})	18.30	73.20
Ca^{+2} (mg L^{-1})	8.00	32.10
Mg^{+2} (mg L^{-1})	4.86	19.46
NO_2^--N (μg L^{-1})	0.00	5.21
NO_3^--N (μg L^{-1})	0.00	105.00
NH_4^--N (μg L^{-1})	0.00	106.90
PO_4^{-3}-P (μg L^{-1})	0.00	10.95
SiO_2^- (μg L^{-1})	258.50	2516.30
Chlorophyll-a (μg L^{-1})	0.00	2.32

Environmental variables data was used to show relationships among the lakes by means of using test of Unweighted Pair Group Mean Averages (UPGMA) analysis. In this analysis, logarithmic transformation was applied to all data except pH. Result of UPGMA clustering showed that the similarity of the lakes is >88% (Fig. 2).

Taxonomic structure: In total, 33 Crustacean taxa, comprising 21 branchiopods, 9 copepods and 3 ostracods, respectively were identified (Table 3). All the taxa identified are new records for their localities except *C. ponticus*.

Among the copepods, *A. acutilobatus* was the dominant species (In 5 basins at 46 stations). *A. acutilobatus* is important copepod species and reaches high densities at the water bodies of mountainous regions

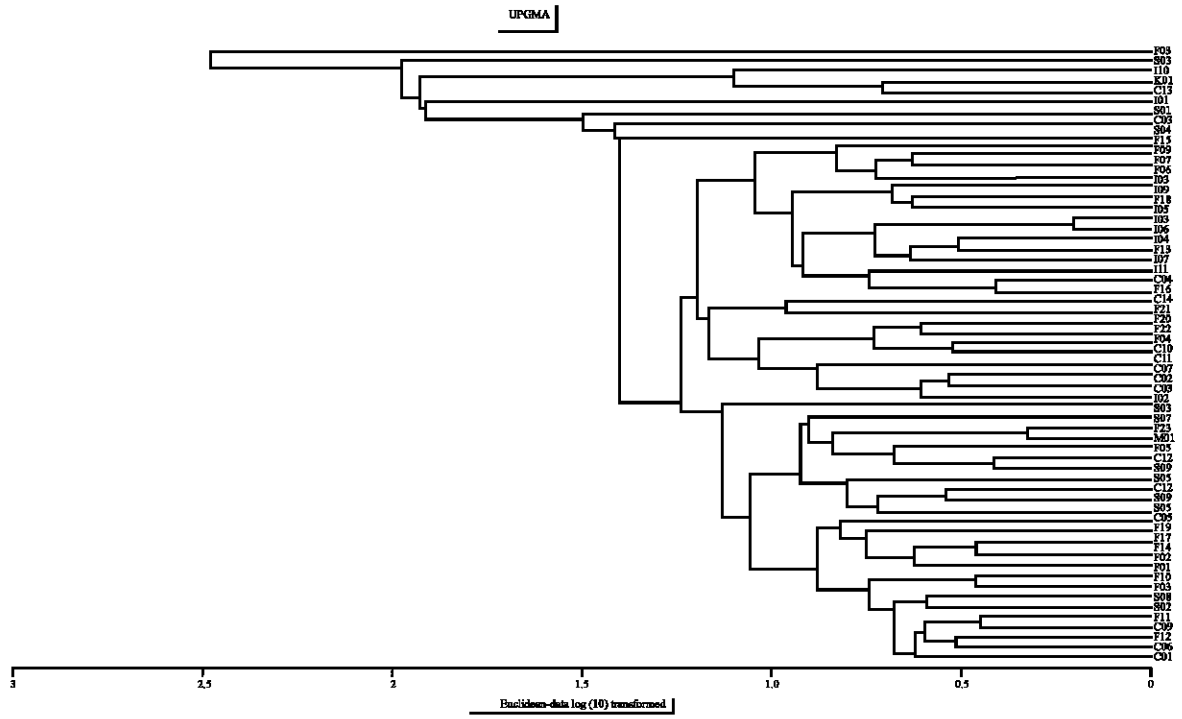

Fig. 2: Result of UPGMA clustering showed that the similarity of the lakes

Table 3: Branchiopoda, Maxillopoda and Ostracoda composition and distribution of the lakes

	Basin					
Species of crustacean	Coruh	Firtina	Iyidere	Kabisra	Macka	Solakli
Branchiopoda						
Diaphanosoma brachyurum (Lievin,1848)	C8	-	-	-	-	-
Daphnia cucullata (Sars, 1862)	-	F9	-	-	-	-
Daphnia curvicornis (Eylmann, 1887)	C1, C12	F12	I3, I4	-	-	S9
Daphnia hyaline (Leydig, 1860)	-	F20	-	-	M1	-
Daphnia longispina (O.F. Muller, 1875)	C6	-	I6	K1	-	-
Daphnia pulex (Leydig, 1860)	C8, C9	F4, F11	-	-	-	-
Simocephalus exspinosus (Koch, 1841)	-	F8	-	-	-	-
Simocephalus vetulus (O.F. Muller, 1776)	C3	-	11	-	-	-
Ceriodaphnia laticaudata (P.E. Muller, 1867)	C8, C14	-	I1	K1	-	-
Ceriodaphnia quadrangula (O.F. Muller, 1785)	C1-C4, C7,C8, C11, C13	F3, F5, F8, F12, F16	I10, I11	-	-	S1, S4, S5
Scapholeberis kingi (Sars, 1903)	C2	-	-	-	-	-
Scapholeberis mucronata (O.F. Muller, 1785)	C11	F8	-	-	-	-
Macrothrix hirsuticornis (Norman and Brady, 1867)	C5	F7-F10, F12-F15, F21, F22	I3-I5, I8, I11	-	-	S5
Bosmina longirostris (O.F. Muller, 1785)	C2, C5, C7-C10	F2, F3, F8-F12	I10	-	-	S4
Alonella excisa (Fischer, 1854)	C3, C6, C9, C11, C13, C14	F8	I11	-	M1	-
Chydorus sphaericus (O.F. Muller, 1776)	C1-C6, C8, C10, C11, C13, C14	F1-F4, F6, F8-F11, F13-F17, F19-F23	I1-I9, I11	K1	M1	S3-S9
Alona quadrangularis (O.F. Muller, 1785)	C4, C11	F8, F10, F14	I3, I4, I10, I11	-	M1	-
Alona rectangular (Sars, 1862)		F4, F21				
Biapertura affinis (Leydig, 1860)	C1-C3, C8-C11, C14	F3, F5, F6-F10, F14, F20, F21	I1, I3-I6, I10, I11	K1	M1	S1, S6
Cercopagis pengoi (Ostroumov, 1892)	C8, C10	F11, F14	-	-	-	-
Chirocephalus ponticus (Beladjal and Mertens, 1997)	-	F16, F17	-	-	-	-
Maxillopoda						
Occidodiaptomus dischensis (Brehm, 1938)	C7	F12	-	-	-	-
Arctodiaptomus acutilobatus (G.O. Sars, 1903)	C1-C3, C5-C14	F1-F5, F7, F8, F10-F17, F19, F20, F22, F23	I1-I4, I6, I8, I10, I11	K1	-	S2, S3, S5-S9

Table 3: Continued

Species of crustacean	Basin					
	Coruh	Firtina	Iyidere	Kabisra	Macka	Solakli
Eucyclops serrulatus (Fischer, 1851)	C2, C8, C14	F3, F8, F9, F15	I3, I4	-	-	S1, S3
Cyclops abyssorum (G.O. Sars, 1863)	-	-	-	-	M1	-
Paracyclops fimbriatus (Fischer, 1853)	-	F10	-	-	-	S1
Canthocamptus staphylinus (Jurine, 1820)	C8, C10	-	-	-	-	S7
Bryocamptus zschokkei (Schmeil, 1893)	C10	-	-	-	-	-
Bryocamptus minutus (Claus, 1863)	C10	-	-	-	-	-
Attheyella crassa (G.O. Sars, 1863)	-	F8, F14, F16	-	-	-	S7
Ostracoda						
Prionocypris zenkeri (Chyzer and Toth, 1858)	C10	-	-	-	-	-
Candona neglecta (G.O. Sars, 1887)	C5	F3, F10, F13-F16	I3, I9-I11	K1	-	S1
Fabaeformiscandona balatonica (Daday, 1894)	-	-	-	-	-	S2

of Caucasus (Reddy, 1994). This species was previously recorded from the different parts of Turkey such as Devegecidi dam lake (Gunduz, 1998), Hirfanli dam lake (Yigit and Altindag, 2005), Asi river Kesikkopru dam lake (Yigit, 2006), Yarseli dam lake, Sariyar dam lake (Atici *et al*., 2008). *E. serrulatus* (In 4 basins at 11 stations) is a cosmopolitan species and the 2nd most common copepod of studied lakes. According to Ustaoglu *et al*. (2005) this species is one of the most common copepods of the high mountain lakes located at Taurus mountains. One of the interesting findings of this study is encountering of *O. dischensis* in two lakes (Lake Ustgol and Altkapili). According to Kiefer, *O. dischensis* is endemic to high mountain lakes of Eastern Anatolia and no further records of the species until now. Distribution area of *O. dischensis was* expanded to North by this study. *C. abyssorum*, *P. fimbriatus*, *C. staphylinus*, *B. zschokkei*, *B. minutusand* and *A. crassa* were less frequently encountered species among the lakes of Kackar mountain range.

Among the branchiopods, *C. sphaericus* (48 lakes) and *B. affinis* (29 lakes) were the dominant species, respectively. Endemic *C. ponticus* was unique anostracan species sampled during the study and recorded from type locality. One of the unusual findings of the study is recording of predatory *C. pengoi* from four locality (Lake Buyuk Kapili, Buyukdeniz, Adaligol, Buyukgol). *C. pengoi* is euryhaline and eurytherm ponto-caspic species.

It prefers the brackish-water environment but has also been found in freshwater conditions and warm water environment (Gorokhova *et al*., 2000). This alien species previously recorded from Lake Terkos in Turkish Thrace (Guher, 2004) but never recorded from high mountain lakes. With this study, distribution area of the species in Turkey is expanded.

Three ostracod taxa were collected during the sampling periods (Table 3). *C. neglecta* was the most frequent species, collected from 12 sampling sites. The least frequent (Collected from only one lake) were *P. zenkeri* and *F. balatonica*. Regarding the species diversity of the stations, Station 22 (Lake Atmeydani) had the higher species richness (12 species) followed by Stations 8 and 10 (Lake Adaligol and Buyukgol, respectively) each with 11 species.

CONCLUSION

In this study from the point of view of the regional limnology, the high mountain lakes of the Kackar mountains appear to be homogeneous water bodies easily characterizable and with low levels of pollution. However, the high diversity recorded in the investigated lakes underlines the importance of these fragile habitats which are rarely considered in traditional ecological research. High mountain lakes are increasingly threatened by direct and indirect impacts such as changes in hydrological cycles, water pollution and physical alteration of the habitat structure. The reduction of anthropic impacts on these ecosystems will hopefully become a priority in conservation and restoration projects, especially in protected areas. The present survey will be useful as a baseline for future studies and contributions to the knowledge of Turkey's biodiversity.

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