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Ecological requirements of freshwater Ostracoda (Crustacea) in two limnocrene springs (Bolu, Turkey)

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Ecological requirements of ostracods in two limnocrene springs (Usta and Çetin Bey) were investigated between January 2000 and July 2002 in Bolu, Turkey. Ten taxa *(Candona neglecta, Darwinula stevensoni, Eucypris virens, Eucypris* sp., *Heterocypris incongruens, Herpetocypris* sp., *Ilyocypris bradyi, Potamocypris* sp., *Scottia pseudobrowniana, Tonnacypris lutaria)* were found. Canonical correspondence analysis (CCA) showed that species with wide cosmopolitan distribution could tolerate high levels of changes in environmental variables. CCA explained about 80 % and 77 % of the relationships between species and environmental variables in Usta and Çetin Bey springs, respectively. Electrical conductivity and dissolved oxygen were the two most influential factors on species occurrence in each spring. According to Spearman correlation analysis, there were no significant relationships between the numbers of species and environmental variables in both springs. When dissolved oxygen showed significant negative correlations to electrical conductivity, water and air temperature in Usta spring, such correlation was only negatively significant ($P < 0.05$, $r = -0.46$) between electrical conductivity and dissolved oxygen in Çetin Bey spring. Clustering analysis (UPGMA) of presence/absence data divided species into four main groups. Results may suggest that anthropogenic activities were responsible for decreasing water quality of these springs and reducing species richness. Although increasing incentives for conservation of natural springs were proposed, Çetin Bey spring and especially Usta spring are now highly degraded.

Keywords Ostracoda, springs, ecology, CCA, seasonality.

Introduction

It is known that the distributions of some macroinvertebrates inhabiting springs are related to concentration of particular chemicals and to physical variables such as temperature, pH, and alkalinity (Glazier 1991, Webb et al. 1998, Ruiz et al. 2004). However, little is known about the ecological requirements of ostracods in spring ecosystems (Külköylüoğlu 1999a, Mezquita et al. 2000) despite the fact that ostracods are found in almost all types of water bodies. Species inhabiting springs typically may have limited ranges of tolerance to changes in ecological variables. Thus, species with certain requirements can be used to deduce not only present ecological conditions, but also to infer past conditions and trends in different aquatic environments (Mischke 2001, Külköylüoğlu & Dügel 2004). Clearly, inferences about habitat quality cannot be made unless there are sufficient data about ostracods' ecological preferences. Previous studies in Turkey have focused on ostracods that can be found in a variety of aquatic habitats such as ponds, lakes, and marine environments, but almost nothing is known about spring ostracods (Külköylüoğlu 2003b, c).

Springs are known as natural ecological laboratories because they have relatively stable environmental conditions (Nielson 1950, Külköylüoğlu 1999b, Smith & Wood 2002). Moreover, springs are the open windows of aquifers, reflecting structural and functional changes in such systems on the surface waters. Also, several distinct groups of species are exclusively found in springs (Smith et al. 2003). Despite their uniqueness, spring ecosystems are being lost extensively due to increasing levels of anthropogenic habitat destruc-

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tion and modification (Williams 1991, Külköylüoğlu & Vinyard 2000, Mezquita et al. 2000, Külköylüoğlu 2003a). For example, Särkkä et al. (1997) reported that of 31 springs studied in Finland, 16 were subjected to at least four types of anthropogenic disturbances - agriculture, residential development, gravel extraction and winter road de-icing with NaCl - and that ostracod species in these springs differed in their environmental requirements. Särkkä et al. (1997) also reported that *Potamocypris pallida* was the most abundant ostracod species among the others *(Candona neglecta, C. protzi, C. candida, C. brevicornis,* and *C. parallella).* This species could withstand the effects of road de-icing and gravel extraction, but in general each species had different environmental requirements. Consequently, once springs (or certain environmental conditions) are lost, eventual loss of many spring-dwelling species is inevitable.

The aims of this study are (1) to provide data about ecological requirements of ostracods in two springs, (2) to emphasize the general aspects of springs as being natural laboratories with stable ecological conditions, and (3) to pinpoint the need for their sustainable conservation.

Material and Methods

Study Sites

Usta spring (40°42'92"N 31°29'79"E) and Çetin Bey spring (40°42'57"N 31°31'85"E) have pools with a radius of about 135 and 115 cm, respectively. Both springs are located at similar elevation (710 m for Usta, 730 m for Çetin Bey). Although some ecological information is available for Çetin Bey spring (Külköylüoglu, 2003a), no previous work has been done in Usta spring, nor was there a comparative study between them. There are two large oak (*Quercus* sp.) trees nearby Çetin Bey spring, which provide relatively high shade while there is no trees around Usta spring. In both springs, the bottom is covered by fine sand, gravel and mud, equally. The direction of water flow from the pools differed between the springs : southeast from Çetin Bey and northeast from Usta spring. There is continuum diversion of water from Usta spring for agricultural purposes. The outcome of this action was underlined in discussion.

Sampling and Measurement Procedures

Ostracods were collected monthly from two limnocrene springs (water comes out at the source, creating a small pool) in the Bolu region of northern Anatolia between January 2000 and July 2002 with a plankton hand net (250 µm in mesh size). Samples were taken from the pools of each spring. Eight physical and chemical variables (pH, dissolved oxygen (DO [mg/L]), water temperature (T(w) [°C]), air temperature (T(a) [°C]), electrical conductivity (EC [µS/cm]), redox potential (Eh [mV]), percent oxygen saturation (%Sat), and salinity (S [ppt]) were measured each month in the field (Tables 1 and 2). A mercury thermometer was used to measure simultaneously air temperature. pH and redox potential values were measured with a Hanna model HI-98150 pH/ORP meter. Five other variables including water temperature were measured with an YSI-85 model oxygen-temperature meter. Total dissolved solids (TDS [mg/l]) were measured in the laboratory following standard methods (APHA 1989). Elevation and coordinates were recorded with a geographical positioning system (GPS 45) unit. Samples collected from each station were fixed in 70 % ethanol. In the laboratory, after each sample was filtered from five ((2.0: 1.5: 1.0: 0.5: 0.25 mm mesh size, respectively) standardized sieves, ostracods were hand-sorted at 10x to 40x magnification and preserved in 70 % ethanol. Specimens were dissected in lactophenol solution. Several systematic keys (Bronshtein 1947, Meisch 2000) were used for identification.

Statistical Analyses

Subfossils (empty carapaces and valves), juveniles, and genera represented by less than four individuals were not identified at the species level, and were excluded from statistical analyses. ANOVA with unequal variance of independent t-tests were used to examine whether variances of the mean values of major environmental variables were significantly different between the two springs. Relationships between the occurrence of 10 species and five environmental variables (i.e. pH, dissolved oxygen, water temperature, electrical conductivity, and redox potential were selected due to their common usage in aquatic systems) (Figs. 1 and 2) were examined with Canonical Correspondence Analysis (CCA). During this analysis, as required, numbers of sites were kept higher than the numbers of variables, when rare species and species with no effect were downweighted to mitigate the effect of multicolinearity (Ter Braak, 1986, 1987).

Unweighted Pair Group Mean Average (UPGMA) method applied with Jaccard similarity index was used to classify species based on binary data of species' occurrence (presence/absence) after the data were log-transformed. Spearman rank correlations were used to test for relationships between six independent environ-

Table 1 : Usta spring : measurements of nine variables and occurrence of the ostracod species between May 2000 (My00) and July 2002 (Jl02). The abbreviations of variables (DO (mg/l): dissolved oxygen ; %Sat : oxygen saturation ; T(a) (°C) : air temperature ; T(w) (°C) : water temperature ; pH; EC (µS/cm) : electrical conductivity; S (ppt) : salinity ; TDS (mg/l) : Total Dissolved Solids ; Eh (mV) : redox potential) and species codes are (Cn : *Candona neglecta,* Ib : *Ilyocypris bradyi,* Ev : *Eucypris virens,* Hi : *Heterocypris incongruens,* Ds : *Darwinula stevensoni,* Tl : *Tonnacypris lutaria,* Sp : *Scottia pseudobrowniana,* Pt : *Potamocypris* sp., He : *Herpetocypris* sp., Es : *Eucypris* sp.).

Date	Code	DO	%Sat	T(a)	T(w)	pH	EC	S	TDS	Eh	Species
05.28.00	My00	4.87	53.6	25.2	17.6	7.32	314.5	0.2	210.71	-19	Cn,Pt,Ib,Es
06.30.00	J00	0.48	5.4	29.3	18.4	8.11	663	0.2	444.21	-65	Cn,Ib
07.28.00	Jl00	11.05	114.1	18.3	23.1	7.60	516	0.1	345.72	-39	Cn,Ib
08.31.00	A00	2.55	35.5	24.4	15.0	7.66	622	0.3	416.74	-38	--
09.29.00	S00	4.54	43.3	17.3	11.7		641	0.3	429.47		Cn
10.29.00	O00	5.97	53.2	14.4	10.2	7.39	739	0.4	495.13	-25	Cn
11.26.00	N00	3.67	29.3	12.3	7.1	7.50	517	0.3	346.39	-34	Cn
12.31.00	D00	4.48	38.0	12.0	8.0		793	0.4	531.31		Cn
01.27.01	Ja01	7.75	54.5	8.5	2.2		685	0.3	458.95		Cn
02.28.01	F01	5.31	45.0	9.5	7.5		636	0.3	426.12		Cn
03.31.01	M01	5.06	46.8	6.6	11.6	7.97	659	0.3	441.53	-56.4	Cn,Ev,Tl
04.28.01	Ap01	2.60	26.3	23.0	14.9	7.60	734	0.4	491.78	-33.6	Cn,Ib
05.31.01	My01	3.35	36.2	17.0	16.7	7.67	755	0.4	505.85	-39.8	Cn
06.30.01	J01	1.65	17.1	16.0	15.5	7.57	924	0.5	619.08	-33.7	Cn
07.26.01	Jl01	0.59	7.5	26.3	25.1	7.76	571	0.3	382.57	-47.0	Cn
09.30.01	S01	0.40	4.3	17.5	14.4	7.43	801	0.4	536.67	-4.3	Cn
10.30.01	O01	2.42	18.4	10.4	8.1	7.54	720	0.4	482.40	-23.3	Cn,Tl
11.30.01	N01	13.10	107.2	7.5	6.5	7.41	572	0.3	383.24	-27.3	Cn,Tl
12.29.01	D01	15.08	118.8		4.3	7.59	432.8	0.2	289.97	-37.2	Cn,Tl
02.28.02	F02	8.96	72.4	17.2	10.9	7.74	550	0.3	368.50	-45.5	Cn,Tl
04.27.02	Ap02										Cn
05.27.02	My02										Hi,Ib
07.30.02	Jl02	0.66	3.60		18.7	7.6	841	0.4	563.47	-41.60	--
Mean		**4.98**	**44.31**	**16.36**	**12.73**	**7.61**	**651.7**	**0.32**	**436.66**	**-35.86**	

mental variables and the total number of species. All statistical analyses were conducted using the Multivariate Statistical Package (MVSP) version 3.1 (Kovach 1998) and SPSS version 6.0.

Results

Biological variables

A total of 10 ostracods *(Candona neglecta, Darwinula stevensoni, Eucypris virens, Eucypris* sp., *Heterocypris incongruens, Herpetocypris* sp., *Ilyocypris bradyi, Potamocypris* sp., *Scottia pseudobrowniana, Tonnacypris lutaria)* were found, along with other taxa such as planorbid snails, freshwater clams, gammarid amphipods, and freshwater leeches. Almost all ostracod species except *S. pseudobrowniana* had high tolerances to environmental changes (see discussion for details). *Ilyocypris bradyi* (and gammarids) was dominant in each month at Çetin Bey spring whereas *C. neglecta* was dominant in Usta spring (Tables 1 and 2) ; both species occurred in both springs.

Physical and chemical variables

There were no significant differences ($P > 0.05$) among the means of the major environmental values between the two springs, except pH ($P < 0.05$). Water temperature and dissolved oxygen were relatively constant in Çetin Bey spring during the study period (Fig. 3), but fluctuated in Usta spring (Fig. 4). A nonparametric Spearman correlation analysis failed to show any significant relationships between the numbers of species and environmental variables in both

Table 2. Çetin Bey spring : measurements of nine variables and occurrence of ostracod species between February 2000 (F00) and July 2001 (Jl01). Abbreviations are same as in Table 1.

Date	Code	DO	%Sat	T(a)	T(w)	pH	EC	S	TDS	Eh	Species
02.29.00	F00	4.61		11.3	13.4	7.53	534	0.3	357.78	-23	Ib. Cn
03.31.00	M00	3.80	30	24.4	14.5	6.73	550	0.3	368.5	-18	Ib
04.30.00	Ap00	5.40	36.4	26	15.1	7.06	550	0.3	368.5	-4	Ib,Ev, He,
05.31.00	My00	3.61	31.6	17.4	14.9	8	680	0.3	455.6	-46	Ib,Cn
06.30.00	J00	3.42	34	24.8	14.1	7.86	560	0.3	375.2	-39	Ib,Cn
07.28.00	Jl00	4.66	43.1	18.3	14.5	7.75	689	0.3	461.63	-46	Ib
08.31.00	A00	3.54	36.1	26.2	14.3	7.61	687	0.3	460.29	-36	Ib
09.29.00	S00	3.96	39.8	17	14.2		648	0.3	434.16		Ib
10.29.00	O00	3.06	70.9	11.6	13.4	7.05	672	0.3	450.24	-48	Ib
11.26.00	N00	3.51	33.8	15.7	13.2	7.03	671	0.3	449.57	-1	Ib,Cn
12.31.00	D00	3.93	38.2	11	13.1		671	0.3	449.57		Ib,Cn
01.27.01	O01	3.45	32.3	8.5	12.5		670	0.3	448.9		Ib,Cn
02.28.01	F01	4.12	38.4	8.4	12.6		679	0.3	454.93		Ib,Cn
03.31.01	M01	3.28	32.2	9.2	13.4	7.06	684	0.3	458.28	-4.2	Ib,Cn
04.28.01	Ap01	3.64	35.7	21	14.2	6.93	675	0.3	452.25	2.7	Ib
05.31.01	My01	5.13	49.6	16	14.4	6.94	637	0.3	426.79	2.2	Ds
06.30.01	J01	3.31	33.6	25.1	14.7	6.84	676	0.3	452.92	7.6	Ib,Cn
07.26.01	Jl01	3.36	33.2	30.2	15.7		691	0.3	462.97		Ib
08.28.01	A01	5.61	57.1	27	15.8	7.02	641	0.3	429.47	1.3	Ib,Cn,Ds,Sp
09.30.01	S01	6.10	63	19	14.4	7.02	633	0.3	424.11	-1.1	--
Mean		**5.8**	**38.67**	**18.40**	**14.12**	**7.23**	**645**	**0.3**	**432.08**	**-16.83**	

Table 3 : Çetin Bey spring: Spearman correlation matrix shows the correlation among six environmental variables and numbers of species (NoSpp.). (*) and (**) represent 0.05 and 0.01 significant levels. Abbreviations are same as in Table 1.

	DO	EC	Eh	NoSpp.	pH	T(a)	T(w)
DO	1.00	-0.46*	0.26	0.18	-0.15	0.09	0.27
EC		1.00	-0.15	-0.26	0.25	0.01	0.41
Eh			1.00	0.15	-0.75**	0.26	0.18
NoSpp.				1.00	0.24	-0.07	0.04
pH					1.00	-0.15	-0.12
T(a)						1.00	0.84**
T(w)							1.00

Table 4 : Usta spring : Spearman correlation matrix shows the correlation among six environmental variables and numbers of species (NoSpp.). (*) and (**) represent 0.05 and 0.01 significant levels. Abbreviations are same as in Table 1.

	DO	EC	Eh	NoSpp.	pH	T(a)	T(w)
DO	1.00	-0.54*	0.06	0.25	-0.23	-0.49*	-0.56**
EC		1.00	0.09	-0.45	0.03	-0.21	0.10
Eh			1.00	-0.08	-0.92**	-0.20	-0.41
NoSpp.				1.00	0.08	0.09	0.19
pH					1.00	0.28	0.42
T(a)						1.00	0.83**
T(w)							1.00

springs. However, the correlation between dissolved oxygen and electrical conductivity was negatively significant ($P < 0.05$, $r = -0.46$) in Çetin Bey spring (Table 3) when such negative correlation of dissolved oxygen was observed for the water temperature ($r = -0.55$), air temperature ($r= -0.49$) and electrical conductivity ($r=-0.54$) in Usta spring (Table 4). Similarly, canonical correspondence analyses, which explained 80.3 % and 77.4 % of the relationships between species and five environmental variables (Table 5), showed that electrical conductivity (Usta) and dissolved oxygen (Çetin Bey) were the most influential factors in each spring, respectively (Figs. 1 and 2).

Species Occurrence

Clustering analysis distinguished four groups based on their co-occurrence (seasonality) (Fig. 5). The first group included only one species *(H. incongruens),* a

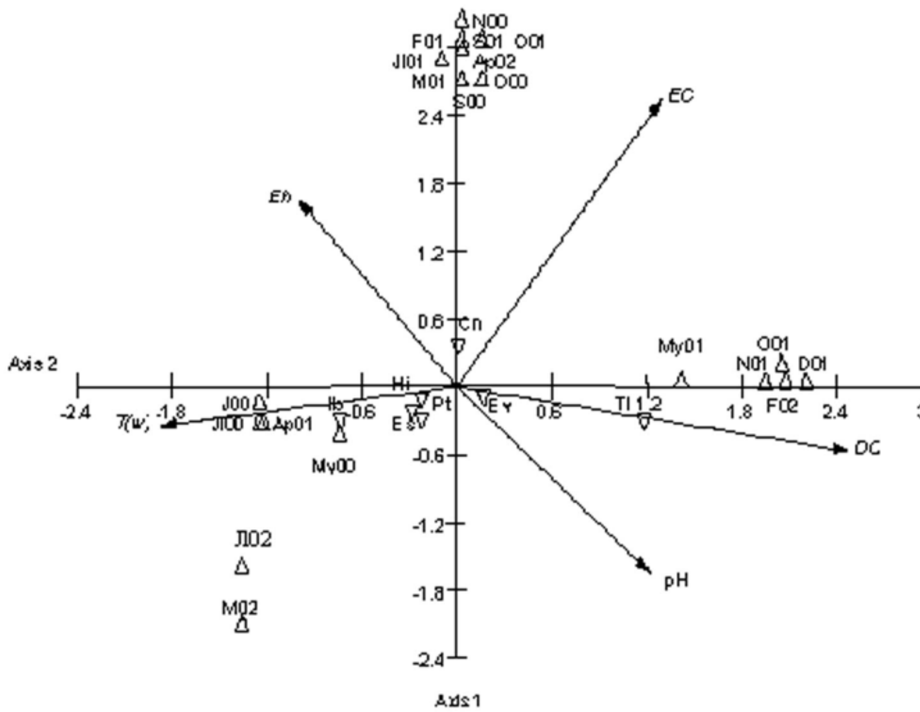

Fig. 1. CCA diagram of Usta spring shows that EC and DO are the two most influential factors on the species occurrence between May 2000 (M00) and July 2002 (Jl02). Species located closer to the center have higher tolerance levels for selected environmental variables. The abbreviations are pH ; DO (mg/L) (dissolved oxygen) ; T(w) (°C) (water temperature); EC (µS/cm) (electrical conductivity) ; Eh (mV) (redox potential). Triangles (△ and ▽ indicate months and species, respectively. Codes for each month and species are given in Table 1.

well-known cosmopolitan species. The second group had two bottom-dependent species *(D. stevensoni* and *S. pseudobrowniana)* that lack swimming setae on the second antenna. The third group consisted of four taxa *(E. virens, Eucypris* sp., *Herpetocypris* sp., and *Potamocypris* sp.). Among them, *E. virens* bears its long swimming setae on the second antenna. The fourth group included three non-swimming species *(C. neglecta, I. bradyi,* and *T. lutaria).* These species were the most prevalent during this study. Results may suggest that such changes in the species dominance and occurrences are most likely associated with anthropogenic environmental changes (see below for details).

Table 5 : CCA eigenvalues of Usta and Çetin Bey springs. Note to the higher values of species and environmental relationships (Spe.-Env. Relation) in Usta *(0.803)* and Çetin bey *(0.774)* springs explained by the first axis of CCA diagram.

	Usta Spring		Çetin Bey Spring	
	Axis 1	**Axis 2**	**Axis 1**	**Axis 2**
Eigen value	0.291	0.120	0.093	0.050
% value	38.764	16.027	22.263	11.982
Total % value	38.764	54.791	22.263	34.245
Total Limited Perct.	65.113	92.035	56.818	87.398
Spe.-Env. Relation	*0.803*	0.641	*0.774*	0.509

Discussion and Conclusions

During development of the indicator species concept (Kolkwitz & Marsson 1908, Pearson 1970, Rygg 1985), both positive indicator species (cosmopolitan species with wide ranges of tolerance to pollution) and negative indicator species (non-cosmopolitan or sensitive species with limited ranges of tolerance) have been used to determine the water quality in variety of aquatic systems (Robert et al. 1999). Accordingly, increasing numbers of cosmopolitan species can signal an increase in levels of human disturbance and pollution. Because cosmopolitans can tolerate substantial changes in water quality, they can extend their geographical distribution into a variety of aquatic environments, which may in turn reduce the total number of native species. One implication is that the proportion

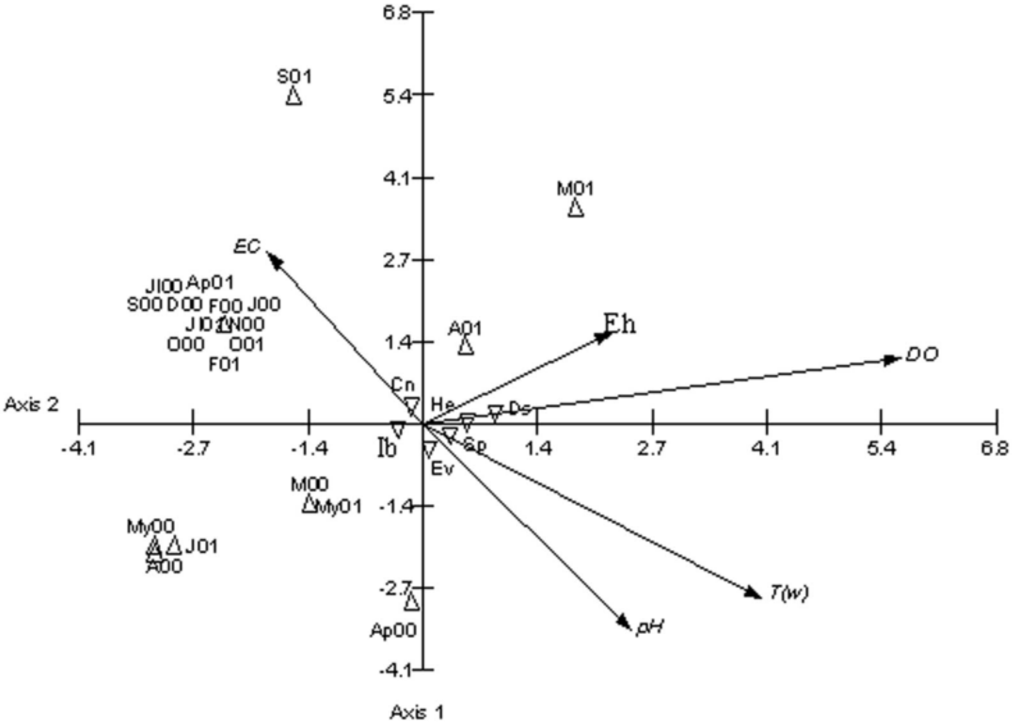

Fig. 2. CCA diagram of Çetin Bey spring shows that dissolved oxygen (DO) and water temperature (T(w)) are the two most influential factors on the species occurrence. The abbreviations are same as in Table 1.

of tolerant and opportunistic cosmopolitan species may be positively correlated with disturbance (Külköylüoğlu 2000, Külköylüoğlu & Vinyard 2000). An increasing number of these indicator species (i.e. cosmopolitans) may coincide with decreasing water quality and a decrease in species diversity. In contrast, a small number of native or non-cosmopolitan species can be expected in waters with low quality because habitat destruction and/or pollution can reduce species richness (Huxham et al. 2000), encourage higher densities of cosmopolitan species and alter community structure. The proportion of six cosmopolitan ostracod species in this study (0.86) can be construed as a low water quality in both Usta and Çetin Bey springs.

Changes in water quality will alter the function and species composition of springs. For example, two cosmopolitan species *(I. bradyi* and *C. neglecta)* found in both springs showed different temporal pattern of occurrence. *Ilyocypris bradyi* was encountered almost monthly in Çetin Bey spring whereas *C. neglecta* was found in Usta spring. Because pH seemed to be the only major environmental variable that was significantly different between the springs (Tables 3 and 4), anthropogenic factors are one possible explanation for the difference in species occurrence. This is probably the diversion of water from Usta spring for agricultural purposes might have caused changes in pH levels and in species occurrence patterns, as well. This is because diversion will reduce water level by altering the physical and chemical properties of the springs. Reduction of water level will increase temperature and total solid materials in spring water standing in the pool. Because of these rapid changes, species should change their tolerance levels to increase their survival chances in this spring. Thus, these circumstances may indicate that *C. neglecta* found in Usta spring might have higher tolerance levels than *I. bradyi.* Indeed, Külköylüoğlu & Dügel (2004) showed that tolerances and optimum preferences of *C. neglecta* were higher than *I. bradyi* in a small man-made lake in Turkey. The presence of these and similar species in different aquatic ecosystems consistently may indicate levels of disturbance, a main objective of biomonitoring studies.

Springs are unique habitats that serve many different purposes, but they are sensitive to artificial modifications and human land use. Higher values of conducti-

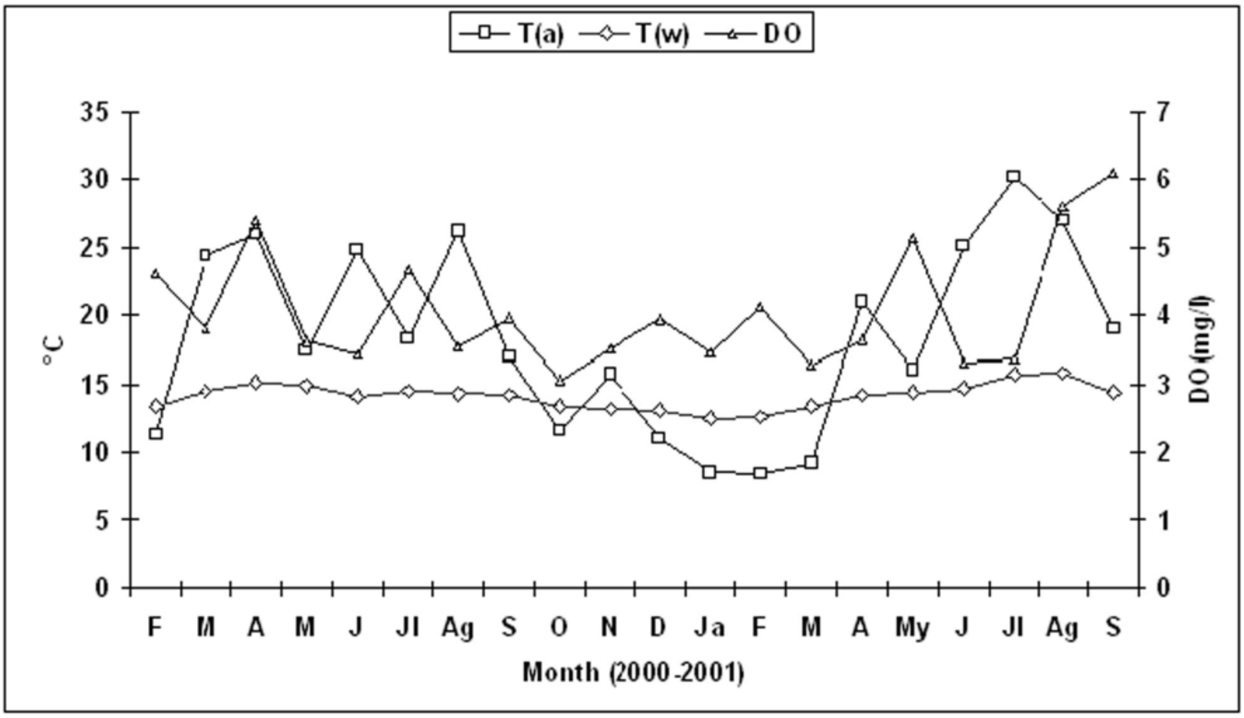

Fig. 3. Çetin Bey spring : monthly changes in three variables, dissolved oxygen (DO), air temperature [T(a)], and water temperature [T(w)] from February 2000 to September 2001. Note that water temperature and dissolved oxygen levels were relatively constant. Water temperature did not seem to be affected by air temperature changes.

vity and lower concentrations of dissolved oxygen, which make springs unsuitable for many aquatic taxa, show some possible consequences of these changes. For example, two of the major environmental variables, temperature and dissolved oxygen, fluctuated in Usta spring (Fig. 4) but were constant in Çetin Bey spring (Fig. 3). Consequently, these two variables may have had different effects on the number of species. However, correlation analysis failed to show any significant correlation between numbers of species and these two (and other) variables (Table 3 and 4). However, in CCA, arrow length expresses the influence of environmental variables (Ter Braak 1989, Birks et al. 1990). In this study, the arrow lengths of electrical conductivity and dissolved oxygen were relatively longer than those of any other variables. In Usta spring, *C. neglecta* is located closer to the arrow of electrical conductivity (Fig. 1). This may suggest a wide tolerance level of *C. neglecta* to conductivity changes. Indeed, during this study, the species was even abundant between maximum (924µS/cm) and minimum (314 µS/cm) conductivity levels in Usta spring (Table 1). Meisch (2000) underlined that *C. neglecta* can also tolerate very low oxygen concentrations during the summer. In Usta spring, the lowest dissolved oxygen value was about 0.4 mg/l in September 2001 and the maximum was 15.08 mg/l in December 2001. Furthermore, this species, previously reported from cold water (5°C) (Holmes 1996), was found in temperature ranges from 2.2°C to 25.1°C in Usta spring. These are the lowest and maximum values reported in the literature so far. All these imply that *C. neglecta* has high tolerance to several ecological changes. Accordingly, studies indicate that this species usually prefers organically rich habitats where it can increase its survival chances.

As noted above, clustering analyses outlined four groups of species based on their ecological preferences. The single cosmopolitan species, *H. incongruens,* found in the first group has been reported from various aquatic ecosystems (Petkowski et al. 2000) in which species were tolerant to wide ranges of environmental variables (Külköylüoğlu 2004). Little is known about the ecological preferences of the rare *S. pseudobrowniana,* one of the two species found in the second

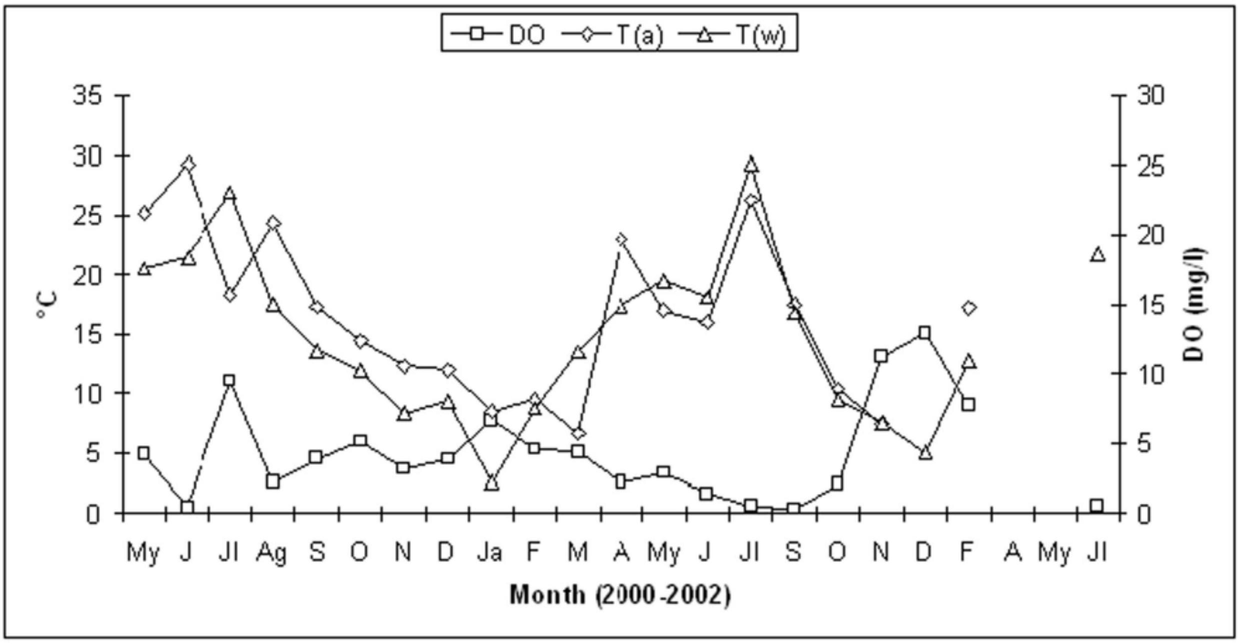

Fig. 4. Usta spring : monthly changes in three variables from May 2000 (My00) to July 2002 (Jl02). Note the asymmetric changes in water temperature [T(w)] and dissolved oxygen (DO) levels whereas water and air temperature [T(a)] values show similar patterns. Data for two months are missing.

group. *S. pseudobrowniana* has been reported from relatively cold spring waters (Külköylüoğlu & Vinyard 2000, Külköylüoğlu 2003a, Smith et al. 2003). The other species in the second group, *D. stevensoni,* is a well-known cosmopolitan species (Meisch 2000) with high environmental tolerance. Co-occurrence of these two species may be related to similarities in their morphology and resource use, although *S. pseudobrowniana* is a (semi)terrestrial ostracod, both species are bottom dependent. Among the four species in the third group, *E. virens* has a wide geographical distribution (Bronshtein 1947) and high tolerance to changes in the values of environmental variables such as pH (Delorme 1991), salinity (Mezquita et al. 1999), and water temperature and dissolved oxygen (Külköylüoğlu 2000, 2004). Three ostracods with almost cosmopolitan characteristics *(I. bradyi, C. neglecta, T. lutaria)* were clustered in the fourth group. These species have at least two main similarities. First, they have highest occurrences. Indeed, the first two species are the most common ostracods and have been reported from almost all kinds of water bodies in Turkey. Second, similar to the second group, the three species are bottom-dependent. In such a case, for example, species should tolerate changes in some of the chemicals in

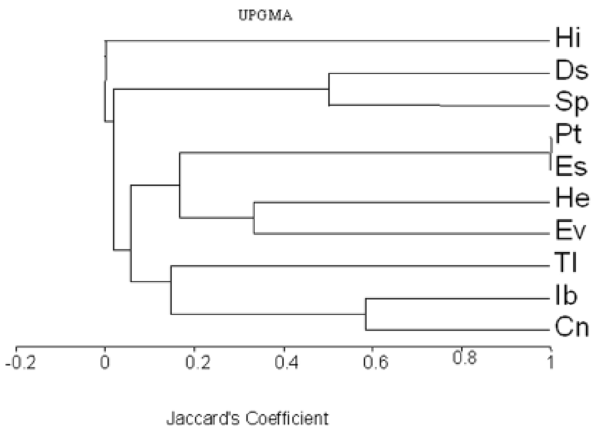

Fig. 5. UPGMA dendrogram showing separation of ten species (Cn : *Candona neglecta,* Ds : *Darwinula stevensoni,* Ev : *Eucypris virens,* Es : *Eucypris* sp., He : *Herpetocypris* sp., Hi : *Heterocypris incongruens,* Ib : *Ilyocypris bradyi,* Pt : *Potamocypris* sp., Sp : *Scottia pseudobrowniana,* Tl : *Tonnacypris lutaria)* into four groups based on binary (presence / absence) data in both Usta and Çetin Bey springs.

water because of low redox potential (Eh) values caused by reduction in water molecules through the sediment. During the study, the mean Eh values were measured between -16.83 mV and -35.86 mV (maximum -65 mV) in Çetin Bey and Usta springs, respectively (Tables 1 and 2).

Finally, these results may suggest that ostracod species may be used as indicator species to understand ecological conditions and the quality of waters. Assemblages of ostracod species, especially cosmopolitan species, may provide an early indication of changes in water quality (Külköylüoğlu 2004). However, such inferences are only possible if we know the ecological preferences of each species. To provide this information, each species should be studied in detail and relationships between species occurrence and ecological variables in different ecosystems should be examined. Like many other natural systems, springs are in danger in Turkey because of both habitat destruction and excessive water extraction from the springs. In some cases, these modifications are long-term, making it difficult to observe degrees and ecological effects of destruction. However, critical habitats (e.g. springs) and sensitive organisms (e.g. ostracods) together can signal negative effects before it is too late. Thus, both springs and ostracods can be used to determine status and trends of ecological conditions in aquatic ecosystems.

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