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Distributional patterns of non-marine Ostracoda (Crustacea) in Adiyaman Province (Turkey)

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Abstract – To understand the distribution and ecological characteristics of non-marine ostracods, the Poisson Method was applied to a total of 41 taxa (26 recent and 15 sub-fossil) from 111 (out of 120) aquatic bodies of Adıyaman Province, Turkey. All taxa were new records for the area and *Schellencandona insueta* and *Gomphocythere* n. sp. were the first records for Turkey. According to the Poisson method, ostracods were randomly distributed among all sampling sites ($P > 0.05$). This is especially true for the cosmopolitan species (*Candona neglecta*, *Heterocypris incongruens*, *Ilyocypris bradyi* and *Psychrodromus olivaceus*) with broader ecological tolerance ranges to different environmental variables. According to canonical correspondence analysis (CCA), the first two axes explained 77.4% of the relationships and the most effective variables were found as electrical conductivity ($F = 3.987$, $P = 0.002$, $\lambda = 0.31$), water temperature ($F = 3.582$, $P = 0.002$, $\lambda = 0.17$), pH ($F = 3.510$, $P = 0.002$, $\lambda = 0.12$) and elevation ($F = 4.491$, $P = 0.02$, $\lambda = 0.37$). Additionally, the ratio (numbers of taxa/site = 2) was found same at lower (450–550 m) and higher (1359–1459 m) ranges, in which *H. incongruens* and *I. bradyi* were the most common species found from different habitats. Overall, random distribution of ostracods among sampling sites seemed to be more affected by random distribution of cosmopolitan species at the regional level than the non-cosmopolitans whose distribution may be uniform or clumped since they prefer certain types of ecological conditions at local level.

Key words: Ostracoda / Poisson distribution / optima and tolerance / elevation / cosmopolitan

Introduction

One of the important characteristics of ecological communities is the spatial patterns of animals and plants because individuals take up space in different forms (Heip, 1975; Ludwig and Reynolds, 1988). The three types of spatial patterns are random, clumped (aggregation) and uniform distribution. A random distribution implies that all individuals have equal probability of occurring anywhere in a habitat. When species are equally spaced throughout an environment or aggregated in an area of favourable conditions, they are considered to have uniform or clumped distributions, respectively (Ludwig and Reynolds, 1988). This spacing of individuals in their environment may be explained by the habitat homogeneity/heterogeneity, non-selective behaviour, social behaviour, reproductive mode, competition, physico-chemical variables of aquatic environments, habitat preferences and human effect on habitats (Gabbutt, 1961; Ludwig and Reynolds, 1988; Kan, 2006; Kiss, 2007; González-Megías *et al.*, 2011). Hence, it can be summarized as the biotic and abiotic factors affecting the usage of space by individuals. The "Poisson Distribution" method (Heip, 1975) is commonly used for estimating the type of distribution displayed by species of interest. In 1837, Siméon Dennis Poisson defined the "Poisson distribution" model as a random distribution with the population variance (s^2) equal to the mean (μ) (Ludwig and Reynolds, 1988; Zar, 1999; Kan, 2006).

The other types of distribution (uniform and clumped) are found by measuring the amount when the ratio of variance to mean departs from random distribution values. Based on this ratio (s^2/μ), several types of the indices of dispersion have been proposed such as Green's index, index of dispersion, index of clumping, standardized Morisita index (Morisita, 1959; Ludwig and Reynolds, 1988). Among them, the index of dispersion is widely used (Heip, 1976) to predict uniform and clumped distribution. Accordingly, if $s^2/\mu = 1$ (Poisson distribution), organisms (or population) show a random distribution, but if $s^2/\mu > 1$ (negative binomial), they display a clumped pattern. When $s^2/\mu < 1$ (positive binomial), a uniform pattern is being exhibited.

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Ostracods (Crustacea) are small bivalved aquatic invertebrates and one of the oldest living microfauna first recorded back in the Cambrian period (Delorme, 1991; Meisch, 2000). They inhabit a variety of aquatic bodies ranging from fresh to saline waters (*e.g.*, lakes, troughs (like narrow canal designed to hold water), ponds, springs, caves) (Delorme, 1991; Yavuzatmaca *et al.*, 2012; Külköylüoğlu *et al.*, 2013) and are used as bio-indicator of water quality (Delorme, 1991). Published studies are available describing ostracod habitat preferences (Benzie, 1989; Dügel *et al.*, 2008), habitat similarities (Sarı and Külköylüoğlu, 2010), and ecology and distribution (Teeter, 1973; Malmqvist *et al.*, 1997; Mezquita *et al.*, 1999; Kiss, 2007; Pieri *et al.*, 2009; Van der Meeren *et al.*, 2010; Külköylüoğlu *et al.*, 2013). However, with the exception of Heip (1976), there is no specific research on the distributional patterns of ostracods using Poisson probabilities. Heip (1976) attempted to test the spatial pattern of a single species (*Cyprideis torosa* (Jones, 1850)) in a small brackish pond in Northern Belgium during a single sampling event in January 1971. He concluded that *C. torosa* showed aggregated distribution in this pond. In contrast, the present study covers many species of ostracods occurring in a wide geographical area within several different types of aquatic habitats where application of Poisson probabilities were suitable.

There are about 140 non-marine free-living freshwater ostracods have been reported from Turkey (Külköylüoğlu, 2013; unpublished data). This number of ostracods in Turkey is higher than in Germany (126 spp.), Great Britain (90 spp.), Austria (81 spp.) and Belgium (71 spp.) but lower than in Italy (151 spp.) (for more details see Pieri *et al.*, 2013) and India (152 spp.) (Karuthapandi *et al.*, 2014). However, we believe that numbers of Turkish non-marine ostracods are underestimated because of lack of information about ostracod diversity from other regions of Turkey. Until the present study, such knowledge was also scarce for Adıyaman region, where there was no extensive study on ostracods. The main objectives of this study are: (i) to test the hypothesis of Poisson as "Ostracods are randomly distributed among sampling sites in Adıyaman Province"; (ii) to determine the importance of regional (spatial) or local factors on the ostracod assemblages; and (iii) to contribute knowledge into the ostracod fauna of Adıyaman Province along with estimating ecological optimum and tolerance levels of individual species for different ecological variables.

Material and methods

Site description

Adıyaman is located in the middle of Euphrates (south east of Turkey) between 38°11′–37°25′N and 39°14′–37°31′E, covering about 7164 km^2 of surface area. The north part of the city is surrounded by the Malatya Mountains that are the extensions of Toros Mountains. The south part elevation begins to decrease to the lowland plain. Southern parts are usually hot and dry during summer season, whereas northern parts are cooler and dry during winter season. The minimum and maximum air temperature of summer and winter fluctuate between 28–47 and −10 to 10 °C, respectively (Adıyaman valiliği, 2014).

Sampling and measurements

Total of 120 samples were collected from randomly selected 12 types of aquatic bodies (limnocrene, rheocrene and helocrene springs, lake, dam, pond, pool, creek, stream, water fall, irrigation canal and troughs) in Adıyaman Province during 16–19 July 2012 (Fig. 1). At each site, environmental variables, including dissolved oxygen (mg.L^{-1}), per cent oxygen saturation (% sat.), water temperature (°C), electrical conductivity (μS.cm^{-1}), total dissolved solids (TDS) (mg.L^{-1}), salinity (ppt), pH and atmospheric pressure (mmHg) were recorded by YSI-Professional Plus. A Testo 410-2 model anemometer was used to obtain air temperature (°C), wind speed (km.h^{-1}) and air moisture (%), while basic geographical data (elevation, coordinates) were recorded with a geographical positioning system (GARMIN etrex Vista H GPS) *in situ*. All of the physico-chemical variables of aquatic habitats were measured before sampling for ostracods to prevent possible results of pseudoreplication (Hurlbert, 1984). Ostracod samples collected from each site with a standard sized hand net (200 μm mesh size) were stored in 250 mL plastic bottle and fixed with 70% alcohol *in situ*.

In the laboratory, each sample was filtered through four standard sized sieves (0.5, 1.0, 1.5 and 2.0 mm mesh size) under tap water and then preserved in 70% alcohol for further studies. Ostracod specimens were picked up from sediments under a stereomicroscope and the soft body parts were dissected in lactophenol solution for taxonomic identification. Carapace and valves were kept in micropalaeontological slides for further use. The taxonomic key of Meisch (2000) was primarily used for taxonomic classification and species identification, supplemented with Bronhstein (1947) and Karanovic (2012) when needed. All of the ostracod samples were stored in the Limnology Laboratory of Abant İzzet Baysal University Bolu, Turkey and are available upon request.

Statistical analysis

The hypothesis of a random pattern of Poisson distribution (versus aggregated and uniform distribution) was tested by the application of Poisson probabilities along with chi-square test. Using the number of species collected in each site, the observed number of sites (f) that harbour 0, 1, 2, 3, 4 or more (4+) species was computed (Fig. 2). The mean (μ) was calculated by multiplying the number of species (*i.e.*, 0, 1,…,4+) by the numbers of sites where they observed, then dividing by the total number of sampling sites (Ludwig and Reynolds, 1988). Then, the Poisson probability of x occurrences (x represents the number of species in a habitat as 0, 1, 2, 3, 4+) in a

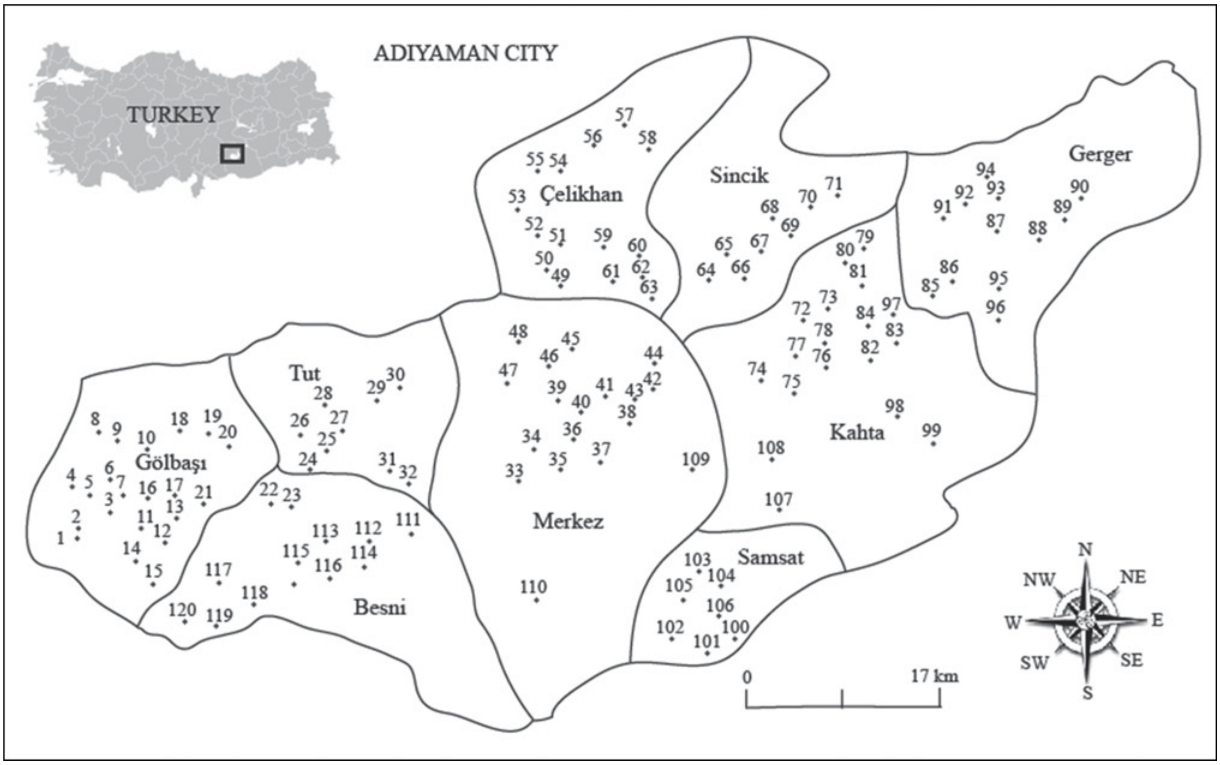

Fig. 1. The distribution of 120 randomly selected sample sites from 9 (Gölbaşı, Tut, Besni, Merkez, Samsat, Kahta, Gerger, Sincik and Çelikhan) counties of Adıyaman Province, Turkey.

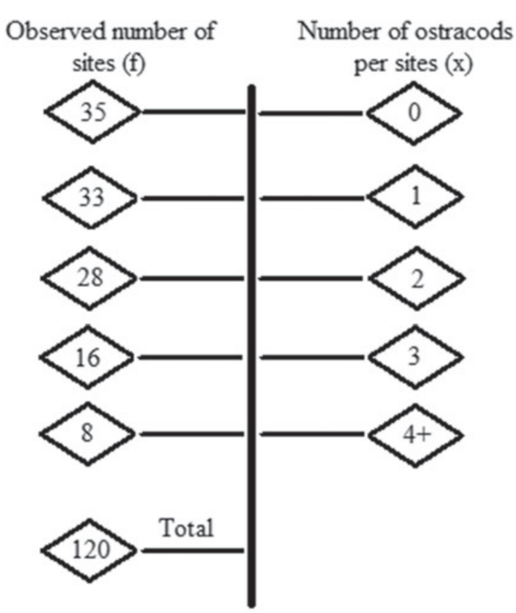

Fig. 2. The number of sites carrying 0, 1, 2, 3, 4 or more (4 +) occurrences of ostracod species (not including empty valves and carapaces).

sampling unit $P(x)$ was calculated by equation (1) (Table 1) as

$$P(x, \mu) = \frac{\mu^X e^{-\mu}}{X!} \quad (1)$$

where e is the Euler's number and is equal to approximately 2.71828; μ the mean number of successes that occur in a specified region; x the actual number of successes that occur in a specified region; $P(x; \mu)$ the Poisson probability that exactly x successes occur in a Poisson experiment, when the mean number of successes is μ.

Table 1. Poisson probabilities of 0, 1, 2, 3, 4(+) occurrences of ostracod species calculated using equation (1).

$P(x=0)$ probability of no occurrence	0.2446
$P(x=1)$ probability of one occurrence	0.3444
$P(x=2)$ probability of two occurrences	0.2425
$P(x=3)$ probability of three occurrences	0.1139
$P(x=4+)$ probability of four (+) occurrences	0.0401

In addition, hypothesis testing of Poisson distribution can also be done with a chi-square (χ^2) statistic (if $N > 30$) (Ludwig and Reynolds, 1988) which is used to investigate whether distributions of observed frequencies (O) differ from expected frequencies (E) of the actual number of successes that occurs in a sampling unit (equation 2, Table 2). Expected probabilities were counted by total samples times with Poisson probability of each occurrences ($P(x=0)$, $P(x=1)$, $P(x=2)$, $P(x=3)$, $P(x=4+)$) which were given in Table 2. Thus, chi-square is computed by the following equation (2),

$$\chi^2 = \sum_{n=0}^{n} \frac{(O-E)^2}{E} \quad (2)$$

Finally, the departure from Poisson distribution was tested by application of the index of dispersion (s^2/μ). The other test statistics for d (equation (4)) when the total

Table 2. The calculated chi-square values of five different classes (chi-square test was used to compare observed (O) and expected (E) frequencies). Expected frequency = N × Poisson Probability; five classes with two constants (habitat and species) so degrees of freedom $= n - 2 = 5 - 2 = 3$*; chi-square $= \sum(O-E)^2/E$.

Class	x	Obs. Freq.	Exp. Freq.	$O-E$	$(O-E)^2$	$(O-E)^2/E$
1	0	35	29.35	5.65	31.97	1.09
2	1	33	41.33	− 8.33	69.37	1.68
3	2	28	29.10	− 1.10	1.22	0.04
4	3	16	13.66	2.34	5.47	0.40
5	4	8	4.81	3.19	10.17	2.12
		$N = 120$		(χ^2)		5.33

Table 3. Summary of CCA. First two axes explain 77.4% of relationships between species and environmental variables of total variance.

Axes	1	2	3	4	Total inertia
Lengths of gradient[a]	5.14	3.44	2.89	4.70	
Eigenvalues	0.32	0.18	0.12	0.02	4.57
Species–environment correlations	0.71	0.53	0.48	0.23	
Cumulative percentage variance					
Of species data	6.9	10.8	13.4	13.9	
Of species–environment relation	49.6	77.4	96	99.4	
Sum of all eigenvalues					4.57
Sum of all canonical eigenvalues					0.64

[a]Shows the results of DCA (if the value of DCA is ≥ 3, data are suitable for the usage of CCA for more see ter Braak, 1987; Birks *et al*., 1990).

sample size ≥ 30 were used to measure the departure of index of dispersion (ID) from 1.0. The value of d statistic was also calculated by equation (4) for measuring the agreement with Poisson. Before calculation of d statistics, the value of chi-square (χ^2) is computed by equation (3).

$$\chi^2 = \mathrm{ID}\,(N-1) \quad (3)$$

where χ^2 is chi-square, N the total sample size; ID the index of dispersion.

$$d = \sqrt{2\chi^2} - \sqrt{2(N-1)-1} \quad (4)$$

where χ^2 from equation (3).

Canonical correspondence analysis (CCA) was used to examine relationships between 11 species (with 3 or more occurrences during the study) and the 5 most commonly used environmental variables (electrical conductivity (EC), water temperature (Tw), dissolved oxygen (DO), pH and elevation (Elev.)). All data were log-transformed (ter Braak, 1987; Birks *et al*., 1990) and tested with Monte Carlo Permutation tests (499), where rare species were eliminated from analysis to prevent the effect of multi-colinearity and arc-effect (software package CANOCO for windows 4.5). We used C2 software (Juggins, 2003) to estimate species tolerance (t_k) and optimum (μ_k) levels for different ecological variables after using a transfer function of weighted averaging regression. During the analysis, living adults (specimens with undamaged soft body parts and carapaces when collected) were used. The Alpha diversity indices (*i.e*., Shannon–Wiener Diversity) of different habitat types were calculated using the Species Diversity and Richness 4 software (Seaby and Henderson, 2006). Microsoft Excel 2010 was also used to draw the relationships among numbers of taxa per sampled sites.

Results

A total of 41 ostracod taxa (26 recent and 15 sub-fossil (empty valves and carapaces)) were reported from 111 of 120 randomly selected aquatic bodies (see the Appendix). To our knowledge all of these taxa are new reports for the region. Living (recent) forms of *Schellencandona insueta* (Klie) and *Gomphocythere* n. sp. (in preparation) are new records for the Turkish Ostracoda fauna.

The Poisson probabilities of $P(x=0)$, $P(x=1)$, $P(x=2)$, $P(x=3)$ and $P(x=4+)$ occurrences were calculated by equation (1) are like that 0.2446, 0.3444, 0.2425, 0.1139 and 0.0401, respectively (Table 1). Accordingly, the expected probabilities of them (*e.g*., $P(x=0)$, $P(x=1)$,..., $P(x=4+)$ were founded as follows 29.35, 41.33, 29.10, 13.66 and 4.81, respectively (Table 2). The chi-square (χ^2) table value (7.81) at the 5 % probability level (degrees of freedom (d.f.) = 3) is larger than χ^2 calculated (5.33) (Table 2) so the result is not significant and we accepted the random distribution hypothesis. After the application of Poisson method, the variance (s^2) = 1.508 and mean (μ) of the observed frequencies counts = 1.408 resulting in the ratio of $s^2/\mu = 1.06$. This ratio was found slightly larger than 1.0 which was not a significant ($P > 0.05$) difference suggesting a random distribution of ostracods among sampling sites. The results of d statistic (0.488) also support a random distribution of ostracods in Adıyaman Province.

The first two axes of CCA diagram explained 77.4% (Table 3) with relatively high variance (10.8%) of the relationships between 11 species and 5 environmental variables (Fig. 3). Based on the effectiveness, electrical conductivity ($F = 3.987$, $P = 0.002$, $\lambda = 0.31$), water

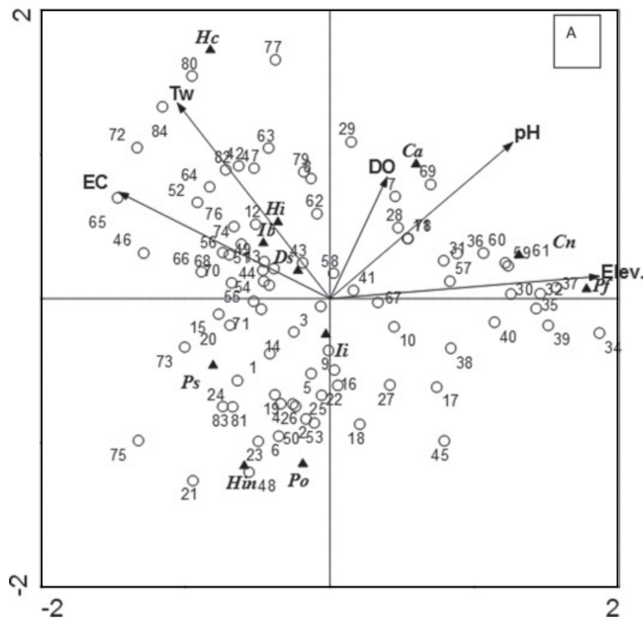

Fig. 3. CCA diagram shows the effect of the five most important environmental variables (arrows) on the distribution of 11 species with 3 or more occurrences from 83 sampling sites. Triangles show the species code, whereas open circles (o) represent the sites number. DO (dissolved oxygen, $mg.L^{-1}$), EC (electrical conductivity, $\mu S.cm^{-1}$), Tw (water temperature, °C) and Elev. (elevation, m). See the Appendix for codes of species.

temperature ($F = 3.582$, $P = 0.002$, $\lambda = 0.17$), pH ($F = 3.510$, $P = 0.002$, $\lambda = 0.12$) and elevation ($F = 4.491$, $P = 0.02$, $\lambda = 0.37$) seemed to be the most important factors on species while dissolved oxygen ($F = 0.967$, $P = 0.37$, $\lambda = 0.08$) did not show any significant effect. Three species (*Candona angulata* Müller, *Candona neglecta* Sars, *Potamocypris fallax* Fox) located on the right upper part of the CCA diagram (Fig. 3) showed a positive correlation to dissolved oxygen, pH and elevation, while four species (*Heterocypris incongruens* (Ramdohr), *Darwinula stevensoni* (Brady and Robertson), *Herpetocypris chevreuxi* (Sars), *Ilyocypris bradyi* Sars) placed on the opposite side seemed to have a close relationship to water temperature and electrical conductivity. The other species (*Psychrodromus olivaceus* (Brady and Norman), *Herpetocypris intermedia* (Kaufmann), *Potamocypris similis* G.W. Müller, *Ilyocypris inermis* Kaufmann) did not show a direct correlation to the variables used.

The ecological tolerance and optimum levels of the most frequently occurring eight species to different environmental variables indicated that species with cosmopolitan characteristics (*e.g.*, *C. neglecta*, *H. incongruens*, *I. bradyi* and *P. olivaceus*) tend to have broader tolerance ranges than those of the non-cosmopolitan species (Table 4).

Among the sampling sites, springs ($H = 2.32$), creeks ($H = 2.19$) and ponds ($H = 2.10$) displayed higher Shannon diversity values where numbers of species encountered were also higher than the other habitats (Table 5). Although we did not recognize particular habitat preferences of some of those well-known cosmopolitan species (*e.g.*, *H. incongruens*, *I. bradyi*), it appeared that most non-cosmopolitans with low occurrence frequency (*e.g.*, *Fabaeformiscandona brevicornis* (Klie), *P. fulva* (Brady), etc.) showed tendency for habitat preferences with specific local factors (*e.g.*, pH, DO). The ratio of the numbers of taxa per site (= 2) was not significantly different between lower (450–550 m) and higher (1359–1459 m) elevational ranges (Fig. 4).

Discussion

This is the first comprehensive study in Adıyaman Province resulting in all taxa (41 ostracod taxa) being new reports for the region. Although it may seem like a high diversity, the number of recent species (26) in Adıyaman (with 7164 km^2 surface area) is lower than the diversity of cities nearby such as Van (30 species; with 21 334 km^2 surface area) (Külköylüoğlu *et al.*, 2012a), Diyarbakır (29 species, with 15 272 km^2 surface area) (Akdemir and Külköylüoğlu, 2011) and Kahramanmaraş (32 species, 14 346 km^2 surface area) (Külköylüoğlu *et al.*, 2012b). In spite of we sampled each site only once during a 4-day period in July 2012, many species were collected from a variety of habitats, thus providing important contributions towards ostracod distribution and ecology. For example, finding *S. insueta* and a new species of genus *Gomphocythere* Sars (in preparation) was of significance for their distribution in Turkey. The presence of living species of *Gomphocythere* has been known to be restricted to mostly big lakes in Africa and a river in Israel (Martens, 1993). Most recently, Boomer and Gearey (2010) reported a fossil species, *Gomphocythere geareyi* from Domuztepe region (Kahramanmaraş, Turkey). This was the most northern record of the genus so far but the finding of *Gomphocythere* n. sp. from Besni (Adıyaman) changed its distribution to the north–east part of Domuztepe.

After testing the Poisson probabilities, we found random distributions of ostracods in the study area. However, our value of index of dispersion suggested a clumped distribution. This brings out a critical controversy on species distribution. According to Elliott (1973) if the absolute d value is smaller than 1.96 (or $|d| < 1.96$), a population shows random dispersion, but if $d < -1.96$ or $d > 1.96$, the distribution can be uniform or clumped, respectively. In our case, since the d statistic value (0.488) was smaller than 1.96, the distribution of ostracods were random, considering that the 0.06 difference is not statistically significant departure from 1.0.

Similar results of random distribution have already been reported for other taxonomic groups such as fleas (aphids) on leaves and some sessile invertebrates (Gabbutt, 1961; Schmidt, 1982), when some studies have revealed clumped distribution for some freshwater (Heip, 1976), marine benthic (Heip, 1975) and some sessile invertebrates (Schmidt, 1982). All of these spatial patterns of invertebrates may be explained by individual species habitat preferences affected by biotic and/or abiotic

Table 4. The optimum (u_k) and tolerance (t_k) levels of eight species (with five or more occurrences) to four different ecological variables. N_2 represents Hill's coefficient value (measure of effective number of occurrences). DO (dissolved oxygen, mg.L^{-1}), EC (electrical conductivity, µS.cm^{-1}) and Tw (water temperature, °C).

				pH		DO		EC		Tw	
Species	Count	Max	N_2	u_k	t_k	u_k	t_k	u_k	t_k	u_k	t_k
I. inermis	21	87	11.67	7.95	0.37	7.01	1.27	441.38	96.89	19.64	4.74
H. incongruens	46	89	10.97	7.93	0.31	8.00	1.81	500.28	230.83	22.47	6.21
I. bradyi	25	103	7.47	7.96	0.45	7.46	3.22	570.41	164.62	22.36	4.28
P. fallax	15	93	7.00	8.32	0.21	8.31	0.79	256.62	78.45	17.58	1.68
P. olivaceus	15	97	6.29	7.79	0.25	6.55	1.01	424.30	91.98	17.90	3.37
C. neglecta	6	21	3.65	8.36	0.36	7.93	1.09	342.49	134.38	18.84	2.74
H. intermedia	10	107	2.86	7.83	0.32	6.23	1.87	323.06	127.86	20.74	2.58
H. chevreuxi	5	21	2.80	8.33	0.56	8.83	1.43	421.53	128.86	30.60	4.13
			Mean	8.06	0.36	7.54	1.56	410.01	131.73	21.27	3.72
			Max.	8.36	0.56	8.83	3.22	570.41	230.83	30.60	6.21
			Min.	7.79	0.21	6.23	0.79	256.62	78.45	17.58	1.68

Table 5. The occurrence of 26 species in nine different aquatic bodies. Springs include three spring types as limnocrene, rheocrene and helocrene.

Species	Code	Spring ($n=44$)	Creek ($n=22$)	Pond ($n=26$)	Irrigation c. ($n=6$)	Trough ($n=11$)	Dam ($n=3$)	Stream ($n=4$)	Lake ($n=3$)	Water f. ($n=1$)
C. angulata	Ca		1	2						
C. neglecta	Cn	5			1					
D. stevensoni	Ds	1		1			1			
F. brevicornis	Fb	1								
H. brevicaudata	Hb		1		1					
H. chevreuxi	Hc	1	1	3						
H. helenae	Hh		1							
H. intermedia	Hin	5	1	3		1				
H. incongruens	Hi	16	8	7	4	6	1	2		1
I. bradyi	Ib	10	8	1	2	1	2	1		
I. gibba	Ig						1			
I. inermis	Ii	10	4	6	1					
Gomphocythere n. sp.	Gb	1								
L. inopinata	Li				1		1			
P. fallax	Pf	6	7		1	1				
P. fulva	Pfu	1								
P. pallida	Pp					1				
P. similis	Ps	1	1			1				
P. smaragdina	Psm		2							
P. variegata	Pv			1						
P. albicans	Pa	1		1						
P. semicognita	Pse		1							
P. olivaceus	Po	11	2	1		1				
S. insueta	Si	1								
T. clavata	Tc	1		1						
Z. costata	Zc	1								
	H	2.32	2.19	2.10	1.77	1.59	1.56	0.64	0.00	0.00
Shannon	Variance H	0.01	0.02	0.03	0.06	0.09	0.07	0.09	0.00	0.00
	Exp. H	10.20	8.89	8.15	5.86	4.90	4.76	1.89	1.00	1.00

Water f., water fall; Irrigation c., irrigation canal; H, Shannon diversity value; Exp. H, Expected Shannon diversity value. All Sample Index = 2.48 and Jackknife Standart Error = 0.09.

factors (Benzie, 1989; Kiss, 2007; Dügel *et al.*, 2008; González-Megías *et al.*, 2011). In the present study, random distributional patterns of ostracods among a variety of sampling sites may be supported by the dominant occurrence of cosmopolitan species (*e.g.*, *C. neglecta*, *D. stevensoni*, *H. incongruens*, *I. bradyi*, *I. gibba* (Ramdohr), *P. olivaceus*, *L. inopinata* (Baird)) (for the details see Appendix). This is probably due to a wide geographic distribution of cosmopolitans with relatively high tolerance levels to different ecological variables (Külköylüoğlu, 2004). Thus, having such an advantage over non-cosmopolitan species, cosmopolitans can be easily adapted to conditions which may not be suitable for others. Consequently, a relatively higher frequency of

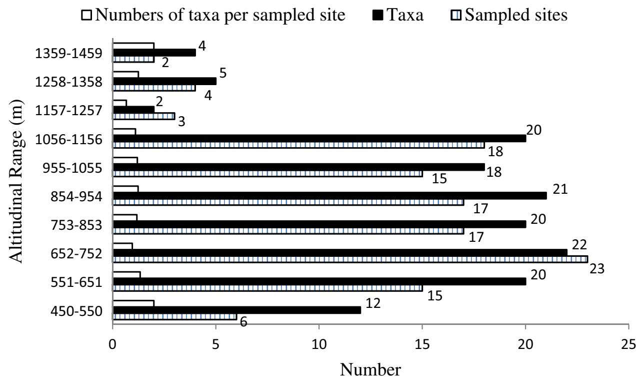

Fig. 4. The numbers of taxa, sites and taxa per sampled site located at 100-m of elevational ranges.

their occurrence may be one of the explanations for finding random distribution of the species among sampling sites. The other important reason for explaining the random distribution of ostracods may be related to their desiccation and freezing resistant eggs (Delorme, 1991). Although the species may die, their eggs can survive in unfavourable conditions for many years until the conditions are appropriate for hatching and the continued survival of the species in the habitat. Having such resistant eggs is a great advantage for ostracods and might contribute to their random distribution in an area. This can also be done by the passive dispersion modes such as human, bird, fish, wind (for prevailing resting eggs), plants, amphibians and insects (McKenzie and Moroni, 1986; Horne and Martens, 1998; Rossi *et al.*, 2003; Rodriguez-Lazaro and Ruiz-Muñoz, 2012). However, because the null hypothesis was accepted, we were not able to test the other distribution patterns (clumped and regular). Thus, such results cannot be generalized at the moment.

Similar to some of the previous studies (*e.g.*, Sarı, 2007; Van der Meeren *et al.*, 2010; Szlauer-Łukaszewska, 2014; Uçak *et al.*, 2014), four species (*I. inermis*, *I. bradyi*, *H. incongruens* and *D. stevensoni*) are located relatively closer to the centre of diagram (Fig. 3). Considering that these four species have almost cosmopolitan distribution (also called "cosmoecious species" for their high tolerance levels in wide geographical distribution by Külköylüoğlu (2013)), one may interpret that such variables did not have a critical influence on these species. In contrast, three species (*H. intermedia*, *P. similis* and *P. olivaceus*) located on the left bottom of the CCA diagram seem to show a negative correlation with the environmental variables used in this analysis. Since ecological data are so scarce about *P. similis*, such knowledge is better for the *H. intermedia* and *P. olivaceus* which displayed relatively lower optimum and tolerance values than the mean values calculated for eight species (Table 4). In stark contrast, Külköylüoğlu and Sarı (2012) showed high tolerance values of *P. olivaceus* to different variables. *H. intermedia*, however, appears to have relatively low tolerance levels for pH ($t_k = 0.9$), electrical conductivity ($t_k = 299$), water temperature ($t_k = 2.3$) and elevation ($t_k = 171.4$) (Külköylüoğlu *et al.*, 2012b). Unlike *H. intermedia*, *H. chevreuxi* showed higher optimum and tolerance values to temperature than the mean calculated for other species (Table 4), supporting the result of CCA (Fig. 3). Similarly, Roca and Baltanás (1993) and Viehberg (2006) pipointed the preferences and high tolerance of *H. chevreuxi* for temperature. Two other species (*C. neglecta* and *P. fallax*) are located nearby the arrow of elevation (Fig. 3). It is already known that *C. neglecta* has a wide elevational range from 0 m (Külköylüoğlu *et al.*, 2012c) to 3194 m a.s.l. (Külköylüoğlu, 2013). Similarly, Poquet and Mesquita-Joanes (2011) illustrated a positive correlation of *C. neglecta* with the elevation. On the other hand, such distribution is limited for *P. fallax* between 780–1383 m a.s.l. (this study). This corresponds with the previously known range (605–1954 m a.s.l.) (Külköylüoğlu *et al.*, 2012c; Akdemir and Külköylüoğlu, 2014). Such correlations revealed by the results of CCA partially correspond to the optimum and tolerance values of individual species (Table 4). Even though correlations cannot be counted as causation (Aldrich, 1995), one possible reason (other than biological reasons) of finding different correlations for these species might be related to species individual habitat preferences and conditions (as mentioned above). Indeed, findings of tolerance and optimum levels of the eight most common species (Table 4) implied that individual species showed species-specific tolerance and optimum levels to four of the environmental variables. Of which, the species *H. incongruens* has the higher tolerance level for water temperature, while *I. bradyi* has higher tolerance levels than the mean values of pH, dissolved oxygen, electrical conductivity and temperature (Table 4). Similarly, the previous studies in different geographical areas (Karakaş-Sarı and Külköylüoğlu, 2008; Külköylüoğlu *et al.*, 2013; Uçak *et al.*, 2014) indicated that the tolerance levels of species to different variables can change from species to species. However, such knowledge is limited for most species. For example, *F. brevicornis* has been reported from slow flowing stagnant water bodies connected to cold spring habitats (Meisch, 2000). Indeed, we found this species from a rheocrene spring where water temperature was 15.3 °C. This value shows similarity with its previously known ranges for temperature from 8.73 °C (Külköylüoğlu *et al.*, 2014) to 22.6 °C (Sarı, 2007). Accompanying species, *P. fulva* prefers shallow, slow flowing waters, cave and interstitial habitats of streams. Therefore, it was characterized as a stygophilic species by Meisch (2000). The ranges of this species are wider than *F. brevicornis* for temperature (27.40–1.56 °C) (Sarı, 2007; Külköylüoğlu *et al.*, 2007).

Based on the results of the CCA, the elevation was among the most four effective factors but we did not find a significant effect of elevation on the species occurring at different elevational ranges (Fig. 4). This is because of the ratio (taxa per sampled site) at the lower and higher elevational ranges equal to each other and the ratio from 551 to 1156 m a.s.l. were also closer to each other (Fig. 4).

Although there is a conflict about the role of elevation on species (Mezquita *et al.*, 1999; Laprida *et al.*, 2006; Külköylüoğlu *et al.*, 2012c; Külköylüoğlu, 2013), based on the results we accept that the elevation may play a secondary role on species distribution. For example, since water temperature decreases as the elevation increases, constituents of many physico-chemical characteristics of water (*e.g.*, oxygen, pH and solid materials) can be changed (Reeves *et al.*, 2007). Such changes can eventually affect the species. In this case, species with higher tolerances can increase their overall distribution better than the other species.

Values of Shannon diversity index of spring, creek and ponds (Table 5) in here are higher than those previously reported for the flowing waters of Eastern Iberian Peninsula ($H = 0.826 \pm 0.533$) (Mezquita *et al.*, 1999) and for a shallow lake (Lake Świdwie) ($H = 1.668$) in Poland (Szlauer-Łukaszewska, 2012). These differences may be associated with the differences in sampling time, numbers and types of sampling sites and geographical differences. On the other hand, a study (Külköylüoğlu *et al.*, 2012b) done in Kahramanmaraş (Turkey) showed similar results with ours that the authors arranged the sites with their high diversity values as limnocrene spring ($H = 2.89$), pond ($H = 2.2$), stream ($H = 2.08$) and creek ($H = 1.95$). Overall, the studies mentioned above, pond, spring and creek may be better and suitable habitats for ostracods reported herein.

Conclusion

Finally, our results suggest that ostracods (especially cosmopolitans) have a high tendency for a random distribution. Külköylüoğlu (2013) used a new term “cosmoecious species” for those cosmopolitans with wide geographical distribution and relatively high tolerance levels to different environmental variables. Therefore, it seems that cosmopolitans gaining better opportunity for feeding and reproduction than non-cosmopolitans in variety of habitats contribute more on the random distribution. At least three results of the present study support this idea as: (i) finding most of the cosmopolitan species closer to the centre of the CCA diagram (Fig. 3); (ii) encountering well-known cosmopolitans (*e.g.*, *H. incongruens* and *I. bradyi*) from lowest (450–550 m) to highest (1359–1459 m, Fig. 4) elevational ranges; and (iii) wider occurrences in different habitats (Table 5). It appears that if conditions are suitable for ostracods, they can be found in many kinds of aquatic habitats. Thus, it is most likely true that neither regional (spatial) (*e.g.*, elevation, habitat type) nor local factors (*e.g.*, water temperature, pH and EC) are critically effective on most cosmopolitan species. However, since non-cosmopolitan species prefer certain types of habitat conditions, local factors seem to be more important drivers than regional factors. On the other hand, these results cannot be generalized at the moment due to lack of studies on the subject of Poisson distribution on ostracods.

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Appendix 1. Ecological variables were measured and taxa were reported from different aquatic bodies.

St. no	City	St. Ty	pH	DO	%DO	EC	Sp. EC	Sal	Tw	Ta	TDS	Atm.	Moist.	W. s.	Elev.	Coordinate	Date	Taxa
1	Adıyaman	4	7.52	7.97	84.0	512.0	591.0	0.29	18.0	34.3	0.3835	686.4	30.7	3.8	850	N37°34′422″, E037°28′431″	7/16/2012	Ca; Hin; Hi; Ii; (Pzi; Pysp)
2	Adıyaman	1	7.5	6.3	63.0	454.0	560.0	0.27	15.1	31.4	0.3601	680.8	25.8	4.2	886	N37°36′919″, E037°29′085″	7/16/2012	Hi; Ib
3	Adıyaman	5	7.94	5.61	61.0	549.0	620.0	0.3	19.1	32.3	0.403	682.5	24.2	3.2	859	N37°37′443″, E037°30′217″	7/16/2012	Ib; (Csp; Pzi; Pysp)
4	Adıyaman	4	7.57	2.64	29.6	499.0	561.3	0.27	19.1	32.6	0.3646	678.2	30.0	32.5	915	N37°39′221″, E037°30′517″	7/16/2012	Hin; (Csp; Isp)
5	Adıyaman	1	7.6	6.06	63.7	471.4	550.0	0.27	17.6	32.8	0.3575	676.9	24.5	7.8	937	N37°39′803″, E037°30′811″	7/16/2012	Ib; (Csp; Hsp; Ms)
6	Adıyaman	7	7.4	5.64	59.3	583.0	667.0	0.33	18.4	35.7	0.4355	677.0	25.2	4.0	928	N37°39′239″, E037°30′878″	7/16/2012	
7	Adıyaman	1	7.29	3.97	39.9	545.0	672.0	0.33	15.1	37.9	0.4355	677.0	23.0	1.7	933	N37°39′229″, E037°30′896″	7/16/2012	Ii; Si
8	Adıyaman	6	8.3	6.74	73.9	595.0	656.0	0.32	20.5	33.4	0.4225	672.5	23.0	10.2	981	N37°41′180″, E037°31′865″	7/16/2012	Hi; (Cysp; Isp; Tsp)
9	Adıyaman	11	8	6.51	78.4	667.0	676.0	0.33	24.3	37.7	0.443	673.3	21.3	1.9	987	N37°40′908″, E037°31′502″	7/16/2012	Hi; Ib; (Hts)
10	Adıyaman	1	7.53	6.48	64.5	565.0	689.0	0.34	15.6	40.5	0.4485	673.6	21.8	1.6	991	N37°40′906″, E037°31′775″	7/16/2012	Cn; Po; Zc; (Hts; Hsp; Isp)
11	Adıyaman	6	7.92	4.43	49.6	446.0	479.9	0.23	21.4	39.5	0.312	667.2	13.4	6.5	1050	N37°38′915″, E037°35′497″	7/16/2012	(Hsp; Isp)
12	Adıyaman	7	9.17	12.24	141.7	308.4	315.2	0.15	24.2	38.0	0.2047	665.4	15.0	10.2	1080	N37°39′363″, E037°35′714″	7/16/2012	(Hsp; Isp)
13	Adıyaman	1	8.09	6.1	66.1	450.4	501.7	0.24	19.7	37.4	0.3256	666.3	13.8	6.6	1069	N37°39′431″, E037°35′868″	7/16/2012	(Esp; Isp; Pysp)
14	Adıyaman	2	7.51	5.65	60.3	534.0	608.0	0.3	18.6	37.3	0.3965	670.1	16.3	2.3	1016	N37°39′474″, E037°33′528″	7/16/2012	(Isp)
15	Adıyaman	12	7.84	7.15	70.07	492.0	607.3	0.3	15.2	36.5	0.3946	669.1	15.3	14.2	1023	N37°39′603″, E037°33′447″	7/16/2012	Po; (Isp)
16	Adıyaman	6	8.71	5.4	67.1	484.1	469.0	0.22	26.6	37.0	0.3848	668.3	14.0	11.0	1030	N37°40′735″, E037°32′414″	7/16/2012	
17	Adıyaman	6	8.63	9.0	122.0	1241	1090.0	0.53	32.3	39.0	0.7085	668.7	14.7	0.0	1029	N37°40′818″, E037°32′465″	7/16/2012	(Hsp)
18	Adıyaman	11	8.63	7.52	95.9	389.3	382.6	0.18	25.9	41.5	0.2489	680.2	19.7	5.2	883	N37°44′607″, E037°33′228″	7/16/2012	(Csp; Hsp; Isp)
19	Adıyaman	4	8.5	7.41	89.6	327.3	324.5	0.15	25.4	38.2	0.2112	679.5	13.5	4.0	885	N37°47′885″, E037°39′691″	7/16/2012	(Esp; Isp)
20	Adıyaman	4	8.63	9.02	110.9	322.3	318.0	0.15	25.6	39.3	0.2067	679.5	14.9	4.4	888	N37°47′903″, E037°39′658″	7/16/2012	(Csp; Isp; Pysp)
21	Adıyaman	3	8.12	6.59	70.3	537.0	603.0	0.29	19.4	39.9	0.39	664.5	13.5	1.8	1070	N37°45′028″, E037°42′229″	7/16/2012	Cn; Hi; Ii
22	Adıyaman	5	7.95	6.8	91.3	584.0	549.0	0.26	28.3	37.9	0.3575	683.7	13.9	2.0	849	N37°45′230″, E037°44′987″	7/16/2012	(Csp; Isp; Psp)
23	Adıyaman	8	8.09	7.38	90.0	560.0	557.0	0.27	25.3	39.4	0.364	689.7	13.4	6.8	749	N37°45′203″, E037°49′380″	7/16/2012	Hi; Ib; Li; (Csp; Psp)
24	Adıyaman	9	8.1	7.4	90.2	419.2	416.1	0.2	25.5	42.0	0.2704	687.1	12.0	11.4	780	N37°45′169″, E037°50′127″	7/16/2012	Hi
25	Adıyaman	1	8.19	7.27	80.2	410.7	453.5	0.22	20.1	42.0	0.2944	696.8	15.4	4.5	625	N37°47′000″, E037°50′867″	7/16/2012	Hin; Ib; (Hsp; Pysp)
26	Adıyaman	1	7.82	4.13	46.8	638.0	680.0	0.33	21.8	39.4	0.442	691.9	18.5	2.3	681	N37°46′706″, E037°52′487″	7/16/2012	Hi; Ii; Po
27	Adıyaman	1	7.9	7.01	73.2	382.5	445.2	0.21	17.7	39.5	0.2906	681.2	13.1	2.0	837	N37°46′694″, E037°52′480″	7/16/2012	Hin; Ii; Po; (Hsp)
28	Adıyaman	4	8.25	5.28	62.0	440.5	451.2	0.22	23.7	40.3	0.2931	681.4	12.6	7.5	843	N37°47′233″, E037°52′779″	7/16/2012	(Esp; Isp; Pysp)
29	Adıyaman	1	8.01	8.35	84.0	211.6	256.7	0.12	15.8	37.2	0.167	666.4	15.4	0.0	1028	N37°47′854″, E037°53′669″	7/16/2012	Ib; Pf; Po
30	Adıyaman	1	7.53	5.16	50.7	413.8	515.1	0.25	14.7	36.3	0.3347	666.5	21.9	0.0	1040	N37°47′854″, E037°53′671″	7/16/2012	Po; (Csp; Esp; Isp)
31	Adıyaman	4	7.81	6.1	63.1	460.8	542.1	0.26	17.1	36	0.3542	696.5	14.0	0.0	680	N37°46′408″, E037°57′350″	7/16/2012	Ii; Po; (Hsp)
32	Adıyaman	8	8.04	4.96	58.9	495.8	512.0	0.25	23.3	35.1	0.3321	701.5	24.9	1.6	615	N37°46′316″, E037°58′134″	7/16/2012	Hb; Hi; (Csp; Isp)
33	Adıyaman	1	7.31	7.3	78.2	359.2	418.2	0.2	17.6	36.3	0.2717	696.1	38.0	0.0	678	N37°47′950″, E038°17′906″	7/17/2012	
34	Adıyaman	1	7.42	7.93	82.9	338.1	396.1	0.19	17.4	36.6	0.2574	696.1	28.7	0.0	573	N37°48′018″, E038°17′873″	7/17/2012	Po; (Isp; Psp)
35	Adıyaman	6	8.16	8.84	89.7	314.2	380.0	0.18	15.9	36.5	0.247	699.8	34.1	0.0	629	N37°48′097″, E038°18′304″	7/17/2012	Hi; (Csp; Isp; Psp; Pysp)
36	Adıyaman	1	7.6	6.84	71.8	339.9	392.8	0.19	18.0	35.4	0.2554	691.8	21.5	1.5	730	N37°48′557″, E038°19′953″	7/17/2012	Ib; (Hts; Hsp; Pysp)
37	Adıyaman	9	7.77	6.4	76.6	371.4	394.2	0.19	22.0	35.4	0.2561	692.8	22.0	3.2	716	N37°48′381″, E038°19′992″	7/17/2012	(Hts; Hsp; Isp)
38	Adıyaman	5	7.56	7.63	81.3	476.5	542.3	0.26	18.6	36.4	0.3523	691.7	23.0	0.0	728	N37°48′654″, E038°20′926″	7/17/2012	Hc; Hi; Ii; Ps; Po; (Csp)
39	Adıyaman	9	7.56	7.44	74.3	431.7	526.5	0.26	15.6	36.3	0.3425	678.0	22.1	0.0	915	N37°51′224″, E038°18′678″	7/17/2012	Hin; Hi; Pp
40	Adıyaman	9	7.56	1.47	15.7	523.0	591.0	0.29	19.0	38.4	0.3835	673.7	20.1	2.7	970	N37°51′600″, E038°18′882″	7/17/2012	Pf; (Hsp)
41	Adıyaman	1	8.8	7.74	78.0	362.4	439.6	0.21	15.8	39.6	0.2854	672.5	17.8	4.3	985	N37°51′604″, E038°18′951″	7/17/2012	Pos; (Hts; Isp)
42	Adıyaman	1	7.77	8.27	82.7	325.4	399.5	0.19	15.3	41.2	0.26	670.7	17.0	0.0	1004	N37°51′669″, E038°18′893″	7/17/2012	Hin; Hi; Pos; (Csp)
43	Adıyaman	5	8.48	7.61	84.0	477.8	526.0	0.25	20.2	38.8	0.3419	682.2	22.0	1.7	854	N37°51′801″, E038°17′596″	7/17/2012	Hi; Pf; (Isp; Psp)
44	Adıyaman	4	8.68	9.86	129.0	343.4	315.3	0.15	29.7	36.7	0.2047	674.0	16.4	5.1	850	N37°52′817″, E038°17′395″	7/17/2012	Hc; (Esp; Hsp; Isp; Psp)
45	Adıyaman	1	8.6	8.49	86.7	124.7	150.5	0.07	16.2	34.3	0.1203	652.2	16.7	12.3	1253	N37°54′334″, E038°17′102″	7/17/2012	
46	Adıyaman	1	8.04	6.21	73.2	658.0	677.0	0.33	23.5	39.5	0.442	665.4	15.6	0.0	1089	N37°55′598″, E038°15′676″	7/17/2012	(Hsp; Isp)
47	Adıyaman	9	8.45	8.32	86.0	277.1	329.9	0.16	16.2	35.2	0.2145	664.7	15.4	12.0	1083	N37°55′722″, E038°15′585″	7/17/2012	Hi
48	Adıyaman	5	8.22	8.55	91.6	388.2	442.4	0.21	18.6	38.4	0.2873	664.8	15.0	2.3	1074	N37°56′409″, E038°15′826″	7/17/2012	Ib; Ks; (Hsp)
49	Adıyaman	1	8.4	8.56	84.1	237.5	358.6	0.17	14.6	36.2	0.2334	657.5	14.5	3.5	1172	N37°58′163″, E038°17′896″	7/17/2012	Pos
50	Adıyaman	1	8.52	8.53	87.5	210.6	25.9	0.12	16.6	38.2	0.1631	660	20.0	6.8	1145	N37°54′022″, E038°16′929″	7/17/2012	Pf; (Cvs; Hsp; Isp; Pysp)
51	Adıyaman	6	8.54	7.77	82.4	264.7	300.7	0.14	18.7	37.4	0.1957	661.2	16.1	2.0	1126	N37°59′023″, E038°16′934″	7/17/2012	Pos; (Hts; Hsp; Isp)

Appendex 1. (*Contd.*)

St. no	City	St. Ty	pH	DO	%DO	EC	Sp. EC	Sal	Tw	Ta	TDS	Atm.	Moist.	W. s.	Elev.	Coordinate	Date	Taxa
52	Adıyaman	1	8.04	9.53	86.6	119.3	163.9	0.08	10.7	35.9	0.1073	653.5	16.0	3.5	1213	N37°59′038″, E038°15′535″	7/17/2012	(Isp)
53	Adıyaman	8	8.35	7.99	96.3	407.3	409.9	0.2	24.8	34.8	0.2665	646.7	14.8	12.5	1308	N38°00′958″, E038°12′854″	7/17/2012	(Hsp; Isp; Pos)
54	Adıyaman	5	8.78	10.64	149.7	435.8	372.5	0.17	33.9	36.0	0.2424	647.9	21.0	4.3	1295	N38°01′436″, E038°12′972″	7/17/2012	Hi
55	Adıyaman	1	8.26	10.27	93.2	188.3	255.4	0.12	11.2	37.3	0.1658	648	9.9	3.2	1302	N38°01′629″, E038°10′858″	7/17/2012	Po
56	Adıyaman	4	8.16	9.16	92.4	216.4	261.0	0.12	16.1	34.4	0.1697	647.9	10.0	3.5	1304	N38°01′654″, E038°10′889″	7/17/2012	Hi; (Isp)
57	Adıyaman	5	7.96	6.4	73.9	357.9	377.2	0.18	22.4	34.6	0.2444	642.4	15.6	3.2	1383	N38°02′017″, E038°15′134″	7/17/2012	Hi; Ib; Pf
58	Adıyaman	5	8.2	8.03	81.9	254.9	302.1	0.15	16.6	34.5	0.1963	642.5	16.2	2.5	1383	N38°02′017″, E038°15′094″	7/17/2012	Pf; (Csp)
59	Adıyaman	1	7.93	8.02	80.2	322.6	396.4	0.19	15.3	34.7	0.2574	662.7	19.1	1.9	1132	N37°58′943″, E038°17′943″	7/17/2012	Fb; Hi; Ii; Pfu
60	Adıyaman	1	8.47	9.16	89.5	184.6	232.2	0.11	14.3	35.7	0.1508	662.3	14.5	2.2	1116	N37°58′935″, E038°18′112″	7/17/2012	Cn; Pf
61	Adıyaman	9	8.31	6.29	73.3	197.4	204.3	0.1	23.2	35.7	0.1326	663.1	13.1	0.0	1103	N37°58′921″, E038°18′783″	7/17/2012	
62	Adıyaman	5	8.45	7.97	84.4	178.4	205.6	0.1	18.1	38.7	0.1339	666.2	15.0	3.2	1065	N37°59′129″, E038°19′680″	7/17/2012	Pf
63	Adıyaman	1	8.21	6.31	73.9	362.5	376.8	0.18	23.0	37	0.2451	678.6	18.4	0.0	909	N37°59′066″, E038°21′876″	7/17/2012	Ds; Hin; Hi; Ii; Po
64	Adıyaman	4	8.1	9.51	129.1	449.5	399.8	0.19	31.6	36.9	0.2593	683.4	10.3	3.0	853	N37°58′812″, E038°27′694″	7/17/2012	Hc; (Hsp; Isp)
65	Adıyaman	5	8.27	5.57	68.3	432.7	429.1	0.2	25.5	37.2	0.2789	686.4	11.3	3.3	800	N37°58′992″, E038°27′488″	7/17/2012	Ib; Pf; Po; (Esp; Hsp; Psp)
66	Adıyaman	1	8.03	6.47	77.5	455.2	459.5	0.22	24.5	35.6	0.2983	687.1	20.2	3.5	780	N37°58′745″, E038°28′345″	7/17/2012	Cn; Ii; Pf; Pa; Po
67	Adıyaman	4	8.21	10.61	95.5	139.7	191.4	0.09	10.9	35	0.1241	675.3	12.1	2.7	763	N37°58′577″, E038°30′553″	7/17/2012	Ii; (Hts; Hsp)
68	Adıyaman	1	7.59	2.13	26.6	817.0	792	0.39	26.6	35.9	0.5135	690.1	13.7	4.5	748	N37°58′518″, E038°32′650″	7/17/2012	Hi; (Hts; Isp; Psp)
69	Adıyaman	5	8.26	5.98	71.0	767.0	784	0.38	24.0	34.8	0.507	696.4	15.4	2.7	667	N37°58′214″, E038°34′995″	7/17/2012	Hi
70	Adıyaman	5	7.94	6.18	71.1	674.0	698	0.34	23.2	33.3	0.455	692.2	24.5	2.3	720	N37°58′079″, E038°36′155″	7/17/2012	(Esp; Hts; Hi; Isp; Psp)
71	Adıyaman	5	7.63	5.41	60.2	222.7	240.9	0.11	20.9	31.8	0.156	688.8	28.6	1.7	753	N37°58′076″, E038°36′155″	7/17/2012	Hin; Ib; (Psp)
72	Adıyaman	6	8.14	7.42	85.1	570.0	608.0	0.03	21.7	31.1	0.3965	698.3	27.2	1.5	638	N37°56′632″, E038°36′226″	7/17/2012	Hi; Ib; (Hts)
73	Adıyaman	1	7.67	5.45	58.8	365.0	409.0	0.2	19.5	30.5	0.2659	684.5	25.6	6.5	819	N37°56′634″, E038°36′227″	7/18/2012	(Cvs; Hts; Isp)
74	Adıyaman	1	7.35	8.08	83.8	366.0	431.6	0.21	17.0	31.4	0.2808	683.1	26.2	6.5	858	N37°51′674″, E038°34′643″	7/18/2012	(Esp; Hts; Isp)
75	Adıyaman	1	7.55	7.92	81.8	386.8	459.7	0.22	16.8	31.8	0.3003	683.6	25.6	10.0	855	N37°52′279″, E038°35′337″	7/18/2012	Hi; Ib; (Hts; Pos)
76	Adıyaman	5	8.18	7.08	86.0	490.4	502.7	0.24	23.7	33.5	0.327	699.9	26.8	6.5	659	N37°53′143″, E038°35′627″	7/18/2012	Hh; Hi; Ii; (Psp)
77	Adıyaman	4	7.92	2.72	30.5	326.5	351.9	0.17	26.3	34.5	0.2288	703.5	23.4	2.5	604	N37°55′956″, E038°36′492″	7/18/2012	(Hts; Isp; Pos)
78	Adıyaman	1	7.9	6.49	77.2	771.0	780	0.38	24.4	33.6	0.507	697.8	23.2	8.0	671	N37°55′980″, E038°38′071″	7/18/2012	Hi; (Hts; Isp; Ts)
79	Adıyaman	1	8.11	9.89	94.4	184.3	237.5	0.11	13.3	34.6	0.1547	697.8	22.4	8.5	668	N37°57′022″, E038°39′781″	7/18/2012	(Csp; Isp; Pos)
80	Adıyaman	9	8.18	5.5	60.8	217.1	239.6	0.11	20.1	33.9	0.156	698.4	24.2	7.5	662	N37°57′054″, E038°39′785″	7/18/2012	Hi; Ps
81	Adıyaman	1	7.82	8.9	87.0	280.5	354.0	0.17	14.2	34.6	0.2301	689.1	26.9	2.0	783	N37°54′728″, E038°39′143″	7/18/2012	(Hsp; Isp; Pysp)
82	Adıyaman	5	7.95	6.5	77.8	482.8	487.2	0.23	24.4	36.7	0.3185	687	20	4.5	807	N37°53′088″, E038°41′715″	7/18/2012	Ii; Psm; (Cn; Cvs; Hsp)
83	Adıyaman	1	7.7	6.48	74.2	539.0	565.0	0.27	22.5	40.4	0.3705	682.7	14.8	9.0	856	N37°53′466″, E038°45′647″	7/18/2012	Hin; Hi; Ib
84	Adıyaman	9	7.77	7.07	86.2	543.0	534.0	0.26	26.0	41.0	0.3445	683.5	14.4	0.0	847	N37°54′310″, E038°47′310″	7/18/2012	Hi
85	Adıyaman	1	8.34	7.49	84.2	263.4	284.2	0.14	21.2	39.5	0.1846	663.6	23.0	0.0	1090	N37°56′643″, E038°48′160″	7/18/2012	Hi; Pf; (Csp; Isp)
86	Adıyaman	9	7.65	7.05	78.5	550.0	601.0	0.29	20.6	41.5	0.39	664.3	15.5	2.5	1101	N37°56′912″, E038°48′379″	7/18/2012	Hi; Ib
87	Adıyaman	9	7.87	7.73	74.4	286.3	365.0	0.18	13.7	41.1	0.2379	663.6	18.1	0.0	1110	N37°57′761″, E038°48′771″	7/18/2012	
88	Adıyaman	5	8.37	9.23	95.6	303.2	357.6	0.17	17.0	37.8	0.2327	660.2	15.6	2.5	1145	N37°58′368″, E038°49′049″	7/18/2012	Ca; Ib; Pf; (Psp)
89	Adıyaman	8	8.48	8.03	87.1	320.8	360.6	0.17	19.2	40.6	0.2346	665.7	14.0	3.5	1080	N37°58′932″, E038°49′568″	7/18/2012	Cn; Hi; Ii; Pf
90	Adıyaman	1	8.63	8.92	95.1	239.3	272.2	0.13	18.7	42.3	0.1775	669	26.3	0.0	1038	N37°59′104″, E038°50′025″	7/18/2012	Cn; Hi; Ii; Pf
91	Adıyaman	5	8.16	6.47	77.2	570.0	583.0	0.28	23.9	42.4	0.377	681.2	19.7	0.0	887	N37°58′908″, E038°51′164″	7/18/2012	Hi; Ib; Pse; (Cvs)
92	Adıyaman	4	8.72	4.92	67.2	517.0	457.0	0.22	31.9	42.5	0.299	697.7	20.0	0.0	673	N37°58′844″, E038°53′211″	7/18/2012	Ii; (Csp; Hts; Hsp; Pos; Pysp)
93	Adıyaman	1	8.41	6.71	93.3	444.2	385.6	0.18	33.0	42.9	0.2509	700.5	18.5	1.5	642	N37°58′795″, E038°54′806″	7/18/2012	Hi; Ps; (Isp; Psp)
94	Adıyaman	5	8.07	6.97	79.1	442.1	400.7	0.19	30.5	43.8	0.2606	701.6	12.0	2.5	604	N37°58′186″, E038°53′698″	7/18/2012	
95	Adıyaman	1	7.86	7.49	105.4	552.0	473.0	0.22	33.8	42.8	0.3055	696	15.2	0.0	661	N37°57′870″, E038°54′037″	7/18/2012	Hc; Hi; Ib; (Esp; Hts; Isp; Pos)
96	Adıyaman	4	8.08	6.2	81.5	410.2	376.4	0.18	29.7	40.2	0.2451	694.9	15.0	6.5	675	N37°56′930″, E038°51′564″	7/18/2012	Ds; (Isp; Pos)
97	Adıyaman	4	7.97	6.18	70.7	360.7	381.8	0.18	22.1	36.3	0.2496	661.1	16.5	3.5	1093	N37°56′086″, E038°46′204″	7/18/2012	Ii; Pa; (Pysp)
98	Adıyaman	4	7.93	9.86	126.1	377.0	354.8	0.17	28.3	36.6	0.2307	688.6	18.0	1.5	761	N37°52′063″, E038°40′783″	7/18/2012	Hin; (Isp)
99	Adıyaman	4	9.25	7.33	91.3	217.7	207.6	0.1	27.6	35.8	0.1352	690.5	14.5	2.0	737	N37°51′659″, E038°40′372″	7/18/2012	Hc; (Cysp; Hsp; Isp; Pos)
100	Adıyaman	3	8.4	7.27	90.6	408.2	393.6	0.19	27.0	31.2	0.2561	708.7	21	2.5	543	N37°32′029″, E038°29′155″	7/19/2012	(Esp; Isp)
101	Adıyaman	3	8.31	7.11	88.1	407.4	398.5	0.19	26.1	32.6	0.2593	708.9	20.7	1.5	538	N37°32′205″, E038°29′132″	7/19/2012	Ds; Ib;(Hts)
102	Adıyaman	5	8.1	7.36	78.5	567.0	645.0	0.31	18.6	30.4	0.4225	707.7	24.6	2.5	548	N37°32′185″, E038°27′743″	7/19/2012	Hb; Hi; (Isp)

Appendix 1. (*Contd.*)

St. no	City	St. Ty	pH	DO	%DO	EC	Sp. EC	Sal	Tw	Ta	TDS	Atm.	Moist.	W. s.	Elev.	Coordinate	Date	Taxa
103	Adıyaman	1	7.58	8.92	99.5	1068.0	1165.0	2.58	20.7	32.8	0.754	705.6	31.6	0.0	573	N37°34′084″, E038°27′744″	7/19/2012	Dsp; Hi
104	Adıyaman	5	7.82	4.94	57.0	552.0	578.0	0.28	22.6	33.9	0.377	706.4	27.8	3.5	564	N37°34′046″, E038°27′235″	7/19/2012	Hi; Ib; (Hts; Psp)
105	Adıyaman	3	8.53	6.12	78.5	419.2	393.7	0.19	28.4	35.3	0.2554	708.8	33.3	0.0	537	N37°34′507″, E038°27′223″	7/19/2012	Hi; Ib; Ig; Li; (Cysp)
106	Adıyaman	1	7.36	4.57	49.4	555.0	623.0	0.3	19.4	35.4	0.403	708.3	25.4	2.0	545	N37°34′413″, E038°26′207″	7/19/2012	Ib; (Hsp; Pos)
107	Adıyaman	5	8.2	7.38	83.0	587.0	634.0	0.36	21.3	35.8	0.4095	706	17.6	7.5	567	N37°37′436″, E038°29′332″	7/19/2012	(Esp; Hts)
108	Adıyaman	4	7.6	1.84	20.5	658.0	714.0	0.35	20.9	37.3	0.4615	704.9	15.2	10.5	583	N37°45′315″, E038°32′076″	7/19/2012	Pv; Tc; (Csp; Hts; Hsp; Isp)
109	Adıyaman	2	8.36	6.69	70.5	367.5	359.2	0.17	26.2	37.0	0.2334	696.2	15.6	5.6	687	N37°47′015″, E038°25′252″	7/19/2012	
110	Adıyaman	6	8.27	8.22	99.1	340.8	343.7	0.16	24.5	38.5	0.2236	712.8	12.8	12.5	499	N37°40′912″, E038°05′164″	7/19/2012	
111	Adıyaman	5	8.35	6.6	83.1	510.0	486.0	0.23	27.4	39.4	0.3185	704.4	10.0	11.5	594	N37°42′605″, E037°56′279″	7/19/2012	Ii; (Hsp)
112	Adıyaman	4	8.46	9.44	116.2	790.0	766.0	0.37	26.5	40.0	0.5005	694.8	10.5	2.5	708	N37°41′786″, E037°53′623″	7/19/2012	Hi; Ib
113	Adıyaman	7	8.67	6.53	78.8	298.6	299.5	0.14	24.8	41.0	0.195	678.9	13.2	2.1	898	N37°41′747″, E037°50′944″	7/19/2012	Hi
114	Adıyaman	4	8.18	7.51	99.2	447.0	407.9	0.19	30.2	36.7	0.2639	670.1	11.0	13.0	1000	N37°40′781″, E037°49′092″	7/19/2012	Ii
115	Adıyaman	1	7.82	19.23	247.6	560.0	506.0	0.24	28.6	38.7	0.3315	692.7	15.2	4.5	728	N37°39′280″, E037°48′488″	7/19/2012	Hi; Ib; Tc; (Csp; Psp)
116	Adıyaman	1	7.44	7.5	78.6	462.8	536.5	0.26	17.8	38.1	0.3484	692.6	19.2	0.0	746	N37°39′339″, E037°48′639″	7/19/2012	Ii; Po
117	Adıyaman	4	8.06	10.24	140.6	409.6	358.1	0.17	32.5	40.2	0.2334	684.2	11.8	1.5	845	N37°39′893″, E037°48′209″	7/19/2012	Hi; (Isp; Psp)
118	Adıyaman	1	7.53	7.36	75.0	511.0	609.0	0.3	16.6	38.5	0.3945	701.0	25.3	0.0	637	N37°33′373″, E037°48′596″	7/19/2012	Ii; Ks; Po
119	Adıyaman	4	7.32	10.27	112.0	557.0	592.0	0.29	21.8	36.9	0.3835	700.9	37.5	0.0	605	N37°33′933″, E037°48′575″	7/19/2012	(Csp; Cvs; Hsp; Isp; Pysp)
120	Adıyaman	4	8.01	11.01	154.0	604.0	520.0	0.26	33.3	41.8	0.336	691.7	10.5	2.0	720	N37°32′698″, E037°44′565″	7/19/2012	Hi; (Esp; Isp; Pos)
		Max	9.25	19.23	247.6	1241.0	1165.0	2.58	33.9	43.8	0.754	712.8	38.0	32.5	1383			
		Min	7.29	1.47	15.7	119.3	25.9	0.03	10.7	30.4	0.1073	642.4	9.9	0.0	499			

St. no, site number; St. Ty., site type; DO, dissolved oxygen, mg.L − 1; %DO, per cent saturation; EC, electrical conductivity, µS.cm − 1; Sp. EC, specific electrical conductivity; Sal, salinity, ppt; Tw, water temperature, °C; Ta, air temperature, °C; TDS, total dissolved solid; Atm., atmospheric pressure, mmHg; Moist., moisture, %; W. s., wind speed, km.h − 1; Elev., elevation, m; Ca, *Candona angulata*; Cn, *C. neglecta*; Csp, *Candona* sp.; Cvs, *Cavernocypris* sp.; Cysp, *Cypridopsis* sp.; Ds, *Darwinula stevensoni*; Dsp, *Dolerocypris* sp.; Esp, *Eucypris* sp.; Fb, *Fabaeformiscandona brevicornis*; Gs, *Gomphocythere* n. sp.; Hb, *Herpetocypris brevicaudata*; Hc, *H. chevreuxi*; Hh, *H. helenae*; Hin, *H. intermedia*; Hts, *Herpetocypris* sp.; Hi, *Heterocypris incongruens*; Hsp, *Heterocypris* sp.; Ib, *Ilyocypris bradyi*; Ig, *I. gibba*; Ii, *I. inermis*; Isp, *Ilyocypris* sp.; Li, *Limnocythere inopinata*; Ms, *Mixtacandona* sp.; Pf, *Potamocypris fallax*; Pfu, *P. fulva*; Pp, *P. pallida*; Ps, *P. similis*; Psm, *P. smaragdina*; Pv, *P. variegata*; Pos, *Potamocypris* sp.; Pzi, *Prionocypris zenkeri*; Pa, *Pseudocandona albicans*; Pse, *P. semicognita*; Psp, *Pseudocandona* sp.; Po, *Psychrodromus olivaceus*; Pysp, *Psychrodromus* sp.; Si, *Schellencandona insueta*; Ts, *Tonnacypris* sp.; Tc, *Trajancypris clavata*; Tsp, *Trajancypris* sp.; Zc, *Zonocypris costata*. The sub-fossil forms of taxa were given in the parenthesis. Aquatic habitas: 1, limnocrene spring; 2, rheocrene spring; 3, helocrene spring; 4, lake; 5, dam; 6, pond; 7, pool; 8, creek; 9, stream; 10, water fall; 11, irrigation channel; 12, trough.