Species assemblages and habitat preferences of Ostracoda (Crustacea) in Lake Abant (Bolu, Turkey)

Muzaffer Dügel[1], Okan Külköylüoğlu[1*] & Mustafa Kılıç[2]

[1] **Abant İzzet Baysal University, Department of Biology, Gölköy 14280 Bolu, Turkey.**
[2] **İstanbul University, Department of Biology, Vezneciler, 34650 İstanbul, Turkey.**
Corresponding author : * e-mail: kulkoyluoglu_o@ibu.edu.tr

ABSTRACT. Aquatic habitats are threatened by human activities in Turkey. These threats can lead to changes in ecological conditions and community composition of ostracod species. Overall, reduction in habitat quality may increase the number of tolerant (e.g., generalist) species in relation to the number of native (e.g., specialist) species. This phenomenon is called *pseudorichness* and is also characterized by a critical increase in the total numbers of colonial bacteria. A total of 16 ostracod species were encountered in Lake Abant (Bolu, Turkey) and its environs between 2001 and 2003. Two species (*Psychrodromus fontinalis, Eucypris pigra*) found outside the lake are new records for the region. About 80% of the species in this area have a cosmopolitan distribution throughout the Holarctic region. Four major clustering groups (UPGMA) were recognized based on species occurrences and ecological preferences. Each species was distinctly tolerant to different ecological variables though cosmopolitan species tended to have wider tolerance ranges compared to sensitive species. About 82% of the relationship between species and environmental variables was explained with Canonical Correspondence Analysis ($P<0.05$). Accordingly, temperature, dissolved oxygen and conductivity of water were found to be the three most influential factors affecting species composition. Spearman correlation analysis showed a significant positive relationship ($P<0.01$) between the number of individuals and both dissolved oxygen and the number of species. Generally, to provide long-term conservation of the Lake Abant Nature Park, immediate attention is needed for the wastewater treatment, and help from international organizations.

KEY WORDS : conservation, Lake Abant, Ostracoda, pseudorichness, limnoecology, tolerance.

INTRODUCTION

Among the 16 nature parks in Turkey, Lake Abant Nature Park (LANP) in Bolu (about 1196.5 ha) is one of the most famous. The park includes about 1221 plant and animal species, of which at least 60 are endemic, including 1 rat subspecies (*Muscardinus avellanarius abanticus* Kıvanç, 1983), 1 fish subspecies (*Salmo trutta abanticus* Tortonese, 1954), ca. 50 plant species (e.g., *Crocus abantensis* T. Baytop & B. Mathew 1975), and at least 3 invertebrate species (e.g., *Zerynthia* (*Allancastria) caucasica abanti* Koçak, 1975). However, as with many other natural areas, anthropogenic disturbance (e.g., pollution, habitat fragmentation) threatens species diversity within the park. In the case of LANP, such factors cause a rapid reduction in the quality of the lake water and its environment, causing a decline in the number of native species and an increase in the numbers of cosmopolitan species.

When species assemblages are determined by the ecological preferences and tolerance levels of species, changes in ecological conditions can affect species composition (Dügel & Kazanci, 2004). Thus, one may expect to observe a corresponding decline in both water quality and the "quality" of the species assemblages when the numbers of cosmopolitan species increase. The meaning of "reduction of water quality" refers to the "changes in standard ecological conditions and/or health of lake water and environment". This process is explained by the "pseudorichness hypothesis", in which the total number of species tends to increase in the short-term while the ratio of specialist species to cosmopolitan species tends to decrease (Külköylüoğlu, 2004). However, the levels of decline in species composition may not be recognized with short-term studies, even when species composition includes cosmopolitan species with high tolerance ranges (Yilmaz & Külköylüoğlu, 2006). In such a case, one may mistakenly conclude no (or little) significant effect of environmental changes (e.g., due to anthropogenic disturbance) on community composition. This may lead to acceptance of the null hypothesis when it is actually false, or a Type II error (Hurlbert, 1984; Zar, 1999). The consequences of this error are well described in literature, but almost nothing is known about it, concerning the use of ostracods as ecological indicators.

Ostracods are widely distributed in all types of aquatic environments, from fresh to saline waters, in which they show different tolerances and preferences to various ecological variables. If ecological preferences and tolerance levels of individual species are known, the past, current and future habitat conditions can be estimated (Delorme, 1991; Külköylüoğlu & Dügel, 2004; Külköylüoğlu, 2005a; 2005b). Therefore, ostracods are useful as indicators of water quality in different aquatic bodies (Bromley & Por, 1975; Külköylüoğlu, 1999; Külköylüoğlu & Vinyard, 1998; Mezquita et al., 1999). Consequently, knowledge of species' current habitat requirements and ecological preferences can also be used to reconstruct past and future ecological conditions. Additionally, ostracods are sensitive to changes in different environmental variables, which can thus affect species composition as a whole. Detection of such changes in community composition can be used to interpret conditions in any aquatic body within a broader context. This may also allow estimation of possible future changes in species composition.

However, certain (i.e. cosmopolitan) species tend to have wide tolerance levels, and therefore they can resist changes in water conditions, at least for a wider range than specialists. In such cases, negative environmental effects on species richness of disturbed habitats may not be recognized due to dominancy of common species. Although it is critically important to know the role of cosmopolitan species in community assemblages, our knowledge is far from complete for ostracods, and many other taxa as well. To better understand the relationship between conservation and the pseudorichness hypothesis along with the role of cosmopolitan ostracods, KÜLKÖYLÜOĞLU (2004) proposed two critical questions: i) what kind of environmental conditions do individual ostracod species prefer?, and ii) which ecological factor(s) affect(s) their occurrence most? Although these questions can be applied to different taxonomic groups, they are not easy to answer without detailed studies.

The aim of this study consists of three parts: (1) documenting the species composition of ostracods in Lake Abant, (2) characterizing the relationships between ecological preferences and tolerance levels of ostracods, and (3) highlighting the conservation status of Lake Abant Nature Park, along with its environmental problems.

MATERIALS AND METHODS

Study Area

Lake Abant (Fig. 1) is a monomictic lake (Maximum depth (Zmax): 18m; Elevation: 1345m a.s.l.), which is located in Lake Abant Nature Park (40º36'702" N 31º16'721" E) about 30km west of the city Bolu (Turkey). The lake was formed as a result of land sliding at the northeastern ends (ERINÇ et al., 1961; ORBAY et al., 1994) after tectonic activities about 8000-10000 years ago (NEUGEBAUER et al., 1997). Since this time climatic activities have changed the lake environment. However, the most influential change occurred 3500-4000 years ago, when the first humans settled around the lake (WOLDRING et al., 1986; BOTTEMA et al., 1993). One of the recent effects of human activities occurred about 50 years ago, when the lake surface area was extended from 115ha to 125ha (IRMAK, 1947; AKŞIRAY, 1959) to provide suitable shallow habitats for the juveniles of common rainbow trout (*Oncorhynchus mykiss* (Walbaum, 1792)). This fish, however, reduced the numbers of the endemic fish (*S. t. abanticus*) in the lake. Besides these two, there are five more fish species in the lake: *Tinca tinca* L., 1758 (tench), *Barbus plebejus* (Bonaparte, 1839) (barbus), *Alburnoides bipunctatus* (Bloch, 1782) (chub), *Gobio gobio* (Linnaeus, 1758) (gudgeon), and *Leuciscus cephalus* (Linnaeus, 1758) (freshwater chub) (HOŞ, 2005).

Sampling

Eight physicochemical variables commonly used in studies of aquatic habitats (WRIGHT et al., 1989; RUSE, 1996; MAZLUM et al., 1999; MOUNY & DAUVIN, 2002; KÜLKÖYLÜOĞLU & DÜGEL, 2004), were measured monthly from October 2001 to October 2003: pH, redox potential (Standard Hydrogen Electrode (SHE) [mV]), dissolved oxygen (DO [mg/L]), percent oxygen saturation (%Sat), water (T(w)) and air temperature (T(a) [ºC]), electrical conductivity (EC [µS/cm]), and salinity (S [ppt]). Total dissolved solids (TDS [mg/l]) were measured in the laboratory following standard methods (APHA, 1988). pH and redox potential were measured with a Hanna model HI-98150 pH/ORP meter, while other variables were measured with a YSI-85 model oxygen-temperature meter at each station. Ostracod samples were collected at a water depth of 100cm with a plankton net (0.25mm mesh size) from 10 randomly selected stations around the lake side and fixed in 70% ethanol *in situ* after measuring the ecological variables. In the laboratory, after filtering the samples over four different sieves (0.25: 0.50: 1.0: 2.0mm in mesh size), ostracods were hand-sorted and preserved in 70% ethanol. Subsequently, specimens were mounted in lactophenol solution. Systematic keys of MEISCH (2000) were used for identification. Microbiological analyses followed standard methods (APHA, 1988). Bathymetric measurements were obtained with a Skipper 603 model echosounder (Fig. 2). Geographical data (elevation and coordinates) were recorded with a geographical positioning system (GPS 45) unit.

Statistical Analyses

Canonical Correspondence Analysis (CCA), a gradient analysis technique, was used to examine the relationship between predictor variables (e.g., environmental factors) and the response variable (species). Results of CCA were tested with a Monte Carlo randomization method, which randomly reassigns the values for the species data to the values for the environmental variables. Since some predictor variables can be closely related, arch effects or multicolinearity may exist (TER BRAAK, 1986; 1987). To

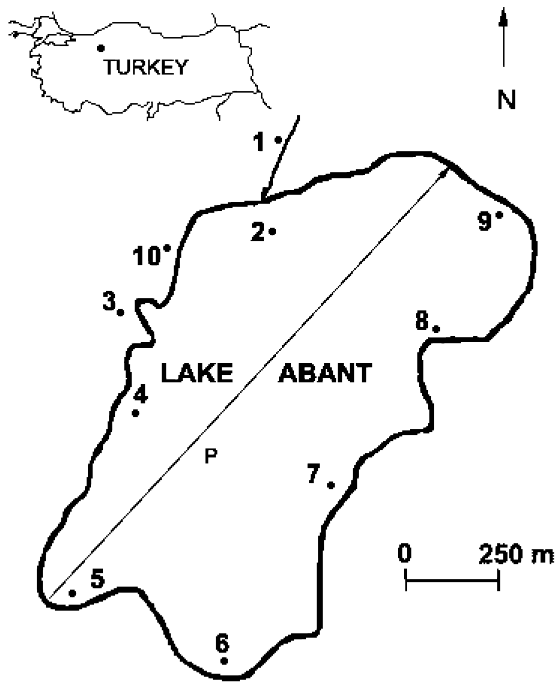

Fig. 1. – The ten sampling stations around Lake Abant. Stations 1, 3, and 10 are located outside the lake. “P” presents the bathymetric line, depicted in Fig. 2, along the longest distance of the lake.

decrease the effects of multicolinearity, the numbers of response variables were kept higher than the numbers of predictor variables and the rare species were down-weighted.

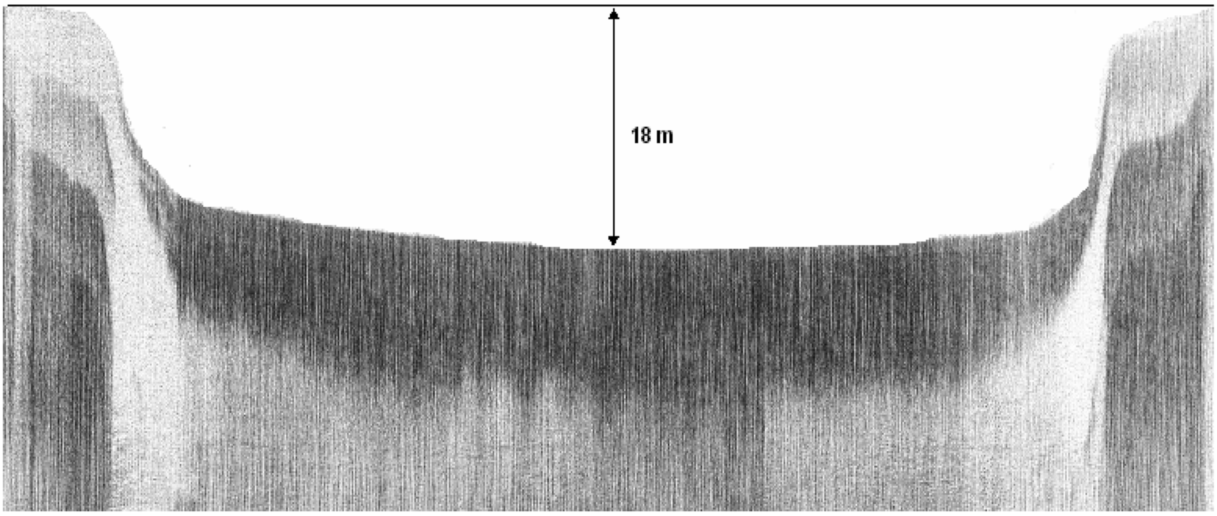

Fig. 2. – Bathymetry of the lake, showing a maximum depth of 18 meters. This is the first bathymetric picture for this lake.

To estimate both tolerance (t_k) and optimum (u_k) values of the six most abundant species, five environmental variables (pH, Eh, DO, Temp., EC, Sal.) were used in a weighted averaging method. Unweighted Pair Group Mean Averages (UPGMA) along with Jaccard's similarity tests were used with log transformed data to display clustering relationships among eight species based on binary data of species' occurrence (presence/absence). Species with only one occurrence were eliminated from the analysis to increase the power of the test. A two-tailed Spearman rank correlation test was used to examine the relationships among six environmental variables, the six most common species, numbers of individuals, and total numbers of species. Hill's N_2 is a kind of diversity index and calculated here as the reciprocal of Simpson index (Hill, 1973). This indicates effective number of occurrences instead of measurement of diversity (Juggins, 2001). (All statistical analyses were conducted using the Multivariate Statistical Package (MVSP) version 3.1 (Kovach, 1998), SPSS version 6.0 and CALIBRATE 1.0 (Juggins, 2001).

RESULTS

Reduction in the quality of Lake Abant water was monitored between 2001 and 2003. Human activities, particularly wastewater discharge into the lake, were the main reason for the decline in water quality. As a result, ostracod species composition was negatively affected, although the mean number of species (3.61 species) was slightly above the average number of species (3.2) found in other lakes of Turkey (Table 1). In total, 16 ostracod species were found in Lake Abant (Bolu, Turkey) and its environs: *Cypridopsis vidua* (O.F. Müller, 1776), *Candona neglecta* (Sars, 1887), *Darwinula stevensoni* (Brady & Robertson, 1870), *Cypria ophtalmica* (Jurine, 1820), *Candona candida* (O.F. Müller, 1776), *Physocypria kraepelini* G.W. Müller, 1903, *Ilyocypris bradyi* Sars, 1890, *Heterocypris incongruens* (Ramdohr, 1808), *Notodromas monacha* (O.F. Müller, 1776), *Pseudocandona compressa* (Koch, 1838), *Eucypris pigra* (Fischer, 1851), *Herpetocypris chevreuxi* (Sars, 1896), *Psychrodromus olivaceus* (Brady & Norman, 1889), *Psychrodromus fontinalis* (Wolf, 1920), *Cypris pubera* O.F. Müller, 1776, *Leucocythere* sp. (see Table 2). Of these species, 80% have a cosmopolitan distribution, at least within the Holarctic region, while two species (*P. fontinalis* and *E. pigra*) are new records for the region. Based on the species occurrence data, the UPGMA dendrogram (Fig. 3) revealed four major clustering groups. The first group includes two cosmopolitan species (*C. ophtalmica*, *C. neglecta*), while the second group consists of one cosmopolitan (*C. candida*) and one non-cosmopolitan species (*P. compressa*), and the third group has two cosmopolitan (*I. bradyi, D. stevensoni*) and one rare species (*N. monacha*). The fourth group covers a single cosmopolitan species *C. vidua*. There was a significant positive relationship ($P<0.01$) between the number of individuals and both dissolved oxygen and the number of species (Table 3). The first axis of the CCA diagram (Fig. 4, Table 4) explained 82% of the relationship between 12 species and six environmental variables ($P<0.05$, F-ratio=5.36). Water temperature, dissolved oxygen, and conductivity were the three factors that most influenced species composition.

The ecological requirements of each species were found unique and species displayed differences in their tolerances to different ecological variables (Table 5). Cosmopolitan species tended to have wider tolerance ranges compared to less common species.

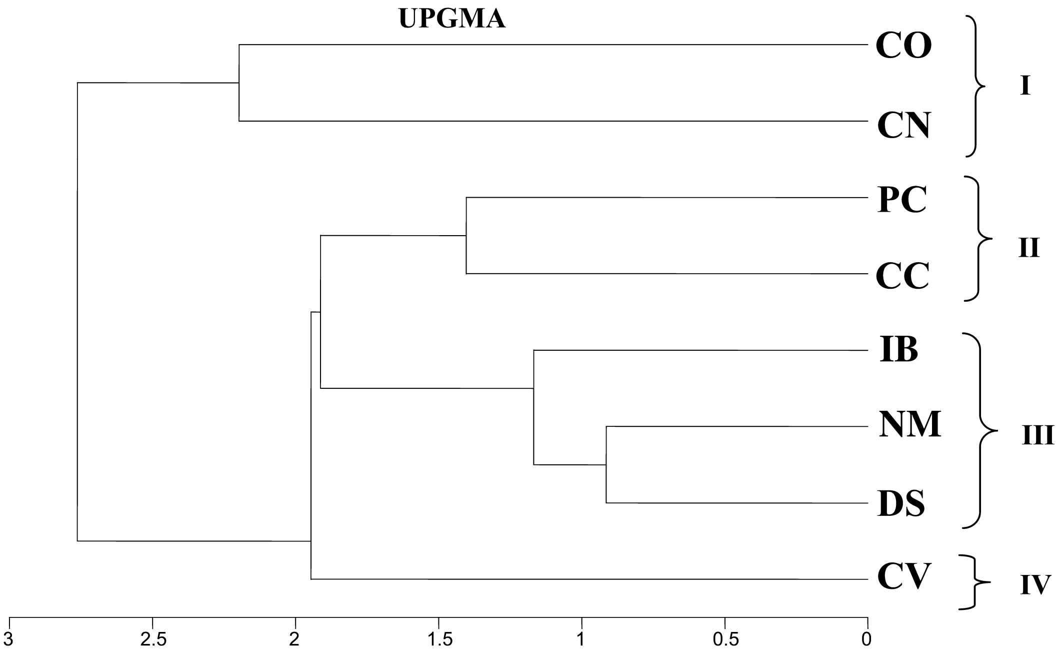

Fig. 3. – UPGMA dendrogram showings four clustering groups (I-IV) for the eight most abundant species, which occurred at least two times in this study.

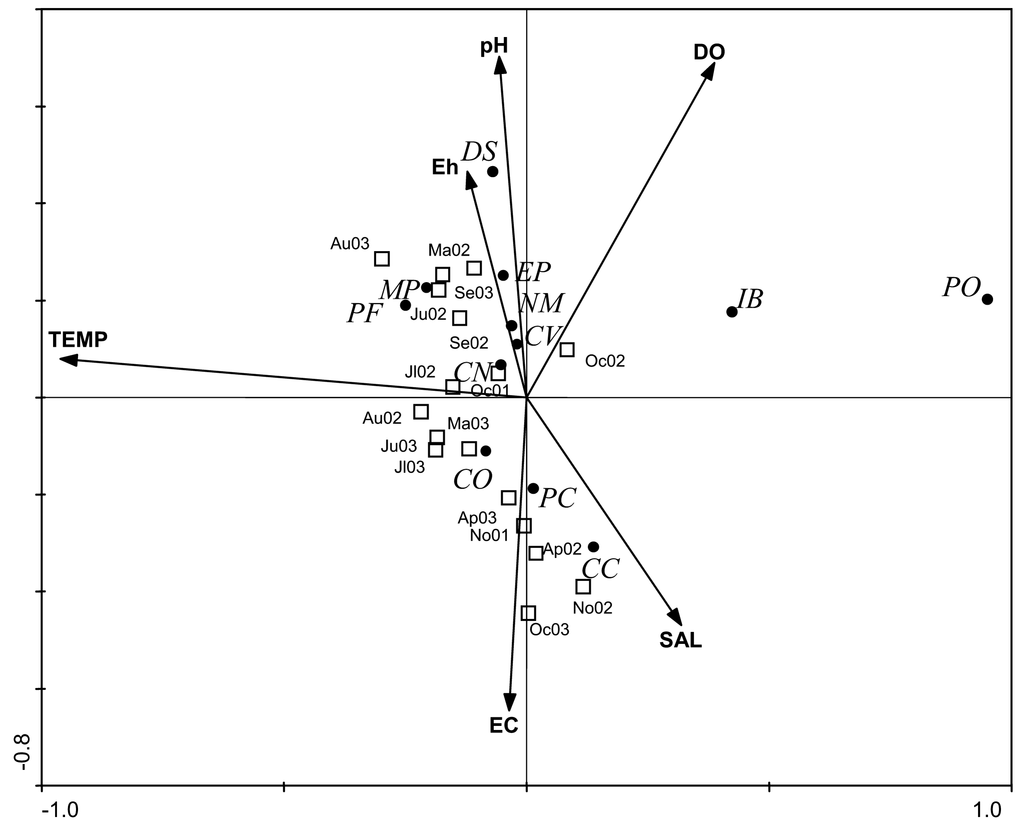

Fig. 4. – CCA diagram, showing the relationships between six environmental variables and 12 species. For abbreviations see Tables 1 and 2.

TABLE 1

The mean values of eight variables measured in Lake Abant between October 2001 (Oc01) and October 2003 (Oc03), completing 20 months of sampling. Abbreviations: pH; Eh (mV) (Standard Hydrogen Electrode or SHE), redox potential; DO (mg/L), dissolved oxygen; Temp (°C), water temperature; EC (μS/cm), electrical conductivity; TDS (mg/L), Total Dissolved Solids; %Sat, oxygen saturation; Sal (ppt), salinity; N_{ind}, Number of individuals; Spp, Numbers of Species. Species codes (Code) are given in Table 2. Codes with bold represent species found from the stations in the lake, others outside of the lake.

Date	pH	Eh	DO	%Sat	Temp	EC	TDS	Sal	N_{ind}	Spp	Code
Oc01	7.86	167.08	8.13	89.96	15.8	260.78	174.72	0.14	68	7	**CV, DS, CN, CO, NM, CC, PC**
N01	7.67	175.57	7.66	69.26	10.4	261.84	175.43	0.13	62	6	**CV, CN, CO, NM, CC, PC**
D01	7.47	187.83	7.58	55.52	1.74	157.38	105.44	0.1			-
Ap02	7.83	166.65	10.50	95.04	12.3	256.07	171.56	0.12	4	1	CV, CN, CO, CC, **PC**
My02	7.97	166.24	9.75	107.40	20.6	267.42	179.17	0.11	2	2	CN, CO, CC, **NM, HC**
Ju02	7.97	165.10	8.96	108.50	23.4	274.84	184.15	0.12	27	5	**CV, CN, CO, NM, LE**
Jl02	7.73	162.90	6.42	89.90	23.6	226.93	152.05	0.11	8	3	**DS, CN, CO**
Ag02	7.96	157.09	8.03	94.52	19.8	218.88	146.65	0.1	5	3	**CN, CO, PC**
S02	7.90	160.68	7.62	81.16	16.0	248.94	166.79	0.11	28	3	**CV, CN, CO**
Oc02	7.91	164.44	10.6	84.80	10.1	253.89	170.11	0.12	83	9	**CV, CN, CO, NM, CC, PC, HI, IB, PK**
N02	8.06	154.99	10.7	86.98	5.1	264.23	177.04	0.12	9	3	CC, **CV, CN, PC**
D02	8.25	145.69	14.5	99.70	0.1	265.30	177.75	0.1			-
Ja03	7.90	175.67	20	141.50	1.68	151.73	101.66	0.13	47	3	**CN, IB, PO**
Ap03	7.95	167.19	7.31	72.42	16.5	268.61	179.97	0.12	11	4	CC, **CV, CN, CO, PC**
My03	7.99	165.53	5.24	56.49	18.9	281.91	188.88	0.11	10	3	**CN, CO, PC**
Ju03	7.97	179.28	4.06	46.81	20.8	286.19	191.75	0.12	3	1	CN, **CO**
Jl03	7.87	171.31	3.62	38.92	19.0	287.92	192.91	0.13	4	1	CN, **CO**
Ag03	na	na	4.78	56.70	23.0	252.13	168.93	0.12	6	2	CV, CO,
S03	7.98	163.45	5.26	53.06	16.2	259.21	173.67	0.13	15	4	CN, **CV, CO, PC, IB**
Oc03	7.78	171.69	4.57	40.29	9.04	274.46	183.89	0.12	15	5	**CV, CN, CO, CC, PC**
Ave	7.90	166.76	8.26	78.44	14.2	250.93	168.13	0.12	22.61	3.61	
Max.	8.30	187.80	20	141	23.6	287.90	192.90	0.1	83	9	
Min.	7.50	145.70	3.6	38.9	0.1	151.70	101.70	0.1	2	1	
StDev.	0.2	9.29	3.9	26.5	7.55	37.12	24.87	0.0	25.2	2.15	

TABLE 2

The 16 species collected from 10 stations around Lake Abant. (*): species with a wide distribution, at least in Holarctic region.

Species		Code	Station No
Cypridopsis vidua	*	CV	1, 2, 3, 4, 6, 8, 9
Darwinula stevensoni	*	DS	2, 6
Candona neglecta	*	CN	1, 2, 3, 6, 8, 9
Candona candida	*	CC	3, 5, 8, 9
Cypria ophtalmica	*	CO	2, 3, 5, 6, 7, 8, 9
Notodromas monacha		NM	4, 8, 9
Pseudocandona compressa	*	PC	1, 3, 4, 5, 6, 8, 9
Eucypris pigra	*	EP	1
Herpetocypris chevreuxi	*	HC	4, 10
Heterocypris incongruens	*	HI	6, 10
Psychrodromus olivaceus	*	PO	8
Psychrodromus fontinalis		PF	1
Physocypria kraepelini	*	PK	8
Ilyocypris bradyi	*	IB	2, 6, 8
Cypris pubera	*	CP	10
Leucocythere sp.		LE	8

TABLE 3

Spearman rank correlation matrix for six environmental variables, number of individual (N_{ind}), number of species (Spp) and six dominant ostracod species. High correlations (P<0.05) are indicated in bold face. Codes are the same as in Tables 1 and 2.

	pH	Eh	DO	Temp	EC	Sal	N_{ind}	Spp	CV	CN	CO	NM	CC	PC
pH	1													
Eh	**-0.56**	1												
DO	0.19	-0.35	1											
Temp	0.12	-0.09	-0.50	1										
EC	0.39	0.14	-0.38	0.24	1									
Sal	-0.13	0.38	-0.13	-0.04	0.25	1								
N_{ind}	-0.29	0.08	**0.75**	-0.27	-0.22	0.33	1							
Spp	-0.25	0.04	0.51	-0.36	0.16	0.45	**0.88**	1						
CV	0.13	0.13	0.36	0.31	0.02	-0.04	0.58	0.09	1					
CN	-0.19	0.10	0.36	-0.54	-0.11	-0.07	**0.56**	0.51	**0.73**	1				
CO	-0.46	0.12	0.41	0.16	-0.06	0.22	**0.67**	0.51	0.54	0.11	1			
NM	0	-0.23	-0.65	0.44	-0.74	**0.87**	-0.19	0.70	-0.80	-0.75	-0.51	1		
CC	-0.25	0.13	0.20	-0.13	0.05	0.41	0.11	-0.49	0.81	-0.32	**0.84**	0	1	
PC	**-0.63**	0.36	0.25	-0.34	-0.41	**0.82**	0.53	**-0.86**	0.10	0.17	0.54	0.32	0.12	1

TABLE 4

Main results of Canonical Correspondence Analyses revealing a significant (P=0.006, F=2.197) result for all canonical axes after 499 permutations in a Monte Carlo test.

Summary					
Axes	1	2	3	4	Total inertia
Eigenvalues:	0.379	0.313	0.082	0.036	4.905
Species-environment correlations:	0.821	0.673	0.415	0.301	
Cumulative percentage variance					
of species data:	7.7	14.1	15.8	16.5	
of species-environment relation:	45.2	82.6	92.3	96.6	
Sum of all eigenvalues					4.905
Sum of all canonical eigenvalues					0.838

TABLE 5

Optimum (Opt), tolerance (Tol) and the effective number of occurrence (Hill's N_2) of the seven most frequently occurring species related to the six environmental variables, selected because of their influences on species occurrence. First six species are ostracods and the last (MP) is an isopod, *Micronecta pusilla* (Horváth, 1895). Analyses included species that occurred more than three times in a total of 71 samplings. (for abbreviations see Tables 1 and 2).

				pH		Eh		DO		Temp		EC		Sal	
Species	**Count**	**Max**	N_2	**Opt**	**Tol**	**Opt**	**Tol**	**Opt**	**Tol**	**Opt**	**Tol**	**Opt**	**Tol**	**Opt**	**Tol**
CV	22	16	10.27	7.86	0.32	-48.57	19.18	8.80	4.53	14.64	5.953	239.25	106.30	0.12	0.06
CN	36	101	7.21	7.70	0.28	-38.65	16.33	7.45	4.33	17.97	5.879	320.69	110.69	0.12	0.06
CO	28	7	18.50	7.49	0.39	-28.87	21.16	4.24	3.20	16.43	4.710	336.70	127.68	0.16	0.09
NM	6	5	3.67	7.97	0.44	-53.89	25.09	9.05	3.95	14.65	4.736	221.90	72.96	0.11	0.03
PC	16	19	6.56	7.34	0.52	-20.83	29.86	5.41	3.70	12.24	3.738	329.88	103.44	0.16	0.06
CC	7	29	4.65	7.19	0.54	-13.96	29.22	5.59	5.32	11.23	6.789	403.98	60.46	0.21	0.06
MP	4	2	3.60	7.84	0.18	-46.52	8.61	8.19	3.45	21.15	3.795	230.02	95.92	0.10	0.06

DISCUSSION

Our results showed that each species has its own specific requirements and tolerance levels to different environmental factors. For example, two almost cosmopolitan species (*C. ophtalmica*, *C. neglecta*) found in the first cluster group had similar optima and tolerance levels to six different variables. Moreover, *C. neglecta* had a higher optimum (7.45mg/L) and tolerance (4.33mg/L) to dissolved oxygen than *C. ophtalmica* (4.24mg/L and 3.20mg/L). Similarly, MEZQUITA et al. (2005) reported that *C. ophtalmica* collected from different water bodies in Spain had slightly higher optimum estimates (9.1mg/L) than *C. neglecta* (8.8mg/L), although there was no significant difference in the tolerance values (2.3mg/L and 2.1mg/L, respectively). Although these optimum estimates are higher than our findings (Table 5), the tolerance values are both lower. Such differences may imply a large range of tolerance for both species found in a variety of similar, organically-rich, habitats. Recently, NAGORSKAYA & KEYSER (2005) reported these two species in ten different water bodies of Belarus, where *C. ophtalmica* showed the highest (0.62) and *C. neglecta* a medium index of commonality (0.13). In a previous investigation, MEISCH (2000) found that both *C. neglecta* and *C. ophtalmica*, both common in organically-rich polluted waters, can tolerate low levels of oxygen values below (3mg/L). *Cypria ophtalmica* was the most abundant species in Lake Caicedo (Spain) where the species was highly tolerant to hypoxic conditions throughout the year (MARTIN-RUBIO et al., 2005). Having a relatively high environmental tolerance index value (ETI=0.77), *C. ophtalmica* showed a wide range of tolerance to water temperatures from 2.1 to 20.1°C in the United States (CURRY, 1999). In a shallow lake (Lake Fehér) of Hungary, KISS (2002) observed *C. ophtalmica* frequently in a reed belt community characterized by a large range of water temperature (1.1-23.2°C), pH (5.76-8.01), and dissolved oxygen (0.0-10.79mg/L). According to RAMDANI et al. (2001), *C. ophtalmica* was the only species found throughout the year in an acidic lake (Megene Chitane) in Tunisia. ROSSETTI et al., (2004) collected *C. ophtalmica* from freshwater wetlands with eutrophic conditions in northern Italy, where it was one of the most common species, surviving a wide range of salinities (from ca. 300 to >900µS/cm), temperatures (up to 35°C), and acidities (usually >7, up to 9.67). In contrast, *C. neglecta* was reported from Lake Edku (Egypt), a freshwater lagoon (BIRKS et al., 2001). A 25-months-long sampling at an organically-enriched small reedbed in Turkey yielded *C. neglecta* in waters with a pH of 7.16-8.65, dissolved oxygen levels of 4.13-15.44mg/L, and a temperature range of 2.13-27.3°C (KÜLKÖYLÜOĞLU, 2005a). The species was most common from November to August in a relatively cold limnocrene spring with low oxygen levels (3.28mg/L) (KÜLKÖYLÜOĞLU, 2003), but its occurrence was negatively correlated to water temperature (KÜLKÖYLÜOĞLU & YILMAZ, 2006). In the present study, *C. neglecta* was revealed near the center of the CCA diagram, which implies the absence of direct effects of environmental variables on its occurrence (Fig. 4). Furthermore, *C. ophtalmica* was located on the negative side of the temperature axis. These findings support the above-cited studies, demonstrating that both species have high tolerances to different environmental variables.

The second group of the UPGMA dendrogram consists of two species (*C. candida*, *P. compressa*) with a broad geographical distribution. In general, *C. candida* can live in a variety of aquatic habitats, such as springs (SÄRKKÄ et al., 1997). According to HARTMANN & HILLER (1977), the species cannot tolerate water temperature above 18ºC during summer. However, more recent studies have revealed the opposite (DELORME, 1991; KÜLKÖYLÜOĞLU & VINYARD, 2000; YILMAZ & KÜLKÖYLÜOĞLU, 2006). The present study reveals that the species has a higher tolerance to water temperature (6.79) and pH (0.54) than the other species (Table 5) found in the littoral zones. Since the species can survive in diverse habitats with extensive geographical distribution, it can be assumed that its tolerance to some of the environmental factors is much higher than previously thought. On the other hand, *P. compressa* seems to have a limited geographical distribution in the Holarctic region (MEISCH, 2000). ROSSETTI et al. (2004) documented the species from freshwater wetlands in northern Italy, along with another common species *C. ophtalmica,* which can be found in similar eutrophic conditions (see above). The authors stated that *P. compressa* occurred less frequently than *C. ophtalmica* in Italy, but its occurrence was most likely related to higher trophic conditions and elevated ionic content. In the present study, *P. compressa* showed the highest tolerance value (29.85) for redox potential (Table 5) with a strong negative correlation to pH ($P<0.05$, $r=-0.63$) and positive correlation to salinity (Table 3). The close relationship between redox potential (due to reduction in water molecules) and changes in ionic contents of waters may suggest that *P. compressa* has much higher tolerance and higher optimum values than previously thought.

The third group of the UPGMA dendrogram consists of two cosmopolitan (*I. bradyi, D. stevensoni*) and one rare species (*N. monacha*). In general, the first two species are very common in different aquatic bodies, but *N. monacha* is found mostly in open waters and seems to have seasonal preferences for specific habitats with certain conditions. Recently, MEZQUITA et al. (2005) reported the tolerance and optimum values for *I. bradyi* (7.81-0.49 for pH, 8.8-2.2mg/L for DO, 14.5-1.8°C for water temperature, and 3.01-0.30mS/cm for electrical conductivity) and *D. stevensoni* (7.74-0.40 for pH, 8.4-2.1mg/L for dissolved oxygen, 16.4-1.2°C for water temperature, and 3.09-0.39mS/cm for electrical conductivity), which are in accordance with earlier records (KÜLKÖYLÜOĞLU, 2000). Despite the fact that both species can have different occurrence patterns throughout the year, they were encountered only three and two times during our study (Tables 2 and 3). Because of their limited occurrence patterns, our results cannot provide unequivocal knowledge about their tolerance and optimum values in Lake Abant at this moment. However, it is well known that both species can tolerate substantial changes in different environmental variables in a variety of habitats, usually preferring cold and well-oxygenated stagnant waters (BRONSHTEIN, 1947; KÜLKÖYLÜOĞLU & VINYARD, 2000; MEISCH, 2000; ROCA et al., 2000; KÜLKÖYLÜOĞLU, 2005c). A rare Holarctic species, *N. monacha*, mostly prefers littoral zones of lakes and ponds rich with aquatic plants. In Germany, it was recorded from May to August from shallow aquatic bodies (HILLER, 1972), while FINN (2005) calculated the optimum and tolerance values for temperature (21.4 and 0.9°C, respectively) of the species during summer. Similarly, KISS (2001) reported the species from a small, slightly acidic (pH 6.66) and shallow (ca. 90cm depth) Lake (Kõhegyi) in Hungary, with dense aquatic macrophytes, where juveniles accounted for 90% of the population in August. KISS (2002) also reported that *N. monacha* was the most common ostracod that occurred from April to October in the reed belt of a small Lake (Fehér, Hungary), with large ranges of water temperature (1.1-23.2°C), pH (5.76-8.01), electrical conductivity (411-2410µS/cm), and relatively low dissolved oxygen (0-10.79mg/L). The species was encountered from October-November and May-June during our study. Overall, it seems that *N. monacha* occurs throughout the year (except the winter months from December-February) in habitats having suitable environmental conditions. Our results agree with those of earlier reports that the species has the highest optimum for dissolved oxygen (9.05) and pH (7.97), while it has a strong positive correlation with salinity (Tables 3; 5). There is not much known about the ecological preferences of the species, but findings suggest that it prefers relatively cool, well-oxygenated habitats covered with aquatic plants.

The fourth clustering group in the UPGMA dendrogram consists of only one species, *C. vidua*, a well-known cosmopolitan species with a wide range of tolerances to different environmental conditions, also found almost all year around. Indeed, during the present study, it was also found in almost all stations, even outside of the lake (Tables 1; 2). In the eastern Iberian Peninsula, MEZQUITA et al. (2005) collected *C. vidua* from different types of aquatic habitats and reported optimum and tolerance values of 7.89-0.48 for pH, 7.9-2.2 for DO, 15.9-1.5°C for temperature, and 3.10-0.41mS/cm for electrical conductivity, respectively. In comparison, the values in our stations were: 7.86-0.32 for pH, 8.8-4.5 for DO, 14.6-5.9°C for temperature, and 239.24-106.30µS/cm for electrical conductivity. These results support the earlier studies of *C. vidua* that document its ability to tolerate large changes in water conditions.

Among the remaining five taxa (*P. kraepelini, H. incongruens, P. olivaceus, H. chevreuxi, Leucocythere* sp.), the first two species are cosmopolitan, whereas the rest have a more limited geographical distribution in the Holarctic region. While *P. kraepelini* usually prefers large aquatic bodies, such as lakes and ponds, *H. incongruens* with a cosmopolitan distribution can be found in different types of habitats such as ditches, ponds and troughs, where it survives high levels of pollution. However, two other species (*P. olivaceus*, *H. chevreuxi*) are generally common in springs or waters associated with spring discharge. Indeed, recently, in Spain, *H. chevreuxi* was collected in August from a shallow pond fed by groundwater, with relatively high dissolved oxygen concentration (17mg/L) (ROSSETTI et al., 2004). This finding agrees with our study in that there are some water inputs from the springs to the sampling sites (stations 4 and 8) where this species was collected (Fig. 1, Table 2). According to FINN (2005), *H. chevreuxi* had high optimum estimates (20.4) but low tolerance (0.3) to water temperature in different types of aquatic habitats of northeast Germany. In the present study, it is interesting that we found this species in a small, shallow pond (ca. 20cm) nearby the lake (Table 1), where temperature (30.3°C) and pH (9.3) values reached maximum levels with relatively high oxygen saturation (12.39mg/L). To our knowledge, these are the highest levels measured for this species so far. On the other hand, it is probable that the occurrence of this species in such extreme conditions of temperature and pH might be only temporary. Therefore, at the moment, one should not generalize the tolerance of *H. chevreuxi* to such extreme conditions for long time intervals. Just as for *H. chevreuxi*, ecological information about *P. olivaceus* is also scarce. Based on previous works (e.g., GÜLEN, 1985; BALTANÁS, 1992; BALTANÁS et al., 1993), we know that it generally prefers cold and well-oxygenated waters. KÜLKÖYLÜOĞLU & YILMAZ (2006) showed that *P. olivaceus* had relatively high optimum (120.16µS/cm) and tolerance (14.76µS/cm) values for electrical conductivity (referring to salinity). In our study, about 26 individuals were collected in very cold (1.67°C under ice-cover) lake water. This suggests that this species may have much higher tolerance and optimum levels to at least some of the main environmental factors than previously estimated. Nevertheless, this cannot be generalized at the moment due to a lack of data. Additionally, because of their scarce occurrence, detailed information on the ecological preferences of three other species (*P. fontinalis, E. pigra, C. pubera*) found at stations outside of the lake is not available, thus general conclusions cannot be drawn concerning their ecological preferences. The first two species are new for the region and tend to prefer cool and well-oxygenated waters, whereas *C. pubera* can have greater tolerance and optimum estimates in different aquatic habitats.

The negative effects of human activities (e.g., pollution, habitat fragmentation) are well documented throughout the world. The eventual consequences of such activities cause habitat destruction and changes in water quality. Thus, even slight changes in water quality can influence the suitability of a habitat for (e.g., ostracod) species communities. Such changes in lake water quality, eventually, will reduce ecological conditions, decreasing the survival chances of specialist ostracods, while increasing the persistence of cosmopolitan species with a wide tolerance range. This is because such fluctuations in habitat conditions can provide better opportunities for generalists and thus increase their dominance over specialist species. Therefore, relatively higher mean numbers of ostracod species in Lake Abant were probably due to an increase in the number of cosmopolitan species. This phenomenon is called pseudorichness; it also occurs in other taxonomic groups such as phytoplankton and colonial bacteria. Pseudorichness hypothesis suggests an overall decrease in the quality of certain habitats (KÜLKÖYLÜOĞLU, 2004). Presumably, the concept of pseudorichness can be generalized to different ecological communities where it can help us to understand past, current, and future water and habitat quality. Results show that the current water quality of Lake Abant has changed from oligotrophic to mesoeutrophic, during which species turnover favors generalist species over specialists. As a result, if anthropogenic activities continue in the same way, such problems will threaten overall species diversity, its functional significance, and habitat quality.

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