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Differences in Ostracoda (Crustacea) Assemblages between Two Maar Lakes and One Sinkhole Lake in the Konya Region of Turkey

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Abstract: For this study, ostracod samples collected from a total of 9 stations in 2 maar lakes (Acı and Meke) and 1 sinkhole lake (Meyil) in Konya, Turkey were investigated. Accordingly, 14 ostracod taxa (*Darwinula stevensoni, Candona angulata, Candona* sp. 1, *Candona* sp. 2, *Pseudocandona marchica*, *Cypria* sp., *Ilyocypris gibba*, *I. bradyi, I. monstrifica, Heterocypris salina, Potamocypris* sp., *Limnocythere* sp., *Paralimnocythere* sp., and *Cythereis* sp.) belonging to 10 genera were identified. Among them, only 2 species (*I. bradyi* and *P. marchica*) were collected alive, while the others were found in sub-fossil form, and some shells of *D. stevensoni* were found containing soft parts. The 3 lakes were compared by species variety and population density, and the Meyil sinkhole lake was found to be richer than the Acı and Meke maar lakes. The reason for this difference is thought to be the low level of salinity and the high level of oxygen in Meyil Lake.

Key Words: Ostracoda, Ecology, Salinity, Maar Lake, Sinkhole Lake, Turkey

Konya Yöresindeki (Türkiye) İki Maar ve Bir Obruk Gölü Arasındaki Ostrakot (Crustacea) Topluluklarının Farklılıkları

Özet: Bu çalışmada, iki maar (Acı ve Meke) ve bir obruk (Meyil) gölüne (Konya-Türkiye) ait 9 istasyondan toplanan ostrakot türleri incelenmiştir. Buna göre 10 cinse ait 14 takson (*Darwinula stevensoni, Candona angulata, Candona* sp. 1, *Candona* sp. 2, *Pseudocandona marchica, Cypria* sp., *Ilyocypris gibba*, *I. bradyi, I.monstrifica, Heterocypris salina, Potamocypris* sp., *Limnocythere* sp., *Paralimnocythere* sp. ve *Cythereis* sp.) saptanmıştır. Bu türlerden *I. bradyi* ve *P. marchica*'nın canlı bireylerine rastlanmışken diğer türlerin yalnızca kabukları bulunmuştur ancak bir kaç *D. stevensoni* kabuğunda bazı yumuşak doku kısımlarına da rastlanmıştır. Göller ostrakot tür çeşitliliği ve populasyon yoğunluğu bakımından karşılaştırılmış ve Meyil Obruk Gölü'nün, Acı ve Meke Maar göllerinden daha zengin olduğu bulunmuştur. Bunda tuzluluğun düşük ve oksijen miktarının yüksek olmasının etkili olduğu düşünülmektedir.

Anahtar Sözcükler: Ostrakot, Ekoloji, Tuzluluk, Maar Gölü, Obruk Gölü, Türkiye

Introduction

Ostracods are used as indicator species because each species prefers certain environmental conditions and demonstrates different levels of tolerance to different environmental factors (Külköylüoğlu, 1999, 2003a). Because most species' habitat requirements have not changed for thousands of years, knowledge of the current ecological preferences of each species can help us understand what conditions were like in the past (Benson, 1990; Delorme, 1991; Smith and Forester, 1994; Külköylüoğlu and Vinyard, 1998, 2000; Külköylüoğlu, 2003a, b). Ostracods have a pair of calcium carbonated shells, which preserve them in fossil form in terrestrial habitats. Thus, ostracods are not only commonly used in biological studies, but are also used in palaeontological studies. Indeed, such information is not only important for studying present ecological conditions, but is also important for understanding the past and predicting future ecological conditions. This issue is important for defining the environment in the geological past (Knox and Gordon, 1999; Schudack, 1999; Mezquita et al., 2001). Since the animals are found in different aquatic bodies, they can help us understand current water quality, as indicator species. However, attempts to understand the ecological preferences of each species and their tolerance levels to environmental variables are few (Hiller, 1972; Mezquita et al., 1999; Külköylüoğlu and Vinyard, 2000; Külköylüoğlu and Dügel, 2004; Külköylüoğlu, 2005a, b), and detailed information on their ecology, biology, distribution, and habitat preferences is required (Mezquita et al., 1999; Külköylüoğlu, 2004). Unfortunately, not much is known about ostracod ecology in Turkey. Thus, the aim of the present study was to provide knowledge about ostracod ecology and compare the ostracod faunal richness of 3 lakes in the Konya region of Turkey; 2 maar lakes (Acı and Meke) and 1 sinkhole lake (Meyil) (Figure 1).

Study Area

Konya (Turkey) has many different formations due to its geological composition. There are many lakes, which were created by the contact of hot magma that rose towards the earth's surface and ground water near the surface. Because of the evaporation and compression rise, explosions created a many depressions in the area. Maar lakes occur when these holes are filled with water (Olanca, 1999). Acı and Meke lakes, located in Karapınar (Konya, Turkey) are maar lakes that formed in this manner.

Acı Lake has an area of 1.1 km^2 and it fills the depression of a vertically edged maar (İnandık, 1965). Although the depth of the lake is not known, it is thought that the lake is quite deep (~100 m) (Biricik, 1992). Sometimes the level of the lake changes, although it is only fed by ground water (Sungur, 1970). As there is no surficial outflow, Lake Acı contains saline water (Cirik and Cirik, 1999).

The development of Meke Lake was more complicated than that of Lake Acı. Meke Lake is one of the most extraordinary lakes in the world. It is a double-timed crater lake, which is the result of 2 volcanic explosions (Sungur, 1970). At first a maar was created during its initial stage; then, subsidiary ascensions took place. That is the way of volcanic ascension (Olanca, 1999). In the following stages, explosions continued and 7 small hills were created, partly belonging to the main cone and partly forming an island. The lake, which covers an area of 0.5 km^2 and has a maximum depth of 12 m, is surrounded by a heavy black ash-type of soil. The saline water of the lake, which contains magnesium and sodium sulphate, comes from underground sources (İnandık, 1965; Anonim, 2000).

The formation process of Lake Meyil was different than both of the maar lakes. This lake is a sinkhole lake created by rock dissolution, which takes place in carstic regions consisting of such rocks as gypsum and limestone (İzbırak, 2001). The total depth of the sinkhole is about 100 m. The lake within the sinkhole has a depth of 40 m. In addition to the changes in climate and ground water

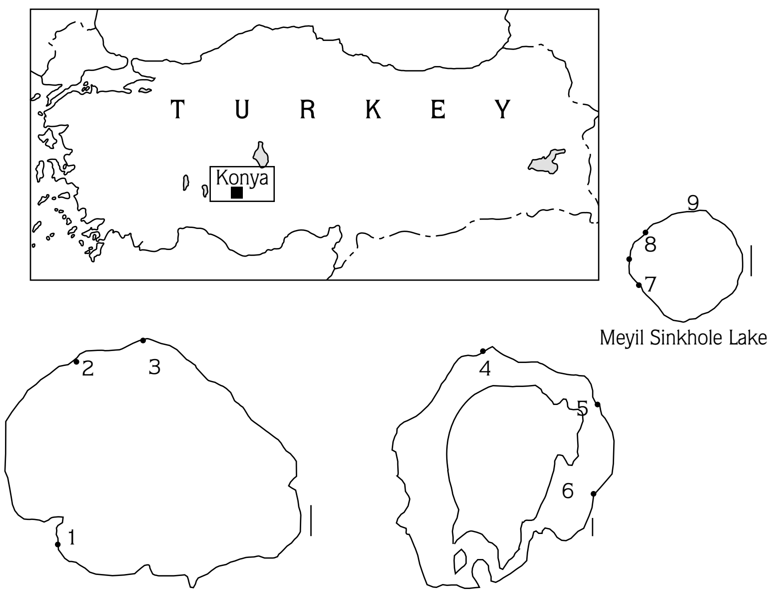


Figure 1. The map shows the 9 stations in Acı, Meke, and Meyil lakes. The bars = 100 m.

level, like at Acı and Meke lakes, the collapse of underground cavities affect the water level of Lake Meyil (Biricik, 1992).

Different types of geological activity resulted in the lakes having different chemical properties and water quality, naturally determining the diversity of species in each. The aim of this work was to compare ostracod species composition and to obtain knowledge about their ecological requirements.

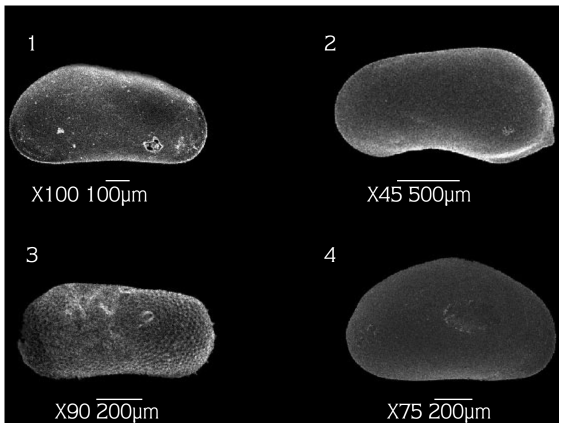
Material and Methods

Samples were collected from a total of 9 stations in the 3 lakes in November 2002, May 2003, and April 2004. Materials were collected from the littoral zone of Lake Meke (maar lake) (St. 5 and 6.) with a plankton hand net (0.025 mm mesh size), but at St. 4 where sampling was not possible directly (approximate depth 80 cm), a dip net (15×25 cm) weighted with lead was used. Materials were obtained using a dip net in Meyil Lake (sinkhole lake) (St. 7-9, average depth 1 m) and Acı Lake (maar lake) (St. 1-3, average depth 5 m), since littoral regions around them were not convenient. The collected samples were kept in glass jars (special 250-ml collecting bottles) containing 4% formaldehyde solution and were fixed in situ.

Afterwards, the samples were washed under pressurized tap water in 4 standardized sieves (1.0, 0.25, 0.16, and 0.08 mm) and residues were preserved in 70% ethanol. Ostracods were separated from sediment under a low-power stereomicroscope. Some specimens were dissected in lactophenol-orange-G solution and mounted in permanent slides. All carapaces were stored in micropalaeontological slides. Species identification was based on valve morphology and soft body parts. Species identification of *I. bradyi* and *P. marchica* was based on soft body parts, whereas identification of the other species was based on valve morphology. During species identification the taxonomic keys of Meisch (2000) and Bronshtein (1947) were used. Water samples were collected for chemical analyses near the margins of Acı and Meke lakes (17/5/2003), and Lake Meyil (18/5/2003). Water temperature, dissolved oxygen (DO (mg/l)), and pH were measured using a portable dissolved-oxygen meter and a pH-meter (WTW OXI 330/SET). Salinity was measured in the laboratory using multi-parameter equipment (Pioneer 65 analytical radiometer). The other hydrochemical analyses were performed in the laboratory according to the standard methods of Greenberg et al. (1985). Photographs of the ostracods were taken with the scanning electron microscope at the Department of Metallurgy and Material Engineering, İstanbul University.

Results

In all, 14 taxa were found during this study (*Darwinula stevensoni*, *Candona angulata*, *Candona* sp. 1, *Candona* sp. 2, *Pseudocandona marchica*, *Cypria* sp., *Ilyocypris gibba*, *I. bradyi*, *I. monstrifica*, *Heterocypris salina*, *Potamocypris* sp., *Limnocythere* sp., *Paralimnocythere* sp., and *Cythereis* sp.) (Table 2). Among the species, *I. gibba* and *H. salina* are new records for the Ostracoda fauna of Lake Meyil, while *I. bradyi* and *D. stevensoni* are new records for Lake Acı, and *C. angulata* and *I. monstrifica* are new records for Acı and Meyil lakes. There were 8 species in Lake Acı, 2 species in Lake Meke, and 12 species in Lake Meyil. Physicochemical characteristics of Acı, Meke, and Meyil lakes are shown Table 1, and the ostracod photographs are shown in the Plate.



PLATE

1. *Pseudocandona marchica* (Hartwig, 1899) (right valve, length 0.85 mm).
2. *Candona angulata* (Müller, 1900) (left valve, length 1.68 mm).
3. *Ilyocypris gibba* (Ramdohr, 1808) (left valve, length 0.82 mm).
4. *Heterocypris salina* (Brady, 1868) (right valve, length 1.22 mm).

Discussion and Conclusion

In the present study some physicochemical characteristics of Acı and Meke maar lakes and Meyil sinkhole lake were determined. Additionally, these lakes

Table 1. Physicochemical characteristics of the lake waters collected 17-18 May 2003. Abbreviations: DO: dissolved oxygen (mg/l); t: (w)-water temperature (°C); Sal.: salinity (%o); TotH: total hardness (ml/Eq); NO_3: nitrate (mg/l); NO_2: nitrite (mg/l).

Name	DO	t (w)	pH	Sal.	TotH	NO_3	NO_2
Lake Acı	9.20	22.1	7.5	62.4	277.16	2.352	0.00026
Lake Meke	2.56	24.7	7.7	69.4	487.84	1.945	0.0034
Lake Meyil	22.8	23.3	8.8	1.0	15.84	0.251	0.0047

were compared in terms of ostracod fauna. As it is known, the method of lake creation is an important factor that affects its chemical composition. As shown in Table 1, the similarity in the chemical values of both Meke and Acı lakes is very obvious. Both lakes are very different from Lake Meyil, in terms of chemical characteristics and water, which probably influenced species diversity and total specimen abundance (Table 2). The ostracod species diversity of Lake Meyil was richer than that of the other 2 lakes. One of the critical causes of the high ostracod species richness (12 species) found in this lake is probably its low salinity (1‰) and relatively high oxygen content (22.9 mg/l). In contrast, Lake Meke, with 2 ostracod species is poorer than the other lakes in terms of species variation and population density. The low species diversity may have been caused by biotic interactions, such as competition and/or predation. A large quantity of *Artemia* sp. was found in the littoral zone of the lake. The low ostracod species diversity in Lake Meke might also be explained by ostracod utilization of the same food as

Table 2. Number of individuals belonging to 14 species in each of 3 lakes (*no species found at this station during sampling).

Lake	ACI									MEKE									MEYİL								
St. No.	1			2			3			4*			5			6			7			8			9		
Coordinate	37°42'35.3"N 33°4 0'23.9"E			37°43'03.6"N 33°40'04.8"E			37°43'02.9"N 33°39'4 0.1"E			37°41'26.6"N 33°38 '20.4"E			37°41' 6.9"N 33°38' 46.5"E			37°41'00.6"N 33°38'45.1"E			37°59'14.4"N 33°21'07.7"E			37°59'15.7"N 33°21' 06.4"E			37°59'19.0"N 33°21' 05.1"E		
Date	30.11.2002	17.05.2003	16.04.2004	30.11.2002	17.05.2003	16.04.2004	30.11.2002	17.05.2003	16.04.2004	30.11.2002	17.05.2003	16.04.2004	30.11.2002	17.05.2003	16.04.2004	30.11.2002	17.05.2003	16.04.2004	30.11.2002	18.05.2003	17.04.2004	30.11.2002	18.05.2003	17.04.2004	30.11.2002	18.05.2003	17.04.2004
Species																											
Darwinula stevensoni	1																			3	5			3			2
Candona angulata				2															4	14	11			5			3
Candona sp. 1	2			2			1												12	30	11			9		1	15
Candona sp. 2			1																		4						
Pseudocandona marchica																				3	3		1♀ 1♂			3	2
Cypria sp.																											1
Ilyocypris gibba																			10	2	1			2		1	
Ilyocypris monstrifica							1												16	7	11			7		1	4
Ilyocypris bradyi		1			4	1													7	2	4+ 1♀			3			3
Heterocypris salina				2		1							2				2	1		4	2			9		1	2
Potamocypris sp.																			4		27			46		6	19
Limnocythere sp.															1												
Paralimnocythere sp.							1																				
Cythereis sp.																								1			

Artemia and *Artemia*'s predominance in Lake Meke. Further research is required to study any ostracod-*Artemia* relationships, which may exist; however, the most important factors that affect ostracod species diversity and population density in Lake Meke are thought to be related to the high salt concentration (69.4‰) and ostracod-*Artemia* interactions.

Lake Acı resembles Lake Meke, based on saltwater content and physicochemical characteristics; however, it is interesting that the number of species in Lake Acı was higher than in Lake Meke. The salinity of Lake Acı was 62.4‰ and it contained 8 species. Another interesting finding is that although their salinity concentrations were similar, no *Artemia* spp. were observed in Lake Acı. Considering this situation leads to 2 alternative inferences: (i) There is a threshold level of salinity in Acı and Meke lakes that ostracods can resist; thus, when concentrations exceeded this level, the number of species was reduced in Lake Meke; (ii) Ostracods and *Artemia* use the same food and *Artemia*'s predominance in Lake Meke can be an explanation for this situation.

Unlike Acı and Meke lakes, Lake Meyil has very low salinity. Consequently, the species number was higher in Lake Meyil, demonstrating an inverse relationship between the salinity of the lake water and ostracod species diversity. Below, some of the most common species are discussed.

Pseudocandona marchica (Hartwig, 1899)

This species was found only in Lake Meyil, which had a pH of 8.8 that corresponds to the pH range of 7.0-10.7 previously reported by Hiller (1972). Although it normally lives in water with salinity of 1.4‰-40‰ (Hiller, 1972), in this study it was encountered at a salinity of 1‰. According to Meisch (2000) this species was found in Eifelian Lake (maar lake), but was not found in Acı or Meke lakes.

Ilyocypris bradyi (Sars, 1890)

In contrast to Acı Lake (maar lake), this species occurred with higher frequency in Meyil Lake (sinkhole lake) and was not recorded in Meke Lake. As stated earlier (Delorme, 1991; Külköylüoğlu, 2004), the dissolved oxygen tolerance of this species is high (3-20 mg/l). The dissolved oxygen content of Lake Meyil was 22.8 mg/l and thus, was even higher than the previously reported values for *I. bradyi.*

Darwinula stevensoni (Brady and Robertson, 1870)

During our study, some shells of *D. stevensoni* were found containing soft parts. They were found at a depth of about 12 m and a pH of 7.5 in Lake Acı, and at a depth of 1.0 m depth and a pH of 8.8 in Lake Meyil. These results match those of Hiller (1972) who stated that this species prefers alkaline waters with a pH between 7.0 and 10.3. Hiller (1972) also underlined that the species prefers water with salinity between 0.5‰ and 15‰. Our record of *D. stevensoni* from Lake Meyil corresponds to these findings; however, a single shell was also found in Lake Acı, which had a much higher salinity. Yet, the single shell recorded from Lake Acı probably does not reflect the measured hydrochemical characteristics of the lake. Further research of this species must be conducted in this lake. This species has also been reported from interstitial groundwater (Meisch, 2000) and, therefore, can come into Lake Acı by way of groundwater input. Moreover, this species was observed in Holzmaar Lake (Scharf, 1991), which is a maar lake like Lake Acı. Yılmaz and Külköylüoğlu (2006) found that *D. stevensoni*'s optimum salinity range is high in Aladağ Lake and that the species can be used as a bioindicator for salinity along with *Limnocythere inopinata.* It appears that the species has a wide tolerance range in different aquatic bodies, as reported earlier. For example, it was found at a depth of 12 m and pH of 7.5 and 8.5 in Gull Lake (Michigan, USA) (McGregor, 1972). Furthermore, the species was also reported from cool spring waters in Nevada (Külköylüoğlu and Vinyard, 2000) and in slow-moving streams (Meisch, 2000).

Biological studies that consider physicochemical characteristics and the data obtained from comparisons help us to understand the habitat preferences of animals of a certain area. Knowing the habitat requirements of a species is essential to understanding the species distribution and the potential of the species to be used as a bioindicator. The larger the range of environmental tolerance of a species, the lower the possibility it can be used as a bioindicator (Külköylüoğlu, 2004). For example, in this study *Heterocypris salina* was found in water with salinity of 60‰ in both Meke and Acı lakes, and in Lake Meyil with salinity of 1‰. Meisch (2000) stated that this species prefers low salinity water, but that it can also live successfully in water that has salinity up to 20‰; therefore, *H. salina* may not be used as an indicator species of salinity.

As a result of our study it was seen that the physicochemical properties of the lakes are related to the formation of water type (and environmental conditions), which has an effect on species variety and population density, and it was also seen that the sinkhole lake was richer in ostracod species and individuals than the 2 maar lakes. It is thought that the main cause of the richness of ostracod fauna in the sinkhole lake is the low level of salinity compared to those of lakes Acı and Meke. This situation can also be explained by the probable stratification of the saline lakes. The maar lakes have possibly well-stratified water bodies, with anoxic conditions at the sediment surface for most of the year. Additional research in similar lakes and more detailed investigations of the studied lakes will provide more insights into the different ostracod communities and their relationship to the environmental parameters of the lakes.

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