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Effects of limnoecological changes on the Ostracoda (Crustacea) community in a shallow lake (Lake Çubuk, Turkey)

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ABSTRACT

We sampled Lake Çubuk, a shallow lake in Bolu (Turkey), for 26 months to investigate the effect of limnoecological changes on the composition of ostracod species. Seventeen ostracod species were identified from the six stations sampled between 2008 and 2010. Numbers of species and individuals were both significantly reduced during 2010, which corresponded to a 3 m water level increase. Ostracod Watch Model (OWM) displayed distinct seasonal occurrences of five species (*Candona neglecta*, *Cypria ophtalmica*, *Cypridopsis vidua*, *Limnocythere inopinata*, *Fabaeformiscandona* cf. *japonica*) when *Physocypria kraepelini* was the only species encountered all year round. Approximately 77.2% of the relationship between species and environmental variables was expressed by the first two axes of Canonical Correspondence Analysis (CCA). Electrical conductivity and water temperature ($P = 0.002$) were the most influential variables on species. There was a significant negative correlation of seven species to conductivity. Of those (*F.* cf. *japonica* and *C. vidua*) showed a significant positive correlation to water temperature, while *C. candida* was negatively correlated to water temperature ($P < 0.05$). *C. neglecta* was the only species to show a positive correlation to dissolved oxygen. Tolerance limits for the most common species were higher than the mean water temperatures, but lower than mean levels of electrical conductivity. Finding the ratio of noncosmopolitan to cosmopolitan species "pseudorichness" as 1.13 suggested significant role of cosmopolitan species to species diversity.

Introduction

Ostracods are microscopic invertebrates widely distributed in almost all continents (Martens and Savatenalinton 2011) and found in almost every kind of natural and artificial aquatic habitat ranging from springs, creeks, and lakes to troughs and wells. Each species shows species-specific tolerance and optimum levels to different ecological variables (Külköylüoğlu 1999) that can be seen in their distribution among habitats. If ecological characteristics (e.g., seasonal occurrence, ecological tolerance and optimum levels, geographic distribution) of living ostracods are known, they can be used as indicator species to estimate past, present and future aquatic conditions (Delorme 1969; De Deckker and Forester 1988; Külköylüoğlu 2003; Külköylüoğlu and Yılmaz 2006). Previous studies (e.g., see Hull 1997; Külköylüoğlu 2005a) showed that changes in species occurrences will eventually alter species diversity, abundance and composition. However, long-term seasonal studies on the relationship between ecological changes and ostracod species diversity are limited (Mezquita et al. 1999; Coma et al. 2000; Ramdani et al. 2001) and scarce in natural lakes (Külköylüoğlu et al., 2007, 2010; Dügel et al. 2008). The occurrence of ostracods is affected by factors external (e.g., climate, anthropogenic factors) and internal (e.g., changes in water structure and quality) to the body of water in which they are found. Accordingly, species can have eurychronal (occurring almost continually throughout the year) and/or stenochronal (occurring with seasonality) occurrences in marine (Hull 1997) and freshwater habitats (Külköylüoğlu and Dügel 2004; Akdemir 2008; Akdemir and Külköylüoğlu 2011). Külköylüoğlu (2004) introduced the concept of "pseudorichness" to explain the relationship between water quality and the presence of cosmopolitan versus noncosmopolitan species. For example, when the ratio of noncosmopolitan/cosmopolitan species is <1, cosmopolitan species are dominant within relatively low water conditions. Thus, descriptions of the ratios of groups of species to each other can be used to make predictions about aquatic habitat

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quality and species composition in the future. The main objectives of this study were to: (1) establish a detailed spatio-temporal record of groups of species and physicochemical characteristics of Lake Çubuk, and (2) to identify the importance of limnoecological factors effecting seasonal species composition and estimate the ecological tolerance and optimum values of individual species for this lake.

Materials and methods

Site description

Lake Çubuk (Göynük, Bolu, Turkey) is a natural landslide lake (40°28′91″ N 30°50′09″ E) located at about 1032 m above sea level (a.s.l.) (Fig. 1). Surrounded by mountain ranges, it is fed by springs, rainfall and snow-melt. The lake was formed in the basin bordered by branches of North Anatolian Fault Zone (Lahn 1948). The lake has approximately 16 ha of surface area with the maximum depth of 8.5 m, mean depth of 6 m, length of 780 m, width of 430 m and volume of 461,788 m^3 (this study). Mean annual precipitation and air temperature of the nearby town of Göynük is approximately 617.4 mm and 10.6 °C, respectively (Türkeş 1999).

Sampling and measurements

One sampling station was established in the approximate geographic middle of the lake to sample the pelagic zone, and 5 were established to sample the littoral zone) were randomly selected and visited monthly from 19 July 2008 to 14 November 2010. Ice cover prohibited sampling in January and February of 2008 and January of 2009. All sampling was done between 06:00 a.m. and 13:00 p.m. Ostracods were collected from the littoral zone with a handmade net (0.2 mm mesh) from water up to 100 cm in depth, while samples from the pelagic zone at the lake bottom were collected with an Ekman Grab. Water samples (ca. 100 ml) for chemical analyses were also taken from each station in the littoral zone and at every meter in the pelagic zone from the water surface to the lake bottom. Approximately 200 ml of samples were fixed with 70% ethyl alcohol in 250 mL jars *in situ* and were brought to laboratory where they were washed through standardized sieves (0.25, 0.50, 1.00 mm mesh). Specimens were separated from the sediment under a stereomicroscope and stored in 70% alcohol for further analyses. Dissected species were stored in a lactophenol solution, while carapace and valves of each species identified were retained in micropaleontological slides. Only initially living adults were included in the analyses while broken carapaces, juveniles and subfossils were excluded. Taxonomic identification of ostracods was done using Meisch (2000), but also some related systematic keys (e.g., Bronshtein 1947). To reduce a possible effect of pseudoreplication (Hurlbert 1984) and Type I and Type II errors, field measurements were taken before sampling collection.

We used bathymetric maps to calculate lake volume, surface area and its bottom morphological structure with the aid of Skipper 603 EchoSounder. A geographical positioning system (GARMIN GPS 45 XL) was used to associate geographical data (altitude and coordinates) for each sampling site. Nine environmental variables (Secchi depth, water temperature, air temperature, percent oxygen saturation, dissolved oxygen (DO), electrical conductivity, salinity, pH and redox potential) were measured at each time sampling occurred. Secchi depth was measured with Secchi disk. A Hanna model HI-98150 pH/ORP meter was used to measure redox potential and pH. Air temperature, wind speed and moisture were measured with Anemometer (Testo- 410). Turbidity (NTU) and biological oxygen demand (BOD_5) (mg L^{-1}) were measured with a turbidity meter from water samples *in vitro*. Measurement of BOD_5 was done following APHA (1989). All other variables (unless otherwise indicated) were measured with a YSI-85 model oxygen-temperature meter. Nitrate, nitrite, ammonium, chlorophyll-a, and total dissolved solids in the water samples were measured in the laboratory. Total dissolved solids (TDS) were calculated by multiplying the value of electrical conductivity by 0.65 (Forester and Brouwers 1985). Analyses of other chemicals, heavy metals and radioactive elements were achieved with the aid of HPIC in the Water Chemistry and Environmental Tritium Laboratory of Hacettepe University, Ankara. SEM photographs of the species were taken in TÜBİTAK-MAM Institute (İstanbul, Turkey). All materials are kept at the Limnology Laboratory of the Department of Biology (Abant İzzet Baysal University) and are available upon request.

Statistical analyses

The mean values of all the water quality variables were used for statistical analyses. The seasonal distribution of adult species was represented with graphical Ostracod Watch Model (OWM) (Külköylüoğlu 1998). Analysis of Variance (ANOVA) with unequal variance along with the *F*-test and *t*-tests in Excel were used to test differences between water quality and species abundance among water stations. Later correlations between species and environmental variables were analyzed with a nonparametric Spearman Rank Correlation analysis along with two-tailed tests at 0.01 or 0.05 significant levels (Magurran 1988). Canonical Correspondence Analysis (CCA) applied with Monte Carlo (499 permutations) tests was used to determine the most effective variable(s) on 11 species occurring at least three times over the study. We used five major environmental variables (water temperature, electrical conductivity, redox potential, pH and turbidity) after the data were log-transformed and tested with a detrended correspondence analysis (DCA) (Ter Braak and Barendregt 1986; Ter Braak 1987; Birks et al. 1990). The gradient length of DCA was found as 4.290 and supported the use of CCA. We also calculated optimum (uk) and ecological tolerance (tk) values for individual species to the variables by means of using C2 program (Juggins 2003) in which weighted averaging of the species and environmental variables were applied for the calculations. CCA outcomes were obtained from the CALIBRATE program, version 1.0 (Juggins 2001) when UPGMA was done in MVSP program, version 3.1 (Kovach 1998).

Results

Physicochemical characteristics of Lake Çubuk

During the study, the water of Lake Çubuk was generally alkaline (mean pH = 7.97) with a mean water temperature of (Tw = 15.66 °C), low levels of dissolved oxygen (DO = 5.65 mg L^{-1}) and electrical conductivity (240 μS cm^{-1}) (Table 1). Some environmental variables showed similar monthly patterns for both years of sampling (Fig. 2). The only negative significant correlation was found between water temperature and electrical conductivity ($P = 0.015$, $r = -0.47$) (Table 2). BOD_5 values ranged between 0.37 and 5.31 mg L^{-1} with the average of 2.94 mg L^{-1} while turbidity changed from 1.3 to 9.6 NTU. The upper (220 cm) and lower (50 cm) levels of Secchi depth were measured in May and October 2010, respectively. There were no significant measurements of phosphorus (PO_4), ammonium (NH_4) and nitrite ($N–NO_2$) levels during this study that almost all measurements were about the standard levels (but see Table 1). Additionally, lake water depth changed from 4.7 to 8.5 m during this study. Because of seasonal changes, lake water depth began to drop down end of summer and remained at lower levels until the middle of winter (February).