

COMPARATIVE ECOLOGY OF OSTRACODA (CRUSTACEA)
IN
TWO RHEOCRENE SPRINGS (BOLU, TURKEY)

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by

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TO MY FAMILY

ABSTRACT

COMPARATIVE ECOLOGY OF OSTRACODA (CRUSTACEA) IN TWO RHEOCRENE SPRINGS (BOLU, TURKEY)

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Increasing human disturbances on freshwater habitats can cause loss of species and habitats. Conservation studies on these habitats deduced bioindicator species concept. Besides, species of Ostracoda with their relatively unchanged habitat preferences from past to present and sensitivity to ecological conditions increase their importance on the usage as bioindicator species.

In this study two rheocene springs were selected in the Bolu region, both having almost the same latitude and altitude. They spread nearly 50-60 meters down from the sources. Two stations were selected in both of these study sites. Materials were collected from these four stations in fifteen months between November 2002 and November 2004. As a result, total of ten species (*Darwinula stevensoni*, *Candona neglecta*, *Cypria ophthalmica*, *Ilyocypris bradyi*, *Eucypris lilljeborgi*, *Prionocypris zenkeri*, *Herpetocypris chevreuxi*, *Psychrodromus olivaceus*, *Heterocypris incongruens*, *Scottia pseudobrowniana*) were recognized. Among these species *Scottia pseudobrowniana* was recorded second time in Turkey from the first station of Çaygökpınar spring. *Eucypris lilljeborgi* is also a new report for the ostracod fauna of Bolu. On the other hand, there was a dominancy of *C. ophthalmica*, *P. zenkeri*, *I. bradyi* and *C. neglecta* in the second stations of both Çaygökpınar and

Çetin Bey springs. *Herpetocypris chevreuxi* was only found in the stagnant waters of the second station of Çetin Bey spring. Both species, *C. ophtalmica* and *D. stevensoni* were collected from the first and second stations of Çaygökpınar spring.

Statistical analyses revealed that similarities among the first stations of Çetin Bey and Çaygökpınar springs and again among the second stations of those springs are much more than the similarities between the first and the second stations of the same spring. Optima, tolerance, and Environmental Tolerance Index (ETI) values put forward the ecological characteristics of species according to the environmental variables. Spearman Correlation Analysis showed that *I. bradyi* had positive relationship with *C. ophtalmica*, the same result is also observed in the UPGMA dendrogram. However, it did not display a significant relationship between environmental variables and species occurrence.

Key Words: Ostracoda (*Crustacea*), Ecology, Springs, Taxonomy, Distribution, Comparative Ecology, Statistical Analyses

ÖZET

İKİ RHEOCRENE KAYNAKTAKİ (BOLU, TÜRKİYE) OSTRAKOD (CRUSTACEA) TÜRLERİNİN KARŞILAŞTIRMALI EKOLOJİSİ

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Tatlısu habitatlarında artan insan müdahalesi tür ve habitat kaybına neden olabilir. Bu habitatlardaki koruma çalışmaları *gösterge tür* kavramını ortaya çıkarmıştır. Bunun yanı sıra zamanla değişmez habitat tercihleri ve ekolojik şartlara duyarlılıkları nedeniyle Ostrakodlar'ın *gösterge tür* olarak kullanılmalarının önemi artmıştır.

Bu çalışmada Bolu bölgesinde aynı enlem ve boylamlarda iki akarpınar kaynak seçilmiştir. Bunlar kaynaktan 50-60 metre kadar aşağı akmaktadırlar. Her iki araştırma alanında iki istasyon seçilmiştir. Kasım 2002 - 2004 tarihleri arasında on beş ay boyunca bu dört istasyondan örnek toplanmıştır. Sonuçta toplam on tür (*Darwinula stevensoni*, *Candona neglecta*, *Cypria ophthalmica*, *Ilyocypris bradyi*, *Eucypris lilljeborgi*, *Prionocypris zenkeri*, *Herpetocypris chevreuxi*, *Psychrodromus olivaceus*, *Heterocypris incongruens*, *Scottia pseudobrowniana*) tanımlanmıştır. Bu türler arasında Çaygökpınar kaynağının ilk istasyonunda *Scottia pseudobrowniana* türüne Türkiye'de ikinci defa rastlanmıştır. *Eucypris lilljeborgi* ise Bolu faunası için yeni bulunan bir kayıttır. Öte yandan Çaygökpınar ve Çetin Bey kaynaklarının her ikisinin de ikinci istasyonunda *C. ophthalmica*, *P. zenkeri*, *I. bradyi* ve *C. neglecta* ya bolca rastlanmıştır. *Herpetocypris chevreuxi* yalnızca Çetin Bey kaynağının ikinci

istasyonundaki durgun sularda bulundu. *Cypria ophthalmica* ve *D. stevensoni* türlerinin her ikisi de Çaygökpınar kaynağının birinci ve ikinci istasyonlarında bulunmuştur.

İstatistik analiz sonuçlarına göre Çetin Bey ve Çaygökpınar kaynaklarının karşılıklı ilk istasyonları ile ikinci istasyonları arasında aynı kaynakların kendi içinde birinci ve ikinci istasyonları arasında olan benzerlikten çok daha fazla benzerlik gözlemlenmiştir. Optimum, tolerans ve ETI (Çevresel Tolerans İndeksi) değerleri çevresel değişkenlere göre türlerin ekolojik özelliklerini ortaya koyar. Spearman Korelasyon Analizi *I. bradyi* ve *C. ophthalmica* arasında olumlu ilişki tespit etmiş; aynı sonuç UPGMA dendogramında da gözlemlenmiştir. Ancak çevresel değişkenlerle türlerin mevsimsel görünüşü arasında önemli bir ilişki gözlemlenememiştir.

Anahtar Kelimeler: Ostrakoda (*Crustacea*), Ekoloji, Kaynaklar, Taksonomi, Yayılım, Karşılaştırmalı Ekoloji, İstatiksel Analizler.

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1. INTRODUCTION

The comparative observation method has a significant past that goes back to Charles Darwin, or even before. Basically, in this approach one compares many species in systems that are presumed to be at different stages or to represent different stages of a single process (Lubchenco and Real, 1991). Also, such ecological comparison states how two or more ecosystems (e.g., springs) are of different and/or similar features. However, understanding such differences requires knowledge not only about the biological processes but also ecological bases of species. Therefore, comparison of ecosystems can be either among environmental factors, or differences in species occurrence, or both. However, due to its characteristics, comparative studies based on both environmental factors and species occurrence are not easy, and especially in ostracods, such studies are not common in the literature. Below, detailed information about the subject organisms, Ostracoda, and the specific habitats, springs are given.

1. 1. Ostracoda

The Ostracoda were first described by Carolus Linnaeus in 1758 and later by O. F. Müller in 1776. This aquatic invertebrates was first named as ‘Ostrachoda’ by Latreille (1802). Then after, the name was changed to ‘Ostracoda’ in 1806 by the same author (Ikeya et al., 2005). Ostracods are small (generally 0.30-5 mm) aquatic invertebrate animals with a pair of calcium carbonated carapace. Some marine pelagic forms can even exceed 30 mm in length (Meisch 2000). The whole body parts of the animal are enclosed in the carapace, including pairs of limbs and organs. In Crustacea, Ostracoda are the most diverse invertebrates with their marine and non-marine species. Nearly 65.000 nominal extant and fossil species have been

described in total and it is estimated that more than 20.000 living species exist (Ikeya et al., 2005).

The Class Ostracoda is represented in the Phylum Arthropoda and the Subphylum Crustacea. There are two subclasses of the Ostracoda, namely Myodocopa and Podocopa (Horne et al., 2002). While the Subclass Podocopa includes Podocopida, Platycopida, Palaeocopida; the subclass Myodocopa includes Myodocopida and Halocyprida (Horne 2003). There are three orders of Ostracoda as Myodocopida, Platycopida, Podocopida (Meisch 2000). When Myodocopa is found in the marine pelagic realm and nektobenthic taxa, Platycopida includes only marine species, and Podocopida includes marine, brackish, and freshwater species (Meisch 2000). Podocopida have three superfamilies as Cypridoidea, Cytheroidea, and Darwinuloidea. Cypridoidea is the most diverse group of the non-marine Podocopids including following 4 orders:

Order: Palaeocopida Henningsmoen, 1953, includes only fossil species.

Order: Myodocopida Sars, 1866, includes only marine species;

Order: Platycopida Sars, 1866, includes marine and few brackish species;

Order: Podocopida Sars, 1866, includes marine, brackish, freshwater, and few terrestrial species.

1. 1. 1. Morphology

Ostracods are bivalved crustaceans. The body is covered by carapace that have two valves. The valves have simple or complex closing mechanisms that are controlled by the central adductor muscles. The attachment sites of these muscles to the valves form muscle scars which have taxonomic importance (Martens 1998). Two valves are connected dorsally with a hinge. Individual valves can be studied by properties like size, shape, and ornament (Boomer et al., 2003). Both valves consist

of inner and outer lamella. The valve shape, size and ornament can be controlled genetically, like sexual dimorphism or the intra-population variability and environmental factors which affect calcification (Boomer et al., 2003). The outer valves of ostracods have pores and some ornaments like spines, nodes, tubercles, pits, etc. (Martens 1998). Moreover, pores have a sensorial function (Meisch 2000). Podocopan ostracods have an eye on the anterodorsal corner of the carapace (Horne et al., 2002). Most organs and appendages are found in pairs. Head generally consists of two pairs of antennae, a pair of mandibulae, and a pair of maxillulae. Thorax consists of 1-3 pairs of appendages including cleaning legs and clasping organs. Abdomen consists of no appendages, a pair of caudal rami, males have one or two hemepenes (Martens 1998). No clear segmentation of ostracod body is recognizable (Meisch 2000). Antennula has locomotory and sensory function. The long natatory setae on the antennula is used for swimming. The main locomotory structure is the antenna and it is used for swimming, walking, climbing and digging. The antennal exopodite is important in classifying the major groups (Horne et al., 2005). Mandibula is used in masticatory process and has strong teeth, joined setose palp. Mandibula is used for gathering, handling and chewing food particles. The fifth, sixth and seventh limbs, with a terminal claw, are generally used in walking. The fifth limb (or first thracopod) is variously used for feeding, respiration and clasping and the sixth limb has the same function (or second thracopod) in all Podocopida (Horne 2003). The seventh limb (or third thracopod) is modified into a cleaning limb in Cyprididae (Martens 1998). Cleaning limbs' setal composition has great taxonomic importance at the generic level of Candoninae (Meisch 2000). The eighth pair of limbs is called furca or caudal rami. Ostracods have calcium carbonated carapace that help them to be protected as fossils. Therefore, fossil

species can also be used as palaeoenvironmental indicators (Horne and Boomer, 2000).

1. 1. 2. Blood Circulation

The Podocopida, freshwater forms does not have a heart or other respiratory organs. The flowing of, oxygenated water inside the carapace is provided by vibratory plates of maxillulae (Meisch, 2000).

1. 1. 3. Nervous system

Nervous system consists of a cerebrum, a circum-oesophagal collar of fused ganglia and a ganglia running antero-posteriorly (Hartmann 1967, in Meisch 2000).

1. 1. 4. Reproduction

The reproductive organs of Podocopida are found in pairs. The male reproductive system is important for its complexity and size. However, the spermatozoa of ostracods are the largest known among the animals (Meisch 2000). Non-marine ostracods generally have three modes of reproduction, being fully bisexual species (males and females present). Mixed reproduction, bisexual reproduction and parthenogenesis have been observed. The ancient asexuals like Darwinuloidea have persisted to reproduce with parthenogenesis over long periods of time (Meisch 2000). Bisexual populations have never been found in extant taxa (Martens 1998).

1. 1. 5. Development

Most Podocopida have eggs either clustered or singly kept. Brood care of the eggs and two or three instars exist in Cytherocopina and all Darwinulocopina, but not in the Cypridicopina (Horne et al., 2002). Ostracods, like other crustaceans grow by moulting, generally there are 8 moulting stages (Mezquita et al., 2000; Wansard and Mezquita 2001). At the end of each moulting the shell calcifies. In

this respect the moulting process is affected by temperature and water chemistry (Wansard and Mezquita 2001), and biological aspects of organisms, as well.

1. 1. 6. Ecology

Ostracods can be found in all types of water bodies including fresh, saline and brackish waters and also a limited number of ostracod taxa are known from semi-terrestrial environments (Külköylüoğlu and Vinyard 2000). They can be found in oceans from littoral zone to the abyssal depths, in every freshwater habitats, in Arctic regions and in tropical zones, also in underground waters. Some cytheroid ostracods can live as symbionts, commensals or ectoparasits (Meisch 2000). Some of the species have a broad geographical distribution depending on their dispersal abilities and tolerances of environmental variables. Dispersal can be achieved through passive or active transport, which is common in freshwater invertebrates (Bilton et al., 2001). Living ostracods can be transported by muds stuck to some parts of birds, by sediment transportation, by fishes and humans (Horne and Boomer, 2000). The wind is also another important factor in the dispersion of resting eggs (Horne and Martens, 1998). Active dispersal is related to the movement of the species via swimming.

Ostracods are sensitive to both environmental variations (elevation, latitude, longitude, seasonal changes) and to the changes in physical variables in waters (temperature, pH, conductivity, dissolved oxygen) (Delorme 1983). Different species prefer different types of water bodies related to their tolerance limits to environmental variations. Cosmopolitan species with broad ranges of tolerance to environmental fluctuations recolonize easily to the new environment (Külköylüoğlu 2005a). The native and endemic species have certain tolerances to the ecological variables and usually have more restricted tolerance limits than cosmopolitan

species. Therefore, an increase in the numbers of cosmopolitan species may imply the effect of disturbance and pollution, causing a reduction in the numbers of native species (Külköylüoğlu 2005b). Such phenomena is called ‘pseudorichness’ (Külköylüoğlu 2004). Moreover ostracods give suitable responses to the environmental pollution by disappearance, replacement, appearance of specific species or presence of morphological anomalies (Geslin et al., 2002, in Ruiz et al., 2004). On the other hand, it is well known that anthropogenic factors affect many freshwater biotic communities (Heino et al., 2005). From this point of view, ostracods as indicator animals can be used to measure the quality of different water bodies (Külköylüoğlu 1999, 2004; Mezquita et al., 1999a). However, during the usage of ostracods as bioindicator species, one should have basic knowledge about the species ecological requirements (Külköylüoğlu 2003a). Moreover, present ecological requirements of the species to environmental variations help us to estimate the past conditions of the habitats. Besides, the calcium carbonate carapace of ostracods could be preserved as fossils, so they can be called as *paleoindicators*. With all respect to earlier studies, Ostracoda ecology has not been completely known yet (Külköylüoğlu 2004).

The knowledge on the ecology of ostracods are important for: (1) understanding the water quality of different aquatic habitats since they can be used as bioindicator species, (2) establishing their role in the food web, since some species are the food source of other living-things, others have active role at second or third trophic levels and some others may be herbivores (Horne and Boomer, 2000), (3) estimating the past conditions since they are preserved as fossils. Hence, they are important invertebrates which can help us to understand and compare past, present and the future conditions in a variety of habitats.

1. 2. Spring Ecology

Springs are the special environments of the terrestrial habitats. They provide their water from underground aquifer and they are also nearly free from the seasonal changes. In general, they have constant values of abiotic factors (e.g., temperature, pH, electrical conductivity, dissolved oxygen, salinity). Longterm sustainability of such abiotic factors in springs are very important for ecological studies (Klkylođlu 2003a).

There are three types of springs (Limnocrene, Helocrene and Rheocrene) which are determined by the stream systems. The structural changes of spring streams determine the physico-chemical features of water. Therefore, the ecology of springs can also change from type to type. In rheocrene springs, water flows directly into a channel of spring stream. Limnocrene spring may discharge into a small basin or a pond and overflows into a channel while the helocrene spring spread over a relatively wide area with moderate flow (Hynes 1970). Because of the fluidity of rheocrene springs, the temperature is lower than the limnocrene and helocrene springs. The oxygen level is higher and the salinity level is lower than the other types of springs. These factors have considerable important in Ostracoda life cycle (Horne and Boomer 2000). Since we assume that the nearly stable conditions of these abiotic factors continue from past to present, we also expect that nearly same population dynamics, a good specialization for niches and conservation of Ostracoda species also continue from past to present (Nielsen 1950). Early invaders can get advantage over the new ones in the modification of the environment, and nearly constant abiotic factors serve them to protect their advantage because after reaching the equilibrium nearly same population dynamics can be observed if there is not an unexpected disturbance. This is the evolutionary and ecologically

advantage for specialization and conservation. Therefore, the oldest springs could have carried endemic species (Roca and Baltanás, 1993). Moreover, many crenobiont Ostracoda species are known to live only in springs (Bronshtein 1947). Despite these ecological importance of springs, ecology of ostracods are generally studied in lake systems (Mezquita et al., 2000).

The aims of this study can be underlied in four questions:

Question 1: How are the characteristics of Ostracoda distribution, abundance (presence/absence) and diversity in two springs?

Question 2: Is there any similarity or dissimilarity between the environmental variables and species composition in the springs?

Question 3: How is the seasonality of ostracods in these springs?

Question 4: What is the relationship between ostracods and environmental variables?

1. 3. History of Ostracoda Studies in Turkey

In Turkey, first studies on Ostracoda were made by H. W. Schäfer in 1954 and later by Hartmann in 1964. Hartmann found many Ostracoda species new for Turkey such as *Candona neglecta*, *Ilyocypris gibba*, *Ilyocypris bradyi*, *Eucypris zenkeri*, *Heterocypris inaequivalves*, *Heterocypris incongruens*, *Herpetocypris chevreuxi*, and *Ilyodromus olivaceus*. Following him, Prof. Dinçer Gülen from University of Istanbul studied hot-springs of Turkey between 1965 and 1971 and reported *Heterocypris* sp. Which will later be a new species for the literature as *H. sabirae*. He mostly studied in the western parts of Anatolia including Eskişehir, Kütahya, İzmir, Çanakkale, Balıkesir during 1971 and 1975. Overall, eleven species were newly recorded for the ostracod fauna of Turkey as (*Cyclocypris ovum*, *Physocypris klielei*, *Ilyocypris divisia*, *Eucypris lutaria* *Eucypris*

hamadanensis, *Eucypris clavata*, *Dolerocypris sinensis*, *Stenocypris malcolmsoni*, *Cypridopsis vidua*, *Cytherissa lacustris* and *Cypretta dubiosa*). Gülen, also studied the western parts of Anatolia during 1977 to 1985 and reported 10 more species new for Turkey as (*Ilyocypris biplicata*, *Candonopsis kingsleii*, *Cypris bispinosa*, *Cypria ophthalmica*, *Eucypris inflata*, *Cypridopsis aculeata*, *Cypridopsis pavra*, *Darwinula stevensoni*, *Limnocythere relictata* and *Heterocypris sabireia*). In 1982, Gülen was able to find two species (*N. persica*, *N. monacha*) of the genus *Notodromas* new for Turkey, along with another species *Cypris pubera*. In 1985, he focused on bisexual populations of ostracods in Anatolia and found bisexual populations of five species. In 1988, Gülen collected samples from Antakya, Mersin, and Adana where 11 ostracod species were reported. In this study, he also paid more attention on the zoogeographical feature of two species *Eucypris inflata* and *Candonopsis kingsleii*.

In 1988, under the supervisorship of Gülen, Altınsaçlı studied in Bergama (İzmir) region and recorded two new species (*Ilyocypris inermis* and *Potamocypris zschokkei*) for Turkey. In 1990, he was able to recognize eight ostracods from Ayvalık (Balıkesir). In 1993, he collected samples from both Lake Sapanca and aquatic habitats from its environments, and found out 25 species, 6 of which were recorded as new for the Ostracoda fauna of Turkey as (*Candona crispata*, *Candona vavrai*, *Candona fabaeformis*, *Candona angulata*, *Tyrrhenocythere amnicola* and *Loxoconchissa immodulata*). Later in his studies at Lake Beyşehir, *Heterocypris rotundata* was a new report for Turkey. Altınsaçlı and Griffiths (2001a) studied in Lake Uluabat and then in Lake Kuş (Altınsaçlı and Griffiths 2001b). Following these studies, they recorded *Hungarocypris* and *Leucocythere* genera from Turkey (Altınsaçlı and Griffiths 2001c).

Kubanç and Altınsaçlı studied in Ayvalık (1990).

Özuluğ et al. (2000) studied in Lake Eğirdir, and these authors were able to report the first parthenogenetic populations of *Plesiocypridopsis newtoni* from Anatolia .

Külköylüoğlu et al. (1993) studied in Lake Küçükçekmece from 1989 to 1990. *Cytheretta adriatica* was a new report for Turkey. Külköylüoğlu et al. (1995) worked in Lake Büyükçekmece where six species were a new report for Turkey (*Potamocypris varigeata*, *Potamocypris longisetosa*, *Loxoconcha tamarindus*, *Callistocythere rostrifera*, *Semicytherura sulcata* and *Heterocythereis albomaculata*). Külköylüoğlu (1998) studied in Lake Şamlar during 1990 and 1991 and two new species were recorded for Marmara region (*Ilyocypris divisa* and *Eucypris lilljeborgi*). In this study, he first introduced a graphical model called Ostracoda Watch Model (OWM) for seasonal occurrence of species. He collected samples from freshwater habitats in Bolu, in which his study was one of the first applied to Canonical Correspondence Analyses on Ostracoda by adding months as variables. In 2003, Külköylüoğlu firstly recorded *Scottia pseudobrowniana* from a limnocrone spring in Turkey (Külköylüoğlu 2003a). After that in 2003 he found a new species (*Isocypris beauchampi*) from Lake Gököy (Külköylüoğlu 2003b), stating that these last two genera were the first reports for Turkey. Külköylüoğlu also studied in lakes and reservoirs in Bolu (Külköylüoğlu 2003c), and reported a rare species *Paralimnocythere psammophila* from Lake Aladağ (Külköylüoğlu 2003d). He studied different aquatic habitats in Bolu region in 2004 also in this study the usage of ostracods as bioindicator species was discussed. Külköylüoğlu and Dügel (2004) worked on the ecology and seasonality of Ostracoda in a man-made lake, located at about 1300 m a.s.l in Bolu. In this study, ostracods seasonal occurrence

were studied over two years of monthly sampling. In 2005, Klkylođlu worked on the species richness in Yumrukaya Reedbeds, a small wetland located in the western part of Bolu (Klkylođlu 2005a). In the same year he worked on the ecological requirements of Ostracoda species (Klkylođlu 2005b). Klkylođlu (2005c) recorded a new species (*Limnocythere inopinata*) from a reservoir Lake Glky as a new report for the Bolu region. His studies on ecology of ostracods and their usage as bioindicator species have still been continued.

In most recently, Ylmaz and Klkylođlu (2005) studied in Lake Aladađ and reported nine ostracod taxa. In addition to these previous studies, several other studies reports total of about 90 freshwater ostracod species in Turkey. However, such number is believed to be underestimated, and is possibly much higher. Two possible reasons for a small numbers of species recorded so far can be either difficulties in taxonomic works that includes many regions unsampled so far, or a few numbers of ostracodologist found not only in Turkey but also in the world.

2. MATERIALS AND METHODS

2. 1. Site Description

Two reocrene springs (Figure 1) were selected for this study in Bolu. First spring (etin Bey Spring 40°42'570"N 31°31'856"E) is located in the western part of Bolu near the Glky reservior at 730 m. of altitude. The second spring (aygkpınar Spring 40°42'342"N 31°41'819"E) is located in the southern part of Bolu at 760 m. of altitude. etin Bey spring flows from west to east, while aygkpınar spring flows from south to north. These two are permanent rheocrene types of springs. They spread nearly 50-60 meters down from the sources. Two oak trees are located around etin Bey spring so the eucrenal (source of spring and its

environment) sites of the spring is shady, but there are no trees around Çaygökpınar spring, except a short bushy flora covered in summer. In this study gammarid amphipods (family Gammaridae), freshwater clams, freshwater snails, pleurobittid gastropods and planarians were found with ostracods in Çetin Bey spring. In Çaygökpınar spring, gammarid amphipods (family Gammaridae), freshwater clams, freshwater snails, pleurobittid gastropods and aquatic insects including *Dytiscus* (Coleoptera) were collected except ostracods.

Çetin Bey spring is located near Lake Gölköy, where public usage is high. Çetin Bey spring was a limnocrene spring until end of 2001, but it was changed to rheocrene type because of the destruction on the physical structure of it by the city's Environmental Protection Foundation that covered the spring with a concrete structure to provide water for public facilities (Külköylüoğlu 2003a). However, Külköylüoğlu (2003a) was able to study ostracod ecology before this human effect seen in Çetin Bey spring. There is a road near Çaygökpınar spring, which is frequently used by lime loaded lorries and other types of vehicles. Consequently, the lower parts of the spring, 50 m away from the eucrenal site, have been disturbed by the lime dust, but no other disturbance or contamination were observed in the source.

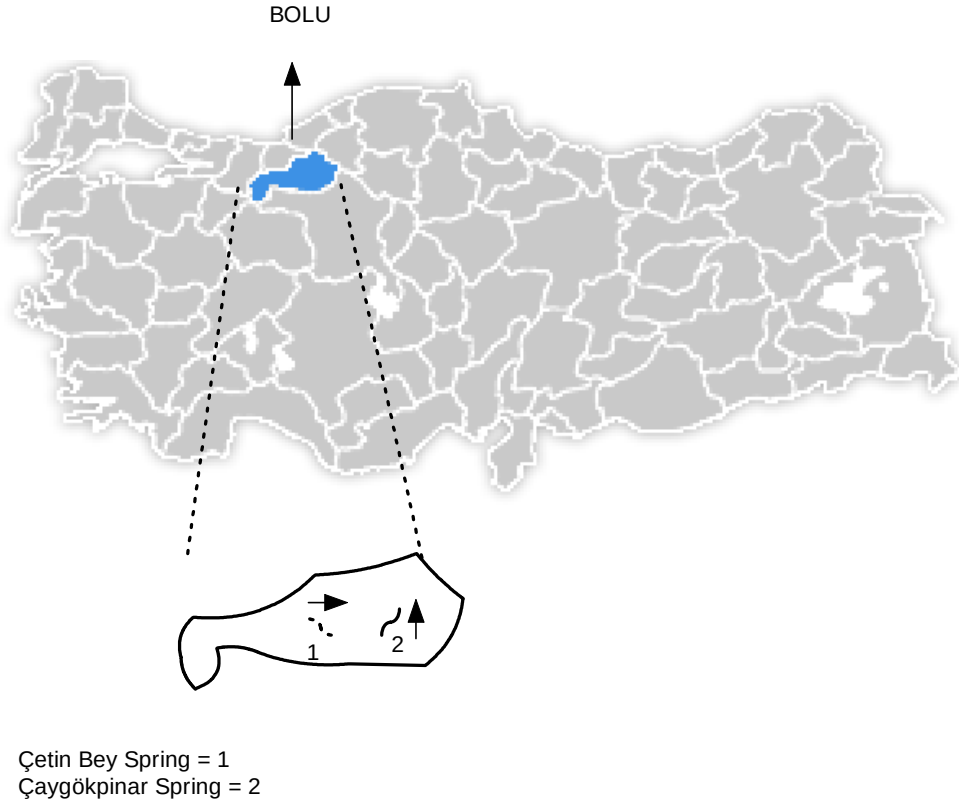


Figure 1. Map shows two study sites in the Bolu region.

2. 2. Methodology

In both study sites, two stations were selected. The first stations are at the eucrenal of the springs and the second stations are selected at the downstream of the springs, 50 m away from the source. The springs were visited between November 2002 and November 2004, during which as suggested major environmental variables (e.g., pH, temperature, electrical conductivity, dissolved oxygen, redox potential and percent oxygen saturation) were measured at the study sites. A Hanna model HI-98150 pH/ORP meter was used to measure pH and redox potential (Eh) and a YSI-85 model oxygen-temperature meter was used to measure the remaining variables.

Redox potantial (Eh) was calculated for the value of SHE (Standard Hidrojen Electrode) as:

$$SHE = Eh + 207 + 0.65 * (25 - T \text{ }^{\circ}\text{C})$$

Geographical data (altitude, latitude, longitude) was recorded with a global positioning system (GPS) unit. The samples were collected from the source of the springs and the downstream of the springs using Müller's plankton net. In the laboratory, samples were washed with pressurized tap water, filtered through four standard-sized sieves (0.25; 0.50; 1.00; 2.00 mm in mesh size) and were stored in 70% ethanol. Species identification was based on the soft body parts and valves. Ostracod species were identified under the Olympus BX-51 model microscope after they were mounted in lactophenol solution for permanent slides. During the identification the systematic keys of Bronshtein (1947), Meisch (2000), and the index and bibliography of non-marine Ostracoda of Kempf (1980, 1997) were used.

For measuring the biological oxygen demand (BOD₅) of species, the samples were collected from stations and kept in 100 ml special jars as suggested by APHA (1998). These jars were taken in the oven at 20°C after five days, and BOD measured, in standard way.

2. 3. Statistical Analyses

In this study the following statistical approaches were used as similarity indices (e.g., Jaccard and Sorenson Similarity Index). They were used to compare community structures based on species presence/absence data.

$$\text{Jaccard Similarity Index} = \frac{c}{(a + b) - c} \times 100$$

$$\text{Sorenson Similarity Index} = \frac{2c}{a + b} \times 100$$

c = the number of species common in both site A and B

a = the number of species found in site A

b = the number of species found in site B

Following similarity indices, tolerance (*tk*) and optima (*uk*) equations were used to estimate tolerance and optimum values of the nine species for six environmental variables (Ter Braak and Barendregt 1986, Klkylođlu and Dgel 2004).

$$Optima\ (uk) = \frac{\sum_{i=1}^n y_{ik}.x_i}{\sum_{i=1}^n y_{ik}} \quad Tolerance\ (tk) = \sqrt{\frac{\sum_{i=1}^n y_{ik}.(x_i - uk)^2}{\sum_{i=1}^n y_{ik}}}$$

Besides, Environmental Tolerance Index (ETI) was calculated for nine species with six variables. ETI used for calculating relative tolerance range of Ostracoda species for different environmental variables (Curry 1999). ETIs range changes from zero to one.

$$ETI = \frac{\text{range of } x_{\text{species}}}{\text{range of } x_{\text{data set}}}$$

Unweighted Pair Group Mean Averages (UPGMA) was used to understand the associations between species. Chi-square test was applied to UPGMA dendrogram. The UPGMA analysis were performed with Multi-Variate Statistical Package (MVSP) version 3. 1. (Kovach 1998). Spearman Correlation analysis was used to observe associations between species and environmental variables. Spearman analyses was performed with SPSS 10.0 software program. T-test for equal variances were used to indicate the relationships between stations at 0.05 significance level.

Ostracod Watch Model (OWM) (Klkylođlu 1998) was used to understand and graph the seasonal distributions of Ostracoda species.

3. RESULTS

Ten species were found in this study. The taxonomy, distribution and ecology of the species are given below.

3. 1. Taxonomy

The species found in this study are belonged to two infraorders (Darwinulocopina, Cypridocopina). Darwinulocopina included one genus (Darwinula) with one species. Cypridocopina had nine genus (Candona, Cypria, Ilyocypris, Eucypris, Prionocypris, Herpetocypris, Psychrodromus, Scottia, Heterocypris) in three families (Cyprididae, Ilyocyprididae, Candonidae). The taxonomy of species found in this study was given below. These species are only from the subclass of Podocopa and order Podocopida.

PHYLUM: ARTHROPODA
SUBPHYLUM: CRUSTACEA Pennant, 1777
CLASS: OSTRACODA Latreille, 1806
SUBCLASS: PODOCOPA Müller, 1894
ORDER: PODOCOPIDA Sars, 1866

Suborder Podocopina Sars, 1866

Infraorder Darwinulocopina Sohn, 1988

Superfamily Darwinuloidea Brady and Norman, 1889

Family Darwinulidae Brady and Norman, 1889

Genus Darwinula Brady and Robertson, 1885

Darwinula stevensoni (Brady and Robertson, 1885)

Infraorder Cypridocopina Jones, 1901

Superfamily Cypridoidea Baird, 1845

Family Candonidae Kaufmann, 1900

Subfamily Candoninae Kaufmann, 1900

Genus Candona Baird, 1845

Candona neglecta Sars, 1887

Subfamily Cyclocypridinae Kaufmann, 1900

Genus Cypria Zenker, 1854

Cypria ophthalmica (Jurine, 1820)

Family Ilyocyprididae Kaufmann, 1900

Subfamily Ilyocypridinae Kaufmann, 1900

Genus Ilyocypris Brady and Norman, 1889

Ilyocypris bradyi Sars, 1890

Family Cyprididae Baird, 1845

Subfamily Eucypridinae Bronshtein, 1947

Genus Eucypris Vávra, 1891

Eucypris lilljeborgi Müller, 1900

Genus Prionocypris Brady and Norman, 1896

Prionocypris zenkeri (Chyzer and Toth, 1858)

Subfamily Herpetocypridinae Kaufmann, 1900

Genus Herpetocypris Brady and Norman, 1889

Herpetocypris chevreuxi (Sars, 1896)

Genus Psychrodromus Danielopol and Mc Kenzie, 1977

Psychrodromus olivaceus (Brady and Norman, 1889)

Subfamily Cyprinotinae Bronshtein, 1947

Genus Heterocypris Claus, 1892

Heterocypris incongruens (Ramdohr, 1808)

Subfamily Scottinae Bronshtein, 1947

Genus Scottia Brady and Norman, 1889

Scottia pseudobrowniana Kempf, 1971

3. 2. Ecology and Distribution

The ecology and distribution of each species reported herein are given below. Species collection date (e.g., 15.11.2003), station number (e.g., St: 1), and numbers of specimen (6 individuals or 6♀) are given in order, respectively.

Darwinula stevensoni (Brady and Robertson, 1885)

15.11.2003; St 4: 6♀

13.12.2003; St 4: 1♀

17.01.2004; St 4: 6♀

27.08.2004; St 4: 2♀; St 3: 1♀

18.09.2004; St 4: 5♀

17.10.2004; St 4: 2♀

13.11.2004; St 4: 1♀

General Distribution: A cosmopolitan species known with its widespread distribution (Meisch 2000).

Old records from Turkey: Bolu, Afyon (Gülen, 1985a), Bolu (Külköylüoğlu, 2003c; Külköylüoğlu 2005c, Yılmaz and Külköylüoğlu 2005), Bursa (Altınsaçlı 1993; Altınsaçlı and Griffiths 2001a), İstanbul (Altınsaçlı and Yılmam 1995), Diyarbakır (Gülen et al., 1996), Kocaeli, Sakarya (Altınsaçlı, 1997), Konya, Isparta (Altınsaçlı et al., 2000a; Özuluğ et al., 2000).

Ecology: *Darwinula stevensoni* has a wide range of tolerance to environmental variables (Ramdani et al, 2001). This benthic detritivorous species is typically found in the littoral, shallow limnic zone of many permanent lentic habitats (Rossi et al., 2004). It generally prefers low temperatures, high oxygen level and low salinity (Külköylüoğlu and Vinyard 2000). It was positively correlated with conductivity (Külköylüoğlu, 2005a), but also tolerated high levels of pH (Yılmaz and Külköylüoğlu, 2005). Due to lack of swimming setae, it is a bottom dwelling ostracod (Külköylüoğlu 2005b).

***Candona neglecta* Sars, 1887**

04.05.2003; St 2: 4	17.01.2004; St 2: 8; St 1: 1; St 4: 5
18.10.2003; St 2: 4; St 4: 1	17.04.2004; St 1: 1
15.11.2003; St 2: 5; St 1: 1; St 4: 2	13.03.2004; St 4: 5
09.07.2004; St 4: 3	27.08.2004; St 3: 2
18.09.2004; St 1: 6	17.10.2004; St 1: 1

General Distribution: Europe (Roca and Baltanás 1993), North Africa (Klie 1938), Central Asia, Russia (Bronshtein 1947), Algeria (Sars 1928) and America (Külköylüoğlu 1999). It has a wide distribution in Europe. It is almost cosmopolitan extending to the south (Roca and Baltanás 1993).

Old records from Turkey: Gaziantep (Hartmann 1964), Kütahya (Gülen 1977, 1984; Gülen and Altınsaçlı 1999), Aydın (Gülen 1984, 1985a), Bilecik, Zonguldak, Bolu (Gülen 1985a, b; Külköylüoğlu 2003a, 2005a, 2005c; Külköylüoğlu and Dügel 2004), Adana (Gülen 1988), İzmir (Gülen 1985a, b; Altınsaçlı, 1999; Aygen and Balık 1998), Bursa (Altınsaçlı and Griffiths 2001a), Sinop, Samsun (Kaleli, 1993), İstanbul (Altınsaçlı and Yılmam 1995), Diyarbakır (Gülen et al., 1996), Kocaeli, Sakarya (Altınsaçlı, 1997), Bilecik, Bolu, Kütahya (Gülen and Altınsaçlı 1999), Isparta (Özuluğ et al., 2000; Altınsaçlı and Griffiths 2001a), Afyon and Konya (Altınsaçlı et al., 2000a, b), Kırklareli (Altınsaçlı and Griffiths 2001b)

Ecology: Earlier reports pinpointed that *Candona neglecta* is a stenothermic cold-loving species but it can only tolerate temperatures above 20°C (Bronshtein 1947). It is however widespread in eutrophic springs that have a high organic matter (Roca and Baltanás 1993). It can be found in lakes, ponds, springs, ditches, streams and rarely underground waters (Meisch 2000). Species can tolerate lower oxygen concentrations and high tolerance of conductivity changes (Külköylüoğlu 2005b).

Moreover, it was frequent in flowing waters (Mezquita et al., 1999b). It has wide range of dissolved oxygen (3.2-15.4 mg/L), pH values (6.8-9.4), conductivity (56-890 μScm^{-1}) (Roca and Baltanás1993).

Cypria ophthalmica (Jurine, 1820)

23.11.2002; St 4: 7 individual	04.05.2003; St 4: 17 individual
18.10.2003; St 4: 2; St 3: 3; St 2: 1 individual	17.01.2004; St 4: 13 individual
13.12.2003; St 4: 11; St 3: 5 individuals	17.04.2004; St 3: 2 individual
15.11.2003; St 4: 3; St 3: 3 individual	09.07.2004; St 4: 2; St 3: 1 individual
27.08.2004; St 4: 2; St 3: 3 individual	18.09.2004; St 4: 7 individual
17.10.2004; St 4: 9 individual	

General Distribution: It shows worldwide distribution except Australia (Meisch 2000). It is almost cosmopolitan.

Old records from Turkey: İstanbul (Gülen 1985a; Altınsaçlı and Yılmam 1995; Külköylüoğlu 1998), Bursa (Altınsaçlı 1999), Trabzon (Gülen et al., 1994a), Kütahya, Eskişehir (Gülen and Altınsaçlı 1999), Diyarbakır (Gülen et al., 1996), Kocaeli, Sakarya (Altınsaçlı 1997), İzmir (Aygen and Balık 1998; Ustaoglu et al., 2003), Konya, Isparta (Altınsaçlı 2001), Bolu (Külköylüoğlu 2003c; 2004, Külköylüoğlu et al., in review).

Ecology: General distribution of *C. ophthalmica* is related to the wide range of environmental variables of the species. It tolerates pH values from very low to very high (Delorme 1991). It has a wide range of temperature, precipitation and hydrochemically tolerance (Curry 1999). The temperature range of species lies between 2.2°C and 8.4°C (Meisch 2000). Because of the ability to swim it has an advantage to colonize easily (Scharf 1998). The species is found from salty habitats,

(5.8 ‰ salinity) which is called oligohaline range (Meisch 2000). It was found in the areas with high ionic content and rich in chloride (Rosetti et al., 2005).

***Ilyocypris bradyi* Sars, 1890**

23.11.2002♀; St 4: 2♀	04.05.2003; St 4: 10♀; St 2: 16♀
18.10.2003; St 4: 1♀; St 2: 12♀	15.11.2003; St 2: 30♀; St 1: 1♀
13.12.2003; St 2: 4♀; St 4: 17♀	17.01.2004; St 4: 5♀; St 2: 16♀
17.04.2004; St 1: 1♀	15.05.2004; St 4: 1♀
12.06.2004; St 4: 4♀	09.07.2004; St 1: 1♀
27.08.2004; St 4: 2♀	18.09.2004; St 4: 1♀; St 1: 6♀
17.10.2004; St 4: 2♀; St 1: 1♀; St 2: 3♀	13.11.2004; St 2: 1♀

General Distribution: The species is well known from holoarctic region (Külköylüoğlu 2005a) but also shows almost cosmopolitan characteristics.

Old records from Turkey: Antakya, Malatya (Hartmann 1964), Eskişehir (Gülen 1977), Bilecik (Gülen 1985a), İstanbul (Külköylüoğlu et al., 1993; Külköylüoğlu et al., 1995; Gülen et al., 1994a), Adapazarı (Altınsaçlı 1997), Bursa (Altınsaçlı 1999), Diyarbakır (Gülen et al., 1996), Bilecik, Balıkesir, Bergama, Amasya, Sivas, Antalya, Trabzon, Van, Kars, Nevşehir and Ankara (Gülen et al., 1994a), Bolu (Külköylüoğlu 2003a, 2004; Külköylüoğlu and Dügel 2004; Külköylüoğlu 2005a, b, c).

Ecology: It shows a widespread distribution in nearly all kinds of freshwaters. It is a bottom dependent species. This species can be used to understand water quality in different habitats of Spain (Mezquita et al., 1999a). The species had a positive correlation to redox potential and a strong negative correlation to pH values (Külköylüoğlu 2005c). It was found in running waters (Cole 1966). The species

prefers cooler waters (14-25°C) and dissolved oxygen level differs 4 to 6.3 mg/L (Külköylüoğlu and Vinyard 2000).

Eucypris lilljeborgi Müller, 1900

13.12.2003; St 4: 2♀

18.09.2004; St 4: 1♀

General Distribution: Iran (Hartmann 1964), Russia, Caucasia, Germany, Sweden (Bronstein 1947).

Old records from Turkey: Gaziantep (Hartmann 1964), İzmir, Antalya (Gülen 1985a), Kocaeli, Sakarya (Altınışlı 1997), Diyarbakır (Gülen et al., 1996), İstanbul (Külköylüoğlu 1998).

Ecology: It is not very common species found from ponds, lakes, ditches in meadowland. It is a stenochronic form (Meisch 2000). Partenogenetic populations are known but Hartmann (1964) found males in Gaziantep (*E. lilljeborgi turcica*).

Prionocypris zenkeri (Chyzer and Toth, 1858)

23.11.2002; St 4: 16♀; St 3: 30♀

04.05.2003; St 4: 19♀; St 2: 45♀

18.10.2003; St 4: 21♀; St 2: 22♀

15.11.2003; St 4: 10♀; St 2: 43♀

13.12.2003; St 4: 30♀; St 2: 5♀

17.01.2004; St 4: 3♀; St 2: 39♀

17.04.2004; St 4: 3♀

15.05.2004; St 4: 11♀

12.06.2004; St 4: 30♀

09.07.2004; St 4: 5♀

18.09.2004; St 4: 9♀

17.10.2004; St 4: 2♀

13.11.2004; St 2: 3♀

General Distribution: England, France, Hungary, Sweden, Yugoslavia (Klie 1938), Germany (Scharf 1976). Generally distributed Europa and Asia minor (Turkey) (Meisch 2000).

Old records from Turkey: Southwest Anatolia (Hartmann 1964), Eskişehir (Gülen 1977), Afyon, Eğirdir-Isparta, Tokat (Gülen et al., 1994a), Lake Eftali-Bolu (Gülen

1985a), Bolu (Külköylüoğlu 2004), İstanbul (Külköylüoğlu et al., 1995; Külköylüoğlu 1998), Diyarbakır (Gülen et al., 1997), Bursa (Altınsaçlı 1999), Isparta (Özuluğ et al., 2000).

Ecology: It prefers springs or habitats connected to springs (Rosetti et al., 2005). The species was found in some of the undisturbed habitats of Bolu, Turkey (Külköylüoğlu 2004). Also prefers slow flowing streams with reach aquatic vegetation (Meisch 2000). It occurred very localized form in the study of Rosetti et al. (2005) since environmental variables could not affect the occurrence of species.

Herpetocypris chevreuxi (Sars, 1896)

04.05.2003; St 2: 4♀	15.11.2003; St 2: 2♀
18.10.2003; St 2: 2♀	13.12.2003; St 2: 1♀
17.01.2004; St 2: 5♀	17.10.2004; St 2: 23♀
13.11.2004; St 2: 5♀	

General Distribution: Germany, Netherlands (Klie 1938), America-Nevada (Külköylüoğlu and Vinyard 2000). There are only a few records. It is widely distributed in the circum-Mediterranean (Meisch 2000).

Old records from Turkey: Antakya (Hartmann 1964), İzmir (Gülen 1977), Bolu (Gülen 1985a; Külköylüoğlu 2004), Bilecik, Kütahya, Muğla, Bursa (Gülen 1985a), İstanbul (Külköylüoğlu et al., 1993), Amasya (Gülen et al., 1994b), Erzurum, Kahramanmaraş (Gülen et al., 1994a), Diyarbakır (Gülen 1985a), Kocaeli, Sakarya (Altınsaçlı 1997).

Ecology: While it prefers stagnant waters also occurs in saline aquatic habitats (Baltanás 1992). It was reported in different habitats in Turkey. It is a holoarctic species which prefers less alkaline (pH 8.0 or more), cooler (15-24°C), high oxygenated (6.3-8 mg/L) waters (Külköylüoğlu and Vinyard 2000). The species

prefers saline springs altitudes below than 1400 m. and it was found pH 7.8, dissolved oxygen 9.0 ppm, conductivity 798 $\mu\text{S cm}^{-1}$ and temperature 16°C in a spring (Roca and Baltanás 1993).

Psychrodromus olivaceus (Brady and Norman, 1889)

23.11.2002; St 2: 1♀; St 3: 4♀; St 4: 17♀

04.05.2003; St 2: 2♀; St 4: 6♀

15.11.2003; St 2: 3♀; St 4: 2♀

15.05.2004; St 4: 1♀

13.11.2004; St 1: 1♀

13.03.2004; St 1: 6♀; St 4: 1♀

27.08.2004; St 4: 1♀

18.09.2004; St 4: 1♀

General Distribution: It was reported from Caucasus (Bronstein 1947), Germany (Klie 1938), Yugoslavia (Gauthier 1928, in Baltanás 1992), Rumania (Danielopol et al., 1977), Bulgaria (Sywula 1967, in Altınsalı et al., 2000a), France (Meisch 1987, in zuluğ et al., 2000). It is common everywhere in suitable habitats (Meisch 2000).

Old records from Turkey: Ktahya (Glen 1977), Bursa (Altınsalı 1993, 1999; Glen 1985a), Afyon (Glen 1985a), İzmir (Altınsalı 1988; Aygen and Balık 1998), İstanbul (Klkyloğlu et al., 1993), Konya (Glen et al., 1994b; Altınsalı et al., 2000a, b), Malatya, Van (Glen et al., 1994a), Kocaeli (Hartmann 1964; Altınsalı 1997), Isparta (Altınsalı 2001; Altınsalı et al., 2000a; zuluğ et al., 2000), Kırklareli (Altınsalı 2001), Bolu (Hartmann 1964; Klkyloğlu 2004; Klkyloğlu and Yılmaz 2005, in review).

Ecology: The species exists commonly spring or habitats connected springs (Keyser and Nagorskaya 1998). It prefers cold waters (Mezquita et al., 1999b). Partenogenetic populations exists but males were recorded from Turkey (Glen 1985b; Klkyloğlu and Yılmaz 2005, in review). It was found at about 600-1380

m. of elevation, temperature 6.5-16.4°C, dissolved oxygen 8.0-9.9 mg/L, pH 6.9-7.4, conductivity 108-636 $\mu\text{S cm}^{-1}$ ranges in a spring (Roca and Baltanás 1993).

Heterocypris incongruens (Ramdohr, 1808)

18, 10, 03; St 2: 6♀ 15, 11, 03; St 2: 1♀

15, 05, 04; St 3: 3♀ 12, 06, 04; St 3: 5♀ 09, 07, 04; St 4: 1♀

General Distribution: The species is of cosmopolitan characteristic. It shows widespread distribution (Meisch 2000).

Old records from Turkey: Antalya, İskenderun (Hartmann 1964), Eskişehir, İzmir (Gülen 1977), Aydın, Bolu, Denizli, Isparta, Kastamonu, Zonguldak (Gülen 1985a), İzmir (Altınsaçlı 1988), İstanbul (Külköylüoğlu et al., 1993; Külköylüoğlu et al., 1995; Külköylüoğlu 1998), Bursa (Altınsaçlı 1999; Altınsaçlı and Griffiths 2001a), Trabzon, Kars, Van (Gülen et al., 1994a), Kocaeli, Sakarya (Altınsaçlı 1997), Kırklareli (Altınsaçlı 2001), Çorum (Gülen et al., 1994a), Diyarbakır (Gülen et al., 1996), Bolu (Külköylüoğlu 2004, 2005a, b).

Ecology: It can live in almost all kind of water bodies, ponds, ditches, limnic or lotic, temporary or permanent habitats (Külköylüoğlu and Vinyard 2000). The species was also found in polluted waters (Mezquita et al., 1999a, b.). Range of different environmental variables is relatively wide comparing to other conspecific taxa (Külköylüoğlu 2004). It can withstand the high salinity (Külköylüoğlu 1999). The species was exist slightly eutrophic springs with a high organic matter content (Roca and Baltanás 1993). It prefers habitats with little interspecific competition (Keyser and Nagorskaya 1998). The species may indicate the trophic conditions of the environment (Mezquita et al., 1999b). The species has wide tolerance levels (pH; 6-9.83, T°C of water; 6-29°C, dissolved oxygen; 0.40-14.5 mg/L, electrical conductivity; 56-2580 μScm^{-1}) (Külköylüoğlu 2005a).

Scottia pseudobrowniana Kempf, 1971

17.04.2004; St 3: 2♀ 2♂

15.05.2004; St 3: 1♀

General Distribution: Russia (Bronstein 1947), Ireland (Douglas and McCall 1992), Germany (Kempf 1971), Slovakia (Petkovski 1966), Hungary (Meisch and Forró 1998), Belgium (Wouters 1989), U.S.A (Külköylüoğlu 1999; Külköylüoğlu and Vinyard 2000).

Old records from Turkey: Bolu (Külköylüoğlu 2003a).

Ecology: The species is not very common overall in the world. It is a crenobiont species (Külköylüoğlu 2003a), showing holarctic distribution (Külköylüoğlu 1999). The species thought to be semi terrestrial (Meisch 2000). The species is classified as cold water stenotherm (Cole 1966). It has a wide tolerance range of environmental variables that the species can tolerate pH between 7.0 to 8.0, temperature 9.2 to 28°C, dissolved oxygen 3.0 to 8.5 mg/L (Külköylüoğlu 2003a). Moreover, its swimming setae absent and the species is considered to be bottom dependent. *S. pseudobrowniana* is detritivorous and probably occur throughout the year (Meisch 2000).

3. 3. Evaluation of Data

During fifteen months, samples were collected and the data gained for 10 species (*Darwinula stevensoni*, *Candona neglecta*, *Cypria ophthalmica*, *Ilyocypris bradyi*, *Eucypris lilljeborgi*, *Prionocypris zenkeri*, *Herpetocypris chevreuxi*, *Psychrodromus olivaceus*, *Heterocypris incongruens*, *Scottia pseudobrowniana*) were evaluated below. In the first station of Çetin Bey spring three species with twenty individuals were found whereas in the second station seven different species with three hundred and ten individuals were found. While the first station of Çaygökpınar spring had seven different species with sixty seven individuals, the

second station of Çaygökpınar spring had seven species with three hundred and fourty six individuals. Among the species *Scottia pseudobrowniana* collected from the first station of Çaygökpınar Spring with five individuals (St: 3) was recorded for the second time in Turkey. *Eucypris lilljeborgi* was found for the first time in Bolu from Çaygökpınar Spring's second station with three individuals (St: 4). On the other hand, there was abundance of *P. zenkeri* and *I. bradyi* in the second stations of both Çaygökpınar and Çetin Bey springs (St: 2 and St: 4), respectively. *Herpetocypris chevreuxi* was only found in the second station of Çetin Bey Spring with fourty two individuals (St: 2). Although *D. stvensoni* was only found from by a majority of Çaygökpınar Spring's second station, the species was only collected with one individual in the second station of Çaygökpınar Spring. Moreover, *C. ophthalmica* was collected from Çaygökpınar Spring's first and second stations (St: 3 and St: 4) while *C. neglecta* and *P. olivaceus* were found from both of the stations. However, *H. incongruens* was not very abundant in the collected materials, it was found both stations except Çetin Bey Spring's first station (St: 1).

The environmental variables were collected for each station for fifteen months period and the species which were found from the stations tabulated in the tables 1-4. Six different environmental variables (pH, redox potential; *Eh*, disolved oxygen; *DO*, electrical conductivity; *EC*, saturation; % *Sat.*, water temperature; *T* °C, salinity; *Sal.*) calculated are shown in the Tables. Abbreviations for the months are given below in the Tables some abbreviations are used for species are given below;

Scottia pseudobrowniana (Sp), *Darwinula stvensoni* (Ds), *Candona neglecta* (Cn), *Cypria ophthalmica* (Co), *Prionocypris zenkeri* (Pz), *Ilyocypris bradyi* (Ib), *Eucypris lilljeborgi* (El), *Heterocypris incongruens* (Hi), *Psychrodromus olivaceus* (Po), *Herpetocypris chevreuxi* (Hc)

Table 1. The monthly measured variables and the species of the Station 1 (Çetin Bey spring first station).

ÇBK1; St: 1

<i>Date</i>	<i>Month</i>	<i>pH</i>	<i>Eh</i>	<i>DO</i>	<i>EC</i>	<i>%Sat.</i>	<i>T°C</i>	<i>Sal.</i>	<i>Species</i>
23.11.02	N02	7.62	176.07	7.89	630	75.5	13.2	0.3	
04.05.03	M02	7.45	190.035	6.26	679	72.9	15.1	0.3	
18.10.03	Oc03	7.57	182.895	7.48	600	73.6	14.7	0.3	
15.11.03	N03	Na	214.86	6.13	652	59.2	12.9	0.3	Cn, lb
13.12.03	De03	7.7	177.9	6.6	Na	61.2	11	0.3	
17.01.04	Ja04	7.47	189.22	4.36	594	44.1	12.2	0.3	Cn
13.03.04	Ma04	7.3	196.83	6.98	536	66.5	12.8	0.2	Po
17.04.04	Ap04	7.12	205.82	8.13	638	80	14.2	0.3	Cn, lb
15.05.04	M04	7.03	211.685	6.32	293	60.8	14.1	0.1	
12.06.04	J04	6.7	230.935	4.97	628	50	15.1	0.3	
09.07.04	Jl04	6.8	208.425	4.32	591	46.4	16.5	0.3	lb
27.08.04	Ag04	7.03	205.915	3.81	679	41.9	19.9	0.3	
18.09.04	S04	6.76	219.52	2.33	647	24.9	18.2	0.3	Cn
17.10.04	O04	6.78	220.675	1.83	674	19.6	17.5	0.3	Cn
13.11.04	N04	6.76	232.09	1.74	381.6	17.1	14.4	0.2	Po
	Mean	7.1493	204.192	5.2767	587.329	52.91	14.787	0.273	
	Min	6.7	176.07	1.74	381.6	17.1	11	0.1	
	Max	7.62	232.09	8.13	679	80	19.9	0.3	

Table 2. The monthly measured variables and the species of the Station 2 (Çetin Bey spring second station). Abbreviations for the months are given in the Table 1.

ÇBK2; St: 2

<i>Month</i>	<i>pH</i>	<i>Eh</i>	<i>DO</i>	<i>EC</i>	<i>%Sat.</i>	<i>T°C</i>	<i>Sal.</i>	<i>Species</i>
N02	8.07	147.065	13.86	614	132.6	12.9	0.3	Po
M02	7.64	179.97	7	680	60.8	17.2	0.3	Pz,Cn,lb,Po,Hc
Oc03	8.18	145.82	4.78	381.7	51.2	16.2	0.2	Co,Pz,Cn,lb,Hc,Hi
N03	Na	214.865	9.22	462.9	87.3	12.9	0.2	Pz,Cn,lb,Po,Hc,Hi
De03	7.99	163	6.49	622	56.6	9	0.3	Pz,lb,Hc
Ja04	8.22	148.895	9.86	558	89.1	10.7	0.3	Pz,Cn,lb,Hc
Ma04	7.62	181.65	9.23	600	85.7	12	0.3	
Ap04	7.46	188.16	10.68	640	104.7	14.6	0.3	
M04	7.29	198.615	8.71	631	83.9	13.9	0.3	
J04	7.15	203.535	6.37	589	65.9	17.1	0.3	
Jl04	7.06	204.47	5.57	628	61.2	19.2	0.3	
Ag04	7.22	196.96	4.05	702	45.3	20.6	0.3	
S04	7.02	209.045	2.33	680	26.7	21.7	0.3	
Oc4	7.43	186.775	2.18	671	23.8	19.5	0.3	lb,Hc
N04	7.37	201.9	2.11	598	21.4	16	0.3	Pz,lb,Hc
Mean	7.55	184.7	6.829	603.84	66.413	15.567	0.287	
Min	7.02	145.82	2.11	381.7	21.4	9	0.2	
Max	8.22	214.865	13.86	702	132.6	21.7	0.3	

Table 3. The monthly measured variables and the species of the Station 3 (Çaygökpınar spring first station).

ÇGP1; St: 3

<i>Month</i>	<i>pH</i>	<i>Eh</i>	<i>DO</i>	<i>EC</i>	<i>%Sat.</i>	<i>T°C</i>	<i>Sal.</i>	<i>Species</i>
N02	7.26	191.065	9.76	671	101.3	16.9	0.3	Pz,Po
M03	7.14	205.875	5.38	717	56.5	17.5	0.4	
Oc03	7.14	204.61	6.03	556	63.4	17.6	0.3	Co
N03	Na	212.72	6.38	343.8	64.7	16.2	0.2	Co
De03	7.23	200.445	5.81	690	59.6	15.7	0.3	Co
Ja04	7.03	208.815	6.39	625	64.2	15.9	0.3	
Ma04	7.25	202.68	6.66	633	67.1	15.8	0.3	
Ap04	7.04	209.87	6.01	685	61.8	17.2	0.4	Co,Sp
M04	6.83	226.81	6.01	692	62.8	17.6	0.4	Sp,Hi
J04	6.91	216.25	4.38	600	46.1	18	0.3	Hi
JI04	6.81	222.305	4.06	624	4.6	15.3	0.3	Co
Ag04	6.9	217.55	4.38	627	44.8	16	0.3	Co,Cn,Ds
S04	7	213.995	2.89	508	19.8	14.7	0.3	
Oc04	6.79	220.66	2.29	584	20.2	14.6	0.3	
N04	6.72	231.035	1.95	682	20.2	17.3	0.3	
Mean	7.003	212.312	5.2253	611.914	50.473	16.42	0.313	
Min	6.72	191.065	1.95	343.8	4.6	14.6	0.2	
Max	7.26	231.035	9.76	717	101.3	18	0.4	

Table 4. The monthly measured variables and the species of the Station 4 (Çaygökpınar spring second station).

ÇGP2; St: 4

<i>Month</i>	<i>pH</i>	<i>Eh</i>	<i>DO</i>	<i>EC</i>	<i>%Sat.</i>	<i>T°C</i>	<i>Sal.</i>	<i>Species</i>
N02	7.86	159.3	13.46	658	137.7	17	0.3	Co,Pz,Ib,Po
M03	7.79	182.99	5.53	688	67.5	24.4	0.3	Co,Pz,Ib,Po
Oc03	7.88	161.955	7.8	364.3	83.1	18.3	0.2	Co,Pz,Ib,Cn
N03	Na	216.295	9.5	656	87.4	10.7	0.3	Co,Pz,Cn,Po,Ds
D03	7.67	179.25	7.6	614	69.2	12	0.3	Co,Pz,Ib,Ds,El
Ja04	7.86	168.055	7.94	272.9	74.2	12.3	0.1	Co,Pz,Cn,Ib,Ds
Ma04	8.27	146.6	7.2	510	65.5	11	0.2	Cn,Po
Ap04	7.48	184.495	12.17	695	129.8	18.7	0.4	Pz
M04	7.36	193.1	6.14	697	63.2	17	0.4	Pz,Ib,Po
J04	7.08	206.375	5.47	708	60.2	19.5	0.3	Pz,Ib
JI04	7.15	203.62	5.75	638	59.2	16.2	0.3	Co,Pz,Cn,Hi
Ag04	7.38	190.875	4.31	581	45.4	17.5	0.3	Co,Ib,Po,Ds
S04	7	211.22	3.64	598	38.7	18.2	0.3	Co,Pz,Ib,Po,Ds,El
Oc04	7.37	190.86	2.46	565	26.7	18.6	0.3	Co,Pz,Ib,Ds
N04	7.31	194.485	2.55	666	26.8	18.1	0.3	Ds
Mean	7.532	185.96	6.768	594.08	68.973	16.633	0.287	
Min	7	146.6	2.46	272.9	26.7	10.7	0.1	
Max	8.27	216.295	13.46	708	137.7	24.4	0.4	

After laboratory and field study, data collected from four stations were evaluated. Table 5 shows the monthly values for some of the environmental variables. The average values of the variables calculated as Dissolved Oxygen (DO) 6.02 mg/L, Saturation (%) 59.69, Eh (mV) 196.79, Electrical Conductivity (EC) 590.48, pH 7.31 Temperature of water (T°C) 15.85°C, salinity 0.29 ppt and Biological Oxygen Demand (BOD) 2.60 mg/L and the air temperature 18.7°C.

Table 5: The monthly measured mean variables of four stations.

<i>Month</i>	<i>pH</i>	<i>Eh</i>	<i>DO</i>	<i>EC</i>	<i>%Sat.</i>	<i>T°C(w)</i>	<i>Sal.</i>	<i>BOD</i>	<i>T°C(a)</i>
N02	7.7025	168.375	11.2425	643.25	111.775	15	0.3	Na	12
M03	7.505	189.7175	6.0425	691	64.425	18.55	0.325	Na	30.3
Oc03	7.6925	173.82	6.5225	475.5	67.825	16.7	0.25	4.61	18
N03	Na	214.6863	7.8075	528.68	74.65	13.175	0.25	4.45	11.8
D03	7.6475	180.1488	6.625	481.5	61.65	11.925	0.3	3.57	6.2
Ja04	7.645	178.7463	7.1375	512.48	67.9	12.775	0.25	3.1	7.1
Ma04	7.61	181.94	7.5175	569.75	71.2	12.9	0.25	3.9	5
Ap04	7.275	197.0863	9.2475	664.5	94.075	16.175	0.35	5.52	17.4
M04	7.1275	207.5525	6.795	578.25	67.675	15.65	0.3	1.85	10.7
J04	6.96	214.2738	5.2975	631.25	55.55	17.425	0.3	1.96	27.2
Jl04	6.955	209.705	4.925	620.25	42.85	16.8	0.3	1.42	29.2
Ag04	7.1325	202.825	4.1375	647.25	44.35	18.5	0.3	1.8	34.1
S04	6.945	213.445	2.7975	608.25	27.525	18.2	0.3	0.63	24.3
Oc04	7.0925	204.7425	2.19	623.5	22.575	17.55	0.3	0.88	25.2
N04	7.04	214.8775	2.0875	581.9	21.375	16.45	0.275	0.16	22.3
Mean	7.3	196.79	6.02	590.48	59.69	15.85	0.29	2.603	18.7
Min	6.945	168.375	2.0875	475.5	21.375	11.925	0.25	0.16	5
Max	7.7025	214.8775	11.2425	664.5	111.775	18.55	0.3	5.52	34.1

Water temperature reached the highest value (30.3°C) in May 2003, minimum in December 2003. Where dissolved oxygen level was maximum in November 2002 and minimum in November 2004, BOD was calculated maximum in April 2004 and minimum in November 2004 (Figure 2). It was obviously seen that there was a positive relationship between DO and BOD. Conductivity reached the highest value in April 2004 and minimum in October 2003. Saturation for the stations were calculated the highest in November 2002 and the lowest was in November 2004 (Figure 3). Maximum value for pH was measured in November 2002 and minimum

pH value was in September 2004 (Figure 5). Moreover, Eh maximum level was found in November 2004 since the minimum value was found in November 2002 (Figure 4). As shown, there was a negative correlation (November 2002, pH: 7.7025, and Eh: 168.375) between Eh and pH.

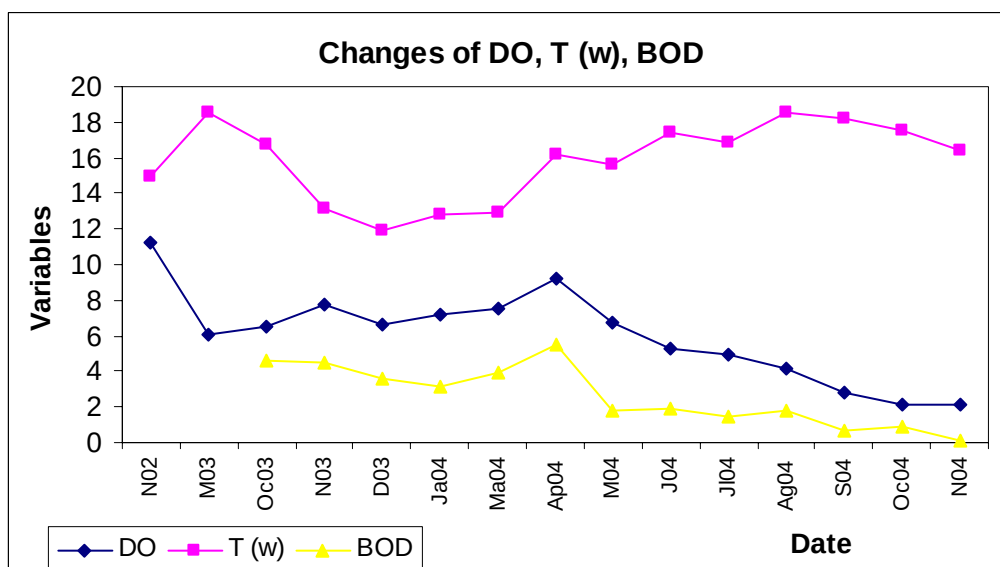


Figure 2. Changes in Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and Temperature of water T (w).

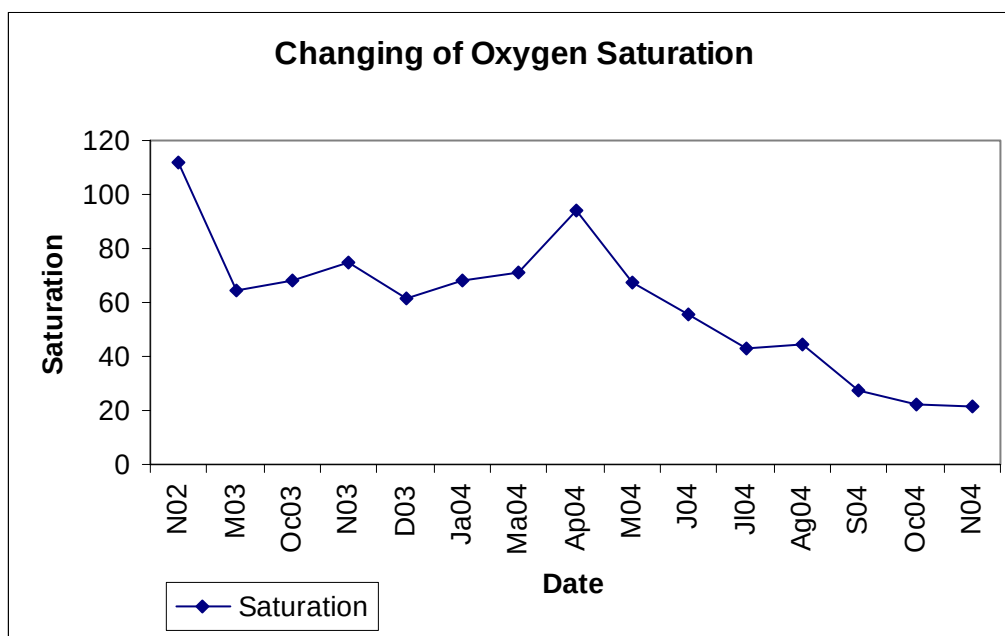


Figure 3. Seasonal changing of oxygen saturation.

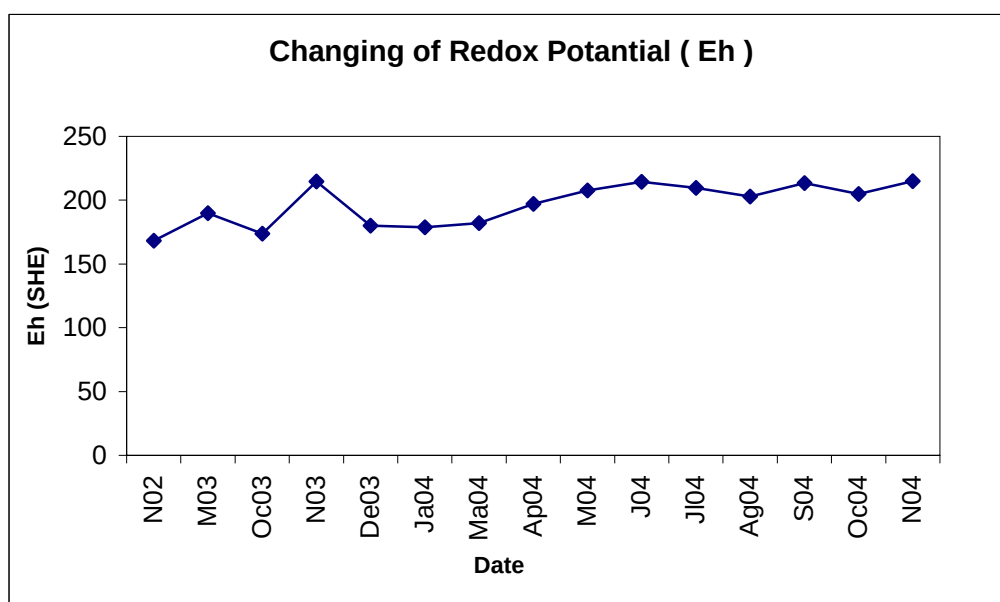


Figure 4. Seasonal changing of Redox potential (Eh).

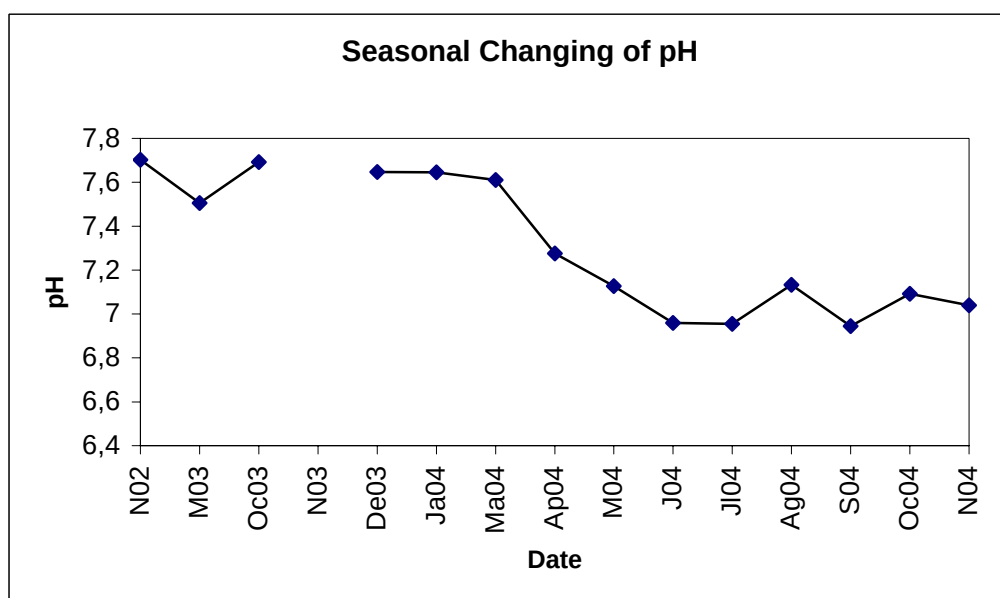


Figure 5. Seasonal changing of pH in stations. Measurement of pH was not able to taken because of inefficiency of HI-98150 pH/ORP meter in November (N03).

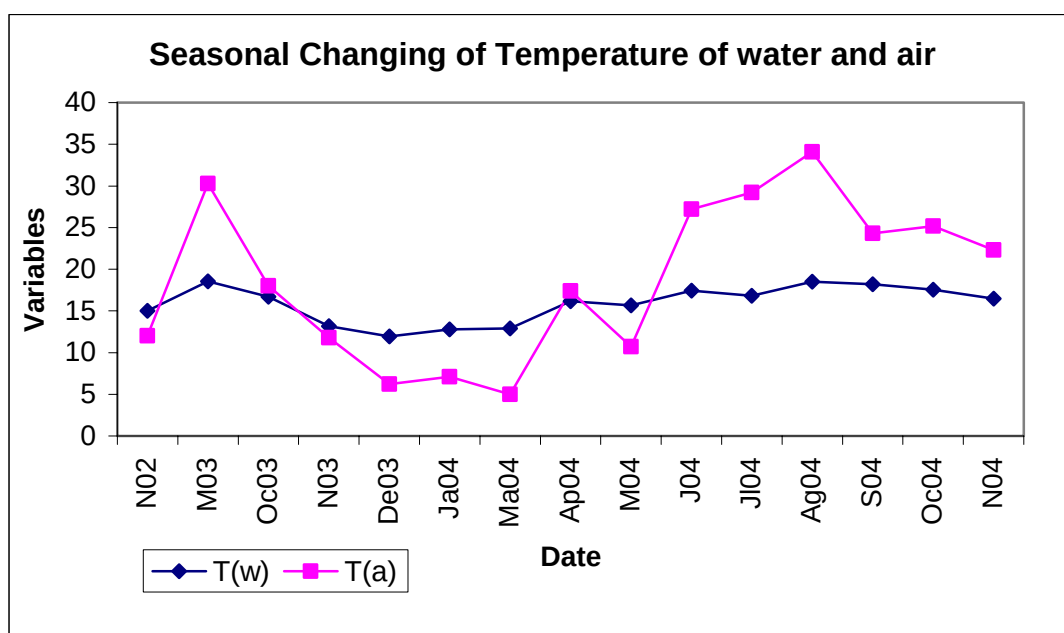


Figure 6. Seasonal changing of temperature of water $T(w)$ and temperature of air $T(a)$ from the mean values of all stations.

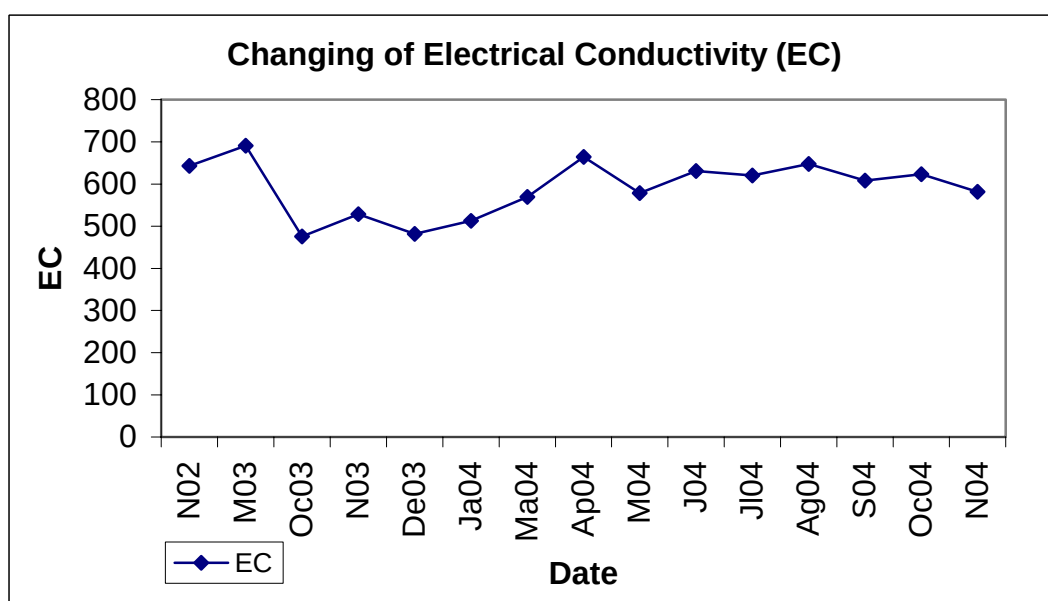


Figure 7. Changing of Electrical Conductivity (EC) for fifteen months period from four stations.

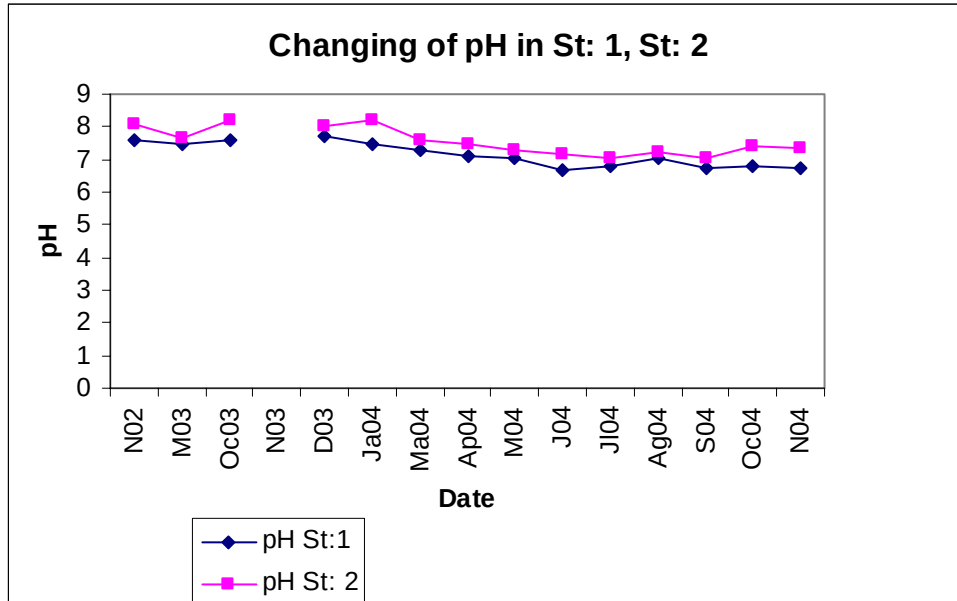


Figure 8. Changing of pH in St: 1 (Çetin Bey spring first station), St: 2 (Çetin Bey spring second station).

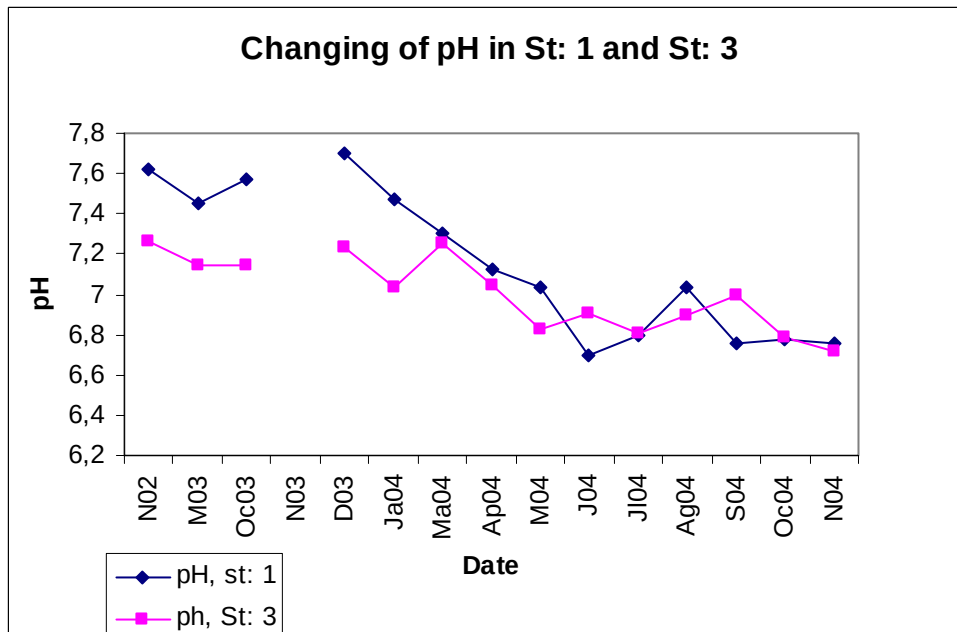


Figure 9. Changing of pH in St: 1 (Çetin Bey spring first station), St: 3 (Çaygökpınar spring first station).

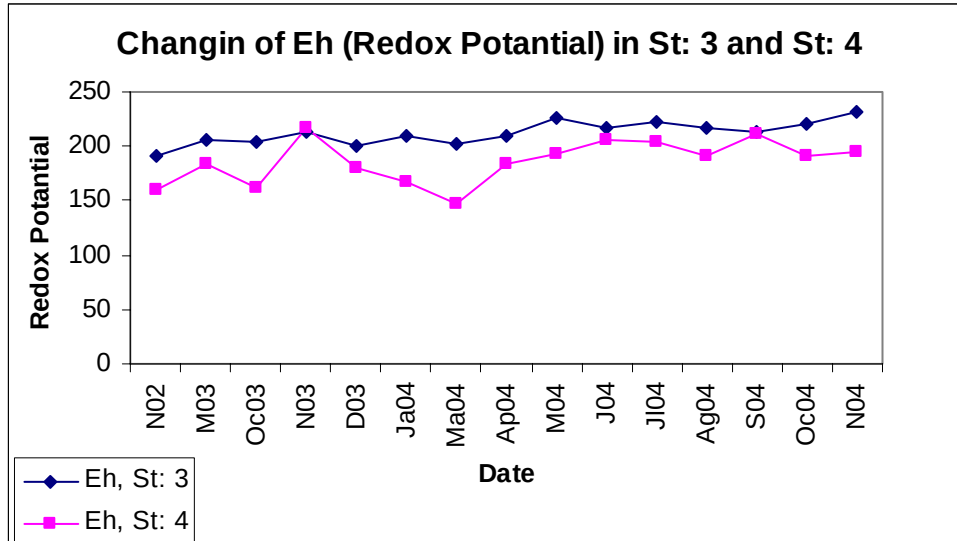


Figure 10. Changing of Eh (Redox Potantial) in St: 3 (Çaygökpınar spring first station), St: 4 (Çaygökpınar spring second station).

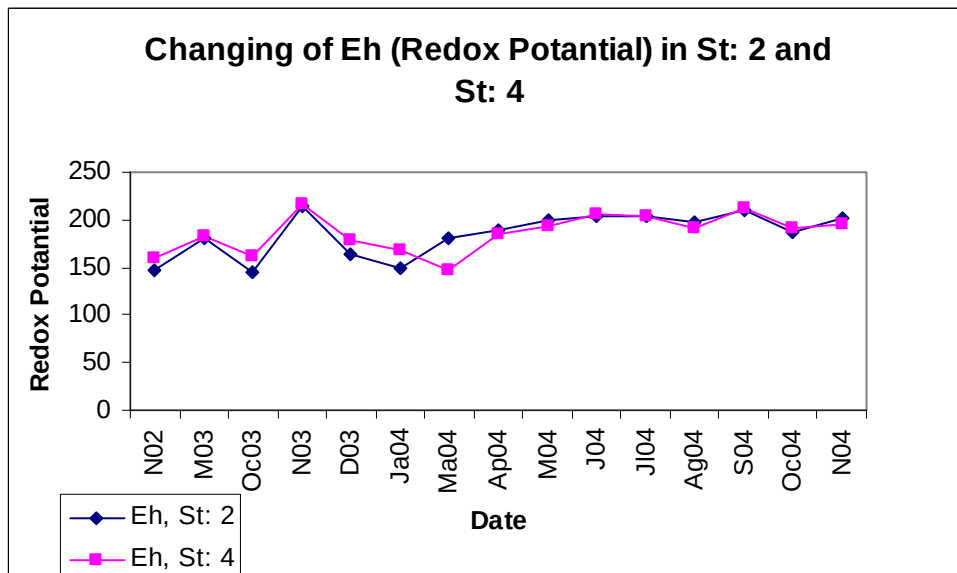


Figure 11. Changing of Eh (Redox Potantial) in St: 2 (Çetin Bey spring second station), St: 4 (Çaygökpınar spring second station).

Unweighted Pair Group Mean Averages (UPGMA) was used to indicate relationships among species (Figure 8). Accordingly, this analysis showed four main clustering groups of species. First group (G. I) includes only one species *P. zenkeri* , when the second clustering group (G. II) consists of five (*H. incongruens*, *E. lilljeborgi*, *S. pseudobrowniana*, *D. stevensoni* and *H. chevreuxi*) species, and third group (G. III) had two species as *P. olivaceus* and *C. neglecta*. Also, fourth clustering group included two species *I. bradyi* and *C. ophthalmica* (G. IV). The species of the first group *P. zenkeri* was found abundantly from all stations, except St:1 in Çetin Bey spring. The species of second group were not found in that high frequency. The species of group three were collected from both stations.

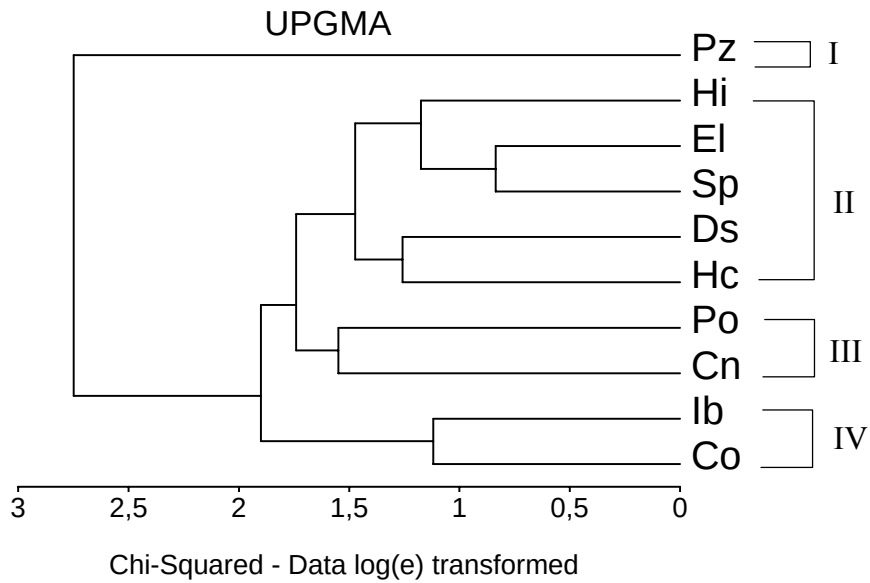


Figure 12. Unweighted Pair Group Mean Averages (UPGMA) shows the clustering relationships of ten ostracods collected from four stations of two springs. Abbreviations for species includes: Pz; *P. zenkeri*, Hi; *H. incongruens*, El; *E. lilljeborgi*, Sp; *S. pseudobrowniana*, Ds; *D. stevensoni*, Hc; *H. chevreuxi*, Po; *P. olivaceus*, Cn; *C. neglecta*, Ib; *I. bradyi*, Co; *C. ophthalmica*.

Table 6. Spearman Correlation shows relationship among environmental variables with species. In this table "*" shows the significant relationship at 0.05 level and "***" shows significant relationship at 0.01 level. '.' is referred to negative relationship. Also "N" is referred to sampling size.

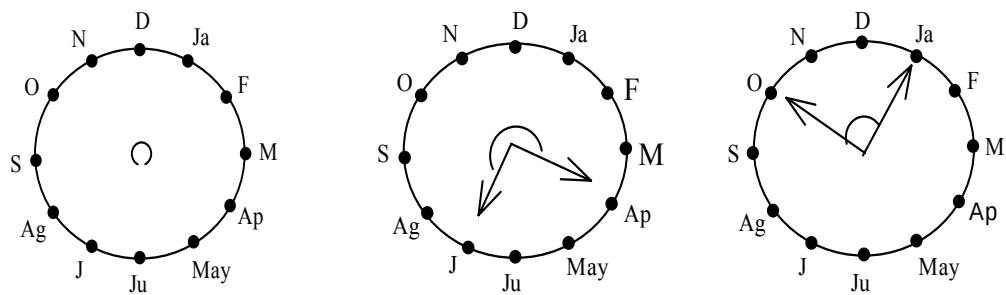
Correlations																
	PH	EH	DO	EC	SAT	TEMP	SAL	CO	PZ	CN	IB	PO	HC	DS	SP	HI
Spearman's rho	1,000	-.952**	.710**	-.253	.754**	-.552*	-.242	.365	.467	.027	.439	.155	.178	-.180	-.043	-.149
Correlation Coefficient	.	.000	.004	.383	.002	.041	.404	.174	.092	.927	.116	.598	.543	.537	.883	.612
Sig. (2-tailed)	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
N		1,000	-.514*	.132	-.554*	.329	.039	-.469	-.256	-.084	-.208	-.017	-.017	.254	.036	.232
Correlation Coefficient		.	.050	.639	.032	.232	.890	.078	.357	.767	.458	.952	.951	.360	.898	.405
Sig. (2-tailed)		15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
N			1,000	-.121	.979**	-.671**	-.094	.022	.399	.115	.115	.251	-.279	-.239	.374	.043
Correlation Coefficient			.	.666	.000	.006	.739	.939	.141	.684	.684	.367	.313	.391	.169	.680
Sig. (2-tailed)			15	15	15	15	15	15	15	15	15	15	15	15	15	15
N				1,000	-.082	.643**	.791**	-.029	-.177	-.262	-.179	.251	-.285	-.289	.205	-.315
Correlation Coefficient			.	.	.771	.010	.000	.919	.528	.345	.524	.367	.303	.296	.463	.253
Sig. (2-tailed)			15	15	15	15	15	15	15	15	15	15	15	15	15	15
N					1,000	-.568*	-.131	.031	.422	.193	.153	.289	-.239	-.248	.332	.066
Correlation Coefficient			.	.	.	.027	.641	.914	.117	.490	.586	.296	.391	.372	.227	.815
Sig. (2-tailed)						15	15	15	15	15	15	15	15	15	15	15
N							1,000	.042	-.168	.005	-.047	.036	-.035	-.083	-.133	.034
Correlation Coefficient						.	.067	.883	.549	.985	.867	.898	.902	.767	.637	.904
Sig. (2-tailed)						15	15	15	15	15	15	15	15	15	15	15
N								1,000	.143	-.069	-.443	-.036	-.319	-.356	.440	-.244
Correlation Coefficient							.	.610	.808	.098	.676	.897	.246	.192	.101	.381
Sig. (2-tailed)							15	15	15	15	15	15	15	15	15	15
N									1,000	.152	.715**	.206	.251	-.028	-.169	.301
Correlation Coefficient								.	.	.588	.003	.462	.367	.921	.546	.276
Sig. (2-tailed)									15	15	15	15	15	15	15	15
N										1,000	.230	.103	.196	.447	-.289	-.062
Correlation Coefficient								.	.051	.263	.003	.997	.068	.160	.161	.143
Sig. (2-tailed)								15	15	15	15	15	15	15	15	15
N									1,000	.152	.715**	.206	.251	-.028	-.169	.301
Correlation Coefficient									.	.588	.003	.462	.367	.921	.546	.276
Sig. (2-tailed)										15	15	15	15	15	15	15
N											1,000	.230	.103	.196	.447	-.289
Correlation Coefficient								.	.051	.263	.003	.997	.068	.160	.161	.143
Sig. (2-tailed)								15	15	15	15	15	15	15	15	15
N									1,000	.152	.715**	.206	.251	-.028	-.169	.301
Correlation Coefficient									.	.588	.003	.462	.367	.921	.546	.276
Sig. (2-tailed)										15	15	15	15	15	15	15
N											1,000	.230	.103	.196	.447	-.289
Correlation Coefficient								.	.051	.263	.003	.997	.068	.160	.161	.143
Sig. (2-tailed)								15	15	15	15	15	15	15	15	15
N									1,000	.152	.715**	.206	.251	-.028	-.169	.301
Correlation Coefficient									.	.588	.003	.462	.367	.921	.546	.276
Sig. (2-tailed)										15	15	15	15	15	15	15
N											1,000	.230	.103	.196	.447	-.289
Correlation Coefficient								.	.051	.263	.003	.997	.068	.160	.161	.143
Sig. (2-tailed)								15	15	15	15	15	15	15	15	15
N									1,000	.152	.715**	.206	.251	-.028	-.169	.301
Correlation Coefficient									.	.588	.003	.462	.367	.921	.546	.276
Sig. (2-tailed)										15	15	15	15	15	15	15
N											1,000	.230	.103	.196	.447	-.289
Correlation Coefficient								.	.051	.263	.003	.997	.068	.160	.161	.143
Sig. (2-tailed)								15	15	15	15	15	15	15	15	15
N									1,000	.152	.715**	.206	.251	-.028	-.169	.301
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N									1,000	.152	.715**	.206	.251	-.028	-.169	.301
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Sig. (2-tailed)								15	15	15	15	15	15	15	15	15
N									1,000	.152	.715**	.206	.251	-.028	-.169	.301
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Sig. (2-tailed)								15	15	15	15	15	15	15	15	15
N									1,000	.152	.715**	.206	.251	-.028	-.169	.301
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N											1,000	.230	.103	.196	.447	-.289
Correlation Coefficient								.	.051	.263	.003	.997	.068	.160	.161	.143
Sig. (2-tailed)								15	15	15	15	15	15	15	15	15
N									1,000	.152	.715**	.206	.251	-.028	-.169	.301
Correlation Coefficient									.	.588	.003	.462	.367	.921	.546	.276
Sig. (2-tailed)										15	15	15	15	15	15	15
N											1,000	.230	.103	.196	.447	-.289
Correlation Coefficient								.	.051	.263	.003	.997	.068	.160	.161	.143
Sig. (2-tailed)								15	15	15	15	15	15	15	15	15
N									1,000	.152	.715**	.206	.251	-.028	-.169	.301
Correlation Coefficient									.	.588	.003	.462	.367	.921	.546	.276
Sig. (2-tailed)										15	15	15	15	15	15	15
N											1,000	.230	.103	.196	.447	-.289
Correlation Coefficient								.	.051	.263	.003	.997	.068	.160	.161	.143
Sig. (2-tailed)								15	15	15	15	15	15	15	15	15
N									1,000	.152	.715**	.206	.251	-.028	-.169	.301
Correlation Coefficient									.	.588	.003	.462	.367	.921	.546	.276
Sig. (2-tailed)										15	15	15	15	15	15	15
N											1,000	.230	.103	.196	.447	-.289
Correlation Coefficient								.	.051	.263	.003	.997	.068	.160	.161	.143
Sig. (2-tailed)								15	15	15	15	15	15	15	15	15
N									1,000	.152	.715**	.206	.251	-.028	-.169	.301
Correlation Coefficient									.	.588	.003	.462	.367	.921	.546	.276
Sig. (2-tailed)										15	15	15	15	15	15	15
N											1,000	.230	.103	.196	.447	-.289
Correlation Coefficient								.	.051	.263	.003	.997	.068	.160	.161	.143
Sig. (2-tailed)								15	15	15	15	15	15	15	15	15
N									1,000	.152	.715**	.206	.251	-.028	-.169	.301
Correlation Coefficient									.	.588	.00					

** .Correlation is significant at the .01 level (2-tailed).

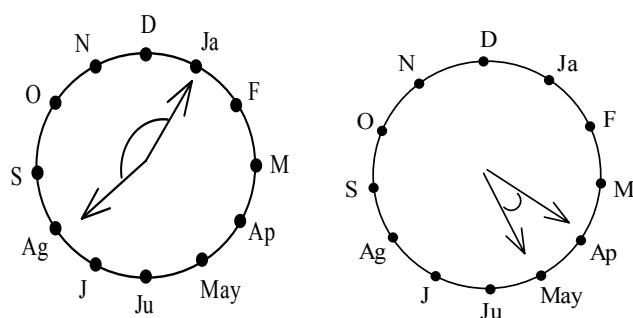
*.Correlation is significant at the .05 level (2-tailed).

Spearman Correlation Analysis was used to observe associations between ten species and seven environmental variables. The outcomes were tabulated in Table 6. Spearman Correlation displayed that there was a negative significant relationship between pH with Eh ($P < 0.01$). Besides, pH had a negative significant relationship to water temperature ($P < 0.05$), but its relationship was positively significant to dissolved oxygen and oxygen saturation ($P < 0.01$). As was expected, water temperature was related to dissolved oxygen and saturation. Increasing of water temperature decreases the dissolved oxygen level, causing an increase in the total dissolved solids (implicate with electrical conductivity) of water due to evaporation effect. Additionally, there was a positive relationship with electrical conductivity and salinity, and saturation with dissolved oxygen ($P < 0.01$). Dissolved oxygen of water and saturation negatively correlated with redox potential ($P < 0.05$).

Although Spearman Correlation clearly showed relationships among some of the environmental variables, it failed to explain the relationships between some environmental variables and species. On the other hand, this analysis was able to put out some important knowledge for interspecific relationships between species. For example, *I. bradyi* displayed a positive relationship with *P. zenkeri* and *C. ophthalmica* ($P < 0.01$), while *C. ophthalmica* and *I. bradyi* had a strong positive relationship. Such findings were also supported by UPGMA analysis. The relationship between these two species may depend on their wide distribution and cosmopolitan characteristics. *Ilyocypris bradyi* also had a positive relation with *H. chevreuxi* ($P < 0.05$). The associations among between *H. chevreuxi*, *P. zenkeri* with *I. bradyi* may also indicate their common ecological characteristics that both species are generally found from similar habitats.



a) *P. zenkeri* and *I. bradyi* b) *C. neglecta* and *C. ophthalmica* c) *H. chevreuxi*



d) *D. stevensoni* e) *S. pseudobrowniana*

Figure 13. Graphical representation of Ostracoda Watch Model (OWM) showed seasonal distribution of species during study period. Angles indicate the occurrence of species in certain months (stenochronal distribution), when full circle shows eurychronal distribution. a) *P. zenkeri* and *I. bradyi* b) *C. neglecta* and *C. ophthalmica* c) *H. chevreuxi* d) *D. stevensoni* e) *S. pseudobrowniana*. Abbreviations include the first letter of each month (e.g., D, December; Ja, January; etc.).

OWM was showed seven species with a unique seasonal distribution and life cycles. *Prionocypris zenkeri* and *I. bradyi* showed similarity in their life cycle since they were existed throughout the year (Figure 9a). *Candona neglecta* and *C. ophthalmica* were recorded from July to April. These two species can exist together in most of the time, except summer. *Herpetocypris chevreuxi* was found from

springs from October to January, in such a case it prefer autumn and winter. *Darwinula stvensoni* was collected from August to January while *S. pseudobrowniana* was encountered only from April to May.

Optima (*uk*), tolerance (*tk*) and ETI formulas were calculated and tabulated in Table 7. Accordingly species have different optimum limits to different environmental variables. ETI values range from zero to one, that some species adapted to environments very well when ETI ranges were calculated as 1. Such values of ETI may be the result of relatively few samples made during the present study. For instance, Curry (1999) calculated ETI ranges of species for 341 different environments pointing that ETI was affected from sampling sizes. In contrast, herein the present study, only four stations were studied for fifteen months (Table 7).

According to Table 7, pH optima values of species are generally ranged from neutral to little basic. However, Tables 1-4 showed that mean pH values of the stations were neutral. Among these species the lowest tolerance limits to pH were found for *P. olivaceus* and *S. pseudobrowniana* (Table 7). ETI ranges for pH showed differences. Generally speaking, it seems that both species were adapted well to the changes in pH of the environment, where ETI values were very high and/or even 1. Among these species only *S. pseudobrowniana* has a lower tolerance for pH with 0.44 of ETI value. Dissolved oxygen (DO) optima values changed from 3.71 to 8.76 mg/L that *H. chevreuxi* had the lowest optima for DO in contrast to Kulköylüoğlu and Vinyard (2000). These authors described that this species prefers high oxygenated waters, but its tolerance ranges can be much higher than previously estimated. The species *P. olivaceus* has higher optima for DO (8.76 mg/L), as reported earlier from Spain by Roca and Baltanás (1993), who found the species with similar values. Moreover, minimum ETI values for dissolved oxygen are 0.31

and 0.26 mg/L (Table 7). While *S. pseudobrowniana* has relatively higher optima for dissolved oxygen 8.76, it has a lower ETI range 0.26 and lower tolerance (*tk*) 0.98. Although *H. incongruens* have 6.17 optima (*uk*) value, it has a lower tolerance of dissolved oxygen 0.31 ETI value and also tolerance (*tk*) was calculated for the species (0.79) was the lowest value for both of them. Similarly, a cosmopolitan species, *H. incongruens* had lower ETI and tolerance (*tk*) values for saturation (Table 7). Unlike *H. incongruens*, *P. olivaceus* and *S. pseudobrowniana* have the highest optima values for saturation (% Sat.). The mean electrical conductivity for all the stations is 590.48 $\mu\text{S cm}^{-1}$ (Table 5). Two species, *P. olivaceus* and *S. pseudobrowniana* have the highest optima values for electrical conductivity as 624.49 $\mu\text{S cm}^{-1}$ for *P. olivaceus* and 647.25 $\mu\text{S cm}^{-1}$ for *S. pseudobrowniana*. Except *S. pseudobrowniana*, both species have ETI values for conductivity higher than 0.7, means that a high tolerance for conductivity of these species. However, it should be pointed that *S. pseudobrowniana* had the lowest tolerance calculated for conductivity. *Scottia pseudobrowniana* seemed to have a very low ETI and tolerance values for temperature, the rest of the species have broader tolerances to the temperature.

Among these species *P. zenkeri* and *I. bradyi* are the most tolerant ostracods with the highest ETI ranges for all of the environmental variables. All species except *S. pseudobrowniana* were considered as cosmopolitan with wide ranges of tolerances and higher ETI values. The species collected rarely like *S. pseudobrowniana* or *H. incongruens* could have deficient data for formulas because of their rarity in the samples. Therefore, such values may not be generalized at the moment.

Table 7. Descriptive statistics, Optima (uk), Tolerances (tk), ETI (Environmental Tolerance Index) for mean pH, Redox potential, (SHE), Dissolved oxygen (DO), Electrical conductivity (EC), Saturation (%Sat.) and Temperature of water (T°C (w)) for nine species.

<i>C. ophthalmica</i>	pH	Eh	DO	EC	%Sat.	T°C (w)
Average	7.359	193.93	6.243	590.55	61.78	15.94
St.deviati.	0.31	15.94	2.68	76.73	26.76	2.38
Maximum	7.7025	214.68	11.24	691	111.77	18.55
Minimum	6.945	168.37	2.19	475.5	22.57	11.92
Range	0.7575	46.311	9.052	215.5	89.2	6.62
ETI	1	0.9958	0.988	1	0.986	1
Optima	7.446	190.27	6.147	581.71	60.83	15.572
Tolerance	0.268	14.67	2.294	81.02	22.47	2.65
<i>P. zenkeri</i>	pH	Eh	DO	EC	%Sat.	T°C (w)
Average	7.298	197.47	6.055	587.71	59.98	15.586
St.deviati.	0.31	17.21	2.67	69.19	26.64	2.1
Maximum	7.702	214.87	11.24	691	111.775	18.55
Minimum	6.94	168.37	2.087	475.5	21.375	11.925
Range	0.75	46.50	9.155	215.5	90.4	6.625
ETI	1	1	1	1	1	1
Optima	7.494	190.40	7.085	576.63	70.55	15.35238
Tolerance	0.266	17.34	1.964	80.24	19.06	2.35915
<i>C. neglecta</i>	pH	Eh	DO	EC	%Sat.	T°C (w)
Average	7.316	196.67	5.832	594.11	57.73	16.13
St.deviati.	0.3	14.86	2.28	70.33	22.57	2.33
Maximum	7.692	214.6	9.247	691	94.07	18.55
Minimum	6.945	173.82	2.19	475.5	22.57	12.77
Range	0.747	40.86	7.057	215.5	71.5	5.77
ETI	0.986	0.878	0.770	1	0.790	0.8716
Optima	7.401	195.137	6.203	567.31	60.46	15.20
Tolerance	0.30	16.10	1.826	64.10	29.50	2.43
<i>D. stevensoni</i>	pH	Eh	DO	EC	%Sat.	T°C (w)
Average	7.250	201.35	4.68	569.07	45.71	14.97
St.deviati.	0.31	15.71	2.46	62.28	22.52	2.79
Maximum	7.647	214.87	7.807	647.25	74.65	17.55
Minimum	6.945	178.74	2.087	481.5	21.375	11.925
Range	0.702	36.13	5.72	165.75	53.275	5.625
ETI	0.927	0.77	0.624	0.769	0.589	0.849
Optima	7.270	201.70	5.38	564.17	52.25	15.08
Tolerance	0.306	15.17	2.262	53.309	20.94	2.6238

Table 7. (cont.)

<i>H. incongruens</i>	pH	Eh	DO	EC	%Sat.	T°C (w)
Average	7.183	204.00	6.26	566.78	61.71	15.95
St.deviasi.	0.34	17.14	1.16	65.05	12.59	1.67
Maximum	7.6925	214.68	7.807	631.25	74.65	17.425
Minimum	6.955	173.82	4.925	475.5	42.85	13.175
Range	0.7375	40.86	2.882	155.75	31.8	4.25
ETI	0.973	0.878	0.314	0.722	0.351	0.641
Optima	7.286	197.58	6.171	555.80	62.82	16.51
Tolerance	0.337	18.571	0.78	67.80	8	1.05
<i>I. bradyi</i>	pH	Eh	DO	EC	%Sat.	T°C (w)
Average	7.286154	197.8572	5.918214	591.9679	58.87143	15.79464
St.deviasi.	0.306	16.6	2.61	68.35	25.94	2.13
Maximum	7.7025	214.8775	11.2425	691	111.775	18.55
Minimum	6.945	168.375	2.0875	475.5	21.375	11.925
Range	0.7575	46.5025	9.155	215.5	90.4	6.625
ETI	1	1	1	1	1	1
Optima	7.521111	192.6943	6.628423	559.1273	65.32538	14.85
Tolerance	0.21766	15.85364	1.42307	80.067	13.1948	2.5857
<i>P. olivaceus</i>	pH	Eh	DO	EC	%Sat.	T°C (w)
Average	7.294643	199.1773	6.053438	606.0406	60.37188	15.58438
St.deviasi.	0.303	17.35	2.99	52.04	29.006	2.28
Maximum	7.7025	214.8775	11.2425	691	111.775	18.55
Minimum	6.945	168.375	2.0875	528.675	21.375	12.7
Range	0.7575	46.5025	9.155	162.325	90.4	5.85
ETI	1	1	1	0.753248	1	0.883019
Optima	7.58561	182.7761	8.764185	624.4951	87.10924	15.20924
Tolerance	0.1897	16.831	2.5582	49.9944	25.5915	1.947
<i>H. chevreuxi</i>	pH	Eh	DO	EC	%Sat.	T°C (w)
Average	6.26375	193.8198	5.4875	556.3643	54.34286	14.76786
St.deviasi.	0.29	17.45	2.35	79.71	22.46	2.62
Maximum	7.6925	214.8775	7.8075	691	74.65	18.55
Minimum	7.04	173.82	2.0875	475.5	21.375	11.925
Range	0.6525	41.0575	5.72	215.5	53.275	6.625
ETI	0.861386	0.88291	0.624795	1	0.589325	1
Optima	7.240125	199.8388	3.713095	596.8149	37.37857	16.11667
Tolerance	0.24376	12.4409	2.2076	57.8499	21.3397	2.2922
<i>S. pseudobrowniana</i>	pH	Eh	DO	EC	%Sat.	T°C (w)
Average	7.20125	202.3194	8.02125	621.375	80.875	15.912
St.deviasi.	0.104	7.4	1.73	60.98	12.59	1.67
Maximum	7.61	207.5525	9.2475	664.5	94.075	16.175
Minimum	7.275	197.0863	6.795	578.25	67.675	15.65
Range	0.335	10.46625	2.4525	86.25	26.4	0.525
ETI	0.44224	0.225069	0.267886	0.400232	0.29203	0.0792
Optima	7.2455	199.1795	8.757	647.25	88.795	16.07
Tolerance	0.131	4.18649	0.981	34.45	10.56	0.21

According to the Table 8, stations 1 and 2 in Çetin Bey spring have lower similarity than the Station 2 with Station 3 and 4 (Çaygökpınar spring's stations with Çetin Bey spring's second station). Such results are not meaningful for Station 1 or poorly related to the other stations.

Table 8. Similarities calculated with Jaccard's and Sorenson Indices among stations.

Jaccard's				Sorenson			
%	St 2.	St 3.	St 4.	%	St 2.	St 3.	St 4.
St 1.	42	25	33	St 1.	60	40	54,5
St 2.		55	66	St 2.		71	80
St 3.			66	St 3.			80

T-test within two samples assuming equal variances of analysis was applied to environmental variables among stations. Interestingly St: 1 and St: 2 (Çetin Bey spring's two stations) and St: 3 and St: 4 (Çaygökpınar spring's two stations) are significantly different for pH and Eh (redox potential) at 0.05 level ($P < 0.05$). While it means that there is a difference between the pH and Eh values of these stations, the rest of variables (dissolved oxygen, electrical conductivity, temperature, saturation and salinity) are not significant ($P > 0.005$). T-test was applied among St: 1 with St: 3 and St: 2 with St: 4 and there is no significant results for each environmental variables and for pH and Eh. In contrast, there was a significant difference for pH and Eh between St: 1 with St: 4 and St: 2 with St: 3 ($P < 0.05$).

Table 9. Some critical results of T-test (Two samples assuming equal variances). Abbreviations; Eh: Redox potential, St: 1: Çetin Bey spring first station, St: 2: Çetin Bey spring second station, St: 3: Çaygökpınar spring first station, St: 4: Çaygökpınar spring second station, “*”symbol indicates significant result ($P > 0.05$).

pH	P(T<=t) two-tail	t Critical two-tail	Eh	P(T<=t) two-tail	t Critical two-tail
St 1 & St 2	0,011*	2,055	St 1 & St 2	0,016*	2,048
St 1.& St 3	0,19	2,055	St 1 & St 3	0,145	2,048
St 1 & St 4	0,009*	2,055	St 1 & St 4	0,014*	2,048
St 2 & St 3	0,0001*	2,055	St 2 & St 3	0,0002*	2,048
St 2 & St 4	0,9	2,055	St 2 & St 4	0,876	2,048
St 3 & St 4	0,00004*	2,055	St 3 & St 4	0,0001*	2,048

4. DISCUSSION and CONCLUSION

Freshwaters are influenced by severe anthropogenic disturbances. Hence, communities of freshwaters and many endemic taxa face with such negative effects. Springs have special importance in these freshwaters since they can be considered ecotone between hypogean and epigean (Smith et al., 2003). However, spring water quality and faunal diversity can give knowledge about both surface and underground waters. Also, the concept of indicator species can easily be used in springs because of easy work on spring depending on their size. On the other hand, springs are highly complex systems with patches and flowing water channels (Roca and Baltanás 1993). However, springs face some treatments like agricultural, inhabitation, gravel extraction, winter road de-icing with NaCl, water abstraction (Särkkä et al., 1997). While applying indicator species concept on ostracods, it can help us quick

knowledge about the current environmental conditions, the first action should include to identify whether species are cosmopolitan or native (Klkylođlu 2004).

Tolerance (*tk*) and Optima (*uk*) values calculated for species are associated with ETI values. When ETI value of a species is higher also tolerance value of species higher, too (Table 7). Also Spearman Correlation supported the UPGMA dendrogram that some species clustered in UPGMA also related to Spearman Correlation (Table 6 and Figure 8), confirming the results. For example, *I. bradyi* in UPGMA dendrogram clustered in the same group with *C. ophthalmica* (Figure 8) that these two species were found related each other in Spearman Correlation analyses (Table 6). The relationship between these species could be explained by the Optima (*uk*) and Tolerance (*tk*) values. Hence optimum and tolerance levels of two species are relatively close each other, but one should also consider that the dissolved oxygen (DO) optimum value for *I. bradyi* is 6.63 mg/L and the tolerance value 1.42 mg/L where *C. ophthalmica* had optimum value for dissolved oxygen 6.14 mg/L and tolerance of 2.29 mg/L (Table 7). However, the saturation ranges can differ a little that *I. bradyi* can tolerate (*tk*) 13.19 % and optimum (*uk*) 65.32 % of saturation whereas *C. ophthalmica* has a lower saturation level than *I. bradyi* 60.83 % and higher tolerance level 22.47 % of saturation. Klkylođlu and Vinyard (2000) found some ranges for *I. bradyi* that dissolved oxygen level varied from 4 to 6.3 mg/L and temperature from 14 to 25°C, supporting the results of the current work. Conductivity optimum (559.12 $\mu\text{S cm}^{-1}$) and tolerance (80.067 $\mu\text{S cm}^{-1}$) ranges of the species found in the present study show relatively higher than previously reported. For example, in North American springs (in Nevada), Klkylođlu and Vinyard (2000) reported *I. bradyi* from lower ranges of conductivities between 134

and 324 ($\mu\text{S cm}^{-1}$). Corresponding to salinity values, this pinpoints higher levels of tolerances to salinity ranges.

Moreover, the species (*I. bradyi*) had a greater tolerance to conductivity that Mezquita et al. (1999a) found species with minimum (1030) and maximum (2320 $\mu\text{S/cm}$) conductivities in Mediterranean river. Also species is sensitive to the pH changes that it has a low tolerance level (Table 7). The species in this study was recorded 0.1-0.4 ppt range for salinity. *I. bradyi* has a wide tolerance limits to environmental variables, although it is sensitive to pH., Meisch (2000) stated that this species exists throughout the year, as one of the critical results of the present study (Figure 9). *Cypria ophthalmica* is a well known cosmopolitan species which was clustered in Group IV with *I. bradyi*. These species appeared to show tolerances to the changes in environmental variables during this study. Meisch (2000) reported that species optimum temperature can lie between (2.2-8.4°C) and he also considered that species have wide tolerance to temperature. This species was collected (11.9-18.5°C) of temperature ranges in this study which was confirmed the authors suggestion. Species was found the range of 0.1 to 0.4 ppt of salinity also have a wide range for salinity. Dissolved oxygen range of species changes (2.46 to 13.46 mg/L) (Table 4). Saturation related with dissolved oxygen species was found (26.7 to 137.7 %) of saturation. In this study, species was found abundantly in station 4, where the high contamination of lime dust was observed on the aquatic plants and of two stations dominated by watercress (see Photo 1 for details). Species was found from July to April from the springs according to the OWM (Figure 9).

UPGMA dendrogram clustered species as Group III which were *P. olivaceus* and *C. neglecta* (Figure 8). Moreover these two species were closely related (Külköylüoğlu and Yılmaz 2005, in review). According to ETI of *P. olivaceus*, this

species can adapt to the environmental conditions with high ETI values in this study (Table 7). While tolerances of species are the lowest for pH and electrical conductivity among the others, the species has relatively higher optimum value for pH and conductivity. Roca and Baltanás (1993) found this species with the range of temperature (6.5-16.4°C), dissolved oxygen (8.0-9.9 mg/L), pH (6.9-7.4), and conductivity (108-636 $\mu\text{S cm}^{-1}$) ranges in a spring. Similarly, Külköylüoğlu and Yılmaz (2005, in review) reported the optimum and tolerance values for this species from the springs as optimum of pH (7.75), conductivity (111.10 $\mu\text{S cm}^{-1}$), dissolved oxygen (8.84 mg/L), and temperature of water (10.9°C). Hence, the data was confirmed in this study (Table 7). The species is called as oligothermophilic (Meisch 2000; Roca and Baltanás 1993). Also, in this study species did not show a clear seasonality that it looks like it can exist throughout the year. The other species in Group III in the UPGMA dendrogram was *C. neglecta*, which was shown with same relationships in the analyses of Külköylüoğlu and Yılmaz (2005, in review). Both *C. neglecta* and *P. olivaceus* can be related because their habitat preferences are similar, two of them are non-swimming species, as well. It was calculated (Table 7) the optimum and tolerance ranges for these two species that were related, in spite of *C. neglecta* has wider tolerances (*tk*) and lower optimum values for dissolved oxygen and saturation. It was calculated that higher dissolved oxygen level and narrow tolerance range for dissolved oxygen is important for *P. olivaceus* than *C. neglecta*, which can be called as cold-stenotherm and oligothermophilic (Roca and Baltanás 1993). Besides, in the present study it has optimum value for temperature (15.20°C), which represents oligothermophilic characteristic, like *P. olivaceus*. The species has relatively high pH tolerance among the other species. Besides, in the present study, *C. neglecta* was found from pH ranges as 6.9 to 7.69, Roca and Baltanás (1993)

reported the species between 6.8 to 9.4 pH ranges. Moreover, Klkylođlu (2005c) was found species from pH (6.73) as well. Overall, these studies suggest that pH tolerance ranges of the species goes from 6.7 to 9.4, which is relatively larger than many other species. It is also considered that *C. neglecta* has higher dissolved oxygen tolerance ranges (Klkylođlu 2003c). Supportive approach comes from Meisch (2000), who underlined that the species could even survive under hypoxic conditions during summer with oxygen levels below (3 mg/L). In the current study, *C. neglecta* was collected from all stations, where minimum (1.83) and maximum (9.86 mg/L) dissolved oxygen levels found (Table 1, 2). This therefore takes species lower tolerance range for oxygen below previously known range, supporting that it can tolerate hypoxic conditions. Although salinity values of all the four stations ranged from 0.1 to 0.4 ppt, the species was found in the range of 0.1 - 0.3 ppt during study period (except in May and June) (Figure 9b). Such result also suggests that the species can be found all year around as mentioned in a man-made lake (Klkylođlu and Dgel 2004).

UPGMA dendrogram was clustered the species in Group II, which included *E. lilljeborgi*, *S. pseudobrowniana*, *H. chevreuxi*, *D. stevensoni*, and *H. incongruens* (Figure 8). Accordingly, *D. stevensoni* and *S. pseudobrowniana* may be related each other based on their habitat preferences that two of them known as bottom dependent forms (Klkylođlu 2005b). Also these two species have a relationship with *H. chevreuxi*, both prefers lentic (still water) habitats. Besides, *S. pseudobrowniana* was known as semi-terrestrial species that three of them may live in the same habitats. Interestingly, in this study these three species were not collected together in the same month. Also *E. lilljeborgi* was only collected two times with three individuals in the same months with *D. stevensoni*. Moreover, *H. incongruens* was clustered in Group

II. (Figure 8). UPGMA might clustered these species in the same group because of the relatively rare numbers and limited occurrences among the stations as mentioned above. Also, ETI values of these species not very higher than the other groups (Table 7). While *H. incongruens* and *D. stevensoni* have lower ETI values for dissolved oxygen and saturation in this study, they have higher ETI values for the other environmental variables.

Another cosmopolitan species was *D. stevensoni* which was collected from only the Çaygökpınar spring. In this study tolerance levels of *D. stevensoni* seemed to be high. Since pH, redox potential (Eh), electrical conductivity (EC) and water temperature were calculated from both ETI and tolerance formulas that show same similarities with high values (Table 7). Moreover, Kulköylüoğlu (2004) this highly environmental tolerances confirmed. When Yılmaz and Kulköylüoğlu (2005) found relatively high dissolved oxygen and oxygen saturation tolerances of the species, the calculated ETI values for these variables were relatively lower in the study (Table 7). Again, it could be the result of few occurrences of species in this study (eight times in sixty samples). Salinity range differs from 0.1 to 0.3 ppt for the species. Ostracoda Watch Model displayed occurrence of individual species from August to January, similar to study of Yılmaz and Kulköylüoğlu (2005). In contrast, Kulköylüoğlu (1999) was collected the species from the springs of Nevada from February to November. It was considered that *D. stevensoni* can exist throughout the year (Kulköylüoğlu 2005c).

Heterocypris incongruens is known with wide tolerance limits and widespread distribution. The species is commonly inhabitant of polluted waters where Schornikov and Trebukhova (2001) deduced that the species could even tolerate heavily polluted water bodies. The species has higher tolerances (*tk*) and ETI values

for pH, redox potential and electrical conductivity among species (Table 7). Temperature tolerance (*tk*) and ETI value is relatively lower (*tk*: 1.0, ETI: 0.64), but it has the highest optima for temperature among species (*uk*: 16.51). Roca and Baltanás (1993) defined temperature range of species between (8.3 and 16.0°C), when Kulköylüoğlu (2005a) recorded the species between in waters with (6.0-29.0°C) temperature ranges. It appears that this species had a wide tolerance range for temperature, but it was also reported from waters with very low oxygen, saturation, tolerance and ETI ranges in this study. While the range of species for dissolved oxygen was very low (DO: 2.88 mg/L), Kulköylüoğlu (2005a) found species dissolved oxygen between 0.40 mg/L to 14.50 mg/L. Although it has wide ranges of tolerances as a cosmopolitan species, in this study species was not found frequently.

Herpetocypris chevreuxi was only collected from the Çetin Bey spring during this study. The species is appeared to have high ETI ranges for environmental conditions, but dissolved oxygen and saturation ETI values are relatively lower (Table 7). Besides, the optimum and tolerance values are low for dissolved oxygen and saturation. Moreover, *H. chevreuxi* was collected from Çetin Bey spring's second station (St: 2) in November when dissolved oxygen was 2.11 mg/L with 23 individuals (most abundant of all collected). Consequently, the range of species for dissolved oxygen is considered to be wider. In this study when species was collected, the maximum dissolved oxygen of water was 9.86 mg/L (Table 2). Temperature range of the species was given between 15-24°C (Kulköylüoğlu and Vinyard 2000). Also, Finn (2005) in Germany found positive correlation between the species and temperature. The temperature that the species was found was 20.7°C (Finn 2005). In present study, species was collected between 9-19.5°C (Table 2). Also, it was found from October to January only at Station 2, in which the water was stagnant and

surrounded with the watercress. There are two other species, *S. pseudobrowniana* and *E. lilljeborgi*, in the same group with *H. chevreuxi* (Group II). *Eucypris lilljeborgi* is not very common species, and taxonomic status of the species is still under investigation. Because species was only collected in two months with three individuals, it was not included in the statistical analyses. Dissolved oxygen was calculated as 3.64 and 7.6 mg/L in two months, respectively. Salinity of water was stable (0.3 ppt), temperature was 12-18.2°C which is appeared oligostenophilic characteristic. It has a relatively high range for dissolved oxygen. It was collected from September and December. It is appeared to be autumn form. *Scottia pseudobrowniana* is known as a crenobiont species. It was collected from only the first station of Çaygökpınar spring (St: 3), in two months with five living individuals. Moreover, a lot of left and right valves were collected from both Stations 1 and 3 Table 7 shows low ETI values of the species. Besides, tolerance values were very low, too. It appears that the species is very sensitive to all environmental values. Interestingly, species was found in two months, during which the salinity was the highest from all collected materials (0.04 ppt) (Table 3). Among species, *S. pseudobrowniana* has the highest optima for dissolved oxygen and saturation. Kulköylüoğlu (1999) showed the oxygen range of species changes between 3.0 to 8.5 mg/L and in this study species found maximum 9.24 mg/L. It appears it has a wide range for dissolved oxygen. Meisch (2000) emphasized that species could have a wide range of environmental variables depending to its thick valves, heavily developed clams, strong muscles and well developed respiratory plates which obtain the species living in semi-terrestrial habitats.

The first group clustered in the UPGMA dendrogram is represented by one species, *P. zenkeri*. ETI values of this species showed “super tolerance” levels but

this is possible because of the relatively few collected samples. Moreover, the tolerance levels of species are also high (Table 7) that *P. zenkeri* has a wide tolerance levels for all ecological conditions calculated and also most abundant species in stations except St: 1 (First station of Çetin Bey spring). The species was found with 157 individuals in the first station of Çetin Bey spring (St: 2), 159 in the fourth station and 59 individuals in (St: 4), and (St: 3) included totally 30 more individuals. This dominance of the species can be related to the high tolerance levels and also quick reproductive features that in different sizes and a lot of juvenils collected in June. Adults can occur throughout the year (Figure 9). Spearman Correlation found *P. zenkeri* strongly related to *I. bradyi* (Table 6). This positive relationship can be arised because both are non-swimming species. Besides, in this study these two species appears to adapted environments very well, with their high ETI ranges and high tolerance (*tk*) levels (Table 7).

Jaccard's, Sorenson Similarity Indices and t-test for equal variances was made to compare stations for all species and environmental variables. The data obtained from the t-test for equal variances among the two stations in two springs have significant differences for Eh (redox potential) and pH (Table 9). Interestingly, between the first stations of two springs and between the second stations of two springs, there was no difference from the data was obtained by the t-test. Eucrenal site of the spring is not relatively contaminated by different matters. Since, the pH value is not changes very significantly. Besides the hypocrenal areas (downstream) deals with to severe destruction of different matters. Therefore, the second stations of two springs and first stations of them can be related to their pH and Eh values supported by Spearman Correlation (Table 6). These two environmental variables can affect each other, either directly. According to the Jaccard's and Sorenson Indices, species similarities

of four station sites generally show values above % 50. Besides, St 1 does not have relatively high values of similarity with other stations, thus the other stations have high similarity values among each other (Table 8). Species compositions of Çaygökpınar spring show closed similarities between its two stations and also Çetin Bey spring's second station has a relatively high degree of similarity with the stations of Çaygökpınar spring. According to these results, we can think that ostracod species have high dispersal abilities which obtain their transport in these two springs. Hence, in general, rheocene type springs have similar environmental conditions. The poor occurrence of species in Çetin Bey spring's first station (three species only, St: 1) shows a possible effects of human disturbances. As already defined by Klkylođlu (2003a) human disturbances in Çetin Bey spring caused by city's Environmental Protection Foundation was covered the spring with concrete structure for public facilities. Although *S. pseudobrowniana* was not found from Çetin Bey spring, it was found in 2001 by Klkylođlu in the same spring (2003a). Moreover, in this study the disturbance levels can be seen from the loss of species when it compared with the study of Klkylođlu (2003a).

Consequently, it appears that ostracoda fauna was dominated by cosmopolitan species except *S. pseudobrowniana* and *E. lilljeborgi* which both found from the Çaygökpınar spring with a few individuals. Increasing disturbances and the number of cosmopolitan species may restrict these rare species habitats. This may cause species lost from the original habitats. Increasing anthropogenic disturbances have long been given damages to the springs. Treatments to protect these habitats may firstly begin with learning their floral and faunal richness, and conducting long term studies on them, as well. This, therefore, can allow us to apply the concept of

bioindicator species when the concept can be great help to deduce the past, current and future conditions of springs.

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Photo 1. Çaygökpınar spring from station 1 (upper stream source) through station 2 (downstream). Attention to the dust flowing on air caused by tracks carrying limestones and soil.



Photo 2. Second station of Çaygökpınar spring from different view.



Photo 3. First station of Çaygökpınar spring seen from downstream to upper source.



Photo 4. Midpoint of Çaygökpınar spring. Attention to the watercress covered all around.



Photo 5. Cattle affect the habitat structure of Çaygökpınar spring.



Photo 6. First station of Çetin Bey spring where cattle highly degraded the habitat structure. Attention to the car passing the road.



Photo 7. First station of Çetin Bey spring after the original spring source closed with concrete structure.



Photo 8. Second station of Çetin Bey spring reaching to Lake Gökçü. Attention to the pool covered by watercress.

