ECOLOGICAL CHANGES AND OSTRACODA (CRUSTACEA) FAUNA OF LAKE SÜNNET (BOLU, TURKEY)

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ECOLOGICAL CHANGES AND OSTRACODA (CRUSTACEA) FAUNA OF LAKE SÜNNET (BOLU, TURKEY)

by

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To My Father and My Mother

HASGÜL and SANİYE

ABSTRACT

ECOLOGICAL CHANGES AND OSTRACODA (CRUSTACEA) FAUNA OF LAKE SÜNNET (BOLU, TURKEY)

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Environmental quality, habitat features and ostracod populations of Lake Sünnet were monitored between May 2005 and September 2007. Biologic, physico-chemical and microbiological analyses were made synchronously both with sediment and water sampling which were collected as a monthly. Water sample were also collected vertically at each meter from surface to bottom and littoral layer of the lake, as well. According to Unweighted Pair Group Mean Analyses (UPGMA) there are three clustering groups. Spearman Correlation analyses indicated that there is a positive correlation between species number and electrical conductivity. Average values were 0.1394 mg/l N for nitrogen and 0.0095 mg/l P for phosphate during two years. According to ANOVA, there were no remarkable differences in the measured variables except turbidity between littoral stations.

At the end of the study, nine living Ostracoda species, which 6 are characterized as cosmopolitan were recorded (*Candona neglecta, Ilyocypris bradyi, Ilyocypris getica, Ilyocypris inermis, Limnocythere inopinata, Physocypria kraepelini, Stenocypria fischeri*, *Pseudocandona* cf. *eremita* and *Pseudocandona albicans*) in the Lake. During the study, species and individual number of Ostracoda was very low comparing to another lakes in Bolu. The ratio of pseudorichness (noncosmopolitan/cosmopolitan) is about 0.33. Accordingly, cosmopolitan species seem to be dominant. Lake water quality display a dynamic behaviour due to large changes in the water levels from 14 to 8 meters. Finding, therefore, suggest the idea that Lake Sünnet show shows mesothrophic characteristics. These physical changes are not only alter ecological charateristics of the lake but also biological diversity. Indeed, this is probable that cosmopolitans tolerate them more than other species.

Key Words: Ostracoda (Crustacea), Lake Sunnet, Lake Ecosystem, Species Richness, Seasonal Changes, Bolu.

ÖZET

SÜNNET GÖLÜ (BOLU, TURKEY) EKOLOJİK DEĞİŞİMLERİ VE OSTRAKOD (CRUSTACEA) FAUNASI

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Sünnet Gölü habitat özellikleri, çevre kalitesi ve dört kıyı istasyonunda ostracod populasyonu Mayıs 2005 ve Ekim 2007 arasında incelenmiştir. Biyolojik, fiziko-kimyasal ve mikrobiyolojik analizler aylık olarak toplanan sediment örneklemesi ile eş zamanlı olarak yapılmıştır. Göl yüzeyinden dikey olarak dip kısmına kadar her metreden su örneklemesi yapılmıştır. Ağırlıksız Basit Çift Grup Ortalama Analizi (Unweighted Pair Group Mean Analyses -UPGMA) sonucuna göre 9 tür 3 grup altında toplanmıştır. Spearman korelasyon analizi ise tür sayısı ile elektrik iletkenliği arasında bir ilişkinin varlığını göstermiştir. İki yıl boyunca nitrat ve fosfatın ortalama değeri 0.1394 mg/l N ve 0.0095 mg/l dir. Çalışma sonunda elde edilen çevresel değişkenler arasında turbidite hariç anlamlı bir farklılık bulunmadığı ANOVA kullanılarak tesbit edilmiştir.

Çalşıma sonu itibarıyla, altısı kozmopolitan özellik gösteren olmak üzere dokuz canlı ostrakot türü (*Candona neglecta, Ilyocypris bradyi, Ilyocypris getica, Ilyocypris inermis, Limnocythere inopinata, Physocypria kraepelini, Stenocypria fischeri*, *Pseudocandona* cf. *eremita* and *Pseudocandona albicans*) kaydedilmiştir. Çalışma süresince gölde bulunan ostrakoda sayısının gerek birey ve gerekse de tür bazında Bolu'da ki diğer göllere göre çok az olduğu gözlemlenmiştir. Türlerin sahte zenginlik oranı (kosmopolitan/kosmopolitan olmayan) 0.33 olarak bulunmuştur. Bunun sonucunda kosmopolitan türler yönünden bir baskınlık kaydedilmiştir. Gül'ün su kalitesi, su seviyesinde ki 14 metreden 8 metreye varan değişiklikden dolayı dinamik bir tavır sergilemektedir. Bulgular Sünnet gölünün mezotrofik bir karakter taşıdığını göstermektedir. Fiziksel değişiklikler yalnızca gölün ekolojik karakterini değiştirmez aynı zamanda biyolojik çeşitliliğinede etki eder. Gerçekten de kosmopolitan türlerin bu değişiklikleri diğer türlerden daha iyi tolere ettiği muhtemeldir.

Anahtar Kelimeler: Ostrakoda (Crustacea), Sünnet Gölü, Ekosistem, Tür zenginliği, Mevsimsel değişimler, Bolu.

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1. Introduction

The class Ostracoda, which takes place taxonomically in phylum Arthropoda and Subphylum bivalved Crustacea with calcerous material, are known from Cambrian strata to modern sediments are commonly benthic animals. The benthic, or epibenthic crustacean has a large living aquatic habitat such as hot spring, caves, fresh, brackish and marine waters in the world. Neale (1964) summarized hydrological, biological and sedimentological factors, which affect dispersion and ecology of Ostracoda. In the recent studies (Külköylüoğlu 2005a; Mezquita et. al., 2005) importance of some abiotic factors on physiology and development of Ostracoda such as pH, DO, temperature, food, photoperiod, hydroperiod and flow are known to be effective. Additionally, Kessling (1956), Proctor (1964) and Külköylüoğlu (1999) put forward that passive dispersion mechanisms of small aquatic organisms as in egg forms supported their widespread geographical distribution.

Species generally are crawling on or through the sediment, living among aquatic plants, and on the submerged plants. Within the class, fi1ter feeders, detritivores, herbivores, scavengers and predaceous carnivores are present. Additionally, Ostracods may be free-swimming for all or part of their life cycle, while some species have also parasitic or commensal feature on other crustaceans, echinoderms, sharks, and polychaete worms (Athersuch et al., 1989).

A characteristic of Ostracoda have been coupled within their a habitat preferences (Külköylüoğlu et al., 1993; Külköylüoğlu & Yılmaz 2006). Ostracoda also play important role in the food chain, more especially juvenile fish feed on them (Bronshtein 1947). Because of sensitivity of Ostracoda to changes in environmental variables (such as temperature, salinity, etc), they can be used as an indicator species for water quality (Külköylüoğlu 2004). Fossil forms due to heavily calcified valves, are scientifically meaningful to estimate past environmental conditions variety of in a particular area while living forms have been used in ecological investigation.

In paleoecological/paleoenvironmental studies, fossil ostracods have been used to determine ecological history of a region (Schudack 2006). Indeed, Külköylüoğlu and Dügel (2004) and also Külköylüoğlu (2003a) argued that past environmental conditions are interpreted if ecological requirements of living Ostracoda. The soft body covered by calcium carbonated bivalved carapace consist of two main parts the head (or cephalon) and the thorax. The outer stracod layers consist of tubercles, spines, nodes and pores that have a sensorial function (Martens 1998; Meisch 2000). There are three thoracic legs; second of them is uniramus and third works as a cleaning organ. Ostracoda have several appandages (soft parts): the antennulae, the antennae, the mandibles, the maxillulae, (A1, A2, Md, Mx1 and three pairs of thoracopods), limbs, furcae (apair of caudal structures), reproductive organs, cephalon, thorax and single naupli eye (Martens, 2003; Matzke-Karasz et al., 2005). The head has five pairs of very hairy legs and usually at least one eye, while back of the body is ended in furca (a multi-pronged tail). Compound eyes are generall absent. In podocopids specificly eye systems have two lateral ocelli and a single ventral ocellus (Tanaka 2006).

Ostracods have typical crustacean head appendages: antennules, two pairs of antennae, a pair of mandibulae, a pair of maxillulae are derived from the cephalon (Delorme 1991). Mandibula of freshwater ostracoda consist of coxa with a toothed endite, and a palp which bases endopodia, while maxillulae are formed with three protopodite endites and an three segmented endopodite (palp) (Horne et al., 2005).

These appendages that are attached to the inner surface of the valves (hard parts) that consist of iner and outer lamella are controlled to feed, move and reproduce by adductor muscles attached to the inside of each valve which form muscle scars on surface of valvaes. There are three groups of muscle scars that are called antennal scars single, double, or triple muscle attachment scars (Smith 1968). The caharacteristics of appandages such as capulatory organs and muscle scars patterns are meaningful to define higher taxonomic level of an ostracoda species (Tsukagoshi 1988). These muscle scars that are hints at identification of the species; arranged in a row in Limnocytheridae, rosed-liked shaped in Darwinulidae, simply grouped in Cypridoidea. These appendages of Ostracoda diversified as a shape and function according to ecologically different habitats. The antennulae has sensory and locomotory (such as swimming, crawling, and diging) functions are in all ostracods uniramous, consisting of between five and eight segments with long setae used for swimming (Meisch 2000). In Cypridoidea, the first uniramous antennulae is mostly characterized by five to seven segments, with long setae and chemosensorial organs. In the nonswimmer Ostracoda like as the darwinulids and the limnocytherids there is no plumose seta of the antenulae, which takes place in the good swimmer as in *Cypridopsis vidua* (Delorme 1991). The biramous antennae (second antennae) are primarily adapted for locomotion (walking, climbing, diging, and swimming) with reduced exopodite, and a well-developed endopodite and long claws. The second antenna composed of a gland. This gland specializes for fixation function to substrate with a sticky fluid. The mandibles consist of a masticatory process with strong teeth used for gathering, handling and chewing food particles and a jointed setose palp with usually carries a well-developed vibratory plate. The maxillules have two functions; feeding and respiration by generate water circulation and also consists of a palp and three endites functionally like the mandibles. The sexually dimorphic maxilla has a hook for copulation in males.

Adult Ostracod species have eight appandages and pairs of limbs; antennules, antennae, mandibles, maxillulae, fifth limbs, sixth limbs, seventh limbs, a pair of copulatory organs and caudal stractura (Meisch 2007). Caudal structura has been called caudal rami (Martens 2003) or uropods (Meisch 2000). In the freshwater Ostracoda, uropodal plates specialized into rod shaped rami which functions locomotion (Meisch 2000).

The fifth, sixth and seventh of them are used in walking. In Darwinuloidea fifth limb, a maxilliped, consist of three segmented endopodite and exopodite branchial plate (Horne et al., 2005). In Podocopida, the furca might process as craling digging by a pair of unsegmented, rod shaped rami consists of claws and setae(Meisch 2000). In Cytheroidea podocopa, the fifth limb using for feding, copulation, or walking derived from cephalic or thoracic origin is leg-like appandage like as in general form to the sixth and seventh limbs (Horne et al., 2005). Cohen and Morin (1990) repored that limbs acitivity such as highly modifed clasping for females in many males has been observed in a few podocopids which are Platycopida, Sigilloidea, and Cypridoidea.

The seventh limb (or third thracopod) is modified into a cIeaning limb in Cyprididae (Martens 1998). Cleaning limbs' setal compasition has great taxonomic importance at the generic level of Candoninae (Meisch 2000).

All freshwater Ostracoda which belongs the Podocopida, does not have a heart or other respiratory organs. The following of, oxygeneted water inside the carapace is provided by vibratory plates of maxillulae (Meisch 2000). However, water-flow within the carapace is generated for respiration and brood chamber ventilation by branchial plates which take place on the mandibulae of Podocopid Ostracoda (Horne et al., 2005). Predicting number of Podocopida species was about 5000 while the total number of live freshwater ostracods in lotic system is unknown (Dole-Olivier et al., 2000). However, this number is known to be more than 15.000 in general (e.g., Kempf 1997).

1.1. Reproduction and Development

Ostracods generally have two developments phase; juvenile and gradual development period. The bivalved Crustaceans secrete calcerous shell, carapace, comprised of the mineral calcite ($CaCO_3$), chitin. They undergo to several changes from juvenile form to mature form during its life cycle that grow by moulting their exoskeleton, eight to nine instars in most cases (Mezquita et al., 2000). In a few hours or copule of days they can secreate easily a new one (Zarikian et al., 2000). Kesling (1952) brong up physical characteristic of Ostracoda carapace has changing ability at every instar stage such as increasing of volume and size untills reach to mature form. Liebau (2005) summarized development of Ostracoda: calcified duplicatures, adductor muscle scar patterns fixation, replacement of valve stoppers, complications of the hinge systems, the formation of conspicuous sculptures and, ecologically, the adaptation to to freshwater environments (Darwinulocopina, Cytherocopina, Cypridocopina) in the different groups.

Cohen and colagues (1990) said that Ostracods do not have larvae and metamorphosis. Ferguson (1944) reported that parthenogenetic and syngamic reproduction were wide-spread characters belongs to these organisms while only parthonegenetic reproducition have been observed in *Cypridopsis vidua*. Development period and appendage characteristics can indicate differences from taxon to another. Indeed, Cohen and Morin (1990) argued that capulatory organs could be used taxonomically at higher Ostracoda taxa. The reproduction organs of Podocopida are found in pairs; the penis has paired tubes extending to the tips of the large hemipenes that are very bulky and generally complex and two genital lobes in females (Cohen and Morin 1990). This genital organ takes place between last thoracopod and furca. The furca is mostly reduced in all the goups except Cypridoidea which has well-developed furca contain two long furcal rami. In sexual podocopa, egg depositors actively receive duty to put into place of a vary habitats.

The male reproductive system is important for its complexity and size. Copulation reproduction system can be observed in Ostracods approximately 7000-8000 species although parthonogenetic reproduction can be observed only in females of a few podocopid species (Cohen et al., 1990). Doninck and colleagues (2002) described taxonimically Ostracoda take place amongst ancient asexual lineages that have partenogenetic characteristic. In behaviour of mating activty, secondary dimorphic sexual characteristics of Ostracoda are important such as valves, eyes and limbs (Cohen and Morin 1990).

The species prefers either parthenogenetic or bisexual reproduction. In such case, the formation of parthenogenetic and bisexual individuals of a species can be explained into two cyc1es: first is apomixis, and second is automixis cycle (Butlin et al., 1998). Parthenogenesis have been seen in some freshwater Ostracods; all Darvinuloidea, some Cypridoidea, and 2 species of Cytheroidea (Cohen and Morin 1990). On the other hand, sexual and asexual reproduction (parthenogenesis) which is restricted in some population and species (Matzke-Karasz et al., 2007).

Parthenogenetic female produces diploid eggs by mitosis (apomixis). Under the best environmental conditions, those eggs undergo some mitotic division. After these developmental stages, a lot of parthenogenetic females are formed. When the environmental conditions are getting worse, the parthenogenetic female reproduces haploid eggs by meiosis. Males are derived from the unfertilized haploid eggs. Then, the male produces haploid sperm and haploid egg fertilized. This is the automixis cycle (Butlin et al., 1998). Cohen and Morin (1990) development stage of Ostracoda depends on taxon characterisics with together temperature, salinity and food. *Cytherissa lacustris, Darwinula stevensoni, Limnocythere inojinata* and *Candona candida* as parthenogenetic species are found commonly in European lakes, while *Cyclocypris* spp. and *Cypria opthalmica* as sexually species are found in seasonal ponds(Griffiths et al., 1995). Additionally, Sexual and parthenogenetic species have to be together in the same habitats (Griffiths et al., 1995).

1.2. Importance of Ostracoda in Science

Schudack (2006) attracted attention to importance of Ostracoda at biostratigraphic and paleoecological/paleoenvironmental investigations because they reflect ecological character of own life time by specialized valve shapes. Researchers have concentrated on two points in aquatic studies, sensitive characteristics of organisms to water quality changes of aquatic environment and its tolerance range (Zarikian et al., 2000). Ostracods importantly have take place in the ecological and paleoecological studies untill 1960s. These bivalved crustacea are taxonomically investigated, had been used especially to understand past-ecological changes. On the other hand, reserachers have preffered a description for Ostracoda species as an environmental indicator (Külköylüoğlu 1999).

Jiang and collagues (2004) maintained that researchers did not focus on serious effects of environmental changes such as global warming on species. Previously, scientists have recently foucused on evaluating of information about Ostracoda to develop indicator characteristics of individual species (Zarikian et al., 2000; Külköylüoğlu and Vinyard 2000). Indeed, Külköylüoğlu (1999) argued that collected scientific data about environmental variables related with developing of a species in a particulary area can be evaluated to describe environmental changes in that particular area. For example, physicochemical characteristics of a water body can be estimated by using optimum tolerance range of species (Külköylüoğlu 2003c). However, cosmopolitan species do have wide range of tolerance levels to environmental variables (Külköylüoğlu 2003c; 2004). Ostracoda conventionally have been used to describe past-ecological and also present-time conditions. The getting deep and specialized knowledge increasingly about Ostracoda direct scientist to gradually using of it as a past-ecological by fossil records, present-ecological and also future ecological indicators at the present time.

1.3. Previous Studies on Ostracoda in Turkey

Until now studies showed little more than 112 freshwater ostracod (Appendix 1 and 2) species in Turkey (Altınsaçlı and Griffiths 2002; Külköylüoğlu 2004). However, this number is believed to be underestimated.

2. Materials and Methodes

2.1. Study Site Description

Lake Sünnet (N 40^{o} 25' 20", E 30^{o} 57' 25", ca. 1050 m a.s.l.) is located about 90 km west of Bolu. It is a naturally landslide dammed lake (Figure 1). Approximately (considering the maximum length 800 m and maximum width about 120 m), the maximum depth of the lake is 13 m with about 156.821,96 m^3 of volume and 1.8 hectare of total surface area (in this study).

As a result of "Landslides of Lake Sünnet", it occurred with moving vertical sides of Gökdere valley to the ford (Hoşgören and Ekinci 2004). Abdüsselamoğlu (1959) argued that as a result of landslide, limestone blockes and rubbles that brook off from highly slope of hill of rivulet caused formation of Lake.

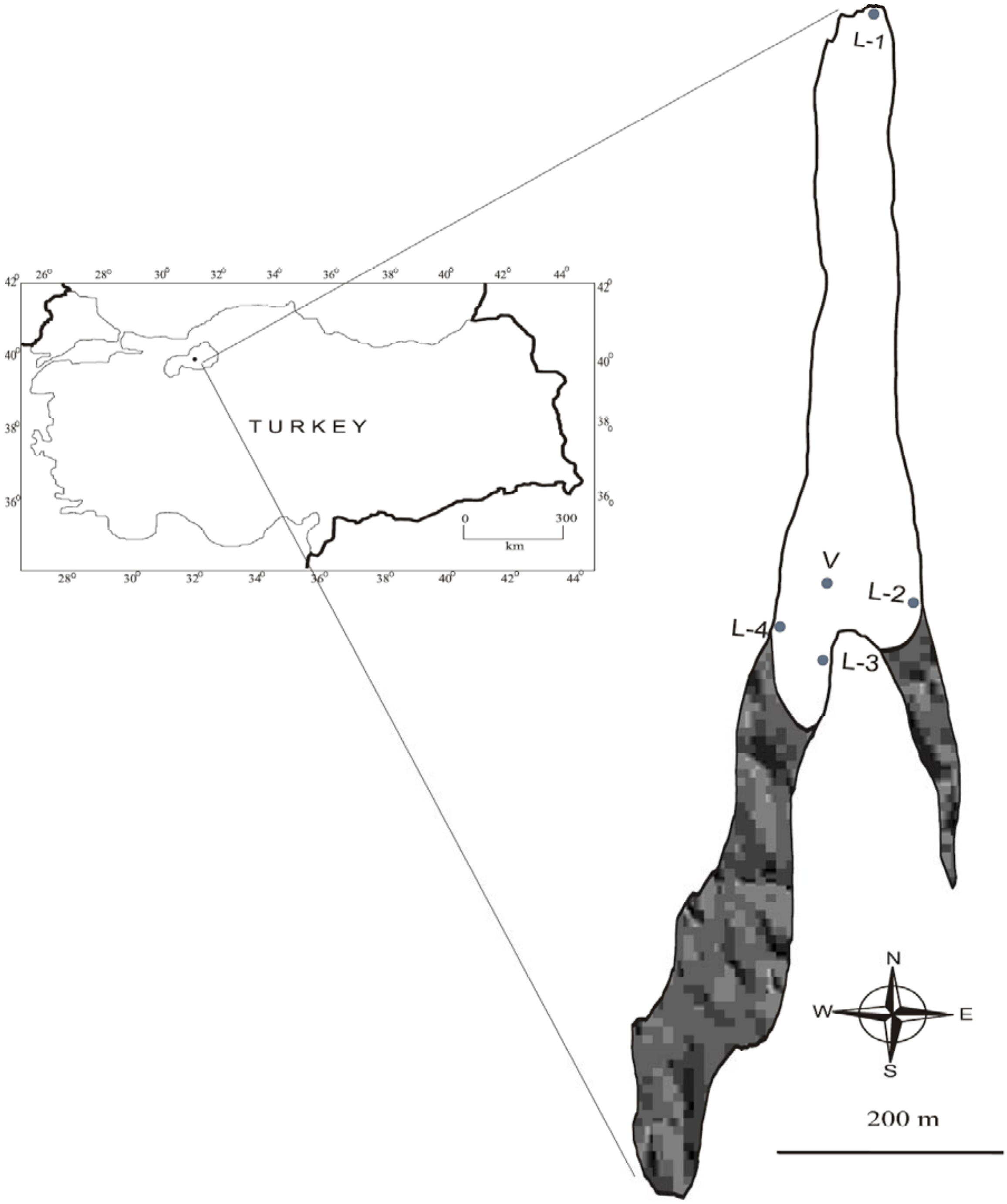

Figure 1. General of appearance of Lake Sünnet with direction and sampling station.

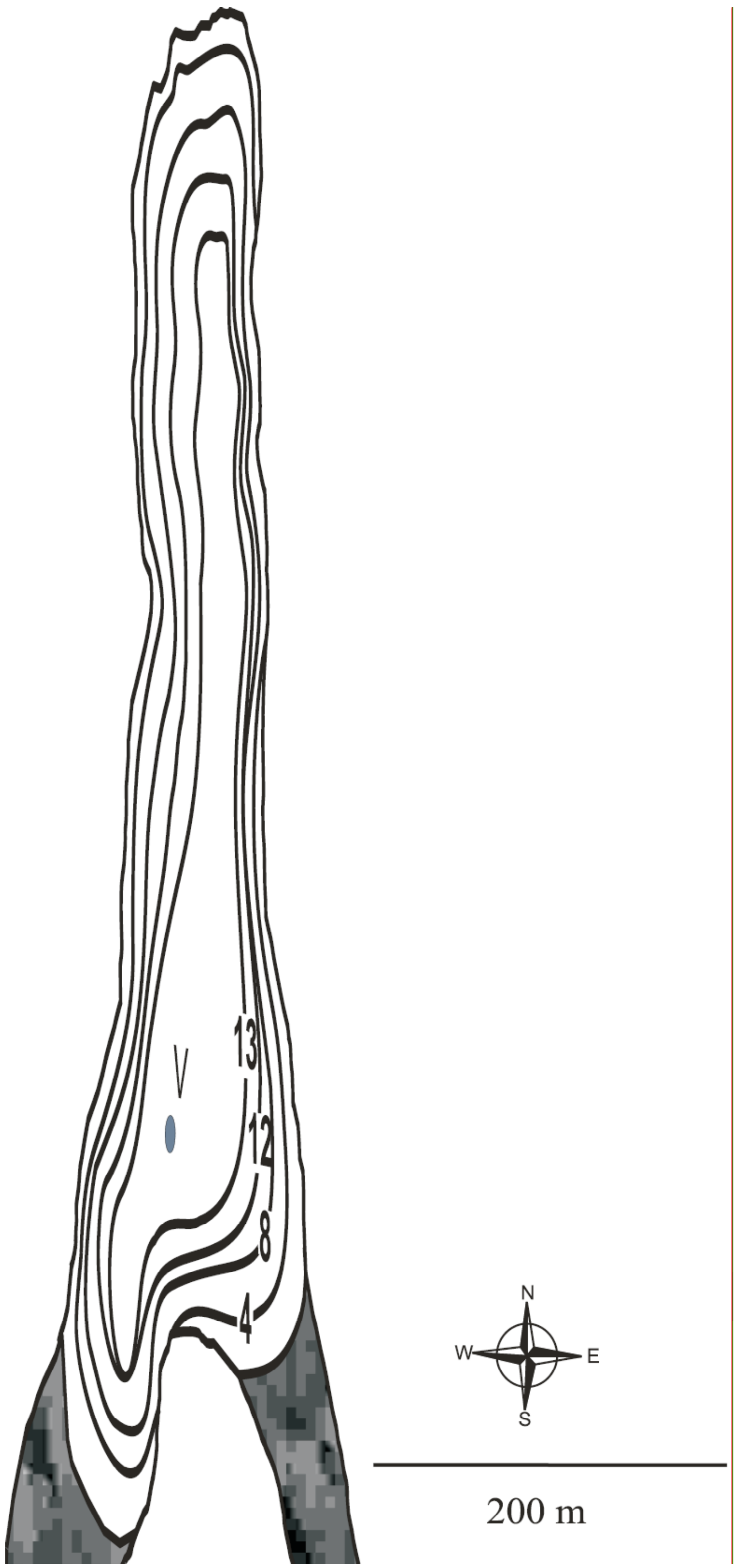

Figure 2. Batymetric graph of Lake Sünnet with depth lines (4, 8, 12, 13 m).

The lake had been partially filled by some creeks, but nowadays only are temporary creek provides water while important amount of water is also discharged from the lake through pump for agricu1tural activities. Abdüsselamoğlu (1959) reported that Lake level have been also affected by water leaking from landslide set. Additionally, annual rainfall and amount of atmosphere temperature have important effect on lake water budget. Water level of the lake decreases untill end of summer and autumn. On the other hand, the water level increase about 8 meters around June, especially during spring. The water level starts increasing and reaches to its maximum level in the late winter and following up spring fall. During winter, lake surface is completely covered by ice for about 2-3 months. Environment of the lake is dominated by pine trees. Lake area, which have not been affected completely human activities, is far from city center and industrial activities. However the touristic hotel that render service to the native and foreign tourists is place on the landsiled set.

2.2. Methodology

Sampling was carried out at four littoral and one pelagic (the depest part) sations of the lake (Figure 1) from May 2005 to September 2007, completing about 21 months. To understand the seasonal stratification of the lake, water samples were collected vertically at each meter from surface to bottom of the pelagic layer of the lake. Water samples are filtered through a 0.8 µm pore size membrane (Whatman GF filter) to use for chemical analysis.

Both physico-chemical and microbiological analyses were made to bring out to understand nutrient cycle and ionic characteristics of the lake. Chemical analyses such as nitrate-nitrogen, nitrite-nitrogen, ammonium-nitrogen, and orto-phosphate were measured by using standart spectrophotometeric methods. Turbidity was measured in the labaoratuary by using Turbidity meter (Nephalo Turbidity Unit). Additionally, water was sampled from all littoral stations of the lake for determining the number of coliform bacteria colony. These samples, which are kept under cool condition (+4 ^{o}C), are inoculated to obtained coliform bacteria on the EMB Agar by using dilution method (Jay 1992). After that, these samples were incubated at 37 ^{o}C for 48 hours to count the colonies of bacteria.

Ostracoda samples were collected from littoral zone with a Müller hand net (0.25 mesh size) while Ekman grab was used for benthic sediment collection. The sediment sample were preserved in 250 ml containers and fixed with 70% a1cohol. In the laboratory samples were filtered under the pressurized tap water with standardized sieves (0.25; 0.50; 1.00; 2.00 in mm mesh size). Ostracoda were separated from sediment under the stereomicroscope and fixed again with 70% alcohol. Idendification of the species was made according to soft body parts and valve characteristics.

Biological oxygen demand (BOD_5) were calculated by YSI-85 model oxygen-temperature meter accoroding to APHA method (1998). Environmental factors affect Ostracoda such as Dissolved Oxygen (DO-mg/l), Percent Oxygen Saturation (%Sat), Salinity (ppt), water temperature (^{o}C), Electrical Conductivity (EC), Redox Potential (mV), pH, Turbidity (NTU), and BOD were measured during investigation periods. Air temperature and amount of rainfall were assured from Bolu Weather Station office. DO, Saturation (%Sat), Salinity (ppt), water temperature (^{o}C), Electrical Conductivity (EC) were measured by using YSI-85 oxygen-temperature meter. pH and SHE were measured with HI-98150 pH/ORP meter. Total volume and surface area of the lake were calculated by means of using bathymetric photographes and data (Figure 3).

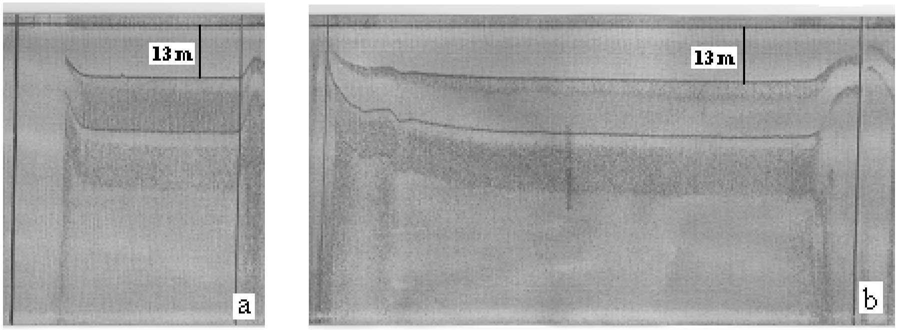

Figure 3. Bathymetric photographs belongs to breadth (a) and length (b) of lake Sünnet with the deepest part.

2.3. Statistical Analyses

The relationship between the environmental variables and living Ostracod species were evaluated by multivariate analysis methods. Subfosil and species with three individuals were not used for statistical analyses. Spearman Correlation Analyses was used to define magnitudes of the relationships among species, chemical, physical and environmental variables. ANOVA was used to compare the mean values of data among the stations. Unweigheted Pair Group Mean Average (UPGMA) was used to illustrate the clustering relationship among nine living Ostracoda species reported from the lake.

Environmental Tolerance Index (ETI), Ecological tolerance (*tk*) and optima (*uk*) values some species were applied to understand ecological requirements of individual species eight selected environmental variables. ETI (Curry 1999), tolerance (*tk*) and optima (*uk*) values (Ter Braak and Barendregt 1986, Külköylüoğlu and Dügel 2004) were calculated according to following formulas, respectively

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

$$Optima\ (\mathrm{uk}) = \frac{\sum_{i=1}^{n} yik\,xi}{\sum_{i=1}^{n} yik} \qquad\qquad Tolerance\ (\mathrm{tk}) = \sqrt{\frac{\sum_{i=1}^{n} yik\,(xi-uk)^2}{\sum_{i=1}^{n} yik}}$$

The aims of this study were (1) to define taxonomy of Ostracoda fauna of Lake Sünnet, (2) to investigate the relationship between Ostracoda and changes in physico-chemical variables in the lake, (3) to understand both ecological and biological assemblages, composition, abundance, and species richness of lake and (4) to evaluate present and future water quality of lake.

3. Results

3.1. Taxonomy of Ostracoda

Phylum or Subpylum: CRUSTACEA Pennant, 1777

Class: OSTRACODA Latreille, 1806

Order: PODOCOPIDA Sars, 1866

Superfamily: Cypridoidea Baird, 1845

Family: Cyprididea Baird, 1845

Subfamily: Herpetocypridinae Kaufmann, 1900

Genus: *Stenocypria* Müller, 1901

Stenocypria fischeri (Lilljeborg 1883)

Family: Ilyocyprididae Kaufmann, 1900

Subfamily: Ilyocypridinae Kaufmann, 1900

Genus: *Ilyocypris* Brady & Norman, 1889

Ilyocypris inermis (Kaufmann 1900)

Ilyocypris getica (Masi 1906)

Ilyocypris bradyi (Sars 1890)

Family: Candonidae Kaufmann, 1900

Subfamily: Candoninae Kaufmann, 1900

Genus: *Candona* Baird, 1845

Candona neglecta (Sars 1887)

Genus: *Pseudocandona* Kaufmann, 1900

Pseudocandona albicans (Brady 1864)

Pseudocandona eremita (Vejdovsky 1882)

Subfamily: Cyclocypridinae Kaufmann, 1900

Genus: *Physocypria* Vávra, 1897

Physocypria kraepelini (G.W. Müller 1903)

Superfamily: Cytheroidea Baird, 1850

Family: Limnocytheridae Klie, 1938

Subfamily: Limnocytheridae Klie, 1938

Genus: *Limnocythere* Brady, 1867

Limnocythere inopinata (Baird 1843)

3.2. Distribution and Ecology of Species

Candona neglecta (Sars 1887)

General Distribution: It has wide distribution in Europe (Roca and Baltanás 1993) but also from North Africa (Klie 1938), Central Asia, Russia (Bronshtein 1947), Algeria (Sars 1928), North America (Külköylüoğlu 1999).

Ecology: *Candona neglecta* is a stenothermic cold-loving species but it can only tolerate temperatures above 20^{o}C (Bronshtein 1947). Roca and Baltanás (1993) reported that it is common species in eutrophic aquatic systems. It has wide living habitats such as lakes, ponds, springs, ditches, streams and rarely underground waters (Meisch 2000). Previously, tolerant characteristics were reported for conductivity (56-890 μScm^{-1}) as higher, for dissolved oxygen concentrations (3.2-15.4 mg/L), pH values (6.8-9.4) (Roca and Baltanás 1993; Külköylüoğlu 2005b) indicating wide ranges of tolerances.

Pseudocandona albicans (Brady 1864)

General Distribution: Northern Italy (Rosetti et al., 2005), Canary Islands, Europe, Western Asia and North America (Meisch 2000).

Ecology: *Pseudocandona albicans* occurs at low temperatures and high altitudes (Griffiths *et al.,* 1996). It lives in permanent, muddy and slowflowing waters, while it prefers very low salt content (Meisch 2000). *Pseuducandona albicans* lives in permanent, muddy and slowflowing waters, while it prefers very low salt content (Meisch 2000). It is a crawling species that shows stygophilic behaviours (Roca and Danielopol 1991).

Pseudocandona eremita **(**Vejdovsky 1882)

General Distribution: General distribution of *Pseudocandona eremita* is eastern, southeastern Europe and Asia Minor (Meisch 2000).

Ecology: It is reported generally from wells, caves, springs and epigean habitats connected with underground waters (Meisch 2000).

Physocypria kraepelini (G.W. Müller 1903)

General Distribution: Europe and Asia (Meisch 2000). Reported from European shallow waters and reservoirs (Kiss 2002). Holarctic species (Külköylüoğlu et al., 2007).

Ecology: *Physocypria kraepelini*, eurythermic species, occurs in less alcaline waters that means high temperature and conductivity. It has a oligohaline range (Meisch 2000). It was recently reported from the aquatic habitats that contained ionic content with higher trophic conditions (Rosetti et al., 2004). It was characterized as polythermophilic, mesohalophilic (Meisch 2000; Yılmaz and Külköylüoğlu 2006).

Ilyocypris bradyi (Sars 1890)

General Distribution: This species is well known from Holarctic region Meisch 2000) but recent studies suggests its distribution is not limited with Holarctic (Külköylüoğlu 2005a).

Ecology: Members of the Ilyocypris genus, which has wide distribution from river to lake, take place in weakly saline waters (Altınsaçlı et al., 2000b). Roca and his colleagues (1993) reported that *I. bradyi* generally present in waters characterized with eutrophication and low alkalinity. *Ilyocypris bradyi* has a widespread distribution in almost all kinds of freshwaters. The species shows a positive correlation to redox potential and a strong negative correlation to pH values (Külköylüoğlu 2005c). It seem to prefer cooler waters (14-25 ^{o}C) but tolerant to low dissolved oxygen levels from 4 to 6.3 mg/L (Külköylüoğlu and Vinyard 2000).

Ilyocypris inermis (Kaufmann 1900)

General Distribution: Northern Italy (Rosetti et al., 2005), Britain, France, Germany, Switzerland, Hungary, Austria, Czech Republic, Belgium, Spain, Luxembourg, Slovakia (Meisch 2000).

Ecology: *Ilyocypris inermis* is recorded from limnocrene spring and there is a positive relationship to redox potential and temperature (Külköylüoğlu and Yılmaz 2006). It is possible to find it in waters with lower oxygen. It is reported from cold waters with low salinity (Meisch 2000).

Ilyocypris getica (Masi 1906)

General Distribution: Europe, North Africa and China (Palaearctic) (Meisch 2000). It is firstly reported from Turkey in this study.

Ecology: *Ilyocypris getica* has been reported from ponds, ditches, and not in lakes (Meisch 2000). However, this species is first report for lake ecosystem in this study. It is not clear that it prefers the temporary habitats such as pools. It has a tolerance to slightly increasing salinity changes (Meisch 2000). Ecologically, there is lack of information about its preferences.

Stenocypria fischeri (Lilljeborg 1883)

General Distribution: Eastern Europe, Middle East and general distribution is palaearctic (Meisch 2000).

Ecology: *Stenocypria fischeri* generally occurs between May and September, approximately summer forms (Meisch 2000). In Turkey, this species was firstly and lastly recorded by Schäfer (1952). This is the second report of this species after about 55 years.

Limnocythere inopinata (Baird 1843)

General Distribution: Sweden (Kile, 1938), Central Asia (Bronshtein, 1947) Scandinavia (Elofson, 1943), Germany (Meisch 2000), Turkey (Külköylüoğlu 2005).

Ecology: Külköylüoğlu (2005), Altınsaçlı and colleagues (1999) mentioned that *L. inopinata* is a cosmopolitan species, which has high tolerance range for salinity, alkalinity and temperature.

3.3. Evaluation of Data

Throughout the study, totaly nine living Ostracoda species, which can be at leat commonly characterized as cosmopolitan in Holarctic region, were recorded (*Candona neglecta, Ilyocypris bradyi, I. getica, I. inermis, Limnocythere inopinata, Physocypria kraepelini, Stenocypria fischeri*, *Pseudocandon* cf. *eremita* and *P. albicans*) in the Lake Sunnet. On the other hand, *Ilyocypris* sp., *Cypridopsis* sp., *Eucypris* sp., *Potamocypris* sp. and *Prionocypris zenkeri* were also reported as fossil forms. The recorded species generally found at the first, third and fourth littoral stations. Although sediments were sampled from deepest part of the Lake, no living forms were found. While *L. inopinata* was almost recorded as dominant species during the study, three species (*S. fischeri*, *I. bradyi* and *P. eremita*) interstingly were recorded only once during approximately two years (Table 1). One individual of *S. fischeri* and *P. eremita* and also two individuals of *I. bradyi* were found throughout the study. Other species (*C. neglecta, I. getica, I. gibba, P. kraepelini,* and *P. albicans*) are oher species that were recorded frequently.

Table 1. (*) indicates living Species recorded monthly.

	PA	LI	CN	IG	PE	II	PK	SF	IB
May–05	*								
Jun–05		*							
Jul–05									
Aug–05		*							
Sep–05									
Oct–05		*							
Nov–05									
Mar–06									
Apr–06									
May–06	*		*	*	*				
Jun–06			*	*		*	*	*	
Jul–06									
Aug–06									
Sep–06		*							*
Oct–06		*				*			
Nov–06		*		*			*		

Unweighted Pair Group Mean Analyses (UPGMA) was used to detect relationship among nine living Ostarcod species. According to this analyses, there are three main clusterin groups (A, B and C). The first group (A) was formed by *L. inopinata* that had been dominantly recorded species. Second group (B) was constituted by *P. albicans*. Third group (C) consists of seven species in two subgroups (C1 and C2); *C. neglecta, I. bradyi, I. getica, I. inermis, P. kraepelini, S. fischeri*, and *P. eremita*.

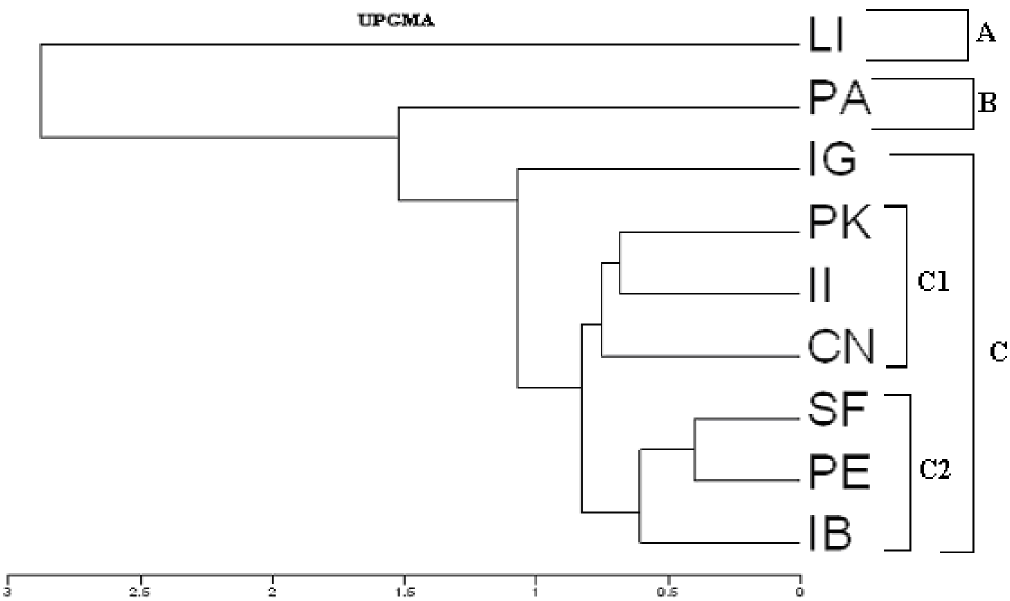

Figure 4. UPGMA (Unweigheted Pair Group Mean Average) illustrates the relationship among nine Ostracod species from the Sunnet Lake. This figure showed three main clustering groups. It was reffered to *L. inopinata* (LI) as a first, *P. albicans* (PA) as second and *I. getica* (IG), *P. kraepelini* (PK), *I. inermis* (II), *C. neglecta* (CN), *S. fischeri* (SF), *P. eremita* (PE), *I. bradyi* (IB) as third group.

The reported biotic and abiotic data were collected monthly during 21 months. During the sampling period from the bottom sulphur gases smelling at higher density and also gas bubles on the surface of the lake were detected. Unfortunately, analyses had not been made to detect amount of sulphur gases but this suggest possible anoxic condition of the bottom of the lake. Among the variables the values of Dissolved oxygen, saturation, turbidity, Secchi depth decreased, while electrical conductivity, water temperature, percentage of dissolved solid materials increased as a result of decreasing of water level at every season (Figure 5).

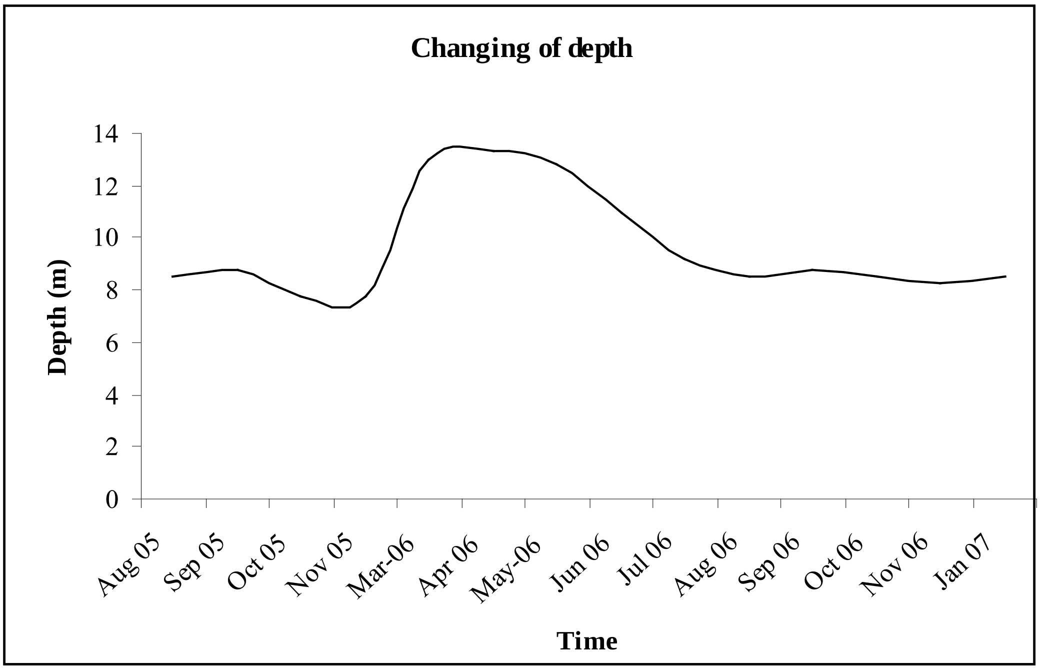

Figure 5. Monthly changing of the lake depth.

Higher level of total coliform bacteria was recorded at second and fourth littoral station although the lake has been not affected directly by human activities. This area is far away from point sources of pollution by means of human activities. On the other hand, there are some turistic and some agricultural activities around the lake.

At the end of the study, it was concluded that diversity, individual number and also species number of Ostracoda did not show significantly differences between the sampling stations in the lake (Table 2 and 5). According to ANOVA, there were no remarkable differences ($p>0.05$) in the measured variables except turbidity between littoral stations.

Table 2. The mean monthly physicochemical variables and secchi depth of the lake. The scientific abbreviations and unit of variables were determined as dissolve oxygen (DO, mg/l), water temperature (Tw, ^{o}C), saturation (Sat, %), SHE (mV), electirical conductivity (EC, µS/cm), total dissolved solids (TDS, mg/l), pH, Salinity (Sal, ppt), biological oxygen demand (BOD-mg/l) and Secchi depth (Sec, cm).

DATE	DO	T (w)	Sat	*SHE*	EC	TDS	pH	Sal	BOD	Secchi
May 05	9.38	17.60	99.60	187.74	316.70	212.19	7.45	0.20	4.38	
Jun 05	4.63	20.93	53.18	195.95	433.70	290.58	7.25	0.23	1.09	
Jul 05	5.20	26.03	62.60	206.33	391.38	262.22	7.46	0.20	2.79	
Aug 05	7.69	20.12	85.13	150.75	400.47	268.32	8.02	0.21	5.37	100
Sep 05	4.58	14.76	46.11	213.66	415.07	278.10	7.94	0.22	2.14	110
Oct 05	9.35	10.37	84.85	216.51	415.36	278.29	7.95	0.21	5.86	120
Nov 05	6.69	5.95	53.87	219.38	411.85	275.94	8.05	0.20	3.07	95
Mar-06	4.05	7.59	34.77	218.31	471.96	316.21	8.21	0.29	2.03	150
Apr 06	2.84	11.06	26.46	216.06	502.04	336.37	7.98	0.24	1.27	110
May 06	2.75	14.14	28.52	214.06	473.76	317.42	7.85	0.24	1.34	140
Jun 06	7.01	15.71	83.76	213.04	453.09	303.57	7.78	0.24	7.40	210
Jul 06	6.68	17.94	73.09	211.59	438.28	293.65	7.81	0.24		115
Aug 06	6.65	17.31	72.88	212.00	415.45	278.35	7.77	0.22	4.70	80
Sep 06	6.57	14.54	66.88	213.80	403.44	270.30	7.72	0.22	5.09	80
Oct 06	6.48	11.44	60.82	179.47	418.19	280.18	7.61	0.22	6.64	80
Nov 06	7.48	6.46	62.09	178.40	418.19	280.19	7.72	0.20	2.69	80
Jan 07	6.52	4.30	50.30	197.09	420.30	281.60	7.38	0.20	3.94	
Mar 07	6.74	5.15	54.17	198.52	784.47	525.59	7.30	0.20	2.38	120
Jul 07	6.93	23.90	66.82	207.98	410.84	275.86	7.59	0.20	3.01	
Aug 07	8.29	22.77	68.29	185.00	429.18	287.57	7.76	0.20	3.16	
Sep 07	8.10	18.70	69.22	205.32	413.47	277.03	7.95	0.20	4.38	
Mean	6.41	14.61	62.07	201.95	439.87	294.74	7.74	0.22	3.64	113.6
Min	2.75	4.30	26.46	150.75	316.70	212.19	7.25	0.20	1.09	80
Max	9.38	26.03	99.60	219.38	784.47	525.59	8.21	0.29	7.40	210

Table 3. The mean monthly measured chemical variables, turbidity, *E.coli*, Coliform number, rainfall and air temperature (Ta) from vertical and littoral zones of the lake, rainfall and air temperature of Bolu (Turkey) region. The scientific unit of variables were determined as rainfall (kg/m^2), air temperature (Ta-^{o}C), Coliform bacteria as coloni forming unit (cfu/ml), Turbidity (NTU), Nitrate (N-NO_3, mg/l), Nitrite (N-NO_2, mg/l), Amoniac (N-NH_4, mg/l), Phosphate (P-PO_4, mg/l) and Sulfphate (SO_4, meq/l).

Time	Rainfall	T (a)	Coliform	Turb	NH_4	NO_3	NO_2	PO_4	SO_4
May-05	42.80	14.40	1	5.80					
Jun 05	59.10	16.30	111	8.17	0.05	0.02	0.014	0.0032	
Jul 05	58.10	20.90	41	9.57	0.07		0.01	0.014	
Aug 05	8.60	21.70		6.12	0.003	0.01	0.002	0.01	0.004
Sep 05	25.90	16.60	4250	8.44	0.07		0.001	0.022	
Oct 05	52.10	10.30	323	4.94	0.07			0.01	0.003
Nov 05	63.70	6.60	275	6.15	0.32			0.01	
Mar-06	49.50	6.70	38	4.23	0.01	0.2	0.021	0.003	0.003
Apr 06	13.70	10.50	100	2.39	0.005	0.04	0.01	0.012	0.003
May-06	37.00	14.00	35	3.68	0.004	0.02	0.01	0.002	0.004
Jun 06	22.60	18.20	2330	2.61	0.006	0.02	0.003	0.002	0.003
Jul 06	12.60	19.40		3.83	0.005	0.002	0.003	0.001	0.004
Aug 06	1.80	23.20	150						
Sep 06	71.90	16.00	338	6.33	0.002	0.01	0.01	0.01	0.004
Oct 06	23.70	13.00	160	4.85	0.004	0.01	0.004	0.01	
Nov 06	37.50	5.60	3	5.17	0.03	0.01	0.01	0.012	
Jan 07	143	2.60	87	3.61	0.02	0.4	0.01	0.02	0.002
Mar-07	8.80	2.40	1	5.70	0.1	0.81	0.01	0.02	0.005
Jul 07	6.30	22.10		8.36	0.01	0.011	0.01	0.01	0.005
Aug 07	25.90	22.00		7.84	0.01	0.01	0.004	0.012	0.005
Sep 07	1	17.30		6.93	0.01	0.01	0.003	0.01	0.007
Mean	36.46	14.28	515	5.74	0.04	0.1	0.01	0.01	0.004
Min	1	2.40	1	2.39	0.002	0.002	0.001	0.001	0.002
Max	143	23.20	4250	9.57	0.32	0.81	0.021	0.022	0.007

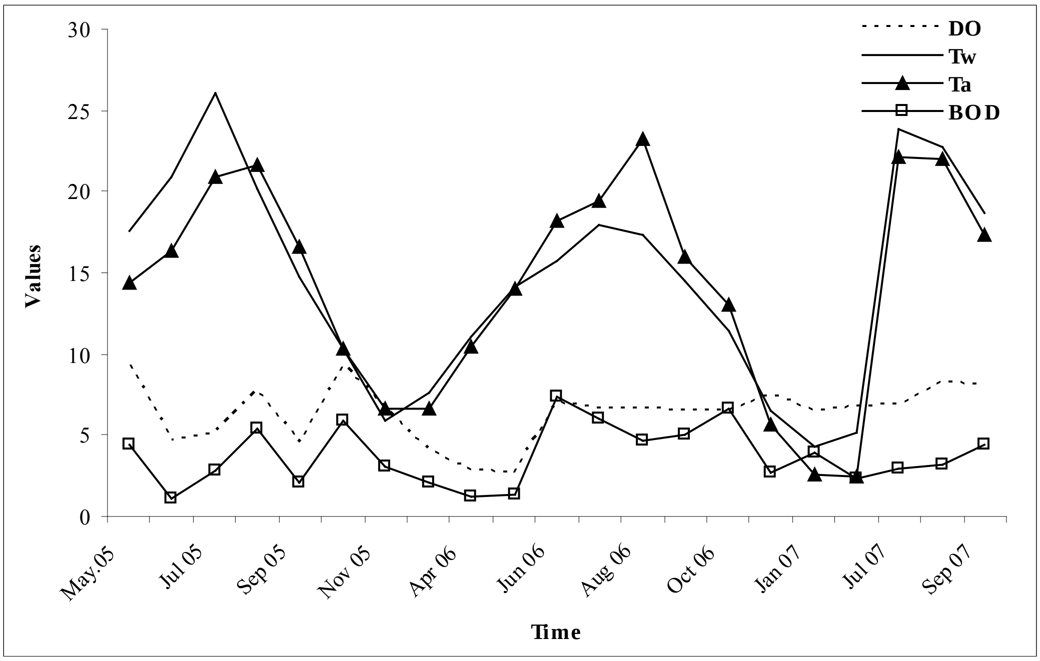

Figure 6. Seasonal changes of Dissolve Oxygen (DO), Temperature of water (Tw), Temperature of air (Ta), and Biological Oxygen Demand (BOD).

Some of the seasonal changes in the measured and environmental variables during two years was illustrated in Figure 6 and 5. However, it couldn't been measured significantly different changes from each other in some of variables, such as salinity and pH. Mean values of salinity and pH had been measured approximately as about 0.22, and 7.74 at the end of study (Table 2). Throughout the monthly sampling period during two years, pH and salinity had been generally recorded to close to its' mean values.

In May 2005, maximum value of dissolved oxygen as 9.38 mg/L and saturation 99.60 % was recorded (Figure 6). Minimum values of these variables were measured for saturation as 26.46 % in April 2006 and dissolved oxygen as 2.75 mg/L in May 2006.

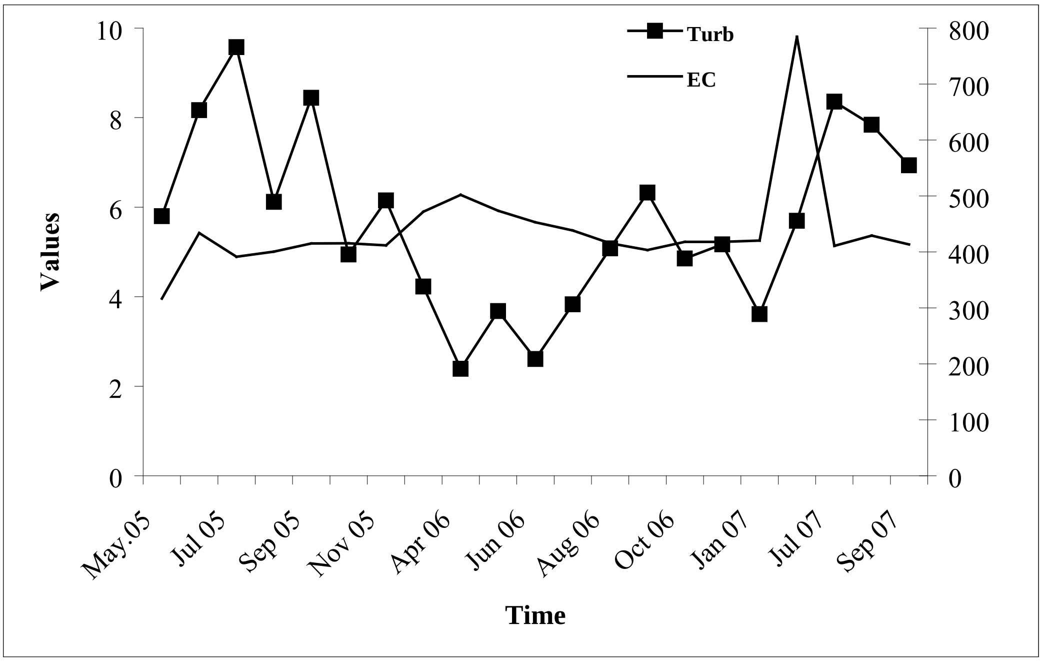

Figure 7. Seasonal changes of Electrical Conductivity (EC) and Turbidity.

In the later sampling period in June 2005 and June 2006 maximum and minimum BOD level measured 7.40 mg/L and 1.09 mg/L (Figure 4), respectively. While EC reached to maximum level in March 2007 and minimum level in May 2005 (Figure 7), the maximum EC value was recorded 9.57 in July 2005, and the minimum value was 2.39 in April 2006. Figure 7 showed a negative relationship between EC and Turbidity.

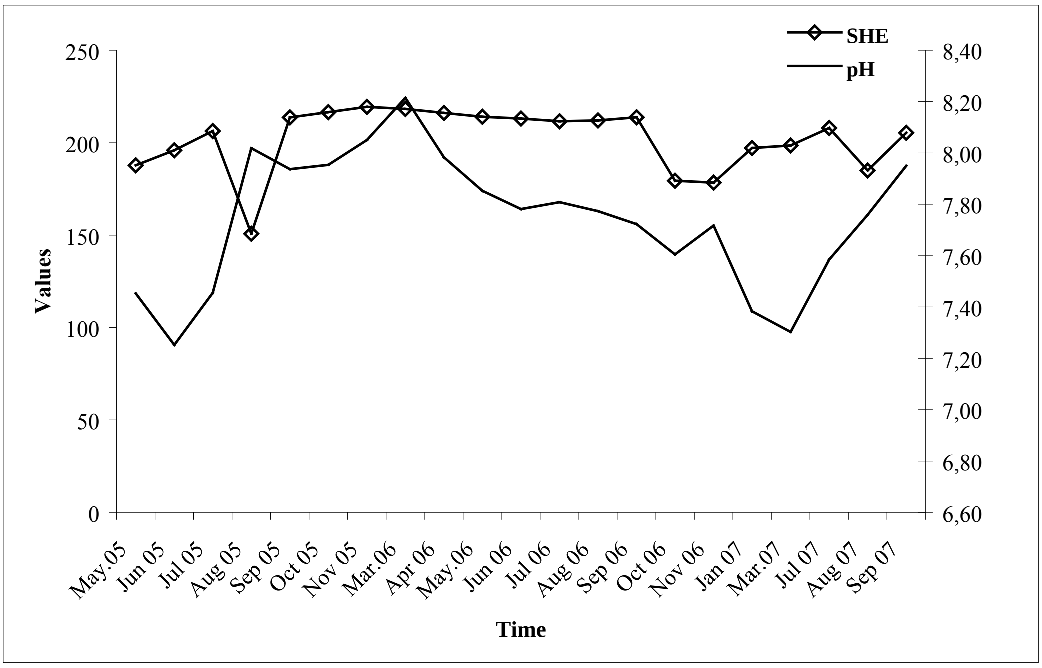

Figure 8. Seasonal changes of SHE and pH during the study.

Spearman Correlation Analyses was performed to describe correlation between nine species and environmental variables. Amount of some variables (nitrite, nitrate, phosphate and sulphate) were found at low levels. This situation and poverty of lake according to species and individual number caused problems to evaluate statistically results of the study. Because of that the outcomes of the Spearman analyses which represented significantly correlated data were tabulated in Table 4. If we evaluate results of Spearman Correlation in the aspect of species number of the lake, only there is a positive correlation ($p<0.01$) between species number and electrical conductivity. Conductivity was positively related to salinity ($p<0.05$) and nitrate ($p<0.01$) (NO_3). In contrast, salinity is negatively correlated with dissolved oxygen, $P\text{-}PO_4$ ($p<0.01$) and turbidity ($p<0.05$). Additionaly, there is a negatively significant relationship of redox potential ($p<0.01$) with pH (Table 4). On the other hand, there is a positive correlation of water temperature on turbidity ($p<0.01$) and SO_4 ($p<0.05$).

Ostracod Watch Model (OWM) developed by Külköylüoğlu (1998) was used to illustrate seasonality dispersion of species (Figure 10). This model was applied on nine species. Among them, *P. albicans*, *P. eremita* and *C. neglecta* were recorded only in spring season, while *S. fischeri* was recorded between May and June. Also, *I. bradyi* was observed only in autumn. Additionaly to OWM models, Circular Data Analyses of Ostracoda (Figure 9) with Number Cruncher Statistical System (NCSS) indicate seasonal similarities and differences between species (Zar 1999).

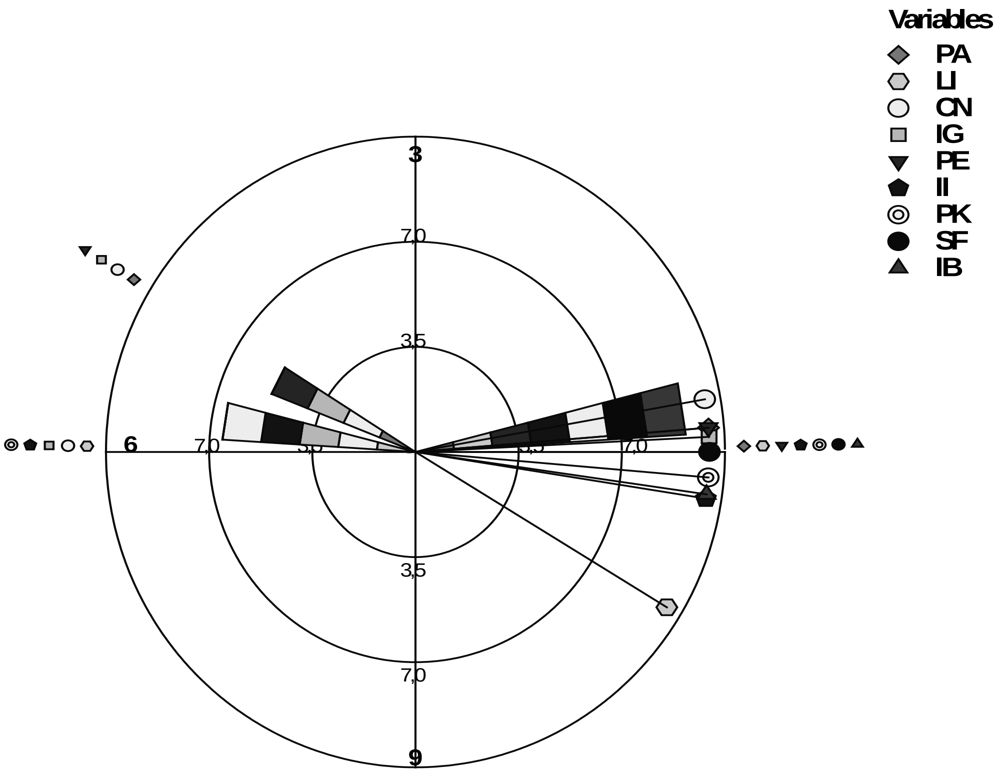

Figure 9. Descriptive Circular Data Analyses of Ostracod with Number Cruncher Statistical System (NCSS) indicate seasonal similarities and differences between species (Zar 1999). *I. getica* (IG), *I. inermis* (II), *L. inopinata* (LI), *S. fischeri* (SF), *C. neglecta* (CN), *P. albicans* (PA), *P. eremita* (PE), *P. kraepelini* (PK) and *I. bradyi* (IB).

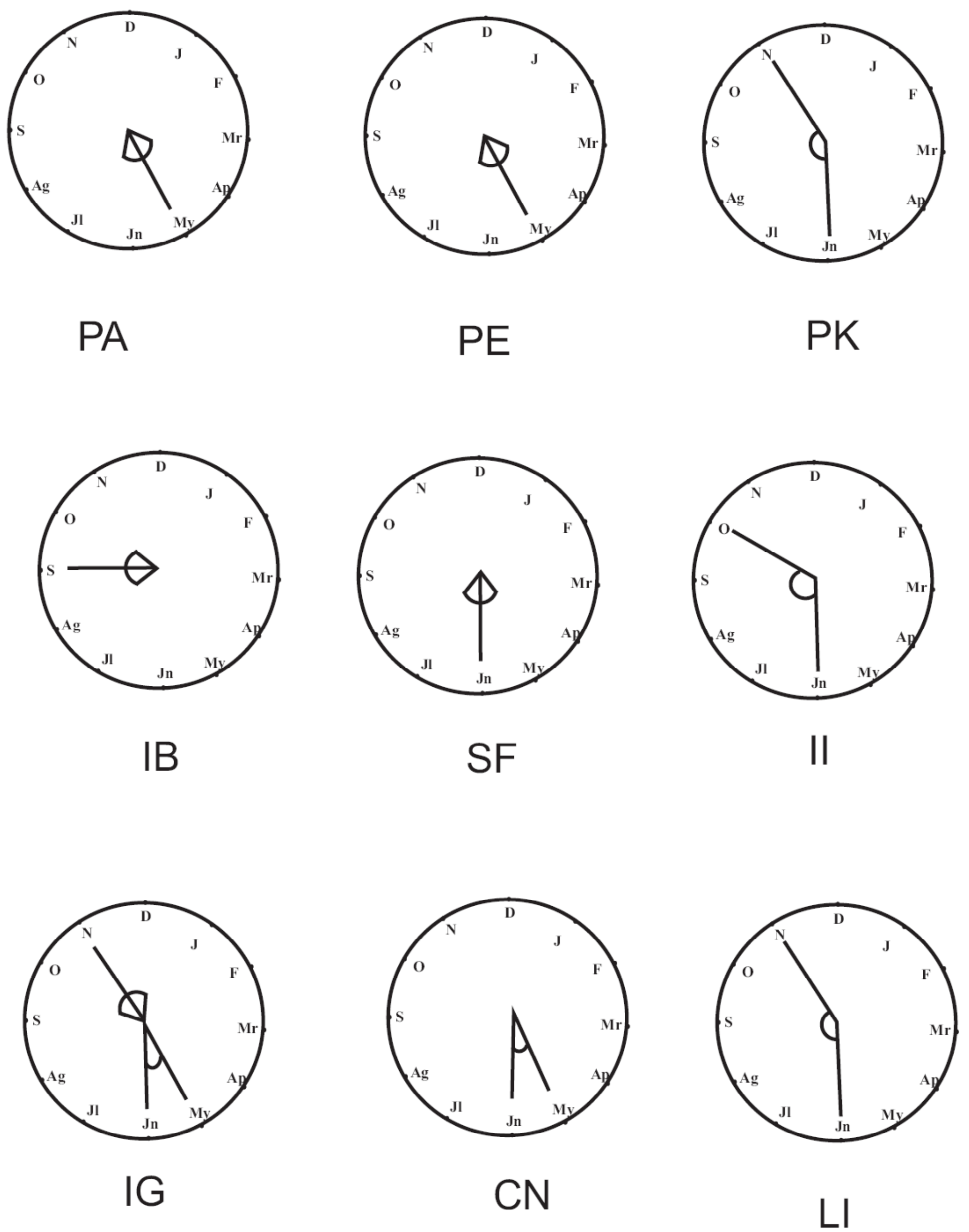

Figure 10. Ostracod Watch Model (OWM) indicate seasonal similarities and differences between species. *I. getica* (IG), *I. inermis* (II), *L. inopinata* (LI), *S. fischeri* (SF), *C. neglecta* (CN), *P. albicans* (PA), *P. eremita* (PE), *P. kraepelini* (PK) and *I. bradyi* (IB).

Table 4. Spearmen correlation illustrates the relationship among species number and thirteen environmental variables. In this table, “*” symbol indicate significant relationship at 0.05 (2-tailed), “**” indicate significant relationship at 0.01 (2-tailed). “-“ reffered to negative relationship.

	DO	**Tw**	**pH**	**EC**	**SHE**	**TURB**	**N-NH_4**	**N-NO_3**	**N-NO_2**	**P-PO_4**	**SO_4**	**Ta**	**Rainfall**	**SPP**
DO	1													
Tw	0.187	1												
pH	-0.053	-0.156	1											
EC	-0.409	-0.413	0.05	1										
SHE	-0.068	-0.029	-0.943(**)	0.053	1									
TURB	0.174	0.589(**)	-0.22	-0.624(**)	0.05	1								
N-NH_4	0.102	-0.177	-0.149	-0.1	0.146	0.405	1							
N-NO_3	-0.317	-0.642(**)	-0.211	0.678(**)	0.292	-0.582(*)	-0.022	1						
N-NO_2	-0.441	-0.272	-0.245	0.372	0.252	-0.125	0.186	0.625(**)	1					
P-PO_4	-0.32	-0.207	-0.277	-0.147	0.216	0.312	0.447	-0.012	-0.01	1				
SO_4	0.495	0.676(*)	-0.308	-0.352	0.044	0.835(**)	-0.038	-0,581(*)	-0.286	0.143	1			
TempA	0.17	0.899(**)	0.016	-0.361	-0.171	0.484(*)	-0.267	-0.686(**)	-0.466	-0.242	0.549	1		
Rainfall	-0.229	-0.329	-0.187	-0.129	0.299	0.035	0.332	0.16	0.347	0.036	-0.632(*)	-0.486(*)	1	
SPP	-0.638	-0.224	-0.052	0.849(**)	0.069	-0.535	0.025	0.486	0.185	-0.476	-0.41	-0.035	-0.207	1

Optime (*uk*), tolerance(*tk*), and environmental tolerance index (ETI) values of the species (Table 5) showed similar results with Spearman correlation analyses. If ETI ranges close to 1, it indicate that this species adapted to environmental changes very well. Table 5 indicated that *P. albicans* has wide tolerance range for conductivity rather than the other species. *L. inopinata* has lower tolerance level for other environmental variables (Table 5) although it was the most dominant species of the lake. Tolerance range level of the species for environmental variables did not show significant differences from each other.

Table 5. Descriptive statistics of the species, Optime (*uk*), Tolerance (*tk*), Environmental tolerance index (ETI) for physicochemical variables.

PA	**DO**	**Temp**	**Sat**	**Eh**	**SHE**	**EC**	**pH**	**Sal**
Average	6.07	15.87	64.06	-36.25	200.90	395.23	7.65	0.22
Std. Deviation	4.69	2.45	50.26	17.23	18.61	111.06	0.28	0.03
Maximum	9.38	17.60	99.60	-24.07	214.06	473.76	7.85	0.24
Minimum	2.75	14.14	28.52	-48.43	187.74	316.70	7.45	0.20
Range	6.63	3.46	71.08	24.36	26.32	157.06	0.40	0.04
ETI	1.00	0.16	0.97	0.46	0.55	0.34	0.42	0.44
Optima	7.49	16.61	79.29	-31.03	195.26	361.57	7.57	0.21
Tolerance	2.99	1.57	32.11	40.06	11.89	70.95	0.18	7.27

CN	**DO**	**Temp**	**Sat**	**Eh**	**SHE**	**EC**	**pH**	**Sal**
Average	4.88	14.93	56.14	-47.53	213.55	463.43	7.82	0.24
Std. Deviation	3.01	1.11	39.06	1.27	0.72	14.62	0.05	0.00
Maximum	7.01	15.71	83.76	-46.63	214.06	473.76	7.85	0.24
Minimum	2.75	14.14	28.52	-48.43	213.04	453.09	7.78	0.24
Range	4.26	1.57	55.24	1.80	1.02	20.67	0.07	0.00
ETI	0.64	0.07	0.76	0.03	0.02	0.04	0.07	0.00
Optima	5.41	15.12	63.04	-47.30	213.42	460.84	7.81	0.24
Tolerance	2.06	0.76	26.74	52.72	0.49	10.01	0.03	5.18

IG	DO	Temp	Sat	Eh	SHE	EC	pH	Sal
Average	5.75	12.10	58.12	-45.24	201.83	448.35	7.78	0.23
Std. Deviation	2.61	4.95	27.83	4.07	20.30	28.09	0.07	0.02
Maximum	7.48	15.71	83.76	-40.65	214.06	473.76	7.85	0.24
Minimum	2.75	6.46	28.52	-48.43	178.40	418.19	7.72	0.20
Range	4.73	9.25	55.24	7.78	35.66	55.57	0.13	0.04
ETI	0.71	0.43	0.76	0.15	0.75	0.12	0.14	0.44
Optima	4.29	12.35	41.51	-46.33	205.06	458.14	7.81	0.23
Tolerance	2.18	3.43	19.16	50.73	15.39	23.74	0.06	4.06

LI	DO	Temp	Sat	Eh	SHE	EC	pH	Sal
Average	7.03	13.98	68.83	-41.32	189.15	414.89	7.71	0.22
Std. Deviation	1.57	5.70	13.27	15.95	24.84	11.96	0.27	0.01
Maximum	9.35	20.93	85.13	-13.70	216.51	433.70	8.02	0.23
Minimum	4.63	6.46	53.18	-59.43	150.75	400.47	7.25	0.20
Range	4.72	14.47	31.95	45.73	65.76	33.23	0.77	0.03
ETI	0.71	0.67	0.44	0.86	1.38	0.07	0.80	0.33
Optima	6.97	11.65	65.59	-42.06	195.90	411.65	7.71	0.22
Tolerance	0.81	3.82	6.48	49.43	18.49	7.89	0.11	6.75

PK	DO	Temp	Sat	Eh	SHE	EC	pH	Sal
Average	7.25	11.09	72.93	-43.64	195.72	435.64	7.75	0.22
Std. Deviation	0.33	6.54	15.32	4.23	24.49	24.68	0.04	0.03
Maximum	7.48	15.71	83.76	-40.65	213.04	453.09	7.78	0.24
Minimum	7.01	6.46	62.09	-46.63	178.40	418.19	7.72	0.20
Range	0.47	9.25	21.67	5.98	34.64	34.90	0.06	0.04
ETI	0.07	0.43	0.30	0.11	0.73	0.07	0.06	0.44
Optima	7.20	12.01	75.09	-44.23	199.19	439.13	7.76	0.22
Tolerance	0.23	4.53	10.61	51.51	16.97	17.10	0.03	6.98

II	DO	Temp	Sat	Eh	SHE	EC	pH	Sal
Average	6.75	13.58	72.29	-41.49	196.26	435.64	7.70	0.23
Std. Deviation	0.37	3.02	16.22	7.27	23.74	24.68	0.12	0.01
Maximum	7.01	15.71	83.76	-36.35	213.04	453.09	7.78	0.24
Minimum	6.48	11.44	60.82	-46.63	179.47	418.19	7.61	0.22
Range	0.53	4.27	22.94	10.28	33.57	34.90	0.17	0.02
ETI	0.08	0.20	0.31	0.19	0.70	0.07	0.18	0.22
Optima	6.94	15.17	80.89	-45.34	208.84	448.72	7.76	0.24
Tolerance	0.18	1.41	7.58	52.40	11.10	11.54	0.06	6.71

3.4. Discussion and Conclusion

Lake Sünnet is one of the natural lakes of Bolu. There is only one study (Külköylüoğlu 2003c) that reported two living ostracods (*C. opthalmica* and *D. stevensoni*) with additional ecological data from the lake. Most recently, Sarı et al., (2004) also provided some biological and chemical information about the lake but they did not report any ostracods in this study. In contrast, these two ostracod species were not recorded during the present study. On the other hand, *Ilyocypris* sp., *Cypridopsis* sp., *Eucypris* sp., *Potamocypris* sp. and *Pr. zenkeri* were recorded to be as a subfossil forms in the lake.

There are three main groups (A, B, C) of species clustered in UPGMA analyses. In the first two groups (A, B) there was only one species in each as *L. inopinata* and *P. albicans*, respectively. *Limnocythere inopinata* was the most domiant and frequently occurring species in monthly sampling. *I. getica*, *I. bradyi*, *I.inermis*, *P. kraepelini, C. neglecta*, *S. fischeri* and *P. eremite* belong to the third group (C). *Limnocythere inopinata, P. albicans,* and C. *neglecta,* were known to be commonly recorded species in flowing waters, but and rarely in springs (Mezquita et al., 1999b). Interestingly, living species of the third group were not recorded during 2005 (Table 1). The member of the third group was recorded at sampling periods in 2006. More interestingly, *I. bradyi*, and *S. fischeri* were reported with one individual at one monthly sampling time in 2006. Spearman correlation analysis did not support the result of UPGMA clustering, because of the insufficient individual number of the species. Overal, we have a correlation datum on species number and environmental variables (Table 4). According to Spearman analysis, there was only significantly detected positive correlation ($p<0.01$) between electrical conductivity and species number during the study. This positive correlation may suggest that the species can be sensitive to chances in conductivity that are directly related the ionic composition of the lake. The ionic composition of the aquatic environment is knownt to be related to water temperature and turbidity, as well.

As mentioned above, *L. inopinata* was recorded from a man made Lake Gölköy in Bolu by Külköylüoğlu (2005). During the study, this species was recorded at different season; June, August and October of 2005 and September, October and November of 2006 (Table 1). In the UPGMA diagram, first group (A) includes *L. inopinata* alone. This situation might be created by temperature tolerance characteristics of the species. Indeed, Külköylüoğlu (2005), Altınsaçlı (1999) mentioned that *L. inopinata* is a cosmopolitan species, which has high tolerance range for salinity, alkalinity and temperature. In this study, optimum and tolerance range of the *L. inopinata* were 0.22±6.75 for salinity and 11.65±3.82 °C for water temperature (Table 5). According to Altınsaçlı (2001), low level of the BOD in lake characterized to lake water as higher quality. Külköylüoğlu and Dügel (2004) argued that appearing of *L. inopinata* in the aquatic system might be evaluated as signal for low water quality. They also claimed that occurrence of *L. inopinata* depends on substrate quality. These results might be evaluated that existence of *L. inopinata* in the Lake Sunnet does not indicate pollution at least. However, in the previous study (Yılmaz and Külköylüoğlu 2006) concluded that *L. inopinata* can be used a sign to indicate negatively changing of water quality.

The second group (B) of the UPGMA diagram consists of a single species, *P. albicans*. It is more tolerant species (Table 5) for salinity (0.21±7.27) in this study. It can be argued that environmental variables have not significantly affect existence of this species, possibly due to its cosmopolitan characteristics. *Pseudocandona albicans* lives in permanent, muddy and slow flowing waters (Gülen 1985 a), while it prefers very low salt content (Meisch 2000). It is a crawling species that shows stygophilic behaviours (Roca and Danielopol 1991).

Third clustering group (C) of the UPGMA diagram, which consists of *I. getica, P. kraepelini I.inermis, C. neglecta, S. fischeri*, *P. eremite* and *I. bradyi*, can be divided into three subgroup that includes; C1) *I. getica*, C2) *P. kraepelini I. inermis* and *C. neglecta* C3) *, S. fischeri*, *P. eremite* and *I. bradyi*.

Member of the Ilyocypris genus, which is has wide distribution from river to lake, take place in weakly saline waters (Altınsaçlı et al., 2000). *Ilyocypris getica* is reported from ponds and ditches (Meisch 2000). It is not clear that it prefers the temporary habitats such as pools. It has a tolerance to slightly increase in salinity (Meisch 2000). On the contrary, this species has lowest salinity tolerance range rather than others in this study (Table 5).

Throughout the study, *P. kraepelini* was other recorded tolerant species for temperature (12±4.53 °C) in the second subgroup (C2) of third clusturing (C) of UPGMA. Indeed, Altınsaçlı (2001a) claimed that *P. kraepelini* is eurythermic species means that it can be tolerating wide range of temperature. Külköylüoğlu (1998) mentioned that *P. kraepelini* was widespread cosmopolitan species for lakes and can live at every environmental condition. In the recent study (Yılmaz and Külköylüoğlu 2006) this species was characterized as polythermophilic, mesohalophilic, eurychronal and also tolerant for high temperature with low alkalinity.

A positive relationship to redox potential and temperature belongs the spring, which *Ilyocypris inermis* was found, were recorded (Külköylüoğlu and Yılmaz 2006). It is possible to find it in waters with lower oxygen and also reported from cold waters with low salinity (Meisch 2000). In the present study, oxygen tolerance level (6.94±0.18) of it actually was the lower than the others. ETI values were also one of the lowest (Table 5).

The last member of the second subgroup (C3) of third cluster (C) is *C. neglecta*. Altınsaçlı and colleagues (2000a) argued that *C. neglecta* is widely common in Anatolia with low water current. In this study, there is no slightly difference according to optimum and tolerance range for salinity when it is compared with other species. On the other hand, Frenzel and Boomer (2005) described *C. neglecta* as halophilic fresh water species. Roca and Baltanás (1993) reported that it is common species in eutrophic aquatic systems. Additionally, Külköylüoğlu and colleagues (2007) mentioned that it was oligothermophilic species while it has also mesohalophilic. During the study, *C. neglecta* was recorded monthly in May and June 2006, although Külköylüoğlu (2005) said that existence of it is recorded continually during the year (eurychronal). Additionally, in these months lowest level of DO and highest level of BOD were recorded (Table 2). In the previous study (Griffiths et al., 1996) indicated existence of P. *albicans* and C. *neglecta* at low temperatures and high altitudes. Additionally, in the same study, a relation was indicated between P. *albicans* and *C. neglecta* and cooler temperatures depends on high altitude. *Prionocypris zenkeri*, which was recroded as subfossil form. *Pseudocandona eremita* is apparently restricted to deeper waters (Martín-Rubio et al., 2005). Roca and Baltanás (1993) reported that *I. bradyi* generally present in waters which can be characterized with eutrophication and low alkalinity. Last subgroup of third cluster of the UPGMA diagram consists of these three species; *S. fischeri*, *P. eremite* and *I. bradyi*. Throughout the study, recording of the species only at one month is specific characteristic of this group (Table 1). *Stenocypria fischeri* generally occurs between May and September, approximately summer forms (Meisch 2000). In the present study, it was recorded in June 2006. In Turkey, this species was firstly and lastly recorded by Schäfer (1952). After that there is no record about it from that time to nowadays. *Ilyocypris* sp., *Cypridopsis* sp., *Eucypris* sp., *Potamocypris* sp. and *Prionocypris zenkeri* were recorded to be as a fossil forms with together living species throughout the study.

Higher level of standart hydrogen electrode (SHE), which represents oxidation-reduction (redox) reactions in water, was recorded in November 2005 while the minimum value in August 2005 (Table 2). On the other hand, the maximum pH value was measured in March 2006 and minimum value was in Jun 2005. Additionally, it is seen a negative realtionship between SHE and pH in figure 8.

During the study, pH values ranged between 7.25 and 8.21, while average of it was value of it was 7.74. Because of these ranges of pH, the lake shows basic characteristic. Because of the high pH level, buffer system has tendency to accumulate bicarbonate in the ecosystem. This condition might cause calcium precipitation as to be $CaCO_3$. Calcium carbonate is important for occurring of Ostracoda shell structure. These situations might be having negative effects on occurring of Ostracoda in the lake because of the precipitation. A positive higher correlation ($p<0.01$) was only recorded between species number and conductivity (Table 8). Nitrogen and phosphate concentration of the lake was at very low level during the study (Table 3) that there were no significant correlation with other variables (Table 8). According to Spearman correlation analyses there was only negatively correlation between ammonia and air temperature. Average value of nitrogen is 0.1394 mg/l N while minimum and maximum values are 0.0046 mg/l and 1.1441 mg/l N. Additionally, average value of phosphate is 0.0095 mg/l P while minimum and maximum values are 0.0009 mg/l – 0.0217 mg/l P. These values are lowest than suggested level of nitrogen (less than 400 mg/l) as oligothrophic and phosphate (less than 10 mg/l) as ultraoligotrophic.

Biological and chemical data imply a mesotrophic conditions. It is possibly monomictic but lack of samples during winter season, this should be tested. Significant effect of air temperature and also water temperarure were concluded on species diversity of the lake. Consequently, it appears that Ostracoda fauna of the lake was dominated mostly cosmopolitan species. Both species number and individual numbers of species were low to evaluate them as indicator. Additionally, effects of sulphur gas on living species in the lake is fact that should be attracted attention. Two species, *C. ophthalmica* and *D. stevensoni* were recorded belongs to November 2001 reported by Külköylüoğlu (2003c). In the present study, these species were not recorded. These situations may be evaluated that for treatment to protect this habitats and new scientific investigations.

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APPENDICES

Appendix 1. 112 species were recorded in Turkey and its numerical cods.

Species	**Codes**		**Species**	**Codes**
Callistocythere rostrifera	CR1		*Ilyocypris hartmanni*	IH
Candona angulata	CA1		*Ilyocypris inermis*	II
Candona candida	CC		*Ilyocypris monstrifica*	IM
Candona muelleri	CM		*Ilyocypris salebrosa*	IS
Candona neglecta	CN		*Ilyocypris turca*	IT
Candonopsis kingsleii	CK		*Isocypris beauchampi*	IB3
Chrissia ousmana	CO1		*Kovalevskiella* sp.	K
Cyclocypris laevis	CL		*Leptocythere castanea*	LC
Cyclocypris ovum	CO2		*Leptocythere histriana*	LH
Cypretta dubiosa	CD		*Limnocythere dubiosa*	LD
Cypretta rotunda	CR2		*Limnocythere inopinata*	LI1
Cypria opthalmica	CO3		*Limnocythere mirabilis*	LM1
Cyprideis torosa	CT		*Limnocythere stationis*	LS
Cypridopsis parva	CP		*Loxoconcha immodulata*	LI2
Cypridopsis hartwigi	CH		*Loxoconcha tamarindus*	LT
Cypridopsis vidua	CV		*Notodromas monacha*	NM
Cypris bispinosa	CB		*Notodromas persica*	NP
Cypris pubera	CP		*Paralimnocythere psammophila*	PP

Cytherissa lacustris	CL2		*Paralimnocythere relicta*	PR
Cytheretta adriatica	CA2		*Physocypria kraepelini*	PK
Darwinula stewensoni	DS1		*Plesiocypridopsis newtoni*	PN
Dolerocypris fasciata	DF		*Potamocypris fallax*	PF
Dolerocypris pellucida	DP		*Potamocypris arcuata*	PA1
Dolerocypris sinensis	DS2		*Potamocypris longisetosa*	PL
Eucypris lilljeborgi	EL		*Potamocypris steueri*	PS
Eucypris pagasti	EP1		*Potamocypris unicaudata*	PU
Eucypris pigra	EP2		*Potamocypris variegata*	PV1
Eucypris hamadanensis	EH		*Potamocypris villosa*	PV2
Eucypris inflata	EI		*Potamocypris zschokkei*	PZ1
Eucypris virens	EV		*Prionocypris zenkeri*	PZ2
Fabaeformiscandona csickii	FC1		*Pseudocandona dispar*	PD
Fabaeformiscandona fabaeformis	FF		*Pseudocandona albicans*	PA2
Fabaeformiscandona fabaeformis potamocypris cf. vulva	FFPV		*Pseudocandona compressa*	PC

Fabaeformiscandona caudata	FC2		*Pseudocandona eremita*	PE
Herpetocypris brevicaudata	HB		*Pseudocandona fontinalis*	PF
Herpetocypris chevreuxi	HC		*Pseudocandona hartwigi*	PH
Heterocypris incongruens	HI		*Pseudocandona marchica*	PM
Herpetocypris reptans	HR1		*Psychrodromus olivaceus*	PO
Heterocypris rotundata	HR2		*Psychrodromus turcicus*	PT
Heterocypris sabirae	HS1		*Sarscypridopsis aculeata*	SA
Heterocypris salina	HS2		*Scottia pseudobrowniana*	SP
Heterocypris turcica	HT		*Semicytherrura sulcata*	SS
Heterocythereis albomaculata	HA		*Stenocypria fischeri*	SF
Humpcypris subterranea	HS3		*Stenocypris malcolmsoni*	SM
Hungarocypris madaraszi	HM		*Tonnacypris laturia*	TL
Ilyocypris biplicata	IB3		*Trajancypris clavata*	TC
Ilyocypris bradyi	IB1		*Trajancypris serrata*	TS

Ilyocypris brehmi	IB2		*Tyrrhenocythere amnicola*	TA
Ilyocypris decipiens	ID1		*Tyrrhenocythere donetziensis*	TD
Ilyocypris divisa	ID2		*Zonocypris* cf. *costata*	ZC
Ilyocypris gibba	IG		*Zonocypris inconspicua*	ZI

Appendix 2. Species list recorded in Turkey from 1903 to 2007.

Time	Source	Location	Species
1903	Von Daday, (1903)	Bursa	LD
1952	Schäfer, (1952).	Çankırı	CP, IB2, EP1, SF, HT, ZI
1964	Hartmann,(1964)	Çankırı	PA1
1964	Hartmann,(1964)	Antakya, Mersin, Ağrı	HS2
1964	Hartmann,(1964)	Antakya, Bolu	PZ1
1964	Hartmann,(1964)	Gaziantep, Malatya	ZC
1964	Hartmann,(1964)	Mersin, Antakya	HI, HC
1964	Hartmann,(1964)	Gaziantep	PT, PZ2, CN, EL, PK
1964	Hartmann,(1964)	Kocaeli, Bolu, Zonguldak	PO, FC1, PD, ID1
1972	Şahin, and Baysal, (1972)	Elazığ	CM
1973	Ghetti,(1973)	Sinop, Samsun	PC, DP, IH
1973	Ghetti,(1973)	Kastamonu	LI1, HI, SM, CO1, CR, IT
1972-1974	Şahin, and Baysal, (1972); Tareen, (1974)	İzmir, Elazığ	EV, CM
1973-1975	Ghetti,(1973); Gülen,(1975)	İzmir, Sinop, Samsun	EV, PC, DP, IH

1973-1977	Ghetti,(1973); Gülen,(1977)	Kütahya, Kastamonu	CO2, HS2, PO, CN, ID2, LI1, HI, SM, CO1, CR, IT
1977	Gülen,(1977)	İzmir	HC, CL2, PA1, HI, EH
1974-1977	Tareen, (1974); Gülen,(1975-77)	Eskişehir, Kütahya, İzmir	CD, EV
1977	Gülen,(1977)	Kütahya	CO2, HS2, PO, CN, ID2
1977-1977	Gülen,(1977); Gülen,(1977)	Eskişehir, İzmir	SM, PZ2, HC, CL2, PA1, HI, EH
1977	Gülen,(1977)	Eskişehir, Kütahya	CD
1977	Gülen, (1977)	Kütahya, İzmir	TL, EV, IG, CP, DS2
1977	Gülen,(1977)	Eskişehir	SM, PZ2
1977	Gülen, (1977)	Kütahya, İzmir	TL, EV, IG, CP, DS2
1977	Gülen, (1977) ; Margaritoria et al., 1977	Sakarya, İzmir, Urfa	PK, TC
1982-1984	Gülen, D., (1982); Gülen,(1984)	İzmir, Aydın, Muğla	HI, NM, NP

1984	Gülen,(1984)	İzmir	HC, EH, HS1, CL2, CT
1984	Gülen,(1984)	Kütahya, Aydın	HS2, CN
1984	Gülen,(1984)	Kütahya	CD, TL, CO2, DS2, CP, IG
1984	Gülen,(1984)	Aydın	EV
1984	Gülen,(1984)	Kütahya, Denizli	ID2
1985	Gülen,(1985 a)	Bursa	IB3
1985	Gülen,(1985 a)	Bilecik	IB3, IB1, CP
1984-1985	Gülen,(1984); Gülen,(1985 a)	Kütahya, Denizli	ID1, CO2, ID2
1985	Gülen,(1985 a)	Antalya, Denizli	ID2
1985	Gülen,(1985 a,b)	Balıkesir, Kütahya, Nevşehir, Bursa, Bilecik	IG, IB3
1985	Gülen,(1985 a)	İzmir, Antalya, Bilecik	EL, IB1
1985	Gülen,(1985 a)	Kütahya	ID1
1985	Gülen,(1985 a)	İstanbul, Çanakkale, Bolu, Zonguldak, Kırklareli, Balıkesir, Antalya, Denizli	CV, ID2
1985	Gülen,(1985 a,b)	İzmir, Balıkesir, Kütahya, Nevşehir	PN, HS1, TC, CT, PA2, IG
1985	Gülen,(1985 a)	İzmir, Antalya	EL
1985	Gülen,(1985 a)	Bursa, Aydın, Eskişehir,	HS2, CV

		Bilecik, Antalya, Bolu, Zonguldak, İstanbul, Çanakkale, Bolu, Zonguldak, Kırklareli, Balıkesir	
1985	Gülen,(1985 a)	İzmir	PN
1985	Gülen,(1985 a)	Kastamonu, Afyon, Aydın, Burdur, Isparta, Antalya, Muğla, Zonguldak	HI
1985	Gülen,(1985 a, b)	Kütahya, Bolu, Bilecik, Muğla, Bursa	HC
1985	Gülen,(1985 a, b)	Bursa, Afyon, Aydın, Eskişehir, Bilecik, Antalya, Bolu, Zonguldak	PO, HS2
1985	Gülen,(1985 a, b)	Isparta, Eskişehir, Bolu, Afyon	PZ2
1985	Gülen,(1985 a)	Istanbul, Muğla, Aydın, Manisa, Afyon, Antalya, Zonguldak, Bursa	EV, PO
1985	Gülen,(1985 a, b)	Van, Isparta, Eskişehir, Bolu, Afyon	LI1, PZ2
1985	Gülen,(1985 a, b)	Bolu, Afyon, Manisa, Antalya	DS1, TL

1985	Gülen,(1985a)	Antalya, Istanbul, Muğla, Aydın, Manisa, Afyon, Antalya, Zonguldak, Bursa	CL2, EV
1985	Gülen,(1985 a)	Istanbul, Van	PE, CO3, PR, SA, LI1
1985	Gülen,(1985 a, b)	İzmir, Aydın, Bilecik, Bolu, Zonguldak, Afyon	CN, DS1
1985	Gülen,(1985 a, b)	Antakya, Antalya	CK, CL2
1985	Gülen,(1985 a)	Istanbul	PE, CO3, PR, SA
1985	Gülen,(1985 a)	Bursa, Balıkesir, Muğla, Bolu, Zonguldak	PK
1985-86-88	Gülen,(1985 a, b); Carbonel et al. (1986); Gülen,(1988)	Antakya	K, CK
1988	Altınsaçlı, (1988)	İzmir	PO, HC, PN, PV2, SA, PZ1, HS1
1988	Altınsaçlı, (1988); Gülen,(1988)	İzmir, Antakya	HS2
1988	Altınsaçlı, (1988); Gülen,(1988)	İzmir, Mersin, Adana	HI
1988	Gülen,(1988)	Mersin, Antakya, Adana	EV

1988	Gülen,(1988)	Mersin, Antakya	TL
1988	Gülen,(1988); Altınsaçlı, (1988)	İzmir, Antakya	CL2, CP, HS2
1988	Gülen,(1988); Altınsaçlı, (1988)	İzmir, Mersin, Adana	CN, EH, HI
1988	Altınsaçlı, (1988); Gülen,(1988)	İzmir, Mersin, Antakya	IB3, IB1, ID1, ID2, II, NM, TL
1988	Gülen,(1988).	Antakya	CL2, CP
1988	Gülen,(1988)	Adana	CN
1988	Altınsaçlı, (1988); Gülen,(1988); Altınsaçlı, (1988)	İzmir, Adanaİzmir	IG, IB3, IB1, ID1, ID2, II, NM
1988	Altınsaçlı, (1988)	Kütahya, İzmir	CP
1988	Altınsaçlı, (1988); Gülen,(1988)	İzmir, Adana	IG
1988	Gülen, (1988); Altınsaçlı, (1988)	Mersin, İzmir	EI
1988	Altınsaçlı, (1988)	Kütahya, İzmir	CP
1990-1988	Altınsaçlı, Kubanç,(1990); Gülen, (1988); Altınsaçlı, (1988)	Balıkesir, Mersin, İzmir	SM, HS2, IB1, EI
1990	Altınsaçlı, and Yılmam,(1990)	İstanbul	TD, CN, LI2, DS1, PC, EI,

			CP, PM, CO3, PK, IB3
1990	Altınsaçlı, and Yılmam,(1990); Altınsaçlı, Kubanç,(1990)	İstanbul, Balıkesir	CV, PN, HI, IG
1990	Altınsaçlı, Kubanç,(1990)	Balıkesir	SM
1990	Altınsaçlı, and Yılmam,(1990); Altınsaçlı, Kubanç,(1990)	İstanbul, Balıkesir	CV, PN
1990	Kubanç, Altınsaçlı, (1990); Altınsaçlı, and Yılmam, (1990); Altınsaçlı, Kubanç, (1990)	Balıkesir, İstanbul, İzmir	CT
1992-1993	Kılıç, (1992); Külköylüoğlu, Altınsaçlı, Kubanç, (1993); Altınsaçlı, (1993); Kaleli, (1993)	İstanbul	ID1, PV2, PO, HC, HI, HS2, EV, IB1, CP, LC, CT, CA2, IB3, CO2, II
1993	Altınsaçlı, (1993); Von	Bursa	DS1, CV, PZ1,

	Daday, (1993); Külköylüoğlu, Altınsaçlı, Kubanç, (1993); Kaleli, (1993)		PZ2, TL, PK, PM, CK, CO3, CO2, CD, S2, CP, LI1, PV2, PO, HC, ID1, HI, HS2, EV, IB1, CN, TD, IB3, II
1993	Külköylüoğlu, Altınsaçlı, Kubanç, (1993); Altınsaçlı, (1993); Kaleli, (1993)	Sinop, Samsun	ID1, PV2, PO, HC, HI, HS2, EV, IB1, CT, CO2, CN, LI2, IB3,
1993	Altınsaçlı, (1993); Von Daday,. (1993); Kaleli, (1993)	Sakarya	TD, LI1, CN, LI2
1993	Kaleli, (1993); Altınsaçlı, (1993)	Kocaeli	CN, LI2
1993-1994	.Külköylüoğlu, Altınsaçlı, Kubanç, (1993); Altınsaçlı, (1993); Gülenet al., 1994a	Antalya, İstanbul, Bursa	LI1, II

1994	Gülen, Altınsaçlı, Kubanç, Kılıç, (1994a, b)	Tokat	PZ2, II
1994	Gülen, Altınsaçlı, Kubanç, Kılıç, (1994a, b)	Van	TS, CL, CP, II, IB1, HI
1994	Gülen, Altınsaçlı, Kubanç, Kılıç, (1994 a,b)	Çorum, Trabzon, Kars	CD, HI
1994	Gülen, Altınsaçlı, Kubanç, Kılıç, (1994 a,b); Gülenet al., 1994a.	Denizli, Uşak, Çankırı, Antalya	HS2, LI1
1994	Gülen, Altınsaçlı, Kubanç, Kılıç, (1994 a, b); Gülen, Altınsaçlı, Kubanç, Kılıç, (1994b)	Trabzon, Tokat	CV, CO3, CP, IB1, IB3, IG, PZ2
1994	Gülen, Altınsaçlı, Kubanç, Kılıç, (1994 a, b)	Konya, Van	PZ1, TS
1994	Gülen, Altınsaçlı, Kubanç, Kılıç, (1994 a,b); Gülen, Altınsaçlı, Kubanç, Kılıç, (1994 a,b)	Malatya, Van, Konya, Denizli, Uşak, Çankırı	PA1, PO, HS2
1994	Gülen, Altınsaçlı, Kubanç, Kılıç, (1994a,b)	Erzurum, Kahramanmaraş, Amasya, Trabzon	HC, CV

1994	Gülen, Altınsaçlı, Kubanç, Kılıç, (1994a, b)	Elazığ, Çorum	TL, II, EH, CD
1994	Gülen, Altınsaçlı, Kubanç, Kılıç, (1994 a,b)	Malatya, Van, Konya	PA1, PO
1994	Gülen, Altınsaçlı, Kubanç, Kılıç, (1994a).	Antalya, Rize	IB3
1994	Gülen, Altınsaçlı, Kubanç, Kılıç, , (1994a,b).	Antalya, Kars, Ankara	IB1
1994	Gülen, Altınsaçlı, Kubanç, Kılıç, (1994b).	Kahramanmaraş	ID2
1994	Gülen, Altınsaçlı, Kubanç, Kılıç, (1994a,b).	Çankırı	IG
1994	Gülen, Altınsaçlı, Kubanç, Kılıç, , (1994a,b).	Kayseri, Antalya, Kars, Ankara	EI, IB1
1994-1995	Gülen, Altınsaçlı, Kubanç, Kılıç, (1994b); Külköylüoğlu, Altınsaçlı, Kubanç and Kılıç, (1995); Öztürk, (1995).	İstanbul, Kahramanmaraş	CT, LI1, EH, ID2
1995	Külköylüoğlu, Altınsaçlı, Kubanç, Kılıç,(1995);	İstanbul	TL, PK, HI, PL, PV1, PV2, PZ1,

	Külköylüoğlu, Altınsaçlı, Kılıç, Kubanç, (1995); Öztürk, (1995)		CP, CV, HS2, PZ2, EV, IB1, IB3, IG, PV1, LT, CR1, PL SS, HA, EI, CT, LI1, EH
1996	Çakıl, (1996); Gülen, Özuluğ, and Bilgin, (1996).	Diyarbakır	DS1, HS2, HR1, PZ2, TC, EP2, EL, CN, CO3, CP, EV, CV, HI, HC, IB1, PA1
1996	Çakıl, (1996); Gülen, Özuluğ, and Bilgin, (1996)	İstanbul	EV, CV, HI, HC, IB1, HS2, CP, CT, IB3, PO
1996	Çakıl, (1996); Gülen, Özuluğ, and Bilgin, (1996)	İzmir,	PA1, EV
1996	Gülen, Özuluğ, and Bilgin, (1996); Çakıl, (1996)	Isparta,	PO
1996	Çakıl, (1996);	Elazığ, Van, Rize	PV2

1997	Altınsaçlı, (1997)	Kocaeli, Sakarya	PK, CO3, CN, HS2, HC, HI, PO, EV, DS1, CA CK FF EL DS2 CP CB, IB3, IB1, CT
1997	Kılıç, (1997); Altınsaçlı, (1997)	Zonguldak, Kastamonu, Kocaeli, Sakarya	PV2, II, PK, CO3, CN, HS2, HC, HI, PO, EV, DS1, CA CK FF EL DS2 CP CB, IB3, CT
1997	Kılıç, (1997); Altınsaçlı, (1997)	Eskişehir, Ordu, Sakarya	CV
1997	Kılıç, (1997)	Giresun	PS
1997	Kılıç, (1997)	Kirklareli	LI1
1997	Kılıç, (1997)	Rize, Kırklareli	CT
1997	Altınsaçlı, (1997)	Eskişehir	IB1
1997	Altınsaçlı, (1997)	Antalya	IB3
1997-1998	Altınsaçlı, (1997); Külköylüoğlu, (1998)	Istanbul, Kocaeli	ID2, EL, IB3, PK, EV, PV1, PV2, TL, ID1, EH, CO3, PZ2,

			HI, CV, IB1
1998	Altınsaçlı, (1998)	İzmir	CT
1998	Aygen and Balık, (1998)	İzmir, Sakarya, Eskişehir	IG, PO, HC, EV, CL2, ID1, CN, CO3, IB1, PZ2, TL, HI, CV, IB1
1999	Gülen, Altınsaçlı, (1999)	Eskişehir, Ankara, Antalya	IB3
1999	Altınsaçlı, (1999)	Bursa	IB1, ID1, DS2, IB3, LI2, CV, HI, TL, HC, PZ2, LI1, PM, CK, CO2, EV
1999	Altınsaçlı, (1999); Altınsaçlı, (1999)	İzmir, Bursa	CN, IB1, ID1, DS2, IB3, LI2, CV, HI, TL, HC, PZ2, LI1, PM, CK, CO2
1999	Gülen, Altınsaçlı, (1999); Gülen, Altınsaçlı, (1999)	Kütahya, Bilecik, Sakarya, Ankara, Eskişehir, Bolu	EV, IB1, TD, PV2, CV, HI, PZ2, IG, CO3, CN, PZ1, PO
1999	Gülen, Altınsaçlı,	İstanbul, Kütahya, İzmir	PK, PZ2, CN

	(1999); Altınsaçlı, (1999)		
1999-2000	Gülen, Altınsaçlı, (1999); Altınsaçlı, Kılıç and Altınsaçlı, (2000 a);	Konya, Isparta, Sakarya,	PZ1, CV, HS2, HI, HR2, PO, PZ2, EV, CN, PC, CO3, PK, IG, IB1, IB3, TD
1999-2000	Gülen and Altınsaçlı,(1999); Koç, (2000)	İstanbul, Bilecik, Bolu, Kütahya	PZ1, PV1, PS, PN, CV, EV, CP, LI1, CO3, PK, CN
1999-2000	Gülen, Altınsaçlı, (1999); Altınsaçlı, Kılıç and Altınsaçlı, (2000 b)	Afyon, Kütahya, Eskişehir	CV, HS2, HI, PO, PZ2, LI1, CA, CN, PC, IG, IB3, CO3
1999-2000	Altınsaçlı, (1999); Altınsaçlı, Kılıç, Altınsaçlı,(2000a)	Konya, Sakarya	DS1, LI1, CA, PK
2000	Kılıç, Altınsaçlı, Balkıs, Balkıs, (2000); Altınsaçlı, Kılıç and Altınsaçlı, (2000 a)	ÇanakkaleKonya, Isparta,	EI, CT, PZ1, CV, HS2, HI, HR2, PO, PZ2, EV, CN, PC, CO3, PK, IG,

			IB1, IB3
2000	Koç, (2000)	İstanbul	PZ1, PV1, PS, PN, CV, EV, CP, LI1, CO3, PK
2000-2001	Altınsaçlı, Kılıç and Altınsaçlı, (2000 b); Altınsaçlı, (2001b)	Kırklareli, Afyon	PM, PH, FF, CN, LS, CT, CK, IM, CB, CO3, LI1, EI, EV, PO, CV, HS2, HI, PO, PZ2, LI1, CA, CN, PC, IG, IB3
2000-2001	Altınsaçlı, Kılıç, Altınsaçlı,(2000a); Altınsaçlı and Griffiths, (2001a,b)	Bursa, Konya	CN, DS1, FC2, CA, HI, HC, TL, CV, PV2, IG, CP, PK, DS1, LI1, CA
2000-2001	Kılıç, Altınsaçlı, Balkıs, Balkıs, (2000); Altınsaçlı and Griffiths, (2001 c)	Konya, Çanakkale	LM1, EI, CT
2001	Özuluğ, Kubanç, Gülen,	Isparta, Kırklareli	HI, HS2, PM,

	(2001); Altınsaçlı, (2001a); Altınsaçlı, (2001b)		PH, PC, FF, CN, LS, CT, CK, IM, CB, CO3, LI1, EI, EV, PO, HI
2001	Kılıç, (2001); Altınsaçlı and Griffiths, (2001a,b)	İstanbul, Bursa	HS2, CN, DS1, FC2, CA, HI, HC, TL, CV, PV2, IG, CP, PK
2001	Altınsaçlı, (2001a); Altınsaçlı and Griffiths, (2001 b); Özuluğ, Kubanç, Gülen, (2001); Altınsaçlı and Griffiths, (2001 c)	Isparta, Konya	CH, PV1, PN, PO, PZ2, CN, EI, IG, CP, LM1, HM
2001	Kılıç, (2001); Özuluğ, Kubanç, Gülen, (2001); Altınsaçlı, (2001a)	Isparta	PF, HI, HS2
2001	Kılıç, (2001)	Giresun, İstanbul	PS, HS2
2001	Altınsaçlı, (2001a,b); Özuluğ, Kubanç, Gülen, (2001); Kılıç, (2001);	Isparta, Kırklareli, Ordu,	CV, CH, PV1, PN, PO, PZ2, CN, EI, IG, CP,

	Altınsaçlı and Griffiths, (2001 b); Özuluğ, Kubanç, Gülen, (2001)		IB1, CO3
2001	Altınsaçlı and Griffiths, (2001 a,b); Özuluğ, Kubanç, and Gülen,(2001); Altınsaçlı, (2001a); Kılıç, (2001); Altınsaçlı and Griffiths, (2001 c)	Bursa, Isparta, Afyon,	DS1, LI1, EV, HM
2001	Kılıç, (2001)	Sinop, Kastamonu	II, PF
2001	Altınsaçlı and Griffiths, (2001b,c); Kılıç, (2001)	Bursa, Kırklareli, Giresun	IB3, PS
2001	Altınsaçlı, (2001a,b); Özuluğ, Kubanç, Gülen, (2001); Kılıç, (2001)	Konya,	CO3, IB1, CV
2001-2002	Altınsaçlı and Griffiths, (2001 a,b); Özuluğ, Kubanç, and Gülen,(2001); Altınsaçlı, (2001a); Kılıç, (2001); Aygen and Balık,(2002)	İzmir, Bursa, Isparta	CP, HM TC, DS1, LI1, EV
2001-	Kılıç, (2001); Aygen and	Bursa, Sinop, Kastamonu	DS1, II

2002	Balık, (2002)		
2001-2002	Altınsaçlı and Griffiths, (2001b,c); Aygen and Balık,(2002)	Kütahya, Bursa, Kırklareli	CP, IB3
2001-2003	Altınsaçlı, (2001a); Özuluğ, Kubanç, and Gülen, (2001); Külköylüoğlu, (2003a)	Bolu, Konya, Isparta	SP, CO3, IB1
2002-2003	Aygen and Balık, (2002); Külköylüoğlu, (2003b,d)	İzmir, Bolu	IB3, PP, CP, HM, TC
2002	Aygen and Balık, (2002)	Kütahya	CP
2002-2003	Aygen and Balık, (2002); Özuluğ, (2003)	Bursa	IS, DS1
2003-2004	Külköylüoğlu, (2003a) ; Aygen et al., 2004	Köyceğiz, Bolu	HS3, HB, SP
2005-2006	Külköylüoğlu, (2005c); Yılmaz, Külköylüoğlu, (2006)	Bolu	LI1, CC, CV, DS1, EV, LI1, PK, TL
2006	Karakaş-Sarı (2006)	Bolu	SP
2007	Külköylüoğlu et al., 2007; Dügel et al., 2007	Bolu	CC, CN, DS1, IB1, CV, CO3, PK, PC

2007	Külköylüoğlu et al., 2007	Bolu	PZ2, EV, HR1, FFPV
2007	Dügel et al., 2007	Bolu	HI, NM, EP2, HC, PO, PF, CP

PHOTOS

Photo 1. Station 1

Photo 2. Station 2

Photo 3. Station 3 and 4.

Photo 4. Water and sediment sampling.