

**DETERMINATION OF EFFECTS OF CLIMATIC AND  
HYDROLOGICAL CHANGES OF LAKE ÇUBUK (BOLU, TURKEY)  
ON OSTRACODA (CRUSTACEA) SPECIES AND  
LIMNOECOLOGICAL STRUCTURE**

**by**

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**THESIS SUBMITTED TO  
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES  
OF  
THE ABANT İZZET BAYSAL UNIVERSITY  
IN PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE DEGREE OF  
DOCTOR OF PHILOSOPHY  
IN  
THE DEPARTMENT OF BIOLOGY**

**SEPTEMBER 2013**

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**TO MY FAMILY**

## ABSTRACT

# DETERMINATION OF EFFECTS OF CLIMATIC AND HYDROLOGICAL CHANGES OF LAKE ÇUBUK (BOLU, TURKEY) ON OSTRACODA (CRUSTACEA) SPECIES AND LIMNOECOLOGICAL STRUCTURE

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September 2013, 214 Pages

During this study, samples were collected from 11 stations (5 being littoral and the other 6 vertical) in Lake Çubuk (Göynük, Bolu, Turkey) between July 2008 and November 2010. 17 species belonging to 10 genera (*Candona neglecta*, *C. candida*, *C. sanociensis*, *C. weltneri*, *Pseudocandona albicans*, *P. eremita*, *P. semicognita*, *P. sucki*, *Fabaeformiscandona brevicornis*, *F. japonica*, *Physocypria kraepelini*, *Cypria ophtalmica*, *Ilyocypris gibba*, *Cypridopsis vidua*, *Limnocythere inopinata*, *Trajancypris serrata*, *Prionocypris zenkeri*) were detected. One of them (*F. japonica*) was registered as a new report for the Turkish Ostracoda fauna, yet another (*P. sucki*) was registered for the second time.

Unweighted Pair Group Mean Averages (UPGMA) of 10 species displayed clustering relationships based on ecological preferences among three groups.

According to Spearman Correlation Analysis concerning 13 species and nine environmental variables, *C. sanociensis* showed positive relation with pH and Biological Oxygen Demand (BOD5), while *C. weltneri* was the only species showing negative correlation with dissolved oxygen.

Canonical correspondence analysis (CCA) explained 77% ( $\pm 1.74\%$  error) of the relationship between the species and four environmental variables (temperature, electrical conductivity, turbidity and redox potential).

The overall surface area and the total volume of the lake was estimated at 16.03 hectares and 651.300 m<sup>3</sup> on the bathymetric map. The length of the lake was 685 m, when its width was measured about 430 m during the present study.

The depth of the lake reached to maximum level in spring (8.5 m) and its Secchi disc transparency was about 134.3 cm.

According to sedimentation analyses, the lake accumulated 0.84 cm of sediment on average per month, while no remarkable accumulation was detected in pesticide (OCP) analyses.

According to Piper diagram analyses water chemistry of the lake evolved from Ca-Mg-HCO<sub>3</sub> water type to Na-Ca-HCO<sub>3</sub> dominance. This result was confirmed by Principal Component Analysis (PCA).

According to thermal stratification data, isogram (isopleth) results, stability analyses, stratification index (SI) and Wedderburn (W) values, Lake Çubuk appeared to be dimictic. Moreover, according to Wedderburn formulation, wind was the more efficient factor than temperature during the turnover time. Based on the average results of both Carlson Trophic State Index (CTSI) and Burns Trophic Level Index (BTLI), the lake has reached the mesotrophic level at the end of this study.

It has been found out that especially the Fall Turnover, ion content and eutrophication rate were very important factors on species composition. Results indicated that swimming and cosmopolitan species were more widespread.

**Keywords:** Ostracoda, dimictic, mesotrophic, Piper Diagram, Lake Çubuk, Bolu

## ÖZET

# ÇUBUK GÖLÜNÜN (BOLU, TÜRKİYE) İKLİMSEL VE HİDROLOJİK DEĞİŞİMLERİNİN OSTRAKODA (CRUSTACEA) TÜRLERİ VE LİMNÖKOLOJİK YAPI ÜZERİNE ETKİLERİNİN BELİRLENMESİ

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Eylül 2013, 214 Sayfa

Bu çalışma boyunca, Çubuk Gölü'ndeki (Göynük, Bolu, Türkiye) toplam 11 istasyondan (5 littoral ve 6 vertikal) Temmuz 2008 ve Kasım 2010 tarihleri arasında örnekleme yapılmıştır. Toplam 10 cinse ait, 17 tür (*Candona neglecta*, *C. candida*, *C. sanociensis*, *C. weltneri*, *Pseudocandona albicans*, *P. eremita*, *P. semicognita*, *P. sucki*, *Fabaeformiscandona brevicornis*, *F. japonica*, *Physocypria kraepelini*, *Cypria ophtalmica*, *Ilyocypris gibba*, *Cypridopsis vidua*, *Limnocythere inopinata*, *Trajanocypris serrata*, *Prionocypris zenkeri*) bulunmuştur. Bir tür (*F. japonica*) Türkiye ostrakot faunası için yeni kayıt olurken , bir tür de (*P. sucki*) ikinci defa rapor edilmiştir.

Ağırlıksız Basit Çift Grup Ortalama Analizi (UPGMA) 10 türün ekolojik tercihlerine göre üç grupta kümelendiğini göstermektedir. Örnekleme boyunca, tespit edilen 13 tür ve dokuz çevresel değişken arasındaki ilişkilerin Spearman Korelasyon Analiz sonuçlarına göre *C. sanociensis* pH ve Biyolojik Oksijen İhtiyacı (BOD5) ile pozitif bir ilişki gösterirken, *C. weltneri* çözünmüş oksijen ile negatif korelasyon gösteren tek türdür.

Çok Yönlü Bağlantılı Uyum Analizi'nin (Canonical correspondence analysis, CCA) ilk eksenini türler ile dört çevresel değişken (sıcaklık, elektriksel iletkenlik, turbidite ve redoks potansiyeli) arasındaki ilişkinin %77 kadarını (%1.74'lük bir hata ile) açıklayabilmektedir.

Batimetrik haritadan gölün toplam yüzey alanı 16.03 hektar ve toplam hacmi 651.300 m<sup>3</sup> olarak hesaplanmıştır. Bu çalışma boyunca gölün boyu 685 m iken, eni 430 m. olarak ölçülmüştür. İlkbahar aylarında göl derinliğinin maksimum seviyeye (8.5 m) ulaşmıştır ve ortalama Secchi disk görüş mesafesi ise 134.3 cm olarak kayıt edilmiştir. Sedimentasyon analizine göre göl aylık ortalama 0.84 cm sediment biriktirirken, pestisit (OCP) analizlerinde kayda değer bir sonuç tespit edilememiştir.

Piper diagram analizinde gölün su kimyasının Ca-Mg-HCO<sub>3</sub> su tipinden, Na-Ca-HCO<sub>3</sub> baskınlığına doğru evrildiği tespit edilmiştir. Temel Bileşen Analizi de (Principal Component Analysis, PCA) bunu doğrulamaktadır.

Termal katmanlaşma verileri, izogram (isopleth) sonuçları, stabilite analizi, stratifikasyon indeksi (SI) ve Wedderburn (W) değerlerine göre Çubuk Gölü dimiktik bir göl olarak karşımıza çıkmaktadır. Ayrıca Wedderburn formülasyonuna göre rüzgar, sıcaklığa göre gölün karışım dönemi boyunca daha etkili bir faktördür. Hem Carlson Trofik Durum İndeksi hem de Burns Trofik Düzey İndeksi ortalama sonuçlarına göre göl, bu çalışma sonunda mesotrofik düzeye ulaşmıştır.

Özellikle sonbahar karışımı, suyun iyon içeriği ve ötrikasyon oranının tür kompozisyonu üzerinde çok etkili faktörler olduğu ortaya çıkmıştır. Sonuçlar yüzücü ve kozmopolitan türlerin daha yaygın olduğunu göstermiştir.

**Anahtar Kelimeler:** Ostrakoda, dimiktik, mesotrofik, Piper Diagram, Çubuk Gölü, Bolu

## ACKNOWLEDGEMENTS

I express sincere appreciation to Prof. Dr. Okan KÜLKÖYLÜOĞLU for his guidance and insight throughout the research. I am greatly indebted to my parents Fikriye-Abdulrezak SARI, for their supports during my education. Also, my wife Pınar KARAKAŞ SARI must be acknowledged for her infinite trust and kind help to me during this study. I am also thankful to committee members, Prof. Dr. Cemal TUNOĞLU, Prof. Dr. Fatih EVRENDİLEK, Prof. Muzaffer DÜGEL and Assoc. Prof. Dr. Azra BOZCAARMUTLU. I offer my sincere thanks to M. Süalp GÜLER and Mehmet YAVUZATMACA for their supports during the field study. Also, I would thank Dr. Sahra KIRMUSAOĞLU and Hatice KARADENİZ for their help in the laboratory and Dr. Derya AKDEMİR for her help during SEM photographing. Dr. Eric WIENCKOWSKI (Monroe, New York, U.S.A.) is also thanked for his help to prepare the bathymetric map of Lake Çubuk. Thanks must also be given to Prof. Dr. Serpil YENİSOY KARAKAŞ for her help during pesticide analyses and Ömer BURAK for his help during core sampling. This study was supported by The Scientific and Technological Research Council of Turkey (TÜBİTAK) with project number 108Y067.

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## 1. INTRODUCTION

One of the oldest crustacean groups, the ostracods can be found in almost all types of aquatic habitats such as brackish, fresh and saline waters, including underground waters, cave waters and semiterrestrial habitats. They have wide tolerance levels to different environmental variables. Any species tolerates in different levels to the different ecological parameters of the aquatic habitats where they live (Delorme 1991). Some ostracod species can be used as bioindicator species to inform about water quality (Klkylođlu 1999b). In total, about 65000 nominal extant (of which approximately 8000 living species; Horne et al., 2002) and fossil species have been described (Ikeya et al., 2005) and it is estimated that more than 20000 living species exist (Horne et al., 2002; Ikeya et al., 2005). There are almost 2000 subjective species with 200 genera of the recent non-marine Ostracoda where two families Cyprididae and Candonidae contained more than 75% of the extant specific diversity including 1000 spp. and 550 spp., respectively (Martens et al., 2008).

Both previous and ongoing studies reported about 140 non-marine ostracod species from Turkey (Klkylođlu, pers. comm.). However, this number is believed to be much higher because of two possible reasons; (1) difficulties in taxonomic works in many regions unsampled so far, and (2) a few ostracodologists are found not only in Turkey but also in the world.

The Bolu province that belongs to western Black Sea Region of Turkey is a transition zone between the three vast regions (Karadeniz, Marmara and Central

Anatolia). Therefore, it is possible that the cosmopolitan and transition species can be more because of their role as a bridge between the different regions.

There are more than 120 natural and about 706 artificial lakes in Turkey (DSİ 2012). The amount of the total available surface water is  $98 \times 10^9 \text{ m}^3$ . Turkey is in the list of countries that have water scarcity, based on the amount of per capita ( $1519 \text{ m}^3$ ). Accordingly, the protection of freshwater resources is of great importance. Here, as a part of this fact, Lake Çubuk is an essential freshwater resources that must be protected.

The term “climatic changes” used in the title refers to changes in the meteorological conditions, not to be confused with climate change.

In the light of this information, the aims of this study were to (1) establish a detailed spatio-temporal record of both species and physicochemical characteristics of Lake Çubuk, (2) report ecological tolerance and optimum values of individual species, (3) identify the effect of hydro-physical/chemical properties of the lake on species composition, (4) determine the trophic state of Lake Çubuk based on eutrophication rate and (5) draw attention to the importance of protecting freshwater resources.

## **1. 1. Ostracoda**

Although the first ostracod (*Monoculus conchapedata*) was firstly named by Linné in 1746 (Ferguson 1944), first formally described of these small bivalved crustaceans was done by O. F. Müller in 1772 (Viehberg 2006). These aquatic invertebrates were first named as ‘Ostrachoda’ by Latreille in 1802, and then, the name was changed to ‘Ostracoda’ in 1806 by him (Ikeya et al., 2005). Ostracods are small aquatic invertebrate animals with an adult length varying between 0.2 and 32

mm (Karanovic 2012) with the majority of freshwater species (Henderson 1990), especially in some marine planktonic Myodocopida (Martens 1998). It is an ancient group with a true fossil record spreading to the Ordovician (Martens 1998). They are bivalved invertebrates with a pair of calcium carbonated carapace. The whole unsegmented body is completely enveloped by the calcified carapace made up of two lateral valves (Martens 1998). Most appendages and organs are so paired that they are enclosed by carapace. Ostracoda are the most diverse crustaceans with their marine and non-marine species. In total, 65000 nominal extant and fossil species have been described and it is guessed that more than 20000 living species exist (Ikeya et al., 2005). The present ostracod diversity in quite different parts of the non-marine habitat, starting about 400 Myr ago. All the three main lineages (Cytheroidea, Cypridoidea and Darwinuloidea) of the recent non-marine ostracods which belong to the order Podocopida were originated in the Palaeozoic between 450 and 360 million years (Martens et al., 2008).

### **1. 1. 1. Classification**

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 and 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. 2. Morphology of ostracods**

The ostracods have two calcified carapace that are connected in the dorsal part with a hinge. The carapace is formed by an inner and an outer lamella which originating dorsally from epidermis. The carapace is mineralized with calcium (magnesium) carbonate and consists of chitinous and protein complex. The exoskeleton shell is originating from mesoderm in very early embryo as in all bilaterian animals. The shells with many different shapes in Ostracoda have very important functions such as protecting the ostracods from the predators, adaptation to the benthic life and keeping the soft body parts.

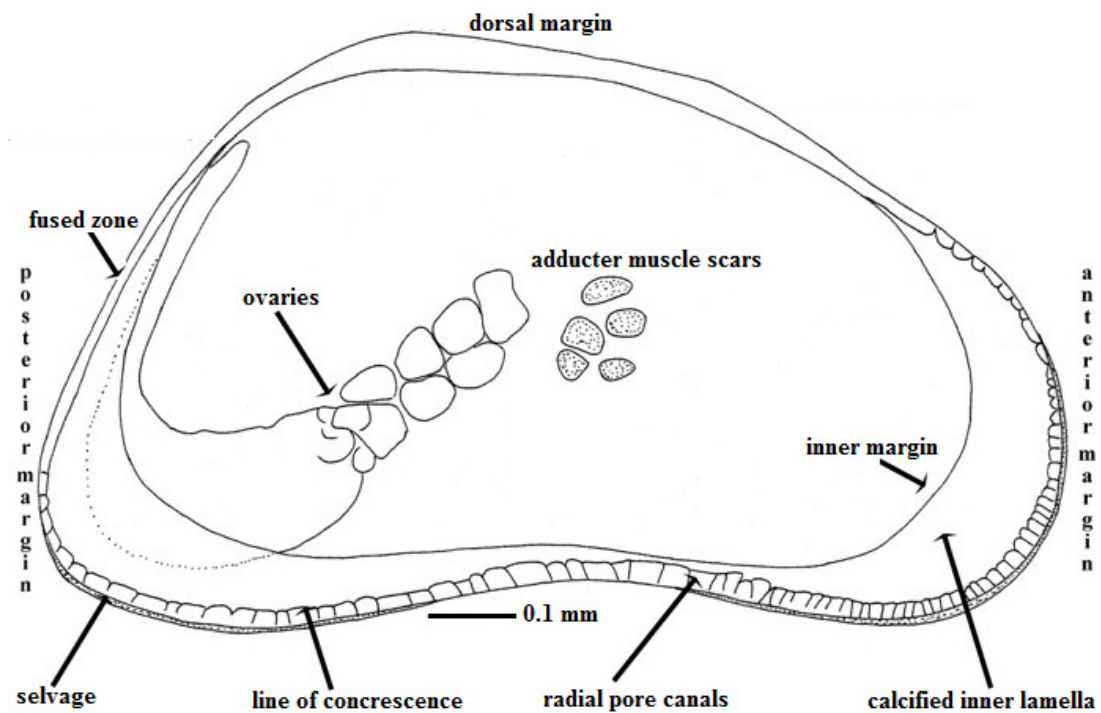


**Figure 1.** Line drawings of interior view of left valve (modified from Karanovic 2012).

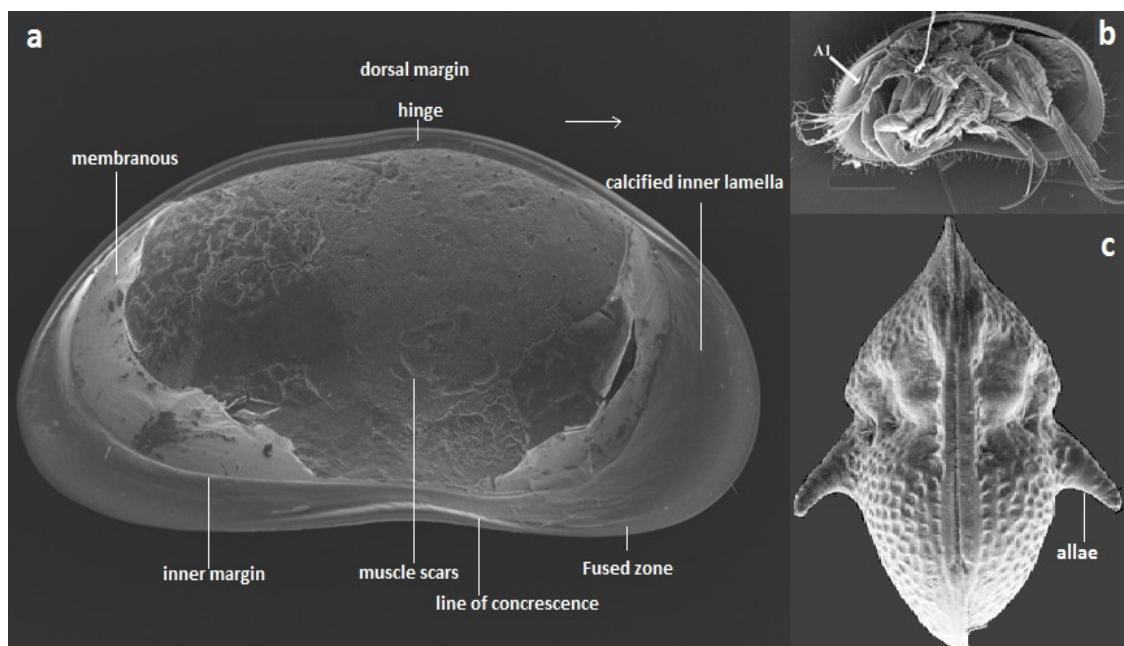


**Figure 2.** *Psychrodromus olivaceus* Brady & Norman, 1889; a. left valve inside, b. right valve inside with soft parts, c. *Limnocythere scutariense* Petkovski, 1961 (a modified from Klkyligl (unpublished); b and c modified from Karanovic 2012).

The first appendage Antennula (A1, Figure 3) is situated in the head side. It fulfills locomotion and sensory functions with aesthetascs. While it shows sexual dimorphism in Myodocopa, there does not exist the same situation in Podocopa (Karanovic 2012).

The antenna (A2) is settled behind the antennula (Figure 3). Its chaetotaxy is usefull taxonomic characters for identification purposes. The antenna is used to walk, dig and swim, while some organs (such as furca) is used to jump. It has locomotory and sensory functions. The group with the largest exopod is Myodocopa (includes only marine species). This appendage is almost reduced in Podocopida.

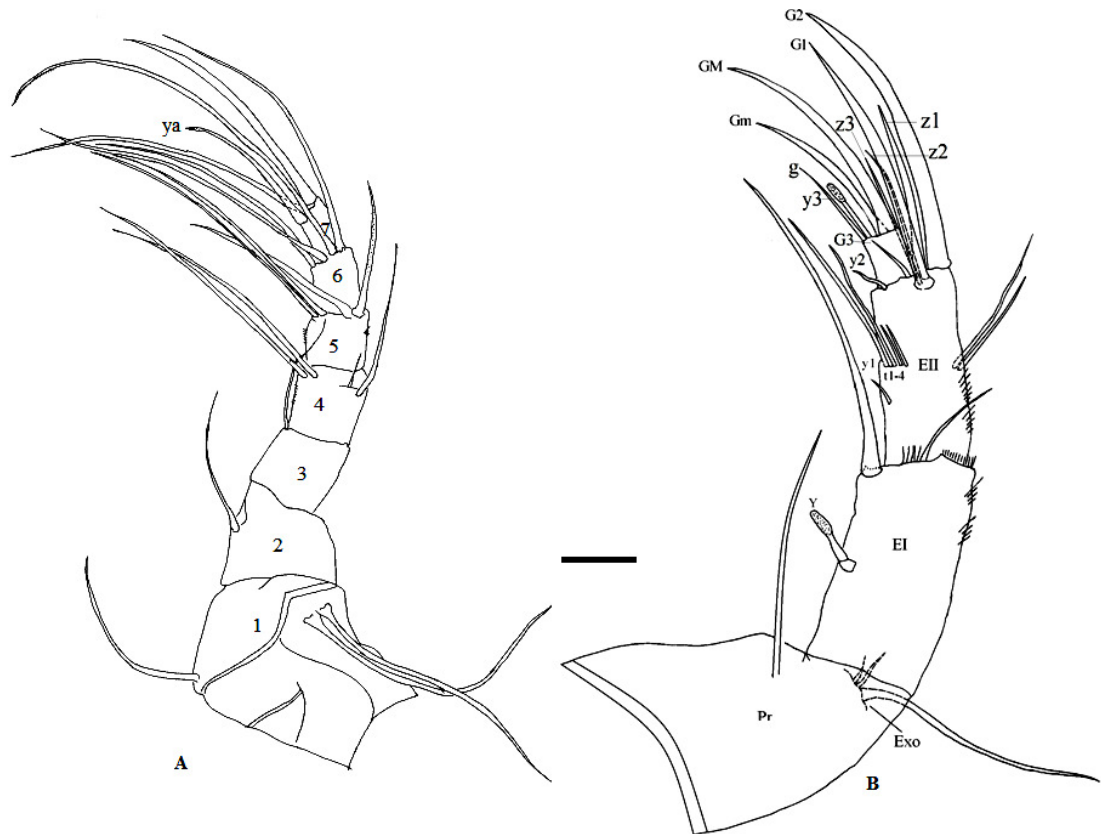


**Figure 3.** A-Antennula and B- Antenna, *Ilyocypris inermis* Kaufmann, 1900 (male).

Scale bar; 71  $\mu$ m for A; 62  $\mu$ m for B (modified from Sarı et al., 2012).

Mandibula (Md) is a feeding appendage (Figure 4). It consists of well developed teeth in masticatory process and joints a vibratory plate. It has diagnostic features for some ostracod level.

Maxillula (Mxl) serves for respiration and feeding (Figure 4). It has a large vibratory plate missing in all Myodocopa. It consists of 2-segmented palp and 3 endites. While vibratory plate has a respiration function, the endites play a role in feeding.

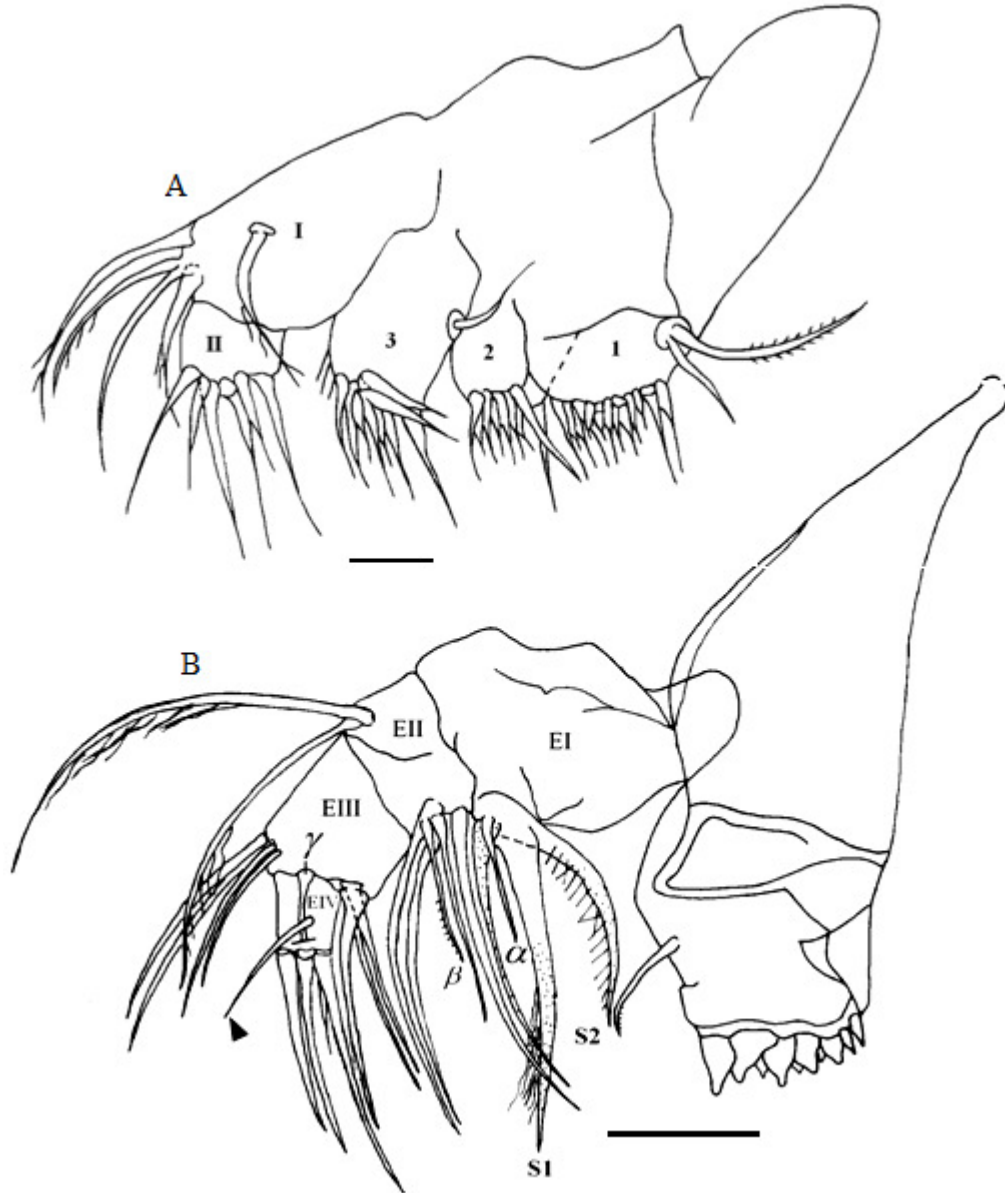


**Figure 4.** A-Maxillula and B- Mandibula, *Ilyocypris inermis* Kaufmann, 1900 (male). Scale bar; 57  $\mu\text{m}$  for A; 69  $\mu\text{m}$  for B (modified from Sarı et al., 2012).

The Fifth Limb (L5 or first thoracopod (T1)) is modified to maxilliped (Mxp) in darwinuloids and cypridoids. This appendage changes from walking leg in the A-4

instar during the larval development of Cypridocopina. The fifth limb is used to feed and walk, besides roles in copulation in males, in Podocopa.

The sixth limb (L6 or second thoracopod (T2)) is walking leg with only one well developed apical claw in order Podocopida.

The seventh podocopid appendage (L7 or third thoracopod (T3)) is transformed to a cleaning leg in Cypridocopina, while it is absent in Podocopa Myodocopa. It consists of two terminal setae and a roller-shape ramus in Halocypridina.

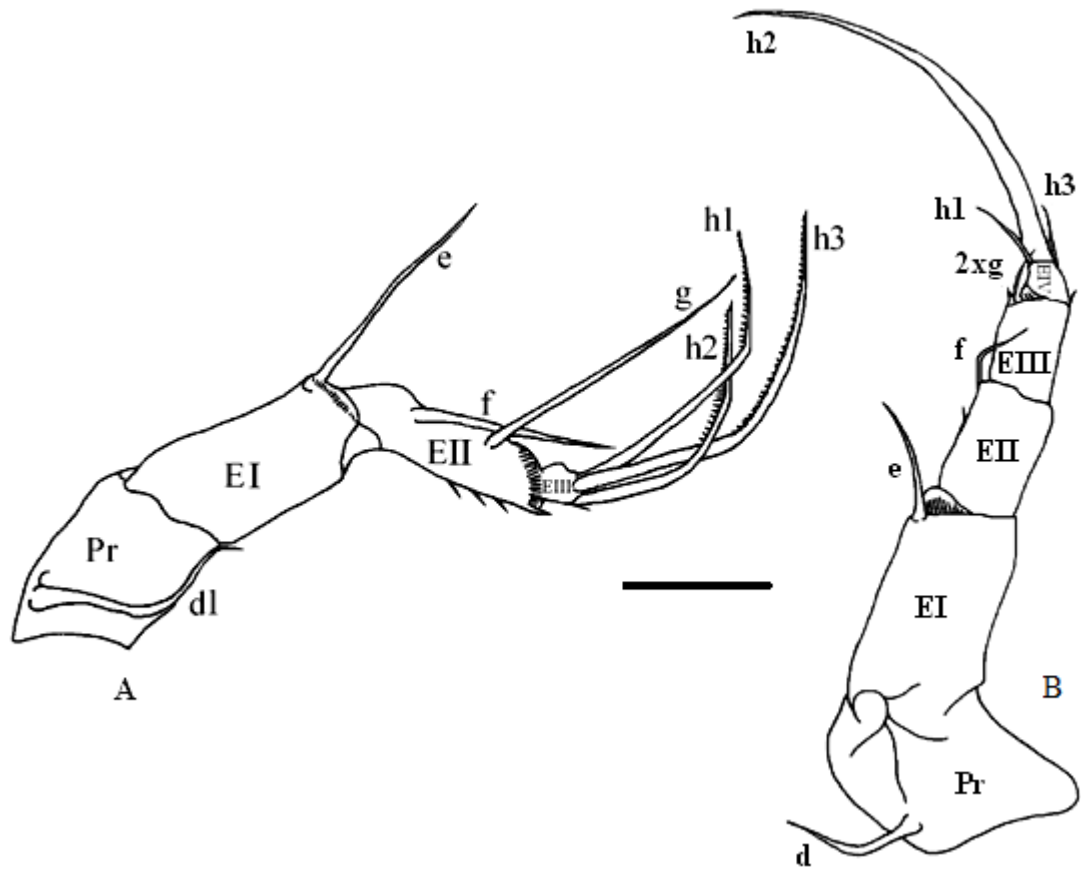


**Figure 5.** A- Cleaning leg (L7); B- Walking leg (L6), *Ilyocypris inermis* Kaufmann, 1900 (male). Scale bar; 61  $\mu\text{m}$  for A; 81  $\mu\text{m}$  for B. (modified from Sarı et al., 2012).

A podocopid pair of uropodal ramus (furca) settled the posterior end of the body, situated behind copulatory appendages (Figure 6). These always unsegmented appendages have two distal claws and one to six setae. The rami are partly reduced to

a flagellum-like in cypridoid females, which is missing in males. This appendage is also used for both walking and feeding (Myodocopa and Platycopida).

Hemipenis (except Halocyprida; Karanovic 2012) is a paired sometimes bigger than body size (Figure 6). It is dorsally connected with the Zenker Organ in Cypridopsinae and taxonomically important.

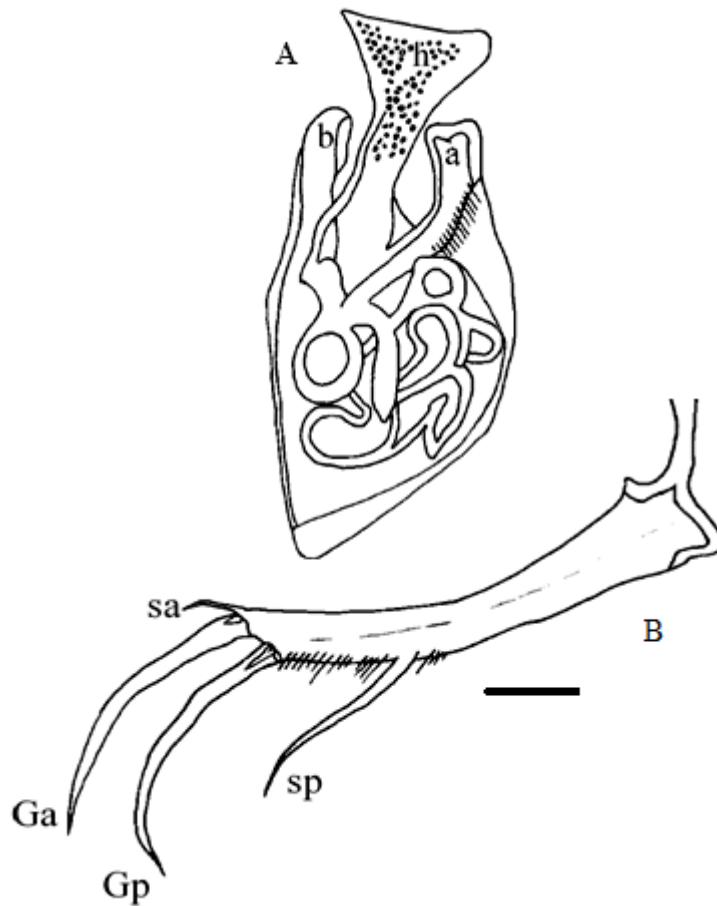


**Figure 6.** A- Hemipenis; B- Uropod, *Ilyocypris inermis* Kaufmann, 1900 (male). Scale bar; 58  $\mu\text{m}$  for A; 61  $\mu\text{m}$  for B. (modified from Sarı et al., 2012). Abbreviations; a, b and h outer, iner and medial lobes of hemipenis, respectively; Ga and Gp anterior and posterior claws of uropod, sa and sp anterior and posterior setae of uropod.

### **1. 1. 3. Anatomy of ostracods**

The cephalon supporting by a strong chitinous framework comprises forehead, upper lip and lower lip. The forehead bears antennula, antenna and eyes. There is the mouth opening between the posterior margin of the upper lip and anterior margin of the lower lip. The chitin supported mandibula and maxillula are connected to the upper margin of the lower lip.

Ostracods do not have any specialized respiration organs, therefore the exchange of respiratory gases occurs through the entire body surface. The flow of oxygenated water is provided by vibratory plate and all parts of maxillulae.

The food is pushed to the mouth opening by the mandibles and then goes to the stomach passing from the oesophagus. The products of paired gland hepatopancreas are sent to the anterior intestine. Then the food passes with peristaltic contractions to the anus. In some species with thin valves, gut content can be seen from outside.

Podocopid ostracods have the typical open circulatory system like many invertebrates. They have no heart except Myodocopids which have a dorsal heart.

They have a central nervous system which consists of cerebrum, a circum-oesophageal collar of fused ganglia and a ventral chain of ganglia running antero-posteriorly (Rome 1947; Hartmann 1967). The eyes are ensconced above the base of the antennulae. In hypogean species the eye pigment is lost, while some podocopids lack the lens cells.

Many setae or modified setae (e.g. aesthetascs) which settle on the different soft body parts or carapace serve as a sensory function (Meisch 20009).

In Podocopids the reproductive organs are paired in both sexes. Near the genital lobe which can be used in taxonomy in females, the ovary leads to the uterus. There is the vaginal opening in front uterine opening (Karanovic 2012).

The seminiferous tubules (testes) which consist of four long coiled tubes of Cypridoidea are situated between the valve lamellae. The vas deferens which shapes the Zenker organ is formed by these long coiled tubes. The Zenker organ pumps the sperms usually longer than the entire animal body during the copulation (Karanovic 2012). The number of the whorls (chitinous tube rings) or other features of the Zenker organ are usefull diagnostic characters mainly above the generic ostracod level.

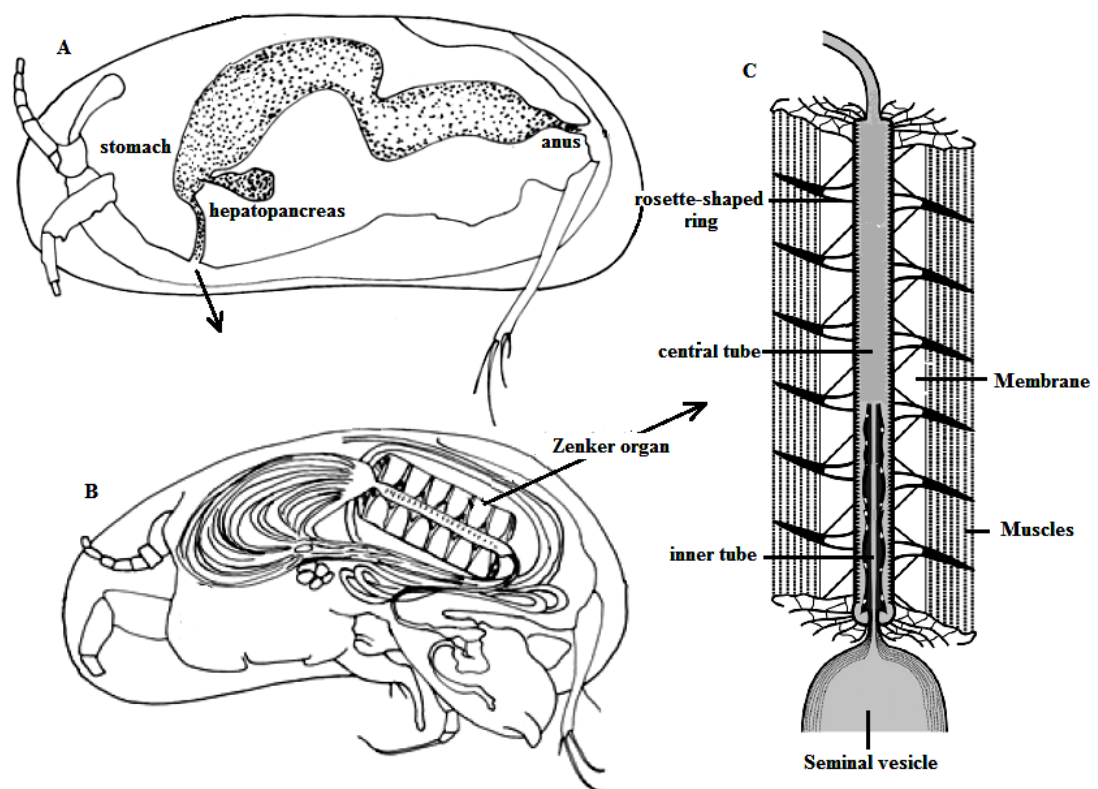


**Figure 7.** A- digestive track, B- reproductive system, C- Zenker organ. (A, B and C modified from Henderson 1990, Meisch 2000 and Yamada and Matzke-Karas 2011, respectively).

#### 1. 1. 4. Ecology of ostracods

Ostracods can be found in various aquatic habitats, such as marine (in the oceans living from the shallow littoral zone to the abyssal depths, from oceanic surface

waters to the lagoons, estuaries and marginal marine environments with fluctuating salinities) or non-marine caves (Yavuzatmaca et al., 2012), limnic or with increased ionic content, epigean or hypogean, stagnant or flowing (Meisch 2000), permanent or temporary. Besides, a limited number of ostracod taxa are known from semi-terrestrial environments (Külköylüoğlu and Vinyard 2000). Indeed, they can be found in Arctic regions and in tropical zones, also in underground waters. In many kinds of waters the ostracods are one of the dominant animal groups and may reach amazing densities. They can live as predators, herbivores, omnivores or detritivores. Some cytheroid ostracods can live as symbionts, commensals or ectoparasits on the appendages of hypogean Isopoda, Decapoda (Meisch 2000). Some species of Ostracoda have a wide geographical distribution depending on their dispersal abilities and tolerances to environmental variables. Distribution can be achieved through passive or active transport, common in freshwater invertebrates (Bilton et al., 2001). Living ostracods can be transported by some parts of birds, by sediment transportation, and by fishes and humans (Külköylüoğlu 1999b, Horne and Boomer 2000). The wind is also another important factor in the dispersion of resting eggs (Horne and Martens 1998).

Ostracods are sensitive to both the physical, chemical and ecological characteristics of different aquatic habitats (temperature, conductivity, dissolved oxygen, pH) (Külköylüoğlu 2005a) and to environmental variations such as elevation, latitude, longitude and seasonal changes (Delorme 1983, Külköylüoğlu et al., 2012a, b). Different species prefer different types of water bodies related to their tolerance limits to environmental variations and different species respond in different ways to the organic pollution (Eager 1999, Mezquita et al., 1999a).

Some species known as cosmopolitans do have broad ranges of tolerances to environmental fluctuations and to changes in such variables in polluted or disturbed habitats (Külköylüoğlu 2004). They can recolonize easily to the new environment (Külköylüoğlu 2005a). The endemic species, however, are of small ranges of tolerances to the ecological variables and usually have more limited tolerance levels than cosmopolitan species. Hence, 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 phenomenon is called ‘pseudorichness’ (Külköylüoğlu 2004). Moreover, ostracods provide suitable responses to the environmental pollution by disappearance, replacement, appearance of specific species or presence of morphological anomalies or the alteration of population dynamics (Geslin et al., 2002). Besides, it is well known that anthropogenic factors adversely affect many freshwater biotic communities (Heino et al., 2005). From this point of view, ostracods as indicator species can be used to characterize past and current ecological conditions of aquatic habitats (Mezquita et al., 1999a; Külköylüoğlu and Dügel 2004). However, using ostracods as bioindicator species requires knowledge about the ecological preferences of individual species (Külköylüoğlu 2003a). Additionally, current ecological requirements of the ostracods in terms of environmental variables helps us to predict past conditions of the habitats. This is because ostracods have a pair of calcium carbonate carapace that can be preserved as fossilized forms which can be called as *paleoindicators* and each species has a specific preference of tolerances for ecological variables such as temperature, salinity and pH (Delorme 1983). Furthermore, they show different spatial and temporal samples in different aquatic habitats (Külköylüoğlu 1998) and have considerably consistent ecological

requirements on the order of thousands of years (Smith and Forrester 1994). They also enable us to test biological theories in evolution and ecology in a great scope because of their long-detailed fossil records and broad life histories (Henderson 1990). Thus, if present ecological requirements of the ostracods are known, it is possible to ascertain past environmental conditions on the basis of fossil evidence (Külköylüoğlu and Dügel 2004). Despite all the accomplishments by the earlier studies, Ostracoda ecology has not been completely known yet (Külköylüoğlu 2004).

## **1. 2. History of Neontologic Ostracoda Studies in Turkey**

Ostracod investigations started with Müller in 18<sup>th</sup> Century in Europe have been aimed to set the taxonomical description and distribution in faunal area. Such studies necessitated the observation of the environmental and ecological variables. Although ostracod studies started with outlander ostracodologists in Turkey, after a while it showed a historical development. Hereafter, there is a brief historical development about freshwater ostracod studies in Turkey.

First studies on Ostracoda in Turkey were started by H. W. Schäfer in 1954 and then by Hartmann in 1964. The species newly found by Hartmann were first records for Ostracoda fauna of Turkey such as *Candona neglecta*, *Ilyocypris gibba*, *Ilyocypris bradyi*, *Eucypris zenkeri*, *Heterocypris inaequivalves*, *Heterocypris incongruens*, *Herpetocypris chevreuxi*, and *Ilyodromus olivaceus*. After that Dr. Dinçer Gülen from University of Istanbul studied hot-springs of Turkey between 1965 and 1971 and reported a new species for the literature as *Heterocypris sabirae*. He studied in Eskişehir, Kütahya, İzmir, Çanakkale, Balıkesir during 1971 and 1975. Thus, eleven species were newly recorded for the ostracod fauna of Turkey.

Gülen also studied the western Anotolia during 1977 to 1985 and reported nine more species new for Turkey. In 1982, Gülen was able to find two species (*Notodromas persica*, *Notodromas monacha*) of the new genus for Turkey *Notodromas*, along with another species *Cypris pubera*. In 1985, he focused on bisexual populations of ostracods in Anatolia and found bisexual populations of five species that were reported for the first time in Turkey (*Candona paralella*, *Ilyodromus olivaceus*, *Cyridopsis newtoni*, *Limnocythere inopinata* and *Cyprideis littoralis*). In 1988, Gülen collected samples including 11 ostracod species from Antakya, Mersin, and Adana. In this study, he also attracted more attention to the zoogeographical feature of two species *Eucpris inflata* and *Candonopsis kingsleii*.

Altınsaçlı (1988) studied in İzmir region and recorded two new species (*Ilyocypris inermis* and *Potamocypris zschokkei*) for ostracod fauna of Turkey. In 1990, he was able to recognize eight ostracods from Balıkesir. In 1993, he sampled in Lake Sapanca with aquatic habitats from its environment and found out 25 species, 6 of which were recorded as new for the Ostracoda fauna of Turkey. Later, he reported a new species (*Heterocypris rotundata*) for Turkey from Lake Beyşehir. Altınsaçlı and Griffiths (2001a) studied in Lake Uluabat and Lake Kuş (Altınsaçlı and Griffiths 2001b). Following these studies, they recorded *Hungarocypris* and *Leucocythere* genera from Turkey (Altınsaçlı and Griffiths 2001c). Kubanç and Altınsaçlı (1990) studied in Ayvalık and reported 20 species of ostracods. Following those studies, Kaleli (1993) collected eight species from the coastal areas of the middle Black Sea Region.

The first parthenogenetic populations of *Plesiocypridopsis newtoni* from Anatolia was reported from Lake Eğirdir (Özuluğ et al., 2000). Kılıç et al. (2000) studied in the coasts of Gökçeada Island, and Kılıç (2001) collected samples from

the Black Sea coasts of Turkey. Koç (2000) studied seasonal distribution of freshwater ostracods in Ömerli reservoir (İstanbul) and found 10 species.

A new bisexual population record of *Hungarocypris madaraszi* was collected by Aygen and Balık (2002) in Küçük Menderes (İzmir). Furthermore, Aygen et al. (2004) studied near Köyceğiz in southwestern Anatolia and found two new species (*Humpcypris subterranea* and *Herpetocypris brevicaudata*) for Turkish non-marine ostracod fauna.

In Thrace, Özuluğ (2005) reported a new species (*Ilyocypris salebroza*) whose living specimens recorded for the first time in Europe. It was also new for the freshwater Ostracoda fauna in Turkey. Akdemir (2008) reported 14 ostracod taxa from two maar lakes and one sinkhole lake in Konya region.

Külköylüoğlu et al. (1993) studied in Lake Küçükçekmece from 1989 to 1990 and reported a brackish water ostracod species including *Cytheretta adriatica* as a new record for Turkey. Külköylüoğlu et al. (1995) worked in Lake Büyükçekmece where *Potamocypris variegeta* was a new report for Turkey. Külköylüoğlu (1998) studied in Lake Şamlar where two new species, *Ilyocypris divisa* and *Eucypris lilljeborgi* were recorded for Marmara region. In this study, he first introduced a graphical model called Ostracoda Watch Model (OWM) for seasonal occurrences of species. He collected samples from freshwater habitats in Bolu, in which his study was one of the first applied Canonical Correspondence Analyses (CCA) to Ostracoda by adding months as a variable. In 2003, Külköylüoğlu firstly recorded *Scottia pseudobrowniana* from a limnocrone spring in Turkey (Külköylüoğlu 2003a). In 2003, he also 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 the Bolu district in 2004 and 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 1231 m a.s.l in Bolu. In this study, ostracods seasonal occurrences were studied over two years of monthly sampling. In 2005, Külköylüoğlu worked on the species richness in Yumrukaya Reedbeds, a small wetland located in the western part of Bolu (Külköylüoğlu 2005a). In the same year he worked on the ecological requirements of Ostracoda species (Külköylüoğlu 2005b). Külköylüoğlu (2005c) recorded a new species (*Limnocythere inopinata*) from a reservoir Lake Gököy as a new report for the Bolu region. Külköylüoğlu not only locally focused on ostracods, but also built a new bridge between the ostracod history of Turkey and a cumulative future monitoring enriched with ecological values. His studies identified the whole water body with all biotic and abiotic factors. Külköylüoğlu (2008) presented a new species *Cyclocypris vinyardi* n. sp. to the literature. Six species of ostracod (*Candona neglecta*, *Heterocypris incongruens*, *Ilyocypris bradyi*, *Darwinula stevensoni*, *Pseudocandona compressa*, and *Psychrodromus olivaceus*) were ascertained in a newly development rheocene spring near Lake Yeniçağa by Külköylüoğlu (2009).

Yılmaz and Külköylüoğlu (2006) studied in Lake Aladağ and reported nine ostracod taxa. Külköylüoğlu et al. (2007) reported 13 species of Ostracoda among which *Potamocypris* cf. *fulva* was a new record for the Turkish freshwater ostracod fauna from a heavily polluted shallow lake Lake Yeniçağa (Bolu). A new marine ostracod genus *Neocopytus* that was defined from Mediterranean Sea was afforded to the science world (Külköylüoğlu et al., 2007). Karakaş-Sarı and Külköylüoğlu

(2008) listed 10 more species from two rheocene springs in Bolu region, where *Scottia pseudobrowniana* was reported for the second time from Turkey. In another study, on freshwater ostracods in Lake Sünnet (Bolu) 9 species including a new report (*I. getica*) were recorded to Turkish ostracod fauna (Külköylüoğlu et al., 2010). 23 freshwater Ostracoda species with a new report (*Herpetocypris intermedia*) for Turkey were defined from Diyarbakır province (Akdemir and Külköylüoğlu, 2011). In northeastern Van province that embraced high altitudinal habitats 29 non-marine ostracod species were recorded from 57 different aquatic sites (Külköylüoğlu et al., 2012a). Testing Rapoport Rule which states negative correlation between species richness and altitude was published with a large investigation about distribution of a/sexual 26 non-marine species from different altitudinal ranges in the province of Ordu (Külköylüoğlu et al., 2012b). The relations between habitat and distribution of alpha diversity of freshwater ostracods were studied in Kahramanmaraş province and 46 ostracod taxa encountered (Külköylüoğlu et al., 2012c). In Bolu region, the ecological characteristics of 40 freshwater ostracod taxa were described (Külköylüoğlu and Sarı 2012), and their habitat similarities were compared with community structure using Sorenson Similarity Index (Sarı and Külköylüoğlu 2010). The genus *Schellencandona* and 12 species were introduced new record for the Turkish Ostracoda fauna (Sarı and Külköylüoğlu 2010). Additionally, the same study reported five other species (*Herpetocypris brevicaudata*, *Heterocypris salina*, *H. rotundata*, *Cyclocypris laevis*, *Trajanocypris serrata*) new for Bolu region.

The first study on species composition and distribution of Turkey in artificially transformed aquatic habitats which called troughs was achieved by Külköylüoğlu et al., (2013). In this study, 105 troughs from 6 different regions (Bolu, Van, Ordu,

Gaziantep, Kahramanmaraş, Erzincan) were investigated and 32 ostracod species with a mean number 2.16 per trough were collected.

Dügel et al., (2008) studied in Lake Abant Nature Park where one of the most famous among 16 nature parks in Turkey. They reported a total of 16 taxa of Ostracoda. About 80% of these species had a cosmopolitan distribution within the Holarctic region, while two of the species (*Ps. fontinalis* and *E. pigra*) among them were recorded for the first time for Ostracoda fauna of the region.

Seven ostracod taxa (*Ilyocypris inermis*, *I. bradyi*, *Ilyocypris* sp., *Candona neglecta*, *Candona* sp., *Pseudocandona* sp., and *Heterocypris* sp.) from different 11 caves in western Black Sea region were sampled, where *Psychrodromus olivaceus* and *Psychrodromus* sp. were recorded from entrance of three caves (Yavuzatmaca et al., 2012). To determine the habitat preferences of swimming and non-swimming ostracod species in Gaziantep, a study was done by Akdemir et al., (2013) with 29 taxa from 70 sampling sites. 37 non-marine ostracod species from 130 different aquatic habitats were collected from Çankırı province in 2011 (unpublished data).

Sarı et al. (2012) brought in the literature for the first and detailed description of male *Ilyocypris inermis* which set from a creek near a small village. Uçak (2012) listed 31 taxa from different aquatic bodies to determine the relationship between species and environmental variables using comparative analysing of diversity hypotheses in Ankara.

Akdemir and Külköylüoğlu (2013) collected 19 recent freshwater ostracods from a total of 70 stations consisting of 12 kinds of aquatic water bodies in Hatay. Meanwhile, in Adıyaman, encountered 41 ostracod taxa from 111 aquatic habitats were tested by application of Poisson Method (Yavuzatmaca et al., 2013). The research on distribution and ecology of non-marine Ostracoda from Karabük should

be mentioned. Yılmaz et al. (2013) recorded 37 non-marine taxa from 81 sites of Karabük region in this study.

### **1. 3. Lake Ecology and Limnoecological structure**

A lake is a body of still water with a considerably important size. They settle in a reservoir surrounded by different forms of flowing water. Lakes are inland water bodies but larger and deeper than ponds. Most lakes are fed and drained by flowing waters.

Natural lakes are generally found in rift zones and areas with ongoing water flow. Other lakes are in a different class of water bodies located in closed watersheds where the topography prevents their drainage to the sea. This class of lakes known as endorheic lakes is usually called terminal or sink lakes. Endorheic lakes do not have a natural outflow and lose water solely by evaporation or underground seepage.

All lakes are temporary if considered in time scales, as they will slowly fill in with sediments. Many artificial lakes are constructed for different anthropogenic purposes.

There is an important obscurity about revealing the difference between lakes and ponds and no current globally accepted definition across scientific disciplines (Kuusisto and Hyvärinen 2000). The lake is defined as water bodies which are simply a larger version of a pond, which can have wave action on the shoreline or where wind-induced turbulence plays a major role in mixing the water column according to limnologists.

Kuusisto and Hyvärinen (2000) proposed to define a lake as a body of water with five characteristics as follows:

- a.** it partially fills one or more basins connected directly,

- b.** it has essentially the same water level in all parts (except varying ice cover, large inflows, etc.),
- c.** it does not have a descent by the sea water,
- d.** a considerable portion of the sediment suspended in the water is captured by the basins,
- e.** the area measured at the mean water level exceeds an arbitrarily chosen threshold.

### **1. 3. 1. Trophic state classification**

The lakes are classified according to several trophic state indices (TSI). The trophic indices are used to define the degree of eutrophication. Several diverse criteria are used to determine the trophic state such as species composition of the phytoplankton, total nutrients concentration, total phosphorus, water's clarity and measured production or potential algal biomass. The United States Environmental Protection Agency (EPA 2010) notes four eutrophication degrees-related classifications; Oligotrophic, Mesotrophic, Eutrophic, and Hypereutrophic (Table 1).

**Table 1.** Nutrient concentrations and biological productivity of Trophic State Classifications (EPA 2010)

| <b>Lake Trophic Classification</b> | <b>Nutrient Concentration</b> | <b>Biological Productivity</b> |
|------------------------------------|-------------------------------|--------------------------------|
| Oligotrophic                       | Low                           | Low                            |
| Mesotrophic                        | Moderate                      | Moderate                       |
| Eutrophic                          | High                          | High                           |
| Hyper-Eutrophic                    | Very High                     | Very High                      |

One of the most commonly used trophic state model is the one based on several parameters such as Secchi's disc transparency, total phosphorus and total chlorophyll-a by Carlson (1977, Table 2). The productivity of the water body which means algal biomass is the point of the index. Carlson's Trophic State Index (CTSI) is an adequate method for characterizing a lake's trophic state which noticeably means the health of the water. Trophic state of a lake or pond (actually all type of water bodies) implies the total biomass weight in it at a specific location and time. It is the biological response for nutrient accumulation to the water bodies (Naumann 1929). However several factors such as seasonal variations, number of mixing depth water and decreasing phytoplankton density can effectively substitute this nutrient additions (Devi Prasad and Siddaraju 2012).

**Table 2.** Carlson Trophic State Classification (1977) scale with attributes.

| Classification         | Sub-classification       | Scale                   | Attributes                                                                                                                                                                                                                                                                                                                                                           |
|------------------------|--------------------------|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Oligotrophic</b>    | Strongly Oligotrophic    | <b>TSI &lt; 26</b>      | <b>Scant nutrition.</b><br><br>Very clear and high drinking-water quality, ample oxygen throughout the year in the hypolimnion, few aquatic plants, not much wildlife.                                                                                                                                                                                               |
|                        | Oligotrophic             | <b>26 ≤ TSI &lt; 33</b> |                                                                                                                                                                                                                                                                                                                                                                      |
|                        | Slightly Oligotrophic    | <b>33 ≤ TSI &lt; 38</b> |                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Mesotrophic</b>     | Slightly Mesotrophic     | <b>38 ≤ TSI &lt; 43</b> | <b>Medium nutrition.</b><br><br>Water moderately clear, but anoxia can occur most probably of during the summer, ample submerged aquatic plants.                                                                                                                                                                                                                     |
|                        | Mesotrophic              | <b>43 ≤ TSI &lt; 49</b> |                                                                                                                                                                                                                                                                                                                                                                      |
|                        | Strongly Mesotrophic     | <b>49 ≤ TSI &lt; 54</b> |                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Eutrophic</b>       | Slightly Eutrophic       | <b>54 ≤ TSI &lt; 58</b> | <b>Abundant nutrition.</b><br><br>Due to excessive nutrients the water body can be dominated by either aquatic plants or algae. If aquatic plants dominate the lake tends to be clear, when algae do it will be come darker. Decreased water clarity, dominance of blue-green algae, presumably algal scum, potentially has extensive situation to support wildlife. |
|                        | Eutrophic                | <b>58 ≤ TSI &lt; 62</b> |                                                                                                                                                                                                                                                                                                                                                                      |
|                        | Strongly Eutrophic       | <b>62 ≤ TSI &lt; 65</b> |                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Hyper-Eutrophic</b> | Slightly Hyper-Eutrophic | <b>65 ≤ TSI &lt; 70</b> | <b>Over-abundant nutrition.</b><br><br>Characterized by severe nuisance of algal blooms throughout the summer, heavy abundance of aquatic plants, very low water transparency. Algal scum, few macrophytes, exiguous summer fish. Large algal blooms can cause biodillution                                                                                          |
|                        | Hyper-Eutrophic          | <b>70 ≤ TSI</b>         |                                                                                                                                                                                                                                                                                                                                                                      |

Trophic Level Index (BTLI; Burns 1999) is another method that classified trophic states of water bodies. This model converts the Secchi depth, concentrations of phosphorus and nitrogen and chlorophyll-a into an index number which is created by log transformation. There is a difference between the scales of the Burns and the Carlson Methods. A scale of 0.0 to 7.0 is used in the Burns Model, while these values are changing from 0 to 100 in the Carlson Model. To make easy comparisons between these the two models, the Burns scale is altered and the lake states are re-classified as shown in Table 3.

**Table 3.** The re-classified Burns Trophic Level Index (BTLI; based on Burns 1999).

| <b>Classification</b>  | <b>Sub-classification</b> | <b>Scale</b>              |
|------------------------|---------------------------|---------------------------|
| <b>Oligotrophic</b>    | Strongly Oligotrophic     | <b>TSI &lt; 2.0</b>       |
|                        | Oligotrophic              | <b>2.0 ≤ TSI &lt; 2.7</b> |
|                        | Slightly Oligotrophic     | <b>2.7 ≤ TSI &lt; 3.0</b> |
| <b>Mesotrophic</b>     | Slightly Mesotrophic      | <b>3.0 ≤ TSI &lt; 3.3</b> |
|                        | Mesotrophic               | <b>3.3 ≤ TSI &lt; 3.7</b> |
|                        | Strongly Mesotrophic      | <b>3.7 ≤ TSI &lt; 4.0</b> |
| <b>Eutrophic</b>       | Slightly Eutrophic        | <b>4.0 ≤ TSI &lt; 4.5</b> |
|                        | Eutrophic                 | <b>4.5 ≤ TSI &lt; 5.0</b> |
|                        | Strongly Eutrophic        | <b>5.0 ≤ TSI &lt; 5.5</b> |
| <b>Hyper-Eutrophic</b> | Slightly Hyper-Eutrophic  | <b>5.5 ≤ TSI &lt; 6.0</b> |
|                        | Hyper-Eutrophic           | <b>6.0 ≤ TSI &lt; 7.0</b> |

Both Carlson and Burns Models can be used in the present study. Because, they need the same variable assets obtained from the samples.

### **1. 3. 2. Mixing classification (Lake types)**

The trophic classification of lakes is made due to their nutrition profile. These types of models heed primary productivity related to phytoplanktons, oxygen concentration, water clarity, composition of aquatic plants or algae and of course basic elements such as phosphorus, nitrogen and their derivatives.

The mixing classification models divide the water bodies to several types based on their temporal thermal variations. One of the common used mixing classification belongs to Hutchinson and Löffler (1956). The number of mixing in a year and the thermal records are used in lake mixing classification by these authors. The

classification established upon the exclusion of shallow lakes divides the lakes to the two main group as meromictic and holomictic. The lakes without intermix among the water layers are called meromictic. It is defined by Findenegg (1935) as a lake which stayed partly or wholly unmixed with main water body during circulation phases. The non-meromictic lakes are called holomictic. Most of lakes are included in this type. The classification types recognized by Hutchinson and Löffler in 1956 are subtypes of holomictic such as amictic, cold monomictic, dimictic, warm monomictic, oligomictic and polymictic. However this mixing classification is revised by Lewis (1983) who incorporated the shallow lakes to the classification as polymictic with prefixes “cold” and “warm. The idea of Hutchinson and Löffler that announced all polymictics as tropical was argued by several limnologists (Paschalski 1964; Dussart 1966; Harvey and Coombs 1971). They usually suggested to change the typology of Hutchinson and Löffler especially about polymictic parts. The type oligomictic is eliminated from the typology by Walker and Likens (1975). Lewis (1983) who brings away oligomictic lakes from the typology divided the lakes into eight classes in the light of these arguments (Table 4).

**Table 4.** The lakes revised classification with characteristics (Lake subtypes are modified after Lewis, 1983)

| No             | Lake Types |                                               | Characteristics                                                                                                                                   |
|----------------|------------|-----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| 1              | Meromictic |                                               | During circulation periods, the water remains partly or wholly unmixed. Deep circulation does not include the entire water body.                  |
| 2              | Holomictic |                                               | Physical mixing due to wind or temperatural differences between the layers of the surface and the deep waters. Homogenize at least once a year.   |
| Lake Sub-types | A          | Amictic                                       | Permanently ice covered, at the highest elevations, stagnant, but can circulate because of diffusion of heat and matter underneath the ice sheet. |
|                | B          | Cold monomictic                               | Ice-covered most of the year, no ice during warm period that not to exceed 4°C.                                                                   |
|                | C          | Continuous cold polymictic (Shallow Lakes)    | Ice-covered part of the year, ice free above 4°C, stratify on daily basis.                                                                        |
|                | D          | Discontinuous cold polymictic (Shallow Lakes) | Ice-covered part of the year, ice free above 4°C, stratify on days to weeks, interrupted irregularly by mixing.                                   |
|                | E          | Dimictic                                      | Ice-covered during cold season and stably stratified during warm period, interfuse at the transition time between two parts of the year.          |
|                | F          | Warm monomictic                               | Mixing once each year, no seasonal ice cover, stably stratified part of the year.                                                                 |
|                | G          | Discontinuous warm polymictic (Shallow Lakes) | No seasonal ice cover, mixing more than once per year, stratifying for days to weeks.                                                             |
|                | H          | Continuous warm polymictic (Shallow Lakes)    | No seasonal ice cover, stratifying at most for a few hours at a time.                                                                             |

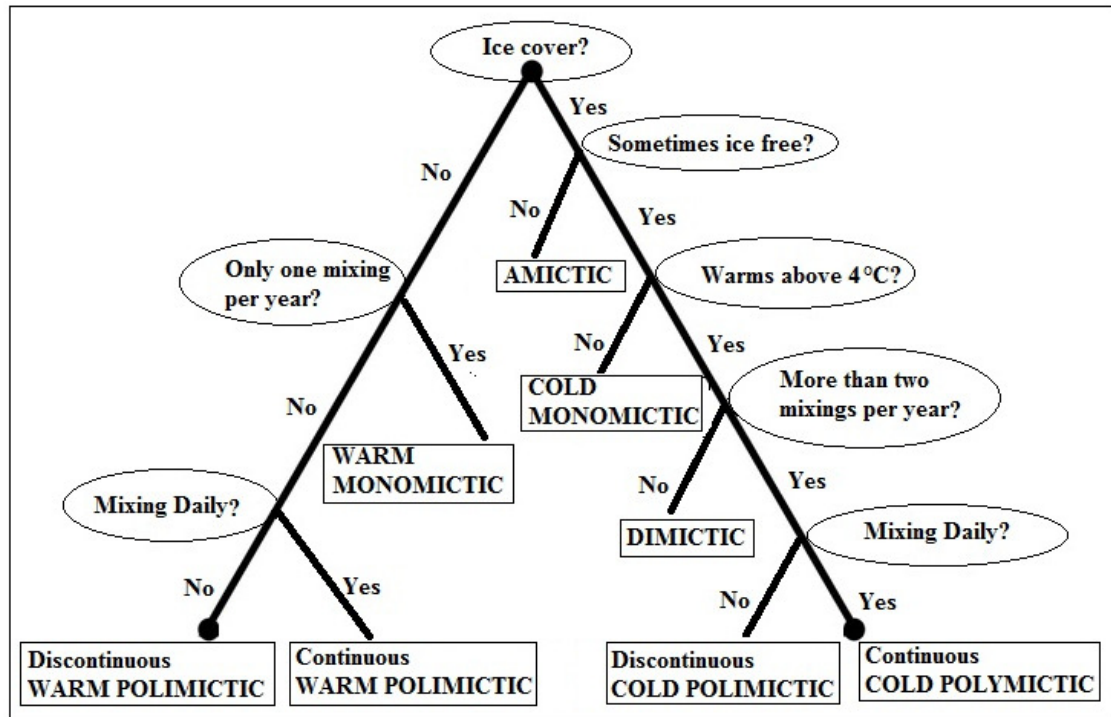


**Figure 8.** Lake Type Key (modified from Lewis, 1983)

### 1. 3. 3. Thermal classification (Lake stratification)

The lakes can also be classified according to their thermal stratification that influences water quality and phytoplankton communities. Several exchanges occur between the lake surface and atmosphere as heat, short/longwave radiation, evaporation etc.. The thermal exchange also occurs between vertical layers of the water column.

When temperature levels of the upper water layer get over the 4°C threshold, the density of water decreases due to warming and eventually the surface becomes thermally isolated from the cooler, denser layer. The changing of the water dense causes the thermal stratification. This situation occurs as summer approaches and reaches into cooler deep water until the cold season starts. In a cold autumn, surface and bottom waters are close to each other themally, and hence, thermal discrepancy expires, mixing period starts.

The warm top water stratum is called epilimnion in thermally stratified lakes. Epilimnion is the well-mixed layer of water body and shows small temperature changes with depth which obtained  $<1\text{ }^{\circ}\text{C}$  per year by Mazumder and Taylor (1994). This relatively warm layer is recognized by high primary production and highlighted. Its temperature, pH and dissolved oxygen concentrations are higher than the other layers. Several authors previously adduced that the thickness of this well-lightened layer changes depending on several factors as temperature (Wetzel 1975), fetch (Patalas 1960, Davies and Colley 1988, Gorham and Boyce 1989, Hanna 1990), surface area (Schindler 1971, Davies and Colley 1988, Gorham and Boyce 1989, Geller 1992), mean depth, lake volume (Schindler 1971, Geller 1992), Secchi depth or water clarity (Mazumder and Taylor 1994), wind's take off (Arai 1981, Davies and Colley 1988), lake shape (Patalas 1960, Okulianis 1981), lake size (Mazumder and Taylor 1994), exposure degree of the lake (Hutchinson 1957), the effects of fish predation and plankton biomass (Mazumder et al., 1990).

Metalimnion commonly known as thermocline in inland water bodies (e.g lakes) shows the most decreasing temperature ranges in water bodies (Hutchinson 1957). It is the middle layer that separates epilimnion and hypolimnion as a contact zone. Because of the stability of the lakes related to the thermally stratification, the water under thermocline becomes anoxic, while epilimnion is well oxygenated. Thermocline contributes as a boom to mixing between epilimnion and hypolimnion. The formation of the thermocline is mainly influenced by the variability of consecutive weather occasions (Skowron 2007).

The layer that backs up from the metalimnion to the lowest part of the water column is known by the name of hypolimnion. Hypolimnion is the most dense layer of the lake and typically cold in warm season, while becomes the most warmest

stratum during winter. It shows slow temperature drifts with depth (Schindler 1978). The decomposition products from the upper layer enrich hypolimnion in nutrients.

Epilimnion is the most rich layer of the water body about phytoplakton due to well absorbating capability of sunlight. The nutrients absorbation from the water by phytoplankton is making the epilimnion poor in nutrients, when hypolimnion is enriched by deceases of them. These conditions cause the decaying dissolved oxygen of hypolimnion and an indigent epilimnion to nutrients.

### 1. 3. 4. Chemical classification (Hydrochemical composition)

A lake contains a wide range of molecules and ions from the weathering of soils, the atmosphere, and the lake bottom. Therefore, the chemical composition of a lake is a function of its climate and its basin geology. Each lake has an ion balance (Table 5) of which are usually present at concentrations expressed as mg/L ppm. The other ions enclosed the nutrients phosphate, nitrate, and ammonium (EPA 2010).

**Table 5.** The ion balance for typical freshwater (EPA 2010).

| <b>ION BALANCE FOR TYPICAL FRESH WATER</b> |                |                  |                |
|--------------------------------------------|----------------|------------------|----------------|
| <b>Anions</b>                              | <b>Percent</b> | <b>Cations</b>   | <b>Percent</b> |
| HCO <sub>3</sub> <sup>-</sup>              | 73%            | Ca <sup>+2</sup> | 63%            |
| SO <sub>4</sub> <sup>-2</sup>              | 16%            | Mg <sup>+2</sup> | 17%            |
| Cl <sup>-</sup>                            | 10%            | Na <sup>+</sup>  | 15%            |
|                                            |                | K <sup>+</sup>   | 4%             |
| other                                      | < 1%           | other            | < 1%           |

Several human factors such as wastewater and urban stormwater add micronutrients (nitrogen and phosphorus) and major ions (chloride and potassium). H<sup>+</sup> which indicates acidity, SO<sub>4</sub><sup>-2</sup> and NO<sub>3</sub><sup>-</sup> are associated with acid rains.

Biodilution is depicted as decreasing in concentration of an element or pollutant with an increase in trophic level (Campbell et al., 2005). Biodilution is primarily caused by an increase in algal biomass. Mercury, cadmium and lead are effective pollutants affecting aquatic ecosystems. These toxins can bioaccumulate in aquatic food webs. Pickhardt et al., (2002) and Rypel (2010) have showed lower mercury concentrations in eutrophic (high level of zooplankton found) as compared to oligotrophic aquatic environments. Phosphorus and nitrogen enrichment reduce the input of heavy metals, into aquatic food webs through biodilution effect.

Lakes with high concentrations of the ions of calcium and magnesium are called “*hardwater lakes*”, while lakes with low concentrations are called “*softwater lakes*”. Concentrations of bicarbonate is highly correlated with the concentrations of  $\text{Ca}^{+2}$ . The ionic concentrations of calcium carbonate ( $\text{CaCO}_3$ ) can collapse phosphate from the water and cause the reducing nutrients.

The total amount of ions in the water is called TDS (Total Dissolved Solids). Both the concentration of TDS and the relative amounts or ratios of different ions influence the species of organisms.

Dissolved substances (chemicals) of the water body influenced the density in different levels (Table 6).

**Table 6.** Contribution of Dissolved substances to the density of water (illustrated from Boehrer and Schultze 2008)

| Substance                   | $\beta_n, \text{ g kg}^{-1}$ |
|-----------------------------|------------------------------|
| $\text{Ca}(\text{HCO}_3)_2$ | $0.807 \times 10^{-3}$       |
| $\text{Mg}(\text{HCO}_3)_2$ | $0.861 \times 10^{-3}$       |
| $\text{Na}(\text{HCO}_3)$   | $0.727 \times 10^{-3}$       |
| $\text{K}(\text{HCO}_3)$    | $0.669 \times 10^{-3}$       |
| $\text{Fe}(\text{HCO}_3)_2$ | $0.838 \times 10^{-3}$       |
| $\text{NH}_4(\text{HCO}_3)$ | $0.462 \times 10^{-3}$       |
| $\text{CO}_2$               | $0.273 \times 10^{-3}$       |
| $\text{CH}_4$               | $-1.250 \times 10^{-3}$      |
| Air                         | $-0.090 \times 10^{-3}$      |

Determination of hydrochemical provides an important information about quality of water. The first method which tried to define the chemical components and composition of water bodies was made by Hill (1940). After four years this theory was a modified to a diagram known as Piper Diagram (Piper 1944). Piper diagram is made in such a way that the relative concentrations of the major cations and anions are plotted on two separate trilinear plots which are projected further into a central diamond. According to this graphical form, water bodies acquire hydrochemically different characters and types (Figure 9). Subdivisions of the diamond field which represent water-type categories were defined by Back and Hanshaw (1965).

## Hydrochemical Classification

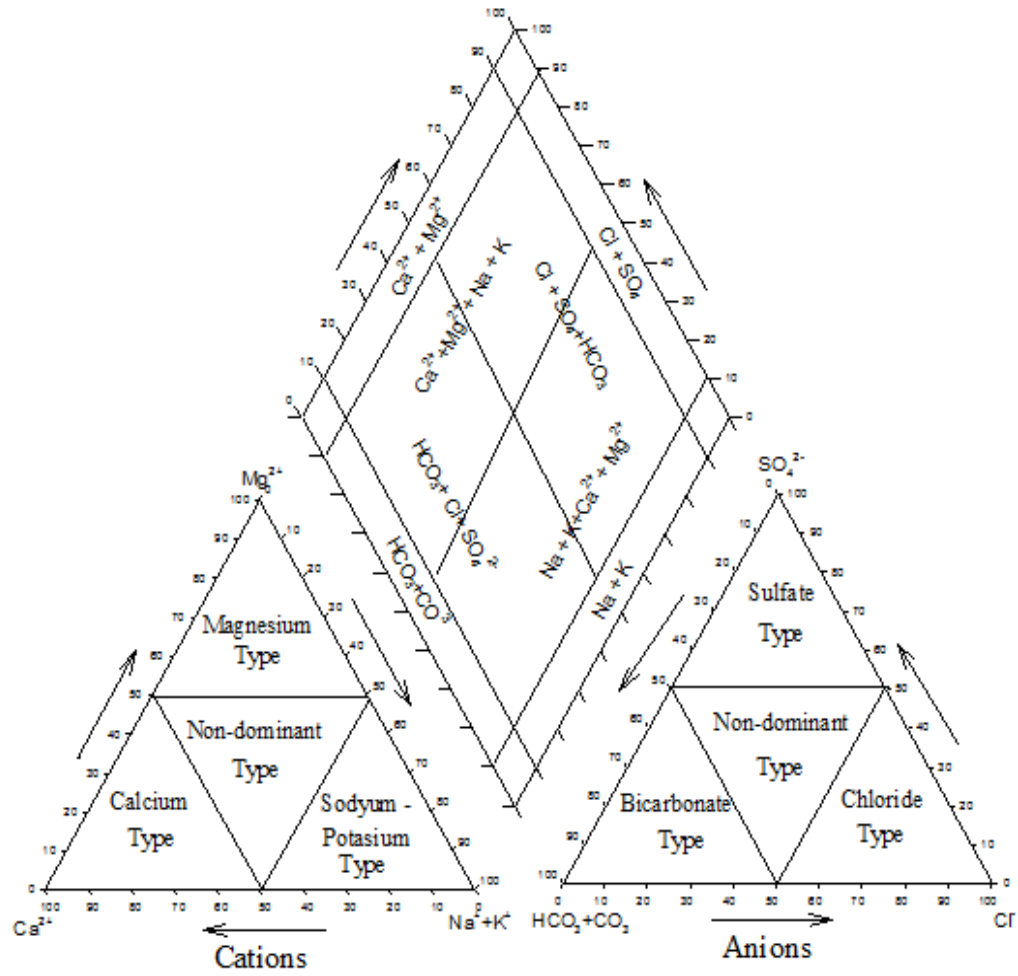


**Figure 9.** Hydrochemical classification of water bodies in Piper Diagram (modified from Back and Hanshaw 1965 in Güler et al., 2002)

## **2. MATERIALS AND METHODS**

### **2. 1. Site Description**

Lake Çubuk (40°28'91"N, 30°50'09"E) is located about 10 km northeast of Göynük county of the Bolu province at an altitude of 1032 m. The lake covers an area about 16 hectares (160.300 m<sup>2</sup>), while lake volume is measured about 651300 m<sup>3</sup>. It has a maximum depth about 8 m, while the average lake water depth is about 5.5 m. The maximum length (fetch) is about 685 m, and the maximum width is about 430 m. It is a paramecium-shaped lake (not rounded, not amoeba) with about 2000 m shoreline (Figure 10). There is Gölbaşı ward closed to the west side of the lake with population 40, while the eastern side is decorated by the windmills. Lake Çubuk is a natural landslide lake which was probably formed by occluding the sides of Kayabaşı Hill leading to the valley.

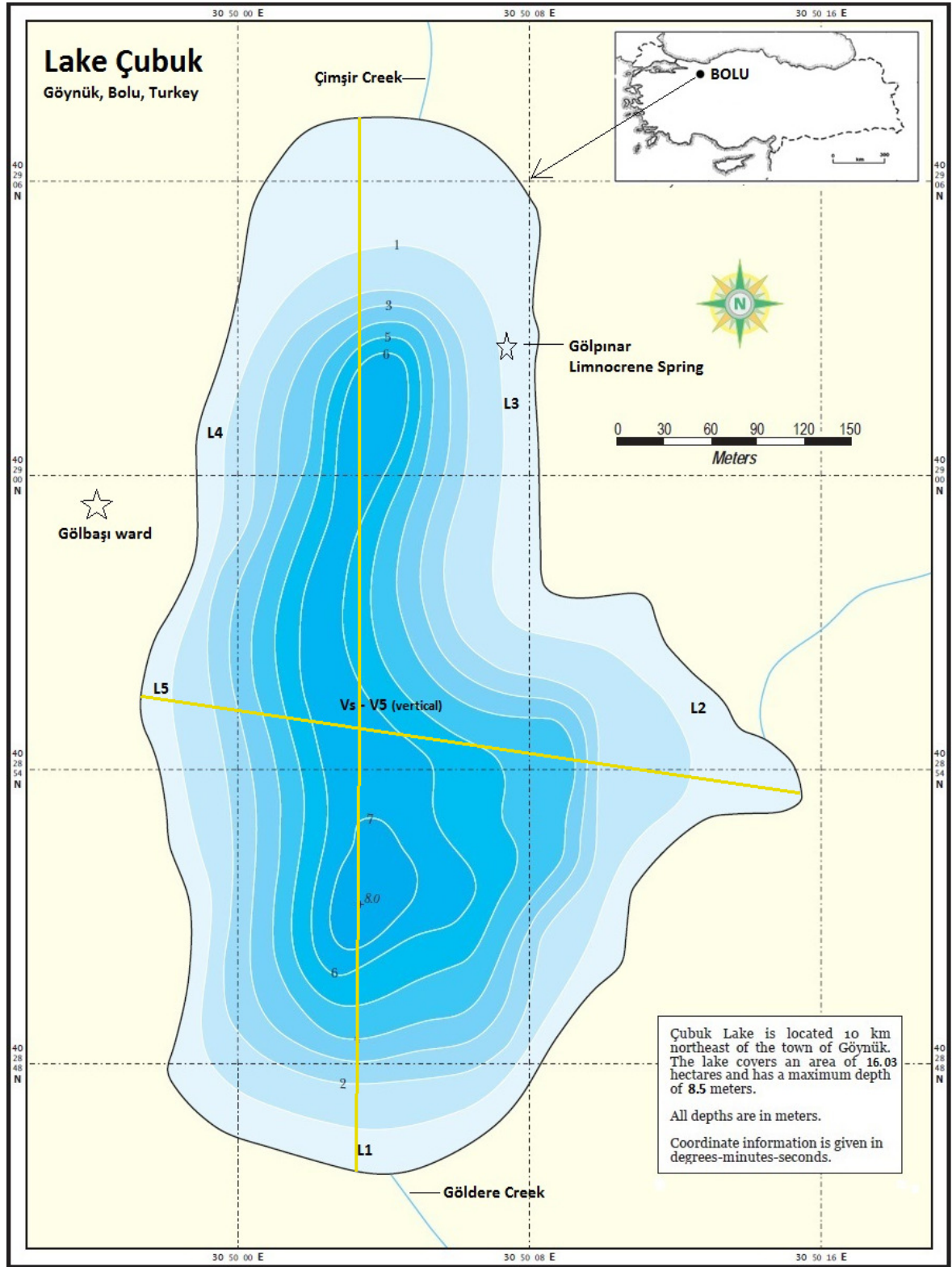


**Figure 10.** Batymetric map of Lake Çubuk and 11 sampling stations (5 littoral (L1, L2, L3, L4, L5) and 6 vertical ( $V_{\text{surface}}$ , V1, V2, V3, V4, V5)). Yellow lines represent the maximum length and width of the lake measured during this study and the direction of bathymetric photographing.

## 2. 2. Methodology

Materials were mostly collected from July 2008 to November 2010 at 5 randomly selected littoral (L1, L2, L3, L4, L5) and 1 pelagic stations. Pelagic station was chosen from the middle of the lake and include 6 points per meter from lake surface to bottom (Vs, V1, V2, V3, V4, V5). The number of vertical stations was risen up to V8 due to unsteady water level and depth in monthly periods (May, June and August in 2010). Additionally, the limnocrone spring located near the third littoral station and named “Gölpınar” this study was sampled. However, the sampling was not carried out from Gölpınar Station for several months because of increased lake water. In January - February 2009 and January 2010 samples were not collected because of ice-cover in the surface lake. Sediment samples from the bottom were taken with Ekman Grab. Van Dorn sampler was used to pump the water from each vertical stations. The analyses of sedimentation samples of 8 stations (L1, L2, L3, L4, L5, V<sub>surface</sub>, V<sub>middle</sub> and V<sub>bottom</sub>) per month according to the end of 48 hours were done using Imhoff Sedimentation Funnel. The penetration of light (transparency, water clarity) was measured by using a Secchi Disc and the photic zone was calculated according to standard triple-Secchi depth rule. A Skipper 603 Echosounder was used to calculate the physical characteristics such as volume, surface area etc. and to create a bathymetric map used to understand the morphological structure of the bottom of the lake. Bathymetric map was also used for a grid pattern used for measuring lake surface area and lake volume with the standard formulae. APHA (1989) standard methods were used to analyse the chemicals. The amount of chlorophyll-a was measured at 665 nm with a spectrophotometric method (Youngman 1978). The analysis of pesticides was done with Solid Phase Extraction method in Limnology Laboratory. Geographical data

(e.g. elevation, coordinates) were enlisted with a Geographical Positioning System (GARMIN GPS 45).

Sediment cores were retrieved at three points of which one was nearby the littoral station 1, while the others were close to station 3. Craelius D-500 Ground Drilling Machine with one nailing-type piston (length 45 cm with 54 calibre) and one borer-type piston (length 150 cm with 76 calibre) was used for drilling. The samples from the cores were investigated in the laboratory.

Ten major environmental variables (pH, redox potential (EH [mV]), electrical conductivity (EC [ $\mu$ S/cm]), dissolved oxygen (DO [mg/L]), percent oxygen saturation (Sat [%]), water temperature ( $T_w$  [°C]), air temperature ( $T_a$  [°C]), Salinity (Sal [ppt]), percent humidity (Hum [%]) and minimum-maximum wind speed (Wind [m/s])) were measured *in situ* before sampling with a Hanna model HI-98150 pH/ORP meter and YSI-85 model oxygen-temperature meter. Turbidity (in Nephelometric Turbidity Units (NTU)) was measured with turbidity meter in laboratory. Biological Oxygen Demand (BOD5) was measured *in vitro*. The amount of Total Dissolved Solids (TDS [mg/L]) was calculated by multiplying conductivity values with 0.65 (Forester and Brouwers 1985). Redox potential (EH) was calculated for the value of SHE (Standard Hydrogen Electrode) as follows:  $SHE = EH + 207 + 0.65 * (25 - T \text{ } ^\circ\text{C})$ . A Testo 410-1 Model Anemometer was used to measured wind speed (m/s), air temperature ( $T_a$  [°C]) and relative humidity (%).

The concept of “pseudorichness” (Külköylüoğlu 2004a) was computed from the ratio of non- cosmopolitan species number to the number of cosmopolitan species.

Ostracod Watch Model (OWM) (Külköylüoğlu 1998) was used to show the montly distribution of each species found in all the stations.

Total coliform analyses were done in the laboratory following standard APHA methods (1989).

Analyses of anions ( $\text{SO}_4$ , Cl, F, Br,  $\text{CO}_3$ ,  $\text{HCO}_3$ ) and cations (Na, K, Ca, Mg, Li) were done by Hacettepe University Water Chemistry (WCL) and Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) Laboratories with High Performance Ion Chromatography (HPIC) equipment.

The materials that include ostracods were collected with a standard hand-net (200  $\mu\text{m}$  mesh size) from the littoral zone at depths up to 100 cm and fixed in 70% ethanol *in situ* and kept in 250 mL measured plastic jars. In the laboratory, samples were filtered under tap water with four standard-sized sieves (0.25; 0.50; 1.00; 1.5 mm in mesh size) and then stored in ethanol. Species identification was based on the soft body parts and carapace structures. The species were identified under the Olympus BX-51 model microscope and saved in lactophenol solution for permanent slides. Taxonomic classification and species identification was done following Broodbakker and Danielopol (1982), Meisch (2000) and a key to the genera of the subfamily Candoninae of Karanovic (2001, 2006) and the index and bibliography of non-marine Ostracoda of Kempf (1980, 1997).

Carapace and valves were retained in micropaleontological slides. Scanning Electron Microscope (SEM) photographs were taken at TÜBİTAK-MAM (The Scientific and Technological Research Council of Turkey, Marmara Research Center, Turkey) with JEOL/JSM-6335F model microscope. Specimens were housed at the Limnology Laboratory of the Department of Biology (Abant İzzet Baysal University).

### 2. 3. Statistical Analyses

Results of hydrochemical analyses were summarized in the Piper Diagram using Sigma Plot 10.0 program. Piper Diagram was plotted in two ways: first, through measured values of anions and cations and second, through calculated values of Total Dissolved Solids (TDS) size for anions and cations in the center diamond. Sigma Plot 10.0 program was also used to show the relations between the ecological and physical parameters of the lake in isopleths. The temporal patterns of thermal stratification are simulated in coloured Filled Contour Plot with Sigma Plot 10.0. A multivariate data analysis technique, Principal Component Analysis (PCA), which aggregated large number of variables was used to determine the correlation between related variables. Varimax rotation delineated with “Kaiser Normalization” applied to PCA was used to explain the effects of the factors on hydrochemical processes. PCA with applying varimax rotation component was run with SPSS 16.0 Software Program. The hardness of lake water was calculated with the standard formulae for French Hardness Level (Fr°) as given below (Freeze and Cherry 1979);

$$[2.5 \times \text{Calcium} + 4.12 \times \text{Magnesium}] \text{ where the cations in mg/L} \quad (1)$$

The epilimnion thickness of Çubuk lake with a surface area of about 0.1603 km<sup>2</sup> (16.03 ha), 685 m fetch and mean Secchi depth < 4 m. (1.34 m.) was calculated using the following equations in Table 7.

**Table 7.** The equations using to calculate the depth of epilimnion layer of Lake Çubuk. It should be noted that wind take off route along central line (wave height) was calculated by the equation  $h = 0.105 \times \sqrt{fetch}$  where *fetch* is the length of the lake to south-north direction that the wind mostly blows.

| After autors                                            |                                                                                                                                                                                    | Formula                                                                   |  |
|---------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|--|
| The actual mean depth of epilimnion's                   |                                                                                                                                                                                    | Thermal Stratification                                                    |  |
| Patalas 1960                                            | <div style="border: 1px solid black; padding: 2px;">Z<sub>epi</sub>= Depth of Epilimnion<br/>W = Wind speed in m/s<br/>F = Fetch in m<br/>A = Surface area in km<sup>2</sup></div> | Z <sub>epi</sub> =4.4 W <sup>0.5</sup>                                    |  |
| Okulanis (1981)                                         |                                                                                                                                                                                    | Z <sub>epi</sub> =7.4 W <sup>0.5</sup>                                    |  |
| Arai (1981)                                             |                                                                                                                                                                                    | Z <sub>epi</sub> =6.22 W <sup>0.304</sup>                                 |  |
| Patalas (1984)                                          |                                                                                                                                                                                    | Z <sub>epi</sub> =4.6 A <sup>0.205</sup>                                  |  |
| Daves and Colley (1988)                                 |                                                                                                                                                                                    | Z <sub>epi</sub> =7.69 W <sup>0.463</sup>                                 |  |
| Skowron (1990)                                          |                                                                                                                                                                                    | Z <sub>epi</sub> =7.7 W <sub>L</sub> <sup>0.5</sup>                       |  |
| Mazumder and Taylor (1994)                              |                                                                                                                                                                                    | Z <sub>epi</sub> =3.94+2.97 Log <sub>10</sub> F                           |  |
| W <sub>L</sub> (Wind take-off route along central line) |                                                                                                                                                                                    | <div style="border: 1px solid black; padding: 2px;">h = 0.105√fetch</div> |  |

The thermocline thickness of the lakes of cross-basin diameter less then 5000 m depends on surface area. A shallow lake Çubuk has a surface area less than 25 km<sup>2</sup> (0.1603 km<sup>2</sup>), hence the following equation (Gorham and Boyce 1989) is used to estimate the thermocline depth;

$$h \cong 2.0 \sqrt{\frac{T}{g \Delta \rho}} \times L^{1/2} \quad \text{where } T = \text{wind stress, } \Delta \rho = \text{contrast density between}$$

epilimnion and hypolimnion,  $g$  = gravitational acceleration (9.8 m/s<sup>2</sup>) and  $L$  =square root of the surface area of the lake. (2)

The density of the lake was measured from each vertical layer at one meter intervals to down to the bottom using the following formula (Kalff 2002):

$$P = (1 - 6.63) \times 10^{-6} (T - 4)^2 \quad \text{where } T = \text{temperature in } ^\circ\text{C} \quad (3)$$

The stratification index (SI) was calculated from the standard deviation of density matrix with the following formula (Plisnier et al., 1999):

$$s = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n-1}} \quad \text{where } s = \text{standard deviation, } X_i = \text{value of sample,}$$

$$\bar{X} = \text{mean of sample values, } n = \text{number of samples} \quad (4)$$

$$SI = sd_m * 10000 \quad \text{where } sd_m = \text{standard deviation of measured density} \quad (5)$$

The stability of water column of Lake Çubuk was measured in ergs ( $\text{g-cm}^2.\text{s}^2$ ) using the below formulae (Schmidt 1928) derived from density;

$$S = \frac{g}{A_0} \int_{z_0}^{z_m} A_z (1 - p_z) (z - z_g) dz \quad \text{where } A_0 = \text{surface area of lake in cm}^2,$$

$z_0$  = first depth in cm,  $z$  = depth in cm,  $z_m$  = maximum depth in cm,  $A_z$  = area at depth  $z$  in  $\text{cm}^2$ ,  $p_z$  = density at depth  $z$ ,  $g$  = gravitational acceleration ( $9.8 \text{ m/s}^2$ ) (6)

$$z_g = \frac{1}{V} \int_{z_0}^{z_m} A_z (1 - p_z) z dz \quad \text{where } V = \text{lake volume in cm}^3, z_g = \text{depth to the}$$

center of gravity of the stratified lake in cm (7)

The Brunt Väisälä Frequency (buoyancy frequency  $N$ ) or stability frequency was measured (unit  $\text{s}^{-2}$ ) using following equation (Moritmer 1974):

$$N^2 = \frac{-g \partial p}{p \partial z} \quad \text{where } p = \text{density, } z = \text{depth in meter, } g = \text{gravitational}$$

acceleration ( $9.8 \text{ m/s}^2$ ) (8)

Wedderburn Number which utilizes the dimensionless parameters (wind speed, ratio of epilimnion depth to overall lake depth, gravity, total lake length, density of both epilimnion and hypolimnion) was calculated using the following model introduced by Thompson and Imberger (1980) and Imberger and Hamblin (1982);

$$W = \frac{g' h_e^2}{\mu_*^2 L} \quad \text{where } h_e = \text{height of epilimnion in meter, } \mu_* = \text{shear velocity}$$

of water at surface of the lake (m/s),  $L$ =length of the lake in meter (9)

$$g' = \frac{g(\rho_h - \rho_e)}{\rho} \quad \text{where } g = \text{gravity } (9.8 \text{ m/s}^2), \quad \rho = \text{reference density,}$$

$\rho_h$  = average density of hypolimnion,  $\rho_e$  = average density of epilimnion (10)

Microsoft Excel was used to both model the stratification patterns and make hypsographic (hypsometric) curve. Hypsographic curve was used to determine lake volume and the relative surface area against the relative depth of the lake.

To ascertain and to compare the trophic state of the lake two indices were used: Carlson Trophic State Index (CTSI) and Burns Trophic Level Index (BTLI). Carlson's Model uses linear numerical values of Secchi transparency in meters, total phosphorus in  $\mu\text{g/l}$  and total chlorophyll-a in  $\mu\text{g/l}$  with a scale from 0 to 100. In this study, measured total phosphorus levels were not statistically significant, therefore were not taken into account to determine CTSI. Carlson Trophic State Index was calculated using the following formulae:

$$TSI = 60 - 14.41 \ln(SD) \quad \text{where } SD = \text{Secchi Depth in meters} \quad (11)$$

$$TSI = 9.81 \ln(Clo-a) + 30.6 \quad \text{where } Clo-a = \text{Chlorophyll in } \mu\text{g/l} \quad (12)$$

$$CTSI = \frac{TSI(SD) + TSI(Clo-a)}{2} \quad (13)$$

Model of Burns uses a scale from 0.0 up to 7.0. Log transformation values of Secchi transparency in meters, total nitrogen level in  $\mu\text{g/l}$ , total phosphorus in  $\mu\text{g/l}$  and total chlorophyll-a in  $\mu\text{g/l}$  are used. Total phosphorus levels measured smaller than 0.001 were not taken into account. Burns Trophic Level Index was calculated using the following formulae:

$$TLI = 5.10 + 2.27 \log\left(\frac{1}{SD} - \frac{1}{40}\right) \text{ where } SD = \text{Secchi Depth in meters} \quad (14)$$

$$TLI = 2.22 + 2.54 \log(Clo-a) \text{ where } Clo-a = \text{Chlorophyll-a in } \mu\text{g/l} \quad (15)$$

$$TLI = -3.61 + 3.01 \log(TN) \quad \text{where } TN = \text{Total Nitrogen in } \mu\text{g/l} \quad (16)$$

$$BTI = \frac{TLI(SD) + TLI(Clo-a) + TLI(TN)}{3} \quad (17)$$

Both CTSI (ln transforms and graphs) and BTI (log transformation and graphs) indices were calculated with Microsoft Excel.

Spearman Rank Correlation analysis was performed with SPSS 16.0 software program to observe associations among 13 species and nine environmental variables. Analysis of Variance (ANOVA) 133 with unequal variance along with the F-test and t-tests in Excel were used to show 134 differences between the environmental variables belongs to stations and abundance of species. Canonical Correspondence Analysis (CCA) with Monte Carlo testing (499 permutations) was used to determine the relationship between environmental variables belongs to stations and the abundance of ostracod species. As suggested (Ter Braak and Barendregt 1986, Ter Braak 1987, Birks et al., 1990), the data used to see for CCA application were log-transformed and tested with Detrended Correspondence Analyses (DCA). Accordingly, length of gradient of DCA (4.290) was found higher than 3, supporting suitability of the data for the CCA application. We used 11 species that occurred at least three times along with five environmental variables (water temperature, electrical conductivity, redox potential, pH and turbidity). The relationship between the four most influential variables with the sampling time (months without species were not shown) and the distribution of the 11 species were illustrated using a CCA diagram.

Unweighted Pair Group Mean Averages (UPGMA) along with Jaccard's coefficient tests was used to evaluate possible clustering relationship among the species. CCA outcomes were gained from the CALIBRATE program, version 1.0 (Juggins 2001) while UPGMA analyses were performed with Multi-Variate Statistical Package (MVSP) version 3. 1. (Kovach 1998).

Species ecological tolerance ( $t_k$ ) and optimum ( $u_k$ ) values were estimated by using C2 program (Juggins 2003). For all statistical analyses, we used only living adults, while juveniles, subfossils and broken valves and/or carapaces were not counted.

Environmental Tolerance Index (ETI) was calculated from species using binary (presence/absence) data for 13 species that occurred at least three times during the study with seven variables (dissolved oxygen, pH, electrical conductivity, redox potential (SHE), salinity, saturation and temperature of water). ETI aims to calculate relative tolerance range of species for different environmental variables (Curry 1999). ETI values range from zero to one, which indicates the highest tolerance range.

$$ETI = \frac{\text{range of } x_{\text{species}}}{\text{range of } X_{\text{data set}}} \quad (18)$$

### 3. RESULTS

The limnoecological characteristics of Lake Çubuk were analysed in the light of the samplings, observations and numerical data in the form hereinafter set forth. 17 species belonging to 10 genera were found in this study. The taxonomy, distribution and ecology of the species in relation to the hydrological, physical and hydrochemical features of Lake Çubuk are given below.

#### 3. 1. Taxonomy

The taxonomy of species found in this study was given below. These species are from order Podocopida. The species found in this study belonged to infraorder Cypridocopina in 10 genera (Candona, Fabaeformiscandona, Pseudocandona, Cypria, Physocypria, Ilyocypris, Trajancypris, Prionocypris, Cypridopsis, and Limnocythere) in four families (Candonidae, Ilyocyprididae, Cyprididae, and Limnocytheridae).

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

**Suborder** Podocopina Sars, 1866

**Infraorder** Cypridocopina Jones, 1901

**Superfamily** Cypridoidea Baird, 1845

**Family** Candonidae Kaufmann, 1900

**Subfamily** Candoninae Kaufmann, 1900

**Genus** Candona Baird, 1845

*Candona candida* (O.F.Müller, 1776)

*Candona neglecta* (Sars, 1887)

*Candona weltneri* (Hartwig, 1899)

*Candona sanociensis* (Sywula, 1971)

**Genus** Fabaeformiscandona Krstic, 1972

*Fabaeformiscandona brevicornis* (Klie, 1925)

*Fabaeformiscandona japonica* (Okubo, 1990)

**Genus** Pseudocandona Kaufmann, 1900

*Pseudocandona albicans* (Brady, 1864)

*Pseudocandona eremita* (Vejdovsky, 1882)

*Pseudocandona sucki* (Hartwig, 1901)

*Pseudocandona semicognita* (Schäfer, 1934)

**Subfamily** Cyclocypridinae Kaufmann, 1900

**Genus** Cypria Zenker, 1854

*Cypria ophtalmica* (Jurine, 1820)

**Subfamily** Cyclocypridinae Kaufmann, 1900

**Genus** Physocypria Vávra, 1897

*Physocypria kraepelini* (G. W. Müller, 1903)

**Family** Ilyocyprididae Kaufmann, 1900

**Subfamily** Ilyocypridinae Kaufmann, 1900

**Genus** Ilyocypris Brady and Norman, 1889

*Ilyocypris gibba* (Ramdohr, 1808)

**Family** Cyprididae Baird, 1845

**Subfamily** Eucypridinae Bronshtein, 1947

**Genus** Trajancypris Martens, 1989

*Trajancypris serrata* (G. W. Müller, 1900)

**Genus** Prionocypris Brady and Norman, 1896

*Prionocypris zenkeri* (Chyzer and Toth, 1858)

**Subfamily** Cypridopsinae Kaufmann, 1900

**Genus** Cypridopsis Brady, 1867

*Cypridopsis vidua* (O. F. Müller, 1776)

**Superfamily** Cytheroidea Baird, 1850

**Family** Limnocytheridae Klie, 1938

**Subfamily** Limnocytherinae Klie, 1938

**Genus** Limnocythere Brady, 1867

*Limnocythere inopinata* (Baird, 1843)

### **3. 2. Ecology and Distribution**

The ecology of each species reported per station in this study is given below while the number of the species are tabulated in Appendices 2 and 6. The numbers in parantheses represent the total number of the individuals in the stations.

***Candona candida*** (O.F.Müller, 1776)

**General Distribution:** Euroasia and North America (Meish 2000, Karanovic 2006).

It is widely distributed in Europe and Britain (Henderson 1990).

**Material Station Numbers:** L2 (2), L4 (2), L5 (2), Gölpınar Spring (3),

**First record from Turkey:** Spring waters in Çanakkale (Altınsaçlı and Griffiths 2002).

**Ecology:** Reported from littoral and profundal zones of lakes, ponds, ditches, swamps, peaty waters with acid conditions, brooks, rivers, springs, wells and

different types of subterranean habitats (Meisch 2000). It prefers permanent waters and not recorded from brackish sites (Henderson 1990).

*Candona neglecta* (Sars, 1887)

**General Distribution:** Europe (Roca and Baltanás 1993), North Africa (Klie 1938), Central Asia, Russia (Bronshtein 1947), Algeria (Sars 1928) and America (Külköylüoğlu 1999b). It has a wide distribution in Europe but also shows almost cosmopolitan distribution throughout the South hemisphere (Roca and Baltanás 1993).

**Material Station Numbers:** L1 (8), L2 (4), L3 (1), L4 (1), L5 (2), Gölpınar Spring (2)

**First record from Turkey:** Gaziantep (Hartmann 1964).

**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). The 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), and is of wide ranges of dissolved oxygen (3.2-15.4 mg/L), pH values (6.8-9.4), conductivity (56-890  $\mu\text{S cm}^{-1}$ ) (Roca and Baltanás 1993).

*Candona weltneri* (Hartwig, 1899)

**General Distribution:** It is known in Britain, Germany, the Netherlands (Meisch 2000) Belgium (Martens and Dumont 1984), Hungary (Meisch and Forró 1998), the Czech Republic (Meisch 2000) and Turkey (Sarı and Külköylüoğlu 2010)

**Material Station Numbers:** L3 (2), L4 (2), L5 (2),

**First record from Turkey:** Bolu (Sarı and Külköylüoğlu 2010).

**Ecology:** It is reported from water bodies where had environmental values such as pH 7.96, relatively high redox potential 157.98 mV, low dissolved oxygen 6.67, relatively low electrical conductivity 459.30  $\mu\text{S cm}^{-1}$ , low saturation 68.1% and relatively low water temperature 15.80°C (Sarı and Külköylüoğlu 2010). It was reported from the lakes, ponds and both permanent and temporary small water bodies, (especially the ditches). It was mainly reported from the littoral zone of the lakes (Meisch 2000).

*Candona sanociensis* (Sywula, 1971)

**General Distribution:** So far only known from Hungary and the Czech Republic, also recorded from southern Poland and Romania (Meisch 2000) and Turkey (Sarı and Külköylüoğlu 2010).

**Material Station Numbers:** L1 (2), L2 (5), L5 (1),

**First record from Turkey:** Bolu (Sarı and Külköylüoğlu 2010).

**Ecology:** The ranges of ecological variables is reported as pH 7.78-8.10, redox potential 145.28-171.14 mV, dissolved oxygen 4.34-7.95 mg/L, conductivity 326.7-530  $\mu\text{Scm}^{-1}$  saturation 56.2-85.7% and temperature of water 7.10-27.50°C. It shows wide distribution as a cosmopolitan species (Sarı and Külköylüoğlu 2010). The species was reported from the waters connected to springs and small ponds (Meisch 2000), small running, muddy and roadside brook at altitude of 1075 m, stagnant and small temporary pond (Sarı and Külköylüoğlu 2010). Its synonymous *Candona dancaui* collected from springs, streams, wells and groundwater (Danielopol 1978).

*Fabaeformiscandona brevicornis* (Klie, 1925)

**General Distribution:** It is known from Germany, the Czech Republic, Slovakia (Absolon 1973), Hungary (Meisch 2000), Poland (Sywula 1971) and Turkey Bolu (Sarı and Külköylüoğlu 2010).

**Material Station Numbers:** L2 (2)

**First record from Turkey:** Bolu (Sarı and Külköylüoğlu 2010).

**Ecology:** The species is reported from a slow flowing creek where nestled more *Gammarus*. It is also reported from the stagnant and slow flowing waters connected to springs (Meisch 2000) and from the hyporheic habitat of a stream (Nüchterlein 1969).

*Fabaeformiscandona japonica* (Okubo, 1990)

**General Distribution:** Japan (Okubo 1990), Spain (Poquet 2003; Mezquita et al., 2005), Thailand (Savatenalinton 2011).

**Material Station Numbers:** L1 (4), L2 (21), L3 (2), L4 (12), Bottom (4),

**First record from Turkey:** First record for Turkish ostracod fauna.

**Ecology:** It is found on/in bottom of a paddy field in Japan (Okubo 1990), reported from shallow lakes close to the rivers in Spain (Poquet 2003) and it is also captured from a river (Millars) in Spain (Mezquita et al., 2005). It is reported from floodplain of Chi River basin in Thailand (Savatenalinton 2011).

*Pseudocandona albicans* (Brady, 1864)

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

**Material Station Numbers:** L1 (5), L2 (6), L4 (2), L5 (15), Gölpınar Spring (2)

**First record from Turkey:** İzmir (Gülen 1985a).

**Ecology:** It lives in permanent, muddy and slowflowing waters, while it prefers very low salt content (Meisch 2000). It is a crawling species that shows stygophilic behaviors (Roca and Danielopol 1991).

*Pseudocandona sucki* (Hartwig 1901)

**General Distribution:** Europa and central Asia (Meisch 2000).

**Material Station Numbers:** L2 (2), L5 (2),

**First record from Turkey:** İstanbul (Yaltalier 2007), this is the second record for Ostracoda fauna of Turkey.

**Ecology:** It prefers shallow and well vegetated water bodies. It can be found in both permanent and temporary water. It was determined in brackish coastal water, and can tolerate in slightly increasing salt content which can define as oligohaline (Meisch 2000).

*Pseudocandona eremita* (Vejdovsky, 1882)

**General Distribution:** Eastern and southeastern Europa and Asia Minor (Meisch 2000).

**Material Station Numbers:** L4 (2), L5 (2), Gölpınar Spring (2)

**First record from Turkey:** İstanbul (Gülen 1985a).

**Ecology:** This stygobitic species is adapting to hypogean habitats. It is reported from wells, caves, springs and surface waters (Meisch 2000).

*Pseudocandona semicognita* (Schäfer, 1934)

**General Distribution:** Bavaria (Scharf 1982), Saxonia (Meisch 2000), Poland (Sywula 1977).

**Material Station Numbers:** L4 (2), L5 (1), Gölpınar Spring (1)

**First record from Turkey:** Bolu (Sarı and Kulköylüoğlu 2010).

**Ecology:** It reported from a few shallow pools and ponds. It likes acidic conditions (Meisch 2000). It is ascertained from a spring near a cultured fish farm with pH level 7, 96 (Sarı and Külköylüoğlu 2010).

*Cypria ophtalmica* (Jurine, 1820)

**General Distribution:** It has worldwide distribution except Australia (Meisch 2000).

**Material Station Numbers:** L1 (28), L2 (14), L3 (16), L4 (14), L5 (14), Bottom (5), Gölpınar Spring (3),

**First record from Turkey:** İstanbul (Gülen 1985a).

**Ecology:** It is described as almost cosmopolitan by Külköylüoğlu (2003c). The species positively related to conductivity, water temperature, dissolved oxygen and pH, while it shows a negative relationship with redox potential (Sarı and Külköylüoğlu 2010). It tolerates pH values from very low to very high (Delorme 1991). It has a wide range of temperature and hydrochemically tolerance (Curry 1999). The temperature range of species is between 2.2°C and 8.4°C (Meisch 2000). It has a high ability to swim due to its long notatory setae. Therefore, it has an advantage to colonize easily by means of active movement (Scharf 1998). The species is reported from the salty habitats, which is called oligohaline range (Meisch 2000). It was found in the areas with high ionic content and eutricate conditions (Rossetti et al., 2005).

*Physocypria kraepelini* (G. W. Müller, 1903)

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

**Material Station Numbers:** L1 (20), L2 (32), L3 (5), L4 (18) , L5 (47), Gölpınar Spring (63),

**First record from Turkey:** Gaziantep (Hartmann 1964).

**Ecology:** A well-known cosmopolitan. It is not affected by the changes in different environmental variables (Sarı and Külköylüoğlu 2010). The species is a polythermophilic, mesohalophilic and eurycronal species (Yılmaz and Külköylüoğlu 2006, Sarı and Külköylüoğlu 2010). It occurs in less alkaline waters that means high temperature and conductivity. It shows a positive correlation with dissolved oxygen and it prefers water with high temperature (Yılmaz and Külköylüoğlu 2006). It has a oligohaline range (Meisch 2000). It was reported from the aquatic habitats that contained ionic content with higher trophic conditions (Rossetti et al., 2004).

*Ilyocypris gibba* (Ramdohr, 1808)

**General Distribution:** Europe, Africa, the Middle East, China, central Asia, America (Meisch 2000) and Turkey (Sarı and Külköylüoğlu 2010).

**Material Station Numbers:** L1 (4), L2 (17), L3 (5), L4 (6), L5 (13),

**First record from Turkey:** İzmir (Gülen 1977).

**Ecology:** *Ilyocypris gibba* shows a positive significant correlation for pH, conductivity and water temperature (Sarı and Külköylüoğlu 2010). It was found from warm waters and possible called as a eurythermophilic species (Külköylüoğlu 2004). It can live in low (Roca and Baltanás 1993), and high (Gülen 1977) water temperature. It is also reported from temporary spring and salty waters (Meisch 2000). It shows cosmopolitan characteristics (Külköylüoğlu 2004).

*Trajancypris serrata* (G. W. Müller, 1900)

**General Distribution:** Europe (Meisch 2000).

**Material Station Numbers:** L5 (4),

**First record from Turkey:** Van (Gülen et al., 1994a).

**Ecology:** Reported from an altitude of 2350 m in the Caucasus (Bronshtein 1947).

The datas about it showed that was a summer forms. Reported from the habitats type that dry up anytimes such as pools and ditches (Meisch 2000).

*Prionocypris zenkeri* (Chyzer and Toth, 1858)

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

**Material Station Numbers:** L2 (3),

**First record from Turkey:** Southwest Anatolia (Hartmann 1964).

**Ecology:** It prefers springs or habitats connected to springs (Rossetti 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 Rossetti et al. (2005) since environmental variables could not affect the occurrence of species.

*Cypridopsis vidua* (O. F. Müller, 1776)

**General Distribution:** Cosmopolitan (Meisch 2000).

**Material Station Numbers:** L2 (9), L4 (9), L5 (14), Gölpınar Spring (2),

**First record from Turkey:** Eskişehir (Gülen 1977).

**Ecology:** An active swimmer that prefers ponds, rivers and littoral zone of the lakes (Meisch 2000) but also reported from the helocrene, limnocrene and rheocrene types of springs (Külköylüoğlu and Yılmaz 2006). Known from habitats with rich vegetation (Mbahinzireki et al., 1991). It tolerates to slight increase salinity (Hiller 1972) with a low tolerance to dissolved oxygen (Meisch 2000). It has been showed a positive correlation to the water temperature (Külköylüoğlu et al., 2007), redox

potential and pH (Külköylüoğlu 2005c). It was collected from about 72 m of depth (Monard 1920 in Meisch 2000).

***Limnocythere inopinata*** (Baird, 1843)

**General Distribution:** Holarctic, rather common in everywhere (Meisch 2000).

**Material Station Numbers:** L1 (20), L5 (13), Gölpınar Spring (5),

**First record from Turkey:** Kastamonu (Ghetti 1973).

**Ecology:** *Limnocythere inopinata* has been reported from a variety of habitats and it is defined with high tolerances to salinity and temperature (Cohen et al. 1983, Mischke 2001, Külköylüoğlu et al., 2012a). It is found in a small reservoir at about 1400 m a.s.l. in Bolu (Yılmaz and Külköylüoğlu 2006). The fossil and living forms of the species were captured from Lake Arendsee (Germany) and Lake Büyükçekmece (Turkey) where show brackish waters character at about zero altitudes (ca. 23 m; Scharf 1998) and (ca. 1 m; Külköylüoğlu et al., 1995), respectively. In the waters of China (Lake Luanhaizi, Lake Qinghai), and nearby aquatic habitats the species was also found at about 3200 and 3450 m a.s.l., (Mischke et al., 2003, Li et al., 2010, respectively).

### **3. 3. Evaluation of Data**

#### **3. 3. 1. The species: Ostracoda**

During this study, samples were collected and data were gathered for 17 species (*Candona neglecta*, *C. candida*, *C. sanociensis*, *C. weltneri*, *Pseudocandona albicans*, *P. eremita*, *P. sucki*, *P. semicognita*, *Fabaeformiscandona brevicornis*, *F. japonica*, *Physocypria kraepelini*, *Cypria ophtalmica*, *Ilyocypris gibba*, *Cypridopsis vidua*, *Limnocythere inopinata*, *Trajancypris serrata*, and *Prionocypris zenkeri*). The

first three stations with the most abundant species numbers of individuals were L5 with 130 numbers, L2 with 119 numbers and L1 with 91 numbers. However, the most species diversity was ascertained from L2 with 13 species, L5 same number with L2 and L4 with 12 species, while the least numbers were found in stations: Bottom (2), L3 (7) and L1 (8). Nine living species (*Candona candida*, *C. neglecta*, *Pseudocandona albicans*, *P. eremita*, *P. semicognita*, *Cypria ophtalmica*, *Physocypria kraepelini*, *Cypridopsis vidua*, and *Limnocythere inopinata*) were detected from the limnocrone spring Gölpınar station, while only two species (*Fabaeformiscandona japonica*, *Cypria ophtalmica*) were captured from the bottom station. The most frequent and abundant species was *Physocypria kraepelini* with 185 individuals from the six stations excluding the bottom station. Although it was found in all the stations (including the bottom), *Cypria ophtalmica* ranked second with 94 living individuals after *Physocypria kraepelini*. The least frequent species were *Fabaeformiscandona brevicornis* (L2), *Prionocypris zenkeri* (L2) and *Trajancypris serrata* (L5) with 2, 3, and 4 individuals, respectively. A cosmopolitan species *Physocypria kraepelini* was also the most abundant species of Gölpınar spring with 63 individuals. For two months (January and February) in 2009 and one month (January) in 2010 the sampling was not done due to hard ice-cover conditions in winter. Except a few subfossil forms of *Candona neglecta* and *Pseudocandona albicans* from L2, no ostracods were found in March 2009, while either living or subfossils were found in July 2010. Both living and subfossil forms of Ostracoda was not be found in several months from stations as: L1 (March, April, May, June in 2009 and February, March, May, July in 2010), L2 (July and September in 2010), L3 (July, October in 2008; March, December in 2009 and February, March, April, July, August, October in 2010), L4 (March in 2009; February, March, June and July

in 2010), L5 (September in 2008; March, April in 2009 and July, September in 2010), and the Bottom station (October in 2008; March, June, August and October in 2009 and April, May, June and July in 2010). The living forms of the cosmopolitan species, *Cypria ophthalmica*, were captured from the bottom in September 2008 (depth 5.15 m) and September 2009 (depth 5.70), while living individuals of *Fabaeformiscandona japonica* were found in September 2008 in the bottom sediments. Excluding the two months, the living forms were not ascertained from the bottom. The highest species abundance values occurred in two months (September and November in 2008) with 69 and 77 individuals, respectively. The species *F. japonica* also found in the bottom sediments with four individuals (bottom-dependent) was recorded for the first time for Turkish Ostracod fauna with a total sum of 43 individuals.

Two species (*P. fontinalis* and *I. bradyi*) previously (in 2006) detected (Sarı and Külköylüoğlu 2010) in Lake Çubuk were not found in the present study.

The mean number of individuals per species was 31.2. There was a significant difference between the numbers of individuals between the years 2009 and 2010 when the numbers of individuals were much lower in 2010 than 2009 ( $P < 0.01$ ,  $F$  test=4.41). Besides, the number of species was almost 50% lower in 2010 (8 species) than 2009 (16 species). Such reductions in the numbers of individuals and species correspond to the high water levels in the year 2010.

The species investigated from the stations with their abundance and the environmental variables for each station were shown in the Appendices 1, 2 and 3. The corresponding data of chemicals (anions/cations etc.) and microbiological results with mean, minimum and maximum values were given in Appendix 4.

Fifteen different measured environmental variables (dissolved oxygen (DO), pH, electrical conductivity (EC), redox potential (EH as SHE), total dissolved solids (TDS), Salinity (Sal), percent oxygen saturation (Sat), water temperature ( $T_w$ °C), air temperature ( $T_a$ °C), biological oxygen demand (BOD5), turbidity (Turb), lake water depth (Depth), Secchi depth (Secchi), percent humidity (Hum), wind speed (Wind)) are shown in Appendix 3.

Some abbreviations used for species are given below;

*Candona candida* (Cc), *Candona neglecta* (Cn), *Candona weltneri* (Cw), *Candona sanociensis* (Cs), *Pseudocandona albicans* (Pa), *Pseudocandona eremite* (Pe), *Pseudocandona sucki* (Ps), *Pseudocandona semicognita* (Pm), *Fabaeformiscandona brevicornis* (Fb), *Fabaeformiscandona japonica* (Fj), *Cypria ophtalmica* (Co), *Physocypria kraepelini* (Pk), *Ilyocypris gibba* (Ig), *Trajancypris serrata* (Ts), *Prionocypris zenkeri* (Pz), *Cypridopsis vidua* (Cv), *Limnocythere inopinata* (Li).

After laboratory and field work, data collected from 12 stations (5 littoral, 6 vertical and 1 spring (Gölpınar) inside the lake) during 26 months (24 months for pelagic stations of which variables) were evaluated. The average values of the variables calculated are as follows: Dissolved Oxygen (DO) 5.67 mg/L, Saturation (Sat) 57.97%, Eh (as SHE) 175.84 mV, Electrical Conductivity (EC) 238.17  $\mu\text{S cm}^{-1}$ , pH 7.96, Temperature of water ( $T^\circ\text{C}$  (w)) 15.51°C, Temperature of air ( $T^\circ\text{C}$  (a)) 17.57°C salinity 0.12 ppt, total dissolved solids (TDS) 154.81 mg/L, biological oxygen demand (BOD5) 2.71 mg/L, turbidity (Turb) 3.86, lake water depth (Depth) 6.24 m, Secchi depth (Secchi) 134.38 cm, humidity (Hum) 47.57% and wind speed (Wind) 3.05 m/s (Appendix 3).

As can be seen in Ostracod Watch Model, the only species obtained throughout the year was *Physocypria kraepelini* (Figure 11). The species which showed with the

arrows have a cycle at the end (*Fabaeformiscandona brevicornis* (Fb), *Pseudocandona semicognita* (Pm), *Prionocypris zenkeri* (Pz), *Pseudocandona eremite* (Pe) and *Trajancypris serrata* (Ts)) were detected either once during the sampling or a few times but in the same month at each time. As seen from the OWM diagram, two species belong to genus Candona (*C. candida* and *C. neglecta*), were usually captured in the same months, while the other two (*C. weltneri* and *C. sanociensis*) settled in different parts of the year. *Cypridopsis vidua* was found from summer to winter (June to December), when *Fabaeformiscandona japonica* had a relatively acute angle from July to September. While the angle of *L. inopinata* scanned August to December, it encompassed *Cy. ophtalmica* with similar preferences. The part of the year from the May until December, four species of genus Pseudocandona (*P. albicans*, *P. eremita*, *P. sucki* and *P. semicognita*) were recorded (Figure 11).

The SEM photographs of the 14 species identified were presented in the two plates (Plate 1 and 2).

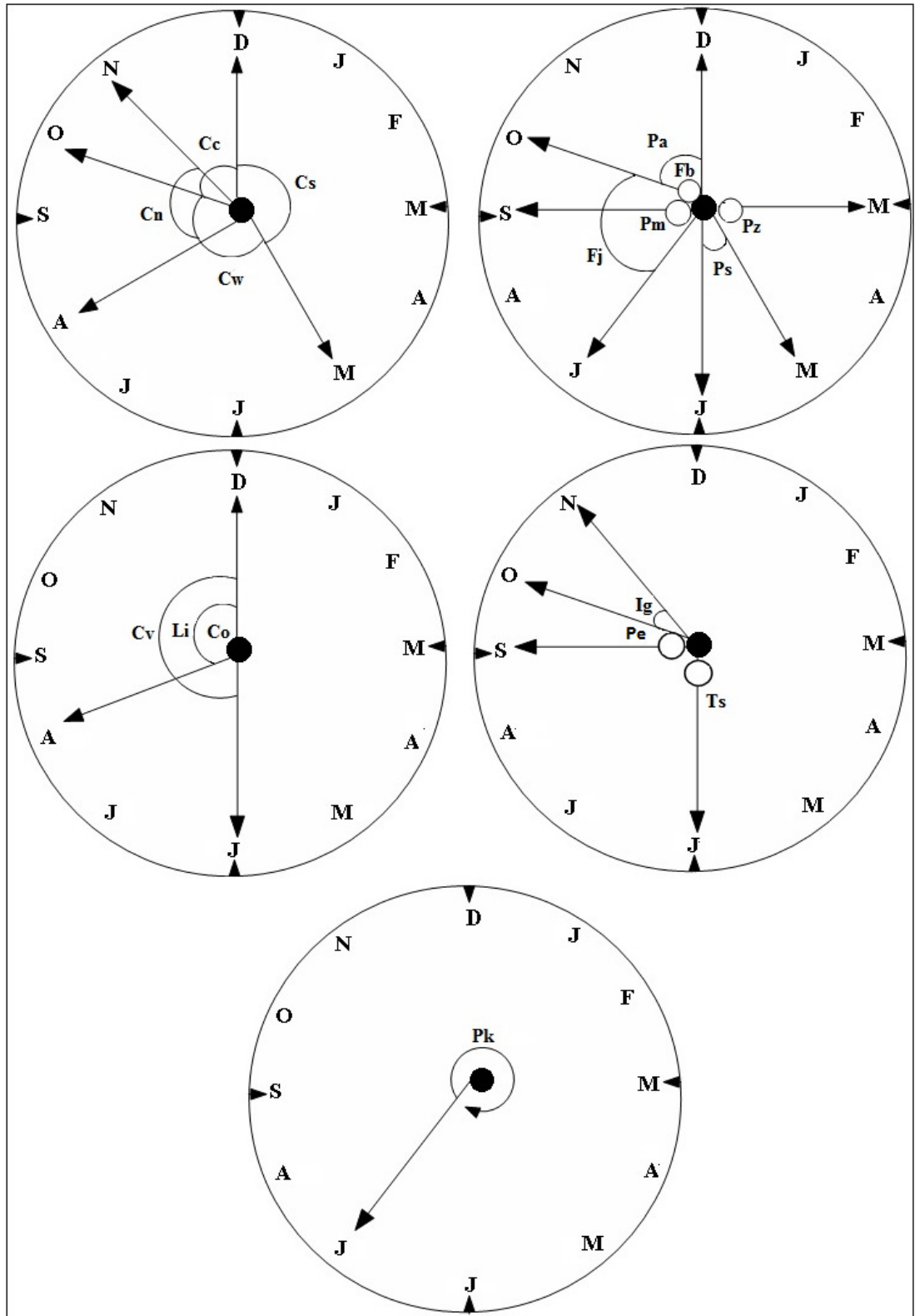


**Figure 11.** Ostracod Watch Model (OWM) for 17 species shows seasonal species occurrences of 17 species from Lake Çubuk. The arrows with a circle at the end represent that the species has been detected once in indicated month.

Unweighted Pair Group Mean Averages (UPGMA) along with Jaccard's coefficient tests were clustered 10 species into three groups. Accordingly, the first group included three species (*T. serrata*, *P. albicans* and *P. sucki*) with a degree about 35%, while the percent relationship in the second group was similar. In the second group, especially *Cs. vidua* and *Cy. ophtalmica* were closed to each other with a high degree. *Ph. kraepelini*, the most common species which was found throughout a year (19 sampling times), was clustered with *F. japonica* (found for eight months) and *C. neglecta* (settled for nine sampling times). They were around 45% of similarity (Figure 12).

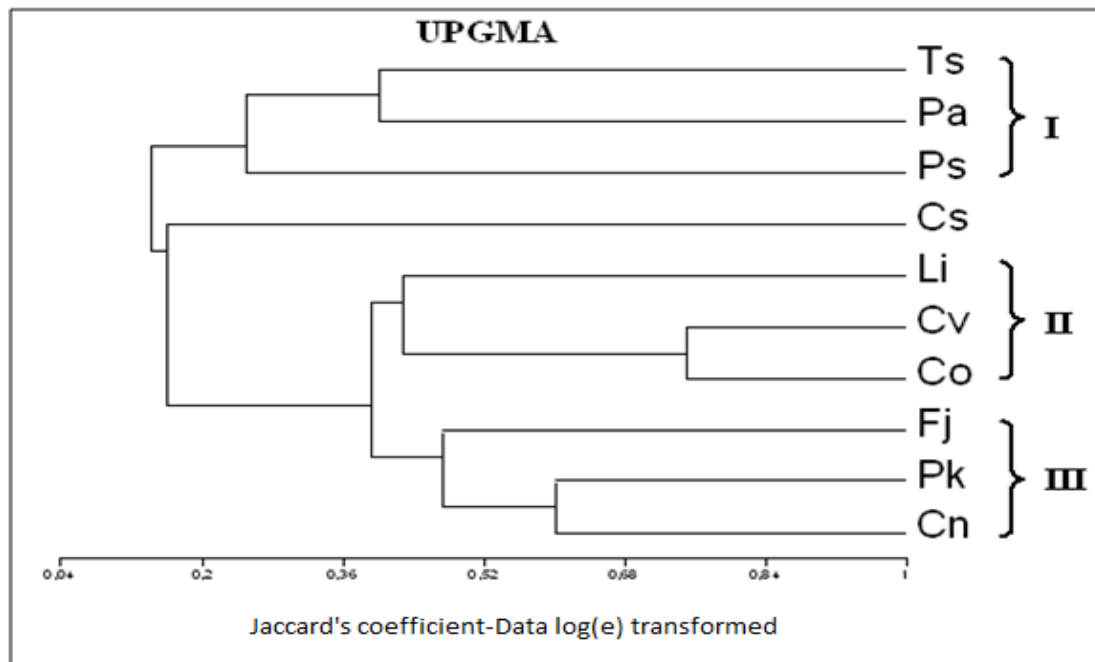


**Figure 12.** Unweighted Pair Group Mean Averages (UPGMA) shows the clustering relationships of 10 ostracods.

Canonical Correspondence Analysis (CCA) was applied to illustrate the relationship among four environmental variables (redox potential, electrical conductivity, turbidity and temperature of water) and 11 species (Figure 13). Besides, critical values of CCA were tabulated in Table 3. Critical values interpreted

from the correlations among the species and environmental variables were 77.2% for the first two axes. According to eigen values of CCA, the most influential variables on species are electrical conductivity and water temperature.

Canonical Correspondence Analysis displayed the most effective variables on species as the electrical conductivity and the temperature of water ( $P = 0.002$ ). These results were also supported by the ETI and Spearman Correlation Analysis. As mentioned before, the placement of the species in CCA shows the relationships between the four environmental variables and 11 species with their settled sampling time. Accordingly, five species (*C. neglecta*, *C. sanociensis*, *Cy. ophtalmica*, *Cs. vidua* and *Ps. kraepelini*) are located closer to the center of CCA diagram. In such a case, the location of these species means that they have wide tolerance ranges for these environmental variables and may not have significant correlation.

Seven species (*C. neglecta*, *P. semicognata*, *P. eremita*, *F. japonica*, *Cy. ophtalmica*, *L. inopinata*, *Cs. vidua*,) showed negative correlation with electrical conductivity when two species (*F. japonica* ( $P < 0.05$ ,  $r = 0.488$ ) and *Cs. vidua* ( $P < 0.05$ ,  $r = 0.433$ ) had a positive correlations with water temperature. The correlation of *C. candida* with the same variable was negative ( $P < 0.05$ ,  $r = -0.572$ ), while a significant correlation was also seen between the other candonid species *C. neglecta* and dissolved oxygen. Although tolerance levels of the most common species were relatively higher than the mean levels (e.g., water temperature) but lower than the mean electrical conductivity (Appendix 2).

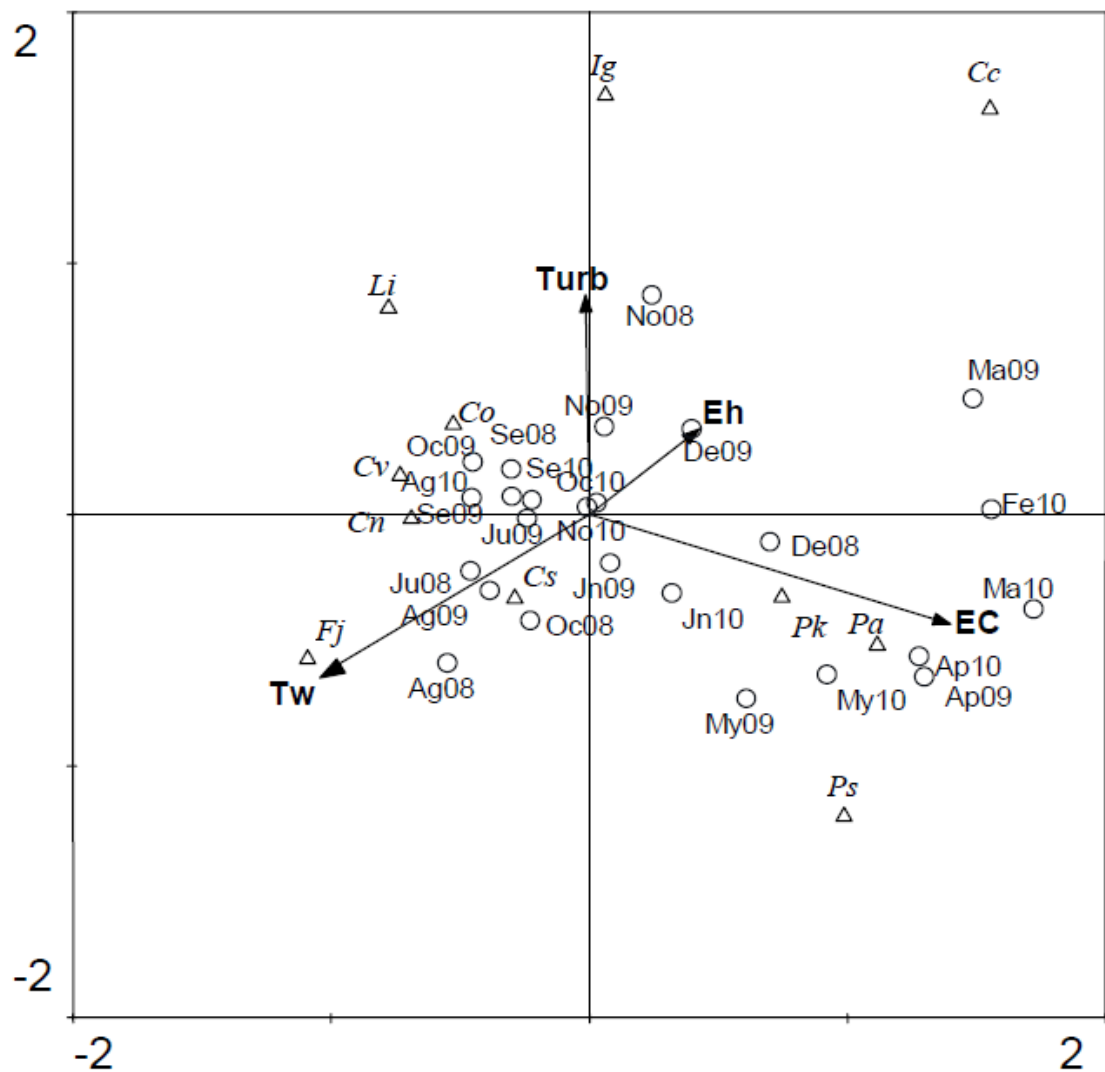


**Figure 13.** CCA diagram shows distribution of 11 species occurred at least three times with 4 environmental variables (EC, Eh, Tw, Turb). Months without species were not shown. Abbreviations and species codes are given in Appendices 1 and 3.

**Table 8.** Summary table of CCA results for five variables with 11 species occurred at least 3 or more times. Data is Log-transformed and rare species were downweighted. Most effective variables are as follow: EC (P = 0.002, f = 3.660), Tw (P = 0.002, f = 2.469), Turbidity (P = 0.086, f = 1.625), pH (P = 0.432, f = 0.994), DO (P = 0.702, f = 0.700)

| Axes                               | 1       | 2     | 3     | 4     | Total inertia |
|------------------------------------|---------|-------|-------|-------|---------------|
| Lengths of gradient                | : 4.290 | 2.511 | 1.761 | 2.087 |               |
| Eigenvalues                        | : 0.263 | 0.166 | 0.071 | 0.056 | 1.744         |
| Species-environment correlations   | : 0.881 | 0.740 | 0.576 | 0.587 |               |
| Cumulative percentage variance     |         |       |       |       |               |
| of species data                    | : 15.1  | 24.6  | 28.7  | 31.9  |               |
| of species-environment relation    | : 47.3  | 77.2  | 89.9  | 100.0 |               |
| Sum of all eigenvalues             |         |       |       |       | 1.744         |
| Sum of all canonical eigenvalues : |         |       |       |       | 0.556         |

Spearman Correlation Analysis was used to observe associations between 13 species and nine environmental variables and outcomes were tabulated in Table 9. There was a positive significant relation of *C. sanociensis* to pH, while, at the same time pH showed an intense negative relationship with electrical conductivity (P<0.05). The relationship between dissolved oxygen (DO) and *C. weltneri* was strongly negative, while it was positively correlated with *L. inopinata*. *C. weltneri* also showed a positive significant relationship with turbidity (Turb; P<0.05), when the relationship between *P. albicans* and percent oxygen saturation (Sat) was to be conspicuous.

Even though Spearman Correlation did not explain enough the relationships between the environmental variables and species, this analysis was able to reveal some important knowledge for interspecific relationships among the species. For example, *L. inopinata* negatively correlated with *C. weltneri*, two members of genus Candona (*C. neglecta* and *C. sanociensis*) showed a significant correlation with each other. Two species (*P. eremita* and *P. semicognita*) seemed to be positively related.

*Cypria ophtalmica*, the most frequent species of the present study displayed a strongly positive relationship with *C. candida*. A common cosmopolitan species *Ps. kraepelini* was negatively correlated with turbidity. The only species which showed a significant positive relationship with BOD5 was *C. sanociensis* with positive character at the 0.05 level. Three species (*F. japonica*, *I. gibba* and *Cs. vidua*) did not correlate with either environmental variables or species, while *C. candida*, *C. neglecta*, *P. eremita*, *P. semicognita*, and *Cy. ophtalmica* did not show any relationship with any environmental variable.

**Table 9.** Significant results of Spearman correlation analysis for 13 species (Spp) and 9 variables (Var). (\*) 0.05 and (\*\*) 0.01 significant levels follow negative or positive coefficient values. Abbreviations and species codes are given in Appendices 1 and 3.

|        | pH      | SHE   | EC      | DO     | Sal    | Sat   | T°C(w) | BOD   | Tur    | Cc      | Cn    | Cw      | Cs    | Pa    | Pe     | Pm    | Fj    | Co    | Pk    | Ig    | Cv    | Li    |
|--------|---------|-------|---------|--------|--------|-------|--------|-------|--------|---------|-------|---------|-------|-------|--------|-------|-------|-------|-------|-------|-------|-------|
| pH     | 1.000   |       |         |        |        |       |        |       |        |         |       |         |       |       |        |       |       |       |       |       |       |       |
| SHE    | -.771   | 1.000 |         |        |        |       |        |       |        |         |       |         |       |       |        |       |       |       |       |       |       |       |
| EC     | -.943** | .829* | 1.000   |        |        |       |        |       |        |         |       |         |       |       |        |       |       |       |       |       |       |       |
| DO     | .174    | -.290 | -.406   | 1.000  |        |       |        |       |        |         |       |         |       |       |        |       |       |       |       |       |       |       |
| Sal    | -.559   | .794  | .765    | -.493  | 1.000  |       |        |       |        |         |       |         |       |       |        |       |       |       |       |       |       |       |
| Sat    | .829*   | -.714 | -.943** | .493   | -.853* | 1.000 |        |       |        |         |       |         |       |       |        |       |       |       |       |       |       |       |
| T°C(w) | .273    | -.638 | -.395   | .092   | -.813* | .516  | 1.000  |       |        |         |       |         |       |       |        |       |       |       |       |       |       |       |
| BOD    | 1.000** | -.771 | -.943** | .174   | -.559  | .829* | .273   | 1.000 |        |         |       |         |       |       |        |       |       |       |       |       |       |       |
| Tur    | .086    | -.314 | .029    | -.725  | -.147  | -.086 | .577   | .086  | 1.000  |         |       |         |       |       |        |       |       |       |       |       |       |       |
| Cc     | -.463   | .463  | .463    | .360   | .318   | -.309 | -.164  | -.463 | -.463  | 1.000   |       |         |       |       |        |       |       |       |       |       |       |       |
| Cn     | .736    | -.324 | -.647   | .373   | -.061  | .500  | -.375  | .736  | -.500  | -.079   | 1.000 |         |       |       |        |       |       |       |       |       |       |       |
| Cw     | -.098   | .098  | .293    | -.891* | .201   | -.293 | .311   | -.098 | .878*  | -.211   | -.503 | 1.000   |       |       |        |       |       |       |       |       |       |       |
| Cs     | .880*   | -.395 | -.759   | .123   | -.250  | .698  | -.032  | .880* | -.152  | -.197   | .844* | -.104   | 1.000 |       |        |       |       |       |       |       |       |       |
| Pa     | .667    | -.377 | -.725   | .603   | -.552  | .841* | .246   | .667  | -.406  | .188    | .627  | -.396   | .770  | 1.000 |        |       |       |       |       |       |       |       |
| Pe     | -.488   | .098  | .293    | .594   | -.201  | -.098 | .311   | -.488 | -.293  | .738    | -.402 | -.333   | -.518 | .099  | 1.000  |       |       |       |       |       |       |       |
| Pm     | -.432   | -.062 | .278    | .423   | -.254  | -.123 | .492   | -.432 | .000   | .633    | -.509 | -.105   | -.557 | -.016 | .949** | 1.000 |       |       |       |       |       |       |
| Fj     | .522    | -.406 | -.261   | -.574  | .000   | .116  | .277   | .522  | .696   | -.250   | .179  | .693    | .462  | .044  | -.495  | -.250 | 1.000 |       |       |       |       |       |
| Co     | .577    | -.577 | -.577   | -.246  | -.375  | .395  | .161   | .577  | .395   | -.984** | .219  | .104    | .290  | -.092 | -.726  | -.623 | .277  | 1.000 |       |       |       |       |
| Pk     | -.086   | .314  | .029    | .696   | .147   | .086  | -.395  | -.086 | -.886* | .772    | .441  | -.683   | .213  | .551  | .488   | .247  | -.464 | -.698 | 1.000 |       |       |       |
| Ig     | .429    | -.200 | -.371   | -.174  | -.412  | .543  | .577   | .429  | .371   | .000    | .000  | .488    | .516  | .580  | -.098  | -.031 | .493  | -.030 | -.086 | 1.000 |       |       |
| Cv     | .088    | -.088 | -.177   | .403   | -.455  | .441  | .563   | .088  | -.088  | .572    | -.091 | .000    | .188  | .672  | .603   | .572  | .000  | -.563 | .441  | .706  | 1.000 |       |
| Li     | .395    | -.395 | -.577   | .832*  | -.406  | .516  | -.161  | .395  | -.698  | -.098   | .625  | -.933** | .290  | .462  | .104   | -.066 | -.493 | .226  | .455  | -.395 | -.094 | 1.000 |

\*\* . Correlation is significant at the 0.01 level (2-tailed).

\* . Correlation is significant at the 0.05 level (2-tailed).

Optima (*uk*), tolerance (*tk*) and ETI formulas were calculated for thirteen species to ten environmental variables and tabulated in Tables 10 and 11. Accordingly, species have different optimum limits to different environmental variables. ETI values range from zero to one, that means that some species adapted to the environment very well.

According to Table 10, pH optima values of species ranged from 7.79 to 8.10. Among 13 species the highest tolerance limits to pH were found for *C. sanociensis*, while the minimum value was for both *Ps. kraepelini* and *L. inopinata* (Table 10). *Limnocythere inopinata* also showed the highest optimum and the least tolerance limit to dissolved oxygen (DO). *C. weltneri* was the species with the least optima values for dissolved oxygen and salinity and the least tolerance levels to electrical conductivity (EC) and salinity. The other candonid species *C. sanociensis* showed usually the lowest optima and tolerance values except pH and biological oxygen demand (BOD5). The high optima and tolerance levels for several variables belong to *C. candida* and *P. eremita*. The optima values for water temperature ( $T^{\circ}\text{C}(\text{w})$ ) changed from 15.07 °C to 16.87 °C of which maximum level belonged to *C. weltneri* and *F. japonica*, while the least one was for *Ps. kraepelini*. *F. japonica* also captured from bottom sediments close to V5 station with *Cy. ophtalmica* showed the least value for saturation tolerance to water temperature. The range of tolerance value of electrical conductivity was very high which changed from 0.65  $\mu\text{S cm}^{-1}$  (*C. weltneri*) to 73.83  $\mu\text{S cm}^{-1}$  (*P. eremita*).

**Table 10.** Tolerance (Tol) and optimum (Opt) estimates of 11 species occurred at least 3 or more times for the six environmental variables during this study. Abbreviations: SHE (redox potential), EC (electrical conductivity), DO (dissolved oxygen), Tw (water temperature), Tur (turbidity), Mean (mean of data), Stdev (standard deviation). Species codes are given in Appendix 1.

| Code  |       |      |      | pH   |      | SHE    |       | EC     |       | DO   |      | Tw    |      | Tur  |      |
|-------|-------|------|------|------|------|--------|-------|--------|-------|------|------|-------|------|------|------|
|       | Count | Max  | N2   | Opt  | Tol  | Opt    | Tol   | Opt    | Tol   | Opt  | Tol  | Opt   | Tol  | Opt  | Tol  |
| Cn    | 11    | 5    | 8.34 | 7.99 | 0.24 | 160.19 | 24.76 | 199.79 | 23.77 | 6.53 | 2.16 | 16.75 | 4.84 | 4.15 | 2.68 |
| Cc    | 3     | 3    | 2.88 | 8.22 | 0.57 | 195.00 | 61.71 | 253.33 | 74.8  | 6.63 | 2.78 | 7.142 | 2.04 | 5.87 | 4.21 |
| Cs    | 4     | 4    | 2.91 | 8.14 | 0.13 | 163.14 | 36.69 | 205.31 | 9.422 | 6.84 | 2.78 | 15.38 | 6.34 | 2.33 | 1.39 |
| Ps    | 3     | 2    | 3.00 | 8.09 | 0.20 | 165.86 | 20.03 | 277.94 | 39.14 | 5.32 | 2.08 | 18.52 | 3.28 | 2.96 | 0.3  |
| Pa    | 7     | 14   | 3.97 | 7.91 | 0.36 | 168.96 | 20.82 | 245.79 | 36.89 | 7.16 | 3.58 | 12.12 | 7.35 | 2.83 | 2.19 |
| Fj    | 7     | 11   | 5.83 | 7.89 | 0.31 | 153.1  | 18.83 | 195.6  | 10.64 | 5.78 | 1.6  | 19.43 | 3.03 | 3.94 | 1.65 |
| Pk    | 21    | 27   | 11.8 | 7.89 | 0.24 | 161.21 | 15.32 | 221.58 | 45.28 | 5.6  | 2.41 | 13.87 | 6.44 | 4.5  | 2.11 |
| Co    | 13    | 19   | 8.34 | 7.99 | 0.26 | 172.08 | 23.97 | 206.4  | 20.33 | 6.37 | 1.83 | 17.52 | 5.95 | 4.7  | 2.87 |
| Cv    | 11    | 8    | 7.90 | 7.87 | 0.29 | 168.43 | 24.16 | 200.7  | 19.7  | 5.96 | 1.45 | 18.69 | 5.48 | 4.35 | 2.61 |
| Li    | 10    | 14   | 5.09 | 7.89 | 0.24 | 158.63 | 19.16 | 196.62 | 10.99 | 4.9  | 1.57 | 15.09 | 6.57 | 4.86 | 1.81 |
| Ig    | 3     | 34   | 1.54 | 7.87 | 0.08 | 162.79 | 5.765 | 209.61 | 7.855 | 7.57 | 3.4  | 9.873 | 4.58 | 8.64 | 3.15 |
| Mean  | 8.455 | 12.8 | 5.6  | 7.98 | 0.27 | 166.31 | 24.66 | 219.33 | 27.17 | 6.24 | 2.33 | 14.94 | 5.08 | 4.47 | 2.27 |
| Stdev | 5.538 | 10.3 | 3.15 | 0.12 | 0.13 | 10.899 | 14.36 | 27.499 | 20.42 | 0.81 | 0.73 | 3.908 | 1.7  | 1.72 | 1.02 |

According to Table 10, the most tolerant species with the highest ETI ranges for both pH (0.88) and redox potential (SHE; 0.90) was *P. semicognita*, which also had the highest tolerance level to turbidity (Turb). This species did also exhibit the least ETI value for oxygen saturation. *Candona weltneri* had the least ETI ranges to pH (0.08) with pursuit of *I. gibba* (0.09). The least ETI values for electrical conductivity and redox potential belonged to *I. gibba*. The ETI ranges in relation to dissolved oxygen (DO) changed from 0.15 (*C. neglecta*) to 0.82 (*P. albicans*). The optima and tolerance values of these two species were between the least and the highest values. *Cy. ophtalmica* was the most common species collected from all the stations including the bottom one. In which case, it already had higher ETI ranges to almost all environmental variables. Its ETI value for water temperature was the highest with other abundant species *Ps. kraepelini* and *L. inopinata*. The highest saturation ETI value is 0.78 that belongs to a cosmopolitan species, *Ps. kraepelini*. Apparently, the species *C. candida* with wide optima and tolerance levels also showed relatively high ETI values for all variables.

**Table 11.** Descriptive statistics, ETI (Environmental Tolerance Index) for mean Dissolved oxygen (DO); pH; Electrical conductivity (EC); Redox potential (SHE); Salinity (Sal); Saturation (%Sat.) and Temperature of water (T°C (w)) for 13 species.

| <i>C. candida</i>     | DO   | pH   | EC     | SHE    | Sal   | Sat   | T°C(w) |
|-----------------------|------|------|--------|--------|-------|-------|--------|
| Max.                  | 8,60 | 8,93 | 348,76 | 273,84 | 0,20  | 74,80 | 8,73   |
| Min.                  | 3,22 | 7,85 | 212,00 | 162,19 | 0,10  | 25,06 | 4,75   |
| ETI                   | 0,54 | 0,65 | 0,79   | 0,79   | 0,87  | 0,55  | 0,21   |
| range                 | 5,38 | 1,08 | 136,76 | 111,65 | 0,10  | 49,74 | 3,98   |
| <i>C. neglecta</i>    | DO   | pH   | EC     | SHE    | Sal   | Sat   | T°C(w) |
| Max.                  | 8,60 | 8,20 | 291,49 | 164,33 | 0,15  | 83,03 | 23,89  |
| Min.                  | 7,10 | 7,46 | 183,00 | 131,87 | 0,09  | 31,63 | 8,73   |
| ETI                   | 0,15 | 0,44 | 0,62   | 0,23   | 0,54  | 0,57  | 0,79   |
| range                 | 1,50 | 0,74 | 108,49 | 32,45  | 0,06  | 51,40 | 15,16  |
| <i>C. weltneri</i>    | DO   | pH   | EC     | SHE    | Sal   | Sat   | T°C(w) |
| Max.                  | 7,24 | 8,05 | 308,50 | 162,19 | 0,16  | 77,05 | 17,88  |
| Min.                  | 3,22 | 7,91 | 219,87 | 148,10 | 0,10  | 25,06 | 4,75   |
| ETI                   | 0,41 | 0,08 | 0,51   | 0,10   | 0,49  | 0,57  | 0,69   |
| range                 | 4,02 | 0,14 | 88,63  | 14,09  | 0,06  | 51,99 | 13,13  |
| <i>C. sanociensis</i> | DO   | pH   | EC     | SHE    | Sal   | Sat   | T°C(w) |
| Max.                  | 7,70 | 8,20 | 219,87 | 197,70 | 0,10  | 77,75 | 22,18  |
| Min.                  | 3,22 | 7,98 | 198,18 | 135,82 | 0,98  | 25,06 | 4,75   |
| ETI                   | 0,45 | 0,13 | 0,12   | 0,44   | -7,62 | 0,58  | 0,91   |
| range                 | 4,48 | 0,22 | 21,69  | 61,88  | -0,88 | 52,69 | 17,42  |
| <i>P. albicans</i>    | DO   | pH   | EC     | SHE    | Sal   | Sat   | T°C(w) |
| Max.                  | 9,22 | 8,30 | 338,70 | 188,75 | 0,18  | 77,75 | 21,16  |
| Min.                  | 1,07 | 7,27 | 208,00 | 135,82 | 0,10  | 12,38 | 6,03   |
| ETI                   | 0,82 | 0,62 | 0,75   | 0,37   | 0,69  | 0,72  | 0,79   |
| range                 | 8,15 | 1,03 | 130,70 | 52,93  | 0,08  | 65,37 | 15,13  |
| <i>P. eremita</i>     | DO   | pH   | EC     | SHE    | Sal   | Sat   | T°C(w) |
| Max.                  | 9,22 | 8,13 | 255,00 | 164,06 | 0,10  | 77,65 | 18,98  |
| Min.                  | 4,32 | 7,46 | 183,00 | 146,41 | 0,98  | 46,04 | 6,03   |
| ETI                   | 0,50 | 0,40 | 0,41   | 0,12   | -7,62 | 0,35  | 0,68   |
| range                 | 4,90 | 0,67 | 72,00  | 17,65  | -0,88 | 31,61 | 12,95  |
| <i>P. semicognita</i> | DO   | pH   | EC     | SHE    | Sal   | Sat   | T°C(w) |
| Max.                  | 7,10 | 8,93 | 348,76 | 273,84 | 0,20  | 61,30 | 18,98  |
| Min.                  | 4,32 | 7,46 | 183,00 | 146,41 | 0,10  | 46,04 | 7,15   |
| ETI                   | 0,28 | 0,88 | 0,95   | 0,90   | 0,87  | 0,17  | 0,62   |
| range                 | 2,78 | 1,47 | 165,76 | 127,43 | 0,10  | 15,26 | 11,83  |

Table 11. cont.

| <i>F. japonica</i>    | DO   | pH   | EC     | SHE    | Sal  | Sat   | T°C(w) |
|-----------------------|------|------|--------|--------|------|-------|--------|
| Max.                  | 7,70 | 8,20 | 208,00 | 197,70 | 0,11 | 83,03 | 23,89  |
| Min.                  | 3,53 | 7,46 | 183,00 | 131,87 | 0,10 | 39,88 | 15,22  |
| ETİ                   | 0,42 | 0,44 | 0,14   | 0,46   | 0,08 | 0,48  | 0,45   |
| range                 | 4,17 | 0,74 | 25,00  | 65,83  | 0,01 | 43,15 | 8,67   |
| <i>Cy. ophtalmica</i> | DO   | pH   | EC     | SHE    | Sal  | Sat   | T°C(w) |
| Max.                  | 9,22 | 8,30 | 255,00 | 197,70 | 0,11 | 77,75 | 23,89  |
| Min.                  | 3,22 | 7,46 | 183,00 | 131,87 | 0,10 | 25,06 | 4,75   |
| ETİ                   | 0,61 | 0,50 | 0,41   | 0,46   | 0,08 | 0,58  | 1,00   |
| range                 | 6,00 | 0,84 | 72,00  | 65,83  | 0,01 | 52,69 | 19,14  |
| <i>Ps. kraepelini</i> | DO   | pH   | EC     | SHE    | Sal  | Sat   | T°C(w) |
| Max.                  | 9,22 | 8,20 | 334,25 | 197,67 | 0,19 | 83,03 | 23,89  |
| Min.                  | 3,11 | 7,27 | 183,00 | 131,87 | 0,09 | 12,38 | 4,75   |
| ETİ                   | 0,62 | 0,56 | 0,87   | 0,46   | 0,85 | 0,78  | 1,00   |
| range                 | 6,11 | 0,93 | 151,25 | 65,80  | 0,10 | 70,65 | 19,14  |
| <i>I. gibba</i>       | DO   | pH   | EC     | SHE    | Sal  | Sat   | T°C(w) |
| Max.                  | 8,60 | 7,99 | 212,00 | 164,33 | 0,11 | 74,80 | 16,60  |
| Min.                  | 3,61 | 7,85 | 200,37 | 154,43 | 0,10 | 31,63 | 8,73   |
| ETİ                   | 0,50 | 0,09 | 0,07   | 0,07   | 0,08 | 0,48  | 0,41   |
| range                 | 4,99 | 0,14 | 11,63  | 9,90   | 0,01 | 43,17 | 7,87   |
| <i>Cp. vidua</i>      | DO   | pH   | EC     | SHE    | Sal  | Sat   | T°C(w) |
| Max.                  | 9,22 | 8,30 | 255,00 | 200,28 | 0,11 | 77,65 | 23,89  |
| Min.                  | 3,53 | 7,46 | 183,00 | 131,87 | 0,09 | 39,88 | 6,03   |
| ETİ                   | 0,58 | 0,50 | 0,41   | 0,48   | 0,14 | 0,42  | 0,93   |
| range                 | 5,69 | 0,84 | 72,00  | 68,40  | 0,02 | 37,77 | 17,86  |
| <i>L. inopinata</i>   | DO   | pH   | EC     | SHE    | Sal  | Sat   | T°C(w) |
| Max.                  | 8,60 | 8,13 | 219,87 | 200,28 | 0,11 | 75,41 | 23,89  |
| Min.                  | 3,22 | 7,46 | 183,00 | 131,87 | 0,09 | 25,06 | 4,75   |
| ETİ                   | 0,54 | 0,40 | 0,21   | 0,48   | 0,14 | 0,56  | 1,00   |
| range                 | 5,38 | 0,67 | 36,87  | 68,40  | 0,02 | 50,35 | 19,14  |

### 3. 3. 2 The Lake Çubuk

The lake was imaged by an echosounder. Accordingly, the lake length was measured in the south-to-north direction, with the width in the west-to-east direction. In bathymetric images the lake depth was 5 m and there was no any other remarkable feature (inlet or outlet water flow) (Figure 14).

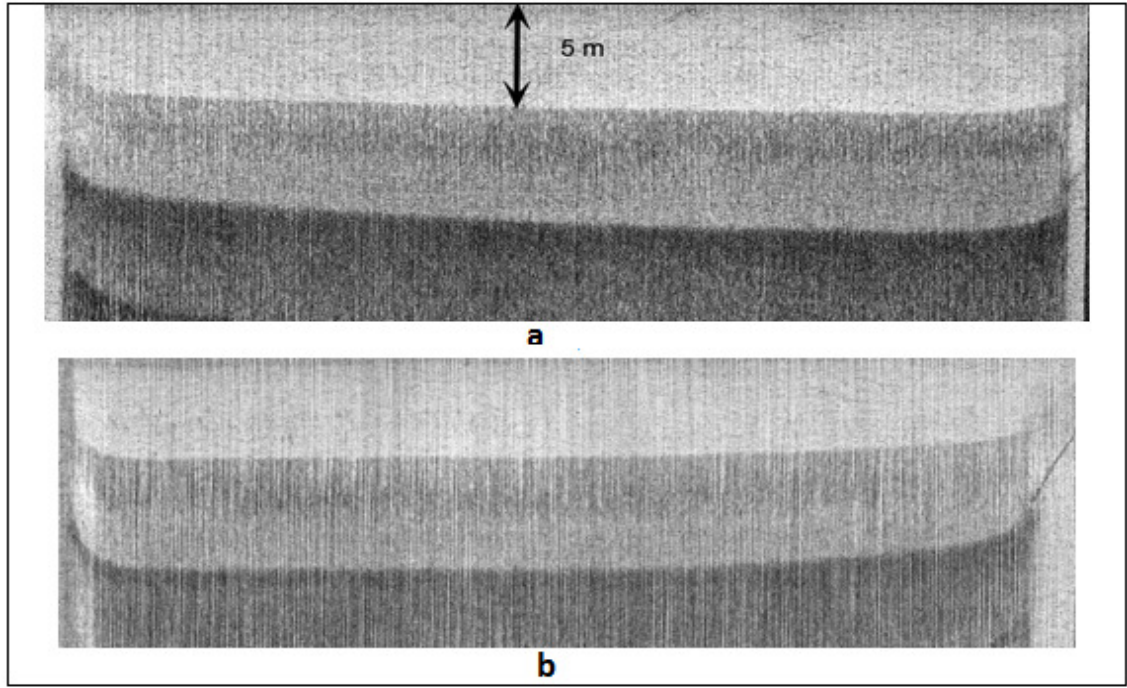


**Figure 14.** The bathymetric photographs of Lake Çubuk; a. south-north direction and b. west-east direction (consulting from Figure 10).

The lake surface area was measured with a grid method by using a bathymetric map (Wetzel and Likens 2000; Figure 10). A grid pattern was put on a lake map with both a known dimension and squares (each one square meter). By using the map scale (200 m), the area represented by one square was determined and thus continued. A hypsographic curve belonging to the lake was drawn using results from physical measurements of the lake and later lake volume was calculated. According to results, the lake surface area was 16.03 ha (0.1603 km<sup>2</sup>), while the volume of lake was emerged as 651300 m<sup>3</sup> (Figure 15).

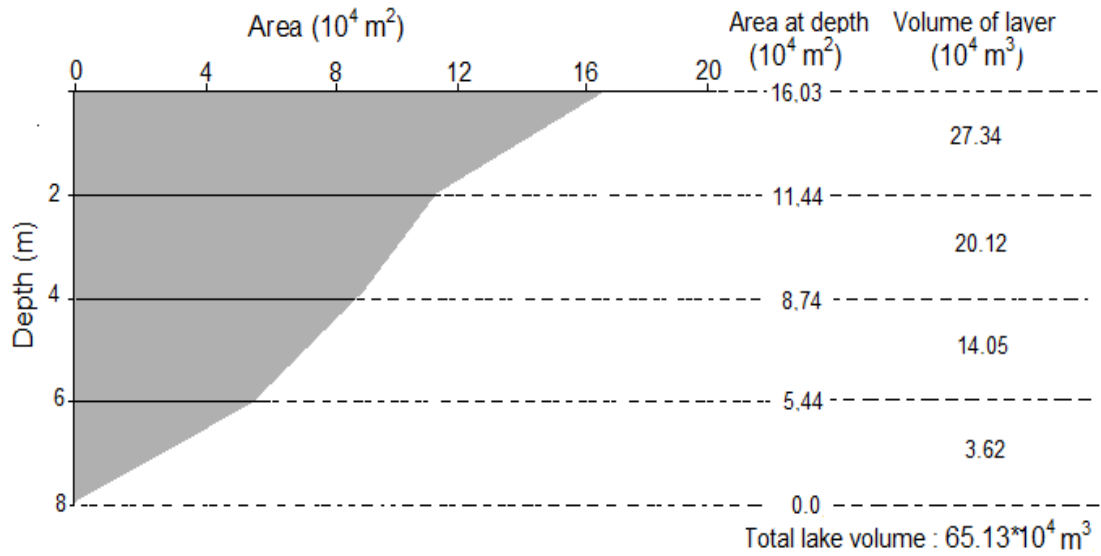


**Figure 15.** The volume of Lake Çubuk according to hypsographic curve with surface area.

The analyses of sedimentation samples of 8 stations (L1, L2, L3, L4, L5, Vs, Vm and Vb) per month were done using Imhoff Sedimentation Funnel during 13 months (Table 12). The average results of sedimentation showed that the maximum sediment accumulation was nearby the first littoral station (L1) during sampling with 1.2 ratio, while the monthly average read 0.84.

**Table 12.** The mean value of sedimentation per 100 ml during 13 months

| Month\Station | L1  | L2  | L3   | L4  | L5  | Vs   | Vm   | Vb  | Mean |
|---------------|-----|-----|------|-----|-----|------|------|-----|------|
| 18.10.2008    | 4   | 4   | 3    | 4   | 4   | 4    | 3    | 4   | 3,75 |
| 22.11.2008    | 1   | 1   | 1    | 1   | 1   | 1    | 1    | 1   | 1    |
| 20.12.2008    | 1   | 1   | 1    | 1   | 1   | 1    | 1    | 1   | 1    |
| 28.03.2009    | 1   | 1   | 0.5  | 0.1 | 0.1 | 1    | 0.1  | 0.5 | 0.54 |
| 25.04.2009    | 0.1 | 0.1 | 0.2  | 0.1 | 0.1 | 0.1  | 0.1  | 0.1 | 0.11 |
| 23.05.2009    | 0.1 | 0.1 | 1    | 1   | 0.1 | 0.1  | 0.1  | 0.4 | 0.36 |
| 20.06.2009    | 0.1 | 0.1 | 0.3  | 0.2 | 0.1 | 0.1  | 0.1  | 0.2 | 0.15 |
| 18.07.2009    | 0.1 | 0.1 | 0.3  | 0.1 | 0.2 | 0.1  | 0.1  | 0.1 | 0.14 |
| 22.08.2009    | 0.4 | 0.3 | 1    | 2   | 0.3 | 1,5  | 0.3  | 0.3 | 0.76 |
| 26.09.2009    | 2   | 0.3 | 0.4  | 0.6 | 0.3 | 0.3  | 0.3  | 0.6 | 0.6  |
| 24.10.2009    | 0.8 | 4   | 3    | 0.4 | 0.4 | 1,3  | 0.3  | 0.2 | 1,3  |
| 21.11.2009    | 2   | 1   | 1    | 0.3 | 0.2 | 0.2  | 0.2  | 0.3 | 0.65 |
| 19.12.2009    | 3   | 0.1 | 0.1  | 0.1 | 0.1 | 0.1  | 0.1  | 1   | 0.57 |
| <b>Mean</b>   | 1,2 | 1   | 0.98 | 0.8 | 0.6 | 0.83 | 0.52 | 0.7 | 0.84 |

On 14 November, the first (L1) and the third (L3) stations were drilled for core.

Although the drilling was done in order to determine the age and the formation of the lake, there was no any notable finding or evidence except a few ostracoda sub-fossils (Table 13). The shells found in cores indicate that the environment of the lake was contained freshwater in the past. In addition to this core sampling, Tunoğlu et al., (2011) investigated the determination of palaeoclimatic and palaeolimnologic changes in the lake in order to define the lake age. In this context, they took samples from 16 bottom graps in littoral zone and one core drilling from the deepest point of the lake. According to their investigation the lake age was found around 1400 years. They also recognized seven Ostracoda taxa (*Candona neglecta*, *Candona* sp., *Limnocythere* sp., *Ilyocypris bradyi*, *Ilyocypris getica*, *Physocypris kraepelini* and *Potamocypris arcuata*) mostly from the 248 cm level of the core samples.

**Table 13.** The numbers of the defined ostracods with levels they found in present study

| L1      | Depth       | Number of valves                         | Species                           |
|---------|-------------|------------------------------------------|-----------------------------------|
| 0-1.5 m | first 10 cm | 6 carapace, 2 broken, 2 unbroken valves  | <i>Candona</i> sp.                |
| 0-1.5 m | first 20 cm | 1 carapace                               | <i>Candona</i> sp. (Juvenile)     |
| 1.5-3 m | first 50 cm | 1 unbroken and 1 undefined-broken valves | <i>Potamocypris</i> sp.           |
| 3-4.5 m | mean part   | 1 carapace, 1 broken valve               | <i>Candona</i> sp.                |
| L3      |             |                                          |                                   |
| 3-4.5 m | first 40 cm | 1 broken valve in half                   | Undefined                         |
| 4.5-6 m | first 10 cm | 1 unbroken, 1 broken valves              | <i>Candona</i> sp.                |
| 4.5-6 m | first 30 cm | 2 unbroken, 1 broken valves              | <i>Ilyocypris</i> sp.             |
| 4.5-6 m | first 30 cm | 1 carapace, 2 unbroken, 1 broken valves  | <i>Candona</i> sp.                |
| 4.5-6 m | first 40 cm | 2 unbroken, 1 broken valves              | <i>Ilyocypris</i> sp.             |
| 4.5-6 m | first 40 cm | 1 carapace, 1 unbroken, 3 broken valves  | <i>Candona</i> sp.                |
| 4.5-6 m | first 40 cm | 1 unbroken valve                         | <i>Candona</i> cf. <i>candida</i> |
| 4.5-6 m | first 50 cm | 8 unbroken, 2 broken valves              | <i>Candona</i> sp.                |

In organochlorine pesticides (OCP) analysis of Lake Çubuk, the identified values were below the critical limits which are stated not to exceed 1100 ng/L in total amount (EPA 2010). Even though the values of the Endolfan sulphate and DDT were comparable to the other studies (Golfinopoulos et al., 2003, Zhang et al., 2003,

Özmen et al., 2008),  $\delta$ -HCH and Endosulfan I were found about ten times lower than these literature values (Table 14). Endosulfan with its derivatives were higher in September, October, June and July which were related to agricultural pesticide applications. There were also no traces of any pesticides from the sediment samples.

**Table 14.** The fixed values of OCP in present study with the critical detection values that was compared.

| OCP\Months                                                               | The results of OCP analyzes of Lake Çubuk |                 |                 |                 |                 |                     |                 |                  |                  |
|--------------------------------------------------------------------------|-------------------------------------------|-----------------|-----------------|-----------------|-----------------|---------------------|-----------------|------------------|------------------|
|                                                                          | S'08                                      | O'08            | Ju'09           | J'09            | Au'09           | S'09                | O'09            | N'09             | D'09             |
| $\delta$ -HCH                                                            |                                           |                 |                 | 4.27 $\pm$ 0.09 |                 | 4.10 $\pm$ 0.019    | 4.76 $\pm$ 0.87 | 4.30 $\pm$ 0.10  | 4.33 $\pm$ 0.20  |
| Endosulfan I                                                             | 2.19 $\pm$ 1.0                            | 2.07 $\pm$ 2.57 |                 |                 |                 |                     |                 |                  |                  |
| Endosulfan Sulphate                                                      |                                           |                 | 48.5 $\pm$ 5.14 | 9.25 $\pm$ 0.16 | 8.87 $\pm$ 0.39 | 9.05 $\pm$ 0.17     | 8.91 $\pm$ 0.71 | 8.83 $\pm$ 0.11  | 8.57 $\pm$ 0.23  |
| 4,4'-DDT                                                                 |                                           |                 |                 |                 |                 | 10.5 $\pm$ 0.035    | 10.5 $\pm$ 0.10 | 10.4 $\pm$ 0.016 | 10.5 $\pm$ 0.072 |
| Detection Limits of some compounds that used in present study (EPA 2010) |                                           |                 |                 |                 |                 |                     |                 |                  |                  |
| Compounds                                                                | $\alpha$ -HCH                             | $\beta$ -HCH    | $\gamma$ -HCH   | $\delta$ -HCH   | Endosulfan I    | Endosulfan sulphate | 4,4'-DDT        | 4,4'-DDE         | 4,4'-DDD         |
| Detection limit(ng/L)                                                    | 0.28                                      | 0.85            | 0.87            | 0.38            | 0.96            | 0.48                | 0.45            | 0.92             | 0.82             |

The cation  $\text{Ca}^{+2}$  and the anion  $\text{HCO}_3^-$  were the most frequent chemicals in lake water samples. According to the water hardness threshold values (Wetzel 1975), the hardness of lake water was moderately soft, which was supported by results of Piper diagram (Figure 16 and 17) and PCA (Table 15), as well.

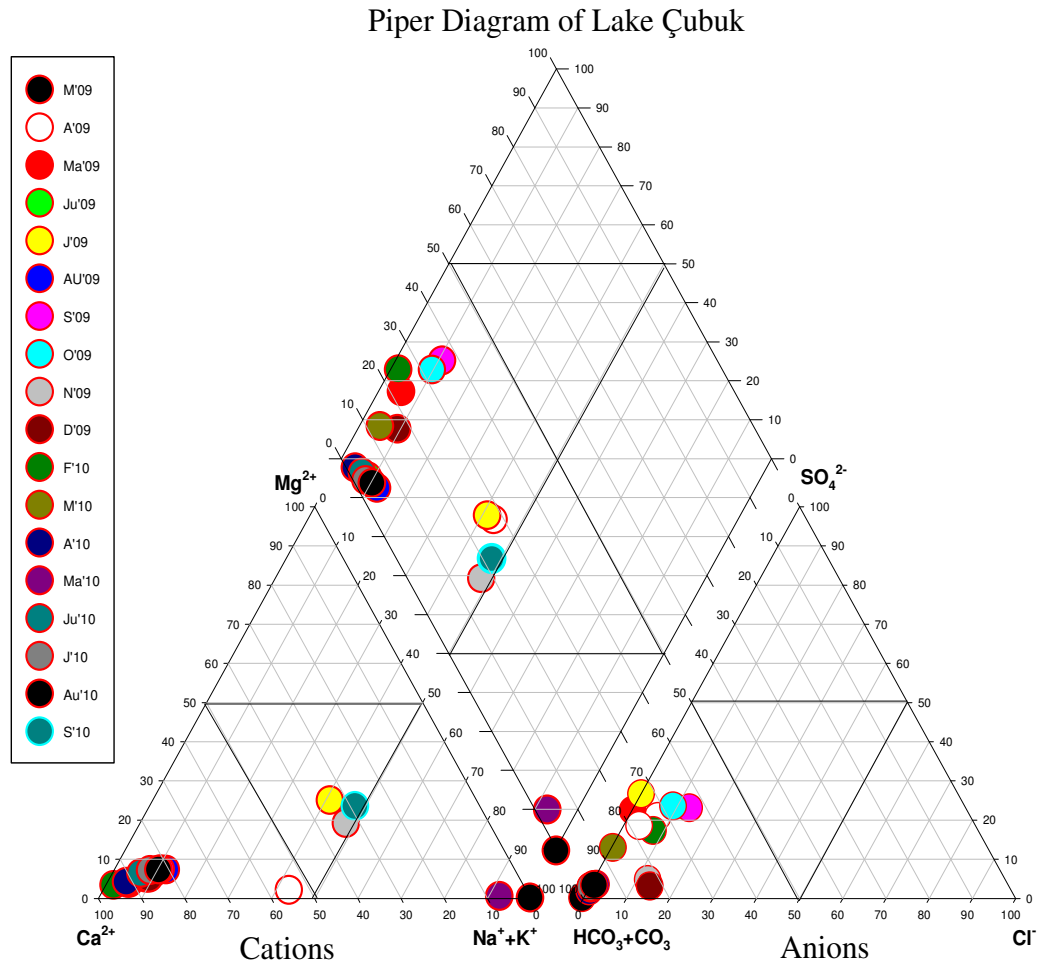


**Figure 16.** The hydrochemical facies of Lake Çubuk on Piper Plot.for 18 months.

Piper diagram is made in such a way that the relative concentrations of the major cations and anions are plotted on two separate trilinear plots which are projected further into a central diamond. In the present study, ions analyses was done during 18 months which started on March 2009. Major cations (Ca, Mg, Na, and K) and anions ( Cl,  $\text{SO}_4$ ,  $\text{CO}_3$  and  $\text{HCO}_3$ ) in ppm were plotted in Piper Diagram to evaluate the water of the Lake Çubuk.

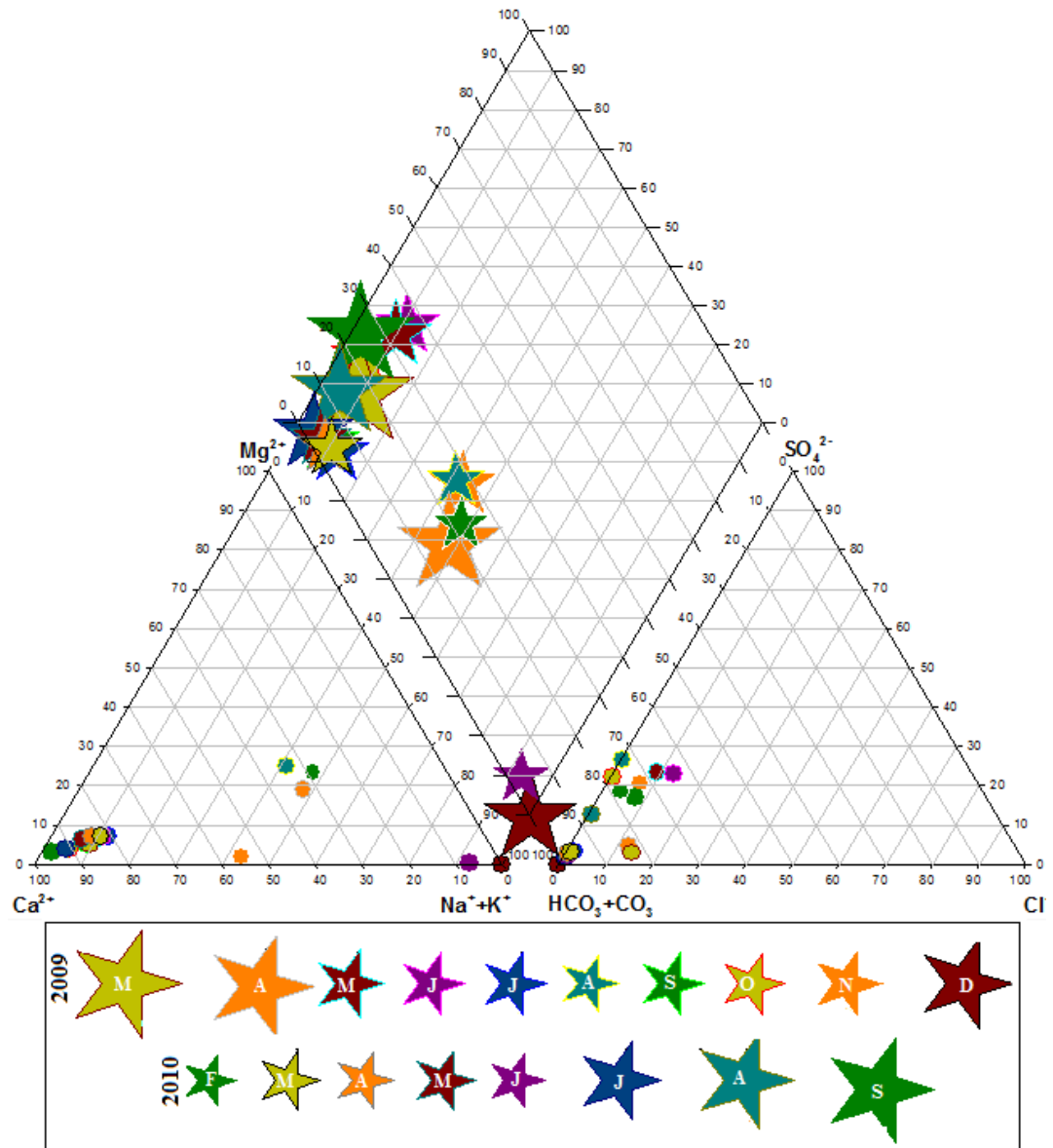


**Figure 17.** Piper diagram with TDS scale size for 18 sampling times. Each star belongs to a sampling time (month) with its own TDS size.

Piper diagram was also obtained by means of using TDS (Total Dissolved Solids) size scale for anions and cations in the center diamond.

**Table 15.** Principal Component Analysis (PCA) Correlation.

| PCA Correlation Matrix        |       |                 |                 |                              |                 |                               |                 |                |                              |
|-------------------------------|-------|-----------------|-----------------|------------------------------|-----------------|-------------------------------|-----------------|----------------|------------------------------|
|                               | EC    | Ca <sup>+</sup> | Mg <sup>+</sup> | SO <sub>4</sub> <sup>-</sup> | Cl <sup>-</sup> | HCO <sub>3</sub> <sup>-</sup> | Na <sup>+</sup> | K <sup>+</sup> | CO <sub>3</sub> <sup>-</sup> |
| EC                            | 1.000 |                 |                 |                              |                 |                               |                 |                |                              |
| Ca <sup>+</sup>               | .419  | 1.000           |                 |                              |                 |                               |                 |                |                              |
| Mg <sup>+</sup>               | -.111 | .696            | 1.000           |                              |                 |                               |                 |                |                              |
| SO <sub>4</sub> <sup>-</sup>  | -.125 | .338            | .727            | 1.000                        |                 |                               |                 |                |                              |
| Cl <sup>-</sup>               | -.022 | .089            | .418            | .437                         | 1.000           |                               |                 |                |                              |
| HCO <sub>3</sub> <sup>-</sup> | .927  | .603            | .132            | .040                         | .053            | 1.000                         |                 |                |                              |
| Na <sup>+</sup>               | .279  | .588            | .611            | .562                         | .470            | .404                          | 1.000           |                |                              |
| K <sup>+</sup>                | -.042 | .369            | .513            | .554                         | .549            | .071                          | .368            | 1.000          |                              |
| CO <sub>3</sub> <sup>-</sup>  | .345  | -.166           | -.291           | .243                         | .374            | .206                          | .355            | .254           | 1.000                        |

Correlation coefficient is commonly used to create a relationship between dependent and independent variables. Principal Component Analysis (PCA) is a non-parametric, orthogonal method. It is a linear transformation that transforms the data to a new coordinate system such that the direction with the greatest variance lies on the first Principal component (the first coordinate or axes), the second greatest variance on the second coordinate, and so on. Principal Component Analysis (PCA) was a good way to determine the correlations between related variables (cation and anions) and to aggregate large number of variables for the present study. Varimax rotation which is delineated with “Kaiser Criterion” was used to explain the factors on hydrochemical processes.

The data consist of measurements on nine chemical variables for 18 samples (months). According to correlation matrix of Principal Component Analysis, there is a strong significant correlation between bicarbonate (HCO<sub>3</sub><sup>-</sup>) and electrical conductivity (EC), while EC shows negative correlations with two cations (Mg<sup>+</sup> and K<sup>+</sup>) and two anions (SO<sub>4</sub><sup>-</sup> and Cl<sup>-</sup>). Although it is low, Ca<sup>+</sup> and Mg<sup>+</sup> are negatively

correlated with  $\text{CO}_3^-$ . The intergroup correlations of cations are clearly positive, which is applicable for anions, too (Table 15).

**Table 16.** The results of the component and rotate component matrix of Principal Component Analysis (PCA).

| Component Matrix                                                             |           |       |       | Rotate Component Matrix                                                                     |           |       |       |
|------------------------------------------------------------------------------|-----------|-------|-------|---------------------------------------------------------------------------------------------|-----------|-------|-------|
|                                                                              | Component |       |       |                                                                                             | Component |       |       |
|                                                                              | PC1       | PC2   | PC3   |                                                                                             | PC1       | PC2   | PC3   |
| EC                                                                           | .332      | .916  | .085  | EC                                                                                          | -.123     | .946  | .217  |
| Ca <sup>+</sup>                                                              | .743      | .266  | -.533 | Ca <sup>+</sup>                                                                             | .474      | .649  | -.511 |
| Mg <sup>+</sup>                                                              | .788      | -.381 | -.458 | Mg <sup>+</sup>                                                                             | .821      | .096  | -.541 |
| SO <sub>4</sub> <sup>-</sup>                                                 | .737      | -.427 | .074  | SO <sub>4</sub> <sup>-</sup>                                                                | .854      | -.033 | -.022 |
| Cl <sup>-</sup>                                                              | .598      | -.315 | .465  | Cl <sup>-</sup>                                                                             | .722      | -.049 | .387  |
| HCO <sub>3</sub> <sup>-</sup>                                                | .509      | .822  | -.086 | HCO <sub>3</sub> <sup>-</sup>                                                               | .059      | .968  | .027  |
| Na <sup>+</sup>                                                              | .841      | .064  | .076  | Na <sup>+</sup>                                                                             | .719      | .445  | .054  |
| K <sup>+</sup>                                                               | .677      | -.343 | .193  | K <sup>+</sup>                                                                              | .775      | -.003 | .111  |
| CO <sub>3</sub> <sup>-</sup>                                                 | .276      | .224  | .890  | CO <sub>3</sub> <sup>-</sup>                                                                | .234      | .217  | .903  |
| <b>Eigenvalues</b>                                                           | 3.68      | 2.18  | 1.56  | <b>Eigenvalues</b>                                                                          | 3.34      | 2.51  | 1.58  |
| <b>Variance (%)</b>                                                          | 40.93     | 24.28 | 17.37 | <b>Variance (%)</b>                                                                         | 37.10     | 27.91 | 17.57 |
| <b>Cumulative(%)</b>                                                         | 40.93     | 65.22 | 82.59 | <b>Cumulative(%)</b>                                                                        | 37.10     | 65.01 | 82.59 |
| Extraction Method: Principal Component Analysis.<br>*3 components extracted. |           |       |       | Rotation Method: Varimax with Kaiser Normalization.<br>*Rotation converged in 6 iterations. |           |       |       |

Conductivity is established according to the number of ions in the sample solution which means that the higher the ions concentration is, the higher the conductivity degree is. EC and pH measurements which can vary greatly are affected by several environmental factors including, climate, local biota (plants and animals), bedrock and human impacts. A strong acid is one whose molecules ionize completely leaving no unionized molecules of acid left in solution. Strong acids, therefore, tend to contain a lot of ions ( $\text{H}^+$  and anions) dissolved in their solutions (e. g.  $\text{HNO}_3^-$  dissociates completely in water to form  $\text{H}^+$  and  $\text{NO}_3^-$ ). This makes them splendid conductors of electricity. Weak acids, on the other hand, only ionize slightly (partially dissociates in water). This means that only a small fraction of their

molecules form ions in water solution, while most of the acid molecules remain in molecular form. Weak acids tend to contain small number of ions in their solutions, and are poor conductors of electric current ( $\text{NH}_4$  dissociates into  $\text{NH}_3$  and  $\text{H}^+$ ).

For the Lake Çubuk, three significant PCs in two extracted methods explain 82% of variance of the original dataset (Table 16). Most of the variance is contained in the PC1 in both extracted component (40.93%) and extracted-rotation component methods (37.1%). This result is associated with the combining of the  $\text{Na}^+$ ,  $\text{Mg}^+$ ,  $\text{Ca}^+$  and  $\text{SO}_4^-$  for extracted method and  $\text{SO}_4^-$ ,  $\text{Mg}^+$ ,  $\text{K}^+$  and  $\text{Cl}^+$  for varimax rotation component which can occur through the interactions between water and soil (Table 16). PC2 explains 24.2% which is associated with EC and  $\text{HCO}_3^-$ , while PC3 connotes nearly 17% due to  $\text{CO}_3^-$  for both methods.

Photic zone (euphotic zone) is exposed to the sufficient sunlight to allow photosynthesis to take place. It is the maximum water depth at which photosynthetic organisms can grow. Its exact depth depend on how transparent the water is. The depth beyond which less than 1% of sunlight penetrates is called aphotic zone. In aphotic zone the food comes from dead organisms sinking to the bottom of the lake. In lakes the photic zone is almost three times of Secchi depth (triple-Secchi rule). The euphotic zone of Lake Çubuk was not too stable but the changes were acceptable during the study period (Figure 18). The decrease in depth of photic zone changed depending on sunlight weakness (cold season) and mixing periods.

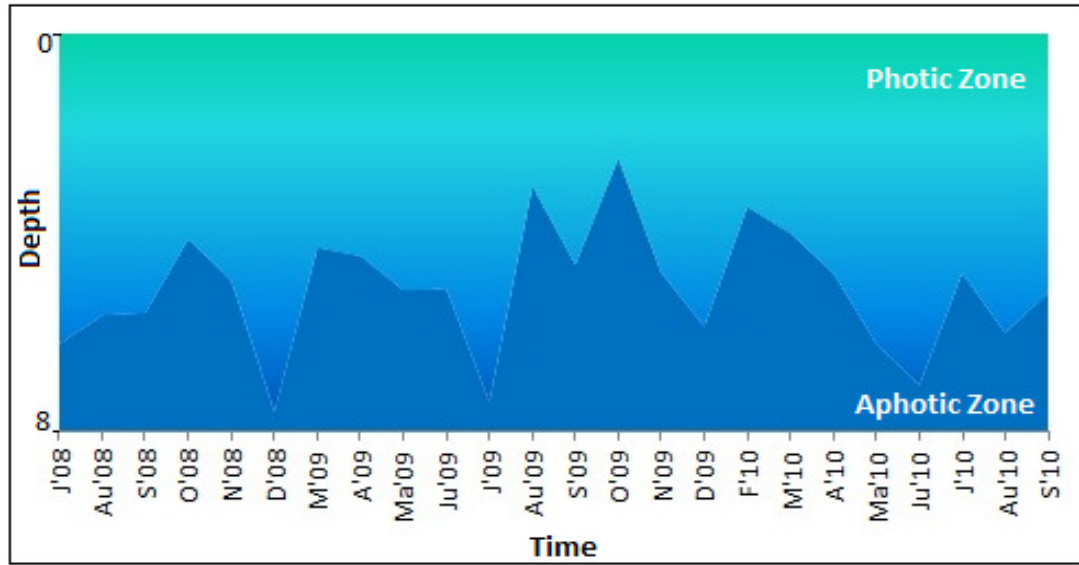


**Figure 18.** The general appearance of zones of Lake Çubuk which directly affected by sunlight or not.

Epilimnion is the well-mixed layer of water body remaining under the influence of meteorological conditions. It shows relatively small temperature changes with depth and low water density. This relatively warm layer is recognized by high primary production and high-lightened. Its pH, temperature and dissolved oxygen concentrations are higher than the other layers.

According to the thermal stratification patterns of Lake Çubuk, the depth of epilimnion was nearly 4 m. The stratification models were created using both montly and mean values of 24 months (sampling process of present study) of temperature, pH and dissolved oxygen. Although the mean depth of lake was 6.24 m, the water level changed from 4.7 m (December 2009) to 8.5 m (May 2010). In generally the water level risid in the begining of the spring season corresponding to an increase in depth of epilimnion. The increase was kept up to autumn time.

Different formulae of several authors about epilimnion thickness have different impact factors. Results of the formulae are changing due to lakes' own characteristics.

Several equations after authors were used to calculate the depth of epilimnion. The formulae separate four groups depend on their parameters which are wind speed, wind's take-off route along the central line (wave height), fetch and surface area. The wave height was measured with the formula in Table 17.

**Table 17.** The comparison of actual epilimnion thickness with calculated results using several formulae which have different range of deviation.

| After authors                                  |                                     | Formula                         | Depth of Epilimnion |
|------------------------------------------------|-------------------------------------|---------------------------------|---------------------|
| The actual mean depth of epilimnion's          |                                     | Thermal Stratification          | 4                   |
| Patalas 1960                                   | $Z_{epi}$ = Depth of Epilimnion     | $Z_{epi}=4.4 W^{0.5}$           | 3,94                |
| Okulani (1981)                                 | W = Wind speed in m/s               | $Z_{epi}=7.4 W^{0.5}$           | 6,53                |
| Arai (1981)                                    | F = Fetch in m                      | $Z_{epi}=6.22 W^{0.304}$        | 5,81                |
| Patalas (1984)                                 | A = Surface area in km <sup>2</sup> | $Z_{epi}=4.6 A^{0.205}$         | 4,39                |
| Daves and Colley (1988)                        |                                     | $Z_{epi}=7.69 W^{0.463}$        | 6,93                |
| Skowron (1990)                                 |                                     | $Z_{epi}=7.7 W_L^{0.5}$         | 3,99                |
| Mazumder and Taylor (1994)                     |                                     | $Z_{epi}=3.94+2.97 \log_{10} F$ | 3,45                |
| $W_L$ (Wind take-off route along central line) |                                     | $h = 0.105 \sqrt{fetch}$        | 0,28                |

The acceptable range of epilimnion depth for Lake Çubuk changed from 3.45 m to 4.39 m close to the actual thickness. Indeed, epilimnion depth range in thermal stratification patterns begins approximately 3 m to finally 4.5 m (Figure 19).

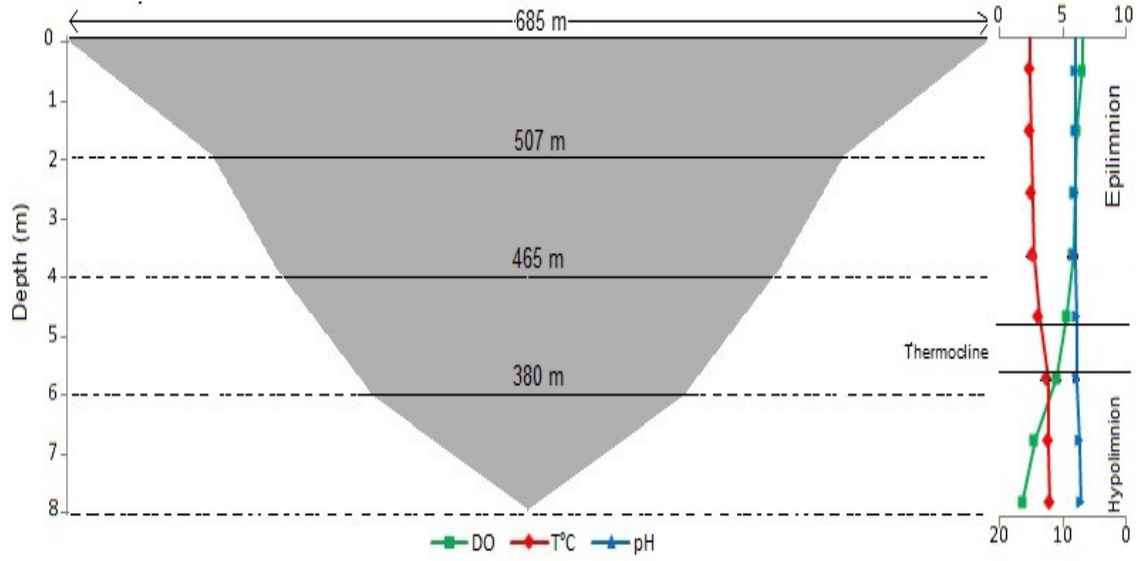


**Figure 19.** Hypsographic curve with length of every two meters to the bottom including mean thermal layers of Lake Çubuk.

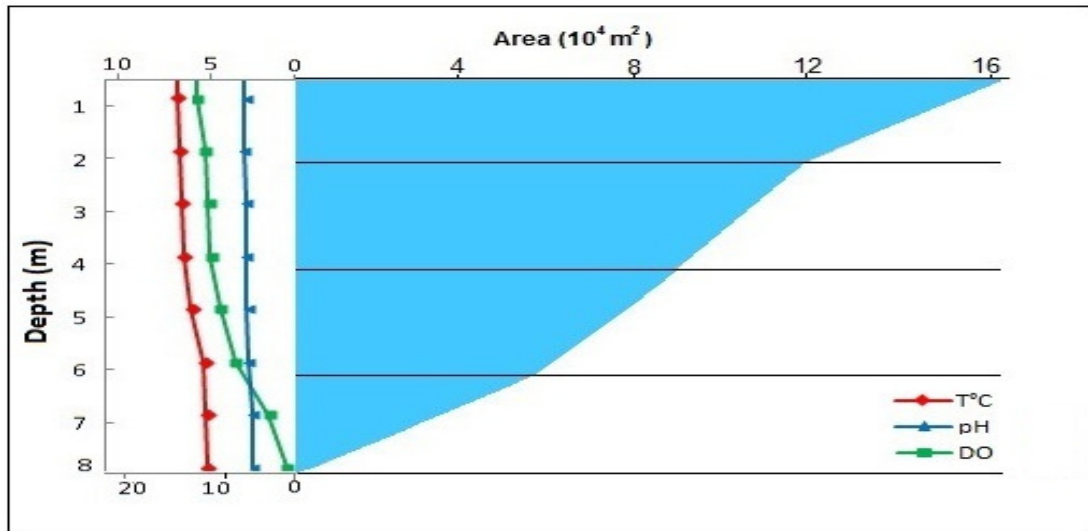


**Figure 20.** Hypsographic curve of Lake Çubuk with surface area including mean thermal stratification.

Measurement of thermocline (metalimnion) stratum of Lake Çubuk was made using Gorham and Boyce (1989) formula (Formula 2) that uses such parameters as disparity of density between upper layer (epilimnion) and lower layer (hypolimnion), gravitational acceleration ( $9.8 \text{ m/s}^2$ ), wind stress and square root of surface area. According to this equation the mean thermocline thickness of Lake

Çubuk is 60 cm which is supported by thermal stratification models (Table 18; Figure 25).

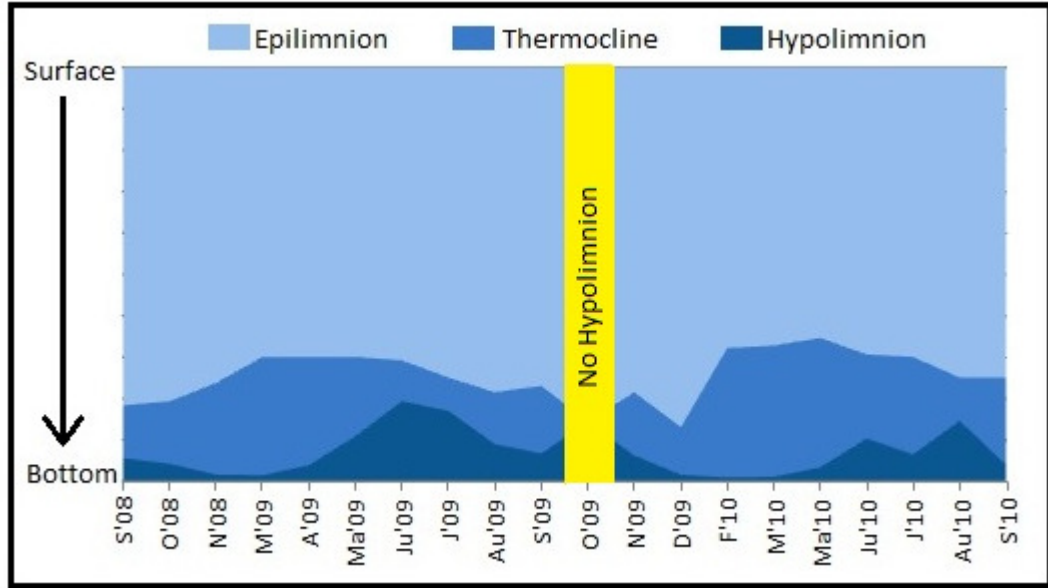


**Figure 21.** The general position of the layers of Lake Çubuk

Interestingly, in October 2009, even though the profundity of the lake was 4.80 the hypolimnion was not seen. In this month, the wind speed (3.2 m/s) and the recorded temperature (16.6 °C) were relatively acceptable. The density difference between the surface and bottom water would be eliminated so increased. The intensity of the density but still not up to the lowest deep month December 2009. December 2009, was the month with the least temperature value (4.75 °C) observed in the present study (Table 18). Apparently the temperature was not as effective as density on thermocline thickness.

**Table 18.** Comparison of layers of Lake Çubuk during 20 months. It should be noted that the thickness of the layers to be measured wind speed could not be determined 4 months. Abbreviations:  $h_t$ , thermocline thickness;  $h_h$ , hypolimnion thickness

| Date  | S'08 | O'08 | N'08 | M'09 | A'09 | Ma'09 | Ju'09 | J'09 | Au'09 | S'09 | O'09 | N'09 | D'09 | F'10 | M'10 | Ma'10 | Ju'10 | J'10 | Au'10 | S'10 | Mean |
|-------|------|------|------|------|------|-------|-------|------|-------|------|------|------|------|------|------|-------|-------|------|-------|------|------|
| Depth | 5,15 | 5,25 | 5,80 | 7,00 | 7,00 | 7,00  | 6,80  | 6,00 | 5,50  | 5,70 | 4,80 | 5,50 | 4,70 | 7,60 | 7,80 | 8,50  | 7,15  | 7,00 | 6,00  | 6,00 | 6,31 |
| $h_t$ | 0,36 | 0,28 | 0,13 | 0,15 | 0,39 | 1,10  | 1,86  | 1,37 | 0,63  | 0,50 | 0,81 | 0,44 | 0,09 | 0,11 | 0,13 | 0,44  | 1,07  | 0,66 | 1,17  | 0,32 | 0,60 |
| $h_h$ | 0,80 | 0,98 | 1,68 | 2,86 | 2,62 | 1,91  | 0,95  | 0,64 | 0,88  | 1,21 | 0,00 | 1,07 | 0,62 | 3,50 | 3,68 | 4,07  | 2,09  | 2,35 | 0,84  | 1,69 | 1,72 |

Thermocline is defined with its attribute as the temperature dropped quickly. It is expressly understood judging from the chart that there is not the hypolimnetic stratification in October 2009 (Figure 25). After all, it is clear the presence of a thin thermocline in December 2009. Even though in May 2010, the highest depth was measured, it decreased with an increase in the depth of the thermocline thickness (Figure 22). There is a sharp drop in temperature of water, whereas the sharp increase in dissolved oxygen (DO) during the month of May. The mean value of height of thermocline was 0.60 m, while hypolimnion depth was 1.72 with an 6.31 m average of lake depth for 20 months.

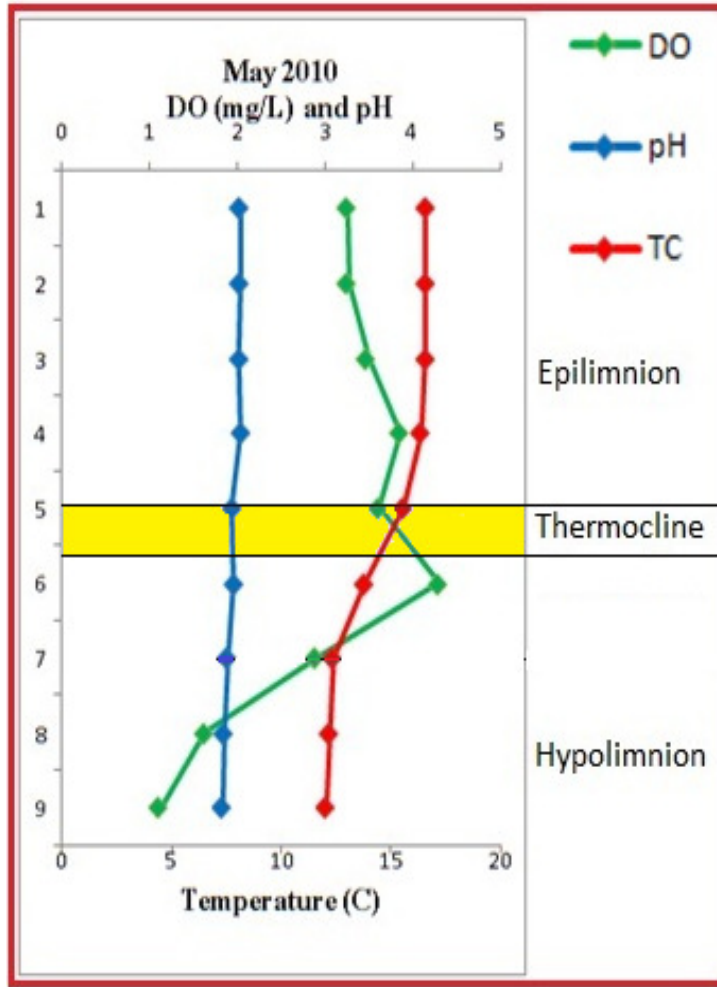


**Figure 22.** The general appearance of the stratum thickness of Lake Çubuk in May 2010

The minimum temperature was recorded in December 2008. The temperature increased throughout the summer and its maximum was recorded in August 2008 (23.89°C), June 2010 (23.60°C) and August 2010 (23.22°C; Appendix 2). The mean annual minimum temperature value was observed in 2009 (14.36°C), while mean annual maximum temperature was 16.69°C in 2010. Vertical temperatures at each of vertical stations varied slightly from surface (epilimnion) to the bottom (hypolimnion) (Figure 25). The variation between the vertical stations was usually weak in the cold season and relatively strong in the warm season. This situation is

typical for all lakes (oligotrophic to eutrophic) that the surface temperature was higher than the bottom one in summer contrary to the cold season (Figure 25 and Appendix 3).

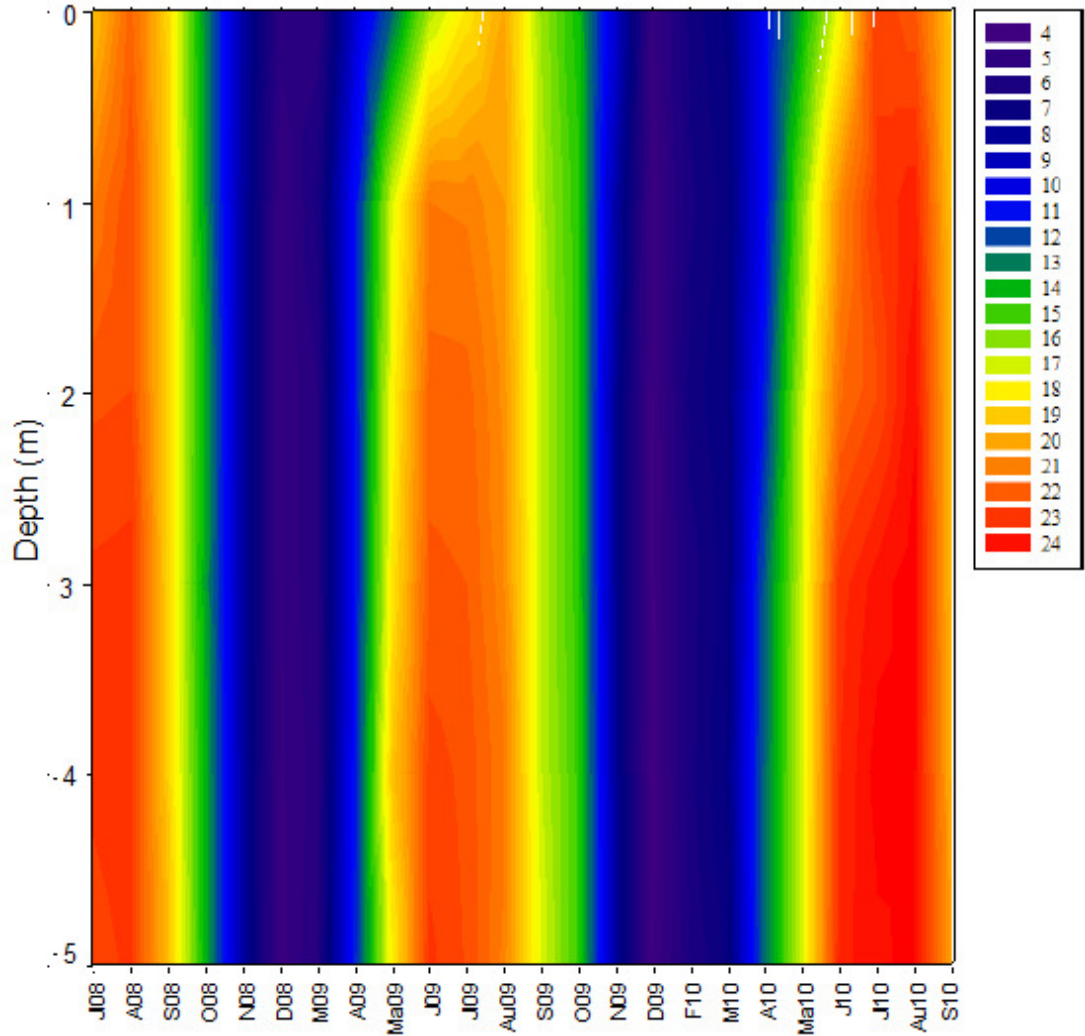


**Figure 23.** The thermal spectrum of Çubuk Lake during sampling time.

The maximum thermal difference between the surface and the bottom was in June 2010, that decreased from 22.4°C to 15.1°C with a standard deviation of 7.3°C. It was followed by May 2009 (18.5°C to 12.5°C) and June 2009 (22.1°C to 16.1°C) (Figure 23). On the contrary, maximum deviation from the surface to the bottom was in December 2009 from 4.6°C to 7.2°C (Figure 25 and Appendix 3). A sharp

decrease in temperature in the transition zone (thermocline or metalimnion) between epilimnion and hypolimnion was observed in May 2010 by 1.8°C (from 15.8°C to 13.8°C) (Figure 25 and Appendix 3). May 2010 was also the month that had maximum water column level (depth) of 8.5 m. The mean temperature of Lake Çubuk rises at rate of almost one degree per year (Figure 24).

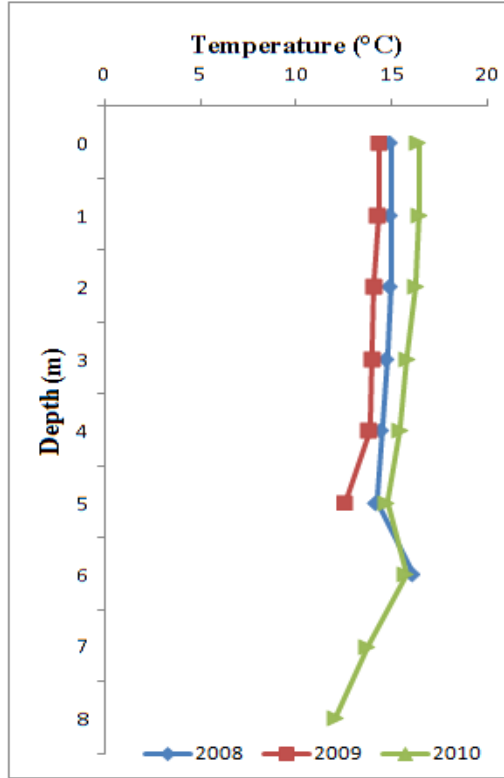


**Figure 24.** The annual ratios of temperature of Lake Çubuk.

The characteristic patterns of water chemistry are caused by thermal stratification and biological activity. In the spring and fall, both oligotrophic and eutrophic lakes have uniform, well-mixed conditions throughout the water column. During the summer stratification, the conditions in each layer diverge. Typically in oligotrophic lakes, there is an inverse proportion between water temperature and dissolved oxygen. The same situation was observed in Lake Çubuk.

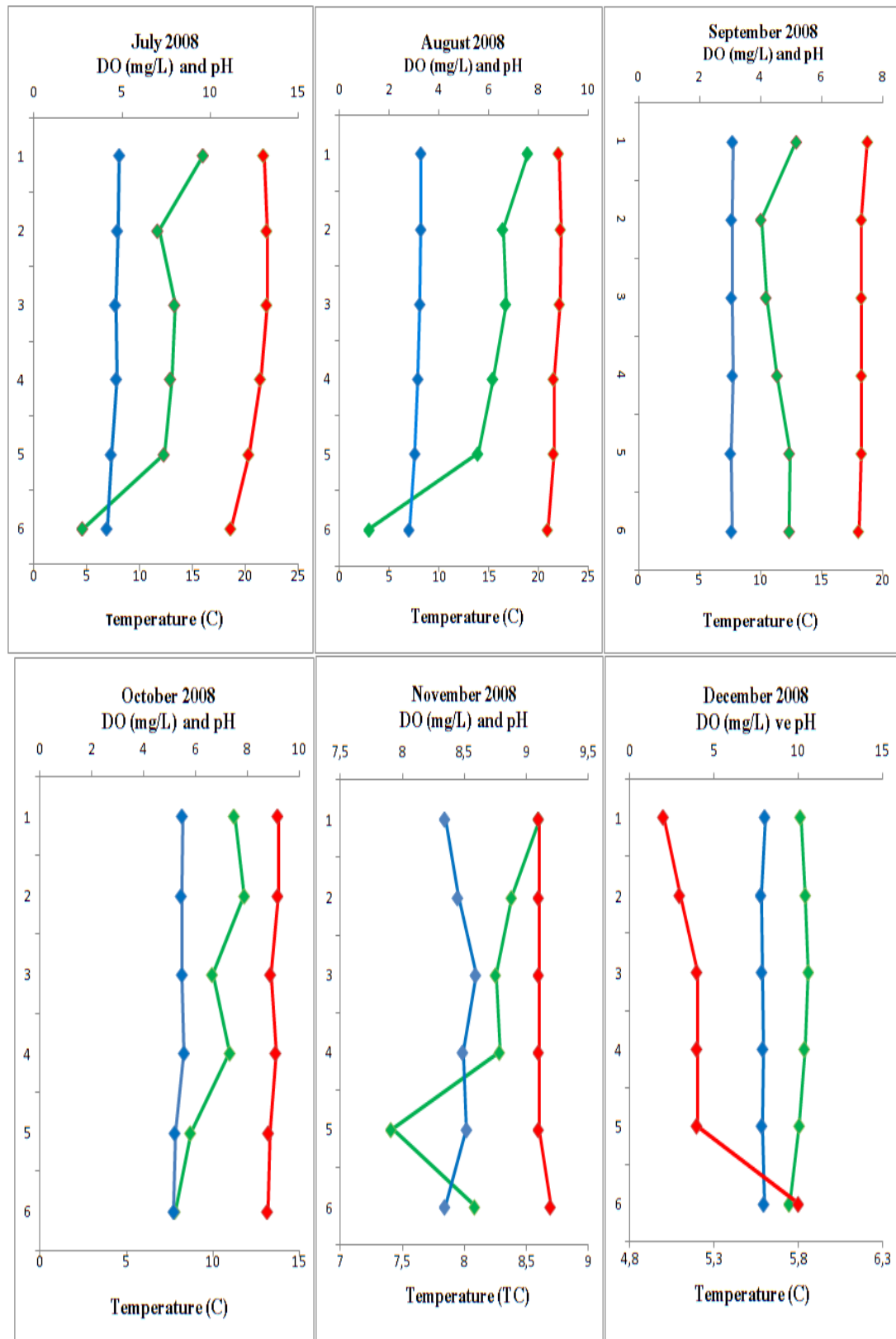


**Figure 25.** Thermal stratification of Lake Çubuk for 25 months

**Figure 25** cont.

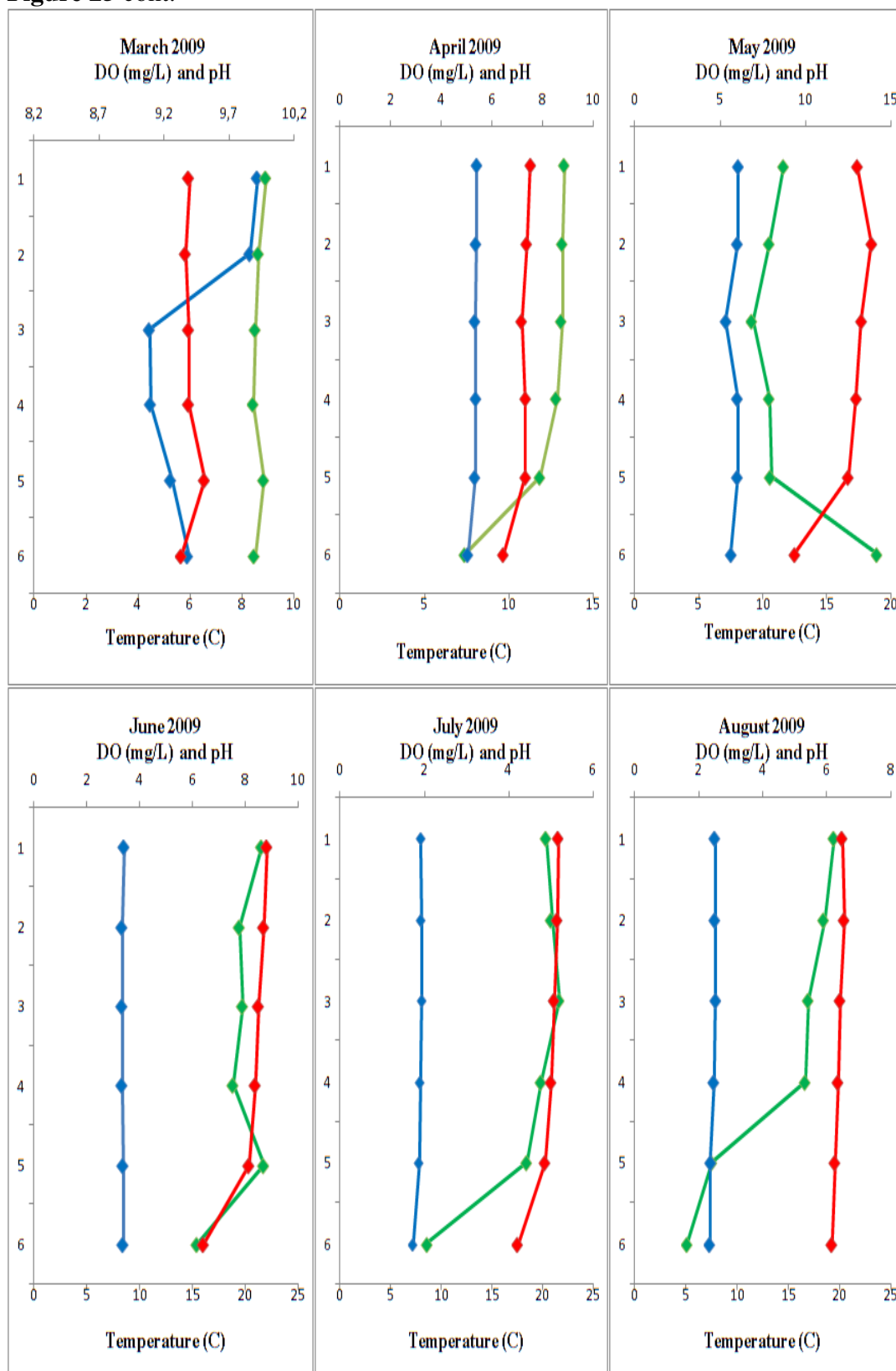


Figure 25 cont.

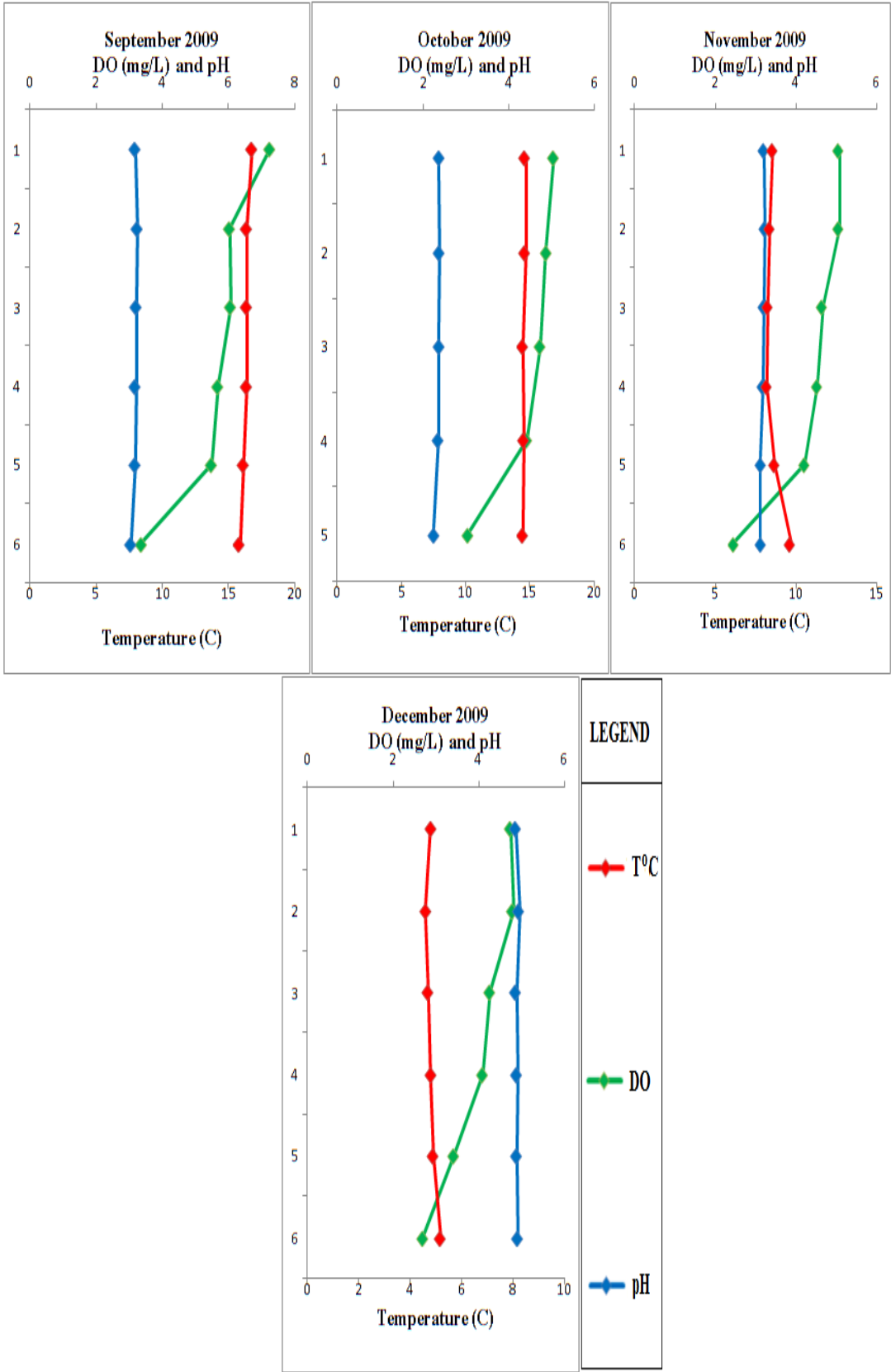


**Figure 25** cont.

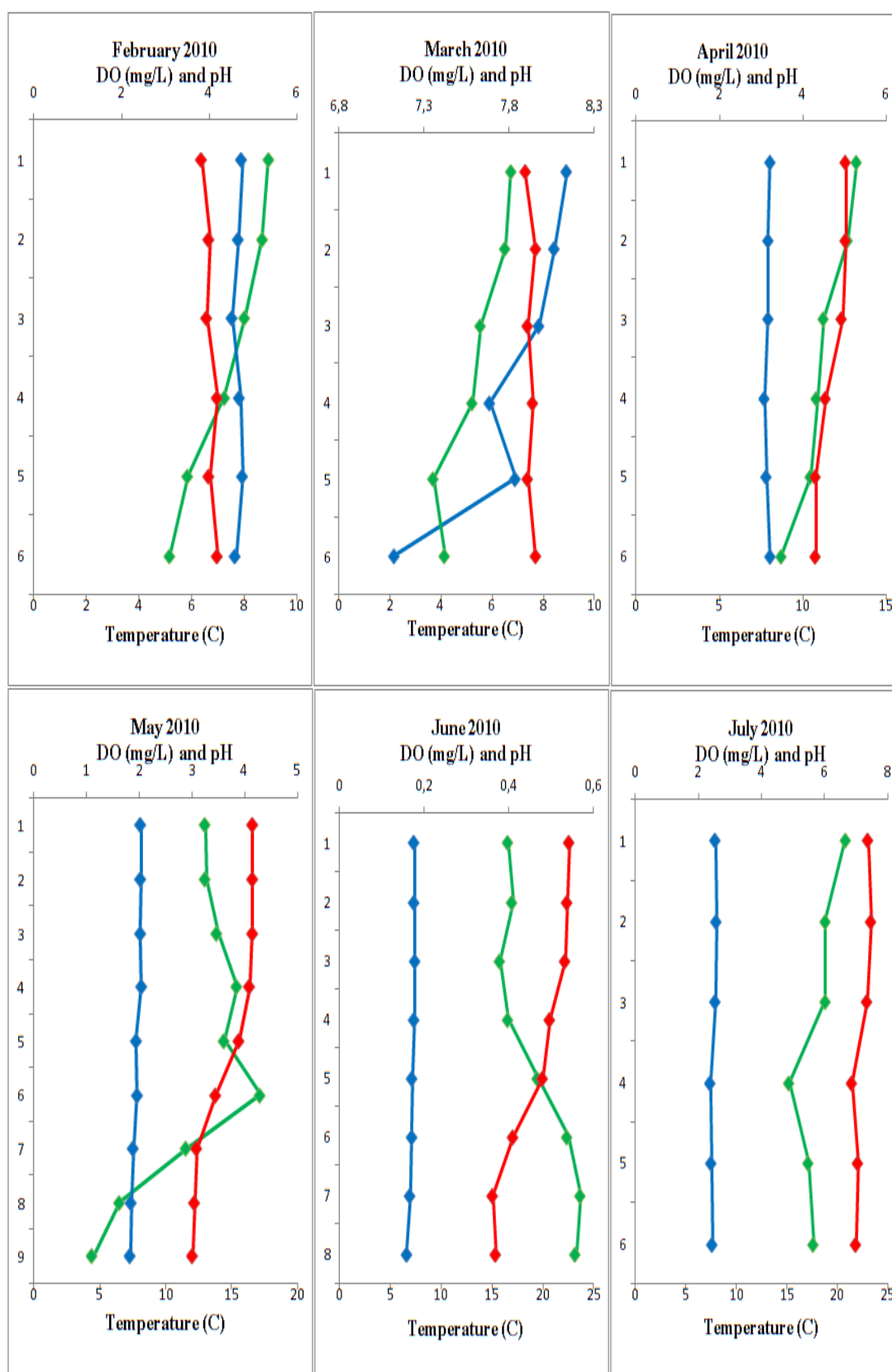
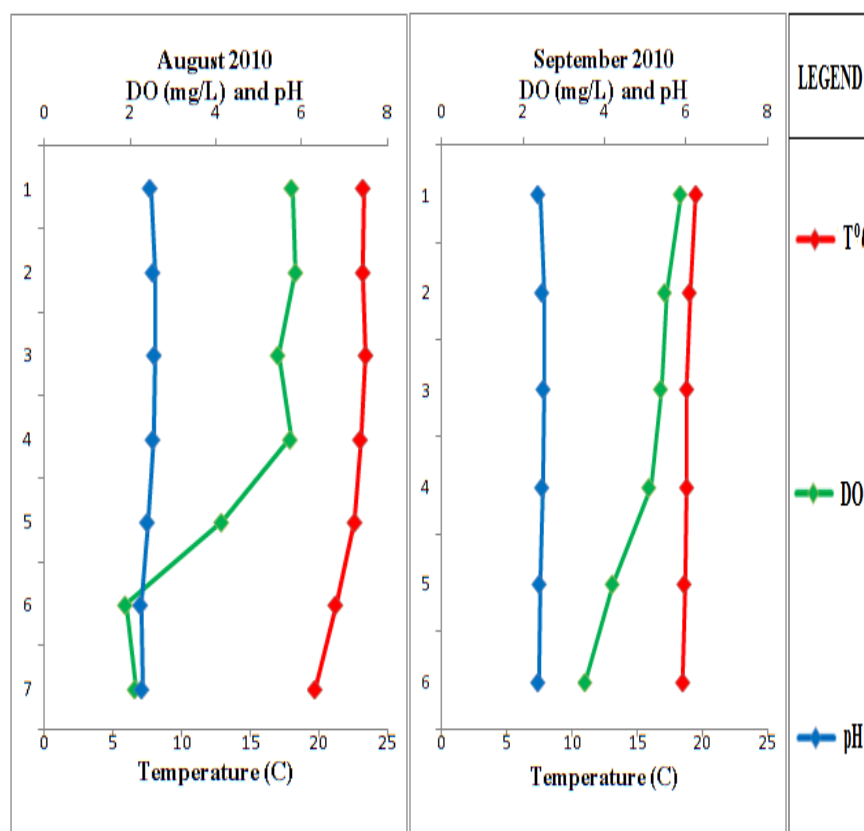


**Figure 25** cont.



The dissolved oxygen concentration in the epilimnion remains high throughout the summer because of photosynthetic activity and exchange with the atmosphere. However, conditions in the hypolimnion vary in that dissolved oxygen declines during the summer because it is cut-off from all sources of oxygen and organisms become just consumer. This may cause an increase in anoxic condition of hypolimnion. In oligotrophic lakes, low algal biomass allows deeper light penetration and less decomposition. The concentrations of dissolved oxygen may therefore increase with depth below the metalimnion where oxygen is more soluble in colder water which is "carrying" higher dissolved oxygen leftover from spring mixing. These differences between eutrophic and oligotrophic lakes disappear with fall turnover.

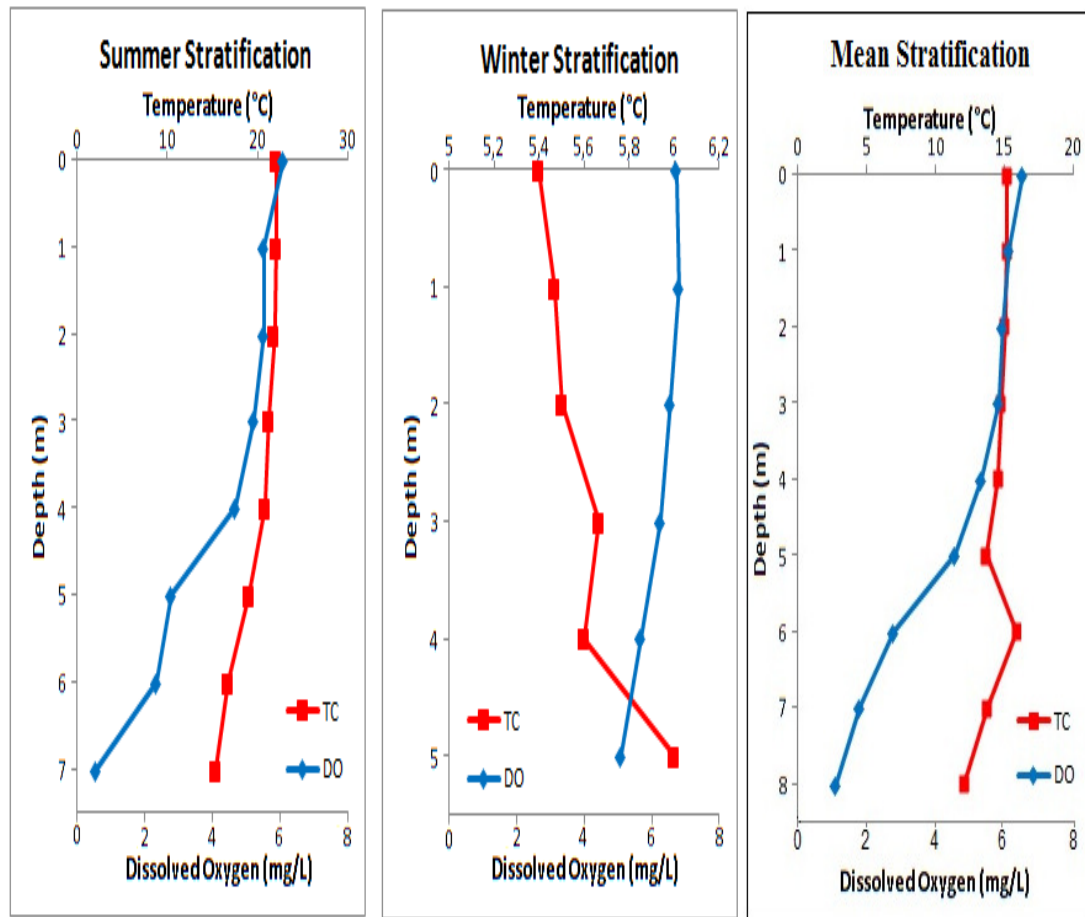


**Figure 26.** Summer, winter and mean of 25 monts thermal stratification

Stratification view of Lake Çubuk seems to be a typical oligotrophic type (Figure 26). It can defined as slightly oligotrophic which is going ahead to mesotrophic. The calculation of trophic level indices for the lake was supported by stratification patterns (Figure 45; Table 22).

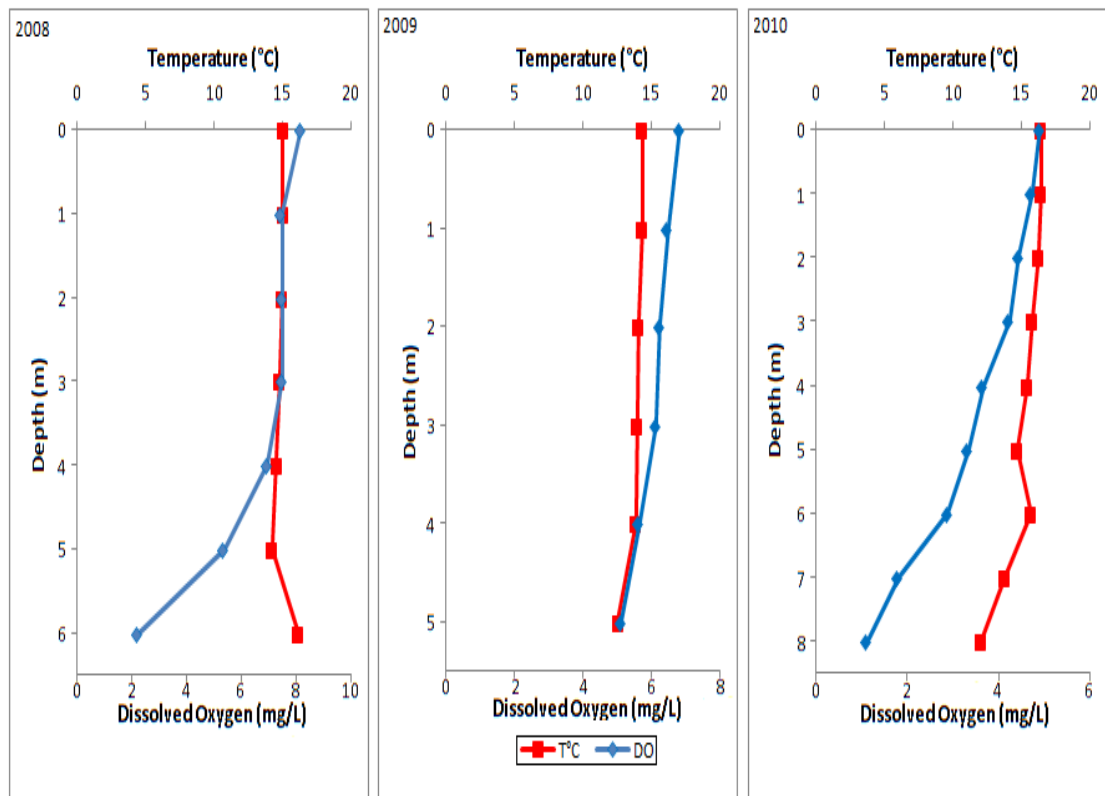


**Figure 27.** Comparison of annual stratification patterns of Lake Çubuk for three years.

Density is another characteristic of water and plays an important role in modifying stratification pattern. Water differs from other compounds being less dense as a solid than as a liquid. Water is most dense at 4°C and becomes less dense at both higher and lower temperatures. Because of the relationship between density and temperature many lakes tend to stratify. When the surface water heats up, its density declines. When the temperature and density of the surface water equal those of the bottom temperature, a weak wind energy is needed to mix the lake completely or so called “lake turnover”. In thermocline the temperature declines rapidly. The density substitutes the thermocline acts as a physical barrier that prevents mixing of the upper and lower layers. The depth of mixing depends on the degree of exposure or shelteredness of the lake, wind, fetch, lake size etc.

In the present study, as can be seen in the density table, in the cold season the density is at the highest level (December in 2008 and 2009; Table 8).

**Table 19.** The vertical density ( $\text{g.cm}^{-3}$ ) values of Lake Çubuk

| Date         | V <sub>s</sub> | V <sub>1</sub> | V <sub>2</sub> | V <sub>3</sub> | V <sub>4</sub> | V <sub>5</sub> | Mean     |
|--------------|----------------|----------------|----------------|----------------|----------------|----------------|----------|
| <b>J'08</b>  | 0.99790        | 0.99783        | 0.99783        | 0.99797        | 0.99822        | 0.99857        | 0.99805  |
| <b>Au'08</b> | 0.99783        | 0.99778        | 0.99780        | 0.99795        | 0.99795        | 0.99808        | 0.99790  |
| <b>S'08</b>  | 0.99855        | 0.99864        | 0.99864        | 0.99864        | 0.99864        | 0.99868        | 0.99863  |
| <b>O'08</b>  | 0.99936        | 0.99936        | 0.99941        | 0.99938        | 0.99943        | 0.99944        | 0.99940  |
| <b>N'08</b>  | 0.99986        | 0.99986        | 0.99986        | 0.99986        | 0.99986        | 0.99985        | 0.99986  |
| <b>D'08</b>  | 0.99999        | 0.99999        | 0.99999        | 0.99999        | 0.99999        | 0.99998        | 0.99999  |
| <b>M'09</b>  | 0.99997        | 0.99998        | 0.99997        | 0.99997        | 0.99996        | 0.99998        | 0.99997  |
| <b>A'09</b>  | 0.99965        | 0.99967        | 0.99969        | 0.99968        | 0.99968        | 0.99978        | 0.99969  |
| <b>Ma'09</b> | 0.99881        | 0.99861        | 0.99876        | 0.99883        | 0.99893        | 0.99952        | 0.99891  |
| <b>Ju'09</b> | 0.99783        | 0.99790        | 0.99802        | 0.99808        | 0.99822        | 0.99903        | 0.99818  |
| <b>J'09</b>  | 0.99795        | 0.99798        | 0.99804        | 0.99810        | 0.99823        | 0.99876        | 0.99818  |
| <b>Au'09</b> | 0.99824        | 0.99819        | 0.99828        | 0.99832        | 0.99839        | 0.99845        | 0.99831  |
| <b>S'09</b>  | 0.99891        | 0.99898        | 0.99898        | 0.99898        | 0.99901        | 0.99906        | 0.99899  |
| <b>O'09</b>  | 0.99924        | 0.99924        | 0.99927        | 0.99926        | 0.99927        | 0.99989        | 0.99936  |
| <b>N'09</b>  | 0.99986        | 0.99987        | 0.99988        | 0.99988        | 0.99985        | 0.99978        | 0.99985  |
| <b>D'09</b>  | 0.999996       | 0.999998       | 0.999997       | 0.999996       | 0.999995       | 0.999990       | 0.999995 |
| <b>F'10</b>  | 0.99996        | 0.99995        | 0.99996        | 0.99994        | 0.99995        | 0.99994        | 0.99995  |
| <b>M'10</b>  | 0.99993        | 0.99991        | 0.99992        | 0.99991        | 0.99992        | 0.99991        | 0.99992  |
| <b>A'10</b>  | 0.99951        | 0.99951        | 0.99953        | 0.99964        | 0.99969        | 0.99969        | 0.99960  |
| <b>Ma'10</b> | 0.99895        | 0.99895        | 0.99895        | 0.99898        | 0.99911        | 0.99936        | 0.99905  |
| <b>Ju'10</b> | 0.99771        | 0.99776        | 0.99780        | 0.99815        | 0.99830        | 0.99886        | 0.99810  |
| <b>J'10</b>  | 0.99758        | 0.99751        | 0.99761        | 0.99796        | 0.99783        | 0.99788        | 0.99773  |
| <b>Au'10</b> | 0.99752        | 0.99754        | 0.99749        | 0.99758        | 0.99769        | 0.99801        | 0.99764  |
| <b>S'10</b>  | 0.99840        | 0.99850        | 0.99854        | 0.99854        | 0.99858        | 0.99860        | 0.99852  |
| <b>Mean</b>  | 0.99890        | 0.99890        | 0.99893        | 0.99898        | 0.99903        | 0.99921        | 0.99899  |

In the case of Lake Çubuk, as can be seen in Figure 27, when the temperature rises, the water density becomes lighter than the water below.

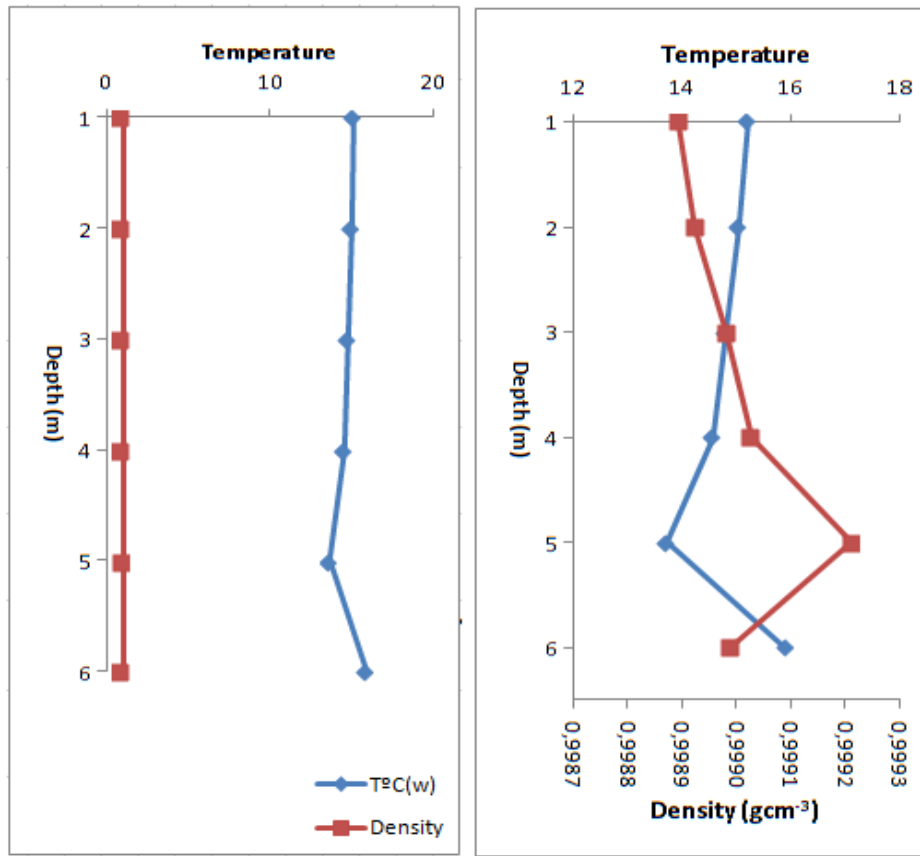


**Figure 28.** The relationship of density and temperature during 25 months in Lake Çubuk.

A stratification index (SI) was measured using the standard deviation of the density matrix (Formula 5) for the present study. The stratification index is a way to quantify thermal stratification; a high SI represents intense thermal stratification and high stability, whereas a low SI indicates very little stratification and low stability. When the temperature of the vertical points was homogenous, the SI was small which can lead to vertical mixing (low stability). The lowest SI value (0.03) was calculated in March 2010 which had quite similar temperature degrees. This result is supported by thermal stratification patterns (Figure 25). The highest SI value was calculated for June 2010 which had the largest temperature range between surface (22.6 °C) and bottom (15.4 °C). June 2009 was the second in that regard as with June 2010. The range was 5 °C and SI rised to 4.00 (Figure 29). In these two months, both

water level and the difference between surface and bottom temperature were high causing high stability and low mixing. The density becomes lower with very high or very low water temperature values. So the disparity between surface and bottom temperature causes density differences and increases SI values. Figure 8 show that during the cold season the stratification was very low (November and December both in 2008 and 2009), while it rapidly increased in July 2008; May, June, July 2009 and May, June, July, August 2010. In small lakes, during cold season, there are no significant thermal differences between the upper and the lower water column. Thus, it causes the similar and relatively low density values which means lower stratification index.

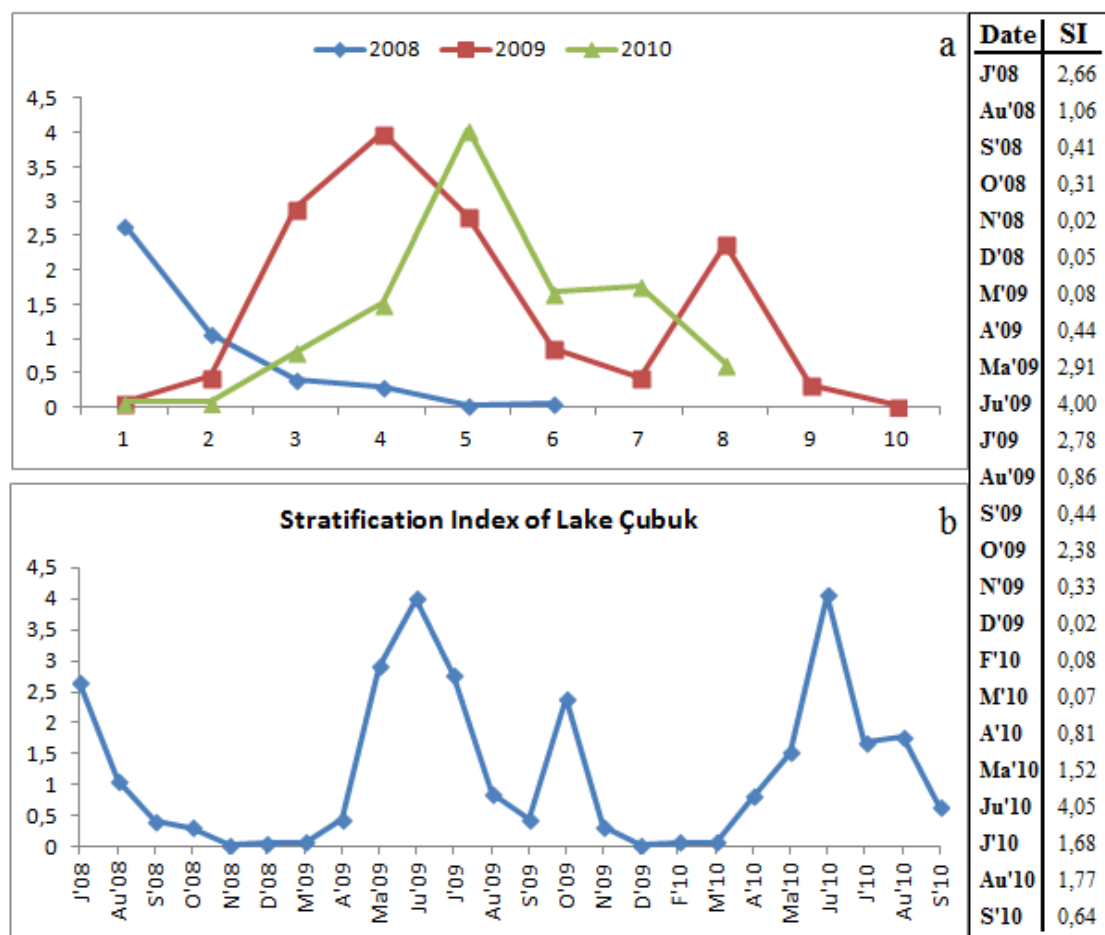


**Figure 29.** Stratification Index(SI) level of Lake Çubuk; a. SI annual cycle of each sampling time, b. SI for 25 months (average 1.22).

Stability is the measurement of the water molecule resistance to movement in water body. Stability is acquired from density of water column which is calculated from the vertical direction. It is also defined as the amount of work required by wind to overcome thermal stratification. It is measured in ergs ( $\text{gcm.cm}^{-2}$ ) and calculated using Equations 6-7. In this case high stratification index means high stability, low mixing and much work for wind. Stability also shows a coherent position with water depth (Figure 30).

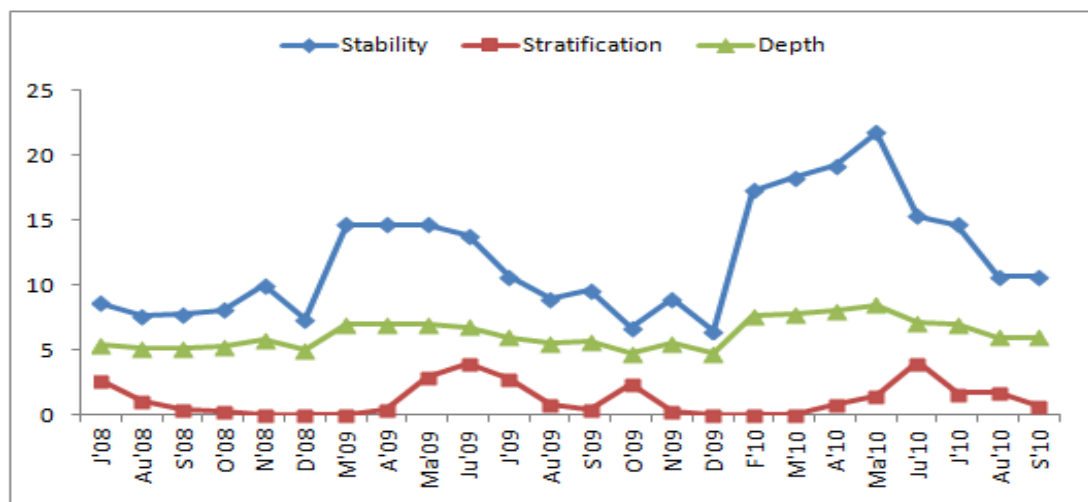


**Figure 30.** The relationship of stability with stratification index and lake water depth.

Stability is an effective factor on nutrient composition and exchange between epilimnion and hypolimnion. Namely, low stability means an inconsiderable energy or work of wind for mixing water column. Therefore, the diffusion of nutrient and other water contents occur between the surface and the bottom. Lake Çubuk showed favourable conditions for such a mixing in the cold seasons as in October, November, December 2008; March, November, December 2009 and February, March, September 2010.

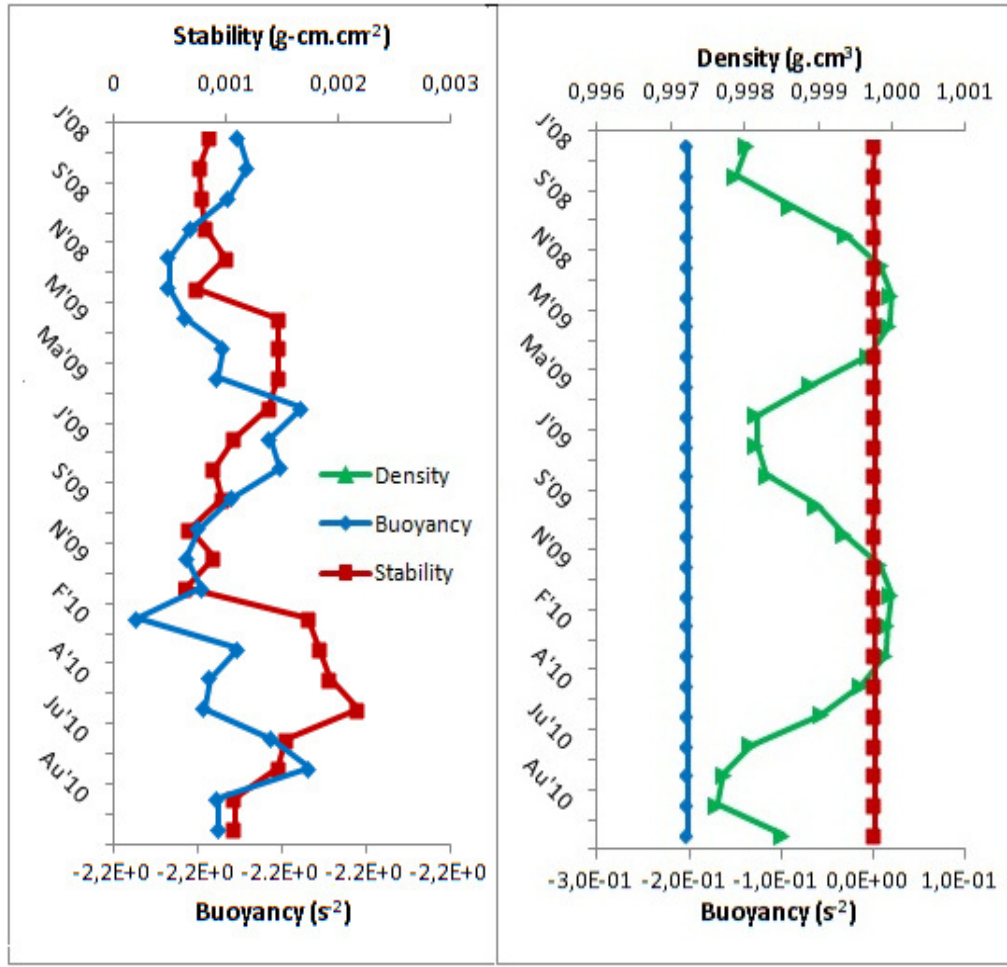


**Figure 31.** The relations of buoyancy, stability and density values during 24 months of Lake Çubuk.

The Brunt-Väisälä frequency is the maximum frequency through which the dispersal of internal waves can be supported by the density stratification. This is equal to the frequency at which a water parcel would oscillate, when it losed its vertical stability. The water tends to restore itself to its equilibrium position after displacement. Buoyancy, in common name, was measured using Equation 8.

When the temperature rises, the upper floating water becomes warm and lighter. It renders the water too buoyant. So surface water tends to mix with the deeper water

much more denser than the upper. Accordingly, in the present study, when the temperature rose in the warm season the buoyancy was expanding or vice versa. As Figure 30 suggests the maximum decrease in of water buoyancy was in June 2009 and August 2010, while in October, November 2008 and in February 2010 the lake water was less buoyant. The water temperature was relatively higher contrary to density in June 2009 (22.06 °C; density 0.9982 gcm<sup>3</sup>) and August 2010 (23.22 °C; density 0.9989 gcm<sup>3</sup>), while there was less values in November 2008 (8.73 °C; density 0.9999 gcm<sup>3</sup>), December 2008 (6.03 °C; density 0.9999 gcm<sup>3</sup>) and February 2010 (7.17 °C; density 0.9999 gcm<sup>3</sup>).

The negative values about the average buoyancy frequency of Lake Çubuk such as  $-2.01 \times 10^{-1}$  designate sinking aptitude of light upper water into the denser lower water. It means that the water parcel shows an oscillating trend. The relatively sudden changes in water density can cause energy needed to prevent mixing. However, in Lake Çubuk, the density did not show sudden changes which indicates the relatively stable water column (Figure 33). When the buoyancy of the upper water develops into directly above the lower water buoyancy, then the water column will be stable. Consequently, as the water warms density decreases, triggers a reduction in lake water mixture. The density of water also depends on depth and intensity of dissolved solids increases.

In lake water column, pressure inherently increases with depth as a result of the weight of the overlying water mass. Increased pressure do density increase which means higher buoyancy. This situation continues untill the water is restored with mixing and becomes stable.

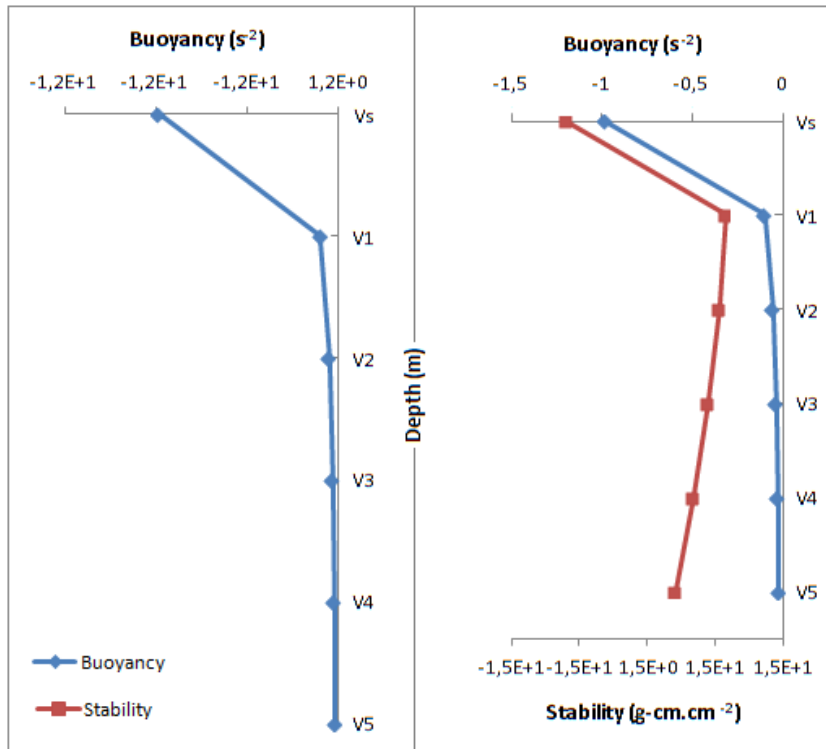


**Figure 32.** The vertical position of buoyancy and stability.

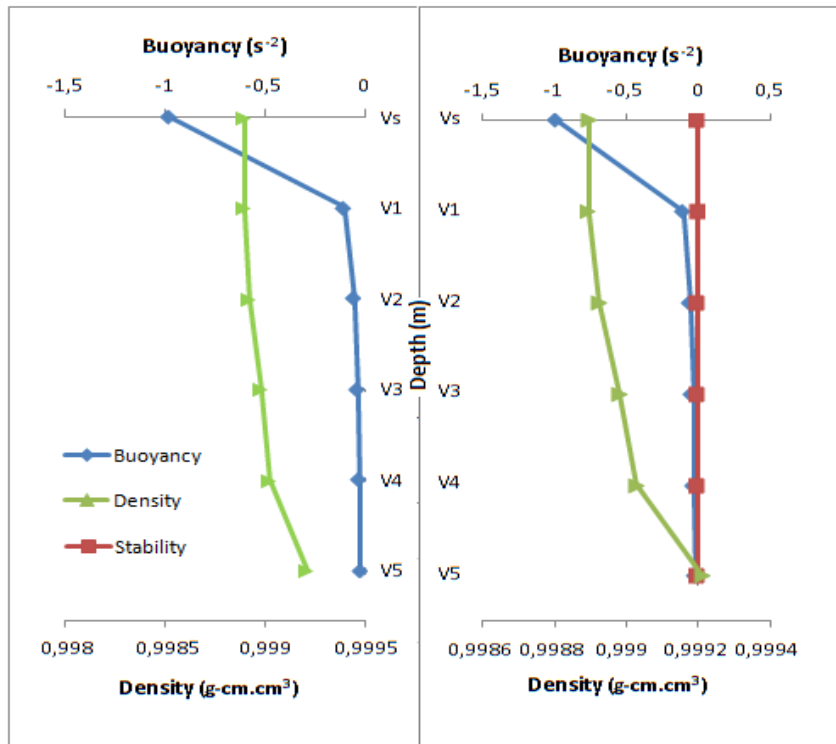


**Figure 33:** The relationship between three parameters which had a common force on vertical stratification and mixing.

The wind displaces the surface water to downward of thermal structure (Wedderburn 1912). The Wedderburn number that was introduced by Imberger and Hamblin (1982) avails to identify the momentum and turbulence by wind which blows over the lake (Hodges et al., 2000) or the inceptive potential energy (Shintani et al., 2010). To describe the general features or dynamics of internal waves after wind was calm (Boegman et al., 2005), the exchange of water between the layers epilimnion and hypolimnion (Monismith 1986).

The dimensionless parameters of Wedderburn number measure the effect of wind stress on the lake surface. There are four classification sections for Wedderburn number:

- a.  $W > \frac{L}{4h_e}$ : strong thermal stratification, little mixing, small internal seiche widthness,
- b.  $\frac{1}{2} < W < \frac{L}{4h_e}$ : wind induced mixing stronger than thermal stratification,
- c.  $\frac{h_e}{L} < W < \frac{1}{2}$ : higher degree of mixing between epilimnion and hypolimnion, unstable thermocline,
- d.  $W < \frac{h_e}{L}$ : mixing completely,

Lake Çubuk is extended in parallel with mountains, therefore the wind direction is predominantly zonal which as north-south (or south-north sometimes) with little angular changes. In the present study, thanks to measured wind directions, the numerical wind values were used in hydrodynamical and physical analyses.

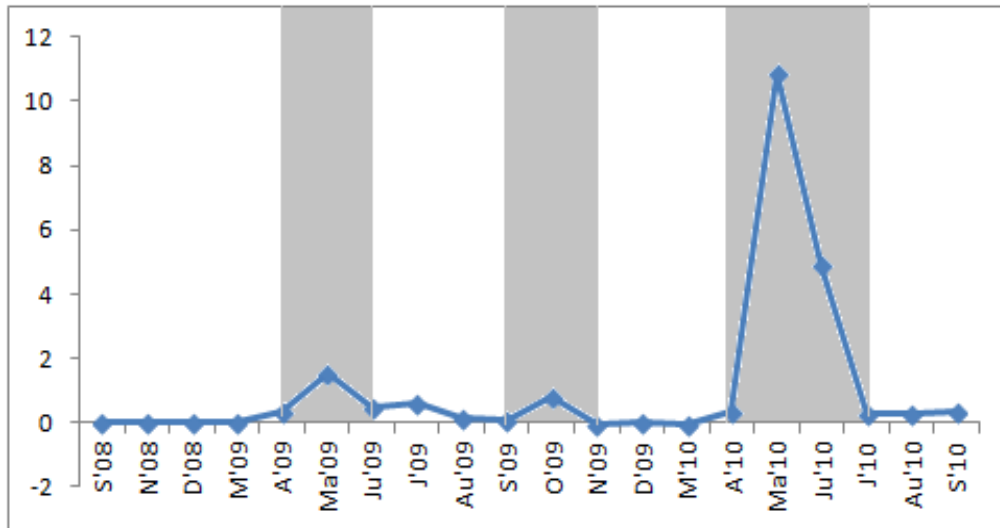


**Figure 34.** The results of calculated Wedderburn number. The filled areas indicate the higher mixing that activated by the wind.

**Table 20.** The Wedderburn classification for Lake Çubuk

| Date  | <i>W</i> | W Class |
|-------|----------|---------|
| S'08  | 0,0450   |         |
| N'08  | -0,0108  |         |
| D'08  | -0,0104  |         |
| M'09  | 0,0064   |         |
| A'09  | 0,3412   |         |
| Ma'09 | 1,5615   |         |
| Ju'09 | 0,5010   |         |
| J'09  | 0,5954   |         |
| Au'09 | 0,1401   |         |
| S'09  | 0,0546   |         |
| O'09  | 0,7911   |         |
| N'09  | -0,0757  |         |
| D'09  | -0,0090  |         |
| M'10  | -0,0322  |         |
| A'10  | 0,3340   |         |
| Ma'10 | 10,9253  |         |
| Ju'10 | 4,9001   |         |
| J'10  | 0,2788   |         |
| Au'10 | 0,2725   |         |
| S'10  | 0,3350   |         |
| Mean  | 1,0472   |         |

$\frac{1}{2} < W < \frac{L}{4h_e}$   
 $\frac{h_e}{L} < W < \frac{1}{2}$   
 $W < \frac{h_e}{L}$

The Wedderburn number is calculated (Formulae 9-10) for 20 months (for four months the measurement of wind speed was not available) (Table 20 and Figure 34). Accordingly, Wedderburn number was negative for five months (November and December 2008; November, December and March 2009). Even though the lake depth and height of the epilimnion was relatively in the common range, the water temperature was low that density of both epilimnion and hypolimnion was relatively higher at this time. According to the classification, the lake seems to complete mixing or overturn (fall overturn). The Wedderburn number was  $>\frac{1}{2}$  ( $<\frac{L}{4h_e}$ ) for six months (May, June, July and October 2009; May and June 2010) which indicates the stronger effect of wind on mixing than thermal stratification. In these months, the temperature was high, density in normal space but the lake water level was relatively high (average 7.13 m; the measured high level (8.5 m) was in May 2010 ). For the remaining nine months, the Wedderburn classification was  $<\frac{1}{2}$  ( $>\frac{h_e}{L}$ ) that signifies to the wind-mixed feature between epilimnetic and hypolimnetic water. The average wind speed was 3.05 m/s during 20 months.

Lewis (1983) who eliminate the lakes defined as “oligomictic” from the typology, divided the lakes into eight classes (Table 4). In all thermal patterns, Lake Çubuk showed a zonation during the warm periods (Figure 25) and a closed temperature affinity between the surface and bottom water just before the cold season (Appendix 3). In the cold season the stratification thermally starts and in this season the bottom temperature is higher than the surface one. In March and April of both 2009 and 2010, the water column temperature showed a resemblance to

September, October and November. These situations indicate the “spring” and “fall” overturn, respectively (Appendix 6).

The isopleths created show changes in water temperature ( $T(w)$  °C), dissolved oxygen (DO), pH and electrical conductivity (EC) in lake water column, which clearly indicated two mixing periods of the lake (Figure 35-38).

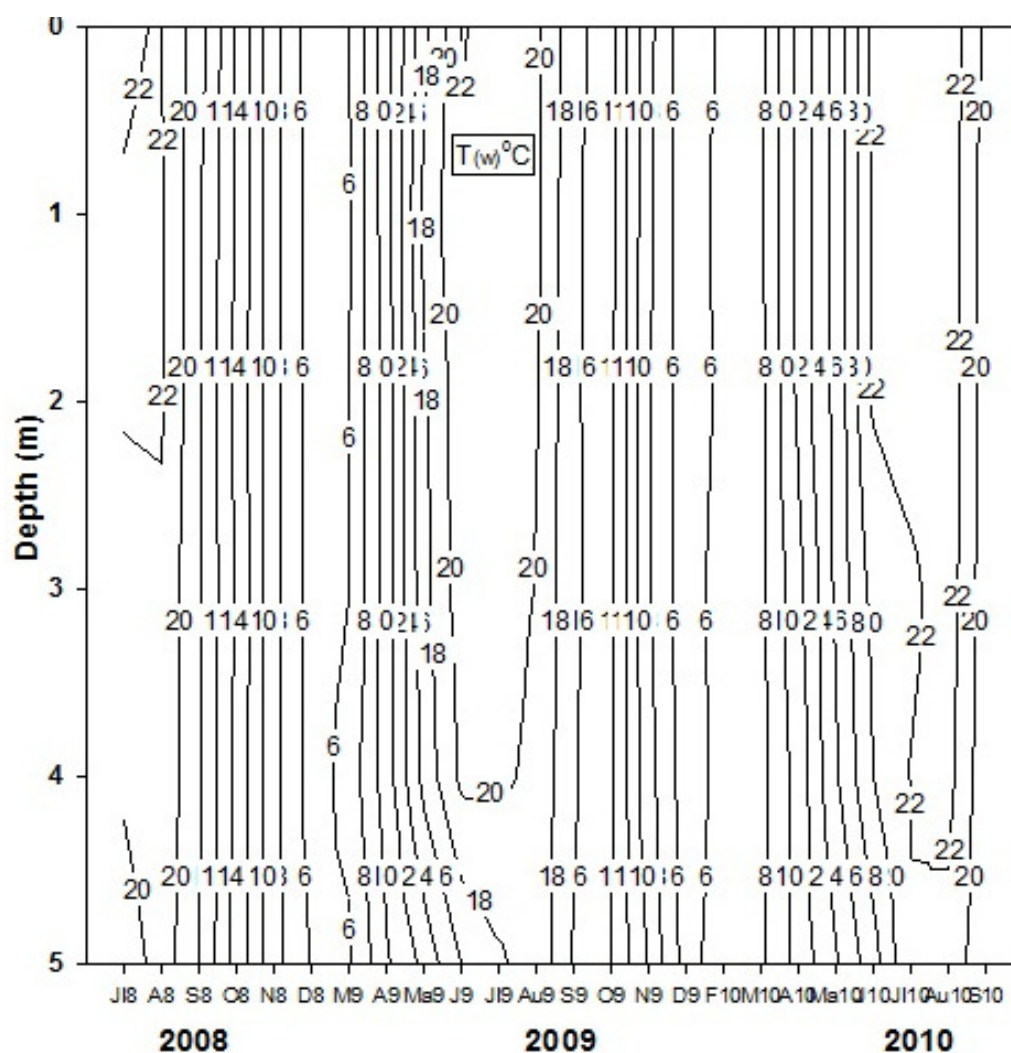


**Figure 35.** The thermal isopleth of Lake Çubuk shown a similarity in temperature between surface and bottom water two times in a year.

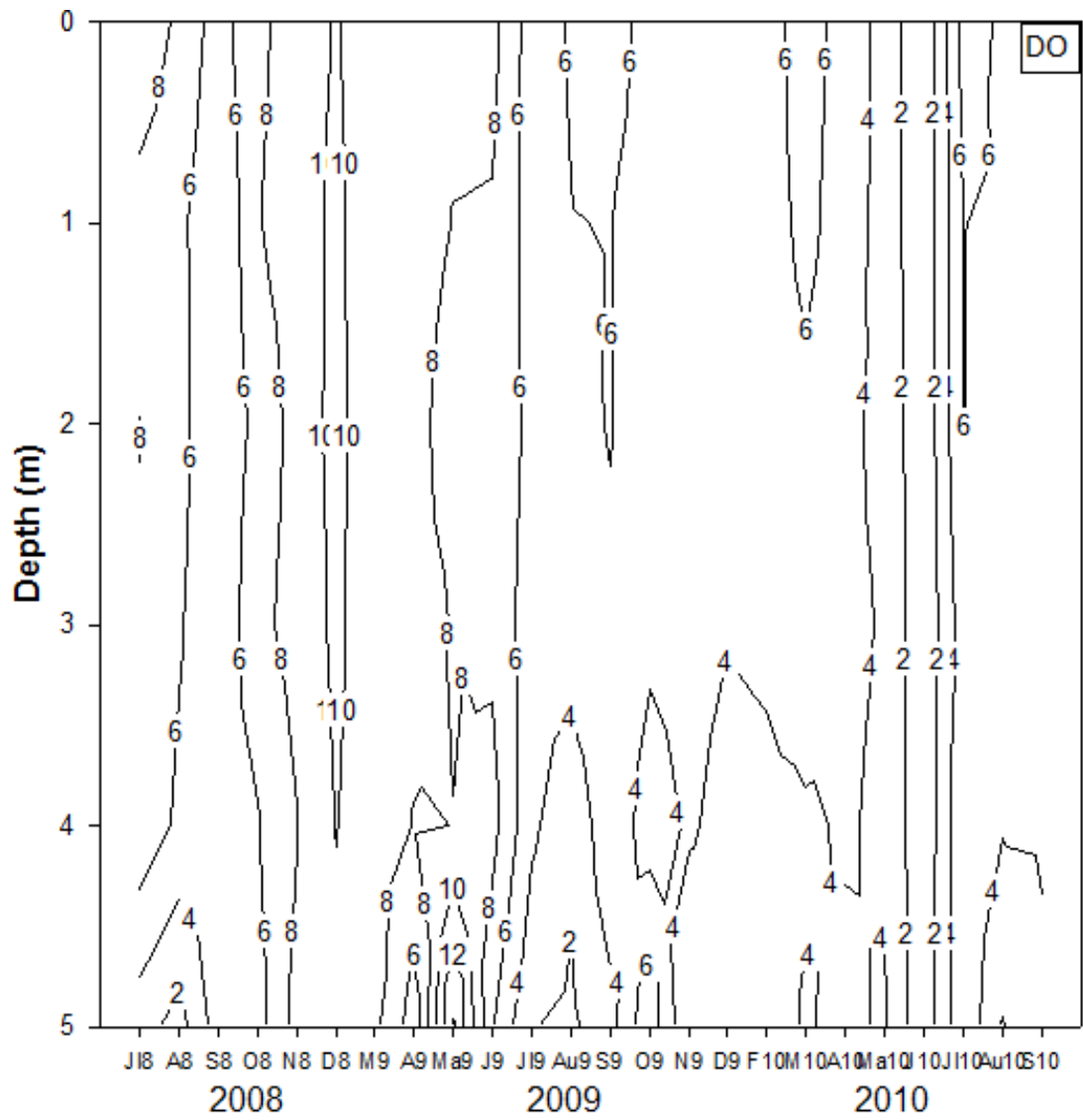


**Figure 36.** The isopleth of dissolved oxygen of Lake Çubuk

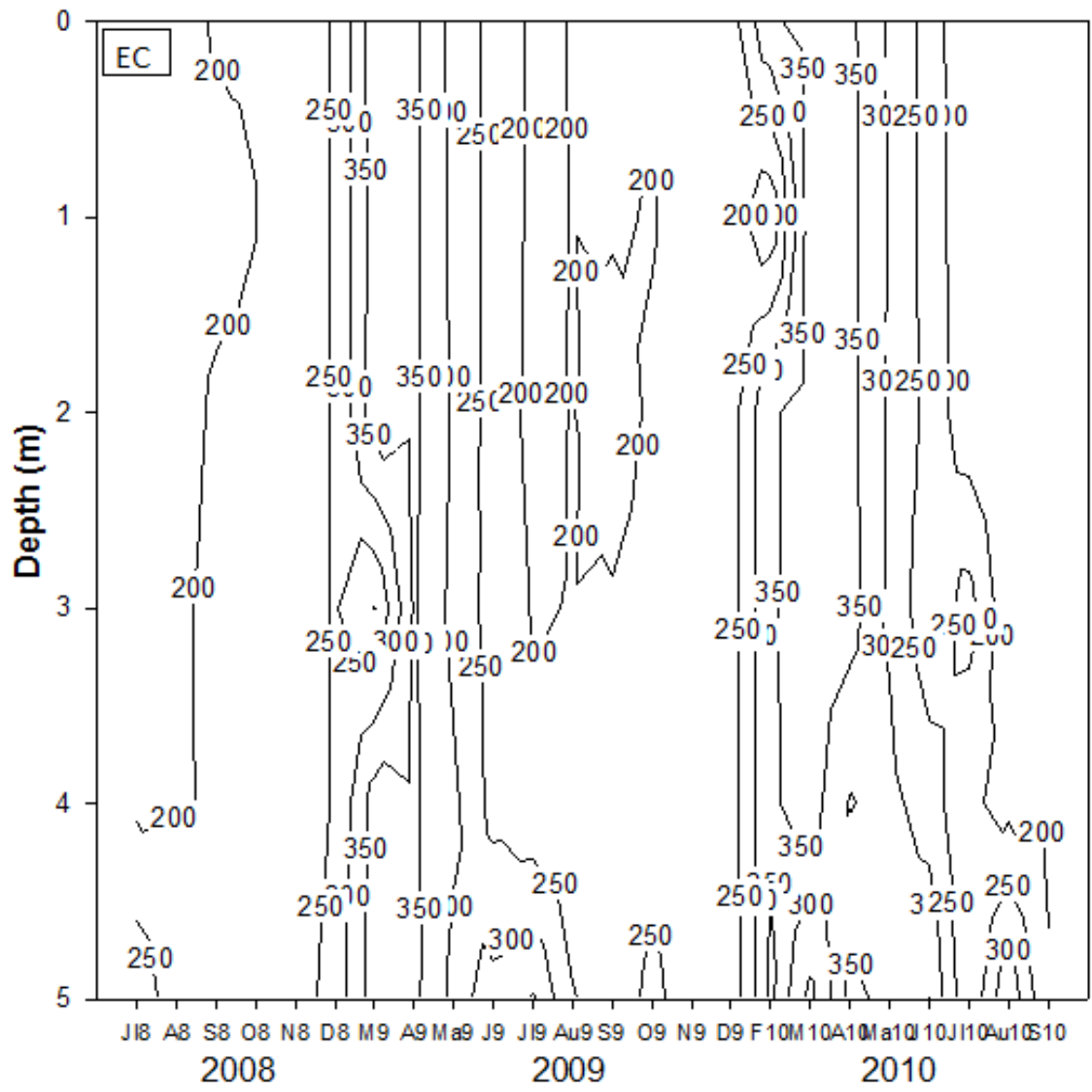


**Figure 37.** The development of electrical conductivity in Lake Çubuk

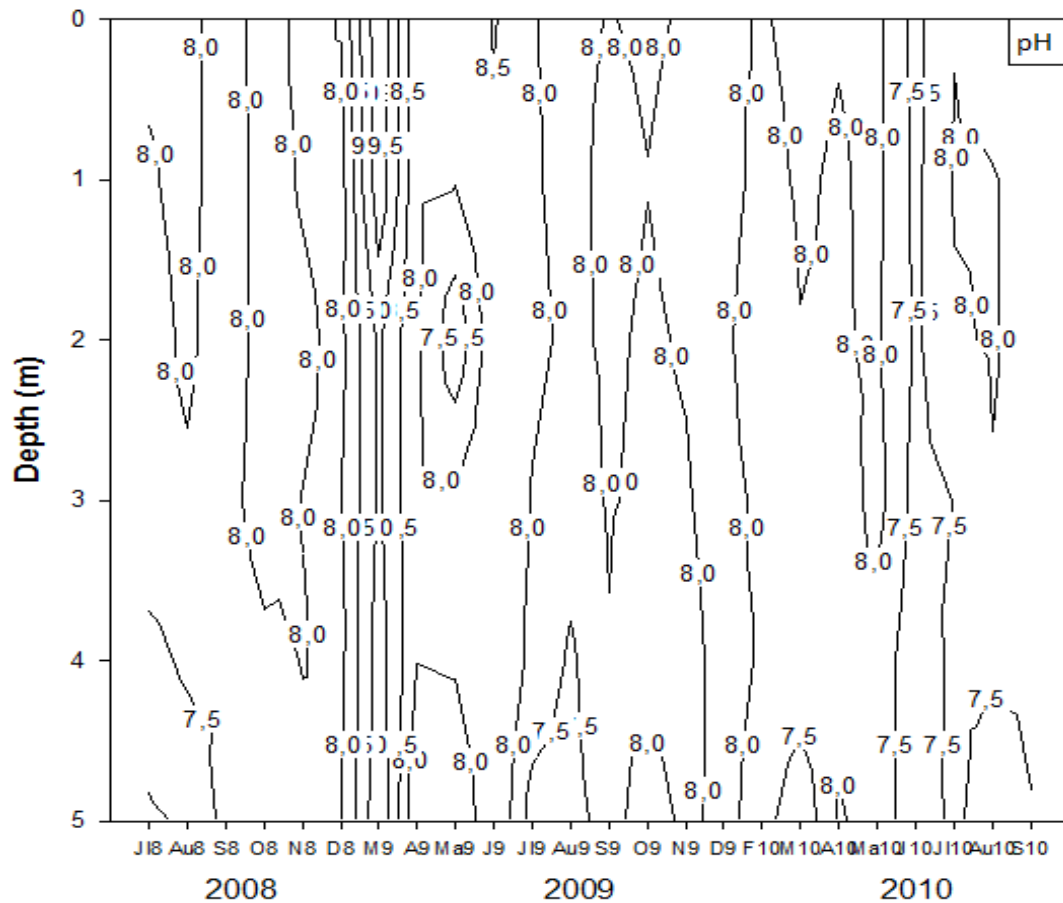


**Figure 38.** The development of pH in Lake Çubuk. The pH values were similar during sampling time with an average as 7.96.

The lake was ice-covered in January and February 2009 and January 2010 which means that it was not ice-covered other part of the year (polimictic lakes are ice-covered typically from November to April (Bengtsson 2012)). In light of these data and the Lewis's (1983) key for mixing type classification (Figure 9), Lake Çubuk can be called as a “dimictic” lake.

Trophic state is determined as the total productivity (biomass) of the water (Carlson 1977) that includes the biological responses for nutrient supplements in a water bodies (Naumann 1929) . A common method, Carlson's Trophic State Index (CTSI) takes its origin from the productivity and the effects on it such as Secchi's

disc transparency, and the weight of chlorophyll-a which commonly comes from phytoplankton and phosphorus.

The parameters required for CTSI were measured in the present study. Accordingly, the least Secchi disc transparency was 50 cm reached at 220 cm, while the average was 134.4 cm (Appendix 3). The least value was measured in October 2009. Higher turbidity (5.02 NTUs) and the lower dissolved oxygen (3.68 mg/L). Even though total analysed chlorophyll was 17.9 µg/L approximately below the lake average (25.3 µg/L), the relatively high count (Appendix 3). In the highest transparency value (220 cm; Appendix 3) month, May 2010, weight of chlorophyll was 19.8 µg/L while the turbidity was 2.74 NTUs. However, the highest value of the depth of the lake (8.5 m) was this month which bordered 3 µg/L of dissolved oxygen.

Respectively by the years 2008 to 2010, the values of TSI of Secchi transparency were 10.37, 7.03 and 19.16. Based on these results, the appearance of the lake is strongly oligotrophic (Figure 39).

With a very wide range of chlorophyll-a (7.1 to 96 µg/L) values, the lowest recorded was in August 2009, the highest in May 2009. The amount of chlorophyll-a gives a prediction of algal concentration (1-2% dry weight of algae), so it is used to determine fertilisation of water bodies.

In May 2009, the course of nitrogen compounds were low, while Secchi disc transparency measured (150 cm) was above the average. Total phosphorus measured was very low (<0.001 ppm) during the sampling, therefore it was not taken into account for analyzing the indices.

**Table 21.** The general scale of two indices

| Classification  | BTLI-Scale                  | CTSI-Scale                |
|-----------------|-----------------------------|---------------------------|
| Oligotrophic    | $2.0 \leq \text{TSI} < 3.0$ | $26 \leq \text{TSI} < 38$ |
| Mesotrophic     | $3.0 \leq \text{TSI} < 4.0$ | $38 \leq \text{TSI} < 54$ |
| Eutrophic       | $4.0 \leq \text{TSI} < 5.5$ | $54 \leq \text{TSI} < 65$ |
| Hyper-Eutrophic | $5.5 \leq \text{TSI} < 7.0$ | $65 \leq \text{TSI}$      |

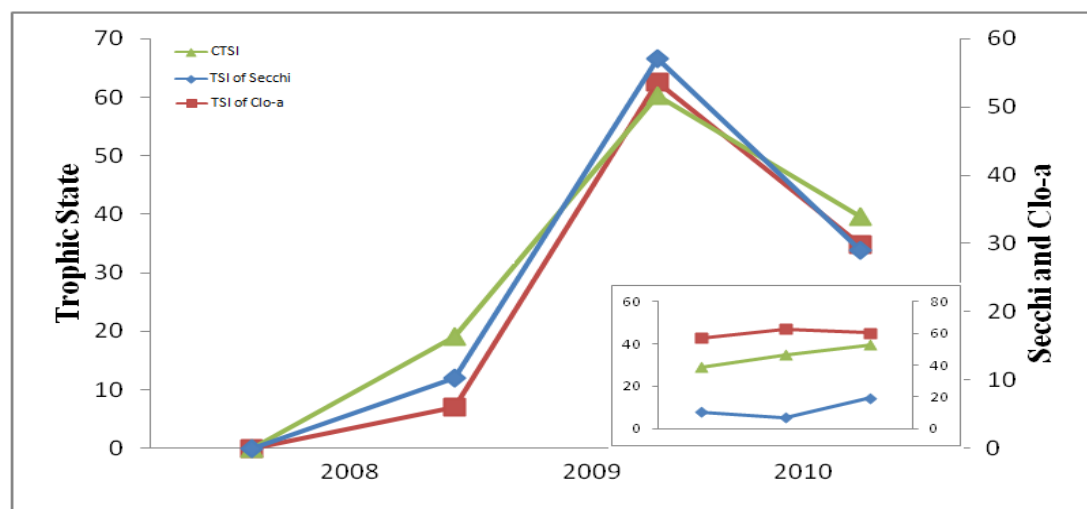


**Figure 39.** The Carlson trophic state index (CTSI) comparing with trophic state indices of Secchi's disc transparency and chlorophyll-a.

According to the CTSI results, with regard to the chlorophyll-a, the lake appears to be hyper-eutrophic. Year basis, moving the lake towards high productivity. Trophic state index (TSI) of chlorophyll-a ascended from 57.02 in 2008 to 62.56 in 2009 and then came down to 60.17 in 2010 (Figure 39 and Figure 40).

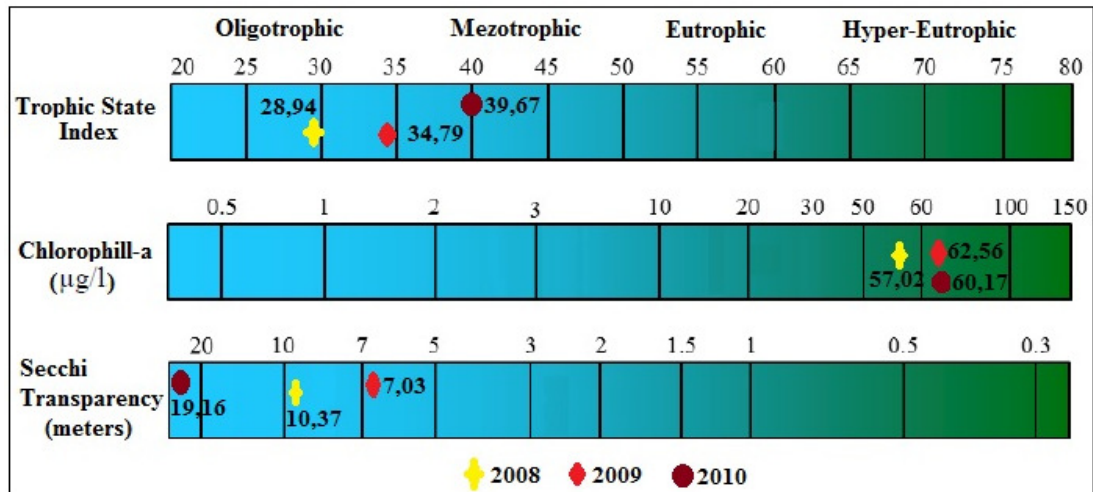


**Figure 40.** The appearance of Lake Çubuk by the years for each value of Carlson Trophic State Index (CTSI) components.

Of each year, based on their CTSI average, the lake exhibited a general view that was oligotrophic in 2008, while slightly down oligotrophic conditions dominated Lake Çubuk in 2009. In 2010, even though the average of Secchi transparency was high (annual average was 156.25 cm) and CTSI was (19.16) (Appendix 4), the relatively aggravated conditions swept the lake implying slightly mesotrophic conditions (Figure 41; Table 22).

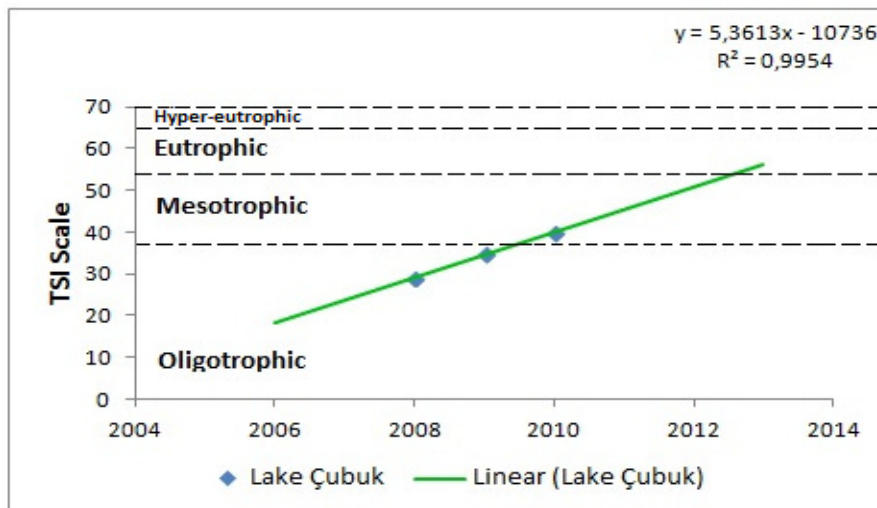


**Figure 41.** Overall change of eutrophication rate for Lake Çubuk according to Carlson Trophic State Index.

For a simple prediction about changes in eutrophication degree, a linear trendline was created using trophic state index quantities (Figure 41). Even though Lake Çubuk is classified as slightly mesotrophic in 2010 (the eutrophication class was Slightly Oligotrophic for three years, Table 22; Appendix 5), its overall classification is Slightly Eutrophic (Figure 41).

Burns who studied New Zeland Lakes created an index (Trophic Level Index; TLI) with converted Secchi depth, the amount of chlorophyll and total concentration of nitrogen and phosphorus. As with the previous index, the amount of phosphorus was not taken into account to define Burns Trophic Level Index (BTLI).

**Table 22.** The annual representation of the numerical data with its visual form for both Carlson and Burns Models. For detailed scale see Table 2 and Table 3.

| Strongly Oligotrophic | Oligotrophic |       | Slightly Mesotrophic |       | Mesotrophic |       | Strongly Mesotrophic |       | Eutrophic |       |       |       |  |
|-----------------------|--------------|-------|----------------------|-------|-------------|-------|----------------------|-------|-----------|-------|-------|-------|--|
| 2008                  | J            | Au    | S                    | O     | N           | D     |                      |       |           |       | Mean  | Class |  |
| CTSI                  | 33,12        | 4,16  | 33,93                | 27,82 | 32,80       | 41,87 |                      |       |           |       | 28,95 |       |  |
| BTLI                  | 5,50         | 5,23  | 5,87                 | 2,38  | 2,17        | 2,02  |                      |       |           |       | 3,86  |       |  |
| 2009                  | M            | A     | Ma                   | Ju    | J           | Au    | S                    | O     | N         | D     |       |       |  |
| CTSI                  | 33,53        | 38,90 | 46,93                | 39,21 | 43,65       | 16,80 | 34,17                | 20,66 | 36,45     | 37,68 | 34,80 |       |  |
| BTLI                  | 5,64         | 2,46  | 6,44                 | 2,26  | 1,93        | 2,07  | 2,45                 | 2,42  | 6,86      | 6,58  | 3,91  |       |  |
| 2010                  | F            | M     | A                    | Ma    | Ju          | J     | Au                   | S     |           |       |       |       |  |
| CTSI                  | 34,43        | 36,89 | 40,64                | 47,92 | 45,54       | 35,98 | 39,49                | 36,46 |           |       | 39,67 |       |  |
| BTLI                  | 6,65         | 6,56  | 6,31                 | 2,06  | 1,97        | 2,09  | 5,84                 | 6,70  |           |       | 4,77  |       |  |

From this index, the trophic level of concentration of total nitrogen varies significantly over the years. Accordingly, the trophic level of the lake is getting worse year by year. Namely, the BTLI value of 3.86 in 2008 increased slightly to 3.91 in 2009 and then, went sharply up to 4.77 in 2010. Although the BTLI value of nitrogen fell down to 1 in 2009, it showed a rise again to 4.12 after a certain time in 2010 (Appendix 4).

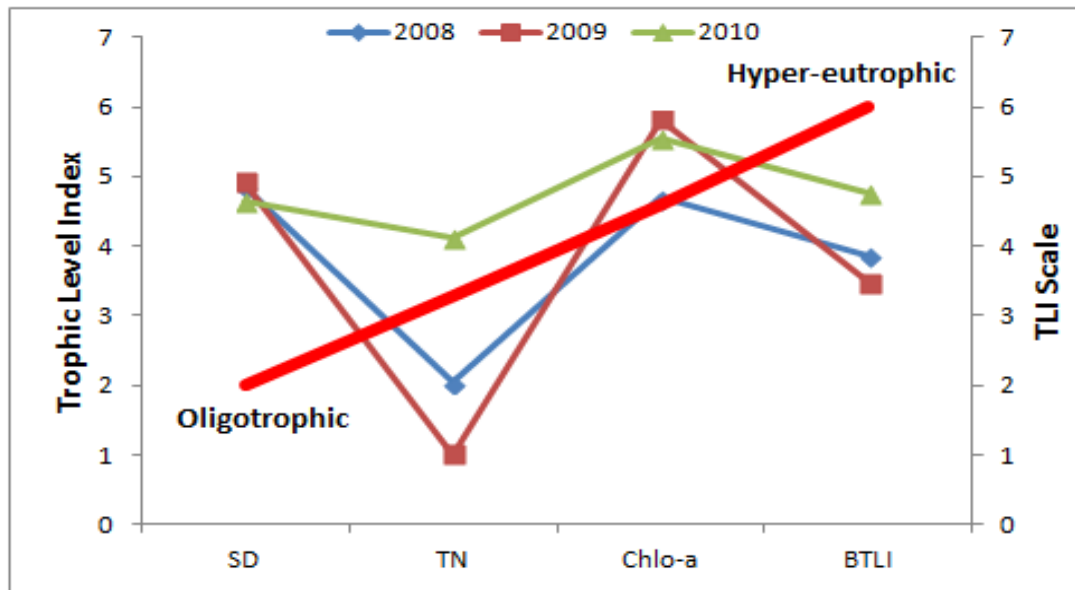


**Figure 42.** The annual change in the level of lake trophic according to Burns Model

The BTLI which provides the quantities via a log transformation also uses the Secchi data to determine the rate of eutrophication. As Carlson index used, the converted values of Secchi disc transparency had an undisputed effect on the results. According to BTLI, the general view of the lake was slightly mesotrophic in terms of nutritional regime in 2008, the status in the following year, seems to have continued (Figure 42). By the beginning of 2010, the result of BTLI appears to be effective, but eutrification Appendix 4). In May, June and July 2010 which reach the relatively high depth of the lake (8.5, 7.15 and 7 m, respectively), the regular efficiency of oligotrophy was observed according to BTLI. During the other months of 2010, the lake showed an increasing eutrophication rate (Figure 43; Figure 45).

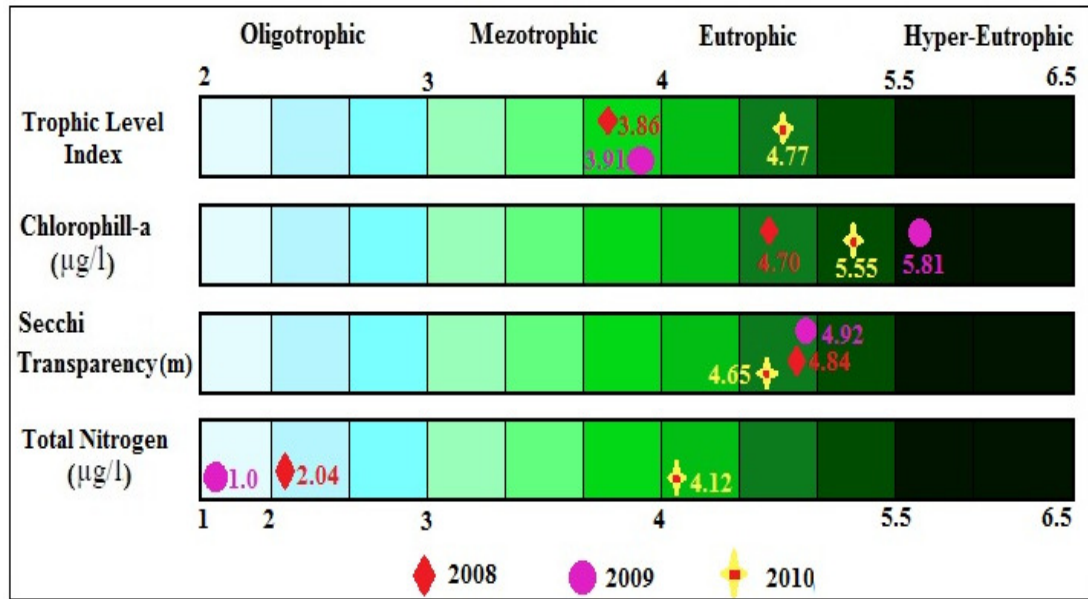


**Figure 43.** The appearance of Lake Çubuk by the years for each value of Burns Trophic Level Index (BTLI) components

The average level of trophication according to Burns indicates the lake as Slightly Eutrophic, while it was classified as eutrophic in 2010 (Table 22; Appendix 5). The visual representation of the overall classification of Çubuk Lake shows a trend towards Slightly Hyper-eutrophic (Figure 44).

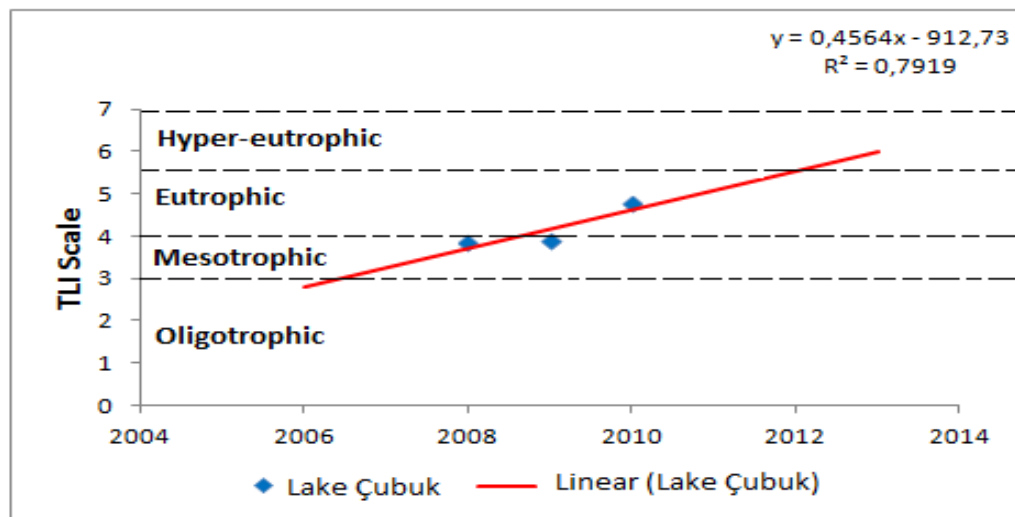


**Figure 44.** Overall change of eutrophication rate for Lake Çubuk according to Burns Trophic Level Index.

The general level of eutrophication rate of Lake Çubuk in terms of both models (CTSI and BTLI) shows a worsening state (Figure 45). An estimate of the linear trendlines in this direction also reveals that the forward-looking. This is clearly seen, especially judging by the chlorophyll-a values of both indices (Figure 40 and Figure 43). The Secchi transparency levels of Burns index also particularly confirm this belief (Figure 43).

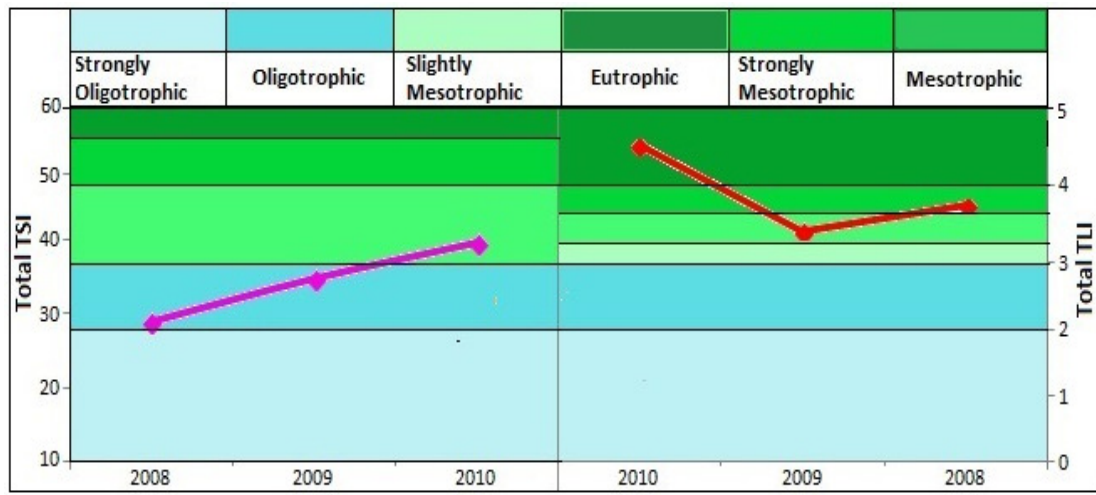


**Figure 45:** The annual change of eutrophication rate in terms of both indices

Summer and winter stratification of both temperature and dissolved oxygen showed the typical features of slightly oligotroph (almost evaluate as slightly mesotrophic) lakes as was the case for Çubuk Lake (Figure 26). The summer stratification of dissolved oxygen in eutrophic lakes is almost parallel with water temperature and, the dissolved oxygen completely finishes depend on the depth under 10 °C (EPA 2010). In this regard, the lake, found to be changing from slightly oligotroph to slightly mesotroph justified by the Carlson Model (Table 22; Appendix 6).

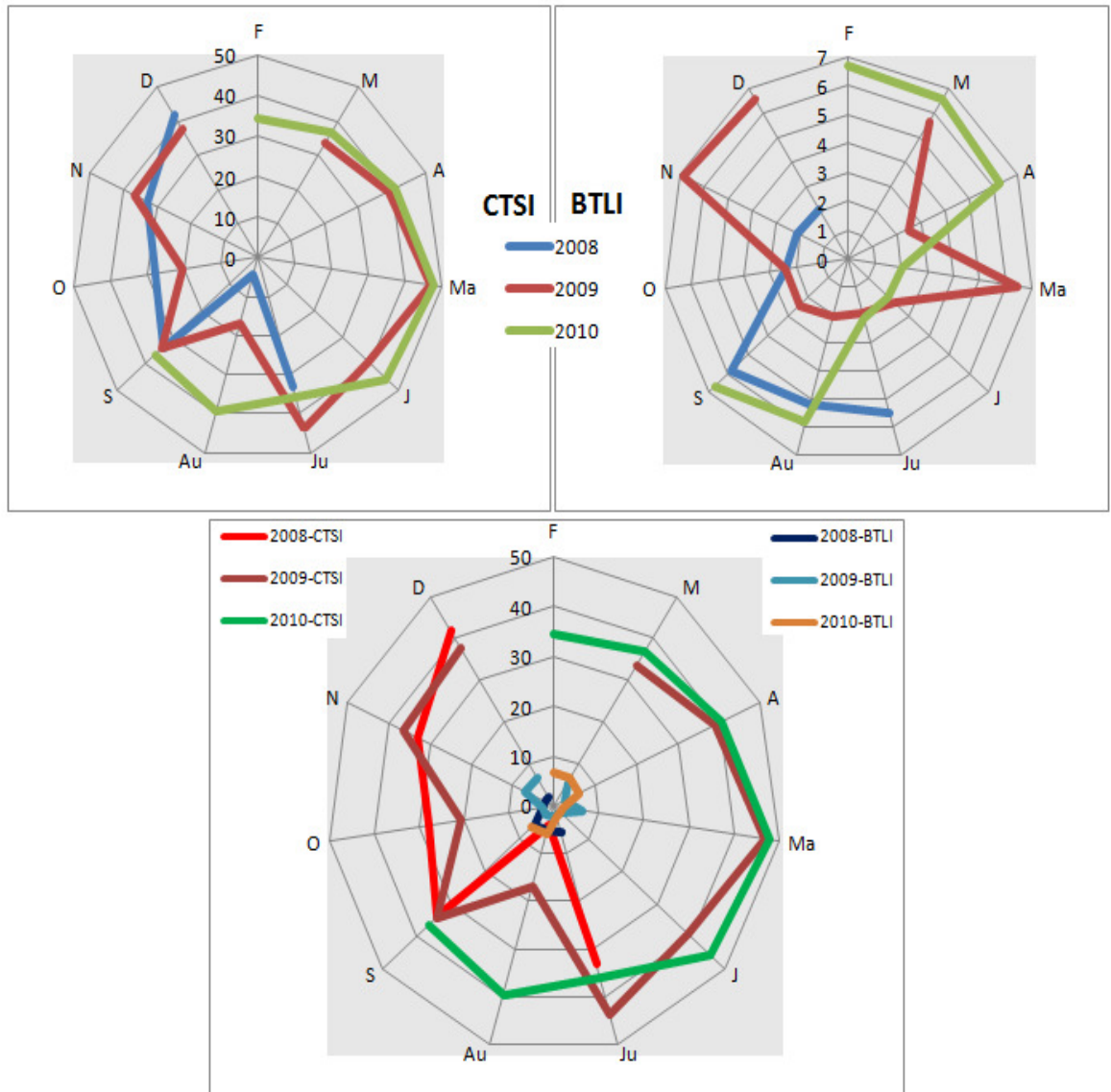


**Figure 46.** The radar diagram of both indices for Lake Çubuk.

#### 4. DISCUSSION and CONCLUSION

17 ostracod species collected from 7 points (L1, L1, L3, L4, L5, Gölpınar spring and Bottom) of Lake Çubuk for 26 sampling times (months) from July 2008 to November 2010 were determined in the present study. For four months (January, February in 2009 and January 2010 due to ice-covered and November in 2010 due to lack of technical equipments) the sampling was not done due to winter condition and no ostracods were detected in July 2010. Among which one species (*F. japonica*) is new report for freshwater Ostracoda fauna of Turkey, while one (*P. sucki*) is registered for second time. *Physocypria kraepelini* was the most common species with total of 185 individuals all year around during the sampling time. *Cypria ophtalmica* was the most frequent species with an abundancy value of seven which means its presence in all the seven stations, the frequency of *Ps. kraepelini* was six excluded the bottom one. Two littoral stations (L2 and L5) were the most affluent stations with 13 species. These two stations were followed by L4 with 12 different species, while the least number of species were naturally ascertained from the bottom point. The living individuals of *F. japonica* and *Cy. ophtalmica* were captured from the bottom. The third station (L3) containing intense gravel and sand was relatively poor about species abundancy with seven. The limnocrene spring Gölpınar sampled just for the first five months due to the rise of the lake water, housed nine species which were already found in the other stations. In a previous study (Külköylüoğlu and Sarı 2012), the dissolved oxygen level was measured as 13.95 mg/L from a point very close to L1 in July 2006, whereas the highest value measured for this parameter was 10.95 mg/L (October 2010) with an average of 5.65 mg/L in the present study

(Appendix 2).

When compared to the earlier works in similar habitats, ostracod species richness of this lake with 17 species is higher than the mean ostracod species per lake (13.2 species) in Turkey. However, the mean numbers of individuals per species (31.2) was not significantly high. This is also reflected among the stations with a significant difference ( $P < 0.05$ ) for the numbers of species and individuals (Appendix 1, Appendix 2). Five possible reasons for such differences in the diversity can be discussed as follows: (i) physico- (mixing, irrigation process, soil structure, waste discharge, vegetation, water clarity (transparency), amount of algal biomass) and hydro-chemical (ions balance, nutrition (micronutrients as nitrogen and phosphorus) characteristics specific to the stations, (ii) seasonal (perhaps based on the monthly changes in abundancy cycle of species) differences in the water level fluctuations, (iii) the trophic stress due to fertilisation level at each of the points (iv) swimming ability of species and (v) the geographical (spatial) position of the station (topography, angle of the shore which effect the depth, duration of exposure to the wind, sunbathing angle and time and littoral position). Considering that total numbers of species was found 50% lower in the year 2010 (10 species) than 2009 (17 species), numbers of individuals were also lower in the year 2010 (8) than 2009 (20.3;  $P < 0.01$ , F- test = 4.41). Both reductions were coupled with an increasing water level (up to 3.5 m increase in depth) in the year 2010 where the flood zone was covered by intrusion more than five meters to the landside on especially stations L3 and L4 due to their geographical position, depth and shore angle (Figure 10). Külköylüoğlu et al. (2010) reached similar results in Lake Sünnet (Turkey), where numbers of individuals were higher (ca. 56 individuals) between 7.75 and 8.75 m of depth than the depth between 9.0 and 12.8 m (ca. 31 individuals), but no living

species were found above 13 m. Among the species, *L. inopinata* was not covered above 9 m of depth while *I. gibba* and *Ps. kraepelini* were common in both zones. When the station L4 (observed 11 species) was invaded by macrophytes, the littoral L3 (5 species, the most rare species diversity of the present study) station very closed to a common stabilized path was usually covered with lime. Besides, the neighborliness of a small barn and a chicken farm to L4 and the dune base structure of L3 should be considered. In June 2010, the detection of 7000 cfu/ml coliform bacteria in total at the station L4 should be noted to grasp the hydrochemical content of the water. Small garden trees surrounding the station in the form of half a circle was both protecting there against the wind and affecting the duration of the sunlight.

The other two stations close to the road were L1 and L5 (Figure 10). When L5 was the richest station in terms of species diversity (13), L1 (8) was located nearby the popular turistic windmills. L1 was the only station adjacent to outlet of the creek “Göldere” carrying water from the lake, while there was the only restaurant of the village close to L5. With a small wharf L5, the another station that detected coliform bacteria also been found zebra mussels (*Dreissena polymorpha*), which tend to accumulate the pollutants and toxins. So, the most probability discharging of sewage from the restaurant to the station might be the only source of changing water quality. The presence of mussels and relatively high amount of bacteria support this view. This station has a steeper shoreline that was deepened more than the other littoral points (L1, L2, L3 and L4).

The effect of irrigation activities was observed in station L1. Even though this station was complicated with household waste, in the most shallow part of the lake in south, eight species (five cosmopolitan as *C. neglecta*, *Cy. ophtalmica*, *Ps. kraepelini*, *I. gibba* and *L. inopinata*; three non-cosmopolitan that *C. sanociensis*, *P.*

*albicans* and *F. japonica*) were recorded. Partially protected more than the others thanks to its location, L2 hosted 13 species as with L5 (Figure Map). It was a little bit away from the stabilized road, and there was noticeable vegetation. Such a flood invasion of so happen within about a couple of hours or days that only some species can be able to migrate onto the flooding zone. The swimming ostracod species such as *Cs. vidua*, *Ps. kraepelini* and *Cy. ophtalmica* invaded the flooding zone after 24 hours of intrusion (Szlauer-Łukaszewska 2008) when bottom dependent (or crawling species with no swimming setae on second antenna) species (e.g., *L. inopinata*, *Ilyocypris* spp.) were superior in the river bed and medial zones of River Odra, Poland. We did not observe a significant difference between swimming and crawling forms among the most frequently occurring five species common to all the stations. Hence, we believe that water flow direction may be important for the numbers of species in the stations 3 and 4 since each is located on the northern parts of the lake, from which water flows in the opposite direction down to the southern parts. Eventually, effect of flow from north to southern parts of the lake may bring more individuals to these areas. As a result, all these factors can cause changes in characteristics, even though they are a different part of “the same concern”.

When temperature and dissolved oxygen values of the lake water was 8.73 °C, 8.69 mg/L in November 2008, the number of the species identified reached nine the number of the species identified. However, it was zero in July 2009, while this number was four in the previous summer, July 2008 (Appendix 2). *Fabaeformiscandona japonica* which was captured almost all the points of the lake except L5 and the spring, was not seen after September 2009. Three species of *Pseudocandona* (*P. eremite*, *P. sucki*, *P. semicognita*) were caught two times during the sampling with *T. serrata*, while *Pr. zenkeri* was encountered once in March 2009.

On average, 17 species were found along Lake Çubuk. The number of cosmopolitan species that eight of them (*C. candida*, *C. neglecta*, *Ps. kraepelini*, *Cy. ophtalmica*, *Cs. vidua*, *L. inopinata*, *Pr. zenkeri*, *I. gibba*) is higher than the mean number of species per lake in Turkey. Furthermore, in the context of “pseudorichness” concept, if the ratio of PR (non-cosmopolitan/cosmopolitan) is greater than unity then it indicates the predominancy of non-cosmopolitans. It means that non-cosmopolitan species can tolerate the conditions relatively and “temporarily”. But again, the number of non-cosmopolitan species does not change the fact that the lake “began to wear” based on quality/health. The “PR” ratio is 1.125 (9 non-cosmopolitan/8 cosmopolitan) that is relatively higher than similar habitats (Külköylüoğlu and Dügel 2004; Külköylüoğlu 2005; Yılmaz and Külköylüoğlu 2006; Külköylüoğlu et al., 2007; Dügel et al., 2008). A rapid indication about the water body disturbed by different factors can be provided by ostracods. However, knowing that the cosmopolitans in water body can give clear information, this rised the concept “pseudorichness” up to a critical level for water quality. And again, a water body with not hosting the native species not have to be called as one with disturbed or poor water quality (Külköylüoğlu 2004).

A distinct seasonal occurrence for five species was identified (*C. neglecta*, *L. inopinata*, *Cy. ophtalmica*, *Cs. vidua*, and *F. japonica*) while one species (*Ps. kraepelini*) was encountered throughout the year (Figure 11). Four of these species (except *F. japonica*) are known with a widespread geographical distribution and with relatively high tolerance levels to different ecological variables (Külköylüoğlu, in press).

Taxonomic problems with the poorly known species *F. japonica* are discussed in details by Escrivà et al. (2012). *F. japonica* is found on/in the bottom of a paddy field

in Japan (Okubo 1990), reported from shallow lakes close to the rivers (Poquet 2003) and from Millars river in Spain (Mezquita et al., 2005). This bottom-dependent species was also captured from floodplain of Chi River basin in Thailand (Savatenalinton 2011).

Tolerance (*tk*) and Optima (*uk*) values calculated for species are associated with ETI values. The higher ETI value of a species is, the higher species tolerance value is (Tables 10 and 11). Also UPGMA dendrogram supported these results and some species clustered in UPGMA were also related to Canonical Correspondence Analysis (Figures 12 and 13), confirming the results. For example, UPGMA dendrogram clustered species as Group I (*T. serrata*, *P. albicans* and *P. semicognita*) (Figure 12). These three species were located distally to the center of CCA, while *P. albicans* was settled close to electrical conductivity with *Ps. kraepelini* in April 2009 and 2010 (Figure 12). Three cosmopolitan species (*L. inopinata*, *Cy. ophtalmica* and *Cs. vidua*) were clustered in the second group (Group II) (Figure 12), while Group III hosted two cosmopolitan (*Ps. kraepelini* and *C. neglecta*) and one non-cosmopolitan (*F. japonica*) species (Figure 12).

According to the thermal classification, the stratification index and Wedderburn number (thermal isopleths and stability results also supported) Lake Çubuk is a dimictic lake with two mixing periods during the year. As seen in Table 23, the “spring turnover” (dark gray filled) occurs from March to the end of April, while “fall turnover” (light gray filled) shows its effect as of September until the beginning of December. The stability of the water column of the lake was very low (Figure 31) just as the stratification index. As observed in this study, the abundancy of the species in fall turnover is higher than spring turnover. While *Prionocypris zenkeri* and *Pseudocandona sucki* was not determined in fall mixing period. 13 species

determined were *Candona neglecta*, *Candona weltneri*, *Candona sanociensis*, *Pseudocandona eremite*, *P. sucki*, *P. semicognita*, *Fabaeformiscandona brevicornis*, *F. japonica*, *Cypria ophtalmica*, *Ilyocypris gibba*, *Trajanocypris serrata*, *Cypridopsis vidua* and *Limnocythere inopinata*. Only four species (*C. candida*, *P. albicans*, *Ps. kraepelini* and *Pr. zenkeri*) were captured in spring turnover (Table 23). *C. weltneri*, *P. sucki* and non-cosmopolitan swimmer *T. serrata* were not found in both mixing periods, while *C. candida*, *P. albicans* and *Ps. kraepelini* were captured in both overturn periods. Although *Ps. kraepelini* was also seen in spring overturn, the number of individuals were much lower than fall turnover time (Table 23 and Table 25). The main difference between the two mixing periods arises from the difference between water and air temperatures. So, the less numbers of *Ps. kraepelini* in the spring period occurred due to the temperature changes; namely, the temperature is the limiting factor for species abundance. Among which, although there was no the swimming (natatory) setae on second antenna of *C. candida* and *P. albicans*, *Ps. kraepelini* is a very well swimmer with its very long natatory setae. Although *P. albicans*, which can survive for several weeks in the bottom-mud when water dries (Meisch 2000), is not a swimmer, include *C. candida*, their success during mixing periods is admirable. Detection of these non-swimming species may be caused by water hitting them two the littoral zone or, of course, their strong involvement to the bottom mud. Additionally, the vegetation of the littoral sampling points can be both a nest to hold on and a barricade as a breakwater.

**Table 23.** Comparing the composition of species with stratification index (SI) and wind stress effect on lake water based on Wedderburn number (W). Light gray filled indicate “Fall turnover”, while the dark gray filled specify the “Spring Turnover”.

| Date       | Non-swimming Species |    |    |    |    |    |    |    |    |    |    |    | Swimming Species |    |    |    |    | SI   | W     | Year |
|------------|----------------------|----|----|----|----|----|----|----|----|----|----|----|------------------|----|----|----|----|------|-------|------|
|            | Cc                   | Cn | Cw | Cs | Pa | Pe | Ps | Pm | Fb | Pz | Li | Fj | Co               | Pk | Ig | Cv | Ts |      |       |      |
| 19.07.2008 | 2                    |    |    |    |    |    |    |    |    |    |    | 5  | 3                |    |    |    |    | 2,66 | 0,05  | 2008 |
| 21.08.2008 | 1                    |    |    |    |    |    |    |    |    |    | 6  | 3  | 6                | 7  |    | 5  |    | 1,06 | -0,01 |      |
| 20.09.2008 | 2                    |    |    |    |    | 3  |    | 3  |    |    | 6  | 11 | 9                | 27 |    | 8  |    | 0,41 | -0,01 |      |
| 18.10.2008 | 3                    |    |    | 4  | 4  |    |    |    |    |    |    | 9  | 5                | 4  |    |    |    | 0,31 | 0,01  |      |
| 22.11.2008 | 3                    | 2  |    |    | 2  |    |    |    | 2  |    | 2  |    | 18               | 13 | 34 | 4  |    | 0,02 | 0,34  |      |
| 20.12.2008 |                      |    |    |    | 14 |    |    |    |    |    |    |    | 2                | 23 |    | 1  | 2  | 0,05 | 1,56  |      |
| 28.03.2009 | 2                    |    |    |    |    |    |    |    |    | 3  |    |    |                  |    |    |    |    | 0,08 | 0,50  | 2009 |
| 25.04.2009 |                      |    |    |    |    |    |    |    |    |    |    |    | 2                |    |    |    |    | 0,44 | 0,60  |      |
| 23.05.2009 | 1                    | 2  |    |    |    |    | 2  |    |    |    |    |    | 5                |    |    |    |    | 2,91 | 0,14  |      |
| 20.06.2009 |                      |    |    |    | 3  |    | 2  |    |    |    |    |    | 19               |    |    | 4  | 2  | 4,00 | 0,05  |      |
| 18.07.2009 |                      |    |    | 2  |    |    |    |    |    |    |    | 4  | 9                |    |    | 3  |    | 2,78 | 0,79  |      |
| 22.08.2009 |                      |    |    |    |    |    |    |    |    |    |    | 7  |                  | 3  |    | 3  |    | 0,86 | -0,08 |      |
| 26.09.2009 | 5                    |    |    |    |    | 2  |    | 1  |    |    | 4  | 4  | 7                | 13 |    | 1  |    | 0,44 | -0,01 |      |
| 24.10.2009 |                      |    |    |    |    |    |    |    |    |    | 2  |    | 3                | 24 | 6  |    |    | 2,38 | -0,03 |      |
| 21.11.2009 | 1                    |    |    |    |    |    |    |    |    |    | 14 |    |                  | 8  | 3  |    |    | 0,33 | 0,33  |      |
| 19.12.2009 | 2                    |    | 2  | 1  |    |    |    |    |    |    | 1  |    | 1                | 20 |    |    |    | 0,02 | 10,93 | 2010 |
| 20.02.2010 |                      |    |    |    |    |    |    |    |    |    |    |    | 2                |    |    |    |    | 0,08 | 4,90  |      |
| 20.03.2010 |                      |    |    |    |    |    |    |    |    |    |    |    | 5                |    |    |    |    | 0,07 | 0,28  |      |
| 17.04.2010 |                      |    |    |    | 2  |    |    |    |    |    |    |    | 2                |    |    |    |    | 0,81 | 0,27  |      |
| 22.05.2010 |                      | 2  |    |    |    |    |    |    |    |    |    |    | 6                |    |    |    |    | 1,52 | 0,34  |      |
| 19.06.2010 |                      |    |    |    |    | 5  |    |    |    |    |    |    | 4                |    |    |    |    | 4,05 | 1,05  |      |
| 24.07.2010 |                      |    |    |    |    |    |    |    |    |    |    |    |                  |    |    |    |    | 1,68 | na    |      |
| 21.08.2010 | 2                    |    |    |    |    |    |    |    |    |    | 1  |    | 4                | 9  |    | 1  |    | 1,77 | na    |      |
| 18.09.2010 |                      |    |    |    |    |    |    |    |    |    | 2  |    | 8                |    |    | 3  |    | 0,64 | na    |      |
| 24.10.2010 | 2                    |    |    | 1  |    |    |    |    |    |    |    |    | 3                | 5  | 2  | 1  |    | na   | na    |      |

The plentiful occurrence of the swimming species (all of them are cypridid species) in especially mixing periods can be due to their reproduction times. For example, *Cy. ophtalmica* produces two generation per year and the hatchings occur from April to August and September to December (Meisch 2000), during the summer and winter generations. Although it cannot be detected from March to May, the average life of adults is one year (Meisch 2000). In this study the winter generation of this species was captured (Table 23). The larval period of all year long species such as *Ps. kraepelini* takes place between March and September. In present study,

the abundance of the species from March to September is very rare, while the captured number of individuals was increasing after September. Some ostracod species spawn in cold conditions to protect their eggs from dessication like *Cy. ophtalmica* whose eggs were found at 4-5 °C (Meisch 2000). When the animals lay the eggs, they can be more vulnerable and act more slowly, then they can be caught more easily. *Ilyocypris gibba*, another swimming species, although producing two generations annually like *Cy. ophtalmica*, usually dissapears in winter, as was determined in this study (Table 23). Even though Meisch (2000) determined *Trajancypris serrata*, the other swimmer, as a summer form, in the present study it was caught both in December and in June. Unlike the other swimmers, it could not be found at mixing periods. *Cs. vidua* also produces two annual generations which can be divided as summer and spring forms. The summer production starts from May and maturation occurs in late July, while fertilization in spring occurs in late August to September. In the present study, the occurrence of the species moves on both forms.

A common point of these species is both number and time of reproduction. Four of them (*Cy.ophtalmica*, *Ps. kraepelini*, *I. gibba* and *Cs. vidua*) have two annual generations, while one (*Trajancypris serrata*) is poorly known about its life history. The lessen species in winter *I. gibba* and *T. serrata* were the most rare swimmers in this study, while the other species with two generations were seen all year round (Table 23 and Appendix 2).

As we know that, the ostracod species are long-lived animals relative to most microorganisms (De Deckker and Forester 1988). Their life cycle may be as long as a year or more (Delorme 1978). Although, Delorme and Zoltai (1984) showed that the distribution of shallow-lake species may be defined in terms of water/air

temperature, we know that the mixing in lakes occurs due to differences of temperature levels both between different layers of water and between water and air which cause wind stress. So, if the temperature has a certain effect on the species distribution (and variation) (Delorme and Zoltai 1984) and on the reaching to maturity (Martens et al., 1985), change in water (and air) temperature during the transition times can cause changes in species composition. The fall turnover in 2009, almost no found non-cosmopolitan species (at the beginning of the fall mixing, just three of non-cosmopolitan and bottom-dependent species as *P. eremita*, *P. semicognita* and *F. japonica* in low numbers were captured) (Table 25). Besides, there are almost no ostracods (non or cosmopolitan) at spring turnover time (the dominance of *Ps. kraepelini* continues). The biggest difference between fall and spring turnover periods appears as the ratio between the water and air temperatures (Table 25). Accordingly, the range between these parameters at spring turnover is more than fall turnover. The mean temperature of fall turnover time is also more (14.3, 14.5 and 16.45 at fall mixing periods of 2008, 2009 and 2010, respectively) than the temperature of spring turnover (9.6 and 11.05 at spring mixing periods of 2009 and 2010, respectively). Hence, the temperature can be said to be effective on the occurrence of ostracods, perhaps hatching or maturation. Comparing the optima and tolerance levels of the cosmopolitan species to the water temperature with non-cosmopolitans, these values appear to be relatively higher for cosmopolitan species (Table 10). According to estimated tolerance level, any species non-tolerant (or with very low tolerance) to the temperature of water (*C. weltneri*, *C. sanociensis*, *F. japonica* and *I. gibba*) did not appear at spring turnover, the period when the temperature differences were wider than any time (Table 10).

On the other hand, the decrease in the numbers of cosmopolitan species may be due to the increase in eutrophication rate. The primary production of lake water is increasing year by year according to the two indices (Carlson and Burns Models; Figure 40, 43 and 45). The increase in the primary production beyond the normal values of the water can have a limiting effect on the distribution and occurrence of these animals. Because, withstand the maximum values is exceeded, albeit not tolerate the cosmopolitan animals.

Another factor in the occurrence and distribution of ostracoda may be the severity of the mixing due to the density differences between the upper and the lower layers of the host water. The Wedderburn classification (W) gives a clear clue about intensity of the mixing (Table 20 and Figure 34). According to W number, in spring mixing time, the degree of mixing between epilimnion and hypolimnion is too high ( $W > h_e/L$ ;  $W=0.162$ ,  $h_e/L=0.006$ ) which causes an unstable thermocline. It means that, due to the differences in temperature degrees, all water column tends to become homogenous in terms of temperature (or a durable stratification) and in this instance, the temperature is more effective on mixing. Due to this rapid process, the species cannot have enough time to migrate or hold onto something near. Besides, the sudden temperature changes (the variation between water and air temperature is also higher than fall turnover) can damage the specimens and remove them from the environment. However, in fall mixing time the balance process in different way and W was smaller than  $h_e/L$  ( $W=0.003$ ,  $h_e/L=0.06$ ) (Table 20). At that rate, a complete mixing occur but the disparity between water and air temperature is lower and wind is more effective than temperature on mixing. The absence of sharp changes in temperature between epilimnion and hypolimnion gives time to the species to take a

position. Then, the species composition is shaped in accordance with their tolerances to the temperature.

The severity of the mixing may also due to the density differences between upper and lower layers of the host water. The diffusion (or exchange) between climates and host water can control the ostracod occurrence and productivity (De Deckker and Forester 1988). The life cycle of ostracods can be related to their hydrological environment (Delorme 1969). The coupling between water and atmosphere is usually based on temperature. In dimictic lakes, just as in the present case, turbulence generated by wind moves the heat down to the subsurface, then the densities between the layers of water column get close to each other. In Lake Çubuk, the density of layers was changeable based on the season (Table 18). In both mixing times, typically the density of epilimnion and below were almost similar. But, when in spring turnover interlayer densities became equal at almost  $1 \text{ g.cm}^{-3}$ , in fall turnover this parameter was balanced at a slightly lower value ( $<0.99$ ). Namely it means, the surface water in warm season (epilimnion is well-lightened) is milder and can mix well and more easily than cold season. Finally, the mixture will be so severe that the ostracods and even those that are bottom-dependent, are not able to cling to their ambient water, sediment or herbs.

The species composition may be also explained by the changes in ion content. In temperate areas, the water column is typically dominated by  $\text{Ca}^{+2}$  and  $\text{HCO}_3^-$ . Under wet climates, whether warm or cold conditions, inorganic mineral precipitation is minimal contrary to biogenic mineral production. Biogenic mineral production also occur as calcite in ostracods in such waters and biogenic carbonat may not be stored in the sediment (De Deckker and Forester 1988). Under dry conditions, due to evaporation exceeds precipitation the concentration of salinity increases and mineral

precipitation occurs (De Deckker and Forester 1988). Just as in the present study, when the temperature of air increased (18.8 °C, fall mixing), the amount of  $\text{Ca}^{+2}$  and  $\text{HCO}_3^-$  is decreasing in contrast to  $\text{Mg}^{+2}$  quantity (Table 24). At the same time, the water hardness is becoming soft, the amount of  $\text{Na}^+$  is almost the same and accompanies an increase in the amount of  $\text{K}^+$ . It was observed that an increased amount of Mg increases the number of ostracods in the fall mixing period (Table 24). The calcite carapaces of ostracods are moulting to larger valves up to nine times (from A-8 instar to sexually matur and fully formed adult A) to reach maturity. The species-specific dependent Mg content of valves is affected by the Mg content or Mg/Ca ratio of the water they lived (Chivas et al., 1986). Viehberg (2006) detected that water temperature, Ca and Mg (and lake area) were the most significant variables for variation in the distribution of ostracod assemblages. Furthermore, in a recent study on inland-water habitats, the authors recognized that inhabiting different habitat types did not make a clear difference on ostracod assemblages which was related to a raised water level in the spring time (Iglikowska and Namiotko 2012). In the same study, they found the main factors that limited the distribution of ostracods were low ionic content of water in addition to low pH. However, in present study, although the total ionic content in fall mixing time was lower than spring turnover time, the abundancy of ostracods (in numbers both species and individuals) was higher. The difference in terms of ionic content between two periods was the difference in the amount of Mg (Table 24 and Appendix 4). As argued above, when the air temperature was higher the amount of Ca and  $\text{HCO}_3$  lower and the amount of Mg almost double or vice versa (Figure 47 and Table 24). As a result, it seems that Mg content of host water is a significant limiting factor on ostracod assemblages. It may be that indigent to Mg (species-specific) to moult their valves to skip stages (A-

8 to A) until reaching maturity, they disappear in the spring time. The species whose moulting periods are long (there is more time between nine moulting stage due to their life as long as a year; e.g *Ps. kraepelini*) can evade the time with relatively lower Mg content like spring turnover (Tables 23 and 24). Indeed, an entirely calcsified carapace occurs at stage A-7 (Kubanç et al., 2007), so they will be able to develop their valves owing to enough time.

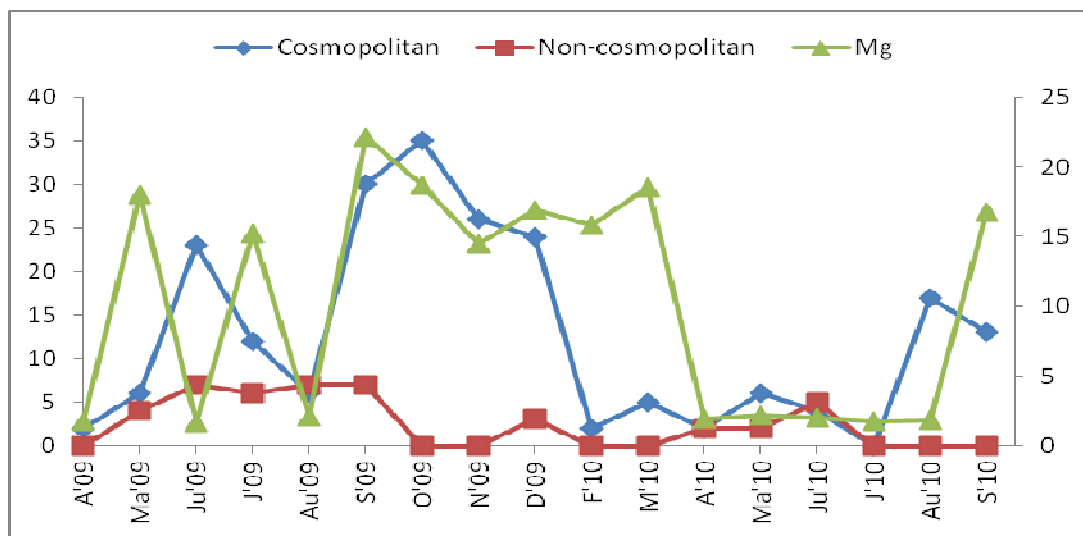


**Figure 47.** The general changes in numbers of non/cosmopolitan species and Mg

In case of Iglíkowska and Namiotko (2012), even though the homogeneity of ostracods is associated with the high water level which caused the connection between different habitats, this probability seems weak for the present study due to absence of a connecting water body around. But perhaps, at least some water can reach the lake by snow melting (Çimşir Creek can be responsible for it) and can cause heterogeneity. The reason for disappearance of some species after a certain time (*P. eremita*, *P. semicognita*, *F. brevicornis* and *Pr. zenkeri*; Table 25) may be due to this relationship. Especially *Pr. zenkeri* is a good example to this situation; namely, it was captured one time in late March 2009, when the lake depth was 7 m (above average; Appendix 3) and never appeared after that time (Table 25).

**Table 24.** The ion contents of Lake Çubuk based on mixing times.

| Date        | Hardness     | Ca            | Mg           | HCO <sub>3</sub> | Na           | K            | T <sup>0</sup> C(a) | Turnover |
|-------------|--------------|---------------|--------------|------------------|--------------|--------------|---------------------|----------|
| 28.03.2009  | na           | na            | na           | 242              | na           | na           | 2,20                | spring   |
| 25.04.2009  | 20,96        | 81            | 2            | 203              | 46           | 12           | 16,40               |          |
| 20.03.2010  | 19,65        | 757           | 19           | 237              | 28           | 1            | 12,5                |          |
| 17.04.2010  | 18,94        | 72,62         | 1,93         | 220,97           | 3,02         | 1,02         | 20,6                |          |
| <b>Mean</b> | <b>19,85</b> | <b>303,66</b> | <b>7,40</b>  | <b>225,76</b>    | <b>25,47</b> | <b>4,63</b>  | <b>12,93</b>        |          |
| 26.09.2009  | 11,3         | 416           | 22           | 129              | 37           | 16           | 15,10               | fall     |
| 24.10.2009  | 11,04        | 411           | 19           | 125              | 34           | 10           | 22,3                |          |
| 21.11.2009  | 10,98        | 42            | 14           | 130              | 6            | 12           | 11,2                |          |
| 18.09.2010  | 15,42        | 34,06         | 16,76        | 122,63           | 22,85        | 3,71         | 26,6                |          |
| <b>Mean</b> | <b>12,18</b> | <b>225,71</b> | <b>18,04</b> | <b>126,72</b>    | <b>24,82</b> | <b>10,33</b> | <b>18,80</b>        |          |

Four species of swimmers except *T. serrata* are well cosmopolitan. All of these swimming cosmopolitans could be found at mixing periods, while we could neither detect nor observe an increase in the number of *T. serrata*. Even though it is a swimmer, its absence at mixing time may be due to the relatively high degree of changes in the environmental and hydrochemical composition of the lake water in the turnover periods. The number of cosmopolitan species were 427 (80% of total species number), 358 of which (67% of total number of all species, 84% of cosmopolitans) belonged to swimmers (*Cy. ophtalmica*, *Ps. kraepelini*, *Cs. vidua* and *I. gibba*). During the sampling time (25 months) , except for July 2010, there is no month that did not see at least one cosmopolitan. Interestingly, in July 2010, we could detect neither cosmopolitan nor non-cosmopolitan, whereas for a total number of nine months, non-cosmopolitan species could not be determined. Especially the last three months there was no non-cosmopolitan inside the samples.

**Table 25.** The composition of the cosmopolitan and non-cosmopolitan species depending on the turnover periods in terms of temperature degrees of water and air.

|       | Cosmopolitan |    |    |     |    |    |    |    |       | Non-cosmopolitan |    |    |    |    |    |    |    |    |       | T°C  |      |      |      |      |
|-------|--------------|----|----|-----|----|----|----|----|-------|------------------|----|----|----|----|----|----|----|----|-------|------|------|------|------|------|
| Date  | Cc           | Cn | Co | Pk  | Ig | Pz | Cv | Li | Total | Cw               | Cs | Pa | Pe | Ps | Pm | Fb | Fj | Ts | Total | w    | a    |      |      |      |
| J'08  | 2            |    | 3  |     |    |    |    |    | 5     |                  |    |    |    |    |    |    |    | 5  |       | 5    | 22,2 | na   |      |      |
| Au'08 | 1            | 6  | 7  |     |    |    | 5  | 6  | 25    |                  |    |    |    |    |    |    |    | 3  |       | 3    | 23,9 | na   |      |      |
| S'08  | 2            | 9  | 27 |     |    |    | 8  | 6  | 52    |                  |    |    |    | 3  | 3  |    |    | 11 | 17    | 19,0 | 20,6 |      |      |      |
| O'08  | 3            | 5  | 4  |     |    |    |    |    |       | 12               | 4  | 4  |    |    |    |    | 9  |    | 17    | 15,2 | 21,0 |      |      |      |
| N'08  | 3            | 2  | 18 | 13  | 34 | 4  |    | 2  | 76    |                  |    | 2  |    |    |    |    | 2  |    | 4     | 8,7  | 11,3 |      |      |      |
| D'08  | 2            |    |    | 23  | 1  |    |    |    |       |                  | 26 | 14 |    |    |    |    |    |    | 2     | 16   | 6,0  | 9,3  |      |      |
| M'09  | 2            |    |    |     |    | 3  |    |    | 5     |                  |    |    |    |    |    |    |    |    | 0     | 7,1  | 2,2  |      |      |      |
| A'09  |              |    |    | 2   |    |    |    |    |       | 2                |    |    |    |    |    |    |    |    |       | 0    | 12,1 | 16,4 |      |      |
| Ma'09 | 1            |    | 5  |     |    |    |    |    | 6     | 2                |    |    |    |    | 2  |    |    |    | 4     | 17,9 | 22,0 |      |      |      |
| Ju'09 |              |    |    | 19  |    |    |    | 4  | 23    |                  |    | 3  | 2  |    |    |    |    |    | 2     | 7    | 22,1 | 23,8 |      |      |
| J'09  |              |    |    | 9   |    |    |    | 3  | 12    | 2                |    |    |    |    |    |    |    |    | 4     | 6    | 22,2 | 25,1 |      |      |
| Au'09 |              |    |    | 3   |    |    | 3  |    | 6     |                  |    |    |    |    |    |    |    | 7  |       | 7    | 21,2 | 19,6 |      |      |
| S'09  | 5            |    | 7  | 13  |    |    |    | 1  | 4     | 30               |    |    |    |    | 2  | 1  |    |    | 4     | 7    | 17,5 | 15,1 |      |      |
| O'09  |              |    |    | 3   | 24 | 6  | 2  |    |       | 35               |    |    |    |    |    |    |    |    |       |      |      | 0    | 16,6 | 22,3 |
| N'09  | 1            |    | 8  |     |    | 3  | 14 |    |       | 26               |    |    |    |    |    |    |    |    |       |      |      | 0    | 9,4  | 11,2 |
| D'09  | 2            | 1  |    | 20  |    |    |    | 1  | 24    | 2                | 1  |    |    |    |    |    |    |    |       |      | 3    | 4,8  | 4,1  |      |
| F'10  |              |    |    | 2   |    |    |    |    |       | 2                |    |    |    |    |    |    |    |    |       |      |      | 0    | 7,2  | 14,6 |
| M'10  |              |    |    | 5   |    |    |    |    |       | 5                |    |    |    |    |    |    |    |    |       |      |      | 0    | 8,5  | 12,5 |
| A'10  |              |    |    | 2   |    |    |    |    |       | 2                | 2  |    |    |    |    |    |    |    |       |      |      | 2    | 13,6 | 20,6 |
| Ma'10 |              |    |    | 6   |    |    |    |    |       | 6                | 2  |    |    |    |    |    |    |    |       |      | 2    | 15,6 | 17,2 |      |
| Ju'10 |              |    |    | 4   |    |    |    |    |       | 4                | 5  |    |    |    |    |    |    |    |       |      |      | 5    | 21,2 | 24,8 |
| J'10  |              |    |    |     |    |    |    |    | 0     |                  |    |    |    |    |    |    |    |    |       |      | 0    | 23,6 | 22,1 |      |
| Au'10 | 2            |    | 4  | 9   |    |    |    | 1  | 1     | 17               |    |    |    |    |    |    |    |    |       |      |      | 0    | 23,2 | 24,1 |
| S'10  |              |    |    | 8   |    |    | 3  |    |       | 2                | 13 |    |    |    |    |    |    |    |       |      |      | 0    | 19,9 | 26,6 |
| O'10  | 2            | 3  |    | 5   | 2  | 1  |    |    | 13    | 1                |    |    |    |    |    |    |    |    |       | 1    | 13,0 | 12,4 |      |      |
| Total | 9            | 19 | 94 | 185 | 45 | 3  | 34 | 38 | 427   | 6                | 8  | 30 | 5  | 4  | 4  | 2  | 43 | 4  | 106   | 15,7 | 17,3 |      |      |      |

Of course, the abundancy or frequency of the species affected from the limnoecological structure of the lake water is also depending on reproduction times and generation numbers. Lake Çubuk is a dimictic, mesotrophic and moderately soft quality water lake. As can be seen in Table 25 and already mentioned above, the mixing type (being dimictic) affects the species composition. Accordingly, the trophic analysis stated that the productivity of the lake is rising up. Carlson Trophic State Index (CTSI) predicts that the journey of the water biomass compound is

becoming mesotrophic which was supported by the linear estimation (Figure 39). In the same way but more radically, Burns Trophic Level Index (BTLI) evaluated the lake as eutrophic (Figure 42). Whether non-cosmopolitans or swimmers, the presence of the species is decreasing year by year. The eutrophication level of the water body has been influencing the species diversity and composition. The species diversity decreased to 10 from 17 in 2010 due to all the impacts on the lake water health.

According to Piper plot, the hydrochemical views of the lake were indicated as Ca-Mg-HCO<sub>3</sub> (March, May, July, August, September, October, December in 2009; February, March, April, May, June, July and August in 2010), and Na-Ca-HCO<sub>3</sub> (April, July and November in 2009; September in 2010) water types (Figure 16). For two months in 2010 (May and August) the water type seems to be of Na-HCO<sub>3</sub> water type. The trend of the sample chemistry from calciummagnesiumbicarbonate-dominated water to sodiumcalciumbicarbonate-dominated water type in the Piper plot suggests an evolution of water from calcium-dominance to sodium-dominance due to cation exchange. The results of hardness degree are changing from soft water quality to moderately hard water degrees. When Piper diagram was plotted the water type of Lake Çubuk as Na-Ca-HCO<sub>3</sub>-dominance, the average hardness degree of water was soft (14.1 Fr°). The indication of Na-HCO<sub>3</sub> water type (May and August in 2010) with mean degree was 12.9 Fr° which means more softly than the others. With the highest average level (14.26 Fr°) Ca-Mg-HCO<sub>3</sub> (March, May, July, August, September, October, December in 2009; February, March, April, May, June, July and August in 2010) water type is of the moderately hard type. In general, average of the lake water shows a soft character with degree of 14.07 Fr° which is close to the maximum range of French Classification for soft hardness (Appendix 4).

Accordingly, the unsuitable balance between ions caused changes in hardness degree. The results of Piper Plot were supported by hardness data.

Figure 17 displays the sampling time has a size that changes in direct proportion with own specific TDS values. Accordingly, the lake conserved its general composition during three months (March, June and July in both 2009 and 2010) in two years, while several changes of usual variances occurred on the at the other sampling times. This position predicates the evaluation of water chemistry as conclusion of hardness (Appendix 4) and trophic level indices (Figure 44, Table 22 and Appendix 6).

PCA was used to reduce alkaline earth (Ca and Mg) with respect to alkalis (Na and K) and relevance of weak and strong acids to each other. According to extracted three component PCs without varimax rotation, 91% (EC in PC2, 0.91) of lake water samples showed an accretion of strong acid with respect to weak acid, while with Kaiser normalization it showed a weak acid point (EC in PC1, -0.12; Table 16). In rotate matrix actually there is two main groups which are separated unrelated to their charge. First group is negative electrical conductivity (EC) and the second group is negative and positive charged ions. All ionic content of the lake is in the same group independently of their charge.

When Secchi depth becomes deeper, the water absorbs greater of solar radiation. Then, algae, the major influence on water clarity, can do high absorption degree of which changes depending on their size or biomass (Mazumder et al., 1990). Fish predation and the resulting size biomass of plankton can influence thermal structure of small lakes by changing water clarity. Fish predation can also effect the heat content of lake. So, water clarity can be a result of biomass and size of plankton. Epilimnion depth (mixing depth) becomes deeper with increasing water clarity.

A well-known cosmopolitan species *Physocypria kraepelini* was characterized as a nektonic species (Altınsalı and Griffiths 2001a) and reported as a most common species from the lakes of Turkey (Klkylođlu 1998). Yılmaz and Klkylođlu (2006) identified *Ps. kraepelini* as a polythermophilic, mesohalophilic and eurycronal species which has been standed by the present study. *Ps. kraepelini* was clustered in the third group with *C. neglecta* and *F. japonica*. It is the species that have a relatively low tolerance value for pH (0.24) and redox potential (15.32) with *I. gibba* (Table 10). Also, its optima value for pH and electrical conductivity are very low, while its tolerance value for electrical conductivity was the highest, that was settled closed to EC in CCA diagram (Figure 13). Klkylođlu (2005c) stated mean pH values ranging from 6.73 to 8.97, dissolved oxygen from 6.37 mg/L to 11.79 mg/L and temperature of water from 9.78°C to 27.91°C for *Ps. kraepelini*, while these variables for *Ps. kraepelini* were reported as follows: pH 7.74 to 8.25, dissolved oxygen 4.10 mg/L to 6.45 mg/L and water temperature 21.70°C to 24.70°C by Klkylođlu and Sarı (2012). *Physocypria kraepelini* was the most frequently occurring species with an eurychronal distribution in all the stations. Earlier studies indicated similar patterns of seasonality. For example, in a manmade shallow water reservoir, Lake Aladađ (Turkey) Yılmaz and Klkylođlu (2006) found this species almost ten consecutive months from January to November while its overlapping occurrence was detected in other lakes (Şamlar and Yeniađa lakes) of Turkey from March to November (Klkylođlu 1998; Klkylođlu et al. 2007, respectively).

*Ps. kraepelini* is known with high tolerance to different environmental variables (Klkylođlu 2005c) including eutrophic conditions (Shornikov and Trebukhova 2001; Klkylođlu et al. 2007; Yu et al. 2007, 2008). In the present study, the total number of individuals increased in 2008 and 2009 and decreased in 2009 and 2010

(53, 89, 43 included spring results, respectively), while the mean frequencies (number of finding /number of sampling) of each year changed to 1.00 (6 findings in 6 samplings), 0.70 (7 findings in 10 samplings) and 0.77 (7 findings in 9 samplings), respectively (Appendix 1).

When the trophic state of the lake changed from slightly oligotrophic to slightly mesotrophic according to CTSI and strongly mesotrophic to eutrophic according to BTLI, it is clear from Figure 48 that it prefers oligo-mesotrophic conditions. It should be noted that in April and May 2010, when the trophic conditions were at the most severe level according to CTSI, just *Ps. kraepelini* was the captured in both months with a low number of individuals as 5 and 2 respectively. In May of the same year, *P. albicans* was also captured with 2 individuals (Appendix 3). Besides, in December 2009, when the wind stress was much stronger on mixing than thermal classification (actually, no thermal stratification (Figure 25) and wind was the most strongest impact level of the study on mixing according to Wedderburn number which was 10.93, stability and buoyancy very low and stratification index 0.02 (Table 23). *Ps. kraepelini* was the most abundant species (20 individuals) found from the lake among the five other species (*C. candida*, *C. weltneri*, *C. sanociensis*, *Cy. ophtalmica*, and *L. inopinata*).

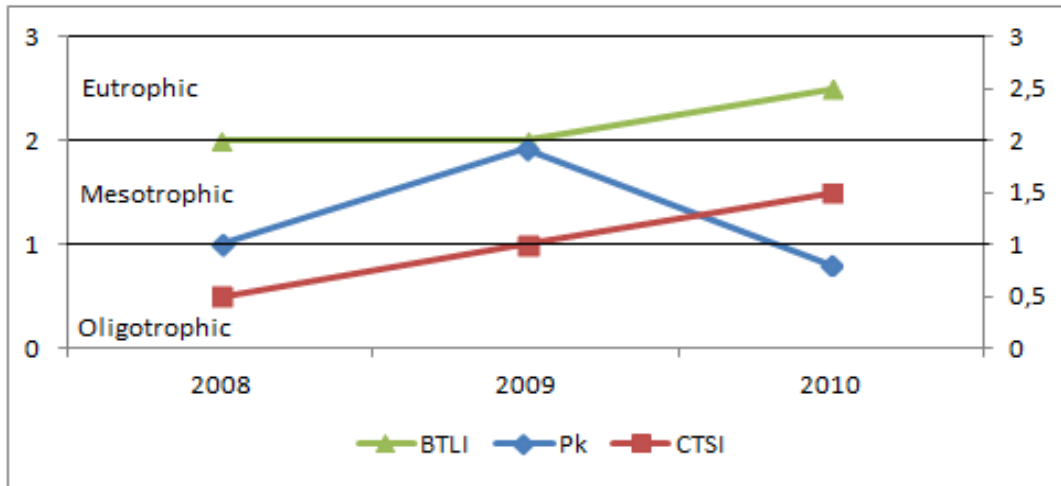


**Figure 48.** The changing of the abundancy (frequency) of *Physocypria kraepelini* due to trophic conditions.

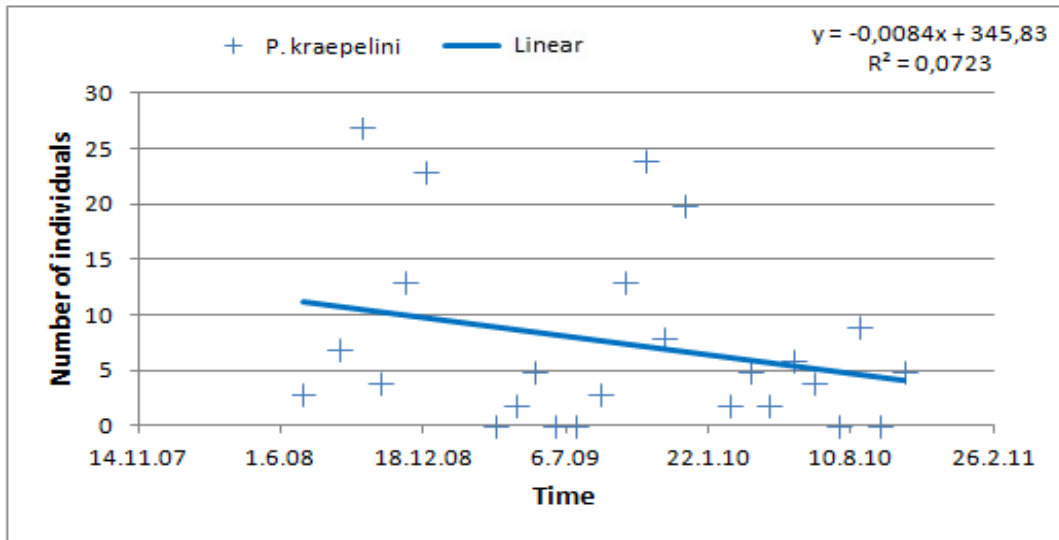


**Figure 49.** Overall situation of *Physocypria kraepelini*

The linear forecast of *Ps. kraepelini* showed the ongoing position of the species related to the level of productivity with the other environmental variables. Even though the species was found throughout the year, it was decreasing in numbers. So, the future of this species in Lake Çubuk seems to be uncertain.

According to experimental studies by Yu et al. (2009), *Ps. kraepelini* showed high tolerance ranges to ammonia, phosphate and pH values. It prefers littoral to pelagic zones of the lakes, ponds and reservoir (Külköylüoğlu 1998; Kiss 2002) but

it was only found in the pelagic zone of Lake Sünnet (Turkey), where the species showed higher tolerance level to water temperature ( $tk = 4.53^{\circ}\text{C}$ ) with relatively high optimum value for dissolved oxygen ( $7.20 \text{ mg L}^{-1}$ ) (Külköylüoğlu et al. 2010). Meisch (2000) assigned the species as meso-to polytitanophilic due to its tolerance to calcium levels in waters 266 ( $>72 \text{ mg Ca L}^{-1}$ ). Külköylüoğlu and Yılmaz (2006) reported the species in rheocene and helocene springs in a negative correlation with water temperature. In Italian water bodies (Rossetti et al. 2004) and a landslide lake (Lake Sünnet) in Turkey the species was collected with rich ionic content related to higher trophic conditions. In River Odra, Poland, this swimming species was one of the most common forms in flooding zone (Szlauer-Łukaszewska 2008). In the present study, the species was located on the right side of the CCA diagram nearby electrical conductivity, thus suggesting a close relationship (Figure 13). Indeed, the species showed highest tolerance value to electrical conductivity ( $tk = 45.28$ ) among the other most common species (Table 10). Thus, studies suggest that *Ps. kraepelini* has a wide range of geographical distribution and high ecological tolerances to different variables, supporting its cosmopolitan characteristics.

*Limnocythere inopinata* is another crawling species that was found from the stations 1, 2 and 5 when water level was below 6 m. This species was absent in the flooding zone. This is probably that this species is bottom-dependent and during flood it may not have enough time to migrate to the flooding zone. Supporting evidence comes from a study on a landslide lake (Lake Sünnet, Turkey) by Külköylüoğlu et al. (2010) who reported the species when water level was the lowest between 7.75-8.75 m. In contrast, *L. inopinata* was absent above a depth of nine meters. During the present study, the species was collected from late August to December but was absent in the rest of the season. A similar conclusion was also

drawn for Lake Sünnet from June to December (Külköylüoğlu et al. 2010) but the species was only reported in July from a man-made lake (Lake Aladağ) with relatively high water temperature (24.06 °C) (Yılmaz and Külköylüoğlu 2006). According to Cohen et al. (1983), *L. inopinata* can be used as an indicator of moderate to high salinity and alkalinity values. Supporting evidence for this view comes from previous studies which showed that it was accompanied by *Leucocythere mirabilis* (in one station together) in water bodies with a wide range of salinity (0.10 to 17.60) in eastern Turkey (Külköylüoğlu et al., 2012a). The study in question the range of altitude for *L. inopinata* was 1851 to 1950 m.

Unlike the studies above, the species - except water temperature- did not show high levels of tolerance and optimum values. Considering tolerance and optimum levels of the species (Table 10), however, overall results support the idea that *L. inopinata* with a widespread geographical distribution and tolerating relatively against wide ranges of environmental variables can be called cosmoeccious species (Külköylüoğlu in press).

*Limnocythere inopinata* was common in streams, lakes and reservoirs with eutrophic conditions (Scharf 1993; Kılıç 2001; Mezquita et al. 2001; Külköylüoğlu and Dügel 2004). In the present study, the total number of individuals were increasing in 2008 and 2009 and decreasing sharply in 2009 and 2010 (14, 21, 3, respectively), while the mean frequencies (number of finding /number of sampling) of each year changed to 0.50 (3 findings in 6 samplings), 0.40 (4 findings in 10 samplings) and 0.22 (2 findings in 9 samplings), respectively (Appendix 1). When the trophic state of lake was changing from slightly oligotrophic to slightly mesotrophic according to CTSI and strongly mesotrophic to eutrophic according to BTLI, it is clear from the Figure 50 that it is running to the oligotrophic conditions.

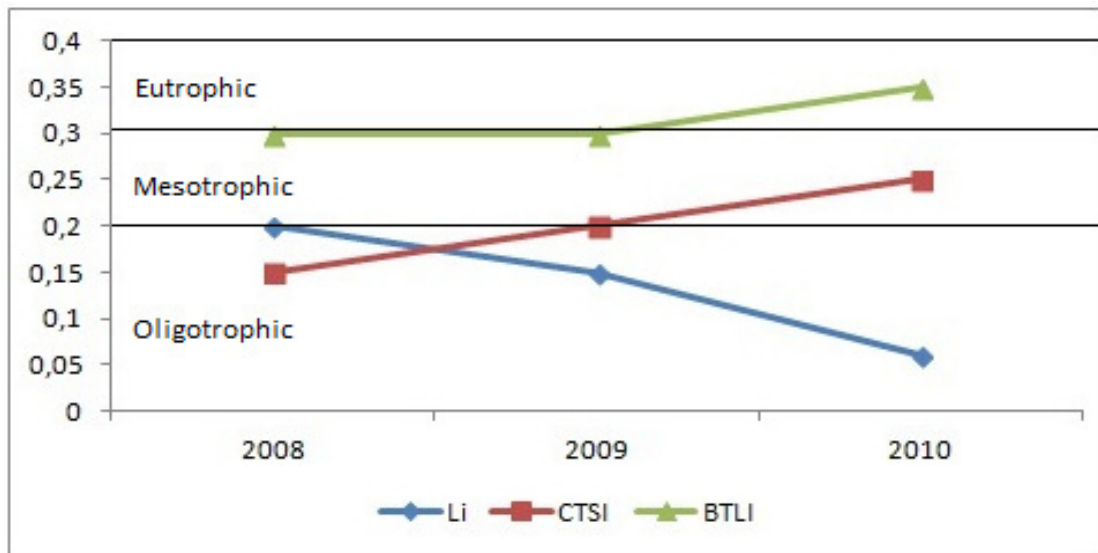


**Figure 50.** The changing of the abundancy (frequence) of *Limnocythere inopinata* due to trophic conditions.

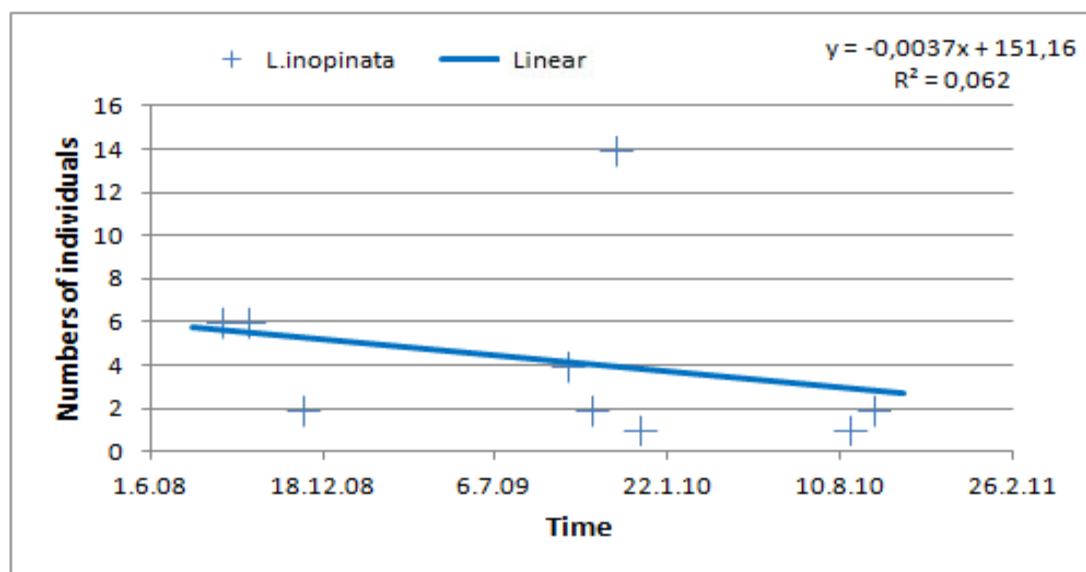


**Figure 51.** Overall situation of *Limnocythere inopinata*

The linear forecast of *Limnocythere inopinata* has been shown the ongoing position of the species related to the level of productivity with other environmental variables. Both the frequence and the number of the individuals are decreasing year by year.

The analysis of mixing time and stability showed that between August and June for each year the stability of the lake was the highest, which corresponded to the occurrence of *L. inopinata* (Figure 31; Appendix 2). It means at mixing time, lack of its swimming setae on second antenna (bottom-dependent) can cause to be dispersed and turn-over of the water obstructs to hold on it to the water column.

*C. neglecta* can be called as cold-stenotherm and oligothermophilic (Roca and Baltanás 1993). Mischke (2001) pinpointed that *C. neglecta* is known from Holarctic regions with a wide tolerance to cold and organically rich habitats. The adults of this crawling species were found from April to November (Appendix 2), while juveniles were rarely observed almost from May to November. Such occurrence patterns are consistent with some earlier studies. For example, in Germany, Hiller (1972) observed adults from the littoral zones of the lakes between May and October but its abundance was highest in November and December. Similarly, in Turkey, Dügel et al. (2008) reported adults of *C. neglecta* from a natural lake (Lake Abant) between April and November. In a polymictic and highly eutrophic lake (Lake Yeniçağa, Turkey), Külköylüoğlu et al. (2007) showed that the species was common in the littoral zone from May to December. Külköylüoğlu (2005) also reported the species from the end of February to November in a dam lake (Lake Gököy, Turkey). Similar occurrence was also reported from a small reservoir (Lake Gölcük) where the species was common from April to December (Külköylüoğlu and Dügel 2004). The occurrence of *C. neglecta*, however, is not limited to lake habitats that it has been reported from other types 290 of aquatic bodies too. Thus, overall findings suggest that *C. neglecta* has almost euychronal occurrence in several different habitats. Meisch (2000) underlined that reproduction and larval development of *C. neglecta* are mainly affected by fluctuations in environmental conditions. According to

Külcöylüoğlu (in press), *C. neglecta* was categorized as a cosmoecious species due to its cosmopolitan distribution and high levels of tolerances to different environmental variables. *Candona neglecta* was found from a newly developing spring water with low levels of oxygen about 0.32 mg/L (Külcöylüoğlu 2009). Previously, it was also reported within a wide temperature ranges from 2.2 to ca. 28 °C (Külcöylüoğlu 2005c). Besides, the species was the last one disappearing from eutrophication in Lake Mondsee, Australia (Danielopol et al. 1993), indicating its high tolerances to increasing pollution levels in the lake. Külcöylüoğlu and Yılmaz (2006) found a strong negative correlation between the species and water temperature along with highest tolerance to water temperature ( $tk = 3.8$  °C) and optimum estimates for dissolved oxygen ( $uk = 9.08$  mg L<sup>-1</sup>304 ) in a cold helocrene spring. Most recent studies from Germany (Viehberg 2005), Iberian Peninsula (Mezquita et al. 2005), and Turkey (Yavuzatmaca et al. 2012) revealed similar results about high tolerance levels of species in relatively wide ranges of environmental variables. In this study, the placement of the species in CCA diagram indicated that it has a positive significant correlation especially with water temperature (Figure 13). Supporting studies also come from optima and tolerance levels of the species (Table 4). Moreover, Karakaş-Sarı and Külcöylüoğlu (2008) reported the species from pH 6.9 and Külcöylüoğlu (2005c) found species from pH 6.73. It is also counted that *C. neglecta* has higher dissolved oxygen tolerance ranges (Külcöylüoğlu 2003c). Meisch (2000) suggested that the species could even survive under hypoxic conditions with oxygen levels below (3 mg/L). In present study, the optima and tolerance levels of *C. neglecta* for dissolved oxygen were as 6.53 mg/L and 2.16 mg/L and turbidity as 4.15 and 2.68 (Table 10). Correspondence analysis shows a negative significant correlation between *C. neglecta* and the two

environmental variables of redox potential and electrical conductivity, while its occurrence positively related to turbidity and water temperature (Figure 13). Although, Spearman analysis (Table 9) does not show any positive significant correlation between *C. neglecta* and environmental variables, while the only positive correlation was with *C. sanociensis* (Table 10). Such a result also suggests that the species may be considered as stenochronal and oligothermophilic species. Our results approved that *C. neglecta* preferring lentic habitats can also be found in almost all different water bodies in a wide geographical range.

In the present study, the total number of individuals increased in 2008 and 2009 and decreased sharply in 2009 and 2010 (10, 7, 2, respectively), while the mean frequencies (number of finding /number of sampling) of each year were changing as 0.83 (5 findings in 6 samplings), 0.30 (3 findings in 10 samplings) and 0.11 (1 findings in 9 samplings), respectively (Appendix 1). When the trophic state of lake was changing from slightly oligotrophic to slightly mesotrophic according to CTSI and strongly mesotrophic to eutrophic according to BTLI, it is clear from the Figure 52 that it prefers meso-oligotrophic conditions.

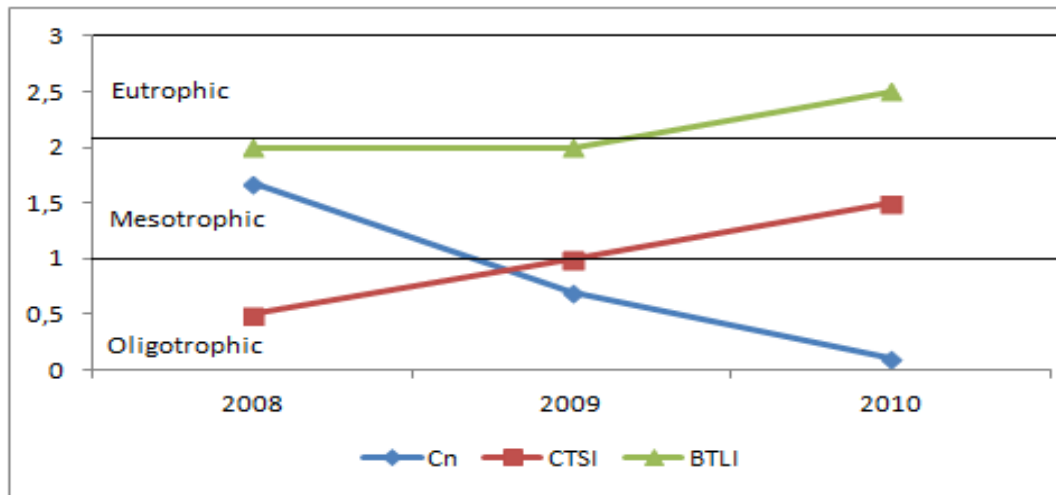


**Figure 52.** The changing of the abundancy (frequence) of *Candona neglecta* due to trophic conditions.

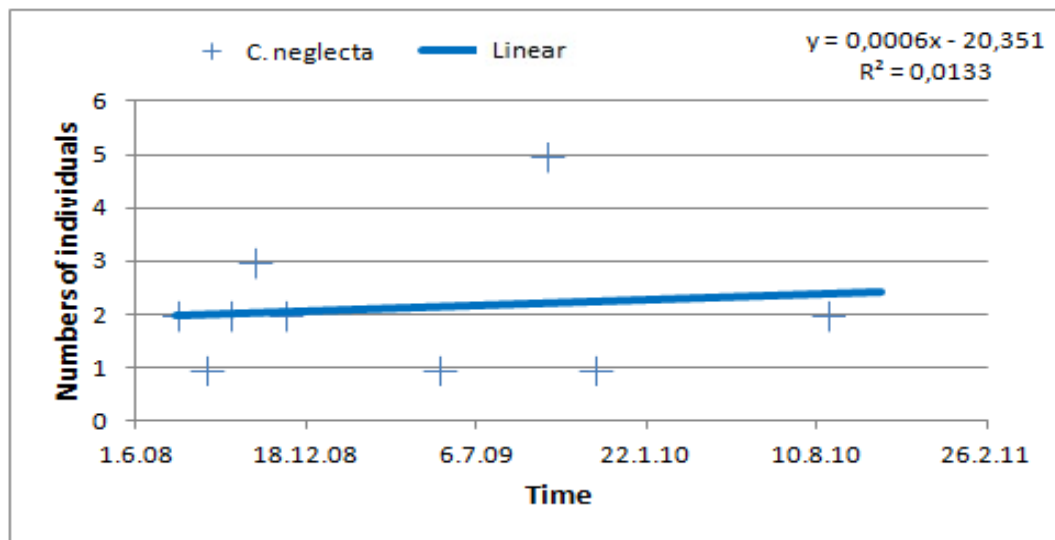


**Figure 53.** Overall situation of *Candona neglecta*

The linear forecast of *Candona neglecta* has been shown the ongoing position of the species related to the level of productivity with other environmental variables. Even though, both the frequency and the number of the individuals were decreasing year by the year, the linear estimation is moving with an upward angle.

As we seen on *L. inopinata* case, the occurrence time period of this species coincides with the most stable time of the lake water column. (Figure 31; Appendix 2). It means at mixing time, lack of its swimming setae on second antenna (bottom-

dependent) can cause to be dispersed and turn-over of the water obstructs to hold on it to the water column.

The juvenils of *C. neglecta* was usually found a time period between May to August, while the subfossil forms of this species was seen all around the year.

One of the most common species of present study *Cypria ophtalmica* was captured from late June to December in Lake Çubuk. *Cypria ophtalmica* which described as cosmopolitan by Kùlköylüoğlu (2003c) was found from all of the stations include spring and bottom with 94 inidividuals. This well swimmer species comes to the fore with its presence at fall mixing time (fall mixing type species) (Appendix 6). These species appeared to show tolerances to the changes in environmental variables during this study. The optima levels to turbidity (3.92) and water temperature were relatively high (16.64 °C) (Table 10), while ETI value for water temperature was already high, but low for turbidity (Table 11). 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. Even though, this species was shown high optima (*uk*: 57.37) level for saturation in present study (Table 10), ETI value for saturation (0.08) was very lower than the others (Table 11). The single positive correlation of these species according to Spearman Correlation was to *C. candida*, while it does not show any significant correlation to any environmental variables (Table 9). Moreover, Keyser and Nagorskaya (1998) suggested that the species used to thrive in eutrophic conditions, when Rossetti et al. (2005) found it from a spring where could be characterized by high ionic content and rich chloride (13 g l<sup>-1</sup>). Species was found all around the year with different range of water conductivity 183 to 255 µS cm<sup>-1</sup>. Kùlköylüoğlu and Sarı (2012) found that the oxygen saturation related to dissolved oxygen species as 16 and 92.2%, respectively .

When Karakaş-Sarı (2006) found the species abundantly in a rheocene spring where the high contamination of lime dust was observed on the aquatic plants, Rossetti et al. (2005) commonly collected *Cy. ophtalmica* from the springs with high degree of eutrophication. *Cy. ophtalmica* was located closer to the center of CCA diagram by close to *Cs. vidua* (Figure CCA). CCA diagram displays that the species positively related to turbidity, while it shows a negative relationship with redox potential and electrical conductivity. Meisch (2000) underlined its occurrence in all different types of waters throughout the year when it shows remarkable tolerance to wide ranges of environmental variables. In northern Italy, the species was among the most frequently occurring species from variety of water bodies (Rossetti et al. 2006) in the samples from May to December. During the present study, we found *Cy. ophtalmica* from late April to the end of October in Lake Çubuk, similar to another lake (Lake Abant) in Turkey (see Dügel et al. 2008). On the other hand, the species was collected in a highly eutrophic lake (Lake Yeniçağa) from April to October, except that of June and September months (Külköylüoğlu et al. 2007). On the other hand, one of the most recent studies in the some Portuguese ponds revealed that *Cy. ophtalmica* was also common from December to April and it was among the common species after inundation (Martins et al. 2010). This supports the idea that *Cy. ophtalmica* does not have a limited seasonal occurrence which may also be depend on suitability of habitats. In the present study, this species showed almost all highest tolerance and optimum values for five environmental variables among the most frequently occurring species dealt here. For example, we found a negative correlation between *Cy. ophtalmica* and electrical conductivity of lake water which is also supported by CCA diagram where the species was located on the left upper corner against to the arrow of electrical conductivity (Fig. 4). This finding also

corresponds with the earlier results (Delorme 1991; Bellavere et al. 1999; Klkylođlu 2000, 2004) who reported this species in a wide ranges of variables such as temperature (3.5–33.0 °C), dissolved oxygen (0.00–20.00 mg/L) (Delorme 1991), and conductivities (87–5260  $\mu\text{S cm}^{-1}$ ) and pH (5.0–13.0). Comparing to other species (e.g., *Cs. vidua*), the altitudinal range of the species is however seemed to be narrower from 36 m (Rossetti et al. 2005) to 1347 m a.s.l. (Klkylođlu 2004). Overall, results suggest that *Cy. ophtalmica* has a wide range of tolerances to different environmental variables along with wide geographical distribution, implying its cosmoecious characters. According to our findings, several species do have different seasonal occurrences and ecological tolerances to different environmental variables. Although it is argued that cosmopolitanism is not common in nonmarine ostracods (Martens et al. 2008), results suggest that several species discussed above do have much wider geographical distribution and can tolerate higher levels of different environmental variables than known before.

In present study, the total number of individuals are increasing in year by the year from 2008 to 2010 (40, 39, 15, respectively), while the mean frequencies (number of finding /number of sampling) of each year were changing as 0.83 (5 findings in 6 samplings), 0.50 (5 findings in 10 samplings) and 0.33 (3 findings in 9 samplings), respectively (Appendix 1). When the trophic state of lake was changing from slightly oligotrophic to slightly mesotrophic according to Carlson Trophic State Index (CTSI) and strongly mesotrophic to eutrophic according to Burns Trophic Level Index (BTLI), it is clear from the Figure 54 that it prefers the trophic range slightly oligotrophic to be maximum strongly oligotrophic conditions.

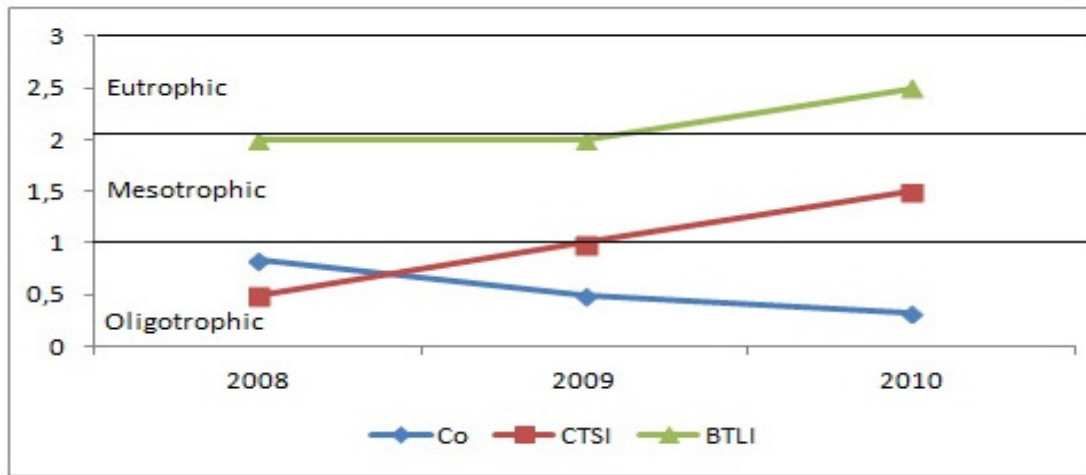


**Figure 54.** The changing of the abundancy (frequence) of *Cypria ophtalmica* due to trophic conditions.

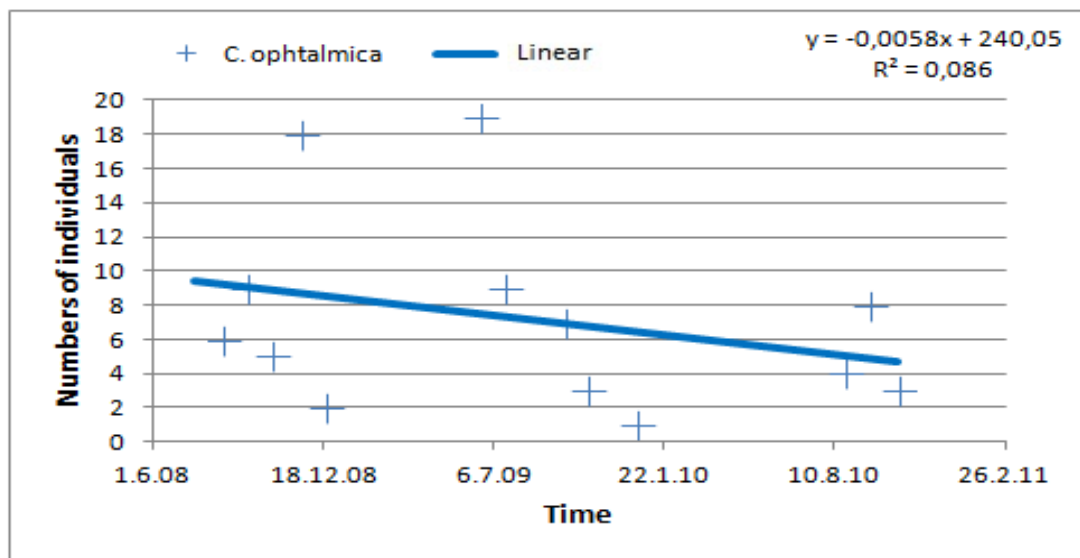


**Figure 55.** The linear position of *Cypria ophtalmica*.

The linear forecast of *Cy. ophtalmica* has been shown the ongoing position of the species related to the eutrophication rate with other environmental variables. Both the frequence and the number of the individuals are decreasing year by the year.

The other common species of this study was *Cyridopsis vidua*. *Cs. vidua* is a well known cosmopolitan species, which can be found in different types fresh to

saline aquatic bodies from sea level to 2175 m of altitude 338 (Saldarriaga and Martínez 2010). Studies of Ganning (1967, 1971) showed that *Cs. vidua* was able to tolerate to low (1 ppt) to high (20 ppt) salinity ranges, referring to mesohalophilic species (Meisch 2000). This was supported with previous studies in Canary and Cape Verde islands with low (37 mS cm<sup>-1</sup>) to very high values of conductivities (7410 mS cm<sup>-1</sup>). It is collected from four stations (L2, L4, L5 and Gölpınar spring) with 34 living forms. According to Spearman correlation analysis, the most high correlation degree was to *I. gibba*, while analysis displayed that the species was not related to environmental variables (Table 9). CCA diagram (Figure 13) located both species on the left of the diagram, indicating possible correlation to water temperature and turbidity. Overall, our results support that *Cs. vidua* can be called a cosmoeccius species. Indeed, its values shown that it could tolerate high levels of environmental variables which confirmed suggestion of Lim and Wong (1986), Kiss (2001) and Külköylüoğlu et al. (2007). They reported the species from different habitats by order of water with high levels of pesticides from ricefield and heavily polluted shallow lakes. Especially, the report of Kiss (2001) emphasized that the species could be occurred in waters with pH level increasing up to 9.09 which confirmed suggestion (8.93) of the present study. Interestingly, Mbahinzireki et al. (1991) submitted that presence of *Cs. vidua* was closely related to the aquatic plant *Chara* because of preferring it as a shelter food source. Moreover, the highest ETI value of *Cs. vidua* was for water temperature (0.93) and the least for salinity (0.14) (Table 11). Indeed, this species showed relatively high tolerance ( $tk = 5.48$  °C) and optimum estimates ( $uk = 18.69$  °C) to water temperature comparing to the mean of other species (Table 10). The optimum and estimated tolerance levels were normal other parameters, but the optima value for redox potential (163.64) was the highest among

13 species. The tolerance value for pH of *Cs. vidua* was very low (0.18). According to Klkylođlu (2003c), tolerance of *Cs. vidua* is not limited to salinity ranges that the species can tolerate different variables. Most recent study done in the waters of Portugal showed that the species survived in low oxygenated waters (Martins et al. 2010). In another current study done in about 150 sampling sites of Bolu region, Turkey, *Cs. vidua* displayed the highest optimum and tolerance values to water temperature (uk = 28.33 °C, tk = 5.96°C), pH (uk = 9.29, tk = 1.21) and altitude (uk = 1378.23m, tk = 478.17 m) as well (Klkylođlu and Sarı 2012). During the study from October 2009 to August 2010 it could not find, after that for three months (end of study) just a few individuals were captured. This species was one of the “fall mixing type species” of this study. Ecological features of *Cs. vidua* were characterized as polythermophilic, mesorheophilic (Hiller 1972), phytophilic (Danielopol and Roca 1991) and oligohalophilic (Meisch 2000).

In present study, the total number of individuals are increasing in year by the year from 2008 to 2010 (18, 11, 5, respectively), while the mean frequencies (number of finding /number of sampling) of each year were changing as 0.66 (4 findings in 6 samplings), 0.40 (4 findings in 10 samplings) and 0.33 (3 findings in 9 samplings), respectively (Appendix 1). When the trophic state of lake was changing from slightly oligotrophic to slightly mesotrophic according to Carlson Trophic State Index (CTSI) and strongly mesotrophic to eutrophic according to Burns Trophic Level Index (BTLI), it is clear from the Figure 56 that it prefers the trophic range oligotrophic to be slightly oligotrophic at the end.

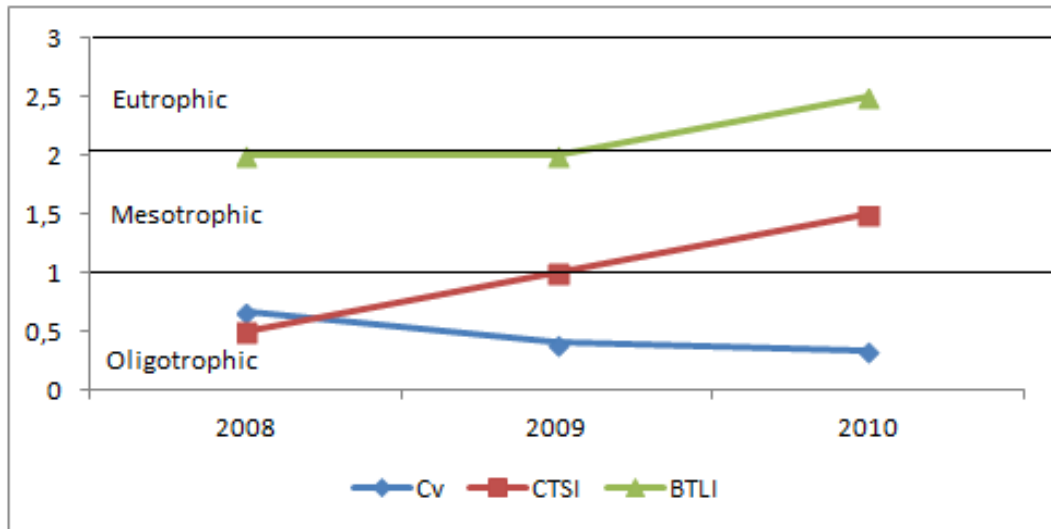


**Figure 56.** The changing of the abundancy (frequence) of *Cypridopsis vidua* due to trophic conditions.

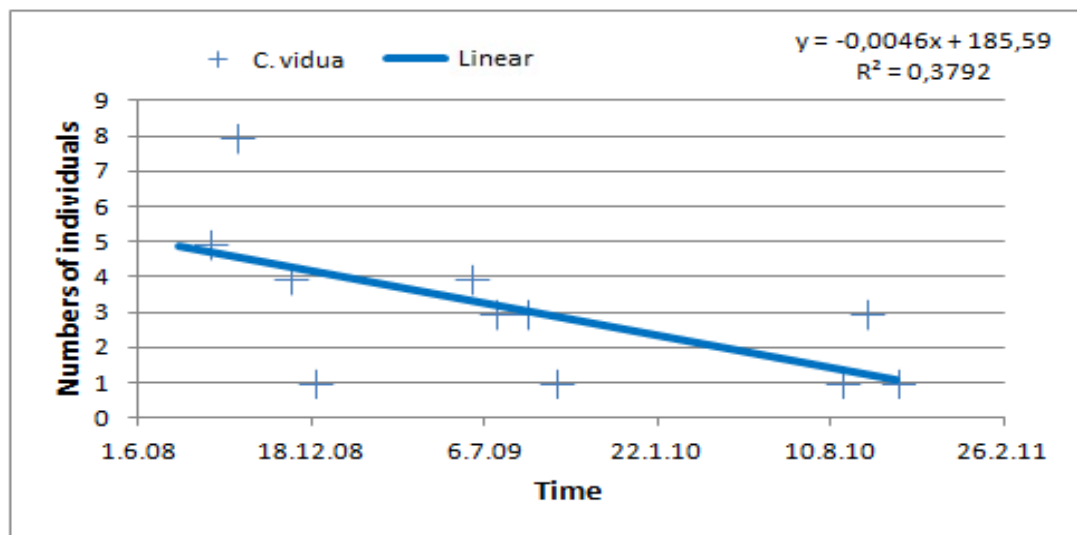


**Figure 57.** The linear position of *Cypridopsis vidua*

The linear forecast of *Cs. vidua* has been shown the ongoing position of the species related to the eutrophication rate with other environmental variables. Both the frequency and the number of the individuals are decreasing year by the year.

*C. candida* was described as oligothermophilic (Hiller 1972), mesohalophilic, stenochronal, cold stenothermal (Yılmaz 2005), euchronal (Keyser and Nagorskaya

1998) and cosmopolitan (Külköylüoğlu 2004). Indeed, the location outside the center of the species in the CCA ordination diagram was referred that *C. candida* had negative correlation especially with water temperature (Figure 13). Moreover, in this study, bisexual populations of species were found from four stations with very low (9) individuals (Appendix 2). Spearman correlation analysis shows that the only significant correlation of *C. candida* was negatively to *Cy. ophtalmica*, while no significance to any environmental parameters (Table 9). Though, (Yılmaz 2005) suggested that *C. candida* was negatively correlated with increasing of water temperature and positively related to high oxygen concentration, the location of the species outside the center of CCA diagram (Figure 4) displayed that *C. candida* was positively related to three environmental variables (pH, Eh, and turbidity) which calculated in this study. ETI values of *C. candida* to environmental variables were relatively high but water temperature (Table 11), while optima and tolerance estimation analysis confirmed that *C. candida* had the highest optima value (*uk* : 174.77) for TDS and redox potential (170.69) (Table 10). Optima and tolerance values (*uk*: 268.57 and *tk*: 68.78) for electrical conductivity were lower in contrast to Külköylüoğlu and Sarı (2012) .The authors submitted these values 422.31 and 121.38, while the tolerance value of the species for dissolved oxygen cited very low in such study. This cosmopolitan and non-swimming species was record four times during sampling and two times were fall mixing period wahile one was at spring turnover time. It has a standard (very low in numbers of both individuals and frequency) (Appendix 2 and Appendix 6).

*I. gibba* (Ig) was collected from all littoral stations with 45 individuals for four times (Appendix 1). Although, Spearman analysis shows that there is not a significant correlation between *I. gibba* and environmental variables, it implies a

relatively high positive relationship with *P. albicans* (Table 9). The location of *I. gibba* on CCA diagram displays that it shows a positive significant correlation for turbidity and redox potential (Figure 13). The highest ETI value of the species was for dissolved oxygen (0.50 °C), while the least one for electrical conductivity (0.17 mg/L) and redox potential (0.17). Optima and tolerance estimation analysis denotes relatively low values, while similar to Klkylođlu (2004) and Klkylođlu and Sarı (2012) the species was collected from water bodies with low oxygen. It was determined as a cosmopolitan (Klkylođlu 2004), mesothermophilic to polythermophilic, rheouryplastic (Hartmann and Hiller 1977) and oligohalophilic (Meisch 2000) species. Interestingly, *I. gibba* only four time was determined that all four of them at fall mixing time (Appendix 6). *I. gibba* which disapeared at the first five sampling of the study was one of the six species found at last sampling with 2 individuals in October 2010. The presence of the species in lake seems to be short (two months) from October to late December. This double-generational (in central and northern Europe; Meisch 2000) species was defined as summer form, but it seems the winter form is also available in western Asia (Turkey, present study). This species was previously recorded between June and August 2006 in the same region (Bolu) (Klkylođlu and Sarı 2012).

*Candona weltneri* was found in three stations (L2, L3, L4) with six individuals in three times. This is its second record for both Turkish and region (Bolu) freshwater ostracod fauna. The first record was in 2006 from a point where had environmental values such as pH 7.96, relatively high redox potential 157.98 mV, low dissolved oxygen 6.67, relatively low electrical conductivity 459.30  $\mu\text{Scm}^{-1}$ , low saturation 68.1% and relatively low water temperature 15.80°C (Sarı and Klkylođlu 2010). Acording to estimated optima and tolerance level, its tolarences

to almost all variables were relatively very low (Table 10). ETI values of this species relatively low but the highest ETI value (0.69) was for temperature of water, while the level to pH (0.08) was the lowest (Table 11). Hiller (1972) determined two intraspecific forms of the species as *C. weltneri* forma *weltneri* and *C. weltneri* forma *obtusa*. The form *obtusa* may be an autumnal form which usually appears in lakes in autumn and vanish in spring, while the form *weltneri* used to appear in winter time usually in ditches (Meisch 2000). However, the species that were found three times in present study appeared two times in May (2009 and 2010) and once in December 2009 (Appendix 2). So, because of its maturity time, the calculated datas and ecological preferences, the forms of this study may be forma *obtusa* for May modes (autumn) and forma *weltneri* for December mode. Meisch (2000) suggested the forma *obtusa* as oligothermophilic (prefering cold waters) and oligorheophilic (occurring in flowing waters), while defining of forma *weltneri* as cold stenothermal, oligorheophilic and oligohalophilic. This non-swimming species did not appear in mixing times (Appendix 6).

*Candona sanociensis* which is the second record for both Turkish and Bolu region freshwater Ostracoda fauna like *C. weltneri*. It was found from littoral 1, 2 and 5 stations with total eight individuals for four times (Appendix 6). Three times it was appeared in cold season (in October two times and in December once) and one time was found in July 2009. In contrast to *C. weltneri* this non-swimming species was found at fall turnover periods (2008 and 2010) (Appendix 6). The ranges of ecological variables were previously defined as pH 7.78-8.10, redox potential 145.28-171.14 mV, dissolved oxygen 4.34-7.95 mg/L, conductivity 326.7-530  $\mu\text{Scm}^{-1}$ , saturation 56.2-85.7% and temperature of water 7.10-27.50°C (Sarı and Külköylüoğlu 2010). The descriptive results was shown in mentioned study that *C.*

*sanociensis* shows wide distribution as a cosmopolitan. It was detected from a small running, muddy and roadside brook at altitude of 1075 m and a stagnant and small temporary pond (Sarı and Külköylüoğlu 2010). The remaining unknown life history of this species need more information which obtained from long-term studies.

*Prionocypris zenkeri* was collected one time from one station with 3 individuals (Appendix 1). It was also previously detected at the same habitat (Lake Çubuk) from two points (one close to L1, while the other near L3 in total 10 individuals) (Sarı and Külköylüoğlu 2010). Even though in this mentioned study, the ETI, optima and tolerance estimation values of *Pr. zenkeri* were calculated relatively low, Karakaş-Sarı and Külköylüoğlu (2008) defined that the species had “super tolerance” ETI levels to environmental variables. In these two studies, Spearman Correlation showed *Pr. zenkeri* strongly related to *I. bradyi* and a significant correlation to two environmental variables; pH and redox potential. Moreover, Sarı and Külköylüoğlu (2008) showed in Spearman analysis that *Pr. zenkeri* was also strongly related to *Ps. olivaceus* and *I. inermis* all and they came up with positive relationship could be arisen their non-swimming and cosmopolitan features.

*Trajancypris serrata* which is second record for freshwater habitats of Bolu region is collected from station L5 with 4 individuals for two times (Appendix 1 and Appendix 6). The first record of these species from the region (Bolu) was at altitude of 1439 (Sarı and Külköylüoğlu 2010). Sywula et al. (1982) collected from Poland the juveniles in springtime and adults in autumn which could be called summer form (Meisch 2000). This statement is accordance with our findings. Namely, two specimens were captured from L5 in late December 2008, while the other two individuals were found in same station in late June 2009 (Appendix 6). Sarı and Külköylüoğlu (2010) found the species from a point where was a muddy and

stagnant water near a slow flowing creek rich in algae and very close to a very busy path. Likewise, it was found in two small creek in northeastern Van region (Turkey) with the range of environmental variables such as dissolved oxygen 4.44 to 5.93 mg/L, electrical conductivity 625 to 656  $\mu\text{S cm}^{-1}$ , water temperature 18.90 to 19.10 °C and pH 8.17 to 8.65 at a maximum altitude 1715 m in July 2009 (Külköylüoğlu et al., 2012a). The same parameters for the species was like pH 9.45, redox potential 53.34 mV, dissolved oxygen 5.60 mg/L, water conductivity 77.1  $\mu\text{S cm}^{-1}$ , oxygen saturation 87.1% and temperature of water 29.1°C in the study previously done in Bolu (Külköylüoğlu and Sarı 2012). Bronshtein (1947) captured the species at altitude of 2350 m. Keyser and Nagorskaya (1998) collected *T. serrata* from the small shallow and muddy ponds where they were shown mesotrophic conditions, while the authors determined it as Palearctic. The higher the level of eutrophication rate in Lake Çubuk, it seems to be that the frequency of this species is decreasing. The presence of this swimming cosmopolitan species could not be detected after June 2009 (Appendix 6).

*Fabaeformiscandona* is a genus of family *Candonidae*. It contains ca 50 recent species (Meisch 2000). So far known three (*F. caudata*, *F. csickii* and *F. fabaeformis*; Altınsağılı and Griffiths 2002) and six (*F. balatonica*, *F. fabaeformis*, *F. breuli*, *F. brevicornis*, *F. protzi* and *F. latens*; Sarı and Külköylüoğlu 2010) in total nine species of *Fabaeformiscandona* from Turkey.

*Fabaeformiscandona brevicornis* (Fb) which is captured from station L2 in numbers two for one time is second report for Turkey and Bolu region. The species finding station in present study was well vegetated, while previously was found in a slow flowing creek in the middle of the forest (well-protected) with high density of *Gammarus sp* (Sarı and Külköylüoğlu 2010). In mentioned study, it was found in

relatively high electrical conductivity ( $605 \mu\text{Scm}^{-1}$ ) and temperature of water ( $22.6^{\circ}\text{C}$ ) conditions. Even though its life history is poorly known, it is reported from both hyporheic habitat of a stream (Nüchterlein 1969) and slow flowing waters (Meisch 2000). Moreover, the ecological characterization of *F. brevicornis* is given as coldstenothermal, mesorheophilic and euryplastic for the substrate by Nüchterlein (1969). Accordingly, the datas of this study relatively confirms the suggestion of the author. It was detected at fall turnover time in November 2008 when the temperature of water was relatively cold ( $8.7^{\circ}\text{C}$ ).

*Fabaeformiscandona japonica* is a new record for Turkish freshwater osracod fauna. It was found seven times with 43 individuals from four littoral (L1, L2, L3 and L4) and bottom. It was one of two species (with *Cy. ophtalmica*) that detected in bottom sediments. In September 2008, when the water depth was 5.15 m and temperature of water was read as  $18.98^{\circ}\text{C}$  this species appeared in bottom samples (Appendix 1, Appendix 3 and Appendix 6). Besides, in three sampling times (21 August 2008, 22 November 2008, 25 April 2009) in total seven subfossils of this species also found from bottom sediments. The first description of this species was done by Okubo (1990). Okubo (1990) caught the living specimens when they were creeping on and/or in bottom mud of paddy fields. Although, the author did not give any information about the host water, it must not be too deep where it captured. There is no natatory setae (swimming setae) on the second antenna that is not a swimmer. The littoral stations that was appeared were well-vegetated, muddy (L3 was usually sandy and relatively low vegetation) and moderately oxygenated stations. Its appearance time coincides between late July to late October. Three times it was detected at fall turnover period (September, October 2008 and September 2009) (Appendix 6). It does nor appear again after September 2009 during study

(Appendix 2). Savatentalinton (2011) found this species from Chi River basin in cool season, while it was previously recorded from Spanish shallow lakes close to Millars and Palància Rivers (Poquet 2003, as *F. cf. fabaeformis*) and from Millars Rivers in 2005 (Mezquita et al.). The changing of eutrophication rate of Lake Çubuk was increasing year by the year but abundance/frequency of *F. japonica* (Appendix 5 and Appendix 6).

*Pseudocandona albicans* is here reported for third time from the region. It was previously found in Lake Sünnet (Külköylüoğlu et al., 2010) and a temporary pond where shows relatively low values to ecologic variables as pH 7.85, redox potential 159.65 mV, dissolved oxygen 6.87 mg/L, conductivity 281.7  $\mu\text{Scm}^{-1}$ , oxygen saturation 65.3%, temperature of water 19.7°C and salinity 0.2 ppt (Sarı and Külköylüoğlu 2010). While Külköylüoğlu et al. (2010) defined it with very high ETI and tolerance level to dissolved oxygen (2.99) and salinity (7.27), it was suggested as stygophilic (Roca and Danielopol 1991), preferring very low salty conditions (Meisch 2000). In present study, the highest ETI value for dissolved oxygen (0.82) was belonging to this species, whereas its ETI level to redox potential (0.37) was relatively low (Table 11). It was recorded from northeastern of Van (Turkey) at an altitude range as 1650-1750 m (Külköylüoğlu et al., 2012). It is mesothermophilic, mesorheophilic (Hartmann and Hiller 1977) and mesohalophilic (Meisch 2000) species. The results of the present study are largely confirming these suggestion. Still, outnumbered of finding both species and station can avoid to think like that. It seems that the mixing period (fall and/or spring turnover) does not effect the presence of the species in the water body (Appendix 6).

*Pseudocandona eremita* The bottom-dependent species *Pseudocandona eremita* was detected from three stations (L4, L5 and Gölpınar spring) for two times with five

individuals (Appendix 1 and Appendix 2). The occurrence of this non-swimming species was obtained at fall turnover in September 2008 and 2009 (Appendix 6). The highest electrical conductivity tolerance value was belonging to *P. eremita* (Table 10), while the ETI value for salinity was interestingly negative (Table 11). In the same region (Bolu) between 2005 and 2007, this species was recorded from Lake Sünnet in very low numbers (it was encountered only once) by Kulköylüoğlu et al., (2010). This stygobitic ostracod species was examined in terms of evolutionary and taxonomically by Iepure (2007). The eight population of this species from Romania were studied with regard to the intra- and interpopulation valve variations. They announced that the flat valves occur in gravel-sand habitats. In our case, the triangular shape of flat carapace was seen in population.

*Pseudocandona sucki* is the second record for freshwater ostracod of Turkish fauna. The first record with three individuals was from Karasu Creek (İstanbul) in spring time with range of several environmental variables such as pH 7.95-8.25, dissolved oxygen 8.4-11.03 mg/L and electrical conductivity 565-716  $\mu\text{S cm}^{-1}$  (Yaltalıer 2007). It was encountered from two station (L2 and L5) two times (Appendix 1 and Appendix 2). From late May to late June it was appeared in lake. This species prefers shallow, swampy and well vegetated water bodies. It was reported from oligohaline brackish coastal water body (Meisch 2000). It is defined as spring form that idea is supported by this study. Its presence period in Lake Çubuk is the period of very stable or thermally stratified water column (Figure 25 and Appendix 6).

*Pseudocandona semicognita* (Pm) was captured from three stations (L4, L5 and Gölpınar spring) with four individuals (Appendix 1 and Appendix 2). Both finding this species coincides to fall turnover (Appendix 6). The tolerance level of the

species for dissolved oxygen (0.09) and salinity (0.03) were very low (Table 10), while the highest ETI value of electrical conductivity was belonging to this species (Table 11). It was previously record in the region (Bolu, this record was also first for Turkish ostracod fauna) from a water body where was a slowflowing creek close to a fish-hatchery an altitude up to 1467 m (Sarı and Külköylüoğlu 2010). In this mentioned study the calculated values for this species were given as dissolved oxygen 5.15 mg/L, electrical conductivity 95.6  $\mu\text{Scm}^{-1}$ , and relatively cold water (20.7°C). It was also recorded from northeastern of Van (Turkey) at an altitude range as 1650-1750 m just like *P. albicans* (Külköylüoğlu et al., 2012). Whereas, Meisch (2000) emphasized that *Pseudocandona semicognita* was reported from a shallow pond with acidic (5.5-6) conditions. *P. semicognita* which produces one generation in the year can survive in different habitats such as pools, seasonal ditches, littoral zones of lakes etc.

Ostracods may be used as bio-indicator species due to their tolerance to environmental parameters (Külköylüoğlu 2004) and might play a role in the detection of such factors as pollution (Külköylüoğlu 2001). As they establish fossile stores with the help of their carapaces including calcite, they might be used as palaeothermometer and palaeosalinometer (Chivas et al., 1986), they can even be used as palaeoecological objects (De Deckker et al., 1999) for an easier and faster reconstruction (Külköylüoğlu 1999b). The ecological data specific to Lake Çubuk points to the fact it provides a preferable environment for cosmopolitan ostracod species. Ever weakening composition of species with low tolerance to changes in the environmental factors supports this argument.

Freshwater resources serve as a special “gene pool” with the diversity of living beings they host. Although they constitute a very small part of the earth, they have

paradoxically much bigger impact which referred to “paradox of freshwater” (Lévêque et al., 2005). For instance, they include 12% of the known animals and 25% of all invertebrate (Martens and Savatnalinton 2011). 2.5% of the overall water volume of the earth is freshwater, only 1.3% of which is surface water (others are either ice mass or underground water). Considering the fact that only 0.26% of overall surface waters are freshwater lakes (Eakins and Sharman 2010), it is even clearer how important it is to protect these special areas. These water masses are living organisms breathing, nourishing and getting polluted. In that sense, the study aims at detecting the living conditions and basic requirements of Lake Çubuk, understanding its “language,” taking its x-ray throughout a compelling 26 weeks of period. Lake Çubuk with its rich flora and fauna, its desire to enhance a real life and its amazing aesthetics requires to be well understood and the thread of pollution is required to be removed. For this purpose, i) resources nourishing Çubuk, being a shallow lake, shall be protected, especially it shall not be exposed to micro-nutrients, ii) the leakage of waste water from villages, poultry houses and chicken farms shall be prevented, measures shall be taken so as to prevent the transfer of indissoluble domestic waste, iii) the sedimentation factors shall be eliminated, vegetation shall be protected, iv) the use of pesticides shall be audited, they shall be prevented to arrive at the lake, v) the use of the water in the lake for irrigation purposes shall be measured, excessive volume losses shall be prevented, and vi) the eutrophication level shall be periodically checked and hence the lake shall not be neglected.

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# **PLATES**

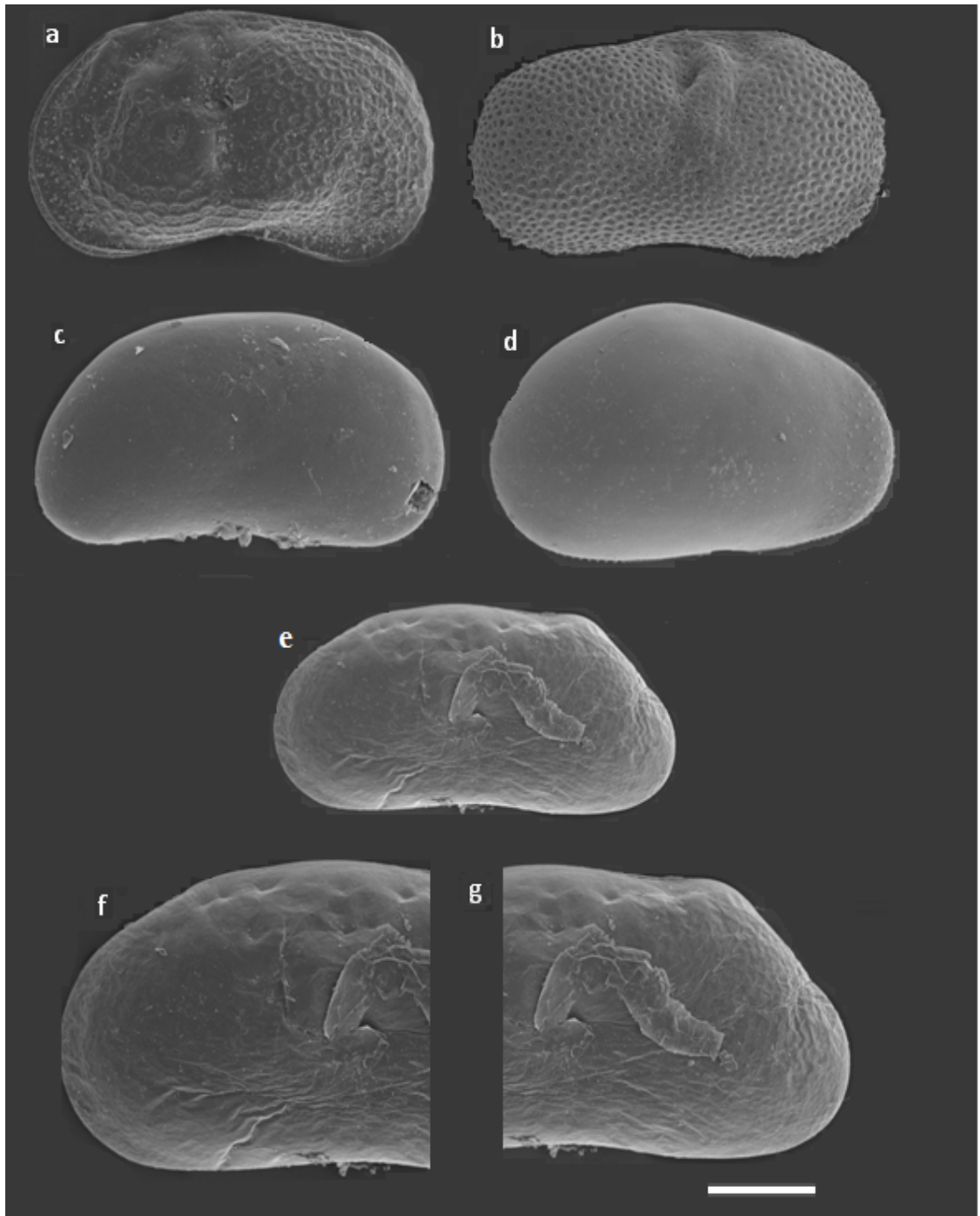


**Plate 1.** a) *Limnocythere inopinata*, b) *Ilyocypris gibba*, c) *Fabaformiscandona brevicornis*, d) *Trajancypsis serrata*, e) *Fabaformiscandona japonica*, f) *F. japonica* (anterior margin), g) *F. japonica* (posterior margin). Scale: 168  $\mu\text{m}$  a; 202  $\mu\text{m}$  b; 200  $\mu\text{m}$  c; 360  $\mu\text{m}$  d, 258  $\mu\text{m}$  e; 190  $\mu\text{m}$  for f and g.

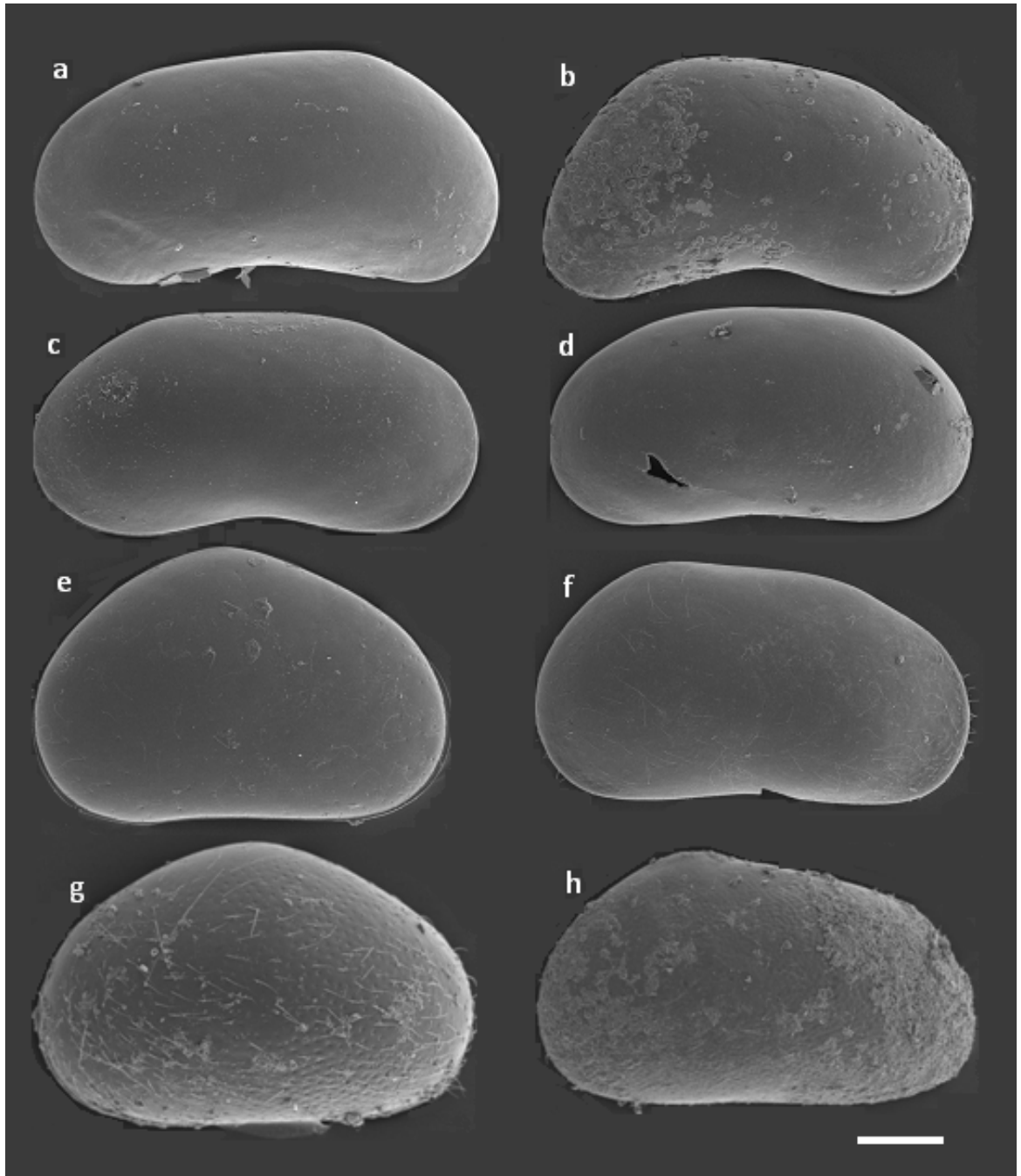


**Plate 2.** a) *Candona neglecta*, b) *C. candida*, c) *C. sanociensis*, d) *C. weltneri*. e) *Cypria ophtalmica*, f) *Pseudocandona semicognita*, g) *Cypridopsis vidua*, h) *Prionocypris zenkeri*. Scale: 172  $\mu\text{m}$  a; 228  $\mu\text{m}$  b; 160  $\mu\text{m}$  c; 218  $\mu\text{m}$  d, 130  $\mu\text{m}$  e; 157  $\mu\text{m}$  f; 105  $\mu\text{m}$  g; and 203  $\mu\text{m}$  for h.

# **APPENDICES**

**Appendix 1.** The presence/absence situation and the number of the species found per stations. Abbreviations: *Candona candida* (Cc), *Candona neglecta* (Cn), *Candona weltneri* (Cw), *Candona sanociensis* (Cs), *Pseudocandona albicans* (Pa), *Pseudocandona eremite* (Pe), *Pseudocandona sucki* (Ps), *Pseudocandona semicognita* (Pm), *Fabaeformiscandona brevicornis* (Fb), *Fabaeformiscandona japonica* (Fj), *Cypria ophtalmica* (Co), *Physocypria kraepelini* (Pk), *Ilyocypris gibba* (Ig), *Trajancypris serrata* (Ts), *Prionocypris zenkeri* (Pz), *Cypridopsis vidua* (Cv), *Limnocythere inopinata* (Li).

|                       | Station   | Cc | Cn | Cw | Cs | Pa | Pe | Ps | Pm | Fb | Fj | Co | Pk  | Ig | Ts | Pz | Cv | Li | Total |
|-----------------------|-----------|----|----|----|----|----|----|----|----|----|----|----|-----|----|----|----|----|----|-------|
| Presence/absence      | L1        | 0  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | 1  | 1   | 1  | 0  | 0  | 0  | 1  | 8     |
|                       | L2        | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 0  | 1  | 1  | 1  | 1   | 1  | 0  | 1  | 1  | 0  | 13    |
|                       | L3        | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0   | 1  | 0  | 0  | 0  | 0  | 5     |
|                       | L4        | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 1  | 1   | 1  | 0  | 0  | 1  | 0  | 11    |
|                       | L5        | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1   | 1  | 1  | 0  | 1  | 1  | 13    |
|                       | Bottom    | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0   | 0  | 0  | 0  | 0  | 0  | 2     |
|                       | Spring    | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 0  | 1  | 1   | 0  | 0  | 0  | 1  | 1  | 9     |
|                       | Frequence | 4  | 6  | 3  | 4  | 5  | 3  | 2  | 3  | 1  | 5  | 7  | 6   | 5  | 1  | 1  | 4  | 3  |       |
| Number of individuals | L1        | 0  | 8  | 0  | 2  | 5  | 0  | 0  | 0  | 0  | 4  | 28 | 20  | 4  | 0  | 0  | 0  | 20 | 91    |
|                       | L2        | 2  | 4  | 2  | 5  | 6  | 0  | 2  | 0  | 2  | 21 | 14 | 32  | 17 | 0  | 3  | 9  | 0  | 119   |
|                       | L3        | 0  | 1  | 2  | 0  | 0  | 0  | 0  | 0  | 0  | 2  | 16 | 5   | 5  | 0  | 0  | 0  | 0  | 31    |
|                       | L4        | 2  | 1  | 2  | 0  | 2  | 2  | 0  | 2  | 0  | 12 | 14 | 18  | 6  | 0  | 0  | 9  | 0  | 70    |
|                       | L5        | 2  | 2  | 0  | 1  | 15 | 2  | 2  | 1  | 0  | 0  | 14 | 47  | 13 | 4  | 0  | 14 | 13 | 130   |
|                       | Bottom    | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 4  | 5  | 0   | 0  | 0  | 0  | 0  | 0  | 9     |
|                       | Spring    | 3  | 2  | 0  | 0  | 2  | 2  | 0  | 1  | 0  | 0  | 3  | 63  | 0  | 0  | 0  | 2  | 5  | 83    |
|                       | Total     | 9  | 18 | 6  | 8  | 30 | 6  | 4  | 4  | 2  | 43 | 94 | 185 | 45 | 4  | 3  | 34 | 38 | 533   |

**Appendix 2.** The number of the species in terms of sampling time with the most effective environmental variables on species. For abbreviations and species codes see Appendix 1.

| Tarih      | pH   | EC     | DO    | Γ°C(w) | Tur  | Cc  | Cn  | Cw | Cs | Pa | Pe  | Ps | Pm | Fb | Fj  | Co  | Pk  | Ig | Ts | Pz | Cv  | Li  | Total | Freq. |
|------------|------|--------|-------|--------|------|-----|-----|----|----|----|-----|----|----|----|-----|-----|-----|----|----|----|-----|-----|-------|-------|
| 19.07.2008 | 7,91 | 198,00 | 7,20  | 22,22  | 4,39 |     | 2   |    |    |    |     |    |    |    | 5   |     | 3   |    |    |    |     |     | 10    | 3     |
| 21.08.2008 | 8,13 | 204,00 | 6,26  | 23,89  | 3,27 |     | 1   |    |    |    |     |    |    |    | 3   | 6   | 7   |    |    |    | 5   | 6   | 28    | 6     |
| 20.09.2008 | 7,46 | 183,00 | 5,74  | 18,98  | 6,00 |     | 2   |    |    |    | 3   |    | 3  |    | 11  | 9   | 27  |    |    |    | 8   | 6   | 69    | 8     |
| 18.10.2008 | 8,20 | 208,00 | 7,70  | 15,22  | 2,23 |     | 3   |    | 4  | 4  |     |    |    |    | 9   | 5   | 4   |    |    |    |     |     | 29    | 6     |
| 22.11.2008 | 7,85 | 212,00 | 8,60  | 8,73   | 9,60 | 3   | 2   |    |    | 2  |     |    |    | 2  |     | 18  | 13  | 34 |    |    | 4   | 2   | 80    | 9     |
| 20.12.2008 | 7,93 | 255,00 | 9,22  | 6,03   | 2,26 |     |     |    |    | 14 |     |    |    |    |     | 2   | 23  |    | 2  |    | 1   |     | 42    | 5     |
| 28.03.2009 | 8,93 | 348,76 | 7,10  | 7,15   | 1,69 | 2   |     |    |    |    |     |    |    |    |     |     |     |    |    | 3  |     |     | 5     | 2     |
| 25.04.2009 | 8,01 | 334,25 | 7,74  | 12,11  | 3,93 |     |     |    |    |    |     |    |    |    |     |     | 2   |    |    |    |     |     | 2     | 1     |
| 23.05.2009 | 8,05 | 291,49 | 7,24  | 17,88  | 2,85 |     | 1   | 2  |    |    |     | 2  |    |    |     |     | 5   |    |    |    |     |     | 10    | 4     |
| 20.06.2009 | 8,30 | 233,82 | 5,61  | 22,06  | 3,30 |     |     |    |    | 3  |     | 2  |    |    |     | 19  |     |    | 2  |    | 4   |     | 30    | 5     |
| 18.07.2009 | 7,98 | 198,18 | 4,87  | 22,18  | 2,63 |     |     |    | 2  |    |     |    |    |    | 4   | 9   |     |    |    |    | 3   |     | 18    | 4     |
| 22.08.2009 | 7,88 | 199,31 | 3,53  | 21,17  | 2,88 |     |     |    |    |    |     |    |    |    | 7   |     | 3   |    |    |    | 3   |     | 13    | 3     |
| 26.09.2009 | 8,13 | 183,98 | 4,32  | 17,55  | 5,27 |     | 5   |    |    |    | 2   |    | 1  |    | 4   | 7   | 13  |    |    |    | 1   | 4   | 37    | 8     |
| 24.10.2009 | 7,99 | 200,37 | 3,68  | 16,60  | 5,02 |     |     |    |    |    |     |    |    |    |     | 3   | 24  | 6  |    |    |     | 2   | 35    | 4     |
| 21.11.2009 | 7,91 | 200,98 | 3,61  | 9,37   | 5,00 |     | 1   |    |    |    |     |    |    |    |     |     | 8   | 3  |    |    |     | 14  | 26    | 4     |
| 19.12.2009 | 8,07 | 219,87 | 3,22  | 4,75   | 4,44 | 2   |     | 2  | 1  |    |     |    |    |    |     | 1   | 20  |    |    |    |     | 1   | 27    | 6     |
| 20.02.2010 | 7,72 | 333,86 | 3,68  | 7,17   | 5,96 |     |     |    |    |    |     |    |    |    |     |     | 2   |    |    |    |     |     | 2     | 1     |
| 20.03.2010 | 7,81 | 347,97 | 4,61  | 8,53   | 5,35 |     |     |    |    |    |     |    |    |    |     |     | 5   |    |    |    |     |     | 5     | 1     |
| 17.04.2010 | 7,89 | 338,70 | 3,94  | 13,55  | 3,38 |     |     |    |    | 2  |     |    |    |    |     |     | 2   |    |    |    |     |     | 4     | 2     |
| 22.05.2010 | 7,91 | 308,50 | 3,11  | 15,60  | 2,74 |     |     | 2  |    |    |     |    |    |    |     |     | 6   |    |    |    |     |     | 8     | 2     |
| 19.06.2010 | 7,27 | 254,43 | 1,07  | 21,16  | 2,80 |     |     |    |    | 5  |     |    |    |    |     |     | 4   |    |    |    |     |     | 9     | 2     |
| 24.07.2010 | 7,96 | 175,00 | 6,75  | 23,61  | 1,32 |     |     |    |    |    |     |    |    |    |     |     |     |    |    |    |     |     | 0     | 0     |
| 21.08.2010 | 7,85 | 195,08 | 5,44  | 23,22  | 3,53 |     | 2   |    |    |    |     |    |    |    |     | 4   | 9   |    |    |    | 1   | 1   | 17    | 5     |
| 18.09.2010 | 7,82 | 183,27 | 6,06  | 19,88  | 2,87 |     |     |    |    |    |     |    |    |    |     | 8   |     |    |    |    | 3   | 2   | 13    | 3     |
| 24.10.2010 | 8,29 | 194,20 | 10,95 | 13,01  | na   | 2   |     |    | 1  |    |     |    |    |    |     | 3   | 5   | 2  |    |    | 1   |     | 14    | 6     |
| Min.       | 7,27 | 175,00 | 1,07  | 4,75   | 1,32 | 2   | 1   | 2  | 1  | 2  | 2   | 2  | 1  | 2  | 3   | 1   | 2   | 2  | 2  | 3  | 1   | 1   | 0     | 0     |
| Max.       | 8,93 | 348,76 | 10,95 | 23,89  | 9,60 | 3   | 5   | 2  | 4  | 14 | 3   | 2  | 3  | 2  | 11  | 19  | 27  | 34 | 2  | 3  | 8   | 14  | 80    | 9     |
| Mean       | 7,97 | 240,08 | 5,65  | 15,66  | 3,86 | 2,3 | 2,1 | 2  | 2  | 5  | 2,5 | 2  | 2  | 2  | 6,1 | 7,2 | 9,3 | 11 | 2  | 3  | 3,1 | 4,2 | 21,3  | 4     |

**Appendix 3.** The measured parameters during sampling. Abbreviations: DO (Dissolved Oxygen), EC (Electrical Conductivity), SHE (Redox potential), TDS (Total Dissolved Solids), Sal (Salinity), Sat (Saturation), TC(w) (Water Temperature), TC(a) (Air temperature), BOD5 (Biological Oxygen Demand), Tur (Turbidity), Hum (Percent humidity)

| Date           | DO    | pH   | EC     | SHE    | TDS    | Sal  | Sat    | T°C(w) | T°C(a) | BOD  | Tur  | Depth | Secchi | Hum   | Wind |
|----------------|-------|------|--------|--------|--------|------|--------|--------|--------|------|------|-------|--------|-------|------|
| 19.07.2008     | 7,20  | 7,91 | 198,00 | 149,63 | 128,70 | 0,11 | 83,03  | 22,22  | Na     | 2,79 | 4,39 | 5,40  | 140    | Na    | Na   |
| 21.08.2008     | 6,26  | 8,13 | 204,00 | 131,87 | 132,60 | 0,11 | 75,41  | 23,89  | Na     | 2,80 | 3,27 | 5,10  | 120    | Na    | Na   |
| 20.09.2008     | 5,74  | 7,46 | 183,00 | 157,78 | 118,95 | 0,10 | 61,30  | 18,98  | 20,60  | 2,99 | 6,00 | 5,15  | 120    | 46,4  | 3,4  |
| 18.10.2008     | 7,70  | 8,20 | 208,00 | 135,82 | 135,20 | 0,10 | 77,75  | 15,22  | 21,00  | 3,36 | 2,23 | 5,25  | 90     | 42,7  | 2,35 |
| 22.11.2008     | 8,60  | 7,85 | 212,00 | 164,33 | 137,80 | 0,11 | 74,80  | 8,73   | 11,30  | 1,47 | 9,60 | 5,80  | 120    | 55,7  | 3,95 |
| 20.12.2008     | 9,22  | 7,93 | 255,00 | 164,06 | 165,75 | 0,10 | 77,65  | 6,03   | 9,30   | 1,94 | 2,26 | 5,00  | 180    | 61,7  | Na   |
| 28.03.2009     | 7,10  | 8,93 | 348,76 | 273,84 | 226,70 | 0,20 | 58,52  | 7,15   | 2,20   | 5,65 | 1,69 | 7,00  | 125    | 48,4  | 3,55 |
| 25.04.2009     | 7,74  | 8,01 | 334,25 | 155,66 | 217,27 | 0,19 | 73,68  | 12,11  | 16,40  | 4,39 | 3,93 | 7,00  | 130    | 35,5  | 2,1  |
| 23.05.2009     | 7,24  | 8,05 | 291,49 | 148,10 | 189,47 | 0,15 | 77,05  | 17,88  | 22,00  | 4,74 | 2,85 | 7,00  | 150    | 47,0  | 2,5  |
| 20.06.2009     | 5,61  | 8,30 | 233,82 | 187,57 | 151,98 | 0,11 | 64,07  | 22,06  | 23,80  | 2,03 | 3,30 | 6,80  | 145    | 39,0  | 5,2  |
| 18.07.2009     | 4,87  | 7,98 | 198,18 | 197,70 | 128,82 | 0,10 | 55,87  | 22,18  | 25,10  | 2,14 | 2,63 | 6,00  | 200    | 43,0  | 4,05 |
| 22.08.2009     | 3,53  | 7,88 | 199,31 | 157,86 | 129,55 | 0,10 | 39,88  | 21,17  | 19,60  | 2,51 | 2,88 | 5,50  | 70     | 54,1  | 3,75 |
| 26.09.2009     | 4,32  | 8,13 | 183,98 | 146,41 | 119,59 | 0,10 | 46,04  | 17,55  | 15,10  | 3,49 | 5,27 | 5,70  | 110    | 67,2  | 4,4  |
| 24.10.2009     | 3,68  | 7,99 | 200,37 | 154,43 | 130,24 | 0,10 | 37,76  | 16,60  | 22,30  | 2,77 | 5,02 | 4,80  | 50     | 40,0  | 3,2  |
| 21.11.2009     | 3,61  | 7,91 | 200,98 | 162,13 | 130,64 | 0,10 | 31,63  | 9,37   | 11,20  | 1,89 | 5,00 | 5,50  | 110    | 43,0  | 3,5  |
| 19.12.2009     | 3,22  | 8,07 | 219,87 | 162,19 | 142,92 | 0,10 | 25,06  | 4,75   | 4,10   | 1,45 | 4,44 | 4,70  | 115    | 79,7  | 2,1  |
| 20.02.2010     | 3,68  | 7,72 | 333,86 | 177,38 | 217,01 | 0,18 | 30,34  | 7,17   | 14,60  | 1,51 | 5,96 | 7,60  | 110    | 43,2  | 1,5  |
| 20.03.2010     | 4,61  | 7,81 | 347,97 | 166,81 | 226,18 | 0,18 | 39,20  | 8,53   | 12,50  | 2,09 | 5,35 | 7,80  | 130    | 25,9  | 2,5  |
| 17.04.2010     | 3,94  | 7,89 | 338,70 | 161,44 | 220,16 | 0,18 | 37,83  | 13,55  | 20,60  | 2,51 | 3,38 | 8,00  | 160    | 33,9  | Na   |
| 22.05.2010     | 3,11  | 7,91 | 308,50 | 161,91 | 200,53 | 0,16 | 30,69  | 15,60  | 17,20  | 2,84 | 2,74 | 8,50  | 220    | 51,5  | 0,8  |
| 19.06.2010     | 1,07  | 7,27 | 254,43 | 188,75 | 165,38 | 0,12 | 12,38  | 21,16  | 24,80  | 0,70 | 2,80 | 7,15  | 210    | 51,9  | 1,9  |
| 24.07.2010     | 6,75  | 7,96 | 175,00 | 268,89 | 113,75 | 0,08 | 79,85  | 23,61  | 22,10  | 4,23 | 1,32 | 7,00  | 140    | 55,6  | 3,7  |
| 21.08.2010     | 5,44  | 7,85 | 195,08 | 197,67 | 126,80 | 0,09 | 63,84  | 23,22  | 24,10  | 4,10 | 3,53 | 6,00  | 150    | 47,6  | 4,75 |
| 18.09.2010     | 6,06  | 7,82 | 183,27 | 200,28 | 119,13 | 0,09 | 66,95  | 19,88  | 26,60  | 0,73 | 2,87 | 6,00  | 130    | 33,5  | 1,85 |
| 24.10.2010     | 10,95 | 8,29 | 194,20 | 204,29 | 126,23 | 0,09 | 102,98 | 13,01  | 12,40  | Na   | Na   | Na    | Na     | Na    | Na   |
| 14.11.2010     | 6,08  | 7,76 | 190,40 | 195,08 | 123,76 | 0,09 | 83,70  | 11,62  | 22,70  | Na   | Na   | Na    | Na     | Na    | Na   |
| <b>Minimum</b> | 1,07  | 7,27 | 175,00 | 131,87 | 113,75 | 0,08 | 12,38  | 4,75   | 2,20   | 0,70 | 1,32 | 4,70  | 50,00  | 25,90 | 0,80 |
| <b>Maximum</b> | 10,95 | 8,93 | 348,76 | 273,84 | 226,70 | 0,20 | 102,98 | 23,89  | 26,60  | 5,65 | 9,60 | 8,50  | 220,00 | 79,70 | 5,20 |
| <b>Mean</b>    | 5,67  | 7,96 | 238,17 | 175,84 | 154,81 | 0,12 | 57,97  | 15,51  | 17,57  | 2,71 | 3,86 | 6,24  | 134,38 | 47,57 | 3,05 |

**Appendix 4:** The ion composition of Lake Çubuk during sampling with total coliform (T. Col) and chlorophyll-a (Clo-a).

|                |         |        |          | Cations |       |         |        |        |                   | Anions            |                   |                   |                 |                 |                  |         |        |        |
|----------------|---------|--------|----------|---------|-------|---------|--------|--------|-------------------|-------------------|-------------------|-------------------|-----------------|-----------------|------------------|---------|--------|--------|
| Date           | T. Col. | Chlo-a | Hardness | Na      | K     | Ca      | Mg     | Li     | N-NH <sub>4</sub> | N-NO <sub>3</sub> | N-NO <sub>2</sub> | P-PO <sub>4</sub> | SO <sub>4</sub> | CO <sub>3</sub> | HCO <sub>3</sub> | Cl      | F      | Br     |
| 19.07.2008     | 5000    | 7,92   | na       | na      | na    | na      | na     | na     | 0,0693            | 0,0123            | -0,001            | na                | na              | na              | na               | na      | na     | na     |
| 21.08.2008     | 333     | Na     | na       | na      | na    | na      | na     | na     | 0,0599            | 0,0333            | 0,002             | na                | na              | na              | na               | na      | na     | na     |
| 20.09.2008     | 0       | 19,12  | na       | na      | na    | na      | na     | na     | -0,1015           | 0,0120            | 0,000             | na                | na              | na              | na               | na      | na     | na     |
| 18.10.2008     | 0       | 20,94  | na       | na      | na    | na      | na     | na     | 0,0967            | -0,0020           | 0,008             | na                | na              | na              | na               | na      | na     | na     |
| 22.11.2008     | 0       | 15,18  | na       | na      | na    | na      | na     | na     | 0,2290            | -0,0088           | 0,043             | na                | na              | na              | na               | na      | na     | na     |
| 20.12.2008     | 0       | 14,66  | na       | na      | na    | na      | na     | na     | 0,2376            | -0,0120           | 0,044             | na                | na              | na              | na               | na      | na     | na     |
| 28.03.2009     | 6       | 14,58  | na       | na      | na    | na      | na     | na     | 0,4236            | 0,0094            | 0,008             | <0.001            | 5,824           | 0               | 242              | 17      | 0,037  | <0.001 |
| 25.04.2009     | 4       | 36,34  | 20,96    | 46      | 12    | 81      | 2      | <0.001 | 0,0717            | -0,0433           | 0,011             | <0.001            | 53,335          | 176             | 203              | 34      | 0,245  | <0.001 |
| 23.05.2009     | 5       | 96,07  | 18,64    | 49      | 0,947 | 717     | 18     | <0.001 | 0,0212            | 0,0137            | -0,120            | <0.001            | 48,882          | 0               | 216              | 2       | 0,084  | <0.001 |
| 20.06.2009     | 17833   | 23,28  | 12,56    | 3       | 0,618 | 48      | 2      | <0.001 | 0,1866            | -1204,79          | 0,000             | <0.001            | 4,700           | 23              | 99               | 1       | 0,026  | <0.001 |
| 18.07.2009     | 0       | 12,92  | 9,18     | 35      | 0,421 | 34      | 15     | <0.001 | 0,1363            | -1354,10          | 0,004             | <0.001            | 47,897          | 0               | 123              | 0,098   | 0,098  | <0.001 |
| 22.08.2009     | 0       | 7,13   | 10,43    | 3,323   | 1,166 | 38,333  | 2,056  | 0,0018 | 0,2216            | -0,0278           | -0,003            | <0.001            | 5,808           | 0               | 120,197          | 1,519   | 0,098  | <0.001 |
| 26.09.2009     | 0       | 30,08  | 11,3     | 37      | 16    | 416     | 22     | <0.001 | 0,2006            | -0,2387           | -0,055            | <0.001            | 47,645          | 0               | 129              | 29      | 0,117  | <0.001 |
| 24.10.2009     | 0       | 17,90  | 11,04    | 34      | 10    | 411     | 19     | <0.001 | -0,0184           | -2,2133           | 0,001             | <0.001            | 48,741          | 0               | 125              | 12      | 0,065  | <0.001 |
| 21.11.2009     | 0       | 47,93  | 10,98    | 6       | 12    | 42      | 14     | <0.001 | 0,3650            | 0,0500            | 0,005             | <0.001            | 55,625          | 0               | 130              | 23      | 0,120  | <0.001 |
| 19.12.2009     | 0       | 50,10  | 12,65    | 4       | 15    | 479     | 17     | <0.001 | -0,0420           | 0,0263            | 0,020             | <0.001            | 58,711          | 0               | 155              | 3       | 0,253  | <0.001 |
| 20.02.2010     | 0       | 31,72  | 19,88    | 41      | 14    | 771     | 16     | <0.001 | 0,3944            | 0,0445            | 0,004             | <0.001            | 6,302           | 0               | 229,31           | 22      | 0,056  | <0.001 |
| 20.03.2010     | 0       | 24,10  | 19,65    | 28      | 1     | 757     | 19     | <0.001 | 0,3946            | 0,0515            | 0,015             | <0.001            | 40,914          | 0               | 237              | 13      | 0,062  | <0.001 |
| 17.04.2010     | 0       | 19,72  | 18,94    | 3,018   | 1,018 | 72,622  | 1,929  | <0.001 | 0,0288            | 0,0401            | 0,011             | <0.001            | 3,545           | 0               | 220,969          | 1,1081  | 0      | <0.001 |
| 22.05.2010     | 0       | 19,83  | na       | na      | na    | na      | na     | na     | -0,1317           | -0,0108           | 0,005             | na                | na              | na              | na               | na      | na     | na     |
| 19.06.2010     | 1167    | 15,15  | 16,4     | 4       | 0,939 | 63      | 2      | <0.001 | 0,1285            | -0,0641           | 0,019             | <0.001            | 3               | 0               | 190,05           | 1.637   | 0,0559 | <0.001 |
| 24.07.2010     | 0       | 14,20  | 12,38    | 3,395   | 0,519 | 46,212  | 2,008  | <0.001 | 0,1439            | -0,0658           | 0,007             | <0.001            | 3,546           | 0               | 147,136          | 1,0631  | <0.001 | <0.001 |
| 21.08.2010     | 0       | 21,08  | na       | na      | na    | na      | na     | na     | 0,0286            | 0,0123            | 0,013             | na                | na              | na              | na               | na      | na     | na     |
| 18.09.2010     | 0       | 22,09  | 0,438    | 2,765   | 0,398 | 34,684  | 1,750  | 0      | 0,1375            | 0,0772            | 0,045             | 0                 | 3,697           | 0               | 123,245          | 0,633   | 0      | 0      |
| 24.10.2010     | na      | na     | 0,457    | 2,954   | 0,817 | 34,621  | 1,829  | 0      | na                | na                | na                | 0                 | 4,175           | 0               | 112,041          | 1,504   | 0      | 0      |
| 14.11.2010     | na      | na     | 4,200    | 22,851  | 3,710 | 34,063  | 16,755 | 0,0274 | na                | na                | na                | 0                 | 36,744          | 0               | 122,629          | 47,766  | 0,789  | 0      |
| <b>Mean</b>    | 1015    | 25,31  | 12,358   | 19,057  | 5,319 | 239,964 | 10,113 | 0,0073 | 0,1367            | -106,72           | 0,004             | 0                 | 26,616          | 11,074          | 162,441          | 102,617 | 0,124  | 0      |
| <b>Minimum</b> | 0       | 7,13   | 0,44     | 2,67    | 0,40  | 34,06   | 1,68   | 0      | -0,13             | -1354,10          | -0,12             | 0                 | 3               | 0               | 98,76            | 0,10    | 0      | 0      |
| <b>Maximum</b> | 17833   | 96,07  | 20,96    | 48,98   | 15,71 | 770,89  | 22,19  | 0,03   | 0,42              | 0,08              | 0,05              | 0                 | 58,71           | 176,47          | 242,21           | 1637    | 0,79   | 0      |

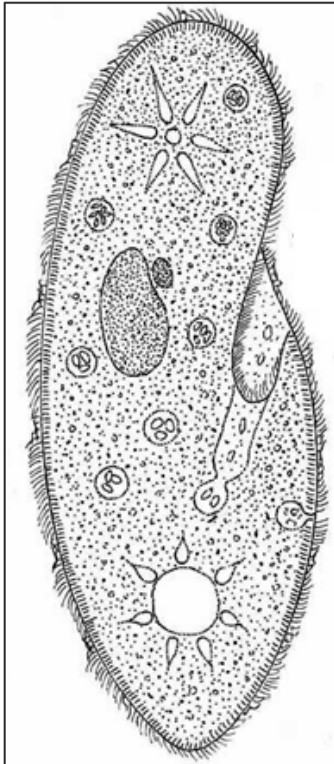
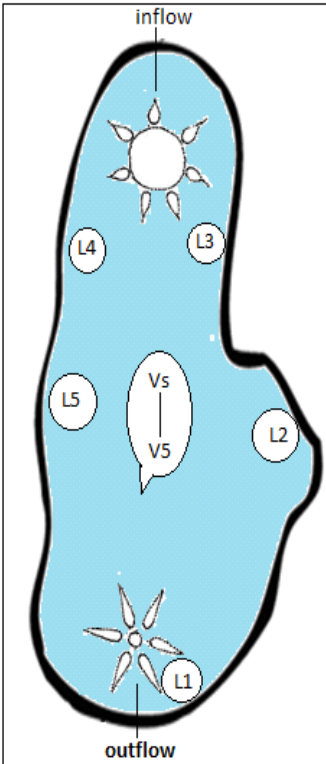
**Appendix 5.** The development of the eutrophication rate of Lake Çubuk in terms of two indices.

|                             | 2008          | J                           | Au    | S     | O     | N     | D      |       | Mean               | Min.  | Max.  | Class                    |                       |
|-----------------------------|---------------|-----------------------------|-------|-------|-------|-------|--------|-------|--------------------|-------|-------|--------------------------|-----------------------|
| Carlson Trophic State Index | TSI of Secchi | 15,34                       | 8,31  | 8,31  | -4,80 | 8,31  | 26,80  |       | 10,38              | -4,80 | 26,80 | Strongly Oligotrophic    | SLIGHTLY OLIGOTROPHIC |
|                             | TSI of Chlo-a | 50,89                       | Na    | 59,55 | 60,44 | 57,28 | 56,94  |       | 57,02              | 50,89 | 60,44 | Slightly Eutrophic       |                       |
|                             | CTSI          | 33,12                       | 4,16  | 33,93 | 27,82 | 32,80 | 41,87  |       | 28,95              | 4,16  | 41,87 | Oligotrophic             |                       |
|                             | 2009          | M                           | A     | Ma    | Ju    | J     | Au     | S     | O                  | N     | D     | OLIGOTROPHIC             |                       |
|                             | TSI of Secchi | 10,17                       | 11,96 | 18,49 | 16,94 | 31,60 | -16,26 | 4,35  | -17,58             | 4,35  | 6,37  | Strongly Oligotrophic    |                       |
|                             | TSI of Chlo-a | 56,89                       | 65,85 | 75,38 | 61,48 | 55,70 | 49,86  | 63,99 | 58,90              | 68,56 | 69,00 | Strongly Eutrophic       |                       |
|                             | CTSI          | 33,53                       | 38,90 | 46,93 | 39,21 | 43,65 | 16,80  | 34,17 | 20,66              | 36,45 | 37,68 | Slightly Oligotrophic    |                       |
|                             | 2010          | F                           | M     | A     | Ma    | Ju    | J      | Au    | S                  |       |       | SLIGHTLY OLIGOTROPH      |                       |
|                             | TSI of Secchi | 4,35                        | 11,96 | 21,43 | 35,95 | 33,82 | 15,34  | 18,49 | 11,96              |       |       | Strongly Oligotrophic    |                       |
|                             | TSI of Chlo-a | 64,51                       | 61,82 | 59,85 | 59,90 | 57,26 | 56,63  | 60,50 | 60,96              |       |       | Eutrophic                |                       |
|                             | CTSI          | 34,43                       | 36,89 | 40,64 | 47,92 | 45,54 | 35,98  | 39,49 | 36,46              |       |       | Slightly Mesotrophic     |                       |
|                             |               | (Averaga of 3 years: 34,47) |       |       |       |       |        |       | SLIGHTLY MESOTROPH |       |       |                          |                       |
|                             | 2008          | J                           | Au    | S     | O     | N     | D      |       | Mean               | Min.  | Max.  |                          |                       |
| Burns Trophic Level Index   | TLI of SD     | 4,73                        | 4,89  | 4,89  | 5,18  | 4,89  | 4,48   |       | 4,84               | 4,48  | 5,18  | Eutrophic                | SLIGHTLY EUTROPHIC    |
|                             | TLI of TN     | 7,26                        | 8,57  | 7,23  | -3,61 | -3,61 | -3,61  |       | 2,04               | -3,61 | 8,57  | Oligotrophic             |                       |
|                             | TLI of Chlo-a | 4,50                        | 2,22  | 5,48  | 5,58  | 5,22  | 5,18   |       | 4,70               | 2,22  | 5,58  | Eutrophic                |                       |
|                             | BTLI          | 5,50                        | 5,23  | 5,87  | 2,38  | 2,17  | 2,02   |       | 3,86               | 2,02  | 5,87  | Strongly Mesotrophic     |                       |
|                             | 2009          | M                           | A     | Ma    | Ju    | J     | Au     | S     | O                  | N     | D     | STRONGLY MESOTROPH       |                       |
|                             | TLI of SD     | 4,85                        | 4,81  | 4,66  | 4,70  | 4,37  | 5,43   | 4,98  | 5,46               | 4,98  | 4,93  | Eutrophic                |                       |
|                             | TLI of TN     | 6,91                        | -3,61 | 7,40  | -3,61 | -3,61 | -3,61  | -3,61 | -3,61              | 9,10  | 8,26  | Strongly Oligotrophic    |                       |
|                             | TLI of Chlo-a | 5,18                        | 6,18  | 7,26  | 5,69  | 5,04  | 4,39   | 5,97  | 5,40               | 6,49  | 6,54  | Slightly Hyper-eutrophic |                       |
|                             | BTLI          | 5,64                        | 2,46  | 6,44  | 2,26  | 1,93  | 2,07   | 2,45  | 2,42               | 6,86  | 6,58  | Strongly Mesotrophic     |                       |
|                             | 2010          | F                           | M     | A     | Ma    | Ju    | J      | Au    | S                  |       |       | STRONGLY MESOTROPH       |                       |
|                             | TLI of SD     | 4,98                        | 4,81  | 4,60  | 4,27  | 4,32  | 4,73   | 4,66  | 4,81               |       |       | Eutrophic                |                       |
|                             | TLI of TN     | 8,95                        | 9,14  | 8,81  | -3,61 | -3,61 | -3,61  | 7,27  | 9,67               |       |       | Slightly Eutrophic       |                       |
|                             | TLI of Chlo-a | 6,03                        | 5,73  | 5,51  | 5,52  | 5,22  | 5,15   | 5,58  | 5,63               |       |       | Slightly Hyper-eutrophic |                       |
|                             | BTLI          | 6,65                        | 6,56  | 6,31  | 2,06  | 1,97  | 2,09   | 5,84  | 6,70               |       |       | Eutrophic                |                       |
|                             |               | (Averaga of 3 years: 4,18)  |       |       |       |       |        |       | EUTROPHIC          |       |       |                          |                       |

**Appendix 6.** Species composition in terms of several environmental variables. Abbreviations: SI (Stratification Index), W (Wedderburn Number), CTSI (Carlson Trophic State Index), BTLI (Burns Trophic Level Index), w (water), a (air). For species codes see Appendix 1.

|          |            | Non-swimming Species |    |    |    |    |    |    |    |    |    |              |    | Swimming |    |     |    |    |      |           |       |         |       |       |      |      |      |      |
|----------|------------|----------------------|----|----|----|----|----|----|----|----|----|--------------|----|----------|----|-----|----|----|------|-----------|-------|---------|-------|-------|------|------|------|------|
| Turnover |            | Non-cosmopolitan     |    |    |    |    |    |    |    |    |    | Cosmopolitan |    |          |    |     |    |    |      | Stability |       | Indices |       | T° C  |      |      |      |      |
|          | Date       | Cw                   | Cs | Pa | Pe | Ps | Pm | Fj | Fb | Ts | Li | Cc           | Cn | Pz       | Co | Pk  | Ig | Cv | SI   | W         | CTSI  | BTLI    | w     | a     | Year |      |      |      |
| Fall     | 19.07.2008 | 5                    |    |    |    |    |    |    |    |    |    | 2            |    |          |    | 3   |    |    |      | 2,66      | 0,05  | 33,1    | 5,5   | 22,2  | na   | 2008 |      |      |
|          | 21.08.2008 | 3                    |    |    |    |    |    |    |    |    |    | 6            | 1  |          |    | 6   | 7  | 5  | 1,06 | -0,01     | 4,2   | 5,2     | 23,9  | na    |      |      |      |      |
|          | 20.09.2008 | 3 11                 |    |    |    |    |    |    |    |    |    | 6            | 2  |          |    | 9   | 27 | 8  | 0,41 | -0,01     | 33,9  | 5,9     | 19,0  | 20,6  |      |      |      |      |
|          | 18.10.2008 | 4                    | 4  | 9  |    |    |    |    |    |    |    |              |    | 3        |    |     |    | 5  | 4    |           |       | 0,31    | 0,01  | 27,8  | 2,4  |      | 15,2 | 21,0 |
|          | 22.11.2008 | 2                    |    |    |    |    |    |    |    |    |    | 2            | 3  | 2        | 18 | 13  | 34 | 4  | 0,02 | 0,34      | 32,8  | 2,2     | 8,7   | 11,3  |      |      |      |      |
|          | 20.12.2008 | 14                   |    |    |    |    |    |    |    |    |    | 2            |    |          |    | 23  | 1  |    | 0,05 | 1,56      | 41,9  | 2,0     | 6,0   | 9,3   |      |      |      |      |
| Spring   | 28.03.2009 |                      |    |    |    |    |    |    |    |    |    | 2            |    |          |    | 3   |    |    |      | 0,08      | 0,50  | 33,5    | 5,6   | 7,1   | 2,2  | 2009 |      |      |
|          | 25.04.2009 |                      |    |    |    |    |    |    |    |    |    | 2            |    |          |    |     |    |    |      | 0,44      | 0,60  | 38,9    | 2,5   | 12,1  | 16,4 |      |      |      |
|          | 23.05.2009 | 2                    | 2  |    |    |    |    |    |    |    |    |              | 1  |          |    |     | 5  |    |      |           | 2,91  | 0,14    | 46,9  | 6,4   | 17,9 |      | 22,0 |      |
|          | 20.06.2009 | 3                    |    |    |    |    |    |    |    |    |    | 2            |    |          |    | 19  |    |    |      | 4         | 4,00  | 0,05    | 39,2  | 2,3   | 22,1 |      | 23,8 |      |
|          | 18.07.2009 | 2                    |    |    |    |    |    |    |    |    |    | 4            |    |          |    | 9   |    |    |      | 3         | 2,78  | 0,79    | 43,7  | 1,9   | 22,2 |      | 25,1 |      |
|          | 22.08.2009 | 7                    |    |    |    |    |    |    |    |    |    | 3            |    |          |    | 3   |    |    |      | 0,86      | -0,08 | 16,8    | 2,1   | 21,2  | 19,6 |      |      |      |
|          | 26.09.2009 | 2                    |    |    |    |    |    |    |    |    |    | 1            | 4  | 4        | 5  | 7   | 13 | 1  | 0,44 | -0,01     | 34,2  | 2,4     | 17,5  | 15,1  |      |      |      |      |
| Fall     | 24.10.2009 |                      |    |    |    |    |    |    |    |    |    | 2            | 3  |          |    |     | 24 | 6  | 2,38 | -0,03     | 20,7  | 2,4     | 16,6  | 22,3  |      |      |      |      |
|          | 21.11.2009 |                      |    |    |    |    |    |    |    |    |    | 14           | 1  |          |    | 8   |    |    |      | 3         | 0,33  | 0,33    | 36,5  | 6,9   | 9,4  | 11,2 |      |      |
|          | 19.12.2009 | 2                    | 1  |    |    |    |    |    |    |    |    |              |    | 1        | 2  | 1   |    |    |      | 20        | 0,02  | 10,93   | 37,7  | 6,6   | 4,8  | 4,1  |      |      |
| Spring   | 20.02.2010 |                      |    |    |    |    |    |    |    |    |    | 2            |    |          |    |     |    |    |      | 0,08      | 4,90  | 34,4    | 6,7   | 7,2   | 14,6 | 2010 |      |      |
|          | 20.03.2010 |                      |    |    |    |    |    |    |    |    |    | 5            |    |          |    |     |    |    |      | 0,07      | 0,28  | 36,9    | 6,6   | 8,5   | 12,5 |      |      |      |
|          | 17.04.2010 | 2                    |    |    |    |    |    |    |    |    |    | 2            |    |          |    |     |    |    |      | 0,81      | 0,27  | 40,6    | 6,3   | 13,6  | 20,6 |      |      |      |
|          | 22.05.2010 | 2                    |    |    |    |    |    |    |    |    |    |              | 6  |          |    |     |    |    |      |           | 1,52  | 0,34    | 47,9  | 2,1   | 15,6 |      | 17,2 |      |
|          | 19.06.2010 | 5                    |    |    |    |    |    |    |    |    |    | 4            |    |          |    |     |    |    |      | 4,05      | 1,05  | 45,5    | 2,0   | 21,2  | 24,8 |      |      |      |
|          | 24.07.2010 |                      |    |    |    |    |    |    |    |    |    | 1            |    |          |    |     |    |    |      | 1,68      | na    | 36,0    | 2,1   | 23,6  | 22,1 |      |      |      |
| Fall     | 21.08.2010 |                      |    |    |    |    |    |    |    |    |    | 1            | 2  |          |    | 4   | 9  | 1  | 1,77 | na        | 39,5  | 5,8     | 23,2  | 24,1  |      |      |      |      |
|          | 18.09.2010 |                      |    |    |    |    |    |    |    |    |    | 2            | 8  |          |    |     | 3  |    |      |           | 0,64  | na      | 36,5  | 6,7   | 19,9 | 26,6 |      |      |
|          | 24.10.2010 | 1                    |    |    |    |    |    |    |    |    |    | 2            |    |          |    | 3   | 5  | 2  | 1    | na        | na    | na      | na    | 13,0  | 12,4 |      |      |      |
|          | Total      | 6                    | 8  | 30 | 5  | 4  | 4  | 43 | 2  | 4  | 38 | 9            | 19 | 3        | 94 | 185 | 45 | 34 | 1,22 | 1,05      | 34,96 | 4,19    | 15,66 | 17,34 | Mean |      |      |      |

**Appendix 7.** The identity card of Lake Çubuk

| THE IDENTITY CARD OF LAKE ÇUBUK                                                     |               |                 |                                                                                                                                                                                                               |                    |                       |       |            |          |           |
|-------------------------------------------------------------------------------------|---------------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|-----------------------|-------|------------|----------|-----------|
| Length                                                                              |               | 685 m           |                                                                                                                                                                                                               | Surface area       | 16.03 ha              |       |            |          |           |
| Width                                                                               |               | 430 m           |                                                                                                                                                                                                               | Volume             | 651300 m <sup>3</sup> |       |            |          |           |
| Shorline                                                                            |               | 2000 m          |                                                                                                                                                                                                               | Age                | 1400 years            |       |            |          |           |
| Min. Depth                                                                          |               | 4.7 m           |                                                                                                                                                                                                               | Altitude           | 1032 m                |       |            |          |           |
| Max. Depth                                                                          |               | 8.5 m           |                                                                                                                                                                                                               | Latitude           | 40°28'91"N            |       |            |          |           |
| Mean Depth                                                                          |               | 6.24 m          |                                                                                                                                                                                                               | Longitude          | 30°50'09"E            |       |            |          |           |
| CLASSIFICATION                                                                      |               |                 |                                                                                                                                                                                                               |                    |                       |       |            |          |           |
| Date                                                                                | Trophic State |                 | Hydrochemical                                                                                                                                                                                                 | Density            |                       |       |            |          |           |
|                                                                                     | CTSI          | BTLI            | Piper Plot                                                                                                                                                                                                    | g.cm <sup>-3</sup> |                       |       |            |          |           |
| 2008                                                                                | Oligotrophic  | Mesotrophic     | Calcium Bicarbonate                                                                                                                                                                                           | 0.9989             |                       |       |            |          |           |
| 2009                                                                                | Oligotrophic  | Mesotrophic     | Calcium Bicarbonate                                                                                                                                                                                           | 0.9991             |                       |       |            |          |           |
| 2010                                                                                | Mesotrophic   | Eutrophic       | Sodium Bicarbonate                                                                                                                                                                                            | 0.9988             |                       |       |            |          |           |
| Mean                                                                                | Oligotrophic  | Mesotrophic     | Calcium-dominated                                                                                                                                                                                             | 0.9989             |                       |       |            |          |           |
| Date                                                                                | Mixing        | Wedderburn      | Hardness                                                                                                                                                                                                      | Stratification     |                       |       |            |          |           |
| 2008                                                                                | Dimictic      | Sublayer Mixing | na                                                                                                                                                                                                            | Low (0.75)         |                       |       |            |          |           |
| 2009                                                                                | Dimictic      | Sublayer Mixing | Moderately Hard                                                                                                                                                                                               | High (1.59)        |                       |       |            |          |           |
| 2010                                                                                | Dimictic      | Surface Mixing  | Soft                                                                                                                                                                                                          | Medium (1.18)      |                       |       |            |          |           |
| Mean                                                                                | Dimictic      | Quite Mixing    | Soft                                                                                                                                                                                                          | Medium             |                       |       |            |          |           |
|  |               |                 | <table><tr><th>SHAPE</th></tr><tr><td>Paramecium</td></tr><tr><th>CREATION</th></tr><tr><td>Landslide</td></tr></table>  |                    |                       | SHAPE | Paramecium | CREATION | Landslide |
| SHAPE                                                                               |               |                 |                                                                                                                                                                                                               |                    |                       |       |            |          |           |
| Paramecium                                                                          |               |                 |                                                                                                                                                                                                               |                    |                       |       |            |          |           |
| CREATION                                                                            |               |                 |                                                                                                                                                                                                               |                    |                       |       |            |          |           |
| Landslide                                                                           |               |                 |                                                                                                                                                                                                               |                    |                       |       |            |          |           |

## CURRICULUM VITAE

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### **Publications :**

#### International Journal Articles

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# PHOTOS



**Photo 1.** 20.03.2010, alone with lake.



**Photo 2.** 28.03.2009, lonely in spring, close to L5.



**Photo 3.** 19.12.2009, hard working at littoral station L1.



**Photo 4.** 19.12.2009, windmills close to L1 station.

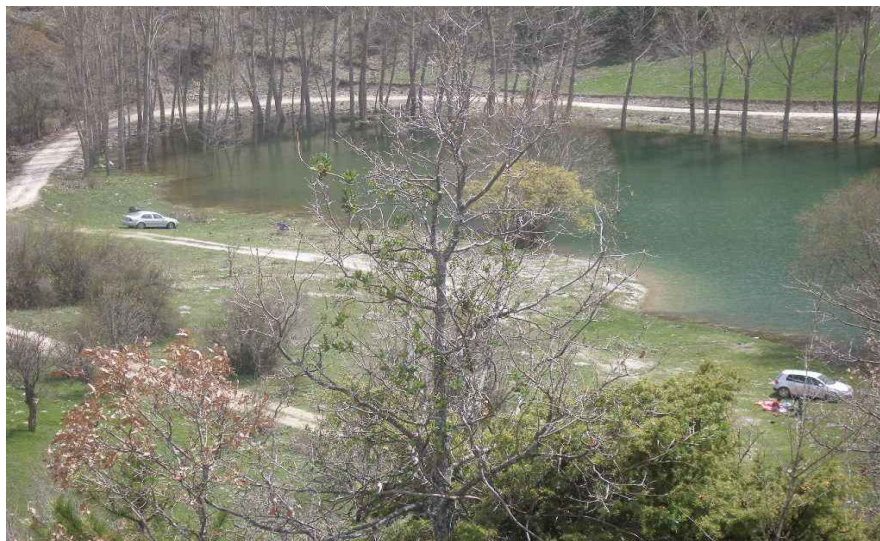


**Photo 5.** 17.04.2010, picnic place, littoral station L2.



**Photo 6.** 17.04.2010, overflow, littoral station L4.



**Photo 7.** 18.09.2010, the general view of lake from L5.



**Photo 8.** 18.09.2010, view of lake above littoral station L3.



**Photo 9.** 19.12.2009, established friendships, leader of team with a leader.



**Photo 10.** 20.03.2010, a worker in harmony with himself.

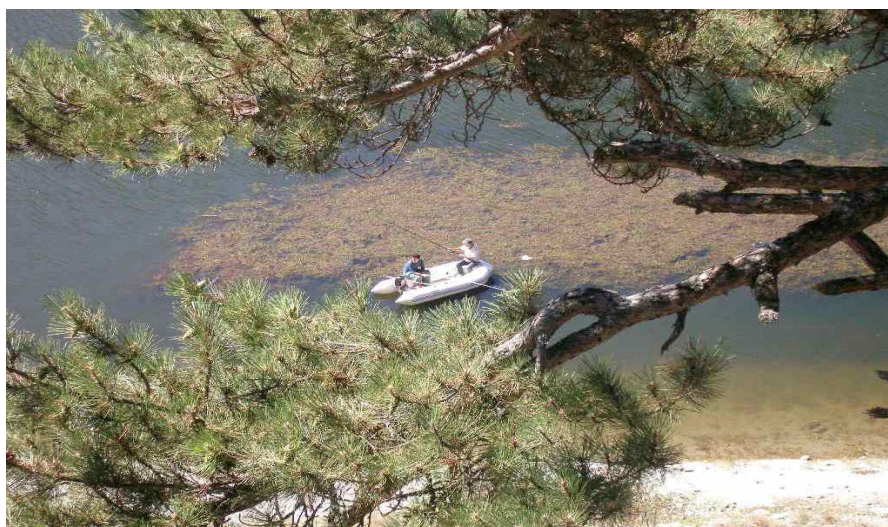


**Photo 11.** 18.09.2010, fishing and to be fished, L3.



**Photo 12.** 18.09.2010, studying at L5.



**Photo 13.** 18.09.2010, struggle with macrophytes close to L5.



**Photo 14.** 18.09.2010, Çubuk village, quite and peaceful.



**Photo 15.** 19.12.2009, dance with shadow.