PALEOLIMNOLOGICAL INVESTIGATIONS FROM MODERN COASTAL LAKES ON THRACE AND BLACK SEA COAST OF TURKEY DURING THE MID-LATE HOLOCENE

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ABSTRACT

PALEOLIMNOLOGICAL INVESTIGATIONS FROM MODERN COASTAL LAKES ON THRACE AND THE BLACK SEA IN TURKEY DURING THE MID-LATE HOLOCENE

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Here, we provide results of mid/late Holocene fresh water Ostracoda analyses from coastal modern lake basins in the Thrace region of Istanbul and Sarıkum Lake, on the Black Sea coast near Sinop. While neither diatoms nor Cladocera are abundant in the sediments, Podocopian (fresh water) ostracods preserved well, but with discontinuous occurences during the mid/late Holocene. Un-noded forms of *Cyprideis torosa*, along with other Podocopian ostracods, dominated the sediments of all three lakes. Studying these three lagoonal basins along the Black Sea and Thracian coasts of Turkey allows reconstruction of long term, regional environmental histories, using the following methods. Loss-on-ignition (LOI) analyses at 1 cm intervals of short and long cores provide stratigraphic cross-correlation and calculations of organic matter, carbonate and mineral weight. At 5 cm intervals, spectrally-inferred chlorophyll-a contents by visible reflectance spectroscopy (Michelutti et al., 2010), provide estimates of algal production. Trace element analysis (Mg/Ca and Sr/Ca) using ICP-AES (coupled plasma atomic emission spectroscopy) is applied to fully calcified adult specimens of un-noded forms of *Cyprideis torosa* shells (which dominate the uppermost 145 cm of Terkos Lake). ^{210}Pb and ^{137}Cs dating of short cores, and AMS ^{14}C dating of long cores, are used to infer sediment accumulation rates and to place specific ages on inferred environmental changes. Benthic foraminifers, gastropods, bivalves, single valves of fossil Glochidia, and Charophyte seeds are the other biological indicators observed within the sediment archive. Based on these data: 1. Terkos Lake sediments contain records of multiple, sub-millennial scale marine incursion events, over the last 2.8 ka, inferred to be the result of severe storms or tsunami on the Black Sea, including the tsunami in AD 1598 and AD 557-543; 2. short core sediments from Sarıkum Lake reveal sharp decreases in organic matter, carbonate, and increases in algal production and sand amount that suggest a storm or more recent earthquake; such as the Great Erzincan Earthquake (26 December, 1939) or the Bartın earthquake (3 September, 1968) while four more such events appear in the undated sediments of the Sarıkum Lake long core; and 3. a large earthquake in AD 447 that affected the entire Sea of Marmara (Leroy et al., 2002) does not appear in the Büyükçekmece Lake sediment record, but there is evidence for a significant hiatus in these deposits before the development of the dam (AD 1989) and after the youngest AMS date (2400 cal yrs BP). This suggests that Büyükçekmece Lagoon was an environment of net erosion prior to its artificial impoundment, either from gradual processes or from scouring by one or more tsunami.

Keywords : Ostracods, *Cyprideis torosa*, Thrace, Black Sea, coastal lakes, Mid-Late Holocene

ÖZ

TÜRKİYE' DE TRAKYA VE KARADENİZ KIYISI ÜZERİNDEKİ MODERN KIYISAL GÖLLERDE ORTA-GEÇ HOLOSEN BOYUNCA PALEOLİMNOLOJİK BULGULAR

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Bu çalışma ile, Istanbul'un Trakya kesimi ve Karadeniz kıyısında Sinop yakınında Sarıkum Gölü olmak üzere kıyısal modern göl tabanlarından orta-geç Holosen tatlı su ostrakod analizi sonuçlarını sağlıyoruz. Ne diyatom ne de Cladocera sedimentlerde yoğun olmamasına rağmen Podocopian (tatlı su ostracodları) ostracodlar iyi korunmuş olup orta-geç Holosen boyunca kesintili varlık göstermektedirler. Diğer Podocopian ostracodlar arasında, yumrusuz *Cyprideis torosa* fromları her üç göl sedimanıda baskındır. Türkiye'nin Karadeniz ve Trakya kıyıları boyunca bu üç lagün havzasını aşağıdaki yöntemlerle çalışılarak uzun vadeli, bölgesel çevre geçmişi ortaya çıkarılmıştır. Kısa ve uzun karotların 1 cm'lik aralıklarda yanma ile kayıp (LOI) analizi stratigrafik çapraz korrelasyonunu ve organik madde, karbonat, mineral ağırlık hesaplamalarını sağlar. 5 cm'lik aralıklarda, görünür reflektans spektroskopi ile spektral anlamlandırılan klorofil-a içeriği (Michelutti et al., 2010) alg üretimi hesaplanmıştır. ICP-AES (eşleşmiş plazma atomik emisyon spektroskopisi) kullanılarak, (Terkos Gölü'nün en üst 145 cm'sinde baskın olan) tamamen kalsifiye yetişkin yumrusuz *Cyprideis torosa* kabuklarına iz element analizi (Mg/Ca ve Sr/Ca) uygulanmıştır. Kısa karotların ^{210}Pb ve ^{137}Cs tarihlendirmeleri ve uzun karotların AMS ^{14}C tarihlendirmesi sediman birikme hızı sonucunu çıkarmayı ve anlamlandırılan çevresel değişikliklerin spesifik yaşlarını belirlemeyi sağlamıştır. Bentik foraminiferler, gastropodlar, çift kabuklular, fosil Glochidia'nın tek kabukları ve Carophyte tohumları, sediman arşivi içinde gözlemlenen diğer biyolojik indikatörlerdir. Bu verilere dayanarak şu sonuçlara ulaşılmıştır: 1. Terkos Gölü sedimanı İS 1598 ve İS 557-543' deki tsunamiler dahil son 2800 yıl boyunca, Karadenizde fırtına veya tsunami yüzünden olduğu düşünülen birden çok, binyıl öncesi, deniz baskını olayları içerir. 2. Sarıkum Gölünden alınan kısa karot Büyük Erzincan Depremi (26 December, 1939) veya Bartın Depremi gibi (3 September, 1968) daha yakın zamanlı depremleri veya fırtına olaylarını akla getiren organik madde, karbonatta ani düşüş ve alg üretimde ve kum miktarında artışı açığa sererken buna benzer dört olay daha tarihlendirilmemiş Sarıkum Gölü uzun karotunda bulunmaktadır. 3. Tüm Marmara denizini etkileyen (Leroy et. al., 2002), İS 447'deki büyük deprem Büyükçekmece Gölü sediman kayıtlarında görünmemektedir fakat bu birikintide, 1989'da barajın yapılması ile eldeki en genç AMS yaşı olan günümüzden 2400 cal yıl öncesi arasında önemli bir kesinti olduğunun kanıtı vardır. Bu durum Büyükçekmece lagününün üzerine baraj yapılmadan önce aşamalı bir süreçle veya bir yada daha fazla tsunaminin oyması ile net erozyon alanı olmuş olduğunu akla getirir.

Anahtar Kelimeler : Ostracod, *Cyprideis torosa*, Karadeniz, kıyısal göller, Orta-Geç Holosen

To Lisa who made me love mud

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CHAPTER 1

INTRODUCTION

1.1 Paleolimnology/Paleobiology in the Quaternary Period

Paleoecological data from natural archives are useful when long term monitoring is not evident. Paleoecology can address specific conservation issues such as habitat naturalness, natural variability, disturbance regimes, biological invasions and ecosystem health (Wills & Birks, 2006). Paleolimnology uses lake sediments as a natural archive to track long-term environmental and climate change by means of proxy data. The diagnostic tools used by paleolimnologists are the physical, chemical, and biological indicators preserved in sedimentary profiles. With these tools, we can estimate background or reference conditions and natural variability, determine when the system became stressed, and infer the causes of these stresses (Smol, 1992; Smol, 2002). Long-term environmental data, created using indirect proxy methods, provide crucial information for the effective management of our aquatic resources. It can help to identify which species will be most vulnerable to future changes. Historical perspective (time series data) is highly valued in ecosystem management because it allows us to develop both past, and future scenarios. Short-term studies can lead to erroneous conclusions by missing infrequent, stochastic, but important random events (Wiens, 1977 adopted from

Weatherhead, 1986). Short-term studies, conducted during an interval of many unusual events, can lead to false interpretations about variability over longer time-scales.

The Quaternary is the geologic time period that we are living in today, and includes the last 2.588 million years (Gibbard and Head, 2009). Sediments, ice sheets and landforms that are young, with more complete records, and resolvable at decadal- to centennial-timescales are the preferred subjects for Quaternary studies (Clauge, 2008). Quaternary scientists provide keys to improving our understanding of the physical processes responsible for natural disasters and for providing reliable data on the frequency and magnitude of past events, such as earthquakes, tsunami, volcanic eruptions, floods and severe storms. This knowledge helps to reduce societal risk (Clauge, 2008). Quaternary history, dominated by the effects of climate change, is the most easily studied period due to the many datable records in marine sediment, Greenland and Antarctic ice sheets, tree rings and lake sediment. Quaternary science is largely interdisciplinary, generally involving teams comprised of geologists, oceanographers, glaciologists, geographers, biologists, chemists, and many others (Clauge, 2008). Within Quaternary studies, investigations of lake sediments have created an enormous “library” of information about lake development and the effects of environmental stressors on lake ecosystems. In this sense, paleolimnology is used to understand the effects of a history of stress, and responses to that stress, by both resistant and susceptible lake systems, an important management issue. The Holocene is most recent epoch of the Quaternary Period and is the timeframe for the work presented here. The Greenland ice core from North GRIP (NGRIP) provides an age of 11,700 calendar years (before AD 2000) for the base of the Holocene, with a maximum counting error of 99 yr (Walker et al., 2009).

The last major climatic transition in most cool-temperate regions occurred around the Pleistocene-Holocene boundary as a result of complex interactions between orbital forcing, atmosphere, ocean and land surface conditions. Repeated, abrupt climate changes appear in isotope records for the Northern Hemisphere, during the last glaciation and early Holocene (Stuiver and Grootes, 2000). These changes also appear in lake level changes in tropical and southern temperate regions. Africa, for instance, experienced significant hydrological fluctuations in the Holocene, with droughts around 8.48 ka and 4.24 ka BP in the northern monsoon domain (Gasse, 2000). During the early Holocene, South West Asia experienced a climate drier than at present (Roberts et. al., 2001). Nevertheless, a Holocene climatic condition in the coastal zone of the eastern Mediterranean region is less clear and needs further studies. The aim of this study is to develop multiple time series of Holocene fresh water ostracoda fauna along the Black Sea coast of Turkey and to differentiate the effects of climate change, tsunami and synoptic storm events by means of multi-proxy approach. Our objective is to identify any regional or local catastrophic events preserved in the sediments. To accomplish this aim, sedimentary archives from coastal lakes are used.

CHAPTER 2

PREVIOUS STUDIES

2.1 Holocene Paleoecology of Turkey

Paleoecological work in Turkey started with ancient palynology studies by Robert J. Braid in the early 1960s, aimed at reconstructing palaeoenvironments of early humans (Bottema 1995). Near East pollen sequences display a marked contrast from the glacial period (Pleistocene) to post glacial (Holocene) when tree pollen types replaced steppe herb pollen types (Bottema, 1995). The shift from Pleistocene steppe biome to modern woodland is also documented in the southwest of Turkey by Elenga et al. (2000). A distinct shift in these Near East pollen sequences indicates that increased moisture encouraged tree growth in southwestern Anatolia after 9000 BP and in eastern Turkey after 7000 BP (Bottema, 1995).

Climate shapes the landscape and vegetation, but thoughtful consideration needs to be given to interpretations, since the same signals may be caused by other factors (e.g. anthropogenic impacts). Pollen diagrams in southwest and central Anatolia display not only vegetation dynamics but also anthropogenic impacts on the environment during the mid-Holocene (Eastwood et al., 1999b; Bottema and Sarpaki, 2003). These human impacts could obscure climatic information for the mid-Holocene. A noticeable change in the pollen record that can be attributed to human impact on the environment is a decrease in forest pollen species and increase in ancient agriculture development during Neolithic (near the beginning of Holocene) (Bottema, 1995). A major, mid-late Holocene period of human impact in Anatolia, known as the Beyşehir Occupation phase(BOP) and first recorded in Lake Beyşehir is dated circa 3000 BP (Eastwood et al., 1999b).

Other pollen evidence of human influence on the landscapes of Turkey is associated with decreased pollen from forest species and increased pollen from cultivated types, such as cereals, weeds, walnuts, olives and grapes. This is highlighted in a well-dated pollen sequence from Golhisar Lake, Burdur (Eastwood et. al., 1999b), with evidence for cultural landscapes appearing at the end of the Early Bronze Age, ca. 3000 BP (Eastwood et al., 1999a). Human induced landscape change during the Holocene is also evident in multi-proxy indicators (pollen, stable isotopes, and charcoals) for Central Anatolia (England et. al., 2008). In the annually-laminated sediments of Nar lake, Cappodocia, the BOP is followed by establishment of woodland from AD 670 to 950 and then re-establishment of cereal-based agriculture after AD 950 (England et. al., 2008).

In the last few decades, long-term environmental history studies of Turkey, by geologists, geographers, and archaeologists, include an expanded toolkit for reconstructing Holocene climate, environmental and land use changes that includes pollen, diatoms, ostracods, physical sediment characteristics (grain size, carbon and pigments content, environmental magnetism, trace element geochemistry) and oxygen and carbon isotopes of lake sediments.

2.2 Evidence of Past Catastrophe

Lake sediments not only keep the information of palaeoenvironments in a region but also provide answers to questions such as when a catastrophic event occurred and what was its distribution. Volcanic ash deposits, or tephras, of the massive eruption of Thera, on the Aegean island Santorini, (Driessen & Macdonald, 1997) were found in the lake sediment cores from Gölcük (Sullivan, 1988) in western Turkey, from Köyceğiz (Sullivan, 1990) and from Gölhisar (Eastwood et al., 1999a) in southwest Turkey and deep sea cores from the Black Sea (Guichard et al., 1993). Peat samples just below this tephra in Gölhisar Lake, are dated 3330 ±70 yrs BP and 3225 ±45 yrs BP (Eastwood et al.,1999a).

Lake sediments can also preserve palaeotsunami records in coastal areas, including those of the small seas around Turkey. According to Leroy et al. (2002), seismites in Lake Manyas sediments are from a tsunami that followed a large earthquake in AD 447, affecting the entire Sea of Marmara. Paleotsunami related changes here are also recorded in Hersek Lagoon, at the north end of the Sea of Marmara, (Bertrand et al., 2011).

In locations, such as in Anatolia, where anthropogenic factors are the predominant influence on faunal and floral assemblages, stable isotopes can provide much useful information about paleoclimatic condition. Oxygen isotope data from the entirely groundwater-fed ancient crater lake, Eski Acıgöl, in Central Anatolia, indicates deep, dilute lake conditions from the onset of the Holocene until ca. 6500 cal yr BP, after which there was a permanent fall in lake level (Roberts et. al., 2001) (Eastwood et. al., 2007). In varved sediments of

Cappadocia's Nar Lake, for instance, oxygen isotope values vary between more negative values, around AD 530, to more positive isotope values around AD 800 and AD 1400, indicating switches between cold and warm climate conditions (England et. al., 2008). Although, their findings refer to arid-semi arid Central Anatolian climate conditions, by comparing these findings with those of the coastal lake archives located in the north, north-western part of Turkey (e.g.Terkos, Büyükçekmece, Sarikum), it is possible to conclude whether a climate event is local or regional in extent. Evidence of trends and multi-centennial oscillations in Turkey's climate, with arid phases around 5300-5000 BP, 4500-3900 BP, and 3100-2800 BP (calibrated cal years) in the eastern Mediterranean, are reviewed by Roberts et al. (2011) using the lake sediment cores, cave speleothems, deep sea sediment core records.

2.3 Regional Palaeoecology in Turkey - Central Anatolia

The sensitivity of the endorphic lakes located in Central Anatolia to salinity and water level change (i.e. Beklioglu et al., 2006) makes them useful in terms of their diatom records (i.e. Leng et al., 1999; Roberts et al., 2001; Kashima, 2003; Woodbridge and Roberts, 2010). However, records from two adjacent lakes, Pinarbasi and Suleymanhaci, show different hydrological regimes (Reed et al., 1999) even though both are residual water bodies of a single, larger and fresher palaeolake in Konya basin. This underlines the importance of site selection for climate-related palaeolimnological investigations. Late Quaternary lake level changes of Konya Basin have been intensively investigated by KOPAL - the Konya Basin Palaeoenvironmental Research programme (Roberts et al., 1999). While the Konya Basin, for the most part, has been dry except for residual marshes and small lakes during the 20th century, it has experienced alternate, climatically controlled lake expansion and contraction over the Late Quaternary with a single extensive lake occupying the basin for no more than 6-7 ka out of the last 50 ka (Roberts et al., 1999).

A climatic change during the Late Quaternary has also been studied by Kashima (2003), in central Anatolia, using diatom assemblages of sediments. In his study, cyclical changes of diatom-inferred salinity (DIS) during the Late Quaternary indicates that high salinity levels were present ca. 10, 100–130 and 200 ka, related with interglacial warm periods, and low salinity levels at 20–30 and 150–160 ka, corresponding to the maximum stages of glacial periods.

2.4 Regional Palaeoecology in Turkey - Eastern Turkey

Lake Van, in eastern Turkey and one of the largest and deepest (440 m) strongly saline soda lakes in the world, has a special importance in terms of paleoenvironmental studies because of its laminated sediments that keep information about late Quaternary environmental changes. For instance, Wick et al (2003) dated the Younger Dryas (HO) event in the Lake Van original varve chronology at 12- 10,5 ka. Lake Van has been under the scope of PALEOVAN project, investigating Quaternary climate evolution in the Near East, within International Continental Scientific Drilling Program (ICDP) (Litt, et al., 2009).

2.5 Regional Palaeoecology in Turkey Coastal Regions

Coastal systems in Turkey are rarely utilized sources of information for palaeolimnological studies. They are dynamic systems and long, continuous records from these types of sediments are unlikely. Short-term physical processes or longer-term changes in climate, eustatic sea level and isostatic land level change are possible driving forces for many of the biological, chemical and sedimentological processes that occur in the coastal systems. Of these, the events with larger impact and of more recent origin are the most likely to be preserved in the sediments. Recently, the sedimentary record of lakes Manyas, Sapanca, Ulubat and Hersek are used as natural archives for paleoseismicity on southern coast of the Sea of Marmara by means of seismites and faunal and palynological remains (Bertrand et al., in press; Gürbüz and Leroy, 2010; Kazancı et al., 2004; Leroy et al., 2002, 2009, 2010; Leroy and Albay, 2010).

2.6 Ostracods as a tool for studying the Palaeoecology of Coastal Regions

Cyprideis torosa (Jones, 1850) is a dominant ostracod species in brackish water bodies in Europe, North America, Asia and Africa. It is a common member of European coastal communities with a known salinity range of 0-60‰ (De Deckker, 1981, adopted from Meisch, 2000). *C. torosa* belongs to the Cytheroidea Superfamily and the Cypridoidea Family. Cytheroidea is common in a wide range of environments from non-marine continental waters bodies to brackish estuaries, lagoons, and marginal seas while Cypridoidea is common in brackish and non-marine, continental waters.

C. torosa comes with two extreme forms: un-noded and noded valves. Noded and smooth forms may be found in a single population, depending on the local salinity range. Noding can be used as an environmental marker for low salinity and/or low calcium content (Keyser, 2005). Ostracods moult their bivalve shells up to 7 times before reaching adult stage, incorporating elements from the host water at the time of shell formation. *C. torosa's* large adult size (1.2 mm) makes it relatively easy to isolate specimens for trace element and stable isotope analyses (weight of sample). Magnesium (Mg) and strontium (Sr), among other elements, occur in trace concentrations within the calcium carbonate lattice during calcite formation. Coefficients of partitioning (KD values) for Mg and Sr in living ostracods has been established from the composition of new shells (Chivas et al. 1986) and potential for relative paleosalinity records exists using Sr/Ca ratios (Holmes, 1996). Since *C. torosa* can reproduce both sexually and asexually, ratios of males versus female and adults versus juveniles is used to infer the environment of deposition (Boomer et al., 2003).

CHAPTER 3

SITE DESCRIPTION

3.1 Climate

The sites selected for this research are Terkos and Büyükçekmece Lakes, in the Thrace region of Istanbul, and Sarikum Lake, on the Black Sea coast near Sinop (Figure 1-2). All of Turkey's coastlines are in the semi-arid Mediterranean climate zone, experiencing strong seasonality of rainfall and air temperature. While the annual rainfall-to-potential evapotranspiration ratio of 0.12 to 1 results in water shortages and droughts in many Mediterranean landscapes for a considerable time of the year (Cobelas, 2005), along the Black Sea rainfall is relatively uniform during the year with a maximum in autumn (Türkeş, 1998). Between 1930 and 1993, mean annual rainfall was 656 mm for Sinop, and 639 mm for Florya, a suburb of Istanbul along the Marmara Sea (Türkeş, 1996). The mean winter temperature at each of the study sites is 6°C, according to observed monthly mean temperatures between 1929-2003 for 70 stations all over Turkey (Türkeş & Erlat, 2008). Stronger negative correlation coefficients between precipitation in Turkey and North Atlantic Oscillation (NAO) indices in winter and autumn were revealed by Türkeş and Erlat (2003). During the strong phase of the Arctic Oscillation (AO), a strong anticyclonic anomaly circulation also dominates Turkey, with northerly and northeasterly airflows from polar regions dominating over the Black Sea (Türkeş & Erlat, 2008). Mid-latitude storm tracks over Europe and Mediterranean are a main impact on the hydroclimate of the Mediterranean region during winter (Brayshaw et al., 2010). Increase in storm activity would be associated with precipitation (Brayshaw et al., 2010). A shift in the pattern of precipitation from wetter to drier conditions in the Mid-Holocene, by means of isotopic data from lakes in Turkey (Roberts et al., 2001) and a long term aridity trend during the Holocene in the Mediterranean and Middle East, based on climate models, are reported (Brayshaw et al., 2010; Black et al., 2011). In Early to Mid-Holocene North Atlantic storm tracks were weaker and further south although Mediterranean storm tracks may have been stronger than at present (Brayshaw et al., 2010). Sediments from lagoonal lakes located on the coastline in the southern part of the Black Sea are expected to contain records of past massive storm events, such as the November 18, 2007 storm which had catastrophic impact on the south-eastern Black Sea coast. 32 storms with significant wave heights more than 6 m were considered in the North East Part of Black Sea by Kuznetsov et al (2005). The average storm frequency in the Azores region is 3.1 storms/year between 1836 and 1998 (Andrade et al., 2008). Negative precipitation anomalies occur during positive phases of the NAO in the Azores and the Black Sea region (Trigo et al., 2004; adopted from Andrade et al., 2008). NAO influenced storminess over the Azores region for a century after AD 1865 however this influence vanished after 1960 (Andrade et al., 2008). These records may occur as a coastal flooding, temporary marine incursions from wave over wash and sea salt aerosols off wave tops, with minimal sand inputs, or as a barrier breach with significant marine influx and sand deposits over a multi-year period.

3.2 Tsunami Hazards

The North Anatolian fault (NAF) is one of three main fault zones in Turkey that make it seismically quite active. The NAF extends from eastern Anatolia to the northern part of the Aegean Sea, paralleling the Black Sea coast about 50-80 km inland (Kuran and Yalçiner, 1993). Tsunamis in the sea of Marmara, northern Aegean and the Black Sea, triggered by large earthquakes along the NAF, are not uncommon (Kuran and Yalçiner, 1993), with 90 tsunamis reported on or around Turkish coasts for the period between 1410 +/-100 B.C and 1999 A.D. Most of these are associated with Istanbul earthquakes (Altınok & Ersoy, 2000). According to Yalçıner et al. (2004), 22 tsunami events have occurred in the Black Sea since the 1st century AD. Ambraseys (2002) also documented seismic activity of the Marmara Sea region over the last 2000 years. At least one tsunami is known to have reached each of the study sites in the last 500 years. In 1598 AD, a major earthquake in north central Anatolia, the Amasya and Corum earthquake (Yalçiner et al., 2004; Altınok & Ersoy, 2000), created a tsunami in the gulf between Sinop and Samsun (Nikonov, 97., adopted from Altınok & Ersoy, 2000). The Istanbul earthquake of 1891 AD (Altınok & Ersoy, 2000) created tsunamis affecting shorelines from Büyükçekmece to Kartal (Öztin & Bayülke, 1991; adopted from Altınok & Ersoy, 2000). A tsunami with no obvious seismic origin was reported on 7 May, 2007, on the Bulgarian Black Sea coastline (Vilibic et all., 2010), probably as a result of submarine landslide (Altinok et al., 2011; Moscardelli et al., 2010).

3.3 Terkos Lake

Terkos Lake (41º33´N, 28º60´E) is a nutrient rich, well-mixing and relatively shallow land-locked lagoon within coastal dune fields of the Black Sea coast. Today, it functions as a bird sanctuary and is used for fishing and drinking water. In fact, it is (together with Büyükçekmece lagoon) one of the most important sources of drinking water for Istanbul's residents. The maximum water depth was 11m in AD 2008, in the main basin. The only recorded bathymetric map of Terkos was developed in 1943 AD, prior to the most recent dam improvements. Despite this, its morphology has changed relatively little since then, except for expansion of the lake into surrounding river valleys and slight increases in the depth of bounding marshlands. The minimal effect of these post-1943 modifications on the overall extent of the lake is due to steep topography around the lake, especially on the southern margin. Terkos' first dam, 2.5 m high, was built in the 1880's. Since then, there have been two dam modifications. The first one, in AD 1960, added 4.5 m height to the original dam, while the second one, in AD 1980, added 3.5 m height (personal communications, Ahmet Uçar, Terkos general manager in 2008).

The small increases in lake extent that followed the last dam modification enhanced an ongoing problem of barrier loss towards the Black Sea by increasing wave-battering and soil erosion along the susceptible dunes of the lake's northern shore. Recent remote-sensing analyses indicate that, at its narrowest point, the land barrier between the Black Sea and Terkos Lake has thinned from 430 m to 230 m within 14 years, between 1984 and 1998 (Maktav et al., 2002). To cope with this problem, in 1974 AD a large area around Terkos Lake was forested with *Pinus pinaster Ait., P. maritime L., P. pinea L.,* and leguminosae (Saatçioğlu, et al., 1978). Dominant NE and NW winds carry sands from the dunes into Terkos Lake, especially during the summer months when the sand is more mobile due to drought (Saatçioğlu et al., 1978).

In addition to the erosion of the barrier dune field, Zebra mussel, eutrophication, sediment-infilling, heavy-metal enrichment, lead poisoning from gunshot, and pressure of urban development and increasing human population size are the ongoing problems for Terkos Lake. “When Constantinople was taken during the Fourth Crusade (AD 1204), the city’s population numbered 400,000 inhabitants, according to Geoffrey of Villehardouin” (adopted by Magdalino, 1993). During the last few decades, population has grown to over 13 million people (Turkish Statistical Institute, 2011). Naturally occurring water resources on the European side of the Bosphorus are, and always have been, scarce. In the 4th century AD, this led to construction of what may be the longest ancient aqueduct system of Mediterranean world, in Istanbul (Bono and Bayliss, 2001).

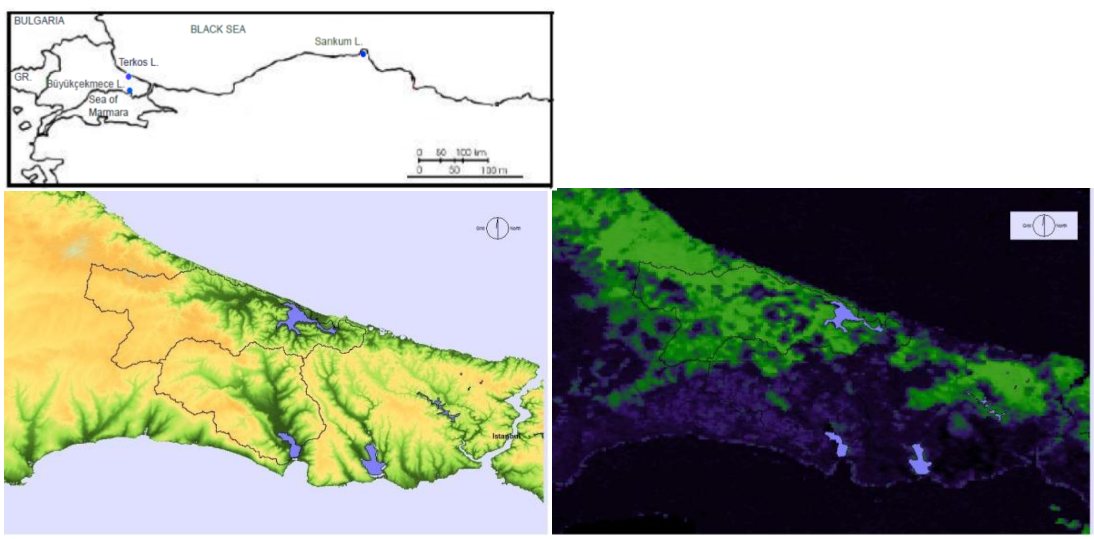


Figure 1. Maps of watershed boundary and forest closeness of Terkos and Büyükçekmece Lakes.

Besides the water-supply deficiency, attack from the west was an important problem for Istanbul during the 4th century AD, because of the absence of natural barriers on that side. Consequently, “The Long Walls of Thrace” were built during the Roman period (Crow, 1993). Although the variety of forms in the Long Walls suggests a number of different periods of construction (Crow, 1993), this must have an important affect on the drainage system of Terkos Lake, or by its old name, Derkos Lake (Durusu Gölü). The Long Walls extend from the Black Sea to the city and cut across the Yıldız R. which flows north-east to Terkos Lake (Crow, 1993).

3.4 Büyükçekmece Lake

Büyükçekmece Lake (41° 04'N, 28°33'E) is another source of drinking water for Istanbul’s residents, today. Like Terkos, Büyükçekmece is a dammed lagoon, but on the Marmara Sea. The dam was built between AD 1983-1988 across the meandering channel connecting the lagoon to the sea. In AD 1943, Büyükçekmece’s lagoon had maximum water depth of 1.7 m, in a shallow basin near the outlet. One main channel drained the northern reaches, which were marsh areas of less than 1 meter depth. The salinity of the northern portion at that time is still unknown but locals claim the lake was fresh water almost to the outlet well before the dam was built. If this is accurate, then the freshwater inputs were presumably enough to prevent tidal incursions in average-to-wet years. Today, the maximum depth is about 6 m, a general increase of 4.3 m since 1943 AD, and associated with a drastic change in the lake’s morphology.

One of the most significant effects of these changes in depth and extent, in terms of ecosystem and coastal management at Büyükçekmece, is the loss of a large area of freshwater marsh which served as a natural fishery and important bird habitat (Environment Foundation of Turkey, 1989). The increase in lake level also increased the area available for generating wind-driven waves (fetch) and decreased the amount of near-shore, rooted, aquatic vegetation. These two factors now leave large areas of shore unprotected against waves which are generally larger and of greater energy than before the lake level change. Thus, the dam-related increase in lake level at Büyükçekmece dramatically increased the available energy for transporting sediments and eroding shorelines while trapping these sediments in the impounded lake. Significantly higher sedimentation rates are expected as a result (Doner and Yalçinar, 2006).

This site has also regional importance since it is seismically active, with recent research concentrated on the location of active submarine faults of the Sea of Marmara. As part of this project, marine incursion events at Büyükçekmece are being examined to determine if they correspond to seismites found on the south side of the Sea of Marmara by (Leroy, et al., 2002). The bedrock around the lake is composed of Quaternary, Miocene and Pliocene carbonates (Ilhan, 1976).

3.5 Sarikum Lake

Sarikum Lake (42° 00'N, 34°55'E) is located on the Black Sea cost in the northeast part of Turkey, in Sinop District. It is a very shallow lake, with a maximum water depth of 1 m in the main basin in AD 2008 (in July). It has a relatively smaller watershed boundary (66 km^2) (Figure 2), compared to Terkos and Büyükçekmece lakes.

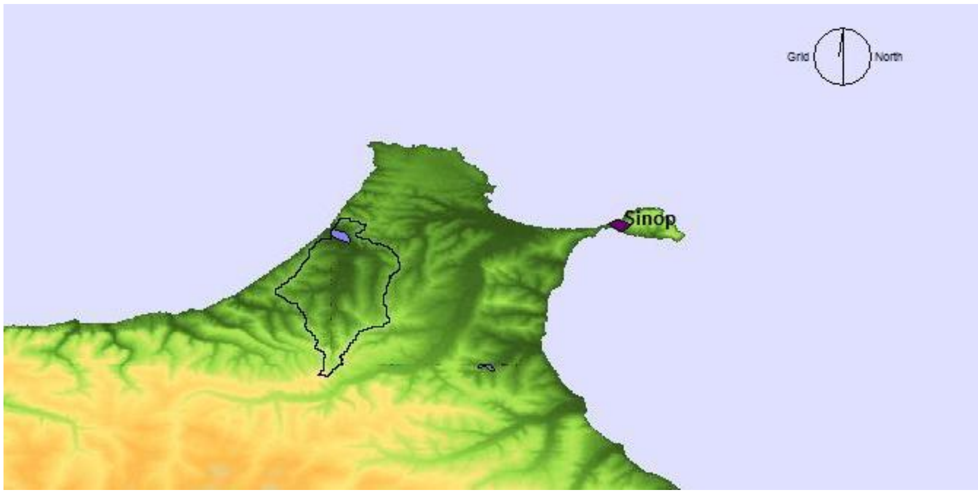


Figure 2. Map of watershed boundary of Sarikum Lake.

It is located entirely within a natural conservation area, since AD1995. Sarikum Lake is separated from the Black Sea with a thin, flat, sandy beach and a narrow channel (Figure 3) (almost 3m width).

Figure 3. Looking north from Sarikum Lake towards the sandy barrier that separates the lake from the Black Sea. The narrow channel carries fresh water from the lake, during times of inland flooding, and sea water to the lake, during very high tides, storm surge or tsunami.

Since the sandy barrier between the Black Sea and Sarikum Lake is so flat today, sea water can easily intrude to the lake and change its chemistry, even during high tides.

CHAPTER 4

METHODS

4.1 Coring, Sampling, and Archiving

Short and long sediment cores from Terkos and Büyükçekmece lakes were collected in 2005 as part of an International Fellowship with Istanbul Technical University's Eurasia Institute funded by the National Science Foundation (USA): (OISE-0401836, PI: Doner, 2004-2007). The subsamples from one core from each lake were freeze-dried and analysed for ^{210}Pb and ^{137}Cs at the St. Croix Water Research Laboratory, Minnesota, USA. The longer piston cores of Terkos and Büyükçekmece were split and photographed, and then scanned on ITU's ITRAX-XRF core scanner, in April-June, 2006. The work halves of Terkos Piston Core 2 (TLC2) and the unsplit, whole core from Büyükçekmece Piston Core 2 (BLC2) were transported to Middle East Technical University (METU) in 2006 for this PhD thesis in Paleobiology. The BLC2 cores were split at METU on September 2006. As additional parts of this Ph.D project, short cores from Sarikum, Uzun, and Cernek lakes, located along the Black Sea cost (Samsun and Sinop), were collected in July 2007. They were extruded in 1 cm intervals and subsampled in the field. Volumetric sediment samples from every centimeter were freeze dried for determination of dry density and water content essential for ^{210}Pb dating and useful for initial detection of changes in the water and organic content of the sediments. Additional short cores and surface samples were collected from Sarikum, Büyükçekmece and Terkos Lakes, in July, 2008.

A single, 4 meter-long core was collected from Sarikum Lake, in July 2008 (Figure 4), using a 50 mm diameter, modified square-rod Livingstone Piston Corer (Wright, 1967). Changes in sediment characteristics prevented retrieval of deeper-lying sediments, perhaps because of the presence of sand or dry clay. The long core from Sarikum was split, photographed, described and sampled at one centimeter, contiguous, intervals at METU. Short cores from the main basin in Sarikum Lake, and along a transect within the channel to the sea, were collected in 2008 using a modified Kajak corer. The short cores were extruded and sub-sampled at 1 cm intervals, in the field.

Only the observations on the uppermost one meter from Sarikum Lake have been studied in this project (Figure 5). Environmental variables that may be important to water quality, such as temperature and dissolved oxygen concentration, pH, and conductivity were recorded at each sampling site. During the sampling at Sarikum, in July 2008, we were quite fortunate to experience an inundation event from the sea, as a result of a multi-day storm blowing seawater against the coast during a high tide period. Maximum water level, pH, dissolved oxygen and conductivity data (Appendix A) in the channel were measured before and after the storm in a full moon (during our sampling for Sarikum Long Core 1), in 2008. Water quality (temp, pH, conductivity and dissolved oxygen) data of the freshwater state of the lake, and also of the salt-water state of the lake, one day later, are present. These samples were stored in the dark, at +4°C.

Figure 4. Long coring at Sarikum Lake in July, 2008.

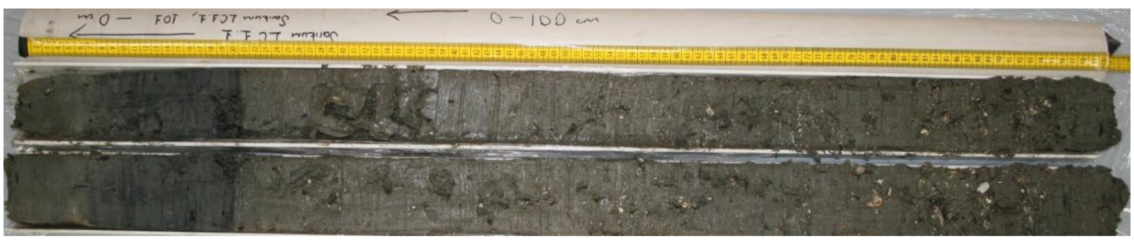


Figure 5. Uppermost 1 meter of Sarikum Long Core 1 studied in this project. Top of the core is to the left. Note the transition from brownish-gray carbonate-rich material to very dark brown, carbonate-poor gyttja, typical of productive lakes, near the top of the core.

4.2 Chronologies

^{210}Pb and ^{137}Cs ages were used to determine sedimentation rates in the upper sedimentary deposits of each lake. ^{210}Pb, a natural radioisotope, is very useful in bridging the gap between radiocarbon dating, which is applicable for materials and events that range in age from several hundred to 45,000 years old, and contemporary observations. ^{210}Pb primarily enters lake environments via atmosphere fallout. This atmospheric ^{210}Pb undergoes radioactive decay and enters a state of disequilibrium with atmospheric ^{210}Pb levels once it is incorporated in the sediment. Some ^{210}Pb enters lake environments via the uranium decay series, when any member of this series is part of the bedrock or groundwater chemistry. This portion of ^{210}Pb is part of the background signal. It is determined by measuring the decay activity in progressively older sediments until the unsupported, atmospheric ^{210}Pb component has become extinct. The remaining signal is that portion of ^{210}Pb that is constantly being renewed from uranium series decay and is more or less constant. Assuming a constant rate of supply, the logarithmic decay curve of unsupported ^{210}Pb reflects the amount of time passed since it was in equilibrium with the atmosphere (Appleby and Oldfield, 1978).

The Sarikum Short Core 1 (SSC1) was extruded in 1 cm intervals and sub-sampled in the field in July, 2007. Volumetric sediment samples from every centimeter were freeze dried for determination of dry density and water content essential for ^{210}Pb dating and for initial detection of changes in the water and organic content of the sediments. Freeze-dried subsamples from SSC1 were analysed for ^{210}Pb and ^{137}Cs dating at University College of London (UCL), Environmental Change Research Centre (ECRC) on April 2008.
AMS ^{14}C dating was used for 7 different bulk samples from different depths throughout Terkos Long Core 2 (TLC2) to establish long-term sediment accumulation rates, on December, 2009 (BETA Analytic Radiocarbon Dating).

4.3 Loss-on-ignition analyses- Organic and Carbonate carbon

Percent Loss-on-ignition (LOI) at 550°C, representing total organic matter (TOC) and 950 °C, representing total inorganic carbon (TIC) , or carbonate, has been calculated by means of the following procedure: 1-2 grams of wet sediments were heated in a muffle furnace at 105 °C for at least 12 hours to calculate the percentage dry weight. To measure TOC and TIC carbon amounts evolved on ignition, the dried sediment samples were placed in pre-weighed crucibles and heated in a furnace to 550°C for 2 hours. Samples were cooled and weighed, then reheated to 925°C for 3.5 hours (ECRC, University College of London) (Dean, 1974). This procedure was applied to every 1 cm of the Terkos Long Core 2 (TLC 2), Büyükçekmece Long Core 2 (BLC 2), and Sarikum Long Core (SLC 1) and also to Terkos Short Core 2 (TSC 2), Büyükçekmece Short Core 3 (BSC3) and Sarikum Short Core 1 (SSC 1). Short and long core sample depths from each lake were cross-correlated using loss-on-ignition results.

4.4 Chlorophyll-a determination

Spectrally inferred chlorophyll-a content (Chl-a) was determined using the visible reflectance spectroscopy method (Michelutti et al., 2010) (Paleoecological Environmental Assessment and Research Laboratory, Queen’s University). In this method, freeze dried sediment samples are sieved at 125 µm, in order to remove the influence of particle size and water content on the spectral signal (Michelutti et. al., 2010). Approximately 1 g of dry sediment is used. For this project, the method was applied to samples at 4 cm intervals from Terkos Long Core 2 and Büyükçekmece Long Core 2, and at 5 cm from Sarikum Long Core 1. In addition, 1 cm-interval samples from the uppermost 15 cm of Terkos Short Core 2, the uppermost 8 cm of Sarikum Short Core 1 and the uppermost 9 cm of Büyükçekmece Short Core 3) were analyzed. Each sample encompasses 1 cm depth.

4. 5 Ostracods

Ostracods are aquatic micro-crustaceans. Their bivalve calcite shells are an excellent fossil record preserved in the lake sediments. They have been used as a potentially valuable tool for the paleoenvironmental and present day salinity and water chemistry, temperature, dissolved oxygen level (Frenzel and Boomer, 2003., Boomer and Eisenhauer, 2002., Boomer et al., 2003). In this study, the compositions of ostracod assemblages at different sediment depths were identified to species level, taking account of taphonomic considerations. Sample sizes aimed to be about >300 specimens per sample. For this, approximately 3 cc of wet sediment per sample were sieved through a 63 µm sieve using a gentle jet of water. The last wash included pre-treatment with methanol to prepare the shells for trace element analyses (Jin et al., 2006). The coarse residue was dried and weighed. The differences of the weights of the dried coarse residue including ostracoda and wet samples used for sieving through the 63um sieve were calculated and also plotted. All ostracod valves were counted from the dry coarse residue fraction.

4.5.1 Ostracoda Species Identification on Fossil Material

Ostracod specimens were picked and mounted on slides, then identified to species level using stereo microscopes under 80x magnification. Samples were collected and analyzed for ostracods in Terkos Long Core 2 and Büyükçekmece Long Core 2, at 4 cm intervals, using 1 cm per sample, and in Sarikum Long Core 1, at 5 cm intervals. In uppermost sediments of the short cores, ostracods were analyzed every centimeter, for the uppermost 15 cm of Terkos Short Core 2, the uppermost 9 cm of Büyükçekmece Short Core 2 and few samples of

Sarikum short core 1 were used for ostracod analyses. Ostracod species are identified with the help of SEM. Reference ostracod assemblages from the top and bottom samples of short cores taken from other Black Sea lagoons (Mert, Erikli, Cernek and Uzun lakes) are used as modern comparators to the paleo-assemblages identified.

The sex of the adult species of Cyprideis torosa can be determined from carapace morphology alone (Meish, 2002), (Plate 1). When sex ratios differ from 1:1, it often means pre-maturation mortality rates differ between the sexes. The sex ratio of ostracods is a useful indicator of both reproductive strategy and paleoenvironment (Abe, 1990). While sex ratios change extensively, they vary less in the fossil record than in the living population (Abe,1990).

4.5.2 Trace Element Analyses on Ostracoda Shell

Cyprideis torosa (Jones, 1850) were used for trace element analyses (Mg, Ca and Sr), by ICP-AES (coupled plasma atomic emission spectroscopy) at the Environmental Change Research Centre, University College London. This trace element analysis was only done on fully calcified, adult specimens of *C. Torosa* shells, of both genders (Table 4). Although *C. torosa* is generally associated with fresh water conditions, it can tolerate increased salinity in an estuarine environment. We use trace element data from the shells to infer water chemistry, and so whether or not the specimens formed their shells under sea inundation or normal freshwater salinity. Ostracods moult their bivalve shells up to 7 times before reaching adult stage, building new shells from elements in the host water obtained only at the time of formation. Mg and Sr, among other elements, is incorporated in trace amounts within the calcium carbonate lattice during calcite formation. For new shells, the coefficients of partitioning (KD values) for Mg and Sr in living ostracods are already established for *Cyprideis torosa* (Chivas et al., 1986):

KD[Sr] = Sr/Ca(shell)/Sr/Ca(water) = 0.475;
KD[Mg] = Sr/Ca(shell)/Sr/Ca(water) = 0.0046.

Thus, we have trace-element data for modern specimens, for which water composition and temperature is known. Totally 98 samples were run for ICP-AES, at 4 cm intervals, between 14-142 cm in TLC 2. (Note: these are the only depths at which *C. torosa* appear in the Terkos Lake long core.) For this analysis, 3 different adult individual valves male or female/ right or left were prepared at each depth, and details were noted (gender, L/R valves, length of the valves, preservation). The results of these geochemical data (Sr & Mg) are plotted against depth-averaged values for each sample. One of the samples, at 30 cm, was skipped during processing. Averages of these 3 different results are used to represent trace element values for each sample depth.

4.6 Other Proxies

Diatoms were extracted from 0.1 g of wet sediment by boiling in 50% HCl to remove the carbonate fraction, followed by distilled water rinses, then treatment with 30% H_2O_2, to eliminate organic matter (Batterbee, 1986). One drop of the final suspension was dried onto cover slips and then mounted onto slides using Naphrax diatom mountant. Slides were analyzed at a magnification of 1000x using Leica DMRB microscopes and phase-contrast optics. Diatom slides were prepared among different samples from different depths of Terkos, Büyükçekmece and Sarikum long and short cores.

CHAPTER 5

RESULTS

5.1 Chronologies

Prior studies established radiocarbon, ^{210}Pb and ^{137}Cs chronologies for Terkos and Büyükçekmece lakes (Doner and Yalçinar, 2006; Doner and Sekeryapan, 2009). These results are presented again here, with permission by the authors.

5.1.1 Büyükçekmece Lake

For Büyükçekmece Lake, 16 samples, representing the uppermost 40 cm of accumulated sediments, were analyzed for ^{210}Pb and ^{137}Cs. The resulting radioactivity extinction curves are best explained by a constant flux: constant sedimentation model (Appleby and Oldfield, 1978) which fits both the Chernobyl and 1963 peaks in the cesium data plus a known transition in AD 1988 when the dam was built (Figures 6 and 8). The ^{210}Pb data indicate that an abrupt change in sedimentation rate occurred when the lagoon was dammed. Also, an unexpected absence of measurable ^{210}Pb below 33 cm, but measurable ^{137}Cs at 30 cm that points to a recent age for those sediments, suggests that some pre-dam material has been eroded. Sediment accumulation rates for the uppermost 20 cm and post-dam period at Büyükçekmece Lake is about 0.58 cm/yr, calculated from the ^{210}Pb data. This relatively high sedimentation rate is reasonable in dammed lakes because sediment outflow is zero. The recent, pre-dam sedimentation rate at Büyükçekmece is 50% lower, about 0.255 cm/yr.

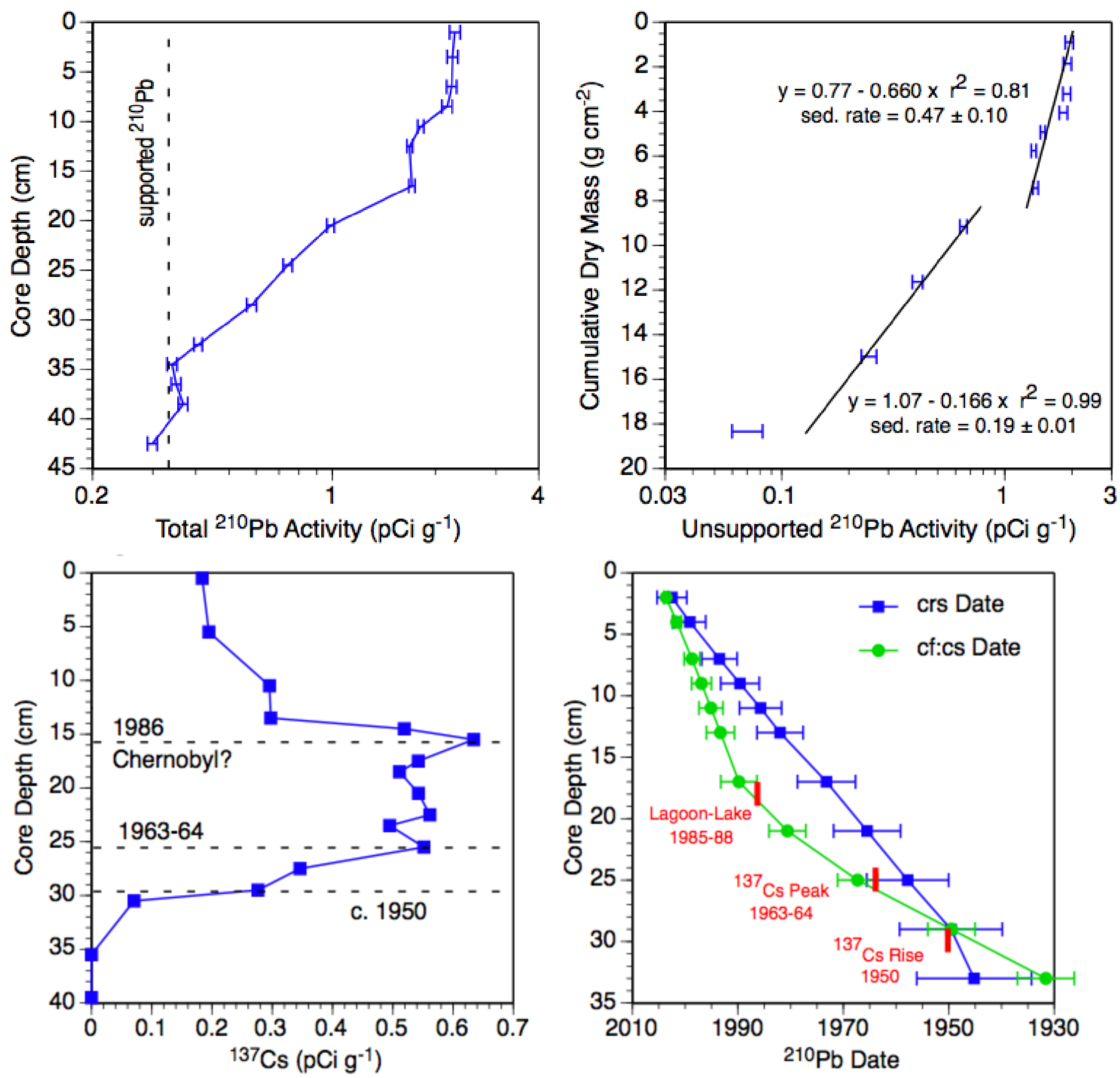


Figure 6. ^{210}Pb and ^{137}Cs activity versus depth plots for Büyükçekmece Short Core (left), in pCi/g. Depth versus age and dry mass accumulation versus ^{210}Pb (right) show results of the CRS and CF:CS accumulation models. In this case, the best fit seems to be the CRS model, with an unexplained ±10 year error (Doner and Yalçinar, 2006).

Radiocarbon results for Büyükçekmece Lake support the inference that there is a gap in the sediment record, called a hiatus. Büyükçekmece's ^{14}C data (Doner and Sekeryapan, 2009), (Figure 7), imply an age of nearly 2500 years for material at 75 cm depth, even though the ^{210}Pb and ^{137}Cs data indicate that material at 30 cm depth is only 70 years old. Extrapolating the sedimentation rate of the constant flux: constant sedimentation model, 75 cm depth should be from about 1770 AD, or 235 yrs old. In consequence, it seems likely that between 33-75 cm, a significant time gap exists. An alternative explanation is that these sediments contain a large amount of old carbon which is creating an old bias in the radiocarbon interpretations. Due to lack of funding for additional radiocarbon dates, these hypotheses are untested.

Regardless of the reason for the apparent time gap, the original idea of reconstructing paleoenvironmental, tsunami or earthquake records for the last couple of millennium at Büyükçekmece Lake is not possible. These data are still useful, however, for comparing modern conditions, both pre- and post-dam, with pre-Roman conditions at Büyükçekmece.

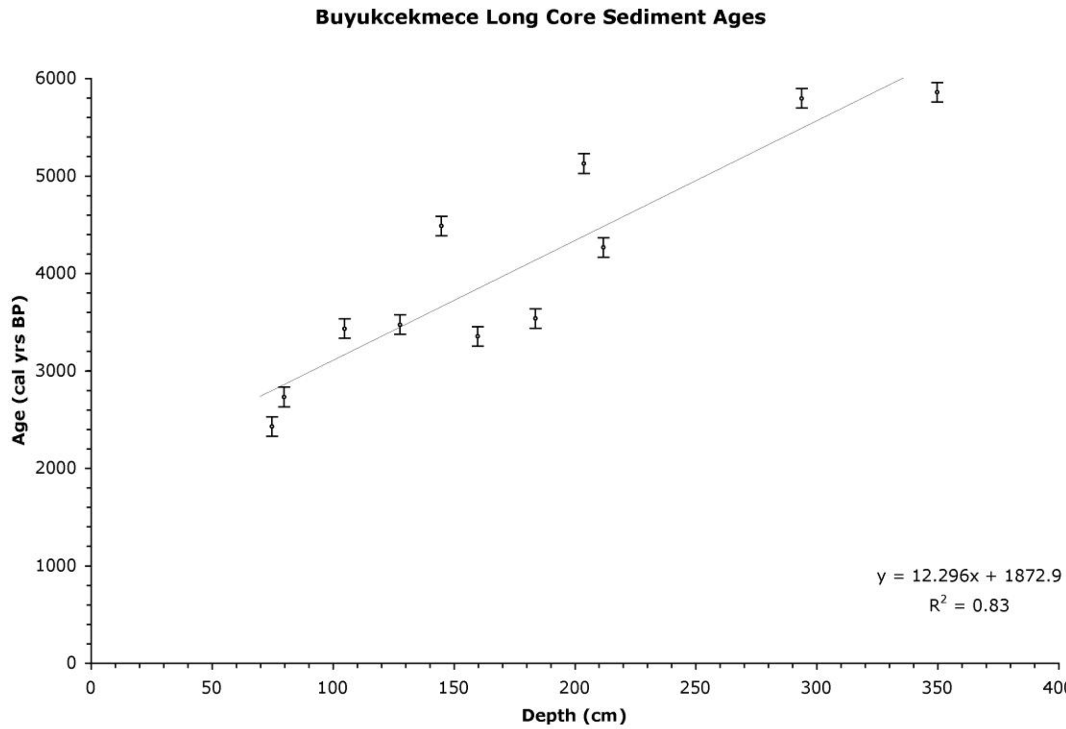


Figure 7. Combined radiocarbon results from three different piston cores collected from Büyükçekmece Lake in 2005 showing that, below 50 cm, of none of these cores apparently contain material younger than 2500 calibrated years before present.

5.1.2 Terkos Lake

^{210}Pb and ^{137}Cs dates for Terkos Lake indicate continuous and rapid sedimentation (Doner and Yalçinar, 2006; Doner and Sekeryapan, 2009), (Figure 8). The ^{210}Pb profile is readily interpreted using the constant rate of supply (crs) model (Appleby and Oldfield, 1978; Dan Engstrom, Director of the St. Croix Water Research Laboratory, USA, pers. comm.) and gives a reasonable age depth profile extending back to about AD 1820. The lowermost dates (pre-1900) have substantial uncertainty because of very low levels of unsupported ^{210}Pb at these depths. Terkos' sediments include the cesium "bomb" peak of AD 1964, at about 17 cm depth, but lack a discernable Chernobyl peak for AD 1986. This should not be taken as evidence that Chernobyl fallout did not reach Terkos; the Büyükçekmece evidence for a Chernobyl peak in Thrace is clear. Rather, the uppermost Terkos sediments were so organic- and water-rich that insufficient material remained for ^{137}Cs analysis after ^{210}Pb analyses were completed. The uppermost ^{210}Pb sample is at 0-1 cm depth but the uppermost ^{137}Cs sample isn't until 6-7 cm depth. The Chernobyl deposits, according to the combined ^{137}Cs and ^{210}Pb accumulation curves, would most likely have been included in the material located at 5-7 cm depth. These chronologies all indicate a 3-fold increase in sediment accumulation, from 0.18 cm/yr before AD 1920 to 0.58 cm/yr afterwards.

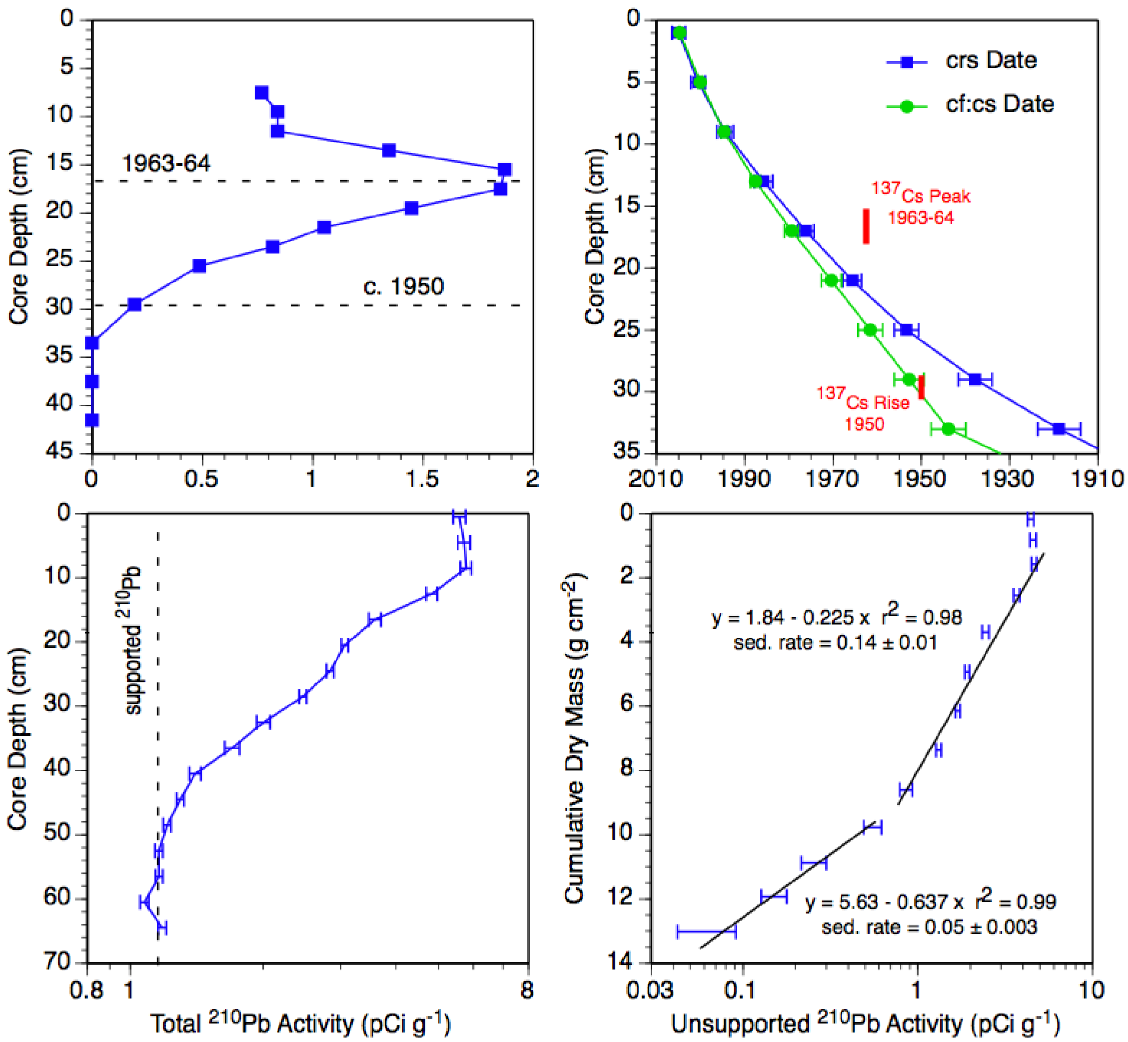


Figure 8. ^{210}Pb and ^{137}Cs activity versus depth plots for Terkos Short Core 2 (left), in pCi/g. Depth versus age and dry mass accumulation versus ^{210}Pb (right) show results of the CRS and CF:CS accumulation models. In this case, the best fit seems to be the CRS model, with an unexplained ±10 year error (Doner and Yalçinar, 2006).

Radiocarbon results for Terkos Lake are detailed in Table 1 and plotted in Figure 9. Linear regression of the 2 sigma median ages for Terkos Lake's radiocarbon data provides an excellent fit (r^2=0.97), which implies a relatively constant sedimentation rate of 0.15 cm/yr, over thousands of years. The oldest date, 3740 cal yrs BP is located over 5 meters beneath the sediment surface. No hiatus is apparent from this data.

Table 1. AMS radiocarbon results for Terkos Long Core 2.

International Sample Code	sample ID	δ13C value	F (δ13C)	Conventional 14C yrs BP	Error ±14C yrs	Depth (cm)	Type	Sample Wt (mg)	Median 1σ age (Cal yrs BP)	Median 2σ age (Cal yrs BP)
BETA 269167	TLC2.1 94-95	-25.8	1503.63	1030	40	95	bulk	1504	948	957.5
BETA 269168	TLC2.1 142-143	-26	1237.43	1190	40	143	bulk	1237	1117.5	1116.5
BETA 269169	TLC2.2 59-60	-25.4	1080.43	1590	40	210	bulk	1080	1470.5	1473
BETA 269170	TLC2.3 39-40	-25.7	2157.93	2510	40	340	bulk	2158	2547	2315.5
BETA 269171	TLC2.3 73-74	-27.6	1165.23	2620	40	374	bulk	1165	2710	2775
BETA 269172	TLC2.3 133-134	-27.9	1213.53	2870	40	434	bulk	1214	3007	2766
BETA 269173	TLC2.4 59-60	-26	1439.93	3470	40	510	bulk	1440	3759	3738.5

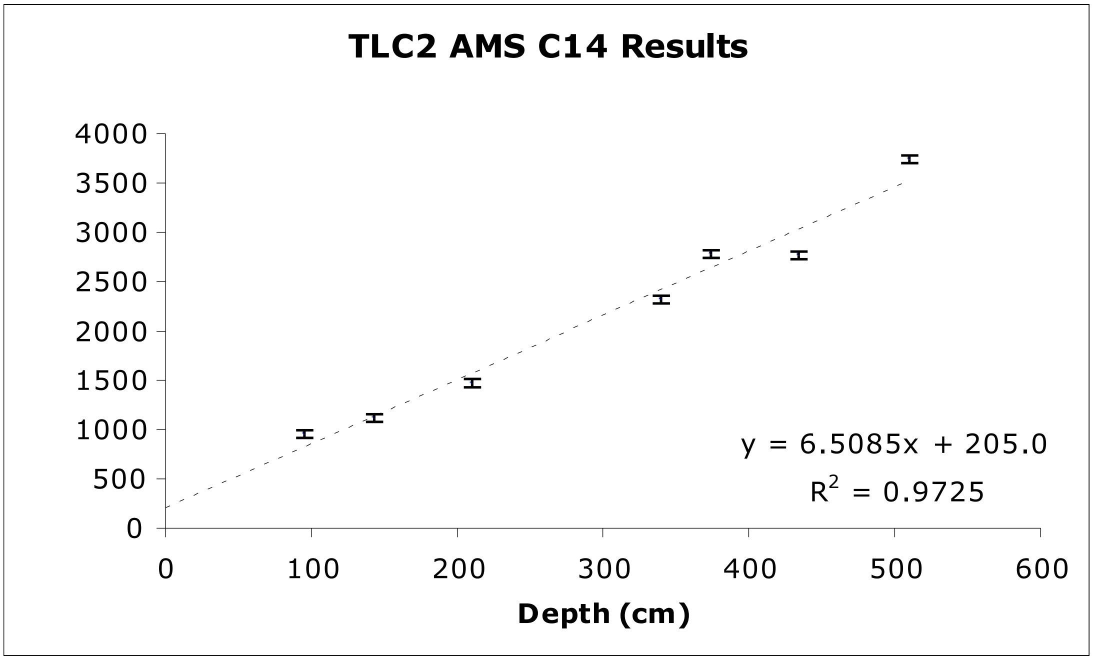


Figure 9. AMS ^{14}C dating results on 7 bulk sediment samples from Terkos Long Core 2 (BETA Analytic Laboratory). Sedimentation rates are calculated as the inverse value of the slope of the regression line (1 cm/6.5085 yrs).

5.1.3 Sarikum Lake

The ^{210}Pb and ^{137}Cs chronologies for Sarıkum Lake are in relatively good agreement, using the CRS dating model (Appleby and Oldfield, 1978). This model puts 1963-64 at about 8 cm, slightly below the 1963-64 layer (at 5 cm) indicated by the ^{137}Cs results. The discrepancy may due to a slump located at 8-13 cm, indicated by the minimal net decline in unsupported ^{210}Pb activities in these layers. Alternatively, there could be an erosional hiatus between 8-13 cm. There is no indication of a Chernobyl peak, which should occur at about 3 cm, according to the model. Dates using the CRS model are given in Table 2 and

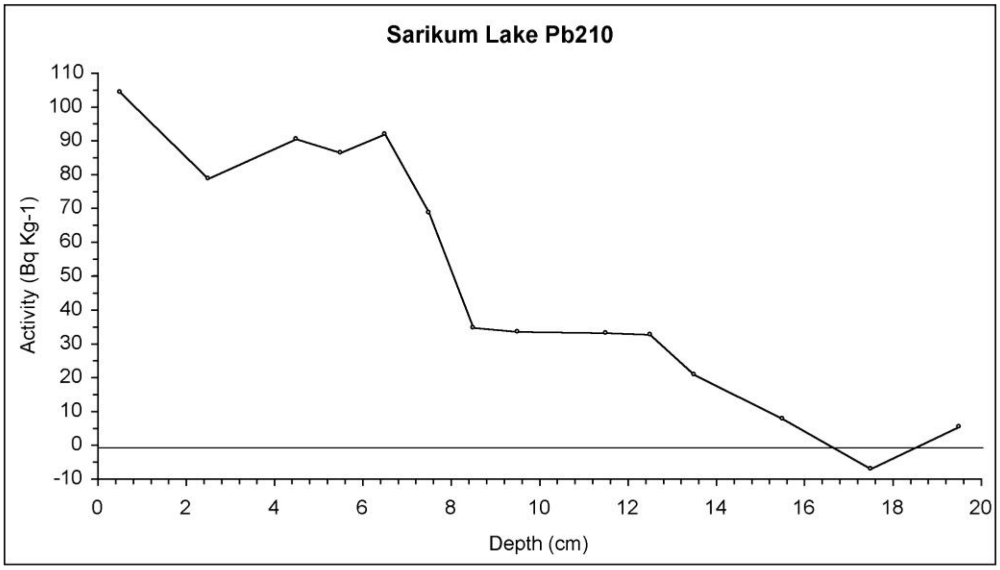
Table 3. Sedimentation rates range throughout the core, with a maximum rate in the middle of the possible slump, around 9 cm, of 0.154 cm/yr. Overall, Sarıkum Lake sedimentation rates in the last 100 years are significantly lower than those at Terkos and Büyükçekmece, averaging 0.12 cm/yr (Table 3).

Table 2. ^{210}Pb results of the Lake Sarikum core SATK1. (University College of London, ECRC).

Depth (cm)	Dry Mass (g cm^{-2})	Total Pb210 ($BqKg^{-1}$)	±	Supp Pb210 (Bq Kg^{-1})	±	Unsupp Pb210 ($BqKg^{-1}$)	±	Cum Unsupp Pb210 ($Bqcm^{-2}$)	±
0.5	0.1294	129.87	17.26	25.53	3.36	104.34	17.58	135.6	17.5
2.5	0.8624	95.68	12.35	16.9	2.37	78.78	12.58	802.3	95.8
4.5	1.6906	113.22	11.62	22.72	2.25	90.5	11.84	1502.2	142.5
5.5	2.138	115.29	15.4	28.81	3.14	86.48	15.72	1898	158.9
6.5	2.5854	113.12	7.73	21.23	1.41	91.89	7.86	2296.9	172.2
7.5	3.0327	95.08	13.3	26.31	3.16	68.77	13.67	2653.7	178.4
8.5	3.4801	61.94	11.93	27.25	2.63	34.69	12.22	2876.5	188.5
9.5	3.9977	55.41	7.08	21.89	1.48	33.52	7.23	3053.1	196.7
11.5	5.0329	57.3	9.46	24.16	1.9	33.14	9.65	3398.1	210.4
12.5	5.5505	55.33	10.47	22.64	2.31	32.69	10.72	3568.4	219.6
13.5	6.1581	43.79	7.23	22.94	1.92	20.85	7.48	3728.4	227.4
15.5	7.3733	30.04	5.98	22.22	1.22	7.82	6.1	3889.9	239.3
17.5	8.6418	16.44	7.67	23.47	1.7	-7.03	7.86	3894.9	253.2
19.5	9.9636	28.85	7.62	23.38	1.61	5.47	7.79	3884.6	273.2

Table 3. Calculated 210Pb chronology for Sarikum Lake, based on a constant rate of supply model.

Depth	Drymass	Chronology			Sedimentation Rate		
		Date	Age				
cm	g cm^{-2}	AD	Yr	±	g cm^{-2}	cm yr^{-1}	± %
0	0	2007	0				
1	0.31	2002	5	2	0.063	0.182	18.8
2	0.68	1996	11	2	0.06	0.143	18.8
3	1.07	1988	19	3	0.051	0.111	19.4
4	1.48	1978	29	3	0.032	0.077	20.4
5	1.91	1962	45	3	0.021	0.091	21.2
6	2.36	1956	51	3	0.064	0.143	17.4
7	2.81	1948	59	3	0.055	0.133	19.3
8	3.26	1941	66	4	0.074	0.154	31.4
9	3.74	1935	72	5	0.085	0.154	33.4
10	4.26	1928	79	6	0.071	0.125	31
11	4.77	1919	88	7	0.055	0.1	36.6
12	5.29	1908	99	10	0.039	0.071	44.2
13	5.85	1891	116	16	0.028	0.059	60.1



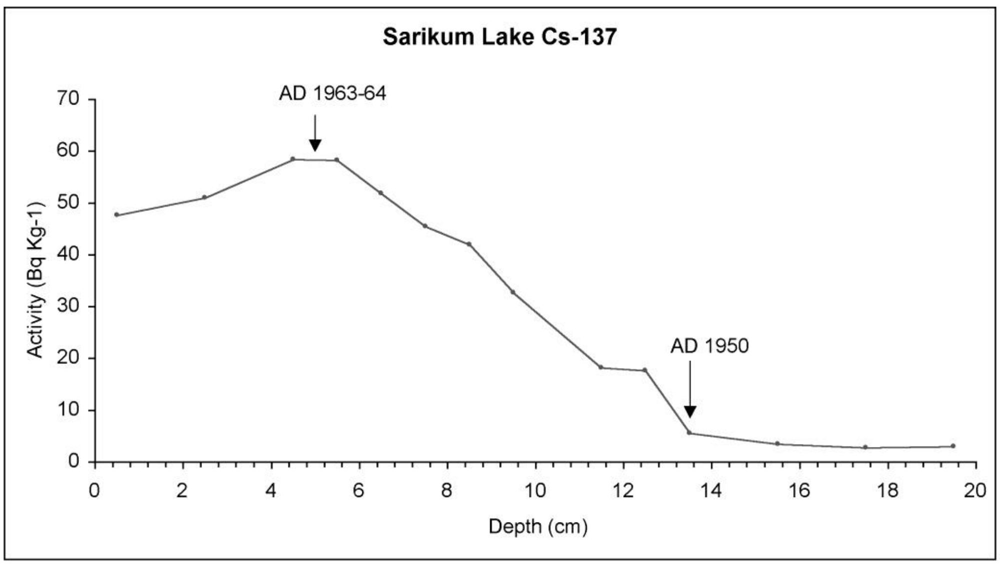


Figure 10. ^{210}Pb and ^{137}Cs activity versus depth plots for Lake Sarikum core SATK1.

5.2 Total Organic Carbon (TOC) and Total Inorganic Carbon (TIC)

Total organic carbon and carbonate are measures of lake productivity that tend to be very consistent within individual lakes. For this reason, they are useful tools for correlating multiple cores from one lake. When LOI is plotted against the sample depth, short and long cores (TLC2 and TSC2; BLC2 and BSC3; SLC1 and SSC1) can be tied together, or spliced (Fig. 11-12-13). Attempts to splice the depths of long and short cores using similarities in measured loss on ignition results are shown in Figures 11-13. Besides TOC, percent TIC is shown in Figure 14-16.

Generally, the LOI results for the short and longs cores from Terkos Lake and Sarikum Lake show an overlap, indicating where the data for each of the cores can be spliced. As expected, because of the probable hiatus, the Büyükçekmece data show no indications of overlapping LOI values between the short and long cores; this splice is not feasible.

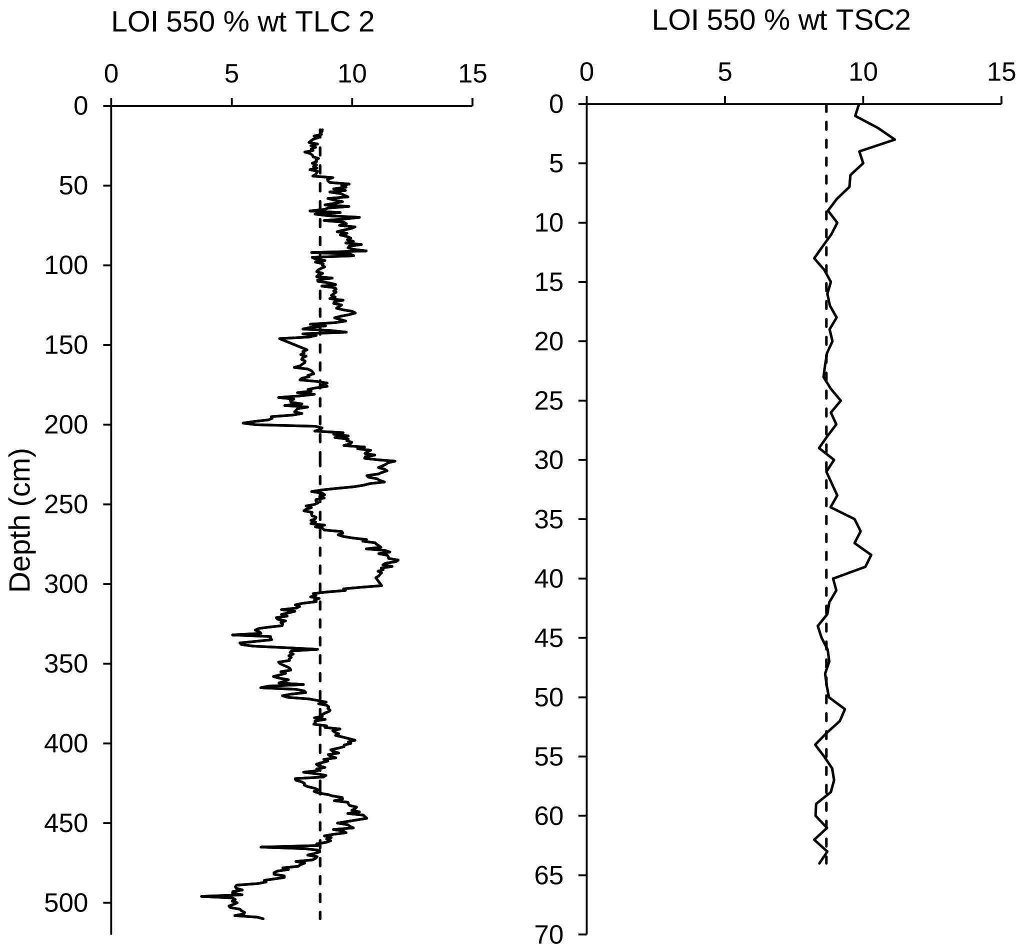


Figure 11. Terkos Long Core 2 (TLC2) and Terkos Short Core 2 (TSC2) sedimentary organic matter. Dashed dots represent mean values.

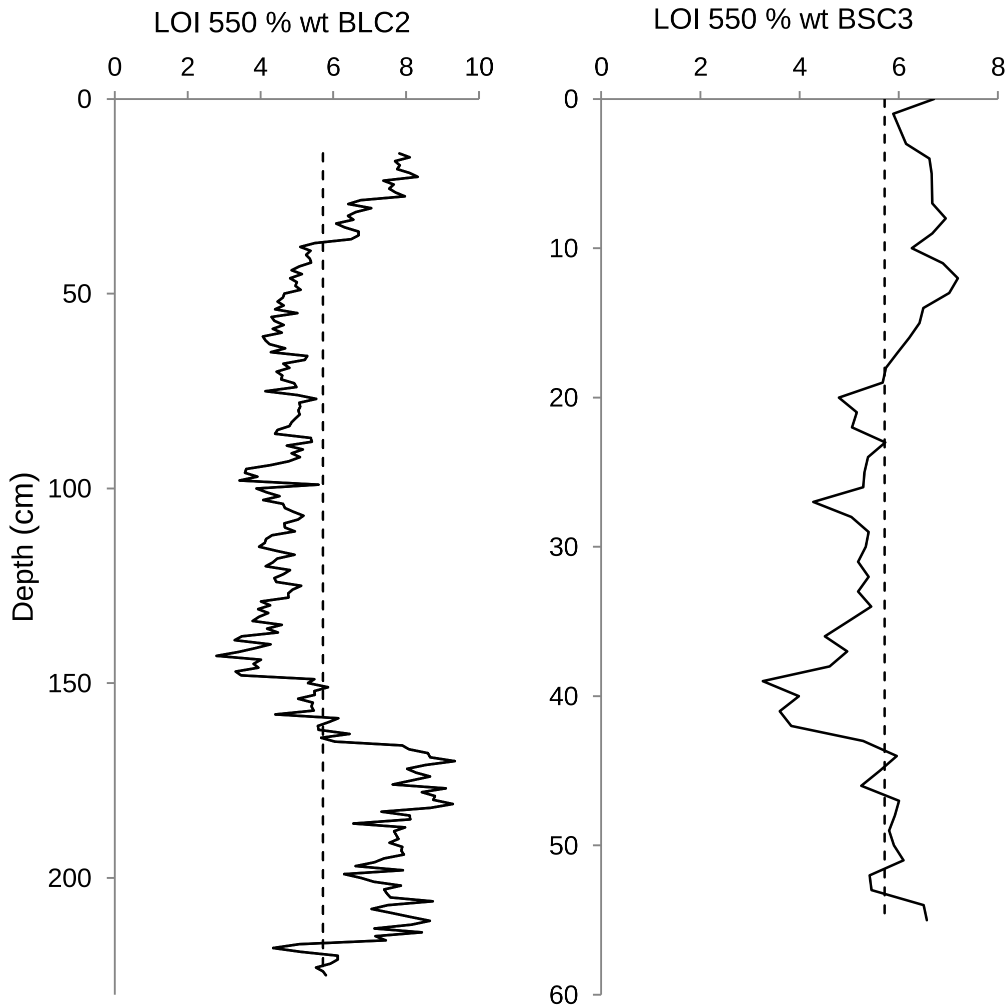


Figure 12. Büyükçekmece Long Core 2 (BLC 2) and Büyükçekmece Short Core 3 (BSC3) organic carbon.

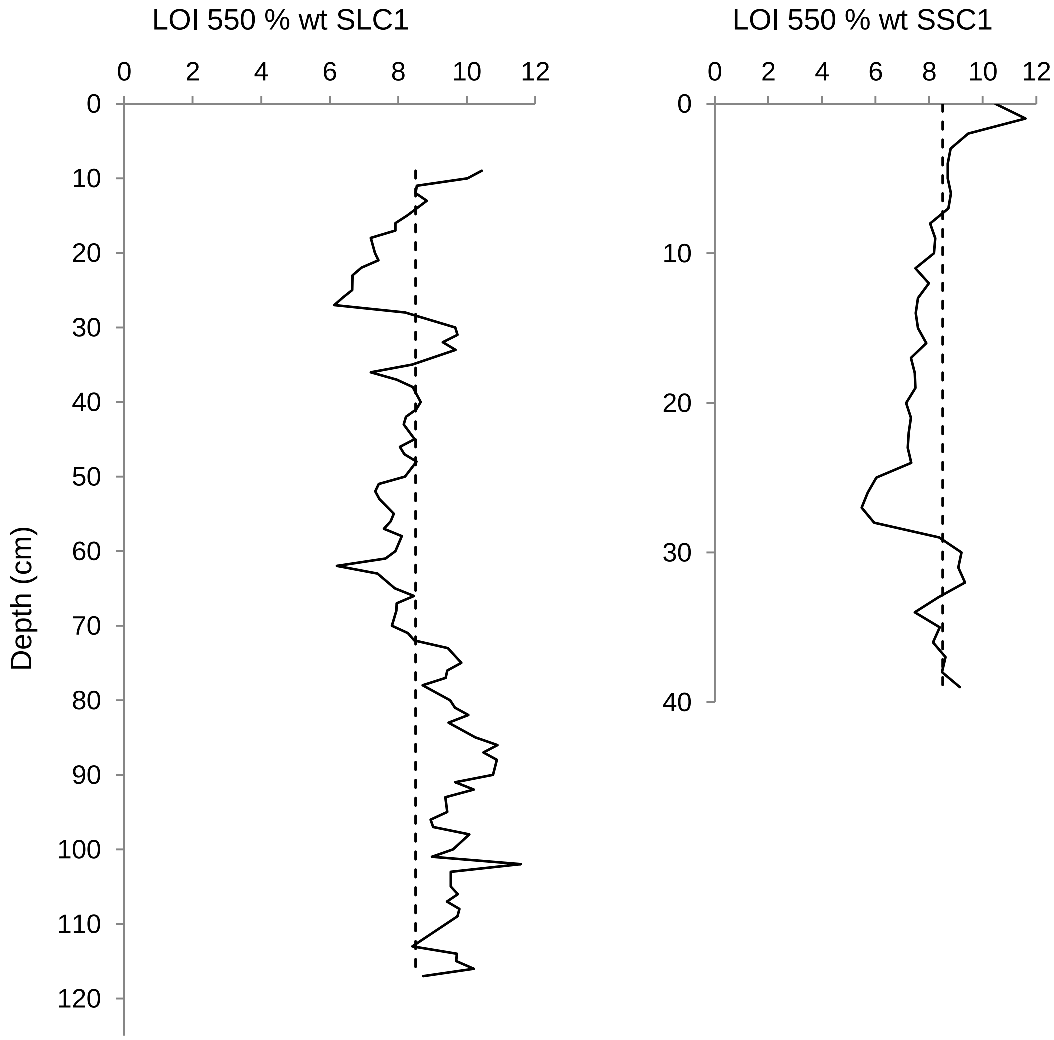


Figure 13. Sarıkum Long Core 1 (SLC1) and Sarıkum Short Core 1 (SSC1) organic carbon.

TOC can indicate changes in primary productivity since the primary source of it is either land- or lake-derived (Meyer & Teranes, 2001). TOC ranges from 11,8-5 % in Terkos, from 8,8-2,7 % in Büyükçekmece and from 11,59-6 % in Sarıkum lacustrine archives, with a mean values 8,68, 5,72, and 8,51 respectively (Figure 14, 15, 16). TOC and TIC values mirror each other in both Terkos and Sarıkum cores (Figure 14-16). TIC is 4,67% for Terkos 9,12% for Büyükçekmece, and 6,39% for Sarıkum. In Terkos Lake, TIC values can reach 13,5% at some depths. In Büyükçekmece Lake, TIC usually varies between 10-15%, but reaches 18,5 at some depths and is 5-10% between 150-190 cm in the Büyükçekmece Long Core. TIC values have two higher maxima of 14 and 17% in the Sarıkum Lake sediments, while TOC values are constant, but Chl-a content increases just before the first peak and decreases by the second peak of TIC in Sarikum Lake Long Core 1 (SLC 1.1) (Figure 16).

In Terkos Lake, TOC has two minima where Chl-a content values are minimum, while TIC values peak, around 2315 and 1473 cal yrs BP (Figure 14). These results suggest either refer a desiccation period in the lake or a marine water intrusion to the Terkos lake. They coincide with the presence of *Darwinula stevensoni,* a more freshwater ostracod species in comparison with *C. torosa,* and *Glochidia*, parasitic, larval stage of unionid freshwater mussels in the Terkos long core. A desiccation scenario does not match with our conditions in Terkos Lake; the fossils, such as *D. stevensoni* and Glochidia, indicate more fresh water conditions in the lake. The Chl-a minima could come from a shift in the pH values in the lake, maybe because of a decrease in lake water concentrations or short residence time either because of excessive rainfall or fresh water incoming or sea water intrusion to the lake.

In Büyükçekmece Lake, TOC is lowest between 40-140 cm but is relatively high during the uppermost 30 cm and also at the bottom of the long core. TIC values are relatively low at the bottom of the long core, but are high through the uppermost layers of the long core and also in the short core. Büyükçekmece Lake changed from lowest TOC to higher TOC values over the hiatus from 2500 cal yrs BP until just before the damming. And, damming did change the lake conditions to being more organic-rich. Damming also created an initial decrease in the TIC values, but these increase again near the present time. So, dam-related increases in the lake level at Büyükçekmece are indicated by the increase in the TOC and a decrease in TIC. Percent sand values indicate decreased sand amounts and increased clay and silt deposition after dam construction (Figure 41). TIC values in the Büyükçekmece Lake Long Core 2 before 2500 cal yrs BP strongly indicate marine conditions. Preserved abundant remains of benthic foraminifera, marine bivalves, and snails in the long core, together with Chara seeds, are evidence of shallow lagoon and marine conditions.

There is a little change in the TOC of the Sarıkum core except for an abrupt decrease followed by a gradual increase at around 30 cm, likely from a catastrophic event. TOC and TIC values mirror each other only until the uppermost 35 cm. Just below that depth, Chl-a content reaches an abrupt minimum in the Sarıkum Long Core. In the uppermost 35 cm, TOC and TIC have similar trends. Below 35 cm, a strong minimum in Chl-a content coincides with low TOC and TIC values, an interruption in the faunal record (Figure 32), decreased sand % and increased clay and silt content. Moreover, none of the marine indicators are observed around that depth. In contrast to the TOC and

TIC values, TOC and Chl-a content have similarities in trend through the whole core.

In Sarikum Lake, the primary source of high organic matter might be submerged plant such as Chara, whose seeds were observed through the whole core. Present conditions also imply a submerged plant-dominated shallow lake in Sarıkum. However, these results indicate the strong possibility of a catastrophic event at about 30 cm that changed the water level or water conditions. Total ostracod valves have relatively low abundance and Chara oospores are interrupted for 10 cm-long intervals in the Sarıkum Lake Long Core 1.1 (SLC 1.1). Chara seeds, for instance, started to be observed again just before AD 1950 until the present conditions.

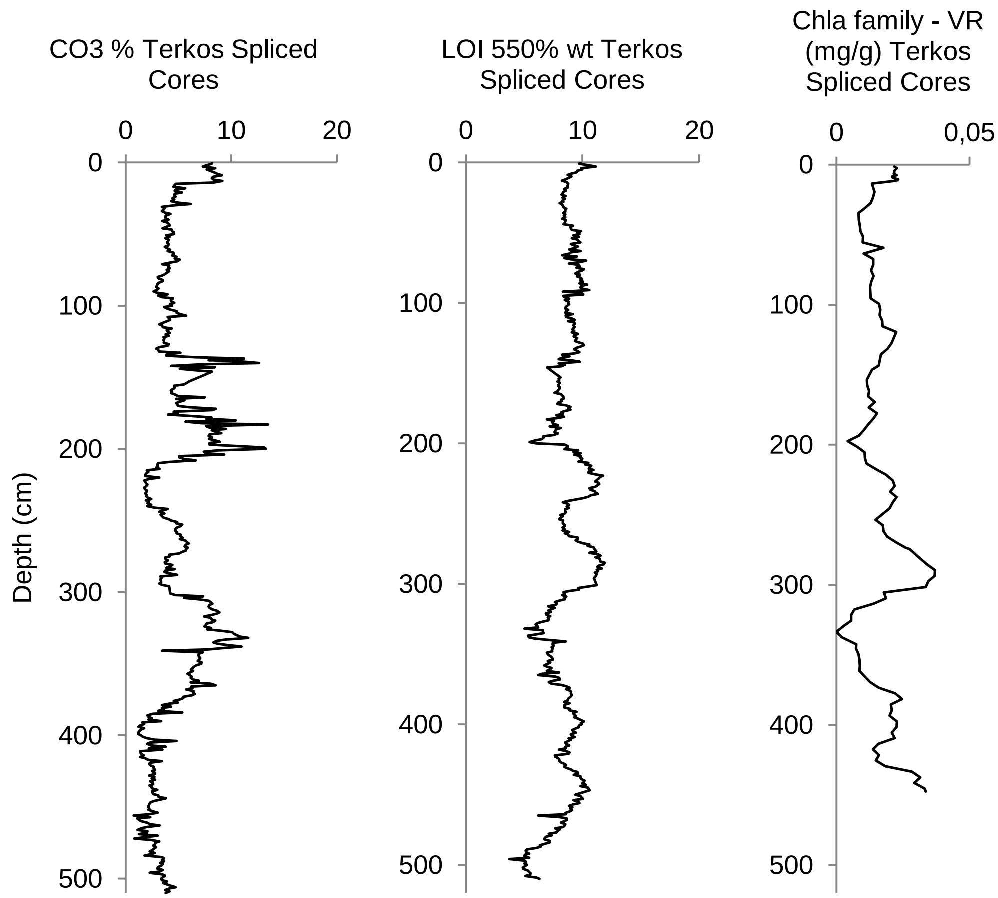


Figure 14. Terkos Spliced Core sedimentary organic matter, carbonate and Chl-a content.

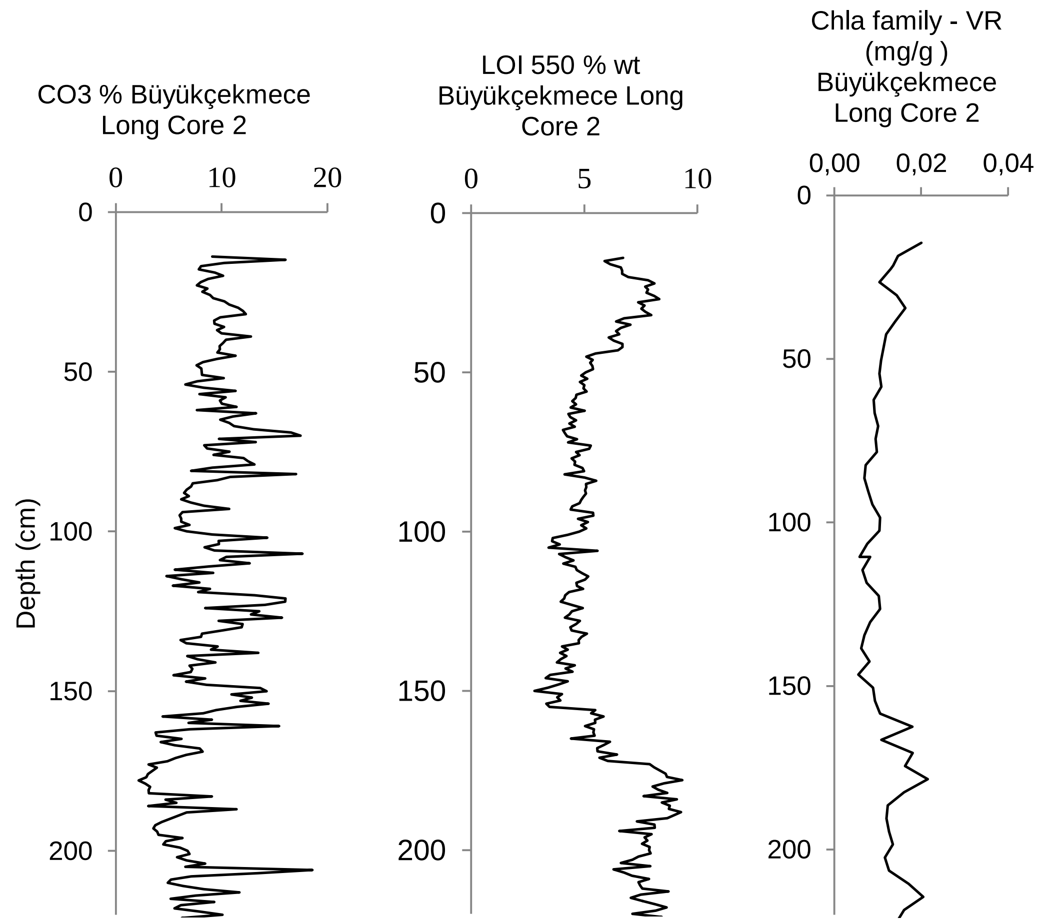


Figure 15. Büyükçekmece Long Core 2 sedimentary organic matter, carbonate and Chl-a content.

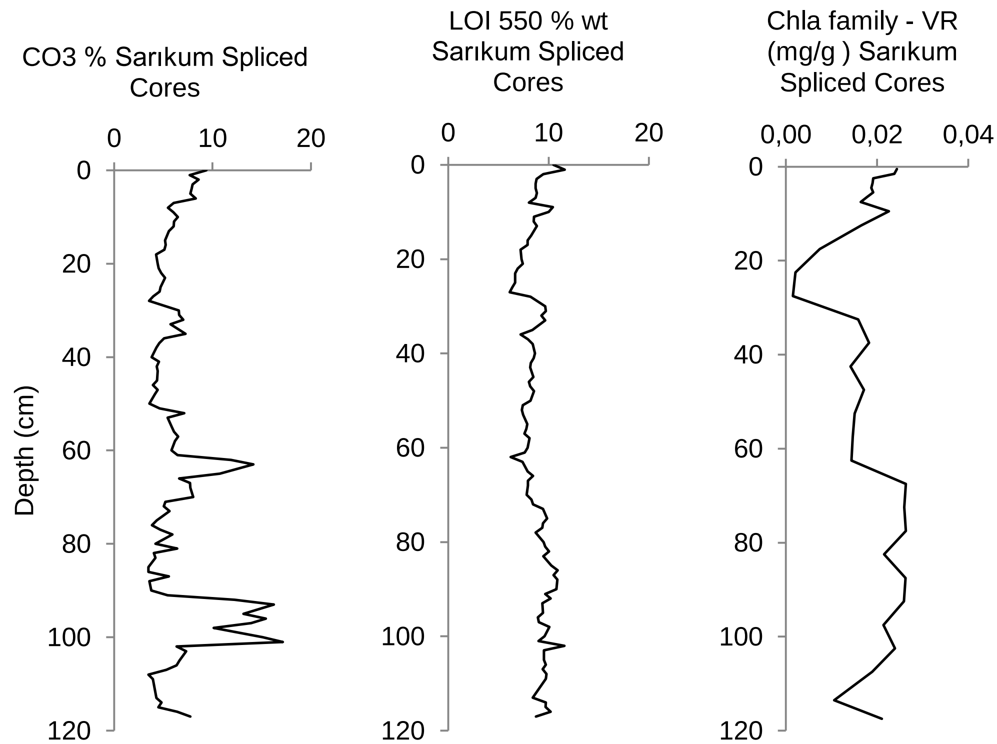


Figure 16. Sarıkum Spliced Cores sedimentary organic matter, carbonate and Chl-a content.

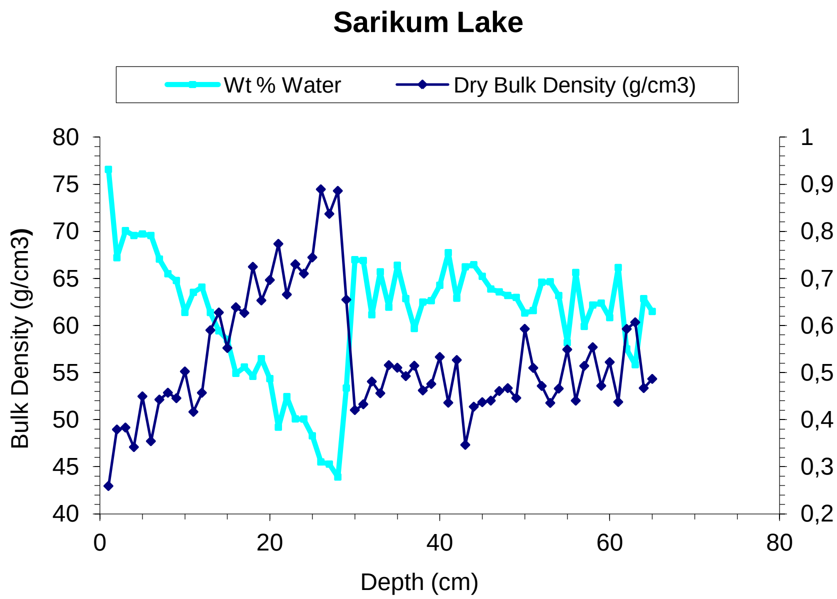


Figure 17. Water content and Dry Bulk Density of Sarikum Short Core 1. The sharp transition in bulk density at 30 cm is matched by decreases in organic and inorganic carbon, and increases in mineral weight (Fig 16).

5.3 Algal Production

Fossil pigments are one of the organic constitutes preserved in the lake sediments such as carotenoids, chlorophylls, photoprotectant compounds, and other lipid-soluble pigments produced by phototrophic organisms in lake and its catchments and also derivatives of most common pigments (Leavitt & Hodgson, 2001). Chlorophyll-a preserved in lake sediment is a reflection of past primary productivity (Wolf, et al., 2006).

In shallow lakes, mostly macrophytes are responsible for primary productivity. Shallow lakes are usually characterized by abundant, submerged macrophytes, by clear water at relatively low nutrient concentrations, and by abundant phytoplankton and turbid water at higher nutrient concentrations (Blindow et al., 1993). At intermediate nutrient concentrations, shallow lakes are dominated by either submerged macrophytes or phytoplankton. However, it has been recognized that changes in nutrient loading to lakes are not the only reason for fluctuations in area coverage of submerged macrophytes. Water level change is another important factor creating oscillations of submerged macrophyte density (Martin & Uhler, 1939 adopted from Blindow et al., 1993). Van der Valk (2005) proposed that water level fluctuation can have both direct and indirect effects on the establishment, growth and survival of wetland plants. Charaphyte oospores observed both in Büyükçekmece and Sarıkum lakes' sediments can refer their macrophyte dominated shallow water conditions. However, Charaphytes are sensitive to eutrophication, water level changes and salinity increase (Riddin & Adams, 2010).

The Alternative Stable States Theory for shallow lakes, by Scheffer (et al., 1993), states that lakes have a tendency for an abrubt shift between a clear and a turbit state. When the system reaches a critical turbidity, macrophytes will disappear whereas, at low nutrient levels, only macrophyte-dominated equilibrium exists (Sheffer &Van Nes, 2007).

In our results from Sarıkum Lake, the sudden drop in Chl-a values might be because of the disappearance of submerged plants (e.g Charaphtes). This is an expected effect of extremely low or high water levels. Sarıkum Lake, open to the Black Sea with a channel, can experience rapid lake level change coupled with storm surge events. Decreases in submerged macrophytes, such as *Chara* *vulgaris,* after storm surge marine inundation events were observed in South African eustuaries (Riddin & Adams, 2010). Besides reductions in the macrophytes, marine inundation can cause reductions in benthic oxygen concentrations which are crucial for benthic microfauna such as ostracods.

Turbidity from terrestrial flooding can also negatively influence submerged macrophyte abundance. For instance, the flat sandy barrier between the Black Sea and the Sarıkum Lake channel is usually closed by December because of the wave activity, making the system a closed lake. Because of the high freshwater input from high winter rainfall in the catchment, the forest surrounding the lake is flooded and turbidity for relatively oligotrophic Sarıkum Lake increases during this time. However, that doesn't explain the absence of benthic fauna such as ostracoda at the same time. Sarıkum is a very shallow lake with ~1 m homogenous depth profile in its main basin and the depth profile is flat. Hysteresis may be more intense in lakes with flat depth profiles (Van Nes, et. al., 2002). Since it is open to the Black Sea, Sarıkum Lake is under the threat of storm surges. Marine inundation from sea temperature warming and/or tsunami waves would result in the loss of submerged macrophytes and reeds in the lake ecosystem. Decreases in the reed density were described to us by local people, during our 2008 visit.

In contrast to Sarıkum's low nutrient, clear water, submerged macrophyte dominated state, Büyükçekmece looks like an intermediate nutrient system that is either macrophyte or phytoplankton dominated. Charaphyte oospores aren't observed before 2500 cal yrs BP but Chl-a values are notably high, at present. Evidence points to Büyükçekmece Lake being relatively deep until around 3200 cal yrs BP, followed by a trend towards shallower conditions.

A maximum in Chara oospores at around 2800 cal yrs BP suggests that this was its shallowest period, and one of a more clear water state.

Terkos Lake has more heterogeneity than either of the other two lakes. It is deeper and more phytoplankton dominated such that sudden shifts in Chl-a and TOC may be more related to its mixing regimes. In lakes with a spatial heterogeneity and depth gradient like that of Terkos, hysteresis may vanish unless horizontal mixing occurs (Van Nes, et al., 2002). In Terkos Lake sediments, there are two Chl-a minima at 2315 cal yrs BP and 1475 cal yrs BP that coincide with low TOC and high TIC, *Darwinula stevensoni* valves and Glochidia, the larval stage of unionid freshwater mussels. Since only adult valves of *D. stevensoni* were observed around these depths, we can't say definitively that this species inhabited the sediment as opposed to being transported in from somewhere else. It is a species that can tolerate less salinity in the coastal places, similarly to *C. torosa*.

We also see an increase in *D. stevensoni* abundance just after the dam modification in Büyükçekmece Lake (Figure 41). Glochidia presence in Terkos sediment indicates the fish abundance. So, at high water levels, Terkos Lake is seemingly unvegetated with abundant fish.

Times of direct input to Terkos from the Black Sea might occur when the barrier beach is breached. This does not necessarily have to be a result of marine flooding. Barrier breaches can occur from high fresh water inflow to the lake and terrestrial flooding. Following a breach, subsequent erosional downcutting by outflowing lake waters can bring the marine barrier height to sea level, and so create conditions for marine inundation. Carbonate peaks at the 2315 cal yrs BP, 1473 cal yrs BP, and 1116 cal yrs BP can explain this. Mixing marine water to the lake would cause meromixis, and anoxic bottom conditions. We didn’t observe representative benthic fauna, such as ostracoda, until 1116 cal yrs BP when *C. torosa* started to inhabit in the sediment (Figure 40). Its initial phase coincides with a salinity increase in the lake water, based on trace element analyses of adult *C. torosa*. Thus, we can say that Terkos lost its connection with the Black Sea after 1116 cal yrs BP, unlike Sarıkum and Büyükçekmece lakes which kept their connectivity into modern times.

Terkos Lake started to became a closed system, after 1116 cal yrs BP. This may be due to climate. During this latter period, foraminifera peaks are important indicators of renewed marine inundation. Increased sea surface temperature, and related changes in wind intensity, wave heights and storm surges during late Holocene /Anthropocene are reported by Pisaric et al. (2011). Storm surge can cause a breach of the sandy barrier beach and result in marine overwash and, eventually, intrusion of large amounts of saline water to the coastal lakes. Lake water levels may also increase. According to these results, until 1116 cal yrs BP, Terkos Lake should have relatively deep water levels and anoxic bottom conditions. Because of reduced mixing and oxygenation from salinity stratification, benthic fauna such as ostracoda could not survive. There is an abrupt two-level increase in both Chl-a values and TOC before and after the second dam modification at AD 1960. Ostracoda (e.g. *C. torosa*) are absent in the sedimentary record following the second dam modification. High Chl-a and TOC levels, and ostracod absence, suggests bottom oxygen depletion related to eutrophication.

5.4 Ostracods

5.4.1 Ostracod Species Assemblages

Ostracods were found in all of the study lakes, and many reference lakes (see Figures 18-27 (Plates 1-10) and Figures 28 and 29). Comparisons between surface sample collections, from 2009 (Appendix B) and sedimentary archives from each lake indicate that modern lake conditions are not well represented by the core materials, and vice versa. For instance, no ostracoda are observed in the uppermost 14 cm of the Terkos short core, TSC 2, although surface samples collected along the edges of Terkos Lake in 2009 show living ostracods in the uppermost sediments. The only ostracod species currently found inhabiting Terkos L., collected from freshwater inlets in July 2009, are *Plesiocypridopsis newtoni* (Brady & Robertson, 1870) and *Loxoconcha immodulata* (Stepanaitys, 1962), (Plate 3). These species are not found in any of the cores.

In the sediment archives of Terkos Lake, 4 species were identified, appearing at different depths within the short and long cores. All the sediments in TLC 2.1 (the uppermost 150 cm of Terkos Long Core 2), which include the period from ca AD 1960-1000 (or 0-950 BP), according to ^{14}C dating, consist of non-noded forms of *Cyprideis torosa* (Plate 1). These also occur in older sediments, in TCL 2.2, 2.3, and 2.4, but with less abundance than in TLC 2.1. Another species observed TLC 2.2 and 2.3 but not in 2.1 and 2.4 is *Darwinula stevensoni* (Plate 1).

In the Büyükçekmece cores, 5 species were noted. *C. torosa* is present throughout the long core from Büyükçekmece Lake (Plate 2). Since the 1950's (according to ^{210}Pb dating of BSC 6), *C. torosa* abundance has decreased, along with ostracod abundance overall, while *D. stevensoni* (Plate 2) has increased. A few *Iiyocypris sp.* and *Loxoconcha sp*. were observed in the long core. *D. stevensoni* and *Iiyocypris sp.* are present in the short core from Büyükçekmece (BSC 3) but *C. torosa* disappears after approximately AD 1986 (based on ^{210}Pb dating), when the dam was built. The dam construction period was AD 1983-1988. No ostracoda are observed in the uppermost 5 cm of the short core, BSC 6. Between 24-76 cm of the Büyükçekmece long core, only *C. torosa* species is present. Below 76 cm (which is when?), *C. torosa* appears together with *Loxoconcha sp*. and *Iiyocypris sp* (Plate 2). Only the Büyükçekmece long core has black colored *C. torosa* male, female and juveniles (Fig. 28).

In the sediment archives of Sarıkum Lake, 2 species were identified. In the Short Core 1 and in the long core (SC1.1), *C. torosa* is the dominant ostracod type. A few *Candona sp*. are also present, especially in the uppermost 20 cm, however their abundance decreases periodically, around 28, 43 and 73 cm.

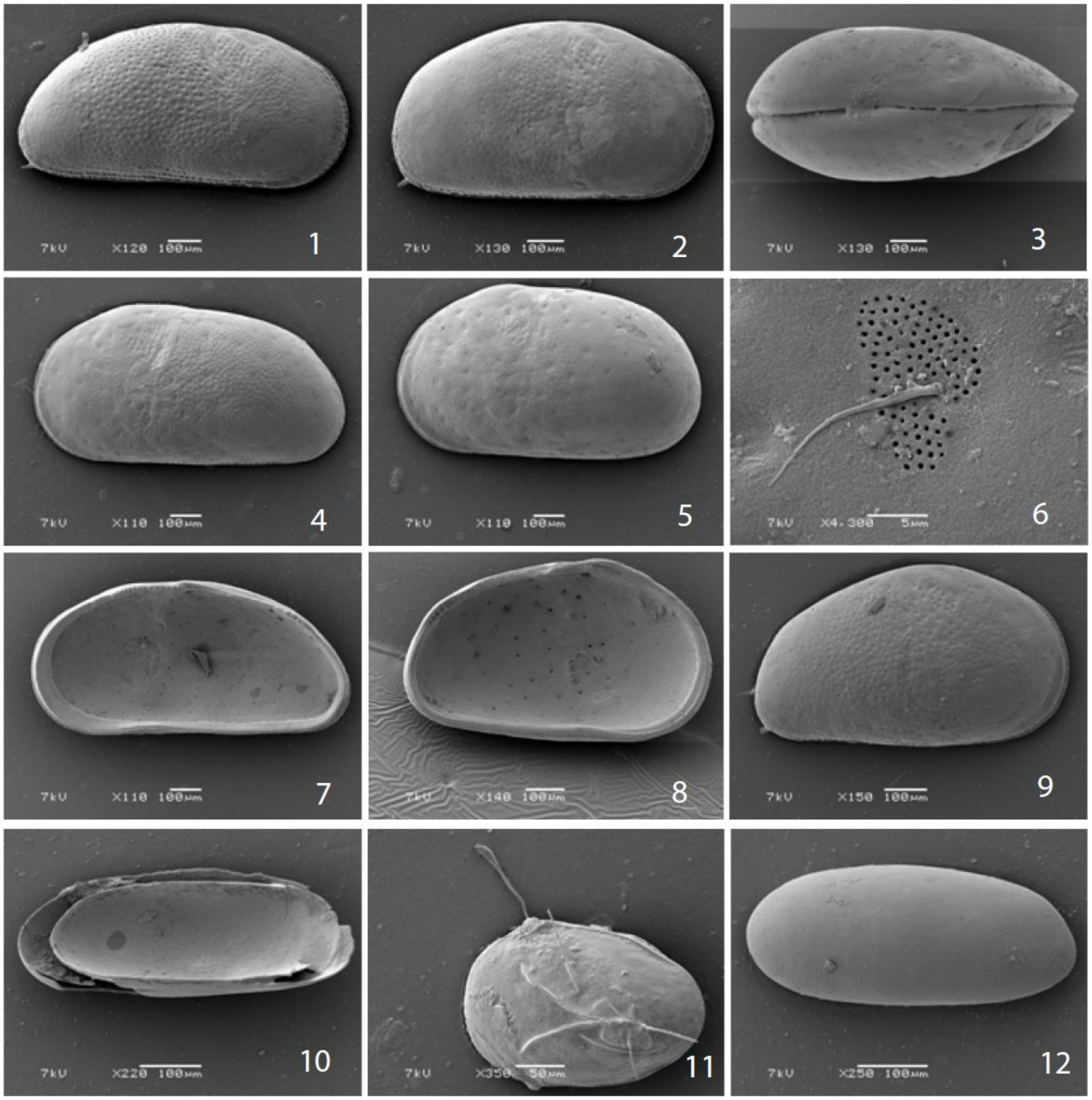


Figure 18. (Plate 1) Terkos L. **Ostracoda:** the uppermost 90 cm of Terkos Long core 2.1. Scanning electron micrographs (SEM) illustrations of valves and carapaces of *Cyprideis torosa* (Jones, 1850) (1-11) and *Darwinula stevensoni* (Brady & Robertson, 1870) (12) species in Terkos Lake sediment. Respectively, (1) external lateral view of male right valve (R,V), (2) female (R,V), (3) smooth carapace of female in dorsal view, (4) external lateral view of male left valve (L,V), (5) female (L,V), (6) irregular sieve pore shape, (7-8) dorsal hinge and muscle scars on the internal surface of the shell of a male and female (LV), (9) juvenile (RV), (10) inner and (11) outer lamella with appendages lying through them, (12) external views for *Darwinula stevensoni* right valve.

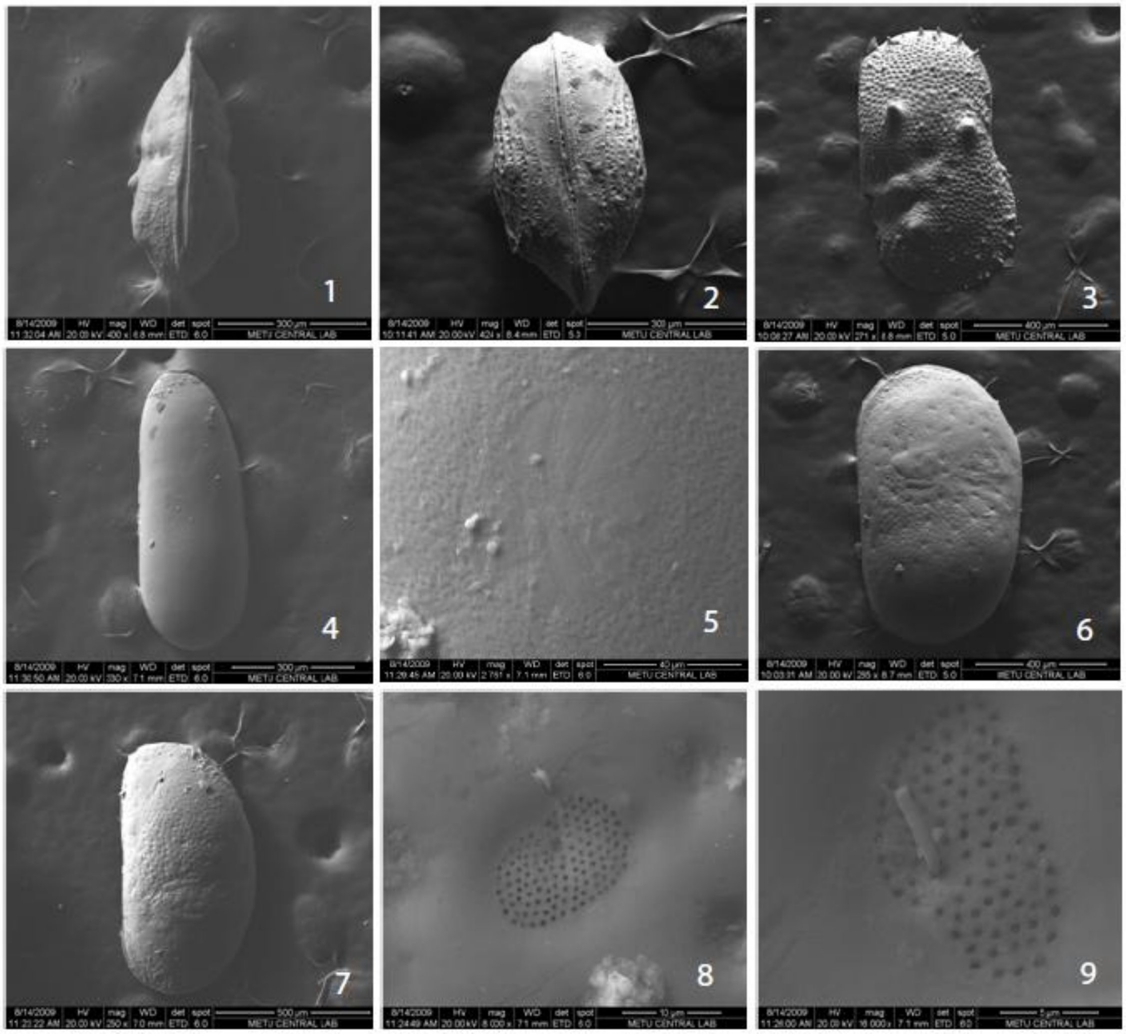


Figure 19. (Plate 2) Büyükçekmece L. **Ostracoda:** uppermost 15-16 cm of Büyükçekmece Long core 2.1, *Limnocythere inopinata (Baird, 1843)* (1) female, dorsal view; *Loxoconcha sp.* (Sars, 1866) (2), dorsal view; *Ilyocypris monstrifica* (Norman, 1862), (3) lateral view; *Darwinula stevensoni* (Brady &Robertson, 1870) (4) lateral view, (5) rosette with central muscle scar. The uppermost 33-34 cm of Büyükçekmece Long core 2.1: *Cyprideis torosa* (Jones, 1857) (6-9), (6) female lateral view RV; (7) male lateral view LV; (8-9) sieve pore shapes, (8) rounded, (9) irregular.

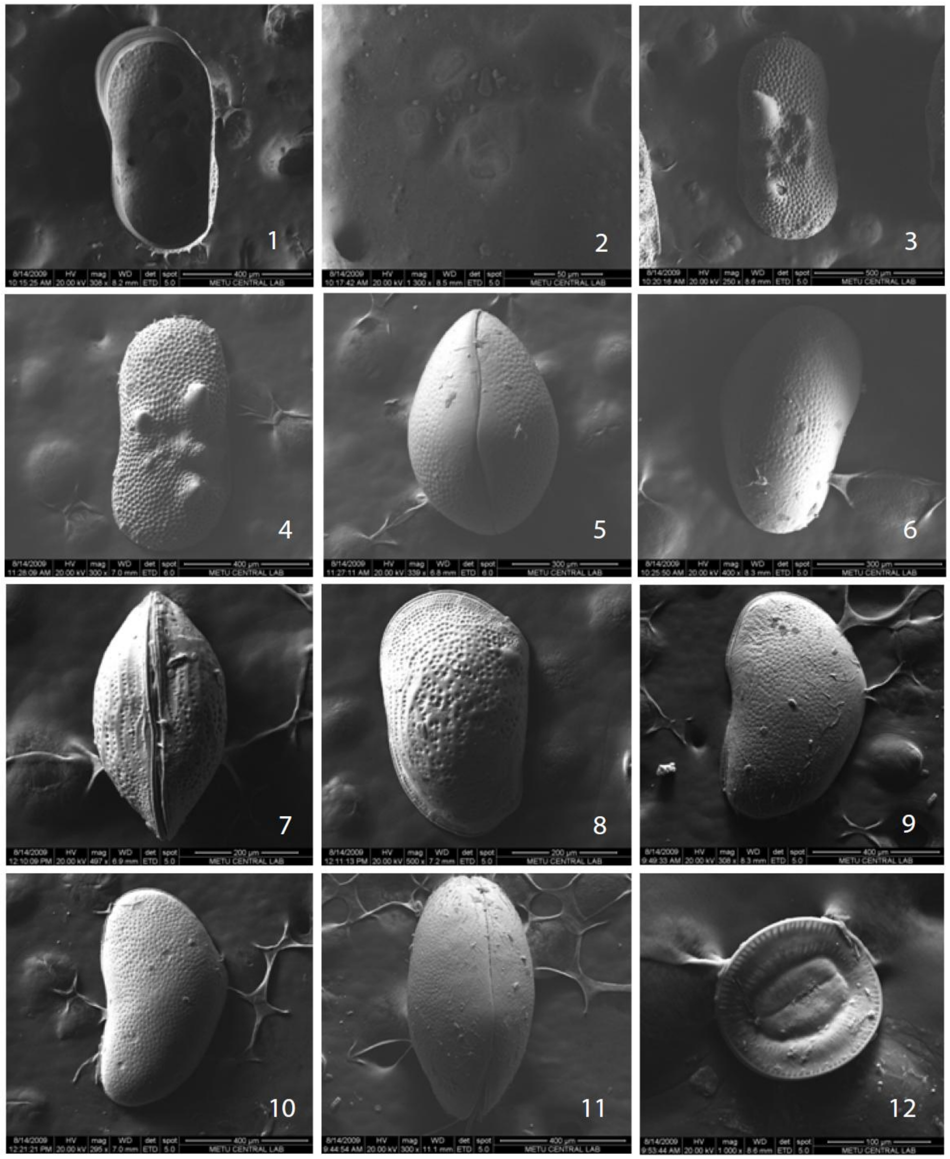


Figure 20. (Plate 3) Büyükçekmece L. **Ostracoda:** surface sediment (sample: BKM 2.2) (1-3) *Ilyocypris monstrifica (*Norman, 1862) (1-3), (1) internal view; (2) detail of central muscle scar; (3) lateral view RV; surface sediment sample BKM 3 *Ilyocypris monstrifica (*Norman, 1862) (4), (4) lateral view LV., *Plesiocypridopsis newtoni* (Brady & Robertson, 1870) (5-6), (5) carapace ventral view, (6) laretal view RV. Terkos L. Surface sediment (sample name: Mevzi, near fw income), *Loxoconcha sp.* (Sars, 1866) (7-8), (7) carapace dorsal view, (8) lateral view; *Plesiocypridopsis newtoni* (Brady & Robertson, 1870) (9-11), (9) female lateral view LV, (10) male lateral view LV, (11) carapace dorsal view, valve detail. **Diatom:** *Campylodiscus clypeus* (Ehrenb.) (12)

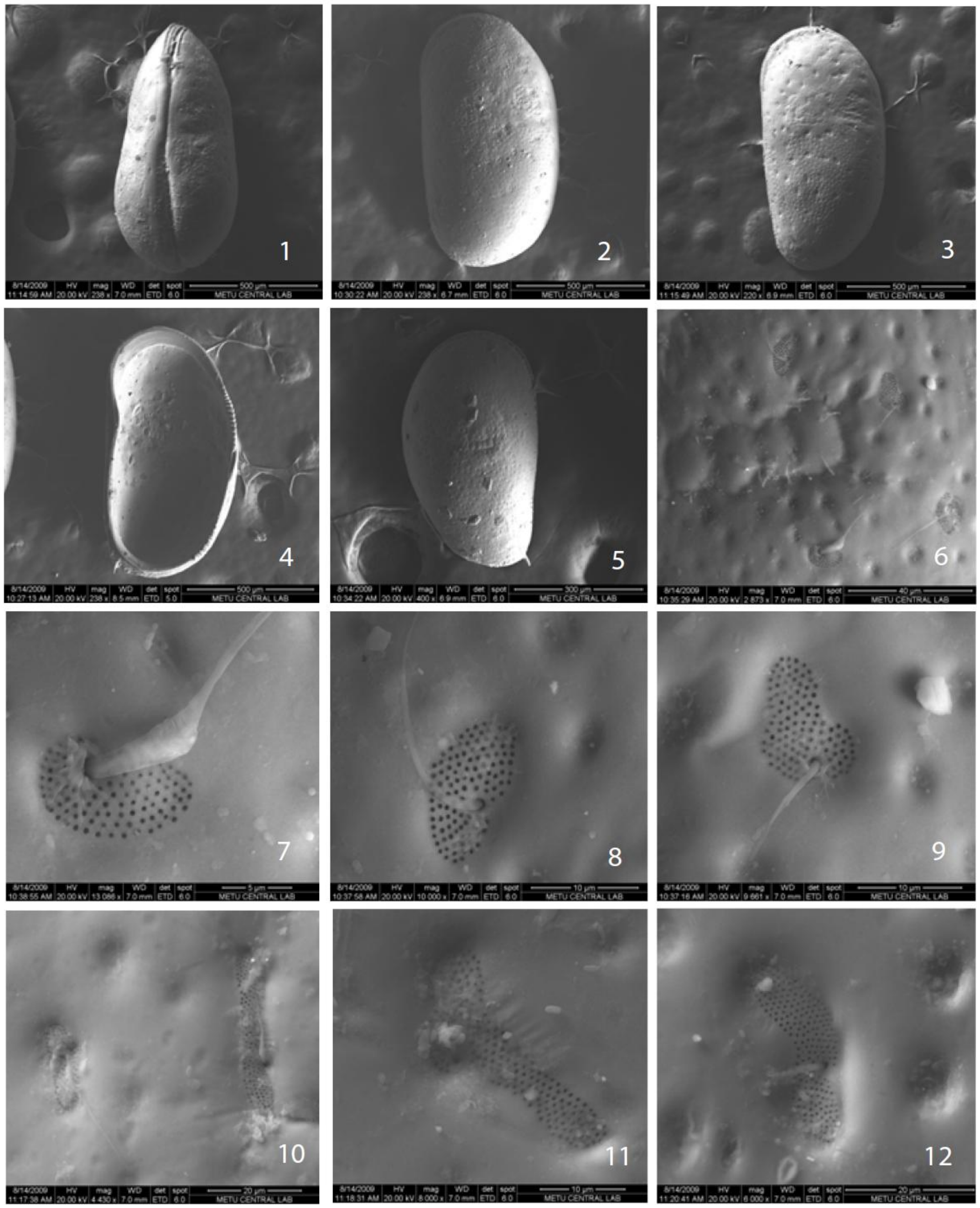


Figure 21. (Plate 4) Sarikum L. **Ostracoda:** surface sediment (sample:s2), *Cyprideis torosa* (Jones, 1857) (1-12) (1) dorsal view, (2) female lateral view LV, (3) male lateralview LV, (4) internal lateral view RV and muscle scar, (5) juvenile lateral view, (6) sieve pore shapes and muscle scars, (7-12) sieve pore shapes, (7) rounded, (8-12) irregular.

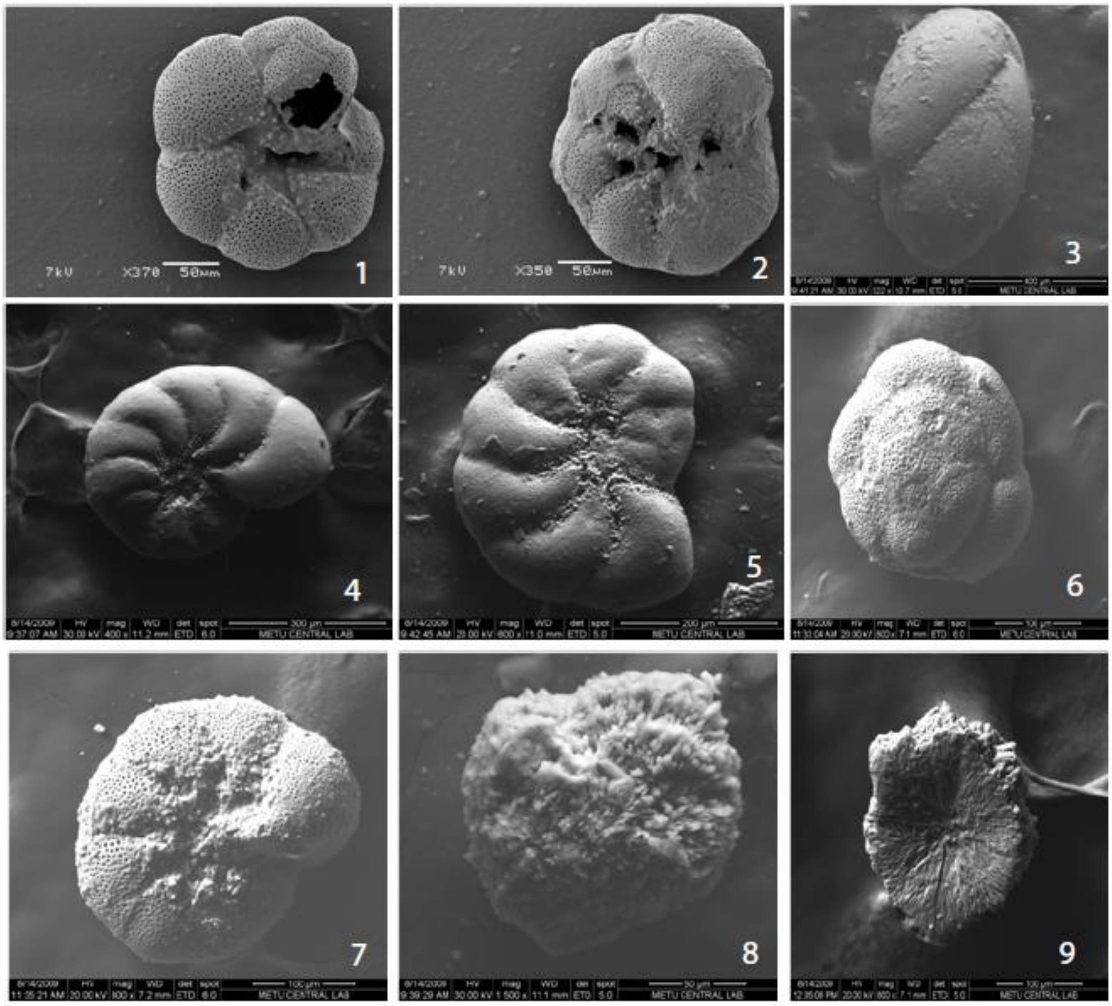


Figure 22. (Plate 5) Terkos L. **Foraminifera:** *Ammonia tepida* (Cushman) (1-2), Terkos Long core (TLC 2.1). Terkos Long core (TLC 2.4) family Miliolidae (D'orbigny, 1839) (3) (between 44-45 cm), *Haynesina anglica* (Murray) (4-5) (*between uppermost 24 and 60 cm) Ammonia tepida* (Cushman), dorsal view (6-7), and rounded cluster of aragonite crystals (from two sides) (8-9).

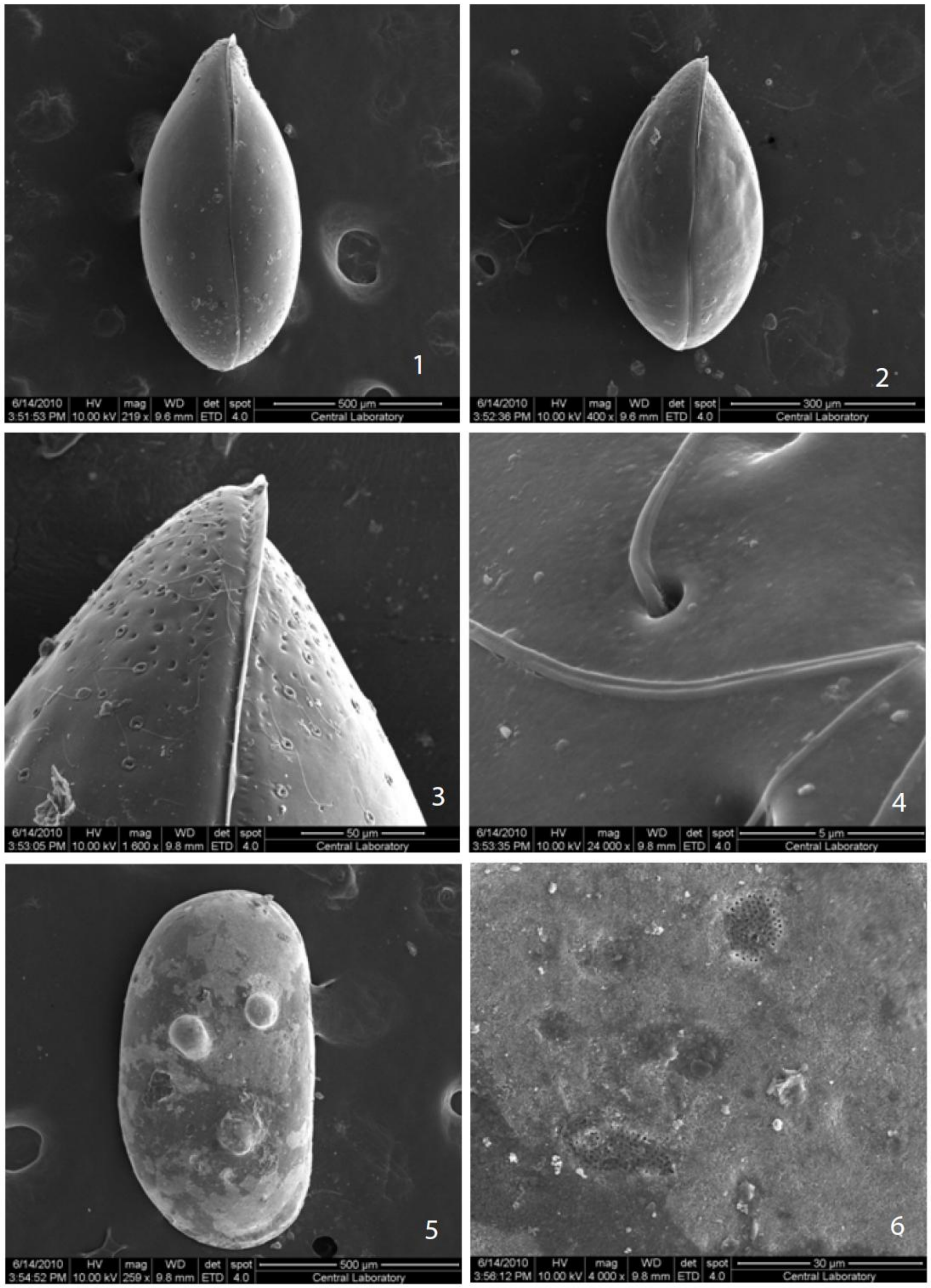


Figure 23. (Plate 6) Mert L. **Ostracoda:** uppermost 27-28 cm of the short core taken in 2006 from the main basin. *Heterocypris incongruens* (Ramdohr, 1808) dorsal view (1-2), anterior (3-4), *Cyprideis torosa* (Jones, 1857) (5-6) (5) Female LV, (6) sieve pore.

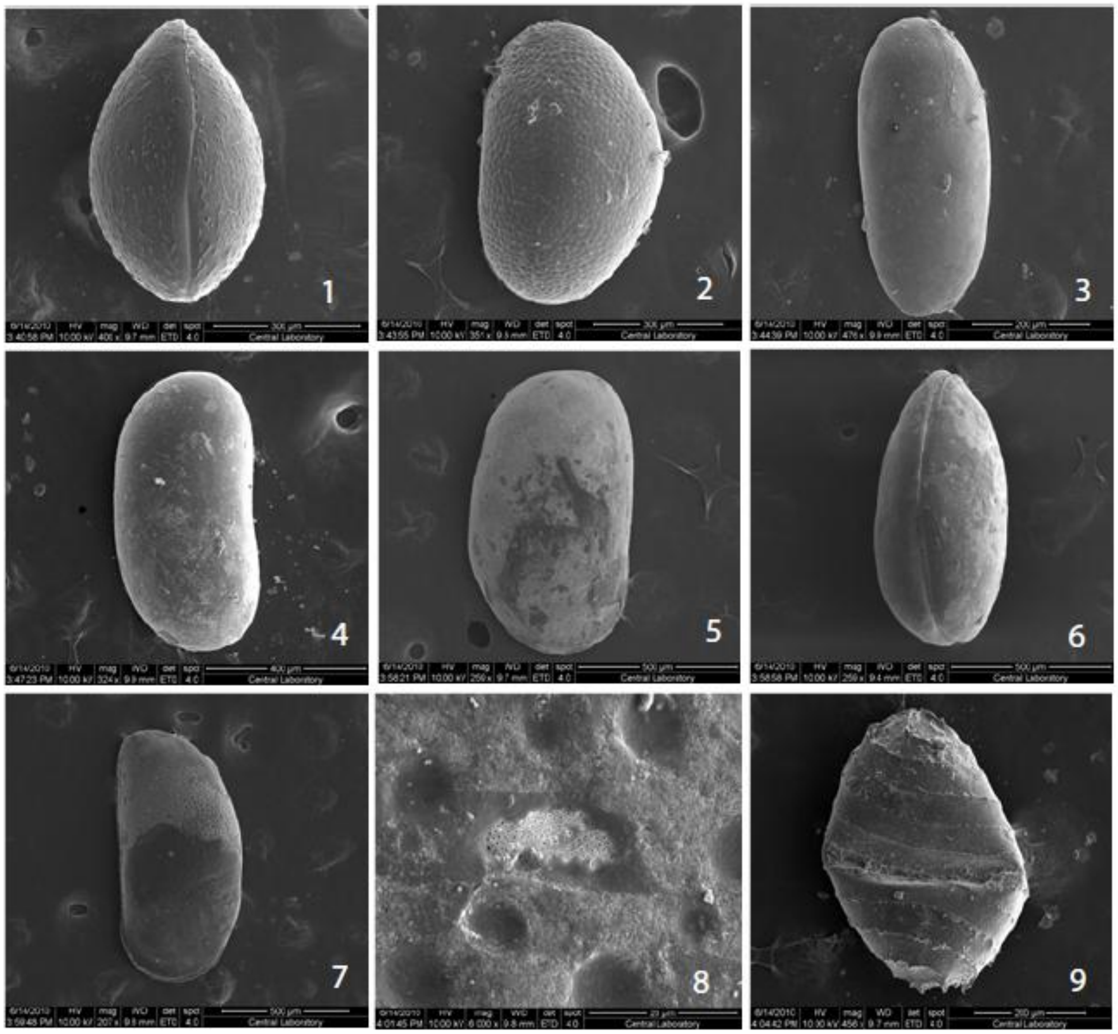


Figure 24 (Plate 7) Uzun L. **Ostracoda:** surface (0-1 cm) from the main basin, *Plesiocypridopsis newtoni* (Brady & Robertson, 1870) (1-2), (1) carapacace ventral view, (2) lateral view LV. Darwinula sp. (Brady & Robertson, 1885) (3) lateral view, Candona sp. (Baird ,1845) (4) lateral view RV, Bottom of the short core 93 cm long: *Cyprideis torosa* (Jones, 1857) (5-8), (5) female lateral, (6) female dorsal, (7) male lateral view, (8) sieve pore shape, (9) Charaphyte oospore.

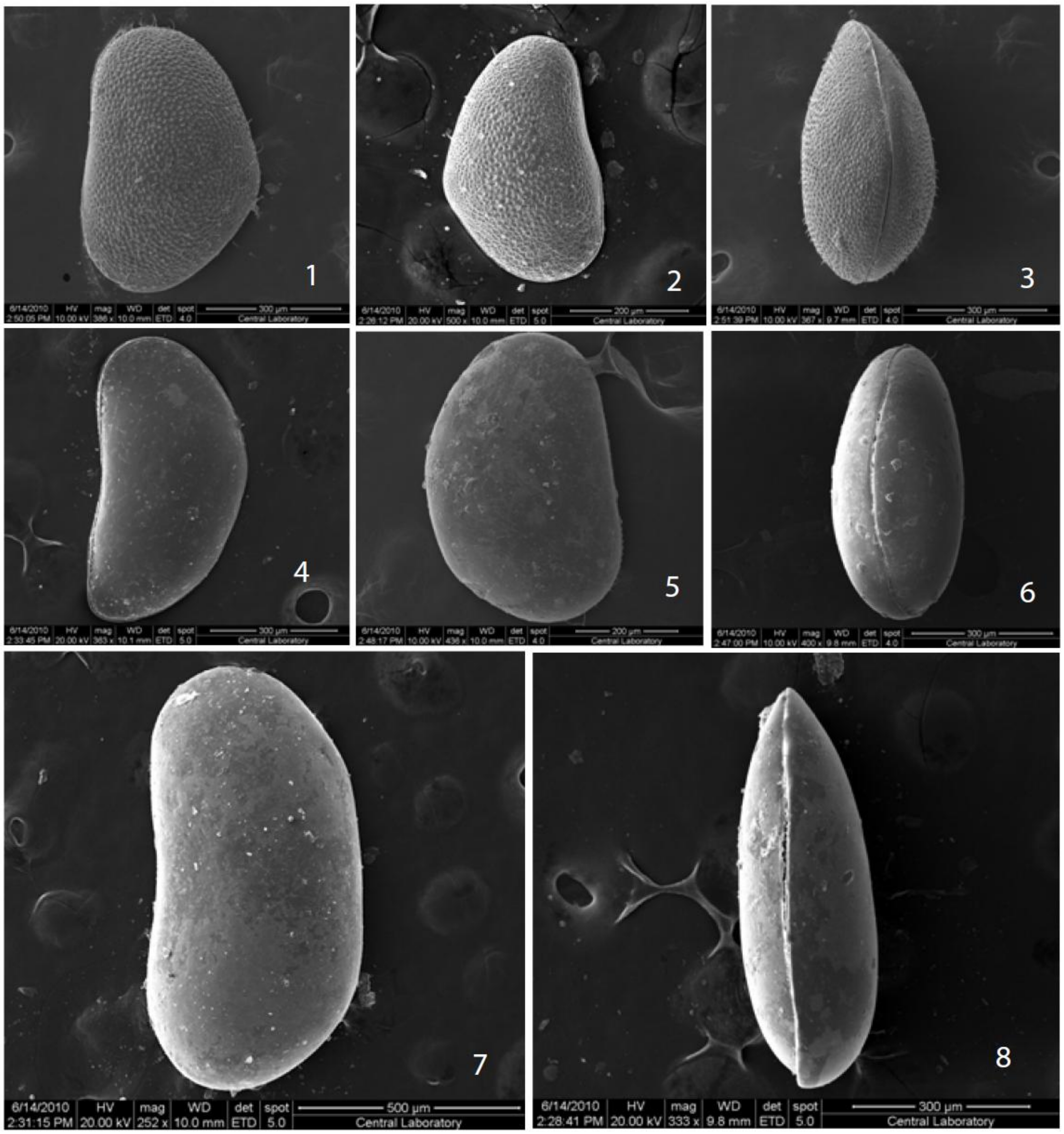


Figure 25. (Plate 8) Cernek L. **Ostracoda:** surface (0-1) cm from the main basin collected inJuly 2007, *Plesiocypridopsis newtoni* (Brady & Robertson, 1870) (1-4),(1) lateral view RV, (2) lateral view LV, (3) dorsal view, (4) lateral view LV (4), *Cypria sp.* (Zenker, 1857) (5-6), (5) lateral view, (6) dorsal view, *Candona sp*. (Baird, 1845) (7-8), (7) lateral view LV, (8) ventral view.

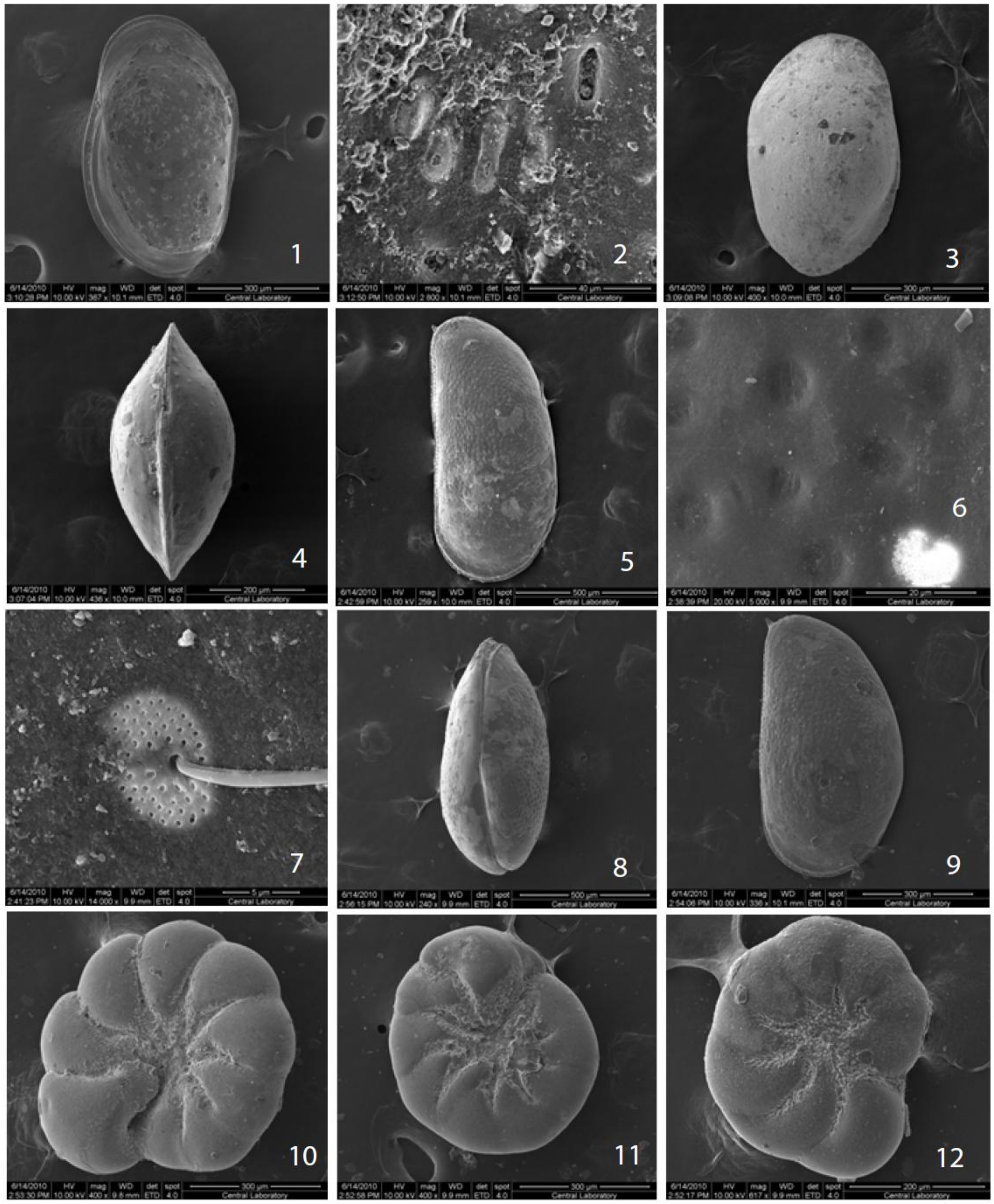


Figure 26. (Plate 9) Cernek L. **Ostracoda:** bottom of the short core 30 cm length collected in July 2007, *Loxoconcha sp.* (Sars, 1866) (1-4): (1) internal lateral view, (2) muscel scar, (3) lateral view, (4) dorsal view, *Cyprideis torosa* (Jones, 1857) (5-9), (5) male lateral view RV,(6-7) sieve pore shapes, (7) rounded sieve pore shape, (8) carapace dorsal view, (9) juvenile lateral view, **Foraminiferea:** *Ammonia parasovica* (10-11), *Haynesina anglica* (Murray) (12).

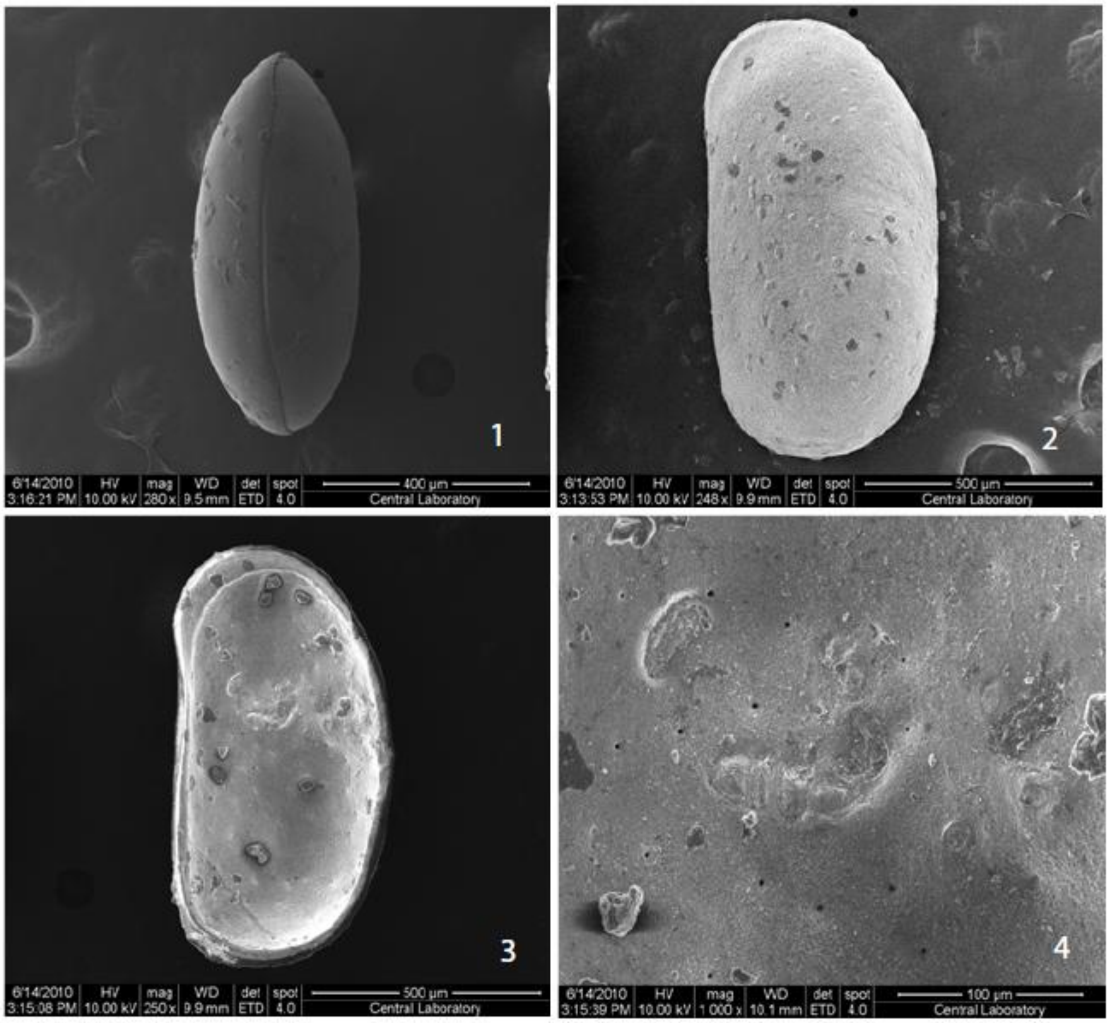


Figure 27. (Plate 10) Erikli L. **Ostracoda:** *Candona sp.* (Baird, 1845), surface collected in 2006, dorsal view (1), bottom of the short core 55 cm long, *Cyprideis torosa* (Jones, 1857) (2-4), (2) female lateral view RV, (3) internal LV, (4) muscle scar.

Figure 28. Observed C. torosa valves and carapaces were identified in a black color in the samples of Buyukcekmece Long Core 2.1, between 57 and 58 cm, which corresponds to a total sediment depth of 57 cm.

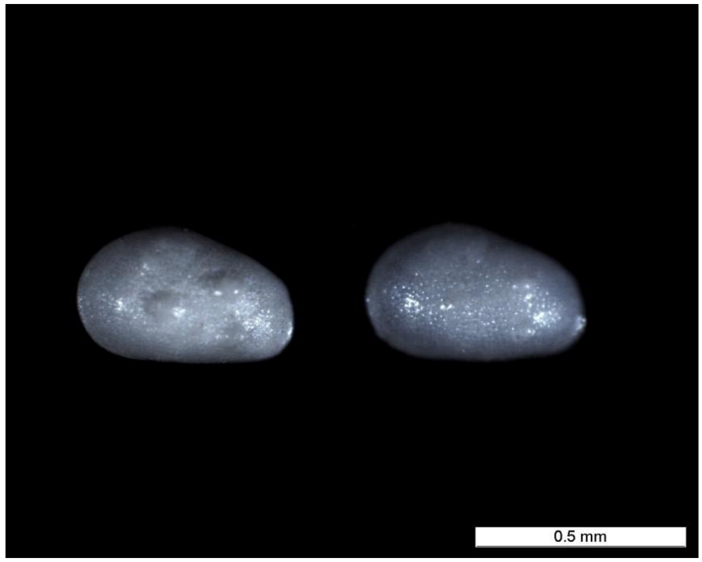


Figure 29. External views of noded C. torosa juvenile valves observed Terkos Long core 2.3 (TLC 2.3) btw 104^{th} and 105^{th} cm.

5.4.2 *Cyprideis torosa* Population Age Structure

Ostracods grow by moulting instars generally eight times until they reach adulthood from the hatching eggs (Holmes, 2001). The age structure techniques are simply based on the percentages of each instar (Ruiz et al., 2003). For instance, in Figure 30, you see size dispersion of *Cyprideis torosa* valves and a representation of population age structure at 33-34 cm in Büyükçekmece Long Core 2.1, near the hiatus, when *C. torosa* is highly abundant. *Darwinula stevensoni* become the dominant ostracod species above this depth.

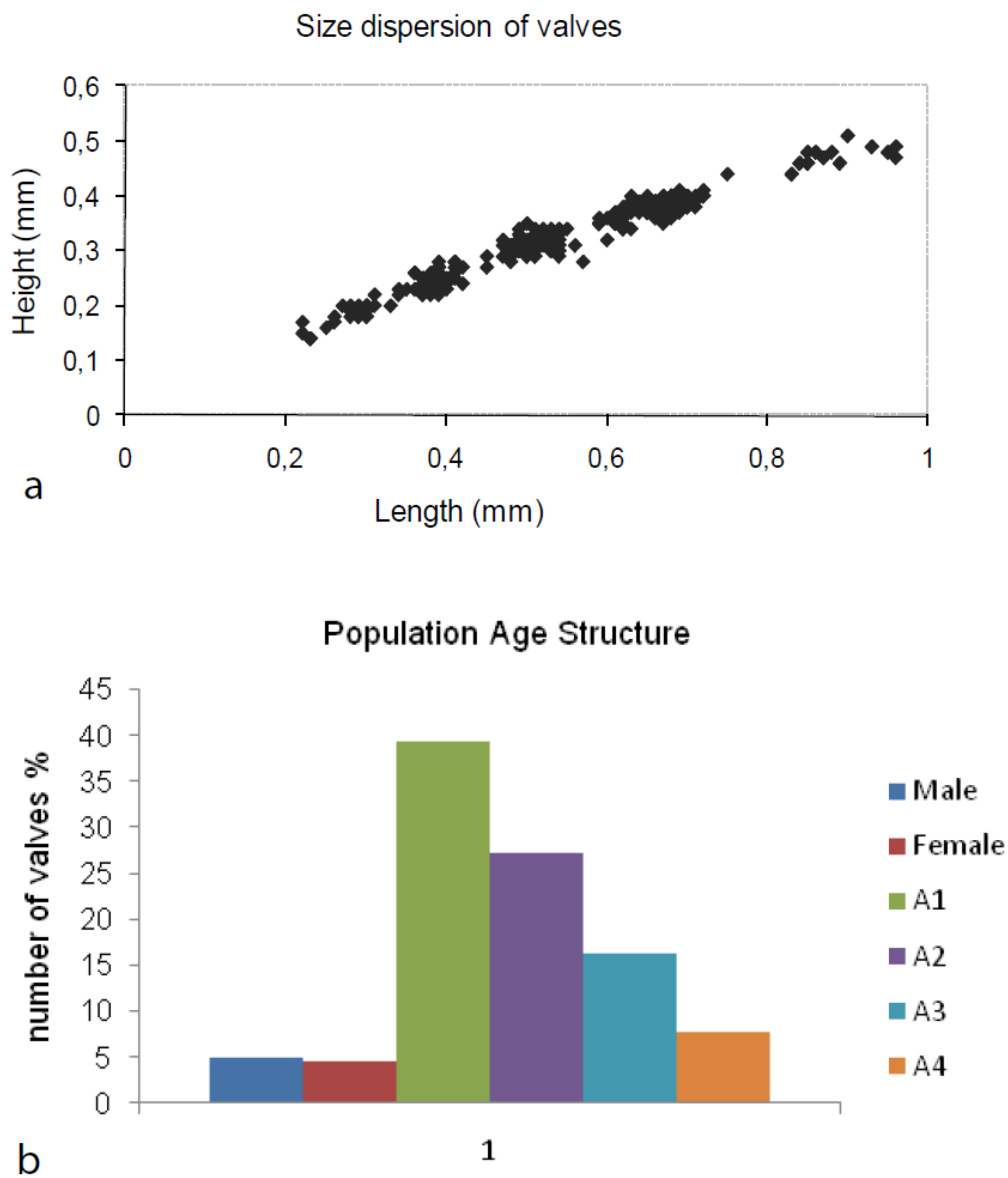


Figure 30. a. Size dispersion of *Cyprideis torosa* valves and b. population age structure, from 283 valves totally at 33-34 cm, Büyükçekmece Long Core 2.1.

5.4.3. Male/Female and Adult/Juvenile Ratios

C. torosa, the most common ostracod species preserved in the sediment records of these three coastal lakes, can reproduce both sexually and asexually. Since male and female specimens can be identified depending on their carapace / valves morphology, preserved ostracod valves in the sediment can be produce historical perspective about their reproductive pattern. Sex-ratios in fossil assemblages were determined by means of carapace/valve morphology alone, for *Cyprideis torosa* in all three study lakes (Figures 31, 33, 34). Since we are dealing with fossil material (adult valves), they refer tertiary sex ratios, which parents doesn't have control over offspring's sex, and representing cumulative effect of several generations (Namiotko, et al., 2008).

Sex ratios showing variability through time in Terkos lake. They may indicate different populations. In both case, at the bottom of the long core and around 260 cm (approximately 2000 cal yrs BP or between 1473 and 2315 cal yrs BP), during the first colonization phases, males initially outnumber females. *C. torosa* is representatively abundant above 150 cm (ca 1116 cal yrs BP), and, again, males outnumber females until around 100 cm 957 cal yrs BP. Extreme deviation from the 1:1 sex ratio occurred around 126 cm, favoring males. Around this depth we also see a foraminifer peak, high Chl-a values, clay & silt and also increased sand % in the sedimentary record of Terkos. The total number of valves (both adults & juveniles) is very low until the bottom of TLC 2.1, around 150 cm, and at 106 cm, when the population of total adults reaches high maximum (Figure 31).

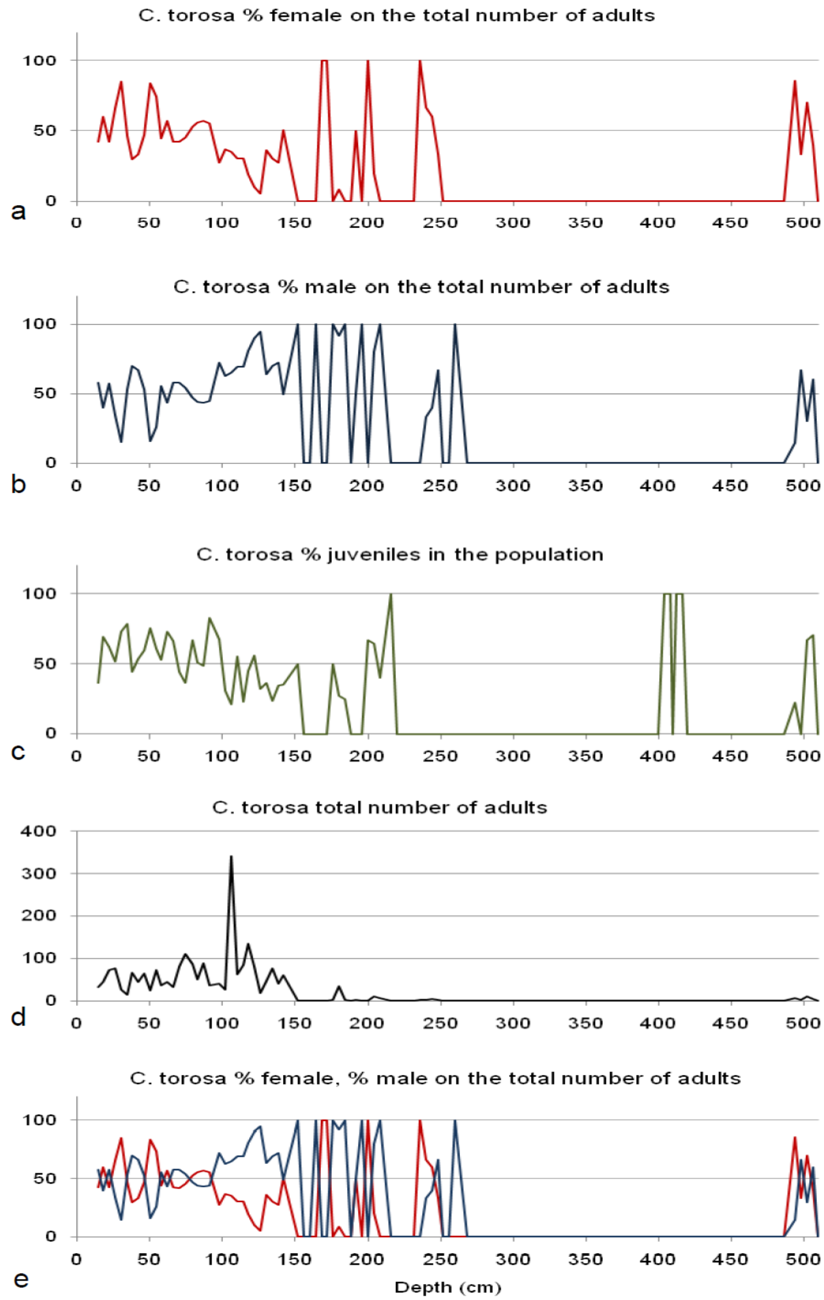


Figure 31. Time series of *C. torosa* distributions in Terkos lake sediments, from top to bottom: a) percentage of females, b) males, c) juveniles, d) total number of adults and e) percentage of females (red) and males (blue), out of the total number of adults.

Generally, the population structure either favors males or females but fewer differences exist in these ratios from 46-87 cm, (most probably before the first dam built), and in the uppermost 5 cm of TLC 2.1, just before 2nd dam modification. All other extreme deviations in the sex ratios, around 50 cm and 30 cm, coincide with foraminifera peaks (Figure 32) that may indicate paleoenvironmental changes. Based on the ostracod species found, foraminifers are more abundant in the salinity ranges of marine water (Frenzel & Boomer, 2005).

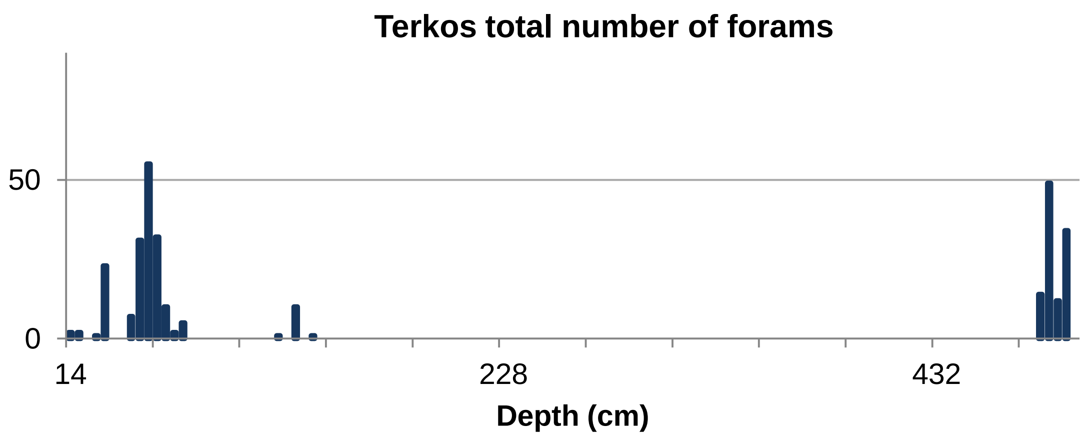


Figure 32. Total number of foraminifera in Terkos Lake sediments.

Cyprideis torosa have two generations in a year (Mezquita, et al., 2000; Cohen & Morin, 1990). During the reproductive seasons (spring and autumn), high numbers of females are observed. In sexual populations of ostracods, males often can't be recognized unless they reach the adult stage (Holmes, 2001). It is assumed that mortality rates between sexes among ostracods are different even before the sexual dimorphism that develops in the penultimate instar, favoring females, in most cases (Abe, 1990). In ostracoda, particular environmental characteristics create differential mortality among juveniles (Namiotko, et al., 2008). For instance, development is positively affected by high temperatures and optimum salinity (Cohen & Morin, 1990). Sex ratios in fossil assemblages suggest ontogeny mortality, reproductive strategy and paleoenvironmental change (Abe, 1990). Sex ratio is not the only proxy dataset based on the carapace morphology of *C. torosa*, however. Carapace morphology (either noded or unnoded forms), sieve pore shapes and trace element ratios (on carapaces) are other indicators of paleoenvironments. Trace element (Sr/Ca and Mg/Ca) molar ratios in *Cyprideis torosa* can help us to estimate paleoenvironment (in the next chapter). In Terkos Lake sediments, we didn't observe any noded forms of *C. torosa* related with low, ambient salinity. However, noded forms of *C. torosa* juveniles were observed (Figure 29) at 404 cm, in a population composed only of juveniles (Figure 31), but in very low abundance. Extreme deviation in sex ratios, favoring males, during the initial times of the population (1116-957 cal yrs BP), may also result from episodic events such as transportation via birds or storm surges. Distribution of individual ostracods and eggs by waterfowl and storm activity is possible (Frenzel & Boomer, 2005).

Figure 33 shows results of ostracod analyses in Büyükçekmece Lake sediments. As with Terkos L., sex ratios vary through time, and male: female sex ratios approach 1 when the population has a high percentage of adults. Just before ~ AD 1950 (33 cm) until 80 cm (where 50 cm is about 2500 cal yrs BP), and also around 100 cm (2750 cal yrs BP), 150 cm (4400 cal yrs BP), and 250 cm (4800 cal yrs BP), the male: female sex ratios are near 1:1.

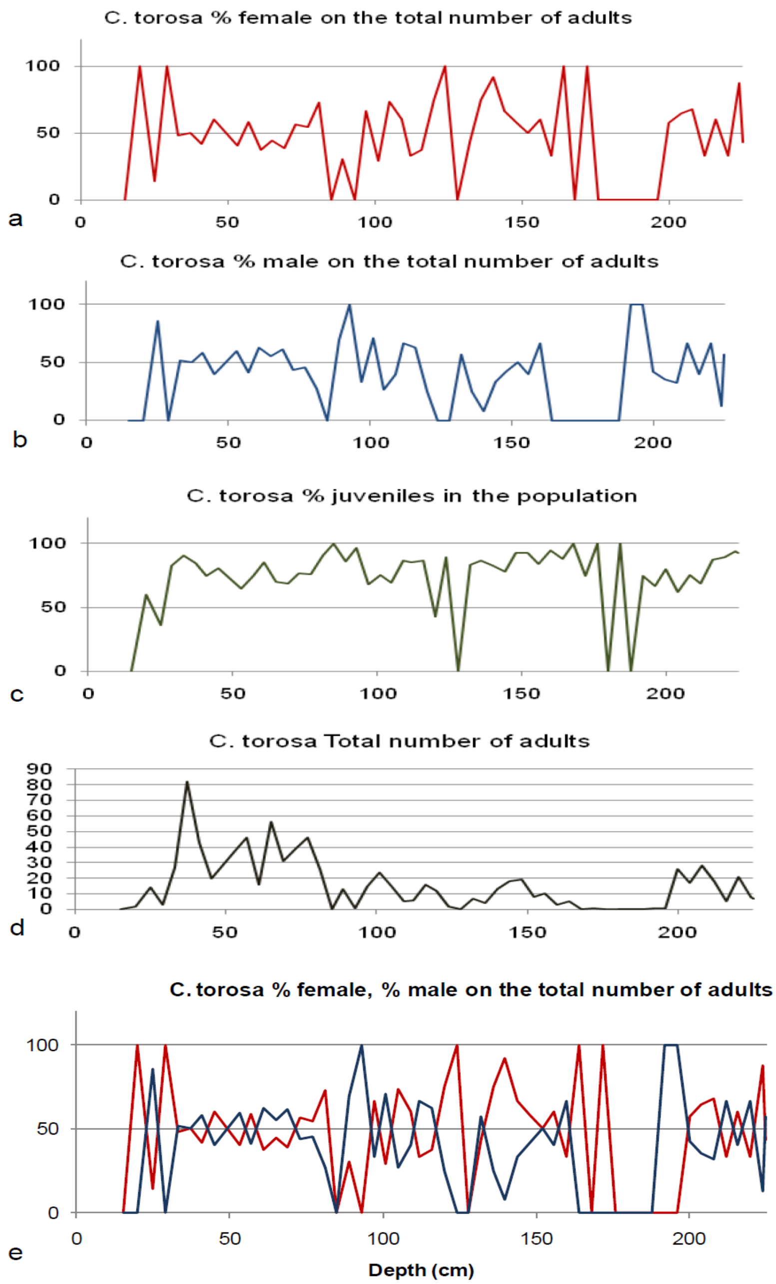


Figure 33. *C. torosa* in Büyükçekmece Lake sediments, from top to bottom: a) percentage of females, b) males, c) juveniles, d) number of adults and e) percentage of females (red) and males (blue), out of the total number of adults.

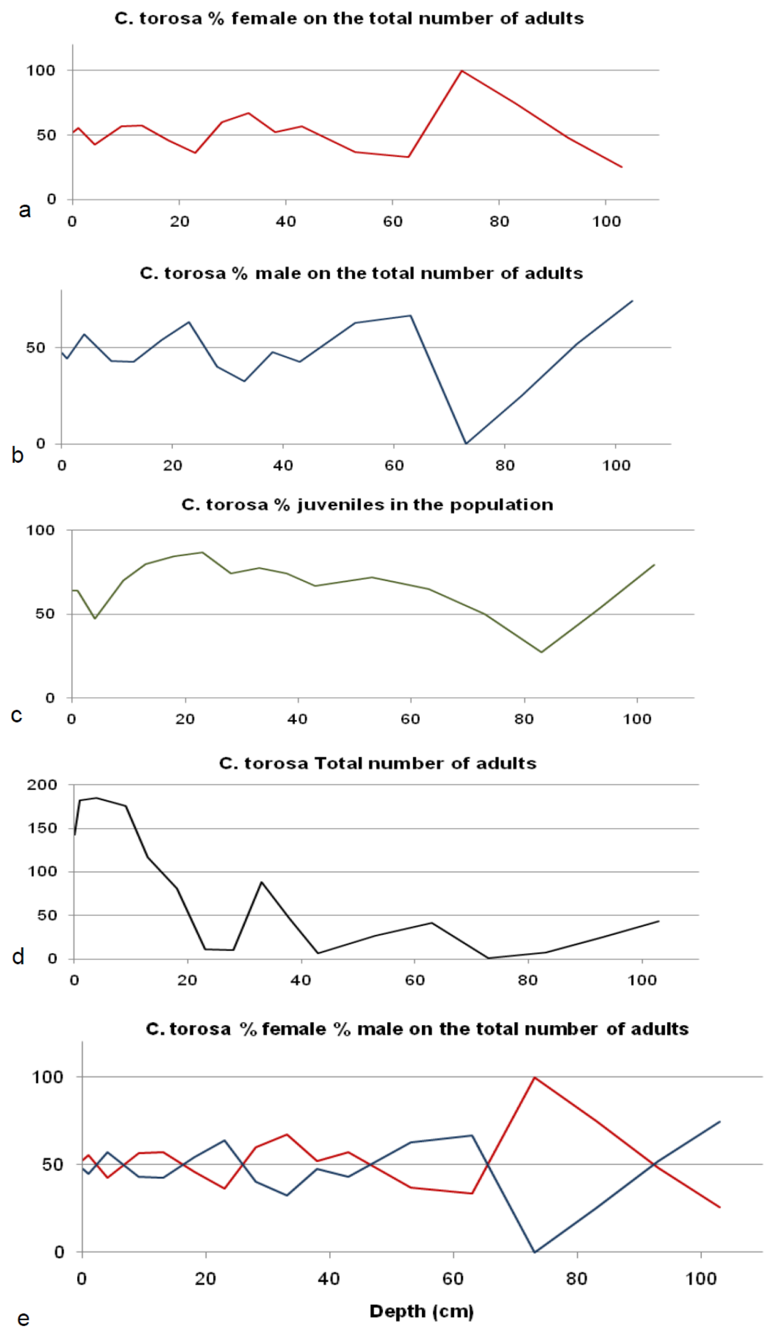


Figure 34. *C. torosa* in Sarikum Lake sediments, from top to bottom: a) percentage of females, b) males, c) juveniles, d)total number of adults and e) percentage of females (red) and males (blue), out of the total number of adults.

5.4.4 Sr/Ca, Mg/Ca Molar Ratios on *C. torosa* shell

Ostracod shells are composed of Ca as a major element, but uptake Mg and Sr as trace elements (Anadon, et al., 2002). The ratios of Ca:Mg:Sr in ostracod shells have been used to track paleosalinities in marginal marine (Anadon, et al., 2002; Boomer & Eisenhauer, 2002) and lacustrine environments (Holmes, 1996). There is a temperature-dependence for Mg uptake, so the Mg/Ca ratio of water reflects the influences of fractionation on Mg (Chivas, et al., 1983; adopted by Holmes, 1996). Sr uptake by ostracod shells depends on the Sr /Ca of the host water and, in comparison to Mg, is little influenced by ambient temperature (Chivas et al. 1986). De Deckker et al. (1999) also pointed out that Mg/Ca between the Mg/Ca ratio in *Cypris* shell is strongly correlated with Mg/Ca of the water as well as temperature. However, they are unlikely follow their normal partition coefficient when Mg/Ca in the ambient water is either very high or very low (<1) since they avoid making valves with high-Mg calcite. The latest works conclude that ostracods don't always provide unambiguous paleosalinity records, but these records are still valuable for comparison with other paleoecological and geochemical indicators (Anadon, et al., 2002, Holmes, et al., 2010).

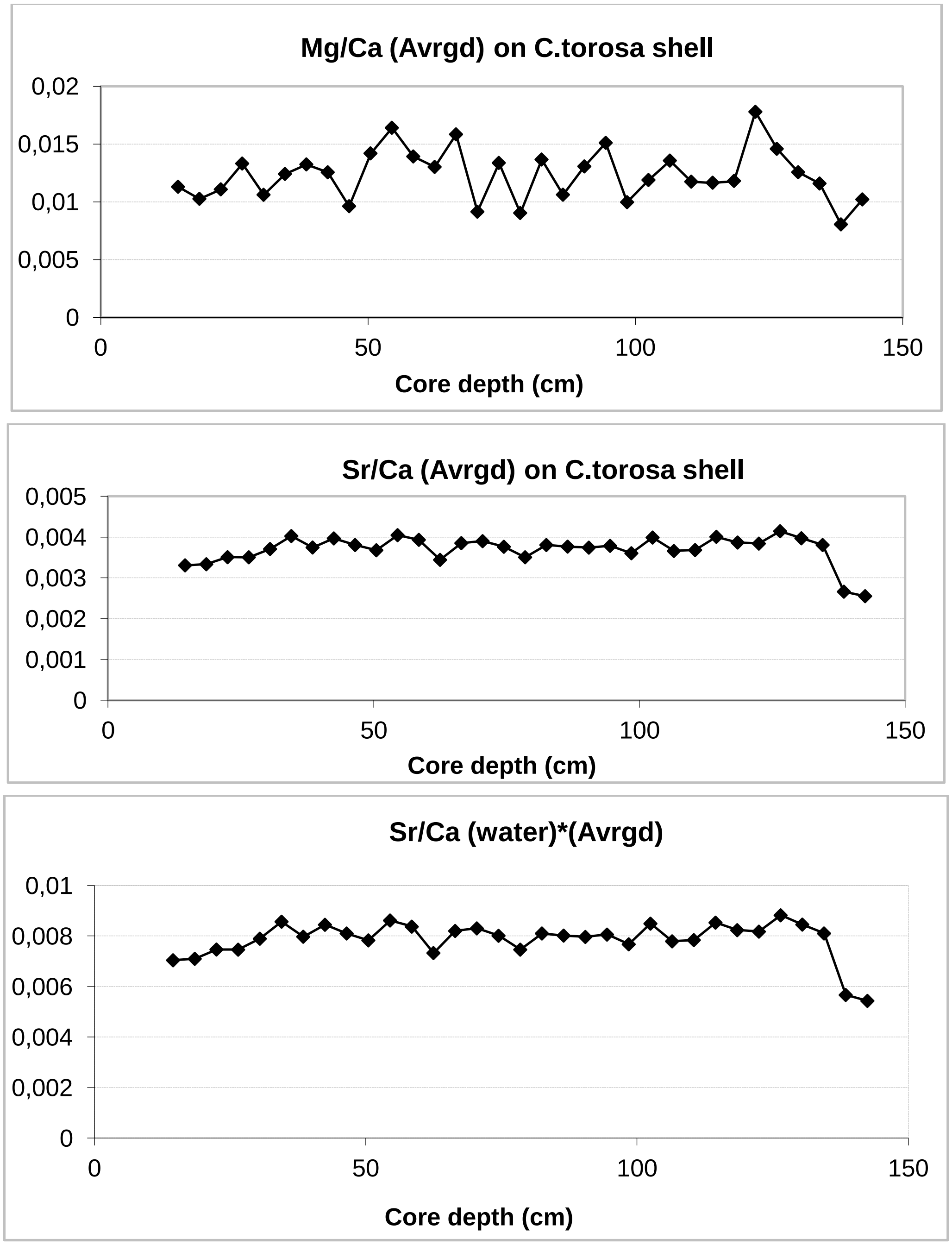


Figure 35. Mg/Ca and Sr/Ca molar ratios on individual ostracoda shells from the samples of TLC 2.1.

Species dependent coefficients of partitioning (KD values) for Mg and Sr in *C. torosa* (Chivas et al. 1986) enable determination of Mg/Ca or Sr/Ca of the waters in which the ostracods live. Figure 35 shows the time series results of Mg/Ca and Sr/Ca molar ratios on ostracoda shells from Terkos Long Core 2.1, and past Sr/Ca ratios for lake water, representative of salinity. Mg/Ca molar ratios in *C. torosa* varied between 0,008 at 138,5 cm (in approximately 1116 cal yrs BP) and 0,018 at 122,5 cm. Sr/Ca molar ratio in *C. torosa* increased from 0,0025 at 1116 cal yrs BP to 0,0041 at 126,5 cm, a near doubling. According our paleoecological data, *C. torosa* first started to dominate Terkos lacustrine sequence in approximately 1116 cal yrs BP. Both Mg/Ca and Sr/Ca ratios show marked, sharp increases around the same depths/times that may be interpreted as an increase of salinity in the lake water. There is also a carbonate peak between these depths (Figure 14). This interval is followed by a foraminifera maximum (Figure 32) and an extreme deviation in the male:female ratio, favoring males (Figure 31). If we assume that these adult male specimens were transported via storm surges or marine inundation, it would also explain sharp increase in the molar Sr/Ca ratios in the water. Fluctuations in Mg/Ca molar ratios since 1116 cal yrs BP may indicate temperature fluctuations in the lake water, especially where Sr/Ca molar ratios are stagnant at 957 cal yrs BP. Decreases in Sr/Ca and an increase Mg/Ca molar ratios, since 1950 cal yrs BP, suggest that other mechanisms may affect trace element partitioning. By reconstructing Mg/Ca and Sr/Ca values for the host water, Sr/Ca molar ratios indicate that, at the bottom of the TLC 2.1, *C. torosa* specimens formed their shells under direct marine inundation or high salinity conditions resulting from lagoon desiccation.

Table 4. Analyses of C. torosa valves from Terkos Long Core 2.1

Core Depth (cm) Top (cm)	Botttom (cm)	Mid-point (cm)	Sex	Valve	Ca (ppm)	Mg (ppm)	Sr (ppm)	Mg/Ca (molar)	Sr/Ca (molar)
14	15	14,5	LV	M	4,59244	0,0314	0,032	0,01128	0,00319
14	15	14,5	LV	F	7,68565	0,0363	0,0533	0,00779	0,00317
14	15	14,5	RV	M	4,76343	0,0429	0,03722	0,01486	0,00357
18	19	18,5	LV	F	6,63527	0,062	0,052	0,01542	0,00358
18	19	18,5	LV	F	5,35007	0,0204	0,02973	0,00628	0,00254
18	19	18,5	LV	F	4,86767	0,0269	0,04138	0,00910	0,00389
22	23	22,5	LV	F	5,6143	0,0374	0,04281	0,01098	0,00349
22	23	22,5	LV	M	5,31169	0,0464	0,04448	0,01440	0,00383
22	23	22,5	LV	M	4,74975	0,0227	0,0334	0,00788	0,00322
26	27	26,5	LV	F	1,39853	0,0164	0,01047	0,01930	0,00342
26	27	26,5	LV	F	3,60608	0,0195	0,028	0,00894	0,00355
26	27	26,5	LV	F	3,33977	0,0237	0,02591	0,01172	0,00355
30	31	30,5	LV	M	2,34625	0,0135	0,01871	0,00948	0,00365
30	31	30,5	LV	M	2,13239	0,0152	0,01761	0,01175	0,00378
34	35	34,5	LV	F	8,57895	0,078	0,07519	0,01499	0,00401
34	35	34,5	LV	F	4,66012	0,0322	0,0407	0,01140	0,00399
34	35	34,5	RV	M	3,37927	0,0223	0,03017	0,01086	0,00408
38	39	38,5	RV	M	4,66925	0,035	0,04032	0,01237	0,00395
38	39	38,5	LV	F	2,46804	0,0248	0,01966	0,01658	0,00364
38	39	38,5	LV	F	2,92067	0,0191	0,02332	0,01079	0,00365
42	43	42,5	LV	M	7,63006	0,0514	0,07022	0,01112	0,00421
42	43	42,5	LV	M	5,01596	0,0396	0,04278	0,01300	0,00390
42	43	42,5	LV	M	6,61399	0,0544	0,05501	0,01357	0,00380
46	47	46,5	LV	F	6,55511	0,0354	0,05366	0,00891	0,00374
46	47	46,5	LV	F	8,61135	0,0572	0,07396	0,01095	0,00393
46	47	46,5	RV	F	5,94194	0,0325	0,0488	0,00903	0,00376
50	51	50,5	RV	F	2,42791	0,0185	0,0211	0,01254	0,00397
50	51	50,5	LV	M	1,87393	0,0183	0,01463	0,01613	0,00357
50	51	50,5	RV	M	1,48073	0,0125	0,01132	0,01393	0,00350
54	55	54,5	LV	F	2,95938	0,0279	0,02629	0,01554	0,00406
54	55	54,5	LV	M	2,47081	0,0291	0,02044	0,01945	0,00378
54	55	54,5	LV	M	2,2102	0,0191	0,02081	0,01425	0,00431
58	59	58,5	LV	M	6,95923	0,0573	0,06001	0,01358	0,00394
58	59	58,5	RV	M	2,06273	0,0144	0,01831	0,01153	0,00406
58	59	58,5	RV	M	3,67991	0,0372	0,03063	0,01668	0,00381
62	63	62,5	LV	M	4,80286	0,0345	0,04083	0,01185	0,00389
62	63	62,5	LV	F	5,05578	0,0462	0,03449	0,01506	0,00312
62	63	62,5	RV	F	4,6826	0,0345	0,03406	0,01216	0,00333
66	67	66,5	LV	F	6,45087	0,0389	0,05165	0,00994	0,00366
66	67	66,5	LV	M	1,89979	0,031	0,01551	0,02694	0,00373

Table 4 Analyses of *C. torosa* valves from Terkos Long Core 2.1 (continued)

66	67	66,5	LV	M	2,01646	0,013	0,0184	0,01065	0,00417
70	71	70,5	LV	F	6,86402	0,0399	0,06043	0,00958	0,00403
70	71	70,5	LV	F	5,14159	0,0219	0,04308	0,00703	0,00383
70	71	70,5	LV	M	4,18452	0,0275	0,03526	0,01084	0,00385
74	75	74,5	LV	M	3,97697	0,0441	0,03293	0,01830	0,00379
74	75	74,5	LV	F	5,93938	0,0356	0,04856	0,00988	0,00374
74	75	74,5	LV	M	2,83862	0,0206	0,02342	0,01194	0,00377
78	79	78,5	RV	F	6,93658	0,0355	0,05143	0,00843	0,00339
78	79	78,5	LV	M	3,61329	0,0199	0,02869	0,00907	0,00363
78	79	78,5	LV	F	6,77577	0,0396	0,0519	0,00962	0,00350
82	83	82,5	LV	F	4,20831	0,0379	0,03383	0,01485	0,00368
82	83	82,5	LV	F	10,5096	0,0823	0,08922	0,01292	0,00388
82	83	82,5	LV	M	9,194	0,0738	0,07779	0,01323	0,00387
86	87	86,5	LV	M	1,99015	0,0148	0,01664	0,01226	0,00382
86	87	86,5	RV	M	2,71303	0,0155	0,02297	0,00943	0,00387
86	87	86,5	LV	M	2,11745	0,0131	0,01673	0,01018	0,00361
90	91	90,5	LV	F	8,60233	0,056	0,07229	0,01074	0,00384
90	91	90,5	LV	F	7,76381	0,0514	0,06653	0,01092	0,00392
90	91	90,5	LV	M	2,39238	0,0255	0,01816	0,01756	0,00347
94	95	94,5	LV	M	7,08053	0,0596	0,06089	0,01388	0,00393
94	95	94,5	LV	F	3,9454	0,0432	0,03036	0,01804	0,00352
94	95	94,5	LV	F	5,96584	0,0485	0,05106	0,01341	0,00391
98	99	98,5	RV	F	8,56628	0,0526	0,07277	0,01013	0,00388
98	99	98,5	LV	F	5,15541	0,0315	0,04309	0,01009	0,00382
98	99	98,5	LV	M	3,40992	0,0201	0,02323	0,00970	0,00312
102	103	102,5	LV	M	4,43583	0,0359	0,04067	0,01333	0,00419
102	103	102,5	LV	F	7,24916	0,0438	0,06059	0,00997	0,00382
102	103	102,5	LV	F	6,46382	0,0486	0,05599	0,01240	0,00396
106	107	106,5	LV	M	5,25741	0,0417	0,04351	0,01308	0,00378
106	107	106,5	LV	F	4,85555	0,0415	0,03769	0,01410	0,00355
106	107	106,5	LV	F	6,63994	0,0545	0,05305	0,01353	0,00365
110	111	110,5	LV	M	8,7768	0,0684	0,06451	0,01284	0,00336
110	111	110,5	LV	F	6,48408	0,036	0,05308	0,00915	0,00374
110	111	110,5	LV	F	6,55275	0,0527	0,05662	0,01326	0,00395
114	115	114,5	LV	M	8,55646	0,0705	0,07618	0,01359	0,00407
114	115	114,5	LV	F	8,97106	0,0561	0,07952	0,01031	0,00405
114	115	114,5	LV	F	6,12873	0,0412	0,05234	0,01108	0,00391
118	119	118,5	LV	M	7,76869	0,0556	0,06807	0,01180	0,00401
118	119	118,5	LV	F	7,87113	0,061	0,06777	0,01277	0,00394
118	119	118,5	LV	F	7,16825	0,0473	0,05748	0,01087	0,00367
122	123	122,5	LV	F	9,59966	0,1217	0,08813	0,02090	0,00420
122	123	122,5	LV	M	6,23141	0,0438	0,04796	0,01160	0,00352
122	123	122,5	LV	M	4,01037	0,0508	0,03343	0,02088	0,00381
126	127	126,5	LV	M	5,12607	0,0453	0,04748	0,01457	0,00424
126	127	126,5	LV	F	10,3473	0,0906	0,09315	0,01444	0,00412
126	127	126,5	LV	F	7,97739	0,0715	0,07133	0,01477	0,00409
130	131	130,5	LV	M	6,74011	0,0523	0,06043	0,01279	0,00410

Table 4 Analyses of C. torosa valves from Terkos Long Core 2.1 (continued)

130	131	130,5	LV	F	8,68815	0,0491	0,07294	0,00932	0,00384
130	131	130,5	LV	F	5,79371	0,0548	0,05048	0,01559	0,00398
134	135	134,5	LV	F	3,03511	0,0216	0,02681	0,01172	0,00404
134	135	134,5	LV	M	5,71451	0,0319	0,04436	0,00921	0,00355
134	135	134,5	LV	M	7,86156	0,066	0,06599	0,01385	0,00384
138	139	138,5	LV	M	10,4192	0,0463	0,06641	0,00733	0,00292
138	139	138,5	RV	M	3,10254	0,0161	0,01726	0,00853	0,00254
138	139	138,5	LV	F	10,8262	0,0545	0,06004	0,00831	0,00254
142	143	142,5	RV	M	7,33354	0,0577	0,04351	0,01298	0,00271
142	143	142,5	LV	F	8,93199	0,0552	0,04551	0,01020	0,00233
142	143	142,5	LV	M	4,15798	0,0188	0,02382	0,00747	0,00262

5.5 Other biological indicators

Although diatom slides were prepared at 4 cm sampling intervals in the Terkos, Büyükçekmece and Sarikum long cores and short cores, poor preservation was a problem. Diatom preservations are usually poor in salt-rich environments. High pH favors ostracods instead of diatom preservation (Boomer, et al., 2003). One very large, brackish water species, *Campylodiscus clypeus* (Ehrenb.) (Plate 3), occurs in Terkos Long Core 2.1, between 50-70 cm. This was noted at 100x magnification during ostracod analyses. Normally, this diatom species isn't seen on slides, apart from broken valves, because of their tendency for excessive breakage during the digestion and slide preparation procedure. Flower (1993) showed that sediment pre-drying alone could play a major role in fragmentation of *Campylodiscus clypeus*. This species has been recorded worldwide in both coastal/ lagoonal environments (Baltic Sea) and inland saline lakes. Its potential as an indicator for reconstructions of past shoreline position and past water level and climate has already been discussed.

Only low abundance, and mostly planktonic, diatoms, such as tychoplanktonic *Aulacoseira granolata* (meso-eutrophic), *Stephanodiscus hantzschii,* *Cyclostephonos invisitatus*, also *Amphora, Cymbella sp., Gomphonema sp., Epithemia sp.* living on periphyton, and *Fragilaria cappuccino*, were observed in the uppermost 0-1 cm of Terkos Short Core 2. This is expected in today's well-mixed, nutrient rich environment of the lake. Abundances of all diatoms, snails, bivalves (Figure 36), foraminifera, Glochidia (Figure 38), and charaphyte oospores (Figure 37) belonging to different Chara species (Haas, 1994) found during sample preparation for ostracods were also estimated and plotted against core depth, for Büyükçekmece and Sarıkum lakes (Figures 41,42).

In Büyükçekmece Lake, since foraminifera is very abundant in 3 cc of wet sediment, it is plotted as relative abundance. Benthic Black Sea forams, such as *Ammonia tepida* (Cushman)*, A. parasovica and* Miliolidae (D'orbigny, 1839) (family), (Figure 39), were observed in the Terkos, Büyükçekmece and Sarikum long cores. These benthic foraminifera are common in shallow waters such as estuaries but are not found in the surface samples of any of the study lakes.

Single valves of fossil Glochidia, were observed in some sediment samples processed for ostracods. Figure 38 shows their SEM illustrations. They are microscopic first larval stage of unionid freshwater mussels. They are obligate parasites on fish, attaching to their gills, fins, or spiny valves to complete their metamorphosis (Aldridge and Horne, 1998). Fossil Glochidia are a potentially powerful tool for both the presence of fish, because of their reproductive strategy making them restricted to the sites with fish population, and for the season of sediment accumulation, since different species of fresh water mussels are known to release Glochidia at different times of year (Aldridge and Horne, 1998), (Figure 38). Larval stages can't be identified to species level, unfortunately. At a

Glochidia peak in the Terkos long core 2.3, a fish tooth, probably a teleost, was also observed and illustrated using SEM (Fig. 38).

Charaphyte oospores/seeds were observed in Büyükçekmece sediments deposited before 2500 AD and throughout the whole Sarıkum Lake long core (Plate 7, Figure 37). The presence of this submerged plant in these watersheds indicates a macrophyte-dominated clear water state in the lakes.

Figure 36. Clams and Snails (BLC 2)

Figure 37. Charaphyte oospores of different species. Illustrated samples are from Sarıkum Long Core 1.1 between 44th and 45th cm.

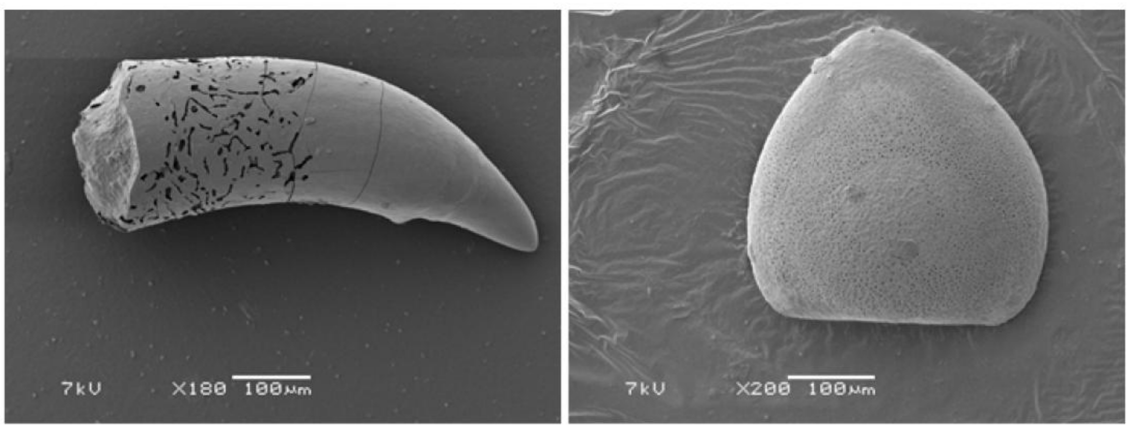


Figure 38. SEM illustrations of a Fish tooth (left) and external view of a single valve of fossil Glochidia larvae (right) observed *between 20th and 21st cm of Terkos LC 2.3.* (cumulative core depth: 313 cm as represented in the Fig. 30 stratigraphy).

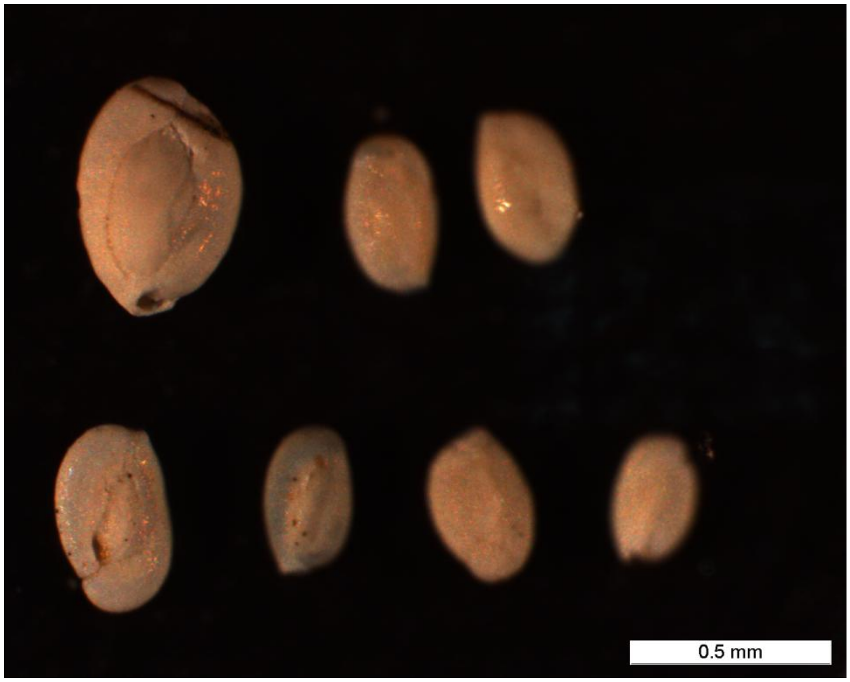


Figure 39. Büyükçekmece L. **Foraminifera:** benthic foraminifera, family Miliolidae (D'orbigny, 1839). Büyükçekmece Long core 2.1, between 98-99 cm.

5.6 The Stratigraphy

Ostracods, algal production (from Chl-a determination), percent sand (which is the differences on the weights of the ostracod sample before and after sieving through the 63 µm), and other faunal elements were plotted against adjusted core depths for Terkos, Büyükçekmece and Sarikum Lakes (Figures 40-42).

Before 2500 AD Büyükçekmece was a shallow lagoon dominated with marginal marine species such as *C. torosa*, *Loxoconcha sp.* (Boomer & Eisenhauer, 2002), *Ilyocypris monstrifica,* littoral *ostracod species* (Meisch, 2000) *and* submerged plant Chara and open to marine inundations evident from abundant benthic foraminifera, marine bivalves and snail remains as the same as Sarikum lake's present conditions. However, there is an alternation of ostracod species to more fresh water such as *D. stevensoni* and *Limnocythere inopinata* during last 50 years (since the first dam built) where we can still have *Ilyocypris monstrifica*. Marine fossils in the long cores suggest that Sarikum L. is generally more often under marine than freshwater conditions but that freshwater conditions have recently started to dominate.

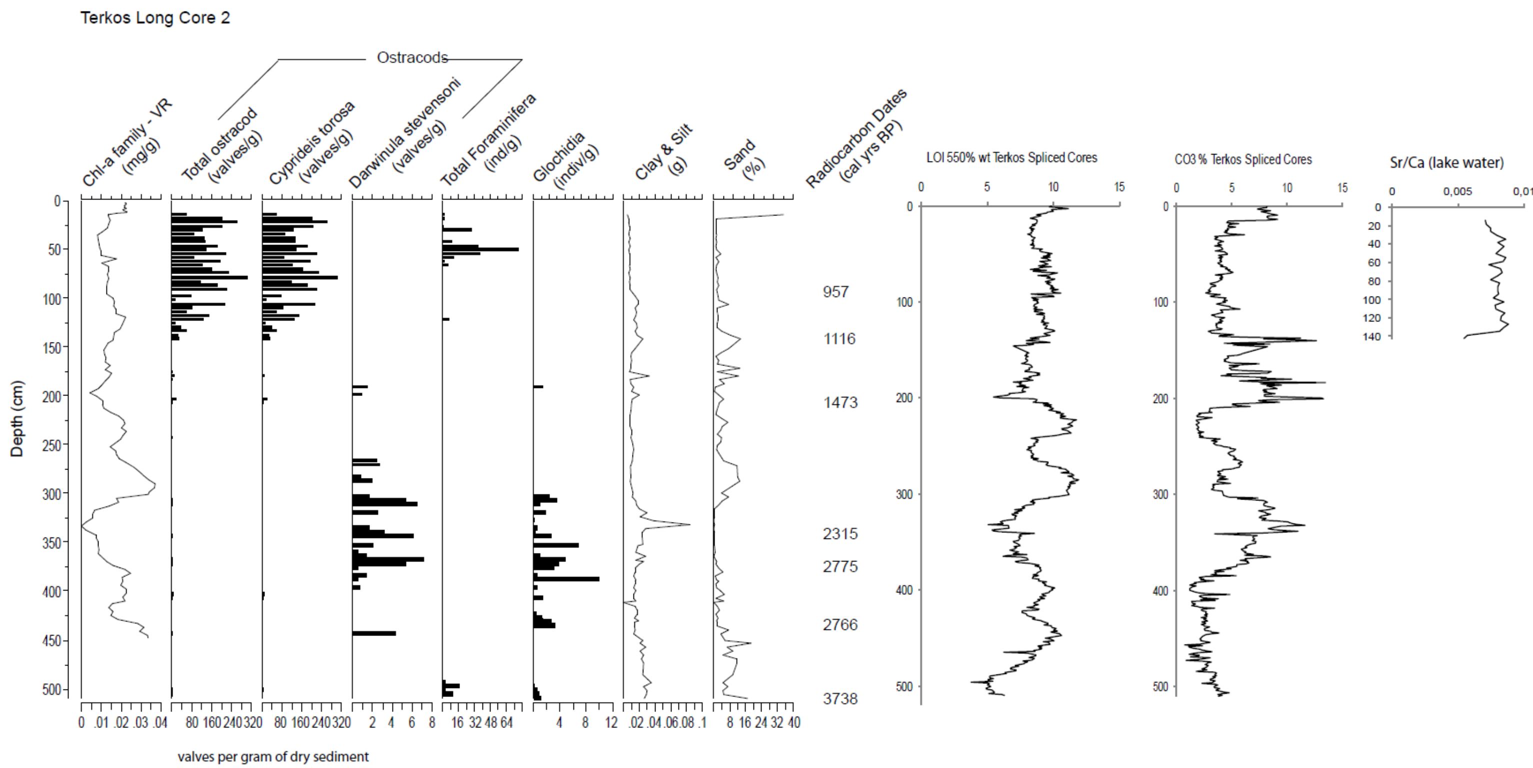


Figure 40. Representation of paleoecological data from Terkos 2 Long and Short Core (combined) ostracoda stratigraphy per g of dry sediment, forams, Glochidia per g, algal production and sand percentage obtained from ostracod analyses and organic and carbonate carbon content.

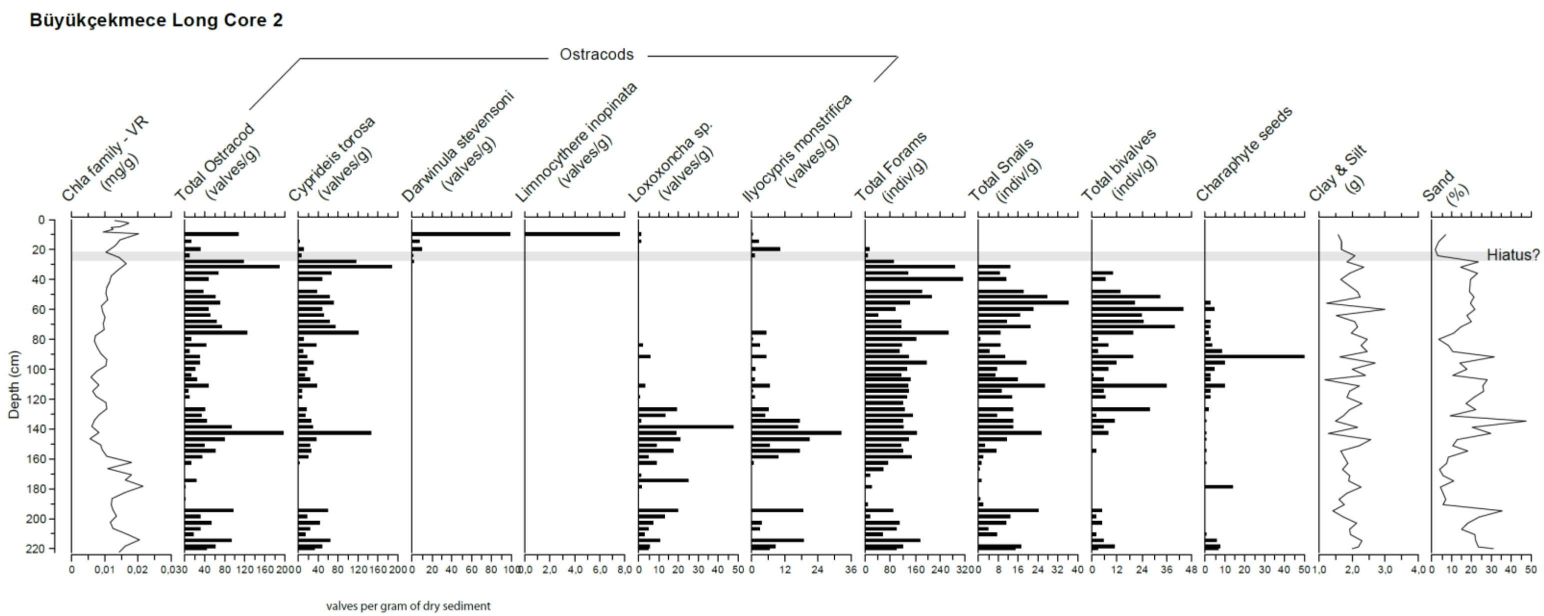


Figure 41. Büyükçekmece Long Core 2 and short core 3 ostracod stratigraphy per g of dry sediment, total forams, snails, bivalves Charaphyte seeds and sand percentage obtained from ostracod analyses.

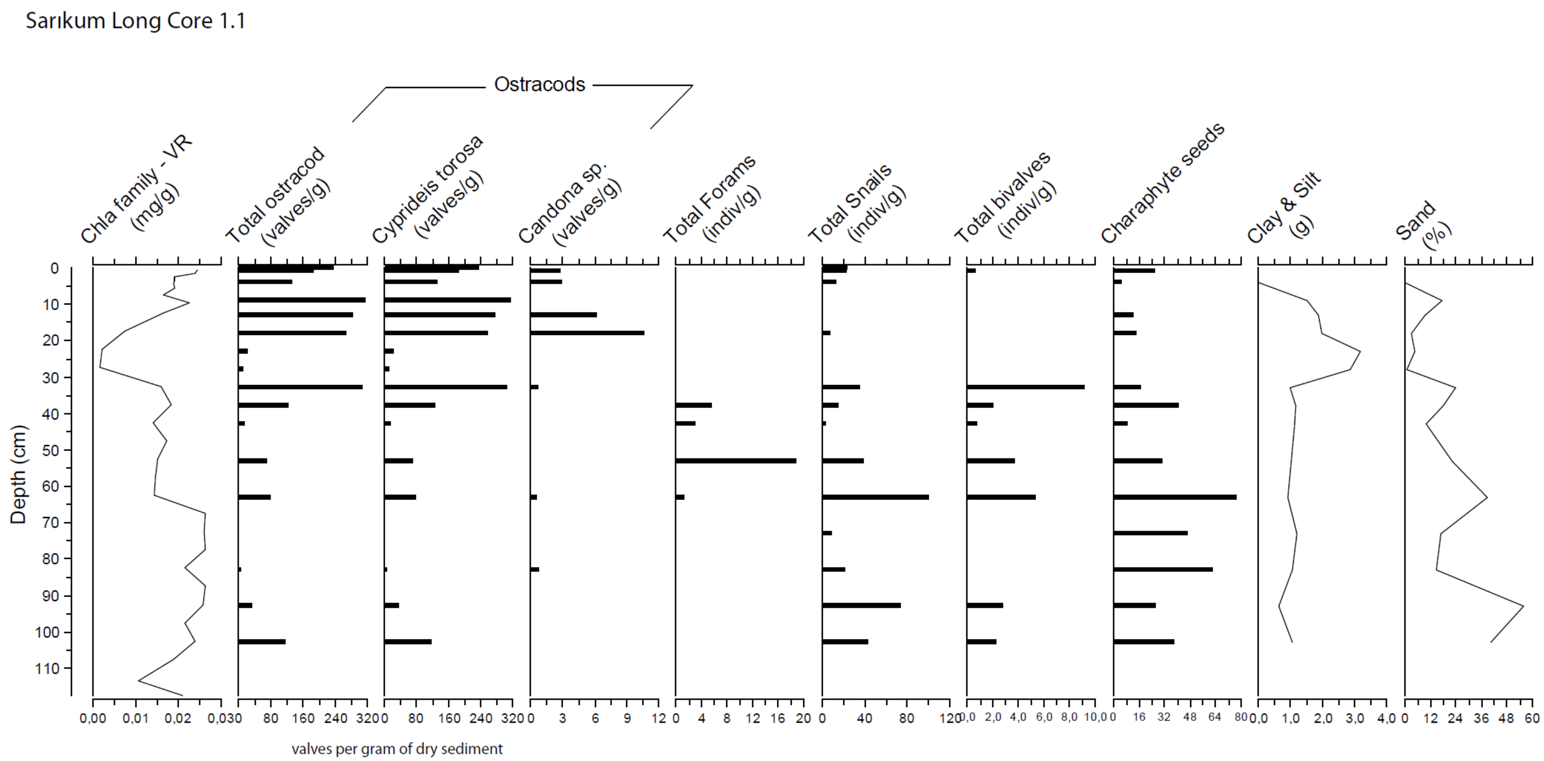


Figure 42. Sarikum Long Core and short core 1 ostracod stratigraphy per g of dry sediment, total forams, snails, bivalves per g, total Charaphyte seeds and sand percentage obtained from ostracod analyses.

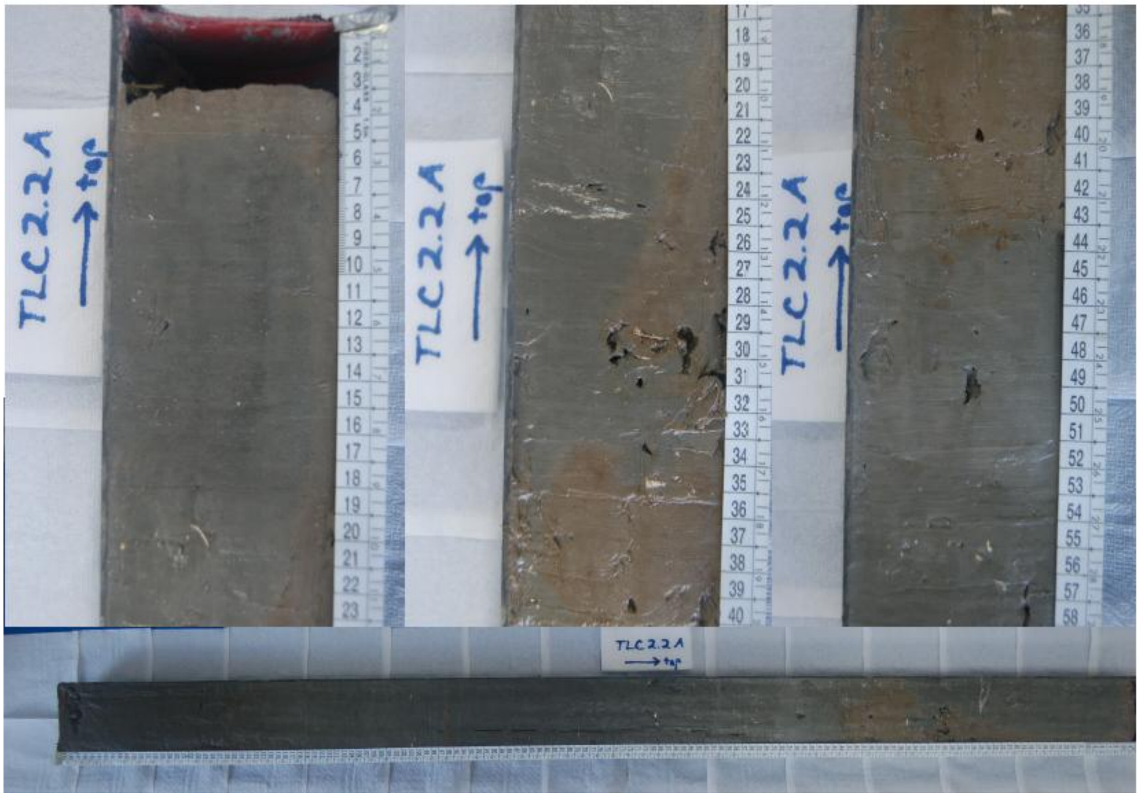


Figure 43 . Terkos Long Core 2.2 photos, including TLC 2.2 50-51 cm (total depth 200 cm) where Chla data has second minima.

Figure 44. Terkos Long Core 2.3 photos, including TLC 2.3 33-34 cm (total depth of 333-334 cm) where Chla showing first minima.

Figure 45. Sarıkum Long Core 1 photos. See the transition between SLC1.1 20-21 cm (total depth of 29 cm after splicing with Sarıkum Short Core 1) and SLC 2.1 7-8 cm total depth of 16 cm).

CHAPTER 6

DISCUSSION

The environmental ranges of Cytheridea and Darwinuloidea, the superfamilies for the two ostracoda species that dominate in Terkos Lake, are somewhat distinct. *Cyprideis torosa*, in the Cytheroidea subfamily, is common in a wide range of environments, from non-marine continental waters bodies to brackish estuaries, lagoons, and marginal seas. According to Heip (1976), this species' main distribution is on soft sediments of shallow brackish waters where large amount of organic detritus are present. Cypridoidea family is common in brackish and non-marine, continental waters with a known salinity range of 0-60‰ (De Deckker, 1981; adopted from Meisch, 2000).

Cyprideis torosa occurs as two extreme forms: unnoded (smooth) and noded valves. "Noded and smooth" forms may be found in a single population, depending on salinity ranges across the habitat, and can be used as an environmental marker for low salinity and/or low calcium content (Keyser, 2005). Although this subject is still open, there is a growing body of evidence that animals with smooth carapaces occur in "high" salinities only, while those with noded valves are found in habitats with low salt content (Hartmann, 1964b; Harten 1996, adopted from Meisch, 2000). Keyser (2005) showed that *C. torosa* develops nodes in low saline water due to the inability of the animal to adjust to the lower osmotic pressure of the surrounding water during the molting process and to low amounts of calcium ions within the animal. This sharply reduces the flexibility of desmosomes and muscles, thereby causing a kind of a cramp and tearing of the structures involved. Noding is therefore ecophenotypic and not a genetic response.

Studies also show a relationship between salinity and the shape of sieve-type pores on the lateral surface of *Cyprideis torosa*. Although these pores, which occur in a number of cytherid families (belonging to the superfamily Cytheroidea), usually possess a round outline, in *C. torosa* they vary from round to oblong to irregular. There is an inverse relationship between the salinity of the environment and the percentage of round pores in *C. torosa* specimens from Northern Germany and Israel (Rosenfeld and Vesper, 1977, adopted from Boomer and Eisenhauer, 2002).

C. torosa can reproduce either sympatrically or by parthenogenesis (Heip, 1976, Abe, 1990). Ratios within individual valves or carapaces for male:female or adult:juvenile can also be used for understanding the environment of deposition (Boomer et al., 2003). Resource competition is a possible cause of sex ration in Cyprideis species (Van Harten, 1983; adopted from Abe,1990). But in general it suggest whether paleoenvironment that species inhabit stable or not (Abe, 1990). Marine ostracods with a biased tertiary sex ratio, they are more r-selective, inhabiting relatively unstable environments, although the number of examples are not enough to generalize it for all ostrocods (Abe,1990).

Besides *Cyprideis*, other genera show salinity differentiation. Darwinuloidea is common in non-marine continental waters. *Darwinula stevensoni* is a cosmopolitan freshwater species that can tolerate increases in the salinity up to a maximum of 15‰ (Hiller, 1972; adapted from Meisch, 2000). They rapidly built up quite large populations since they can reproduce by parthenogenesis (Meisch, 1990; adopted from Meisch, 2000). *Plesiocypridopsis newtoni* is known to inhabit freshwater to slightly brackish-water, in the shallow littoral zone. It is known in coastal waters of the Black Sea, Bulgaria with a salt concentration of 8‰. At the other end of the salinity range, *Loxoconcha sp*. is a euryhaline marine ostracod (Meisch, 2000).

From these known environmental associations, and the time series of species assemblage changes in each of the three study lakes, a number of conclusions are possible.

6.1 Terkos

At Terkos, in AD 1960, about 4.5 m of height was added to the original dam built in AD 1880. Since the second dam modification, which significantly increased the lake extent and perhaps eliminated sea water exchanges, no ostracoda appear in the Terkos lacustrine archive. Absence of *C. torosa*, the only ostracod species present when the second dam modifications occured in Terkos, might be explained by the changing water salinity conditions with some species experiencing difficulties adapting to fresher conditions. Noded forms of *C. torosa*, usually more associated with fresh water, were absent during that time, however. Therefore, an alternative explanation is that salinity changes were not a factor. Rather, since ostracods are completely benthic, bottom water oxygen depletion from either increased eutrophication or meromixus, caused by sea water intrusion to the lake (e.g. by tsunami or storm) prior to the dam modifications, might explain the sudden absence of ostracods. High sand percentages occur (Fig. 30) around that time. Reforestation of the dunes between the lake and the Black Sea, started in 1974 (Saatçioğlu, et al., 1978), are likely in response to high sand mobility. The second dam modification followed these reforestation efforts.

Trace element data obtained from ostracoda shells on Terkos LC2.1 indicate that *C. torosa* started to inhabit the lake sediment with the increasing brackish conditions (salinity) in the lake water (Figure 40). *C. torosa* is a euryhaline species that is tolerant to high salinities; it is common from the continental waters bodies to estuaries, lagoons, and marginal seas. Their dominance in profoundal sediments of Terkos Lake over the last 1000 years is consistant with higher conductivity and/or warmer summer water temperatures, which, in Mediterranean climate regions are often associated with lower lake levels from warmer and/or drier climatic conditions. Another possibiltiy is that a more direct linkage with the Black Sea existed prior to the dam modification than is present now.

Sediment stratigraphic records from Terkos Lake indicate several abrupt shifts in faunal (e.g. ostracoda and forams) and algal productivity (Figure 40). For instance, Black Sea foraminifera species, such as *Ammonia tepida, A. parasovica* and *Milionia sp.*, reach maxima between 50-70 cm (ca. 250-400 cal. yrs BP). In the same interval, the huge brackish water diatom species, *Campylodiscus clypeus* (Ehrenb.), occurs. This diatom's presence doesn't prove a marine intrusion, however; it is also found in fresh, inland water bodies such as around Bolu, Turkey (personal communication, Sena Akçer Ön. Istanbul Technical University). Foraminifera are also abundant near bottom of the

Terkos Long Core 2.4 (3400 cal yrs BP). Chl-a minima, together with Glochodia larvae, a fish tooth and *Darwinula stevensoni* maxima occur at 1473 cal. yrs BP and 2315 cal. yrs. BP. Two Chl-a minima also coincide with low organic but high carbonate carbon.

The Terkos sequence reveals two different zones and the lake's changing characteristics. Paleoecological data together with loss-on-ignition and trace element analyses results reveals that, from 3400 cal yrs BP to 1116 cal yrs BP, the lake was less saline and more dominated with fish than during the approximately last thousand years (Figure 40). Ostracods are almost absent in the lake until 1116 cal yrs BP (*D. Stevensoni* valves are all adult, mostly transported to the lake). Around, 1116 cal yrs BP, a sharp increase of lake salinity allowed only *C. torosa* to inhabit the lake. This also occurred in the Aral Sea, because of anthropogenic impacts (Boomer, et al., 1996). During a freshwater dominated stage, two Chl-a minima, at 2315 and 1473 cal yrs BP, might reflect a shift in pH values of the lake, either related to high freswater inflow or sea water intrusion. The earliest Chl-a minima, about 2315 cal yrs BP, also coincides with an abrupt maximum in magnetic susceptibility (Doner and Sekeryapan, 2009). This MS maximum is noted in all 4 cores collected from Terkos Lake and is apparently a lake-wide event (Figure 46-47). It may result from magnetoactic bacteria that lived in an organic rich deposit. There is evidence of gas near that level (cracks and gaps in the cores). These could result from a flood event that brought fresh deposits to the lagoon from the Stranger metasediments, a tsunami or storm that washed sand and marine clays into the lagoon causing meromixus and highly reducing bottom conditions for a short time, a volcanic ash deposit, or a big erosion event related with intense human occupation and farming activity.

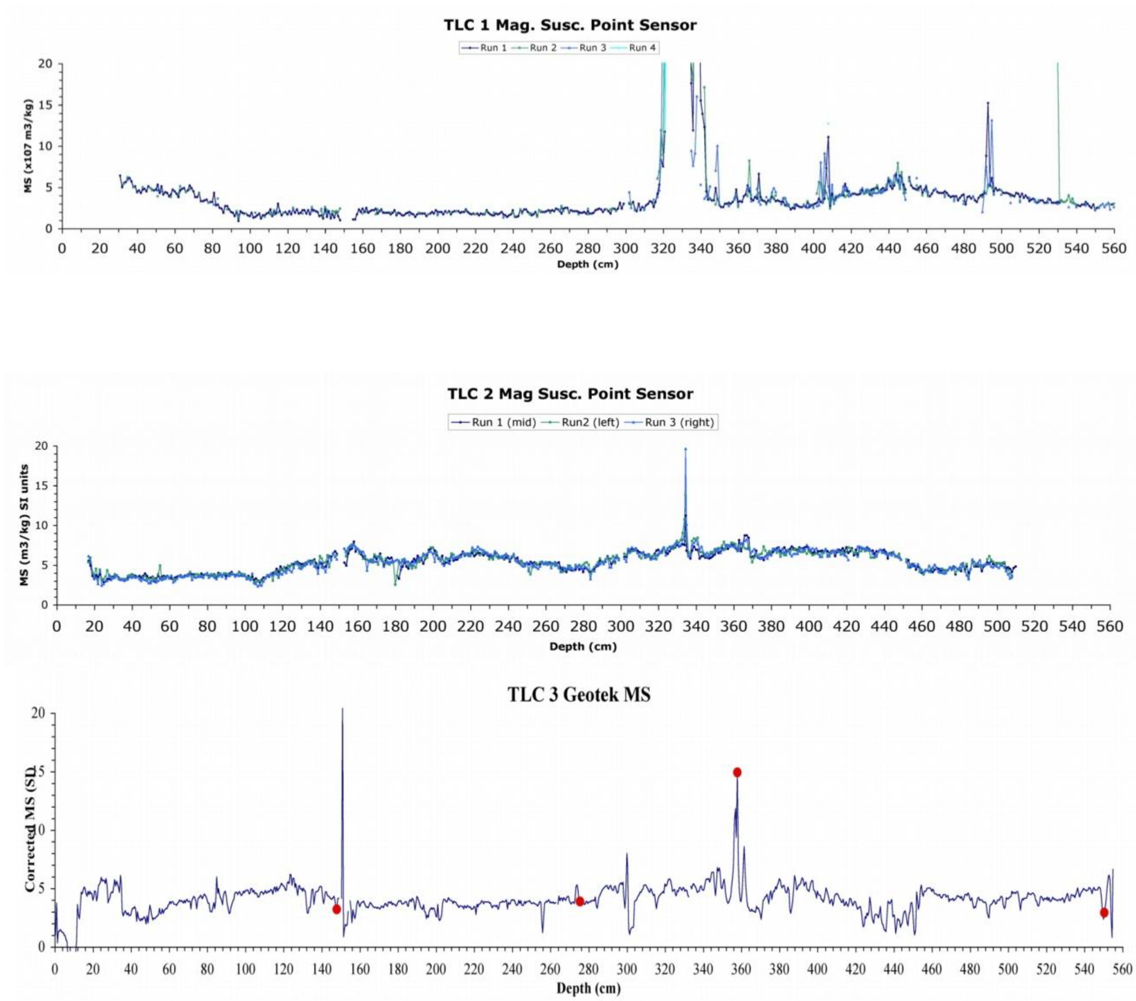


Figure 46. Bartington MS2 point sensor results for TLC1 (top), TLC 2 (middle) and TLC3 (bottom), showing high magnitude MS maxima centered about 330 cm (1375 cal yrs BP), 335 cm (2315 cal yrs BP) and 360 cm (2210 cal yrs BP), respectively. Red circles on the bottom plot show locations of ^{14}C dates. The apparent maximum in TLC3 at 150 cm is actually where the core was cut into multiple segments (of 150 cm each).

Figure 47. Photographic images of TLC 1.3 (left) and TLC2.3 (right). In the left image, the clay layer, air gap and the rust-colored vertical fracture through the clay is clearly visible. In the right image, the clay layer is less apparent but the rust colored stains follow vertical fractures and close scrutiny reveals an air gap (at the arrow). The high magnetic peaks are marked with an M.

6.2 Büyükçekmece

With the construction of first dam in Büyükçekmece, marine ostracod species disappear and only fresh water species inhabit Büyükçekmece's sediments. Actually, it is not completely true, since we suggest there is a hiatus around 30 cm. This is a direct result of the change to fully freshwater conditions in Büyükçekmece Lake after the dam construction. *Darwinula stevensoni*, occur after the dam building of AD 1985 in Büyükçekmece Lake. Interestingly, this resembles a similar pattern, in Terkos Lake sediments, during the two Chl-a minimas at 1473 cal BP and 2315 cal BP (Fig. 40-41). These events were probably related to high freshwater input from the incoming rivers, resulting in rapid freshening.

The presence of Gastropods and Charaphyte seeds found in Büyükçekmece and Sarikum long core indicates the existence of clear, calm, shallow water conditions. There is no sedimentary evidence for changes during the large earthquake in AD 447 that affected the entire Sea of Marmara (Leroy et al.,

2002) in Büyükçekmece Lake. The hiatus in the deposits of Büyükçekmece most probably encompasses this interval, since the youngest ^{14}C ages recorder in Büyükçekmece core sediments are ca. 2400 BP, or nearly 900 years before that Marmara quake (Doner and Sekeryapan, 2009).

Loxoconcha sp. occurred until around 3000 cal yrs BP in Büyükçekmece lake may represent sea level increase since they are marine (Boomer, et al., 1996) species also recorded in the Black Sea sequence during the late glacial to earl Holocene (Boomer, et al., 2010). Since they reproduce sexually only like most of the other marine ostracods, their existence results from direct influence of sea water rather than passive transportation via such as waterfowl (Boomer, et al., 1996). Since we have a hiatus around 30 cm, we can only infer that, Büyükçekmece was shallower and with brackish, lagoon-like conditions between approximately 4000-2500 cal yrs BP. However, more freshwater conditions are present since the first dam built in AD 1963.

6.3 Sarıkum Lake

Research on tsunami-related sediment transport, especially after the 2004 Indonesian tsunami, indicates that large volumes of sediment are transported by the violent currents that develop as incoming and outflowing waters collide onshore (Rhodes et al., 2006; Tuttle et al., 2004; Witter et al., 2001). Many of the pre-existing coastal sediments are rapidly relocated onto the near-shore continental shelf, while inland areas lose height and become prone to tidal flooding (Rhodes et al., 2006). Two tsunami events in the Black Sea during the 19th century, 1966, in Anapa, Russia, and following the Great Erzincan Earthquake (26 December, 1939) (Altinok, et al., 2011), were modeled by

Yalçiner (2004). Sea level receeded 50 m and advanced 20 m near Fatsa (Richter, 1958; adopted from Kuran and Yalçiner, 1993) but also increased at the some tidal stations on the northern coast of the Black Sea (Kuran and Yalçiner, 1993). These model results are consistent with post-tsunami geomorphology studies that indicate significant sediment movement and relative sea level changes following a tsunami event, especially in areas with unconsolidated beach deposits (Rhodes et al., 2006). Many of the recorded tsunami in the Black Sea are the result of earthquake and submarine landslide near the Crimean Peninsula (Yalçiner et al., 2004). Sarikum Lake is directly across the Black Sea from this peninsula, where the Sea is narrowest. Thus, tsunami generated near Crimea, would almost certainly impact the coastal region around Sarikum Lake. 3 September 1968 Bartın event is another eartquake that created tsunami on the southern margin of Black Sea, in Amasra (Altinok et al., 2011) during the 19th century.

The major Amasya and Corum earthquake, in AD 1598, created a tsunami in the Gulf of Sinop and Samsum reaching up to 1m wave height (Nikonov, 1997, adopted from Altınok & Ersoy, 2000). Tsunami waves were inundating between Sinop and Samsun 1.6 km landward causing few thousand people living in towns and villages drowned (Altinok et. al., 2011). This height is enough to create a high-impact marine intrusion event in Sarikum Lake, and perhaps in Terkos Lake as well. Both of these basins are bounded by unconsolidated sedimentary deposits, dominantly sand dunes (Fig. 3). Sarikum Lake is located at sea level with connection to the Black Sea via a narrow channel. During field work in 2008, following three consecutive days of brisk northerly winds, water flow within the channel reversed. Black Sea water began flowing directly into the lake, through what is normally the outlet channel. This channel is actually the deepest part of the lake, probably eroded down by strong outflowing currents during freshwater floods, but possibly from sediment scouring during tsunami or storm.

A rapid increase in sediment accumulation in the 2007 Sarikum Short Core, between 8-12 cm, encompasses maxima in sand and TOC, immediately followed by a TOC minima. The estimated ^{137}Cs age for this interval is AD 1952-58. This interval coincides with a major change in faunal and algal stratigraphic records (Fig. 42), and, while it could be the result of tsunami or storm, there is no documented event for this region in the 1950's. The age basis for the core may be off several years, however. In an ideal sediment record, ^{137}Cs activity rises steadily from AD 1950 to a maximum in 1963-64, and then declines sharply until the 1989 Chernobyl event. The Sarikum record rises steadily from a low of 13 Bq/kg, at 14 cm depth (AD 1950), to a maximum of 58 Bq/kg, at 4-6 cm (AD 1963-64). But above 4 cm, ^{137}Cs does not decline significantly upwards as is expected in a continuous sedimentation situation. Instead, at 2 cm depth, activity is still 47 Bq/kg. This suggests that either: a) the most recent lake sediments are eroded away or, b) the sediments are somewhat mixed for the upper 6 cm such that the 1989 Chernobyl peak has become smeared over several centimeters of recent deposition. The effect of such smearing would be to make exact determination of timing for the post-1963-64 period unreliable. Therefore, we cannot exclude the possibility that the shift in core characteristics centered at 10 cm is from the 1966 tsunami. In fact, Yalçiner et al.'s (2004) modeling results place the Sinop (and Sarikum) region within the 1966 tsunami flooding zone. In interviews with the local people living in the Sarikum village, July 2008, they described an earthquake destructive to the wooden houses locally and that there were woods buried underwater in parts of the lake.

The Sarikum record holds even stronger evidence of an earlier flood, between 25-34 cm in the Sarikum Short Core. This event is accompanied by consecutive increases, starting at 33 cm until 25 cm, in sand, then organic matter, then silt and clay. The event seems to end when dry bulk density reaches maximum value at 25 cm. Extrapolation of ^{137}Cs ages places 25 cm at AD 1931. While this is near the expected AD 1939 tsunami event, the dating differences are problematic. Nevertheless, as with the sediment changes at 8-12 cm, the pattern of change at 25-33 cm is consistent with a tsunami or storm interpretation.

Alternative explanations for the sediment patterns noted during these two periods include terrestrial flooding, involving no marine incursion, or severe storm. Terrestrial floods should leave a debris layer that is rich in terrestrial macrofossils (leaves, twigs, etc), and usually has interbedded sand and silts (Birks et al., 1993). These deposits lack such characteristics. Distinguishing tsunami deposits from those left by severe storms is mostly a matter of scale (Tuttle et al., 2004). The best way to eliminate the interpretation of severe storm in these cases is to monitor sediment transport during severe storms, to assess the scale of impact on the lake bottom deposits.

In AD 1509, a strong earthquake affecting Istanbul, with magnitude close to M8, generated six meter height tsunami waves (Kuran and Yalçiner 1993). Strong earthquakes in AD 557 and 543 created great flooding in Varna Bay, Bulgaria (Yalçıner et al., 2004). Altınok & Ersoy (2000) report that 90 different tsunami occurred on or around Turkish coasts during the 3400-year period between 1410±100 B.C and AD 1999. On the other hand, in AD 555, a non-seismic origin tsunami (meteotsunami) was reported in the southwestern Black Sea (Vilibic, et al., 2010).

6.4 Cyprideis torosa of Southern Black Sea coastal lakes adult/juvenile, male/female ratios

This study examines the geographic and temporal distribution of *Cyprideis torosa*, and other ostracoda species, on the coastal area of the Black Sea and Marmara Sea, in Turkey. Population dynamics of *C. torosa* has been studied by Heip (1976). Non-noding form of *C. torosa* is the dominant ostracoda species observed in the lacustrine archives of these coastal lakes since the mid-late Holocene. However, it is not present in surface samples collected from the littoral zones and main basins of Terkos and Buyukcekmece Lakes on July 2008. Boomer et al (1996) reported that *C. torosa* is the only ostracoda species living in the Aral Sea today. Since *C. torosa* can reproduce both sexually and by parthenogenesis (Heip, 1976; Abe, 1990) it will build a new population easily and quickly if appropriate conditions existed for instance during their passive dispersal via strom surges or waterfowl. Connected coastal lakes on Kızılırmak Delta, in Samsun, which called as Cernek and Uzun lakes do contain *C. torosa* in their surface and recent sediments. The ostracods are present at the surface and the bottom of short cores from Cernak L. (at 30 cm) and Uzun L. (at 93 cm). However, no ostracoda are present at the surface or the bottom of short cores taken from Mert and Erikli Lakes, on the Black Sea coast in Kırklareli.

CHAPTER 7

CONCLUSION

The Black Sea is already famous for being the potential origin of “The Great Flooding”, thought to be the result of barrier collapse between the Black and Marmara Seas during deglaciation (Ryan and Pittman, 2000). Tsunamis in the Black Sea are less well-known but could also account for flooding mythology within the region.

This investigation makes contributions to the full taxonomic revision of Ponto Caspian ostracoda fauna. In addition, the observed rapid transitions in the ostracoda fauna, total organic carbon and algal production, within in the lacustrine archives of these lakes, coincide with times of destructive earthquakes and documented tsunamis. While this evidence does not preclude a storm interpretation, evidence that points to a tsunami origin is very convincing, including changes in forams, Chl-a, etc. For instance, the major Amasya and Corum earthquake, in AD 1598 may be represented in Terkos sediments where we note increased abundances of foraminifera species and the presence of the huge diatom, *Camplodiscus clypeus,* ca. 455 ± 55 cal. yrs BP (AD 1440-1550). Moreover, Chl-a minima, together with low organic matter, carbonate peaks and presence of Glochodia larvae, a fish tooth and a *Darwinula stevensoni* maxima at 1473 ± 84 cal. yrs BP (AD 390-560) strongly suggest tsunami impacts of the AD 557-543 Black Sea events or strong storm. Similar indications of disturbance occur in the sedimentary record of Sarıkum Lake, with an abrupt decrease followed by a gradual increase of Chla and organic matter, and a rapid increase in clay percentage together with very low abundances of ostracod fauna and Charophyte oospores. The AD 1509 Istanbul earthquake in the Marmara Sea migh have created an otherwise unexplained hiatus in Büyükçekmece Lake sediments between 33-75 cm.

These three coastal lakes, Terkos, Büyükçekmece and Sarikum, provide lake-specific and regional environmental histories of Thrace and Black Sea coastal regions during the mid- and late-Holocene. The bio- and geo-stratigraphy of Sarikum Lake's present conditions, with connection to the Black sea through a narrow channel and a flat sandy barrier, seves as a modern analog for brackish conditions in Terkos and Büyükçekmece lakes in the past. According to our results, Terkos lake conditions changed dramatically at about 1116 ± 68 cal yrs BP (AD 870-1000), and the lake was more saline from the end of the Byzantine Period and through the whole Ottoman Period. We know that naturally occurring water resources on the European side of the Bosphorus are, and always have been, scarce. To obtain water, early inhabitants constructed a network of aqueducts in the 4^{th} century AD (Bono et. al. 2001). The data presented in this thesis show that to be a relatively wet period around Istanbul. The construction of extensive aqueducts, even during a wet period, points to long-term water stress in the Thracian region. Elsewhere in Turkey, evidence of higher precipitation during this interval is seen in a marked change to more negative isotope values ca. AD 560-750 in Nar Lake, Cappadocia, Central Anatolia (England et al., 2008). Although Terkos Lake is located in the wetter Marmara region, its sediment record also reveals more freshwater (less saline) conditions between 1473-1116 cal yrs BP (AD 390-1000).

Ostracoda species numbers are generaly low in brackish water bodies, although they can reach high abundances (Frenzel & Boomer, 2005). Diversity of ostracod species, in general, is often low with one or two dominating species, although the abundance of individuals may be remarkably high (Boomer & Eisenhauer, 2002). *Cyprideis torosa* has been the common dominant species in all three study lakes during the late Holocene and Anthropocene. The loss of this species from anthropogenic impacts has been observed in Mediterrenean coastal wetlands and the Aral Sea (Boomer, et al.,1996). Its similar absence following dam modifications in the last 50 years at Terkos Lake, is notable.

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APPENDİX A

PHYSICAL MEASUREMENTS FROM SARIKUM LAKE

Table A. 1 Contemporary physical measurements taken in Sarıkum lake from different sites during field trip in July 2008.

SAMPLE SITES	**SARIKUM SITE 1**	**SARIKUM SITE 2**	**SARIKUM SITE 3**	**SARIKUM SITE 4**
Date	14th of July 2008	14th of July 2008	14th of July 2008	14th of July 2008
Time	11:00 AM	11:30 AM	1:50 PM	1:50 PM
N	36T0659080 UTM	36T0658012 UTM	36T0658060 UTM	36T0657994 UTM
E	4653680 accuracy: 5m	4654129 accuracy: 7m	4653933 accuracy: 4 m	4654081 accuracy: 5 m
Elevation				
Weather	very windy and cloudy %50, altı cumulus, beaufort 3-4		windy and cloudy %80	windy and sunny
Depth at sampling site			1.1 m	1.8 m
Turbidity (Sechi depth)				
Aquatic plants				
Surface Water Sample				
Temperature	~27,25 ˚C	26,5 ˚C	26,7˚C	26,2˚C
Ph	8,69 - 27,5˚C	8,19 - 26,6˚C	8,11	8,11 - 26,2˚C
Dissolved oxygen content	12,1 mg/l - 27,0˚C	9,3 mg/l - 26,6˚C	9,0 mg/l - 26,6˚C	8,7 mg/l - 26,0˚C
Salinity				
Conductivity	12,92 µS/cm - 27,3˚C	13,13 µS/cm - 26,4˚C	13,40 µS/cm - 26,7˚C	13,22 µS/cm - 26,2˚C
TDS				
Bottom Water Sample				
Temperature			26,5˚C	26,0˚C
Ph			8,1	8,07 - 26,1˚C
Dissolved oxygen content			8,2 mg/l - 26,3˚C	7,7 mg/l - 25,9˚C/ 4,9mg/l - 25,5˚C
Salinity				
Conductivity			13,41 µS/cm - 26,7˚C	13,34 µS/cm - 26,0˚C

Table A. 1 continue

SAMPLE SITES	SARIKUM SITE 5	SARIKUM SITE 6		SARIKUM SITE 7
Date	14th of July 2008	14 July 2007	16th of July 2008	17th of July
Time	11:00 AM			
N	36T0658083 UTM	42º00´58,2˝	36T0659282 UTM	36T0658140 UTM
E	4653712 accuracy: 5m	034º55´23,6˝	4653277 accuracy: 9 m	4653686 accuracy: 6 m
Elevation		10 m		
Weather		cloudy	sunny	very windy
Depth at sampling site	1,1 m	~105 cm	0,8 m	1,1 m
Turbidity (Sechi depth)		> max. water depth		
Aquatic plants		very dense		
Surface Water Sample				
Temperature	26,8 ˚C			25,9 ˚C
Ph	8,10 - 26,9˚C	10.38 (25ºC)	8,58 - 27,8˚C	7,97 - 25,9 ˚C
Dissolved oxygen content	8,6 mg/l - 26,8˚C		10,2 mg/l - 27,9˚C	5,7 mg/l - 25,5 ˚C
Salinity		5.1 %0		
Conductivity	13,53 µS/cm - 26,8˚C	9.17 Ms	12,87 µS/cm - 27,9˚C	13,42 µS/cm - 26,0 ˚C
TDS		5030 mg/l		
Bottom Water Sample				
Temperature	26,7 ˚C			25,9 ˚C
Ph	8,10 - 26,8˚C		8,60 - 27,7˚C	7,97 - 25,9 ˚C
Dissolved oxygen content	8,4 mg/l - 26,6˚C		10,9 mg/l - 27,6˚C	5,3 mg/l - 25,7 ˚C
Salinity				
Conductivity	13,55 µS/cm - 26,7˚C		12,90 µS/cm - 27,8˚C	13,45 µS/cm - 26,0 ˚C

APPENDIX B

PHYSICAL MEASUREMENTS AND COLLECTED OSTRACODS

Table B. 1 Contemporary physical measurements and collected ostracods form Terkos, Büyükçekmece and Sarıkum from different points.

Lake	Date	Max depth m	Samples from	Measurements from	Temp ˚C	Ph	Conductivity μS-1	Dissolved oxygen mg/l	Dry coarse residue (gr)
Sarikum kopru s.1 aralıkyazı	July 2008	1,1	lake edge						5,74
Sarikum kopru s.2*	July 2008	1,1	lake edge	lake edge	26,5	8,19	13,13	9,13	13,46
Terkos freshwater incoming 1 (mevzi barrier)*	July 2008	7,5	near inflow	surface water at pelagic	27,9	8	514	5,1mg/l - 27,7˚C	13,24
BKM 1 North side of North road btw yanyol and tem	July 2008		lake edge						0,23
BKM 2.1 South side of yanyol mean lake east side Hezar Fen	July 2008		lake edge						0,15
BKM 2.2*	July 2008		lake edge	lake edge					0,62
BKM 3* North of Tem south of yanyol bridge west of Hezar Fen	July 2008		lake edge	lake edge					0,07
BKM 4 Melek road, west side of lake North of quarry Menekşe	July 2008		lake edge						0,77

Table B.1 continue

Lake	Other biological proxies	Ilyocypris monstrifica			Cyprideis torosa			Plesiocypridopsis newtoni			Loxoconcha immodulata		
		Carapace	Ind. Valves	Juve nile	Carapace	Ind. Valves	Juve nile	Carapace	Ind. Valves	Juve nile	Carapace	Ind. Valves	Juve nile
Sarikum kopru s.1 aralıkyazı													
Sarikum kopru s.2*					Abundant C. torosa								
Terkos freshwater incoming 1 (mevzi barrier)*								10	21	4	26	6	1
BKM 1 North side of North road btw yanyol and tem													
BKM 2.1 South side of yanyol mean lake east side Hezar Fen													
BKM 2.2*		1	5	0									
BKM 3* North of Tem south of yanyol bridge west of Hezar Fen	Abundant Bryozoa												
BKM 4 Melek road, west side of lake North of quarry Menekşe													

VITAE

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EDUCATION

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BS	EGE Univ. Biology	2002
High School	Başkent Süper Lisesi	1998

WORK EXPERIENCE

Year	Place	Enrollment
2002- Present	METU Department of Biological Sciences	Research Assistant

FOREIGN LANGUAGAES

Advanced/Fluent English, Competent User of English, IELTS Overall= 6.0 (08/Nov/2008), ÜDS 81.25 (Spring 2011)

SPECIFIC EXPERIENCE IN THE REGION

September 1, 2009 – February 28, 2010 Palaeoecological Environmental Assessment and Research Laboratory (PEARL), Department of Biology, Queen’s University, Kingston, ON, Canada, Visiting Scholar.

December 1-20, 2008 Consiglio Nazionale delle Ricerche, Istituto per lo Studio degli Ecosistemi, Verbania Pallanza, Milano, Italy, Visiting Researcher.

September 24, 2007- March 3, 2008 Environmental Change Research Centre (ECRC), Department of Geography, University College of London (UCL), London, UK, Erasmus Research Student

TRAINING COURSES

Introduction to Diatom Analysis (Dr Vivian Jones and Professor Rick Battarbee). University College London, Environmental Change Research Centre, London, 2006.

PUBLICATIONS

Berkman, C.C., Dinc, H., Sekeryapan, C., Togan, I (2008). Alu Insertion Polymorphisms and an Assessment of the Genetic Contribution of Central Asia to Anatolia with Respect to the Balkans. American Journal of Physical Anthropology, Vol.136, pp: 11-18.

INTERNATIONAL CONFERENCE PROCEEDINGS

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Dinc, H., Sekeryapan C., and Togan, I. 2005. Genetic Differentiation of Anatolian Turks based on Alu insertions.11th Meeting of PhD Students in Evolutionary Biology, Bordeaux, France, 5-9 September.

HOBBIES

Drawing, Painting, Photography, Tango