A PALEOLIMNOLOGICAL APPROACH TO UNDERSTAND REGIME-SHIFT DYNAMICS IN LADIK LAKE (NORTH TURKEY)

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Abstract. Paleolimnological assessment of Ladik Lake (N Turkey) using diatoms was carried out along a 62 cm-long sediment core recovered from the southeastern part of the lake. The chronology of the sediments was established by ^{137}Cs – ^{210}Pb dating. Accordingly, three major chronostratigraphical diatom assemblage zones (DAZ) were defined by the CONISS (constrained cluster analysis) program. The oldest assemblage, DAZ C (AD 1925-1958), was dominated by *Ulnaria ulna* (Nitzsch) Compère, *Cocconeis placentula* Ehrenb. and *Cocconeis pediculus* Ehrenb. taxon. In DAZ B (AD 1958-1986), in addition to *Ulnaria ulna* species that dominated through the whole core, *Epithemia* spp. occasionally dominated the assemblage in this zone. *Ulnaria ulna* and *Pantocsekiella ocellata* (Pant.) K.T. Kiss & Ács predominated since the beginning of DAZ A (AD 1986-2006). After the first regime of the lake with dystrophic character, the diatom community underwent a significant shift, with decreased abundance of periphytic diatom samples. The improvement of the regulator in 1986 resulted in a larger water level increase that affected the lake ecology, causing a shift from a diverse periphytic diatom to planktonic diatom assemblage. Based on our monitoring it can be inferred that the limnological regime shifts in Ladik Lake during the 20th century are of anthropogenic origin, rather than being due to climatic changes.
Keywords: *monitoring, lake, sediment core, paleolimnological proxies, diatom microfossil*

Introduction

As various geological archives, lake bottom sediments are records that contain and store information about the ecological conditions of the past at the regional and planetary scale with a resolution ranging from thousands of years to a year (Chen et al., 2021). Paleolimnological studies give an opportunity to track signals of natural and anthropogenic changes using lake sediments and determine past environmental conditions that have occurred within the catchment. Paleoenvironmental information can be inferred from diatom assemblages preserved in the sediment record (Sivarajah et al., 2018).

In paleolimnological investigations, fossil diatom assemblages provide a useful tool for examining environmental changes, and they have been used successfully for decades

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to describe environmental changes in lake systems (Michelutti et al., 2015). The ability of diatoms (Bacillariophyceae) to rapidly colonize new habitats and their sensitivity to environmental factors allow them to be used to track changes like water depth, aquatic pH nutrient availability, and salinity in lakes. Due to their siliceous material in their cell walls, diatoms are well preserved in many types of sediments. The properties of diatoms make them ideal for the reconstruction of environmental changes in lake ecosystems (Nelligan et al., 2016).

In temperate lakes, changes in diatom assemblages could be interpreted according to nutrient availability, light conditions, pH or water level fluctuations. Ecosystems are more likely to be affected by temperature near climatic and vegetation boundaries (Panizzo et al., 2013). According to other studies, shifts in the assemblages of fossil diatoms may show changes in seasonal mixing patterns as a result of climate change (Michelutti et al., 2016). Freshwater diatom communities are indirectly affected by fluctuations in water level due to changes in available habitat, light, chemical conditions, stratification, and mixing regimes. In freshwater systems, changes in lake levels are commonly recorded by an increase in the presence of planktonic (free-floating) diatoms. Because more of the lake bottom is exposed to sunlight when lake levels are low, more habitat is typically available for taxa living connected to substrates (benthos) or aquatic vegetation (epiphytes) (Wolin and Stone, 2010).

Numerous paleolimnological records have identified human impacts on lake ecosystems (Reed et al., 2008; Roberts and Reed, 2009). Wick et al. (2003) found evidence of enhanced human manipulation of plant cover during the Late Holocene at Lake Van in eastern Turkey. The Nar lake catchment is reported to have likely experienced an increase in human disturbance, which is thought to have affected lake ecology (Woodbridge and Roberts, 2011). On the other hand, several data sets from NW Anatolia show a direct climatic impact on the ecology (Ülgen et al., 2012). Potential mechanisms of the floristic change may be attributed to climatically caused changes throughout the previous years, according to Perga et al. (2001).

Turkey is ideally suited for combining paleolimnology and paleoclimate studies, although few of these studies have taken an interdisciplinary approach (Ülgen et al., 2012). Paleolimnological studies on diatom microfossils are not too common in Turkey, and are gaining ground in terms of importance. One of the studies from Nar Lake (central Turkey) is paleo-seasonality of the diatom silica was carried out by Dean et al. (2013) and the other is diatom analysis of annually-laminated lake sediment on the same lake (Woodbridge and Roberts, 2010). The relationship between diatom assemblages and varying water depth of the lake was studied in a fragmentary diatom record from Lake Van (Turkey) by North et al. (2017). In another study conducted in Turkey (Ocakoğlu et al., 2015), the effect of climate change or human activity on water level and vegetation structure of Lake Çubuk was assessed through a 2800-year multi-proxy sedimentary record (pollen, spore, diatom, ostracoda). Also, Levi et al. (2016) study multi-proxy paleoecological responses to water level fluctuations in three shallow Turkish lakes (Lake Marmara, Lake Uluabat and Lake Beyşehir).

The primary objectives of this study are *(i)* to investigate the change in diatom composition through time with anthropogenic impact on Ladik Lake considering the significance of the water level change on the lake; *(ii)* to infer the paleoenvironmental history of this poorly documented region; *(iii)* to provide a guidance for future investigation of diatoms from larger sediment records.

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Materials and methods

Site site

The research area (40°50′N to 41°00′N, 35°40′E to 36°05′E) is situated in Samsun Province in Turkey's central Black Sea region (*Fig. 1*). The lake is about 5 km long and 2 km wide. It is 867 m above sea level, and its maximum depth varies seasonally between 3 and 6 m. The lake has a 141.40 km^2 drainage area (State Hydraulic Works, 1997). Along with Küpecik, Çakırgümüş and Tatlıcak inlet streams, the lake is also fed by small streams from the Akdağ Mountain. In its natural state, the lake was much smaller prior to a regulator construction at the Tersakan outlet in 1958 (*Fig. 1*). Although this regulator stabilized the water level, the water depth did not significantly increase until the improvement of the regulator in 1986 (State Hydraulic Works, 1997).

Figure 1. *Sediment core locations in Ladik Lake. "LA-001" is the core investigated in this study, while "LA2006-G", "LA2008-1" and "LA2008-2" were investigated by Avşar (2013). The gray-shaded area is the approximate natural extent of the lake before it became a water reservoir in 1958*

The lake settles on alluvial sediments supplied by the tributaries mainly from the northern slope of Akdağ Mountain. The dominant lithology in the catchment of the lake is volcanic agglomerate of Mesozoic age and conglomerate/sandstone/clastics of Neogene age (Aydın, 1997).

Core collection and chronology

Four gravity cores were collected in July 2006 from Ladik Lake by a UWITEC corer: (1) LA-001 (40.9039˚N, 36.0247˚E), (2) LA2006-G (40.9075˚N, 36.0132˚E), (3) LA2008-1 (40.9084˚N, 36.0133˚E), and (4) LA2008-2 (40.9091˚N, 36.0138˚). The chronology of LA2006-G core was constructed by Avşar (2013) based on the activities of ^{137}Cs and excess ^{210}Pb on 1 cm-thick sediment slices from 22 levels by applying "Constant Flux Constant Sedimentation Rate" model (Goldberg, 1963). Magnetic susceptibility (MS) measurements along LA-001 and LA2006-G cores were done by a

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Bartington MS 2E system with point sensor at 1 cm increments. The organic matter content of the sediments along the LA2006-G core was determined at 2 cm increments by the method of weight loss-on-ignition (LOI) at 550 °C for 4 h (Dean, 1974). The inorganic geochemical properties of the sediments (including Si and Ti) along the LA2008-1 and LA2008-2 cores were determined by ITRAX µXRF core scanner with a resolution of 2 mm and 12 s exposure time with the Mo x-ray tube. The sediment chronology along the LA-001 core is determined by correlating its magnetic susceptibility profile with the one of the LA2006-G core.

Diatom analysis

A total of 16 samples (0-62 cm) were analysed within core LA-001. Using the established methods outlined by Battarbee (2001), diatom valves were isolated from the organic matrix of the sediments. Approximately 1.0 g of wet sediment was digested in a 50:50 concentrated sulfuric (H_2SO_4) and nitric (HNO_3) acid solution to remove residual organic matter. Sub-samples of specific weight were immersed in a boiling water bath for 1 h to accelerate digestion. In order to achieve a pH of neutrality, digested slurries were rinsed multiple times in distilled water. Slurries were dried overnight on coverslips within a slide warmer before being mounted permanently onto microscope slides with Entellan.

Diatom counts were carried out at contiguous 4-cm intervals throughout the LA-001 core using an Olympus BX41 light microscope with a 100x oil-immersion objective. A minimum of 300 valves were counted in each preparation and identified to the lowest possible taxonomic level with reference to photomicrographs of taxa from similar geographic regions and environments (Bahls et al., 2018; Krammer and Lange-Bertalot, 1991a, b, 1999a, b). Current taxonomic classifications follow Guiry and Guiry (2022).

Statistical analysis

Diatom assemblage zones along the LA-001 core were defined by stratigraphically constrained cluster analysis by using the CONISS algorithm (Grimm, 1987). The diatom microfossil profile is shown by using Tilia and Tiligraph (Grimm, 1991). The Shannon diversity index, the evenness and species richness were computed at different depths. The software performed was PRIMER version 5.0 from Plymouth Marine Laboratory for Shannon-Wiener index (Shannon and Weaver, 1949).

Results

Chronology

The sediment chronology for LA-001 core was obtained by stratigraphic correlation with the other cores studied by Avşar (2013), who found an average sedimentation rate (SR) of 0.73 cm/yr along the LA2006-G core. The ^{137}Cs peaks (1986 and 1963) along this core deviate around ± 5 years from the 210Pb-based age model, implying a successful estimation of the SR for LA2006-G. The magnetic susceptibility (MS) profile along the LA-001 core has changed in progress of time since the early 1900s (*Fig. 2a*). If SR values of 0.5 cm/yr, 0.8 cm/yr and 1.15 cm/yr are applied between 0-13 cm, 13-41 cm and 41-62 cm on LA-001, respectively (*Fig. 2a*), the MS profile of LA-001 highly correlates with the MS profile of LA2006-G (*Fig. 2b*).

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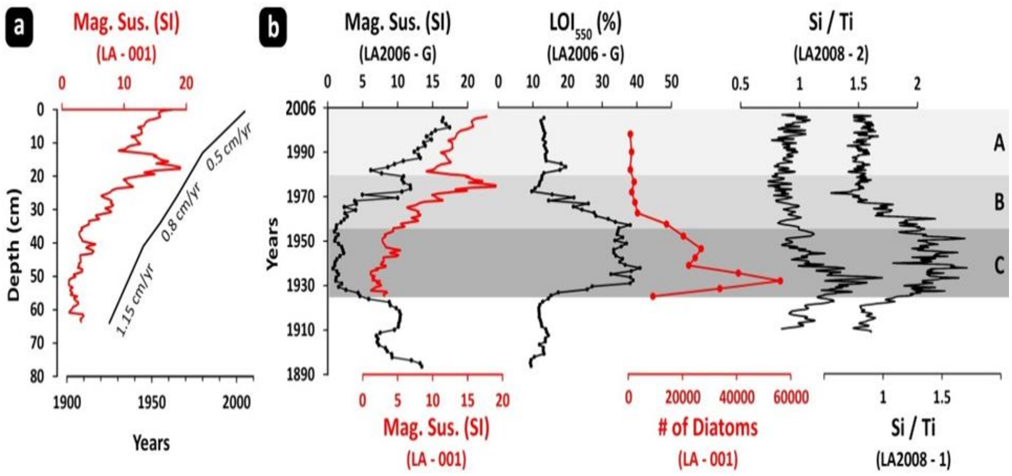

Figure 2. *(a) The magnetic susceptibility profile along the LA-001 and the age-depth model applied to correlate LA-001 to LA2006-G. (b) Magnetic susceptibility, organic matter content (LOI$_{550}$), diatom concentration (# of Diatoms), and Si/Ti profiles for the Ladik cores with respect to time*

Paleo-data

A total of 49 species of diatoms two of which were not identified and most of which were periphytic were recorded in the core samples of Ladik Lake (*Fig. 3*). *Ulnaria ulna* (syn: *Fragilara ulna*), *Cocconeis placentula*, *Cocconeis pediculus*, *Epithemia gibba* (Ehrenb.) Kütz., *Epithemia adnata* (Kütz.) Bréb., *Epithemia turgid*a var. *granulata* (Ehrenb.) Brun., and *Navicula radiosa* Kütz. were found to be the most abundant species in the sampling area.

According to diatom stratigraphy of Ladik Lake, three major diatom assemblage zones (DAZ) were distinguished along the LA-001 core regarding the ecological structure of the lake since ca. 1925 (*Fig. 3*). The earlier zone (DAZ C) showed a higher abundance of diatoms (234.122 r.a.) with a more diverse flora (48 taxa), whereas the last zone (DAZ A) indicated quite declining diatom abundance (2.728 r.a.) with lower diversity (23 taxa). With the construction of the regulator on the outlet of the lake in 1958, although there was no significant decrease in algal diversity (41 taxa) in the second zone (DAZ B), there was a serious decrease in diatom abundance.

DAZ C (34-62 cm, 1925-1958)

Ulnaria ulna dominates the assemblage, *Cocconeis placentula* and *Cocconeis pediculus* are subdominant in this section of the core. While the abundance of *Ulnaria ulna* ranges between 22-39%, *Cocconeis* spp. range from 2 to 22% in this zone (*Fig. 3*). Only at one-depth (48-cm) *Ulnaria ulna* was subdominant, while *Epithemia turgida* var. *granulata* becomes dominant (28%). Also, *Cocconeis pediculus* was the second most abundant organism subsequent to *Ulnaria ulna* at 52-cm depth.

Diatom abundance varies through the core, increasing significantly below 30-cm depth in DAZ C (*Fig. 4*). This increase affects most of the dominant species *Ulnaria ulna*, *Cocconeis placentula*, *Cocconeis pediculus*, *Epithemia turgid*a var. *granulata*, *Epithemia adnata*, *Epithemia gibba*, *Navicula radiosa* (*Fig. 3*), but the largest increase is observed in *Ulnaria ulna* abundance.

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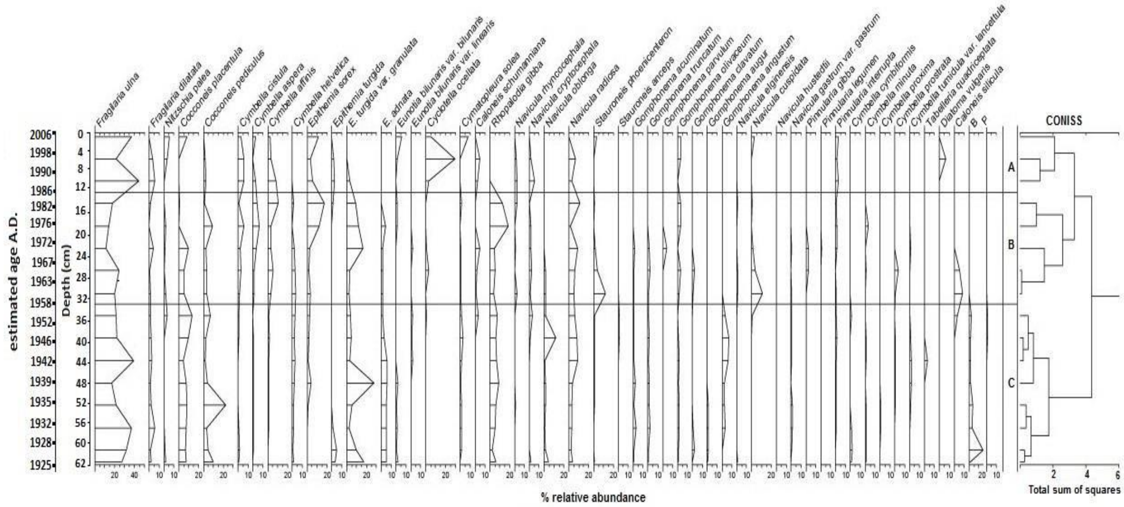

Figure 3. *Diatom stratigraphy of Ladik Lake. Zonation is based on the CONISS algorithm with significant clusters by the broken-stick model (B and P symbols in the graph refer to unidentified species)*

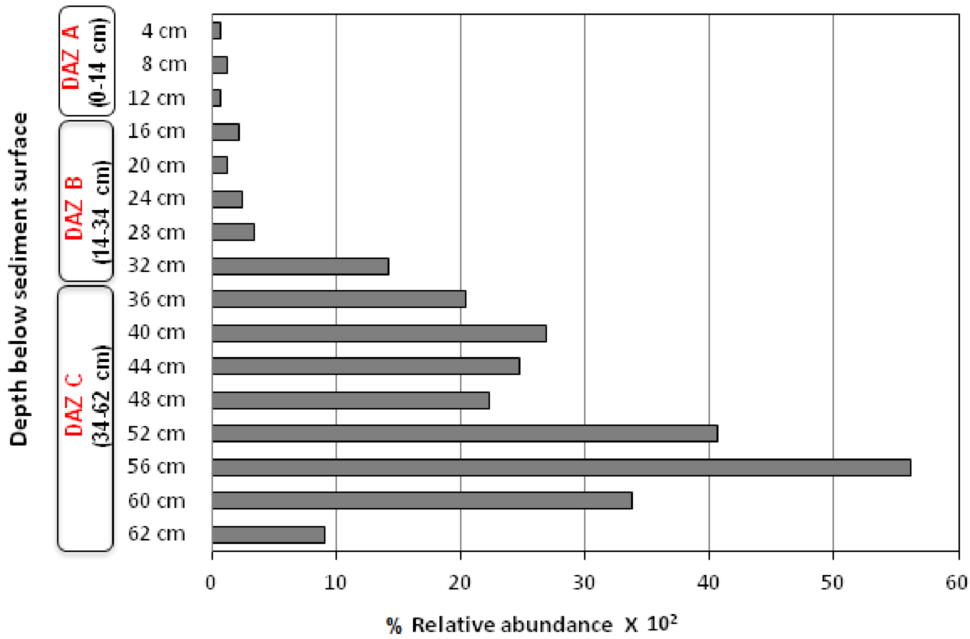

Figure 4. *The variations in total diatom content along LA-001 core*

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Diatom abundance varies through the core, increasing significantly below 30-cm depth in DAZ C (*Fig. 4*). This increase affects most of the dominant species *Ulnaria ulna, Cocconeis placentula, Cocconeis pediculus, Epithemia turgid*a var. *granulata, Epithemia adnata, Epithemia gibba, Navicula radiosa* (*Fig. 3*), but the largest increase is observed in *Ulnaria ulna* abundance.

Sediments contain around 35% organic matter in DAZ C, and organic matter content decreases sharply after the mid-1950s (*Fig. 2b*). Accordingly, sediments in DAZ C were deposited between ca. 1925-1958, in DAZ B between ca. 1958-1986 and in DAZ A after 1986.

DAZ B (14-34 cm, 1958-1986)

Ulnaria ulna is dominant also in this zone, comprising 11-24% of diatoms. This zone is characterized by significant increases of *Stauroneis phoenicenteron* (Nitzsch) Ehrenb. and *Craticula cuspidata* (Kütz.) D.G. Mann at 32-cm depth. *Epithemia gibba* (syn: *Rhopalodia gibba*) was dominant organism for the first time along the core, forming 19% of total diatoms at 20-cm depth. *Epithemia sorex* Kütz. occurs at its maximum abundance at 16-cm as co-dominant. Additional taxa emerging in increased relative abundance in this zone include *Caloneis silicula* (Ehrenb.) Cleve and *Navicula radiosa.*

DAZ A (0-14 cm, 1986-2006)

Pantocsekiella ocellata (syn: *Cyclotella ocellata*) and *Ulnaria ulna* are dominant in this part of the core. This zone is characterized by a relatively increased abundance of *Ulnaria ulna* forming 44% of the diatom community. Known to be of benthic habitat, this species is the most abundant species in all samples. Although *Pantocsekiella ocellata*, a planktonic species, constitutes 30% of the total diatom assemblage in this zone, this species is not dominant in the deeper parts of the sedimentary core.

The core correlation also allows investigation of the relationship between the change in sedimentation and the diatom zonation (*Fig. 2*). The sediment core shows an increase in MS and a decrease in organic matter from about 35% in DAZ C to less than 15% in DAZ A. Sediments contain around 35% organic matter in DAZ C, and organic matter content decreases sharply after the mid-1950s (*Fig. 2b*). Sediments in DAZ C were deposited between ca. 1925-1958, in DAZ B between ca. 1958-1986 and in DAZ A after 1986. Diatoms in DAZ C correspond to organic rich sediments with low magnetic susceptibility (MS) values (*Fig. 2b*), which is characteristic of marshes. The high organic content in DAZ C suggests that most of the lake was colonized by macro aquatic plants that decomposed and formed most of the OM remains in the sediments. This DAZ C is also characterized by high Si/Ti values in LA2008-1 and LA2008-2 cores, which would be related to the high diatom concentration characterizing this zone (*Fig. 4*).

The Shannon Diversity Index (*H′*) ranges from 0.914 to 1.297 bits. The lowest value for species diversity is recorded at 12-cm depth. Obviously, DAZ A has the lowest *H'*

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diversity. The species diversity index (*H′*) increases in DAZ B (14-34 cm) and is high in DAZ C. Species richness is low at the first 20-cm depth (between 1972 and 2006), and progressively increases deeper down the core along DAZ B and DAZ C (*Fig. 5*).

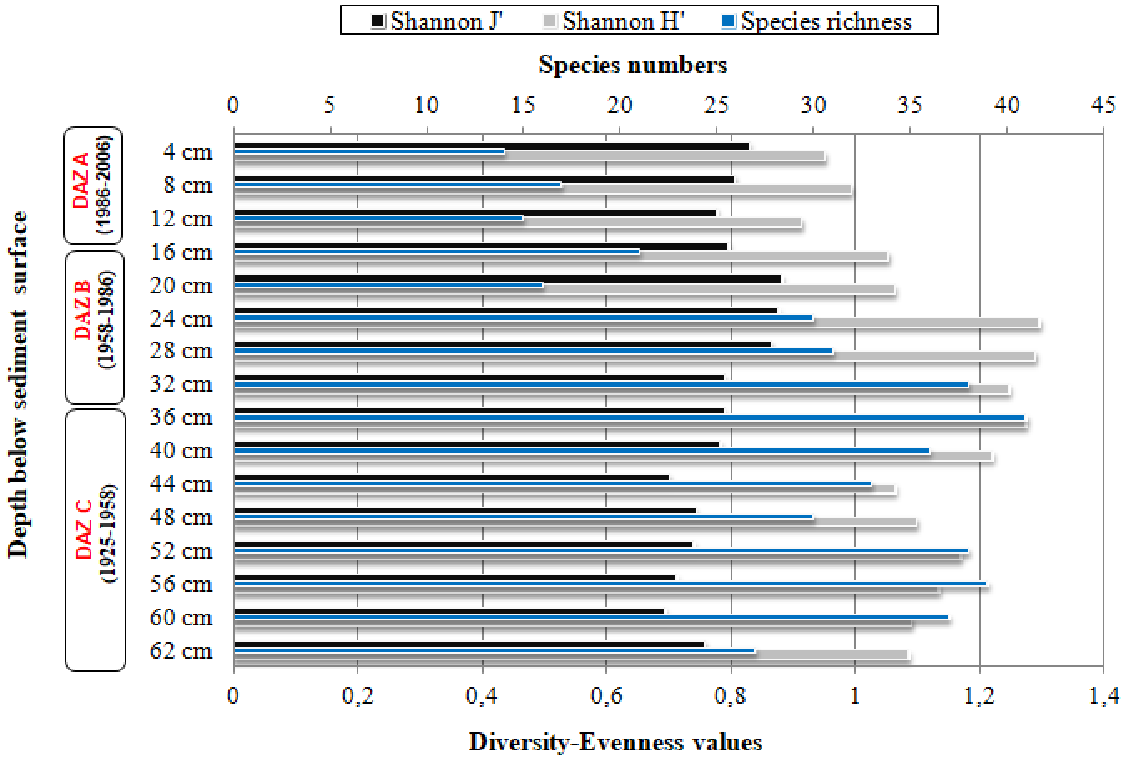

Figure 5. *Shannon Diversity, evenness and species richness at different depths*

Discussion

Unparalleled historical records of organism and environmental change are preserved in lake sediments. Paleolimnologists use lake sediment records to study lake history and landscape development, the timing and magnitude of environmental change at lake and watershed (Burge et al., 2017). Paleolimnological analyses based on diatoms helps to determine the present-day degradation of water quality and significant changes in the ecosystem that occurred. In this research which is made depending on the variety and abundance of the diatoms detected in Ladik sediment, the following result has been reached. Limnological characteristics of Ladik Lake and its ecosystem was significantly affected by the regulator, built in first 1958 and then in 1986 on the outlet of the lake. After the construction of the regulator, the lake lost its original swamp-like dystrophic character and gradually became a eutrophic lake. Once the regulator started functioning, the lacustrine environment changed, and its ecosystem was strongly impacted. As a result of the water level change, the abundant growth of macrophytes retreated progressively to the lake edges and the open water body grew. This shift is obvious in sedimentation. The reduction in macrophytes significantly affected the periphytic diatom assemblages. The strong decrease in the total diatom concentration content at the beginning of DAZ B, i.e. after the mid-1950s (*Fig. 4*). MS in lacustrine sediments is directly related to the terrigenous supply to the lake (Blumentritt and Lascu, 2015). The enhanced sediment input in DAZ A and DAZ B compared to DAZ C would be linked to

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the bank erosion along the lake shore that was triggered by the lake level increase. This terrigenous supply is likely to have changed the nutrient balance in the lake and may have triggered a reduction in depth of the euphotic zone.

The lake ecology was particularly favorable to periphytic biota associated with macrophytes. There seems to be a direct relationship between the diatom zonation and the history of human modifications of the lake outlet that triggered an increase in lake level. Finally, the diatom diversity was high in DAZ C, which point to a good ecological state of the Ladik Lake before the construction of the regulator.

The prevalence of *Cyclotella* spp. in DAZ A suggests that the trophic status of the lake after 1986 is lower than the pre-1986; the ecological amplitude of *Pantocsekiella ocellata* (syn: *Cyclotella ocellata*) has not been entirely clarified, however. This taxon is detected in both shallow (Reed et al., 2001) and deep ultra-oligotrophic environments (Cvetkoska et al., 2012), oligo-mesotrophic (Puusepp and Kangur, 2010) and mesotrophic lakes (Maraşlıoğlu and Gönülol, 2014). According to Choudhury and Bhadury (2015), *Cyclotella* spp. grows in habitats with high silica availability. When it is thought that Ladik Lake is situated on the North Anatolian Fault (NAF), it is expected to be dense of diatoms related to the high amount of silica. Also, Padisák et al. (2009) stated that *Pantocsekiella ocellata* lives generally in mesotrophic small/medium lakes and is sensitive to Si depletion and pH rise. When diatom preservation was good, assemblages of Van Lake are dominated by planktonic diatom *Pantocsekiella ocellata* characteristic of lakes with relatively increased stratification and reduced turnover (North et al., 2017).

Intense presence of organic matter in DAZ C, and the domination of diatom assemblages by *Fragilaria* spp. suggest that the sedimentation pattern during that phase of lake formation was characteristic of oxygen-rich and alkaline water (Zernitskaya et al., 2015). The dominance of these species, especially *Ulnaria ulna* (syn: *Fragilaria ulna*) in the lowermost zone may represent a very shallow water environment in the lake history. *Fragilaria* spp. are widely regarded as pioneering taxa that are frequently connected to early post-glacial times (Stabell, 2008), and that predominate when water levels have drastically decreased (Airill et al., 2016). Studies from Lake Väike Juusa (Punning and Puusepp, 2007) and Lake Ķūži (Puusepp and Kangur, 2010) describe a similar diatom composition at the beginning of the Holocene as characteristic of a freshly formed lake. In Sapanca Lake, *Ulnaria ulna* was described as a species tolerant to pollution by Ongun-Sevindik et al. (2021) as it was associated with high nutritional values (Kavya and Ulavi, 2014; Heramza et al., 2021).

Based on the limnological characteristics and organism diversity that were revealed from the diatom stratigraphy, three main periods were identified regarding the ecological structure of the lake since ca. 1925 (*Fig. 3*).

The earlier period (DAZ C), which corresponds to pre-1958, is characterized by benthic diatom species and high organic matter content that is mainly composed of macrophyte remains. The Si/Ti ratio (*Fig. 2b*) does show a strong enrichment towards the deep part of the LA-001 core, which broadly correlates with a higher percentage of diatoms among the siliceous sediment constituents. According to OM remains in the sediments, high organic matter content also implies high turbidity in lake water. These results imply a very shallow environment. Accordingly, it can be interpreted that the ecological structure of the lake was in dystrophic character during this period.

The later period (DAZ B), which approximately corresponds to the dates between 1958 and 1986, seems to be a transition period. Organic matter content of sediments

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gradually decreased during this period as seen in *Figure 2b*. Since organic matter in Ladik sediments is mostly composed of macrophyte remains, this gradual decrease in organic matter content implies gradual decrease in macrophyte population in the lake due to an increase in water depth as a result of the construction of the regulator in 1958. This increase in water level also resulted in a decrease in the amount of benthic cryptogamic plants. Regarding the trophic state of the lake; as the water level in the lake was stabilized by the regulator, the lake slightly left its dystrophic character, which is typical for very shallow water environments (Avşar, 2013). However, it had not yet reached the water depth in the last period (DAZ A). One of the most obvious indicators of this is the increase in *Epithemia* spp., especially *Epithemia gibba*. They are widespread in fresh and brackish waters and prefer waters rich in calcium, meso- to eutrophic (Şanal, 2016; Rybak et al., 2020). These species are also a precursor of higher nutrient levels of the lake water. Most Epithemiaceae reaches the maximum abundance especially in those microhabitats with high phosphorus and low nitrogen (Kociolek et al., 2015). For this period, by taking only the diatom diversity into account, it would not be accurate to say that the lake became eutrophic. However, both the increases in *Epithemia* spp., which endosymbiotically live together with Cyanobacteria (the main contaminants of eutrophic waters), and the increase in the number of fish belonging to the Cyprinidae family close to the end of this period (Uğurlu et al., 2009), are the precursors of oncoming eutrophication in the lake. Since they contain much higher amounts of water, lake ecosystems may not respond to environmental influences as fast as stream ecosystems do. As it is seen in Ladik Lake, sudden changes in lacustrine ecosystems do not change the trophic structure of a lake together with its biotic diversity in a short time period; rather, it may take several decades.

The last period (DAZ A) implies that the today's eutrophic state of the lake has been continuing since the mid-1980s. In the mid-1980s, there was once again human impact to the regulator area in the lake. The improvement in the regulator in 1986 lead to a larger water level increase that affected the lake ecology as evidenced by diatoms present in DAZ A. As the water depth of the lake has reached 5-6 meters, abundance of planktonic diatoms increased in the lake flora together with the benthic diatoms. The large open water environment is favored by planktonic forms such as *Pantocsekiella ocellata*, which became dominant in DAZ A. Similarly, the common presence of the planktonic *Aulacoseira distans* (Ehrenb.) Simonsen as well in the lake water in 2000 and 2001 (Maraşlıoğlu et al., 2005) confirms a shift from a diverse periphytic diatom to planktonic diatoms in direct link with increase in the lake water depth and the reduction in macrophytes that provided natural habitat structures (Avşar, 2013). Similar to our results, a marked transition from a dominant benthic assemblage to a planktonic one was observed between 1940 and 1980 in Lake Xiaolongwan. However, the reason for these changes was not anthropogenic origin as in Ladik Lake, but increased temperature trends from the region and reconstructed temperature anomalies of the Northern Hemisphere (Panizzo et al., 2013). In this zone, in addition to the planktonic species of *Pantocsekiella ocellata* reflecting the increase in the water level, benthic species of *Ulnaria ulna* which dominated through the whole core is also abundant. This implies that the benthic diatoms, which are related to the macrophytes at the littoral zone of the lake, have still been effective in the lake ecosystem. Because, the floating islands composed of torf on the lake and loamy structure at the lake bottom, which point out benthic structure are also present nowadays in the lake ecosystem. The changes in the forms of life (periphytic *Fragilaria* spp. versus planktonic *Pantocsekiella ocellata*)

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probably reflect an expanded open-water period and an extended growing season (Stabell, 2008; Ampel et al., 2010). The increase in the amount of planktonic diatoms may be explanation of significant rise on lake's water level. Moreover, Puusepp and Kangur (2010) stated that the stability of water depth has a significant impact on the presence of planktonic diatoms.

Fluctuations in the number of the species in fish fauna confirm the diatom records along the core. For example, fish species such as *Esox lucius* L., which thrive in macrophyte-rich environments, was abundant during period B (Uğurlu et al., 2009). However, after the decrease in macrophyte abundance due to the lake level increase in 1986, the number of carnivore fish like *Esox lucius* significantly decreased, where the number of fish of Cyprinidae family (*Squalis, Chondrostoma*, *Capoeta, Blicca* etc.) increased. This change in the fish fauna also indicate that the lake became eutrophic after 1986.

Conclusion

As a result, the following conclusion can be made by all accounts. The regulator at the exit point of Ladik Lake, which was first built in 1958 and then improved in 1986, caused increases in the water level of the lake. This increase in the water level of the lake have affected the ecology of the lake over time, causing a decrease in organic matter and the shift of the dominant algae from the periphytic diatom to the planktonic diatom community. Based on the diatom investigations on the sediments of Ladik Lake, it can be inferred that the limnological regime shifts in Ladik Lake during the 20th century are of anthropogenic origin, rather than being due to climatic changes.

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