

Lakes of Turkey: Comprehensive Review of Lake Çıldır

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ABSTRACT

Lake Çıldır, situated in eastern Turkey, is one of the most noteworthy freshwater lakes in the region, distinguished for its aesthetic allure and its paramount ecological and socio-economic roles. This review thoroughly examines Lake Çıldır, beginning with an introduction that contextualizes its importance. The climatic conditions influencing the lake's dynamics, its hydrographic characteristics, and the physicochemical variables determining its water quality have been specified. Our review synthesizes findings about the lake's biological attributes, including its varied flora and fauna. Detailed sections are dedicated to the fish species, macrophytes, benthic macroinvertebrates, and phytoplankton that inhabit the lake. Using land cover data, temporal changes in the lake's environmental structure have been evaluated. The lake's trophic state and overall ecological health are critically discussed, shedding light on its current status. Furthermore, the potential and existing ecotourism practices around Lake Çıldır are explored, emphasizing its value as a tourist destination. In conclusion, the challenges faced by the lake are addressed, advocating for robust conservation and management initiatives. This comprehensive review of Lake Çıldır's complex ecosystem is a foundation for forthcoming research.

Keywords: Ecology, Ecotourism, Environmental structure, Lake Çıldır, Land cover, Trophic state

INTRODUCTION

Situated in the northern region of East Anatolia, Lake Çıldır is located between the cities of Kars and Ardahan at 41° 00' north latitude and 43° 12' longitude in Turkey. Nestled within the provinces of Ardahan and Kars, Lake Çıldır, with its expanse of 123 km², stands as the second-largest lake in Eastern Anatolia. Positioned at an altitude of 1959 meters above sea level, it reaches a depth of 42 meters, encircled by a vast stretch of approximately 60 kilometers. The lake's genesis can be attributed to a confluence of a lava flow (Aykir & Fıçıcı, 2022). Lake Çıldır's hydrography is an intricate web of inflows and outflows. While myriad streams and springs replenish it, its sole drainage point is the Telek Creek, branching out to the Arpaçay near the Armenian frontier. Adjacent to the Akçakale ruins lies an island, further enhancing the lake's topography (Şimşek, 2019). Despite

its limited vegetation, the lake's vicinities burgeon with pastures, underscoring the socio-economic dependencies on animal husbandry (Yerli, 1993). The regional economy is substantially bolstered by fishing, a year-round activity that persists even during icy winters. Predominantly, the mirror carp (*Cyprinus carpio*) is the prized catch (Yerli, 1997). Ecologically, the lake confronts adversities. Declining water levels in arid spells imperil habitats essential for fish reproduction, while unsustainable fishing practices exacerbate the strains on fish populations (Başçınar et al., 2009). Notably, the lake's northwestern fringes, adorned with wetlands and marshes, amplify its ecological heterogeneity. More than a mere geographic landmark, Lake Çıldır embodies a vibrant ecosystem, an economic linchpin, and a vault of regional heritage. Figure 1 offers a cartographic representation of its location, providing a spatial context;

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according to the Turkish General Directorate of Mapping Data, maps were prepared using *ESRI ArcMap 10.7* software. This paper holistically examines Lake Çıldır, advocating its preservation while spotlighting its multifaceted challenges in our evolving global context.

the connection between the Lake Çıldır basin and the Çıldır Plain, eventually fostering the formation of the lake, nurtured by streams originating from the encompassing terrains (Atalay et al., 2018). The prevalent soil types within the basin are chestnut-colored and basaltic (Karaoğlu & Çelim, 2018). The basaltic soils,

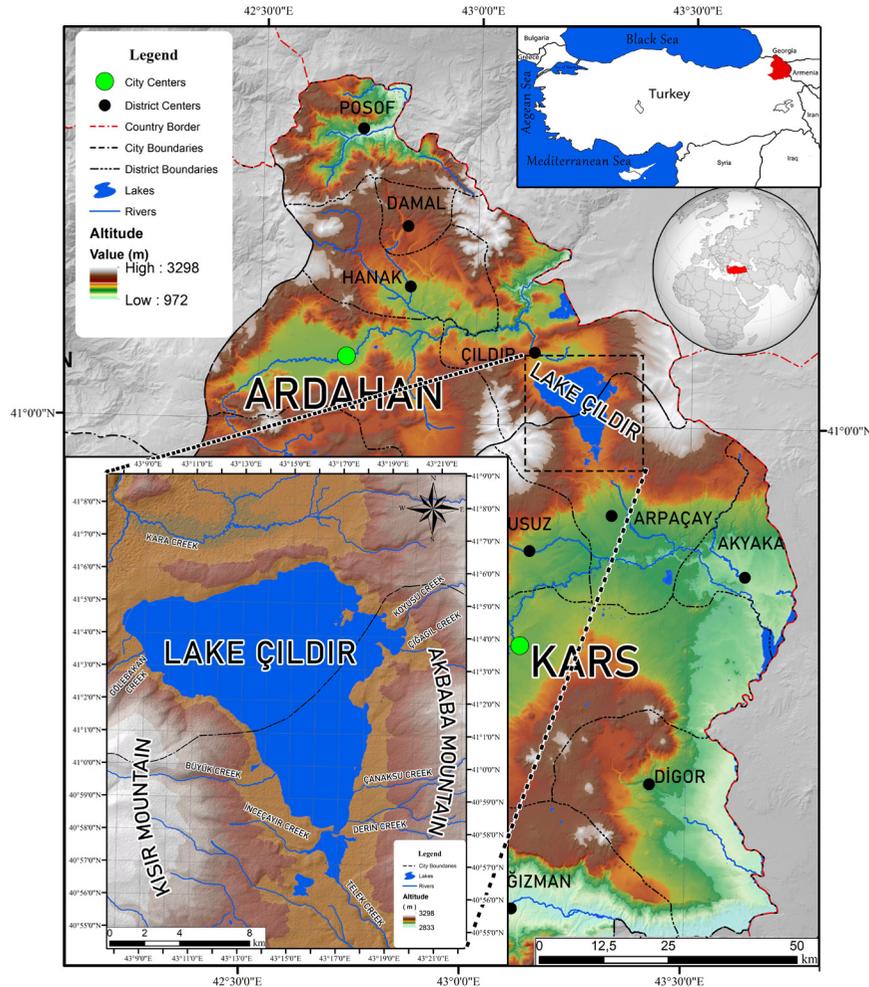


Figure 1. Geographical Position of Lake Çıldır in Turkey.

Geographical features

The geologic foundation of the Lake Çıldır basin is predominantly composed of volcanic tuff, block tuff, andesitic, and basaltic flows, supplemented by younger marl and conglomerates from the post-Oligocene period. During the Pliocene era, the region experienced significant vertical tectonic activities, precipitating block descents along the fault lines (Atalay et al., 2018). Historically, the Lake Çıldır basin and the adjacent Çıldır Plain existed as a unified depression, channeling its hydrologic flow towards the Kura River via the Çıldır Stream (N. E. Akbulut et al., 2022). However, subsequent lava flows partitioned this expansive basin into two distinct sections, creating an intermediary plain between the lava flow's forefront and the Kısır Mountain. Over time, the debris deposited from the Kısır Mountain culminated in the total occlusion of this corridor. This geologic evolution effectively severed

emerging from the volcanic bedrock, are characterized by their proficient drainage capabilities and clayey surface strata (Öztürk et al., 2015).

Climatic features

Situated in the northeastern part of the Eastern Anatolia Region, Lake Çıldır exemplifies the pronounced continental climate characteristic of the area. Due to its distinctive geographical position, the region is one of Turkey's most intensely affected areas by continental climate. This results in short, cool summers and bitterly cold winters (Şimşek, 2019).

The climatic characteristics of a region, encompassing temperature variations and precipitation patterns, are fundamental to comprehending its hydrological and ecological dynamics. Such

knowledge is pivotal for formulating strategies for water resource management, agricultural activities, and the preservation of ecosystems. In this context, an analysis was conducted utilizing meteorological data collated by the Turkish State Meteorological Service from 1931 to 2023 for Kars and Ardahan. Figure 2 shows the precipitation and temperature averages for 2000-2023. As the temperature rises, the decrease in precipitation may pose a problem for species diversity and lake health. The findings indicate that the mean annual temperature for Kars is 4.8°C, reaching a peak in August at 17.8°C and a nadir in January at -10.8°C. Ardahan, on the other hand, exhibits a marginally lower mean annual temperature of 3.7°C, with the highest temperatures recorded in July and August at 16.0°C and the lowest in January at -11.2°C. Concerning precipitation, Kars records an annual average of 506.0 mm, while Ardahan experiences a slightly elevated average of 555.3 mm (Turkish State Meteorological Service, 2018). Notably, May is the month with the highest precipitation in both regions. This characteristic diverges from the typical precipitation patterns observed in other parts of Turkey, where summer is identified as the season with the highest rainfall. Conversely, the winter season is associated with the lowest precipitation levels in both Kars and Ardahan. This climatic information is crucial for developing effective strategies for water resource management, agricultural practices, and ecosystem conservation initiatives.

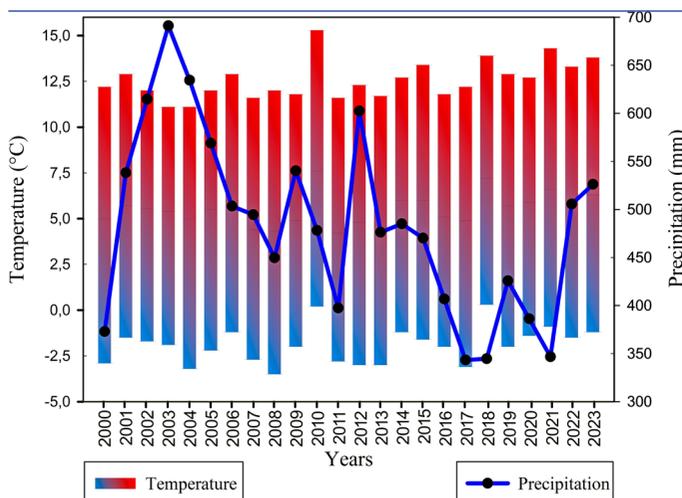


Figure 2. Temperature and precipitation with averages of Lake Çıldır.

Hydrographic features

Lake Çıldır, located in the catchment areas of the Aras and Kura rivers, holds a crucial hydrological role in the region, ultimately discharging into the Caspian Sea via these intersecting rivers in Azerbaijan's Sabirabad. The lake is predominantly replenished by snowmelt and several seasonal and perennial streams, originating from the Kısır Mountains in the west and the Akbaba Mountains in the east. Major tributaries on the western side include the Gölbelen, Kindırğa, and Gölebakan rivers. In contrast, the eastern side receives contributions from the Gülyüzü River and smaller streams passing through the Göldalı and Çanaksu

villages (Lahn, 1947). Lake Çıldır, characterized by its freshwater, has an overflow management mechanism that directs excess water through a narrow corridor near Taşbaşı Village to the Telek Creek and eventually to the Arpaçay. Additionally, the natural barrier between the Çıldır Plain and the lake basin facilitates the lake's assimilation of waters from various sources and streams originating from the plain. As a critical hydrological entity nourished by diverse geographical sources and feeding major river systems, Lake Çıldır's recognition is vital for informed water management and local ecosystem protection (Alkan et al., 2016).

Physicochemical variables

The health and function of lake ecosystems are intrinsically linked to their physicochemical properties, necessitating a comprehensive understanding of the interactions between these factors and their broader ecological consequences (Langdon et al., 2010). Parameters such as temperature, pH, dissolved oxygen, nutrient concentrations, and pollutants are diagnostic tools for assessing water quality and ecological status. These factors influence the metabolic rates of aquatic organisms, their life cycles, ecological interactions, nutrient solubility, productivity, and biodiversity (Brown et al., 2004). Furthermore, nutrient dynamics, particularly nitrogen and phosphorus, play a crucial role in lake ecology. Excessive anthropogenic inputs can lead to eutrophication, which reduces light and oxygen availability, adversely affecting aquatic systems; pollutants, heavy metals, and organic compounds pose significant risks, potentially leading to bioaccumulation and biomagnification in the food chain (Ali & Khan, 2019).

By integrating physicochemical data with environmental and biological indicators, we can comprehensively evaluate lake health and identify potential ecological disturbances (Beck & Hatch, 2009). Such insights are crucial for developing effective management strategies to restore and maintain the balance of lake ecosystems. Therefore, understanding and analyzing the interrelationships between physicochemical properties and biological dynamics is essential for preserving our precious freshwater resources. Table 1 indicates the physicochemical data of Lake Çıldır.

Lake Çıldır has been reported to show no signs of sewage and eutrophication, and it has been characterized as oligotrophic based on physicochemical parameters. However, due to population growth and the effects of pollution elements originating from residential areas and agricultural and livestock enterprises in its vicinity, Lake Çıldır is gradually becoming polluted (Çakır & Çiçek, 2015).

The heavy metal levels in the surface sediments of the northern littoral zone of Lake Çıldır have been studied, and it has been found that the lake is affected by the ecological effects of heavy metals. Additionally, the lake has been found to contain heavy metal levels, including Cu, Pb, Zn, Ni, Mn, Fe, As, Cd, Cr, and Hg, which may have ecological effects (Kükreker et al., 2015).

Biological feature

From a botanical standpoint, Turkey's Central and Eastern Anatolia regions are characterized by the presence of Iran-Turan flora, with a notable distribution in Northeast Anatolia. In contrast, the area surrounding Lake Çıldır dominates the European-Siberian

Table 1. Physicochemical variables in Lake Çıldır (Çelekli et al., 2020).

| Variables | unit | Mean±SD | Minimum | Maximum |
|-------------------|-------|-----------|---------|---------|
| Temperature | °C | 16.9±2.7 | 14.80 | 19.90 |
| pH | | 7.94±1.29 | 6.47 | 8.86 |
| EC | µS/cm | 134±16 | 117.00 | 149.00 |
| Salinity | ppt | 0.10±0.05 | 0.07 | 0.15 |
| DO | mg/l | 8.86±0.29 | 8.53 | 9.05 |
| TSS | mg/l | 19.9±26.1 | 2.80 | 50.00 |
| BOD ₅ | mg/l | 4.7±1.4 | 3.70 | 6.30 |
| COD | mg/l | 19.6±5.0 | 14.50 | 24.40 |
| TOC | mg/l | 2.5±0.4 | 2.10 | 2.80 |
| TN | mg/l | 0.40±0.10 | 0.32 | 0.51 |
| N-NH ₄ | mg/l | 0.11±0.02 | 0.10 | 0.14 |
| N-NO ₂ | mg/l | 0.01±0.01 | 0.00 | 0.01 |
| N-NO ₃ | mg/l | 0.14±0.05 | 0.10 | 0.20 |
| TP | mg/l | 0.14±0.12 | 0.05 | 0.28 |
| P-PO ₄ | mg/l | 0.11±0.16 | 0.01 | 0.30 |
| Secchi depth | m | 3.00±1.32 | 2.50 | 4.00 |

The average and standard deviation (SD) of Lake Çıldır's environmental variables and their minimum and maximum values in brackets are provided. These variables include DO (dissolved oxygen), EC (electrical conductivity), TSS (total suspended solids), BOD5 (biological oxygen demand), TOC (total organic carbon), TN (total nitrogen), N-NO₂ (nitrite), N-NO₃ (nitrate), N-NH₄ (ammonium), P-PO₄ (orthophosphate), and TP (total phosphorus).

phytogeographic elements, reflecting the lake's unique geographic positioning (Atalay et al., 2018). Identifies four distinct vegetation types around the lake: steppe, meadow, rock, and tree-shrub. Salient species include willow variants (*Salix caucasica* and *Salix caprea*), shrubs (*Spiraea hypericifolia*, *Padus avium*), and wild plum (*Prunus spinosa*). The vegetation's diversity can be attributed to the area's short 4-5 months period and distinct geographical conditions. At Lake Çıldır, according to the International Union for Conservation of Nature, endemic plants are in danger. Some endemic plants found in the flora of Kars-Ardahan and Lake Çıldır are *Senecio integrifolius* subsp. *karsianus*, *Veronica thymoides*, *Chaerophyllum karsianum*, *Veronica gentianoides*, *Lathyrus karsianus* (Figure 3), *Festuca karsianum*, *Allium karsianum*, *Nonea karsensis* (Akgül & Aytac, 2008; Armağan et al., 2017).

The aquatic ecosystem of Lake Çıldır is remarkably diverse. The lake is a habitat for native fish species such as the common carp (*Cyprinus carpio*) and the Caspian trout (*Salmo trutta caspius*). Additionally, the Prussian carp - (*Carassius gibelio*) and the crayfish (*Pontastacus leptodactylus*) are shown in Figure 4. There are also rainbow trout populations (*Oncorhynchus mykiss*) within the lake (Çiçek et al., 2022; Çiçek & Birecikligil, 2016; Koçyiğit & Önder, 2018; Zengin et al., 2012).

Avifauna around Lake Çıldır is also noteworthy. Regional data indicates the presence of 86 bird species, including significant ones like velvet ducks (*Melanitta fusca*) and pintails (*Anas acuta*). Two "bird islands" within the lake are hubs for dense bird populations, mainly gulls, providing a visually snow-like spectacle. Historically, pelican species nested here, with recent sightings suggesting potential breeding activity linked to neighboring Lake Aktaş (Kartzahi). The Dalmatian pelican (*Pelecanus crispus*), ruddy shelduck (*Tadorna ferruginea*), common crane (*Grus grus*,

and Armenian gull (*Larus armenicus*) are bird species that meet global and/or, regional Important Bird and Biodiversity Area criteria. The area is a critical stopover for avian migration during spring and autumn. Notably, from mid-September onward, significant numbers of common buzzards (*Buteo buteo*) and lesser spotted eagles (*Aquila pomarina*) can be observed in the north-eastern and southwestern parts of the area. It is possible to monitor with the Bird Observation Tower in Lake Çıldır (Figure 5). However, there is no available data regarding the exact population sizes of these species (Azizoğlu & Adizel, 2020; Crivelli & Vizi, 1981; Özkoç, 2020; Şimşek, 2019; Yılmaz et al., 2018).



Figure 3. *Lathyrus karsianus* a. live plant (Savran, 2021) b. herbarium sample (POWO, 2023).

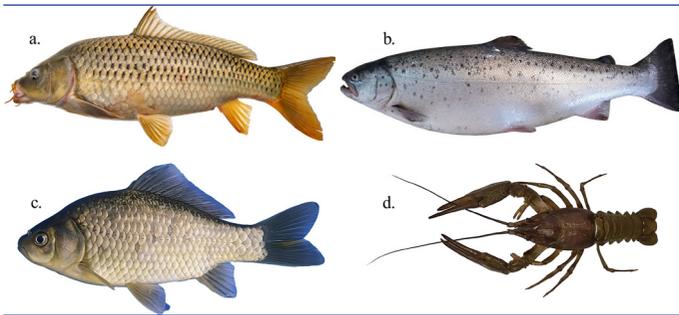


Figure 4. a. *Cyprinus carpio* (The Fishes of North Carolina, 2023), b. *Salmo trutta caspius* (Jouladeh-Roudbar et al., 2020), c. *Carassius gibelio* (Kalous et al., 2012), d. *Pontastacus leptodactylus*.



Figure 5. Photos from the Bird Observation Tower in Lake Çıldır (Çıldır District Governorate, 2023).

Lake Çıldır showcases a diverse macrozoobenthic community, with notable species such as *Armiger crista* and *Paratanytarsus lauterborni*. Recent research has highlighted the lake's rich aquatic oligochaete diversity, identifying 22 species, including new records like *Pristina synclites* and *Bratislavia palmeni*. Furthermore, a comprehensive analysis revealed that the lake's macrozoobenthic fauna encompasses 47 taxa, two unprecedented records for Turkey's Oligochaeta fauna (Arslan & Mercan, 2020; Mercan et al., 2022).

Lake Çıldır is characterized by a rich and varied phytoplankton community, reflecting its ecological complexity and significance in freshwater ecosystems. Phytoplankton play a crucial role in the global carbon cycle and are responsible for producing a significant amount of oxygen. Problems related to the carbon cycle are the causes of global warming and can cause various problems, up to human migrations (Çelekli et al., 2023). Their species diversity and abundance act as water quality indicators due to their different responses to environmental condi-

tions (Çelekli et al., 2020). In addition, phytoplankton are of significant biotechnological importance; some are the removal of harmful dyes. (Zariç et al., 2022). As part of the research, 74 phytoplankton species have been identified from five lakes in the Aras River basin, including Lake Çıldır. *Cocconeis placentula*, *Ulnaria ulna*, *Cymbella affinis*, *Lindavia bodanica*, *Pseudopediatrum boryanum*, and *Ankistrodesmus arcuatus* were among the commonly found species; some of them indicated in Figure 6. Bacillariophyta was the dominant group in the lake based on their values of phytoplankton biovolume in all sampling times. The diatoms contributed (89%) to the total phytoplankton biovolume in Lake Çıldır (Çelekli et al., 2020). As mentioned above, the common diatom species of Lake Çıldır are also the most widespread and abundant in other lakes in Turkey. However, some species were found to be rare, such as *Coscinodiscus* sp., *Staurosirella martyi*, *Didymosphenia geminata*, *Stauroneis acute*, *Diatoma hiemale*, *Aulacoseira ambigua*, and *Ellerbeckia arenaria* (Akbulut & Yıldız, 2002).

In light of the above findings, it is evident that Lake Çıldır represents a complex nexus of biogeographic, ecological, and anthropogenic influences. Given its environmental significance, devising and implementing holistic conservation and management strategies is imperative.

Trophic state and ecological status of Lake Çıldır

Phytoplankton biomass, chlorophyll-a, total phosphorus (TP), and Secchi disk depth are essential indicators of lakes' trophic state and ecological status (Poniewozik & Lenard, 2022). Changes in water color intensity can affect a lake's physical, chemical, and biological parameters, including the concentration of TP and nitrogen and the biomass and composition of phytoplankton (Lenard et al., 2018). Secchi disk depth and TP values obtained during the study were used to determine the trophic status of ecosystems according to OECD criteria. Results of Carlson's trophic state index (Carlson, 1977) based on Secchi depth (TSI_{SD}) indicated that Lake Çıldır was mesotrophic characteristic (Çelekli et al., 2020). The modified phytoplankton trophic index-MPTI (Çelekli, 2016) and the Mediterranean phytoplankton trophic index-Med-PTI (Marchetto et al., 2009) were used to estimate the ecological status of the lake. The high ecological status in the Aras River basin was only found in Lake Çıldır (Çelekli et al., 2020). Although the lake's condition appears better than others, it could be due to its larger surface area compared to others. Continued conservation efforts are necessary because of the significant human impact on the lake.

The land cover changes Lake Çıldır

Lake Çıldır has undergone significant land cover transformations from 2000 to 2018. This was analyzed using CORINE Land Cover (CLC) (EAA,2018) data from the Copernicus Land Monitoring Service and visualized using ESRI ArcMap 10.7 software, as demonstrated in Figure 7 and their results are given in Table 2. This amalgamation of satellite, sensor network data, and land cover data allowed for a thorough examination and intuitive comprehension of the spatial distribution and transformations of various land cover types over the studied period.

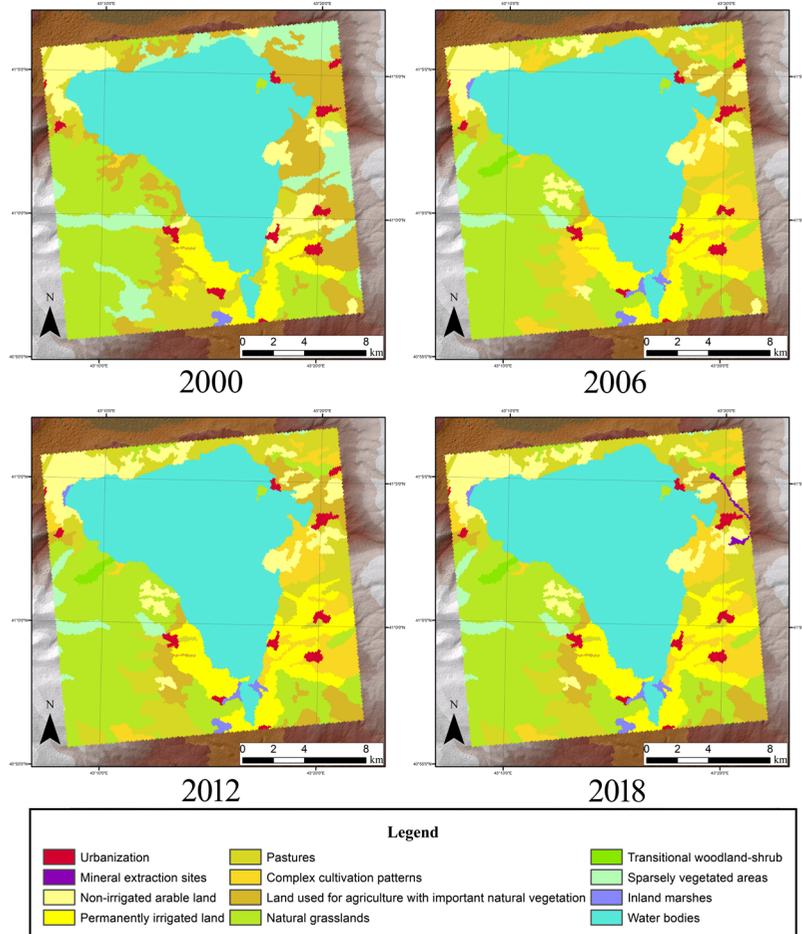
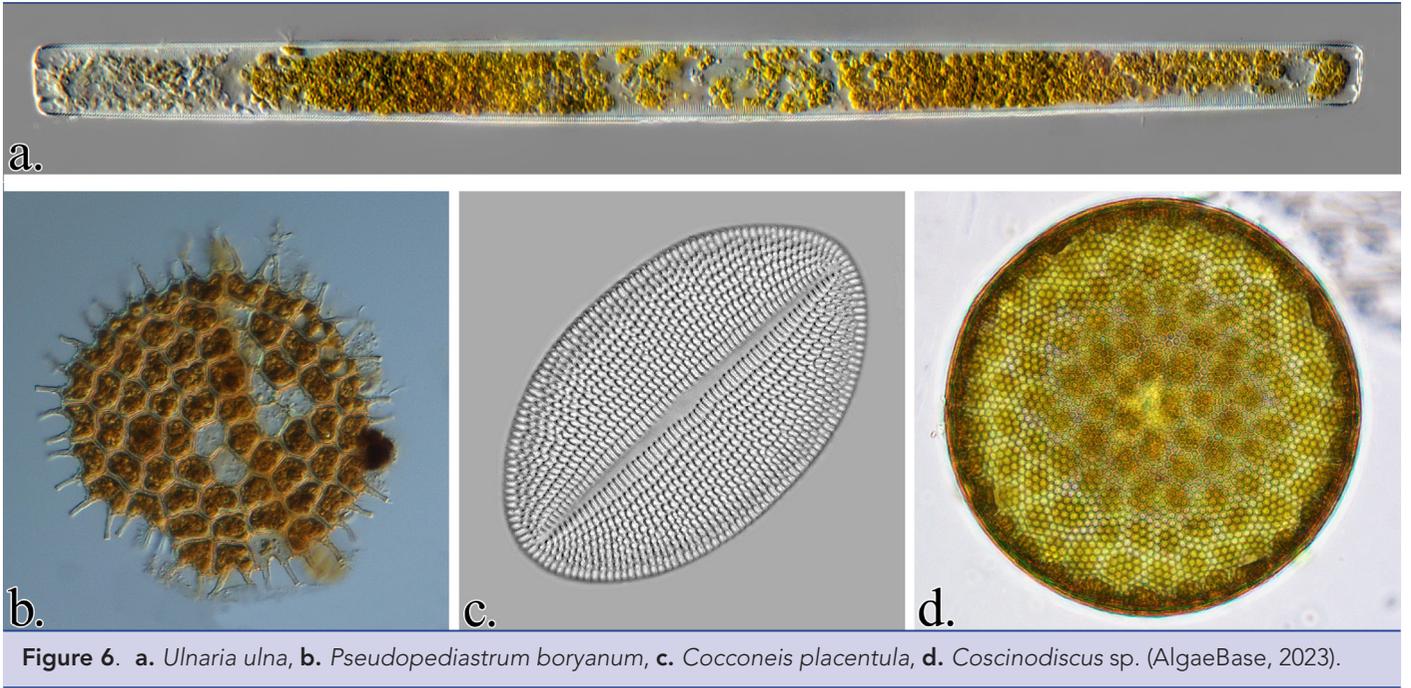


Table 2. Land cover changes around Lake Çıldır from 2000 to 2018 (CLC, 2018).

| Landcover (%) | 2000 | 2006 | 2012 | 2018 |
|------------------------------|-------|-------|-------|-------|
| Urbanization | 0.49 | 0.45 | 0.55 | 0.56 |
| Mineral extraction sites | 0.00 | 0.00 | 0.00 | 0.14 |
| Permanently irrigated land | 2.39 | 3.22 | 3.36 | 3.42 |
| Non-irrigated arable land | 3.54 | 3.90 | 5.06 | 5.35 |
| Pastures | 2.90 | 20.31 | 24.26 | 22.46 |
| Complex cultivation patterns | 0.09 | 5.01 | 3.30 | 3.79 |
| LUAINV | 6.33 | 2.75 | 6.21 | 6.49 |
| Natural grasslands | 39.43 | 50.61 | 40.67 | 40.99 |
| Transitional woodland-shrub | 0.00 | 0.16 | 0.19 | 0.19 |
| Sparsely vegetated areas | 33.48 | 1.28 | 1.79 | 1.81 |
| Inland marshes | 0.10 | 0.24 | 0.22 | 0.23 |
| Water bodies | 11.24 | 12.06 | 14.39 | 14.58 |

LUAINV: Land used for agriculture with important natural vegetation

Lake Çıldır experienced considerable alterations in its land cover between 2000 and 2018, underscoring a significant anthropogenic impact on the region. This period saw an uptick in urbanization, indicating steady urban development near the lake. Concurrently, mineral extraction sites, which were absent until 2006, accounted for a notable proportion of the land use by 2018. Moreover, a marginal increase was observed in irrigated and non-irrigated agricultural lands, hinting at a broader expansion of agriculture in the region. Similarly, the expansion of pastures was observed, which is likely attributable to intensified livestock farming. Conversely, natural grasslands experienced a slight increment, and there was a discernible increase in water bodies, potentially attributable to land use modifications impacting water runoff. These transformations carry profound implications for the ecosystem of Lake Çıldır. The enlargement of agricultural lands and pastures may escalate nutrient runoff into the lake, thereby heightening the risk of eutrophication, a phenomenon detrimental to aquatic life due to the resultant depletion of oxygen levels in the water. Additionally, the advent of mineral extraction sites could adversely affect water quality, contingent on the extraction techniques employed. The augmentation of water bodies might precipitate modifications to the lake's hydrological regime, thereby influencing its water level and, subsequently, its ecological attributes. Furthermore, the marginal alterations in natural grasslands and the reduction in sparsely vegetated areas may engender shifts in the region's flora and fauna, impacting the lake's ecosystem.

In light of these findings, it is imperative to institute robust conservation and management measures to ameliorate the potential adverse repercussions on the Lake Çıldır ecosystem. Such measures should encompass implementing sustainable agricultural practices to curtail nutrient runoff, oversee and regulate mineral extraction operations, and execute land use planning and management strategies to safeguard natural habitats and biodiversity. Additionally, it is crucial to regularly monitor the lake's water quality and ecological attributes to identify and address any untoward alterations expeditiously.

Ecotourism of Lake Çıldır

Lake Çıldır offers significant potential for ecotourism, with its pristine natural beauty, diverse wildlife, and unique ecological characteristics attracting nature enthusiasts and adventure seekers. The establishment of nature trails around the lake allows visitors to explore the surrounding ecosystems, providing a close observation of its rich flora and fauna. The lake and its vicinity host diverse wildlife, including mammals, reptiles, and amphibians. Observation points facilitate the study and appreciation of these local species. Beyond its natural wonders, Lake Çıldır's ecotourism encompasses cultural experiences. Visitors can engage with local communities, learn about their traditional practices and the cultural significance of the lake, and experience artisanal showcases and traditional food tastings. One of the most unique experiences is walking on the frozen expanse of the lake during winter. However, visitors should be mindful of the conditions and prioritize safety. During the peak of winter, when temperatures plummet, the lake freezes over with ice reaching up to 80 cm in thickness (Çimen & Erginal, 2015). This provides a unique opportunity for ice fishing in an "Eskimo-style." The fish caught are then prepared and served, offering the region an authentic taste. Another popular winter activity is taking horse-drawn sleigh tours on the frozen lake, providing a traditional and delightful experience. Organized every February, the Lake Çıldır Festival sees participation from neighboring countries like Georgia, Azerbaijan, Turkmenistan, and Armenia. The Minstrel Festival coincides with this, making it a prime time for visitors to experience winter tourism and cultural festivities. This attraction resembles a frozen city, featuring an ice tower, green caves of pine leaves, a fish museum representing the Lake Çıldır fish, a fruit museum, a crystal cave, and a ghost house. Photographs from the lake Çıldır are shown in Figure 8. Visiting the Ice City, especially when illuminated at night, allows visitors to explore polarly (Çıldır District Governorate, 2023; Sezer, 2022).

Lake Çıldır is a testament to nature's splendor, rich cultural heritage, and diverse ecosystems. It presents a unique blend of ecotourism activities, from walking on its frozen expanse to delving into local traditions, making it an invaluable destination for na-



Figure 8. Lake Çıldır a-c. (Çıldır District Governorate, 2023), d. (Zariç, 2023).

ture aficionados and cultural enthusiasts. As the push for sustainable and immersive travel experiences continues to grow, Lake Çıldır undeniably offers an authentic and enriching journey that resonates with the core values of ecotourism.

CHALLENGES FACING LAKE ÇILDIR AND RECOMMENDATIONS FOR SUSTAINABLE MANAGEMENT

Lake Çıldır a pristine aquatic gem in eastern Turkey. Lake Çıldır has faced ecological challenges since the 1990s. Introducing invasive species, specifically the silver Prussian carp (*Carassius gibelio*) and the narrow-clawed crayfish (*Pontastacus leptodactylus*), has threatened the lake's natural balance. Moreover, attempts at introducing aquaculture, like rainbow trout (*Oncorhynchus mykiss*) farming, have further strained native species and raised sustainability issues. The situation has been aggravated by the operational expansion of the Arpaçay Hydroelectric Plant, which has negatively impacted the lake's shallow coasts, essential breeding grounds for native carp (Zengin et al., 2012). As tourism activities burgeon and exotic species make their mark, an exigent need exists to address these issues with sustainable and academically sound solutions. The following section delineates the challenges faced by the lake and provides recommendations for its sustainable management:

Preservation of current state and ecotourism enhancements:

Recommendation: Ecotourism activities around Lake Çıldır should underscore the importance of environmental education and conservation. It is crucial to instill in visitors the essence of ecosystem preservation, minimizing anthropogenic impacts, and ardently supporting local conservation endeavors. In tandem with this, developing eco-friendly accommodations, such as sustainable eco-lodges and camping sites, can significantly boost the sustainability quotient of ecotourism in the region. Infrastructure developments should be meticulously planned and executed, ensuring a minimal ecological footprint and a relentless commitment to conserving the natural landscape.

Exotic and invasive species

The lake has witnessed the incursion of invasive species, such as the Prussian carp and freshwater crayfish, corroborated by local accounts and other studies (Zengin et al., 2012). Prussian carp are recognized for their aggressive colonization of new environments and their ability to establish dominance, often outcompeting the majority of native species in the process. (Ruppert et al., 2017). Nonetheless, environmental, historical, and anthropogenic processes closely affect the alterations in the native fish population in the ecosystems (Anas & Mandrak, 2021). It is imperative to introduce stringent monitoring systems to track the population dynamics of these exotic species. Furthermore, awareness campaigns should be launched to educate the local

populace about the detrimental impacts of introducing non-native species into the lake.

Environmental hygiene and cleanliness:

Robust sanitation and waste management protocols should be implemented. Regular underwater and on the shores, standard clean-up drives will help maintain the lake's pristine nature. Efforts should also be geared towards sensitizing visitors about the importance of leaving no trace.

Promotion of ecotourism activities

The winter charm of Lake Çıldır, characterized by its frozen expanse, offers many sports and recreational activities. The region can garner significant economic benefits by promoting ice tourism, which appeals to adventure enthusiasts and tourists driven by novelty-seeking motivations. This includes activities like sleigh rides, the Golden Horse Festival, ice skating, ice hockey, and ATV tours. However, it is paramount that these activities are conducted with environmental sensitivity to avoid undue strain on the lake's ecosystem.

Regulation and oversight of local enterprises

Stringent guidelines and regulations should be established for local businesses near the lake. Regular audits and checks can ensure compliance with environmental standards, ensuring the lake's health is not compromised for commercial gains.

Educating and empowering the local community

The local community plays a pivotal role in conserving Lake Çıldır. Organizing workshops, seminars, and interactive sessions can impart knowledge and skills to locals, enabling them to champion the cause of lake conservation. We can foster a collective responsibility toward its well-being by ensuring its stake in the lake's future.

In conclusion, while Lake Çıldır faces multifaceted challenges, with strategic interventions and a commitment to sustainability, it can continue to thrive as both a natural wonder and a hub of ecotourism.

CONCLUSION

Lake Çıldır, situated in Eastern Turkey, presents a significant confluence of ecological and cultural richness. The empirical evaluations underscore its superior environmental status within the Aras River basin. However, its pristine conditions have been incrementally perturbed due to anthropogenic intrusions, notably the introduction of invasive species and burgeoning tourism activities. The repercussions of these interventions are manifested not only in the fluctuating trophic state of the lake but also in its altered phytoplankton composition and biomass.

The juxtaposition of ecological challenges and the robust potential for ecotourism necessitates a paradigm shift in the lake's management strategies. To this end, a suite of recommendations has been advanced, pivoting on sustainable eco-tourism, vigilant monitoring of invasive species, enhanced environmental hygiene protocols, judicious oversight of local enterprises, and a pivotal emphasis on community education and empowerment.

It is paramount to accentuate that the sustainable management of Lake Çıldır not only bears implications for its intrinsic ecological integrity but also resonates with the broader tenets of sustainable ecotourism. Embracing a holistic approach that harmoniously integrates conservation with socio-economic aspirations is, thus, imperative for the lake's future trajectory.

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