



An Updated Assessment of Fishes in Lake Çıldır: A Comprehensive Study and Conservation Recommendations

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Abstract: This study aims to identify the current fish species of Lake Çıldır. Fish sampling was conducted at three stations with high representativeness of the lake, in May 2024, using gill nets with the assistance of local fishermen. The results of the sampling and reviewing literature the presence of 17 species (*Acanthobrama microlepis*, *Alburnoides eichwaldii*, *Alburnus filippii*, *Barbus cyri*, *Capoeta capoeta*, *Carassius carassius*, *Carassius gibelio*, *Chondrostoma cyri*, *Cyprinus carpio* (both native and introduced forms), *Leuciscus aspius*, *Luciobarbus capito*, *Luciobarbus mursa*, *Oncorhynchus mykiss*, *Oxynoemacheilus brandtii*, *Pseudorasbora parva*, *Salmo murathani* and *Squalius turcicus*) were revealed in the lake. Lake Çıldır is a significant freshwater ecosystem with considerable ecological, economic, and cultural importance for Anatolia. However, given the various threats to the lake, urgent and effective measures are needed for its conservation. This study presents the updated fish fauna of Lake Çıldır and discusses recommendations for the health and conservation of the lake. By compiling existing information on the lake's ecosystem, the study aims to highlight the biodiversity of the lake and the environmental factors impacting it.

Keywords: Eastern Anatolia, freshwater fish, ichthyofauna, Aras River.

Çıldır Gölü'ndeki Balık Faunasının Güncellenmiş Değerlendirmesi: Kapsamlı Bir Çalışma ve Koruma Önerileri

Öz: Bu çalışma, Çıldır Gölü'ndeki mevcut balık türlerini belirlemeyi amaçlamaktadır. Balık örnekleme çalışması, Mayıs 2024'te yerel balıkçıların yardımıyla, gölün temsil gücü yüksek üç istasyonunda uzatma ağları kullanılarak gerçekleştirilmiştir. Yapılan örnekleme ve literatür taraması sonucunda gölde 17 türün (*Acanthobrama microlepis*, *Alburnoides eichwaldii*, *Alburnus filippii*, *Barbus cyri*, *Capoeta capoeta*, *Carassius carassius*, *Carassius gibelio*, *Chondrostoma cyri*, *Cyprinus carpio* (hem yerli hem de yabancı formlar), *Leuciscus aspius*, *Luciobarbus capito*, *Luciobarbus mursa*, *Oncorhynchus mykiss*, *Oxynoemacheilus brandtii*, *Pseudorasbora parva*, *Salmo murathani* ve *Squalius turcicus*) varlığı ortaya konmuştur. Çıldır Gölü, Anadolu için önemli bir tatlı su ekosistemi olup, ekolojik, ekonomik ve kültürel açıdan büyük öneme sahiptir. Ancak gölün karşı karşıya olduğu çeşitli tehditler göz önünde bulundurulduğunda, acil ve etkili koruma önlemlerine ihtiyaç duyulmaktadır. Bu çalışma, Çıldır Gölü'nün güncellenmiş balık faunasını sunmakta ve gölün sağlığı ve korunması için önerilerde bulunmaktadır. Göl ekosistemi hakkındaki mevcut bilgileri derleyerek, bu çalışma gölün biyolojik çeşitliliğini ve onu etkileyen çevresel faktörleri vurgulamayı amaçlamaktadır.

Keywords: Doğu Anadolu, ihtiyofauna, Aras Nehri, tatlı su balıkları.

INTRODUCTION

Freshwater ecosystems play a crucial role in water cycling and nutrient density for biological life (Wetzel, 2001). They have greater biodiversity per unit area than

terrestrial and marine ecosystems (Balian et al., 2008; Dudgeon et al., 2006). Their diverse habitats make freshwater ecosystems particularly significant for

biodiversity (Smith et al., 2014). One of the most important regions in the world in this regard is Anatolia, which is home to three biodiversity hotspots (Bayçelebi et al., 2024). Anatolia's freshwater resources are characterized by a wide variety of habitat conditions (Freyhof et al., 2022; Kaya, 2019). The description of several new species (e.g., Bayçelebi et al., 2021; Kaya et al., 2024a, 2024b; Turan et al., 2017; 2022) and ichthyofaunal studies (e.g., Bayçelebi et al., 2020; Kaya et al., 2016; Kurtul et al., 2024a) in Anatolia in recent years further highlights this high diversity.

Lake Çıldır, located in eastern Türkiye between the provinces of Ardahan and Kars, is a significant freshwater lake. It is one of the largest freshwater lakes in the Eastern Anatolia Region, playing a crucial role in the region's ecology and economy. The formation of the lake can be explained by the merging of a lava flow (Aykır & Fıçıcı, 2022) and lava lakes are considered special lakes. Lava lakes form because of volcanic activity and typically occur when lava flows block waterways or fill a valley. This process endows lava lakes with unique geological features that distinguish them from other natural lakes.

Lake Çıldır is situated at an altitude of 1,939 meters, with its deepest point reaching approximately 42 meters, and it covers an area of around 123.5 km² (Zariç et al., 2024). Lake Çıldır supports both aquatic and terrestrial ecosystems and is notable for its rich biodiversity (IUCN, 2024).

The lake is fed by seasonal or perennial streams, primarily from snowmelt. Due to the influence of Siberian air masses, altitude, and continentality, winters are cold and snowy, while summers are short, cool, and rainy (Bağcı & Kılıç, 2023). Lake Çıldır is one of the rare lakes where the surface freezes extensively during winter. The average temperature in the Lake Çıldır varies between -8°C and 6°C.

Several streams, mostly originating from snowmelt, flow into the lake, including approximately 12-13 streams. The outlet of the lake is Telek Creek. It is a tributary of the Arpaçay Stream that is placed to the south of the lake. Major inflows include streams from Gölbelen-Kındırğa and Gölebakan to the west, Gülyüzü Creek to the southwest, water transferred from Lavaşın Lake via a tunnel between Taşbaşı and Taşköprü villages to the south, small streams from Göldalı and Çanakısu villages to the east, and Çingil Creek from Doğruyol village and the 'Northern Derivation Tunnel' to the northeast (Ulutaş, 2011). Various aquatic plants, plankton, benthic organisms, and fish species are commonly found in the lake (Zariç et al., 2024). Additionally, the wetlands surrounding the lake provide breeding and feeding grounds for various bird species, making it an important stopover for migratory birds.

The lake boasts a rich diversity of fish, supporting both commercial and recreational fishing. Some faunistic fish studies have been conducted in the lake and its drainage areas (Çiçek & Sungur Birecikligil, 2016; Kaya et al., 2020), documenting the fish species from the lake. Among the most common fish species are the *Squalius turcicus*, *Capoeta capoeta*, *Leuciscus aspius* and *Cyprinus carpio* (both native and introduced forms), which are particularly targeted by local fishing activities.

In 2021, the total population of the 11 villages around the Lake Çıldır was 3,512 (TÜİK, 2022). Lake Çıldır, a vital water source with significant ecosystem services, faces various pressures from anthropogenic impacts, natural processes, and climate change. This study highlights the Lake Çıldır's freshwater fish fauna by giving and updated list, explains its' natural features and environmental dynamics, and aims to raise awareness about the biological and ecological values of the region, emphasizing the need for the lake's conservation and sustainable management.

MATERIAL AND METHOD

To provide the most current and comprehensive list of the lake's fish fauna, both sampling efforts and historical data collection were undertaken, leading to an updated list.

Sampling study: The Kura-Aras is an international river drainage located in the Southwestern Caucasus (Kibaroglu et al. 2011), encompassing areas from five different countries (Figure 1). Both the Kura and Aras rivers originate in northeastern Türkiye. Lake Çıldır drains to Aras River. To update the fish fauna of Lake Çıldır, sampling was conducted in May 2024 at three stations around the lake with the assistance of local fishermen (Figure 1, Table 1).

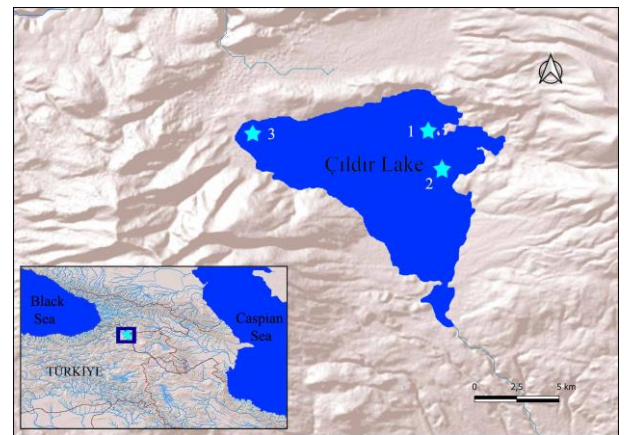


Figure 1. Sampling stations in Lake Çıldır.

Standard gill nets (with 20 and 45 mm mesh opening), used by fishermen during their usual fishing activities, were employed for sampling at these stations.

Fish collected through the fishermen's efforts were euthanized using pure (99.5%) phenoxyethanol (1 ml/L) and preserved in 4% formaldehyde before being transported from the lake to the laboratory (Figure 2). The samples were identified to the species level and recorded in the freshwater fish collection of the Ege University Faculty of Fisheries (ESFM). Species identification was conducted using the works of Kaya et al., (2020) and Turan et al., (2022).



Figure 2. Lake Çıldır, 2024.

To ensure representative sampling of the lake, fish were collected from different regions of the lake with varying ecological characteristics. Fish caught by local fishermen using standard fishing gear were examined, and samples from each species were collected for analysis. The coordinates of the sampling stations in the lake are provided in Table 1.

Table 1. Sampling stations, and location information.

No	Location	Latitude	Longitude
Station 1	Akçakale	41.08096	43.29503
Station 2	Doğruyol	41.04842	43.28149
Station 3	Gölbelen	41.07450	43.15526

Collection of historic ichthyological data: To demonstrate the relevance and diverse biogeographic history of the freshwater ichthyofauna in the Lake Çıldır, historical ichthyological data were collected through an extensive literature review. The recorded species are presented in the Discussion Section (Table 3).

RESULTS

Both our fishing efforts and the historical data combined and according to both the current ichthyofauna of Lake Çıldır includes *Acanthobrama microlepis*, *Alburnoides eichwaldii*, *Alburnus filippii*, *Barbus cyri*, *Capoeta capoeta*, *Carassius carassius*, *C. gibelio*, *Chondrostoma cyri*, *Cyprinus carpio*, *Leuciscus aspius*, *Luciobarbus capito*, *L. mursa*, *Oncorhynchus mykiss*,

Oxynoemacheilus brandtii, *Pseudorasbora parva*, *Salmo murathani* and *Squalius turcicus*. In the lake and its drainage areas, 17 species from 4 families (Cyprinidae, Leuciscidae, Nemacheilidae, Salmonidae) have been identified, including 13 native species, and 5 non-native species (Table 3).

Despite a review of regional records showing no prior evidence of crucian carp (*Carassius carassius*, Figure 3a), a very recent study identified a specimen from Lake Çıldır, captured with a gill net, as belonging to this species based on its morphological features (Kaya, 2024).



Figure 3. Some fishes in the Lake Çıldır: a, *Carassius carassius*, ~22 mm SL; b, *Cyprinus carpio*, ~75 mm SL; c, *Leuciscus aspius*, ~60 mm SL.

DISCUSSION

Updated Fish fauna of Lake Çıldır: There are some previous studies which were recorded some fish species in Lake Çıldır and its drainage areas. Zengin et al., (2012) documented and mentioned *Scardinius erythrophthalmus*, *Salmo trutta*, *Cyprinus carpio*, *Aspius aspius*, *Alburnus filippii*, *Alburnoides eichwaldii*, *Barbus mursa*, *Barbus lacerta*, *Capoeta capoeta*, *Chondrostoma cyri*, *Squalius turcicus*, *Oxynoemacheilus brandtii*, *Oxynoemacheilus cyri*, *Oxynoemacheilus araxensis*, *Scardinius erythrophthalmus* and *Carrasius gibelio* from the Lake Çıldır based on literature and their own observation. Since the early 1990s, natural stocks in the lake have experienced a decline. In contrast, the

introduction of the exotic and invasive species, *Carassius gibelio* and *Pontastacus leptodactylus* (Crayfish) from the 2000s onwards has begun to exert potential pressure on the native fish fauna of the lake (Zengin et al., 2012).

In their study on the taxonomy and ecological characteristics of freshwater fish in the Kura and Aras River basins, Çiçek & Sungur Birecikligil, (2016) reported 14 taxa (*Acanthobrama microlepis*, *Alburnoides eichwaldii*, *Alburnus filippii*, *Capoeta capoeta*, *Carassius gibelio*, *Chondrostoma cyri*, *Cyprinus carpio*, *Leuciscus aspius*, *Luciobarbus capito*, *Luciobarbus mursa*, *Oxynoemacheilus brandtii*, *Pseudorasbora parva*, *Salmo caspius*, *Squalius turcicus* in the Lake Çıldır.

More recent study reported ten species (Kaya et al., 2020). In this study, some species reported in previous studies, such as *Acanthobrama microlepis*, *Luciobarbus capito*, *Luciobarbus mursa*, and *Oxynoemacheilus brandtii* species were not detected. Trout population of the Lake Çıldır has been recently described as *Salmo murathani* by Turan et al., (2022).

In Lake Çıldır, both native and artificially stocked forms of *Cyprinus carpio* (common carp) coexist. The native form, known to the local population as "sarı balık" (yellow fish, Figure 3b), is highly valued for its economic significance. Unfortunately, the native carp population has dwindled over time due to multiple threats including invasive species, pollution, and ghost fishing. Historically, non-native species such as crayfish, *Carassius gibelio*, and *Pseudorasbora parva* have been recorded in the lake. However, the recent introduction of the highly invasive zebra mussel (*Dreissena polymorpha*) has exacerbated the ecological imbalance (Berber et al. 2018; Akkuş et al. 2019). This invasive species has caused a significant decline in the populations of non-native *Cyprinus carpio*, crayfish, and *Carassius gibelio*. The zebra mussels prolific filtering capacity and rapid reproduction rate disrupt the food web, depriving native and economically valuable

species of essential nutrients (MacIsaac, 1996). Consequently, this invasive species not only intensifies the effects of existing threats but also poses a formidable challenge to conservation efforts aimed at preserving the native biodiversity and economic viability of Lake Çıldır's fish populations. *Leuciscus aspius* (Dawn, Figure 3c), which can reach large sizes, is a popular and desired species for the fishermen of the region. However, this species has been very rare for many years and only 1 individual was found during the study.

Although *Scardinius erythrophthalmus* was listed among the fish species of Lake Çıldır by Zengin et al., (2012), subsequent studies have not confirmed the presence of this species in the region (Çiçek & Sungur Birecikligil, 2016; Kaya et al., 2020). Similarly, *Oxynoemacheilus araxensis* and *O. cyri* were listed by Zengin et al., (2012) among the fish species of Lake Çıldır, but subsequent studies have failed to find these species in the lake (Çiçek & Sungur Birecikligil, 2016; Kaya et al., 2020). Given that *O. cyri* is endemic to the upper Kura River, its presence in Lake Çıldır, which drains into the Aras River, is improbable. The records of *O. cyri* in previous studies may actually pertain to *O. veyselorum*, a species distributed in the Aras River. However, further verification is needed to confirm its inclusion in the lake's fauna. These findings highlight the critical need for accurate species identification and thorough documentation in ichthyological research to ensure the integrity of biodiversity records and inform effective conservation strategies.

As the existing and increasing pollution and pressure factors continue to threaten Lake Çıldır and its ecosystem, there is a need to biomonitoring the ichthyofauna of the lake. It is important to understand the current state of the lake to take necessary conservation and precautionary measures.

Table 3. Previous records from Lake Çıldır and the species identified in this study.

Zengin et al. (2012)	Çiçek and Sungur Birecikligil (2016)	Kaya et al. (2020)	Recent status
<i>Alburnoides eichwaldii</i>	<i>Acanthobrama microlepis</i>		* <i>Acanthobrama microlepis</i>
<i>Alburnus filippii</i>	<i>Alburnoides eichwaldii</i>	<i>Alburnoides eichwaldii</i>	* <i>Alburnoides eichwaldii</i>
<i>Barbus lacerta</i>	<i>Alburnus filippii</i>	<i>Alburnus filippii</i>	* <i>Alburnus filippii</i>
<i>Capoeta capoeta</i>		<i>Barbus cyri</i>	* <i>Barbus cyri</i>
<i>Carassius gibelio</i>	<i>Capoeta capoeta</i>	<i>Capoeta capoeta</i>	* <i>Capoeta capoeta</i>
	<i>Carassius gibelio</i>	<i>Carassius gibelio</i>	† <i>Carassius gibelio</i>
			† <i>Carassius carassius</i>
<i>Chondrostoma cyri</i>	<i>Chondrostoma cyri</i>	<i>Chondrostoma cyri</i>	* <i>Chondrostoma cyri</i>
<i>Cyprinus carpio</i>	<i>Cyprinus carpio</i>	<i>Cyprinus carpio</i>	*† <i>Cyprinus carpio</i>
<i>Aspius aspius</i>	<i>Leuciscus aspius</i>	<i>Leuciscus aspius</i>	* <i>Leuciscus aspius</i>
	<i>Luciobarbus capito</i>		* <i>Luciobarbus capito</i>
<i>Barbus mursa</i>	<i>Luciobarbus mursa</i>		* <i>Luciobarbus mursa</i>
<i>Oxynoemacheilus brandtii</i>	<i>Oxynoemacheilus brandtii</i>		* <i>Oxynoemacheilus brandtii</i>
<i>Oxynoemacheilus araxensis</i>			
<i>Oxynoemacheilus cyri</i>			
	<i>Pseudorasbora parva</i>	<i>Oncorhynchus mykiss</i>	† <i>Oncorhynchus mykiss</i>
<i>Salmo trutta</i>	<i>Salmo caspius</i>		† <i>Pseudorasbora parva</i>
<i>Squalius turcicus</i>	<i>Squalius turcicus</i>	<i>Squalius turcicus</i>	* <i>Salmo murathani</i>
<i>Scardinius erythrophthalmus</i>			* <i>Squalius turcicus</i>

*Native, †Non-native

Nonnative species of the lake: The nonnative species in aquatic ecosystems in Türkiye have been thoroughly investigated in previous research (Çetinkaya, 2006; Tarkan et al., 2014; 2015; 2024). The range expansions of some non-native species continue into other parts of Anatolia, becoming invasive in Türkiye's freshwater biomes and causing adverse effects on the native ichthyofauna (Kurtul et al., 2024b). Invasive species, whether introduced intentionally or accidentally, have altered the ichthyofaunal composition of this basin. Three invasive fish species, *Cyprinus carpio*, *Carassius gibelio*, and *Pseudorasbora parva*, have successfully established populations in Lake Çıldır (Çiçek & Sungur Birecikligil, 2016). The introduction of invasive species, including *Carassius gibelio*, *Pontastacus leptodactylus*, along with aquaculture efforts like trout aquaculture activities, are changing the lakes' ecological balance and raised sustainability concerns (Zariç et al., 2024). The spread of those the non-native species in Lake Çıldır represents another threat to the lake ecosystem.

Fisheries activities in Lake Çıldır: In Lake Çıldır, commercial fishing makes a significant contribution to the local economy. Fishermen typically use nets and fishing rods to catch fish. Commercial fishing activities are regulated with specific rules and quotas to maintain the lake's biological balance. The lake is also a popular destination for recreational fishing. Trout fishing, in particular, is favoured by nature enthusiasts and amateur anglers. Various conservation measures are implemented to ensure the sustainability of fishing in Lake Çıldır. Regular stock assessments are conducted to preserve the health and diversity of fish populations, and fishing restrictions are implemented when necessary.

Fishing, a year-round activity even through icy winters, significantly supports the regional economy, with *Cyprinus carpio* being the primary catch (Yerli, 1997). *Cyprinus carpio* is one of the most common and frequently fished species in Lake Çıldır. This species is very important to the local community and is often targeted by both commercial and recreational fishermen. The hunting of *P. leptodactylus* is also a popular activity in the lake and serves as a significant source of income for the local population. Although fishermen have reported that crayfish were once abundant in the lake, they now indicate that the population has declined. *Salmo murathani* is commonly distributed in the streams and rivers around the lake, particularly in trout zones. Trout species are important for sport fishing activities in the region.

The local community around Lake Çıldır not only sustains their livelihoods through fishing activities but also views these activities as cultural and social events. Particularly in winter, ice fishing on the lake is a significant attraction for both locals and tourists. Fishing activities in

Lake Çıldır are managed sustainably to preserve the lake's ecosystem and biological diversity. These activities contribute to the economic development of the region while also aiding in the conservation of natural resources.

Threats in Lake Çıldır: Although Lake Çıldır does not have a high population density around it, various anthropogenic and natural factors have recently been threatening the lakes' ecological balance. This study aims to revise the species distributed in Lake Çıldır and highlight the main threats to the lake, as well as their potential impacts on the lake ecosystem.

Lake Çıldır is under threat from pollution originating from nearby settlements and agricultural areas. Domestic and industrial waste, along with chemical fertilizers and pesticides from agricultural activities, reach the lake and degrade water quality, increasing nutrient loads that can trigger algal blooms. These blooms can lead to oxygen depletion in the water, creating hypoxic conditions that further stress aquatic life and threaten the lake's biodiversity. Furthermore, excessive water use for agriculture, industry, and residential areas causes the water level in the lake to drop. This situation significantly impacts the balance of the lake ecosystem and threatens the sustainability of aquatic life in the lake. Climate change has significant effects on Lake Çıldır. Rising temperatures and altered precipitation patterns adversely affect water levels and water quality in the lake. Particularly during dry periods, the lowering of water levels threatens aquatic life. Fishing activities in Lake Çıldır, especially commercial and overfishing practices, can pose a threat to fish populations in the lake. This situation may lead to a reduction in populations of economically valuable species and disrupt ecosystem balance.

Zebra mussels (*Dreissena polymorpha*) pose a significant threat to Lake Çıldır's ecosystem health. As filter feeders, they consume large amounts of plankton, reducing food availability for native fish and zooplankton and disrupting the aquatic food web (Nalepa & Schloesser, 1992). They attach to hard surfaces, smothering native benthic species and further reducing biodiversity. Additionally, zebra mussels generally clog water intake pipes, filtration systems, and hydroelectric power plants, increasing maintenance costs and reducing efficiency (Prescott et al. 2013). They also damage boats, docks, and recreational areas, and their sharp shells litter beaches. Once established, zebra mussel populations are difficult to control and can cause long-term changes in lake structure and water quality, affecting both the ecosystem and human use.

Suggestions: Lake Çıldır's biological diversity and ecosystem services are critically important for the local population and regional economy. However, various threats such as pollution, overuse of water resources,

fishing pressures, and climate change are disrupting the lake's ecological balance and jeopardizing its sustainability. Therefore, comprehensive and integrated management strategies need to be developed and implemented to conserve the lake.

Efforts to protect Lake Çıldır must prioritize enhancing existing facilities and establishing effective waste management systems to prevent pollutants from surrounding settlements and agricultural areas reaching the lake. Encouraging sustainable agricultural practices such as organic farming and integrated pest management should reduce the use of chemical fertilizers and pesticides in agricultural fields. Continuous research and monitoring programs are essential to assess the lake's sensitivity and adaptive capacity to climate change.

Integrated water management plans should be developed to safeguard the lake's water levels and quality. Measures like monitoring and managing water levels and optimizing water use during drought periods are crucial. Regulation of water usage is imperative to prevent over-extraction.

Regulating fishing activities and preventing overfishing are necessary to ensure the sustainability of fish populations in the lake. Training fishers in sustainable fishing methods is essential, particularly for protecting endangered fish species. Establishing special conservation and breeding areas is vital for their preservation.

Raising awareness among local communities, farmers, and fishers about lake conservation through education programs and awareness campaigns is essential. Encouraging local community involvement in conservation efforts and leveraging their knowledge and experiences are crucial steps towards effective protection.

CONCLUSION

This study provides the recent status of the ichthyofauna of Lake Çıldır. However, gaps in information regarding this fish fauna may still exist. Certain taxa require thorough surveying at previously sampled locations to confirm their presence through specimen examination. Lake Çıldır is one of Türkiye's significant natural assets due to its ecological and climatic characteristics. Preserving Lake Çıldır is of vital importance for the continuity of biological diversity and ecosystem services. Therefore, various measures such as pollution control, sustainable use of water resources, fisheries management, adaptation to climate change, and public awareness initiatives need to be implemented. These measures should be applied comprehensively to maintain the health and sustainability of the lake ecosystem.

The lake and its surroundings are crucial for the economic and cultural well-being of the local population,

owing to their rich biological diversity and ecosystem services. Lake Çıldır faces various anthropogenic and natural threats. Urgent measures are required to manage these threats and protect the lake ecosystem. Monitoring water quality, promoting sustainable water use, regulating fishing activities, and developing adaptation strategies against climate change impacts are essential steps. Long-term conservation and sustainable management of Lake Çıldır are vital for the continuity of biological diversity and ecosystem services in the region.

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