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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

# Fish species composition and seasonal variations in Lake Sapanca and its tributaries

## Sapanca Gölü ve kollarındaki balık tür kompozisyonu ve mevsimsel değişimler

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**Abstract:** The aim of this study was to determine the current fish fauna and their distribution rates in Lake Sapanca and its tributaries. For this purpose, standard benthic and pelagic nets were used in the lake and a portable electroshock device was used in the streams. As a result of the sampling carried out in two different seasons, wet and dry periods, the presence of 26 species from 14 families was determined and the abundance values for many species were higher in the wet season. In terms of species diversity, the Leuciscidae family ranked first with 9 species, while the Gobiidae family was represented by 4 species, the Clupeidae family by 2 species and the remaining 11 families were represented by one species each. In terms of individual density, *Rhodeus amarus* was the most dominant fish in both lake and streams (78.1% lake; 28.3% stream). In the lake, *Blicca bjoerkna*, *Clupeonella cultriventris,* and *Atherina boyeri* were the most abundant species after *R. amarus* (7.2%, 3.2% and 3.2%, respectively). An important finding of the study was that there were almost no individuals of *Silurus glanis*, *Esox lucius,* and *Cyprinus carpio* (4, 8 and 1 individuals, respectively), which are species of high commercial value in the lake. In addition, the fact that *Carassius gibelio*, one of the invasive species reported in previous studies, was not found in the lake is very pleasing in terms of lake biodiversity. In addition, *Leucaspius delineatus*, caught in both seasons, was identified from the lake basin for the first time.

**Keywords:** Biodiversity, exotic fish, life below water, population structure

**Öz:** Bu çalışmanın amacı Sapanca Gölü ve kollarındaki güncel balık faunasını ve dağılım oranlarını belirlemektir. Bu amaçla gölde standart bentik ve pelajik ağlar, akarsularda ise taşınabilir elektroşok cihazı kullanılmıştır. Yağışlı ve kurak olmak üzere iki ayrı mevsimde yapılan örneklemeler sonucunda 14 familyaya ait 26 türün varlığı belirlenmiş olup, birçok türün bolluk değerleri yağışlı mevsimde daha yüksek bulunmuştur. Tür çeşitliliği bakımından Leuciscidae familyası 9 tür ile ilk sırada yer alırken, Gobiidae familyası 4 tür, Clupeidae familyası 2 tür ve kalan 11 familya ise birer tür ile temsil edilmiştir. Birey yoğunluğu bakımından ise *Rhodeus amarus* hem gölde hem de akarsularda en baskın balık olmuştur (%78,1 göl; %28,3 akarsu). Gölde *Blicca bjoerkna*, *Clupeonella cultriventris* ve Atherina boyeri *R. amarus*'tan sonra en bol bulunan türlerdir (%7,2, %3,2 ve %3,2). Çalışmanın önemli bir bulgusu ise ticari değeri yüksek türlerden *Silurus glanis*, *Esox lucius* ve *Cyprinus carpio*'nun (sırasıyla 4, 8 ve 1 birey) gölde neredeyse hiç bulunmamasıdır. Ayrıca önceki çalışmalarda bildirilen istilacı türlerden Carassius gibelio'nun gölde bulunmaması göl biyoçeşitliliği açısından oldukça sevindiricidir. Ayrıca her iki mevsimde yakalanan Leucaspius delineatus türü göl havzasından ilk kez tanımlanmıştır.

**Anahtar kelimeler:** Biyodiversite, egzotik balık, su altında yaşam, popülasyon yapısı

## INTRODUCTION

Whereas their certain importance to be a habitat for aquatic organisms, freshwater lakes also a source of drinking water for us and can be used for domestic, industrial and agricultural activities, energy production, recreation, water sports and tourism. In addition, they are of great importance to mankind, with their including aquatic organisms, by using them in many areas such as food, cosmetics, health, etc. (Messyasz et al, 2018; Hamed, 2016; Mielcarek and Socha, 2022) Therefore, the conservation and sustainable use of all aquatic systems, especially freshwater lakes, is of vital importance (Ferreira et al., 2023). This is an issue that should be considered with the utmost sensitivity, not only for the biodiversity of aquatic organisms, but also for the people who use these services (Özbayram et al., 2022).

Lake Sapanca, one of the most important water bodies in Türkiye, is a freshwater lake of tectonic origin with a maximum depth of 54 m and an average depth of 30 m (Akıner and Akıner, 2021). It is the main source of drinking water for the surrounding settlements and is used for industrial and agricultural activities. The lake, which is also used for water sports and recreation, provides wetland services of high ecological and economic value. It also supports the region's fishing industry, as it is home to many commercially valuable fish species. The lake, which has a water catchment area of about 300 km$^2$, is well fed by the floods and streams (Keçidere, İstanbuldere, Mahmudiye, Yanıkdere and Kurtköy) that come down from the mountains in the south and discharges its outlet water into the Sakarya River from the east through the Çark Stream.

Sapanca Lake and its basin have been the focus of interest of many researchers in the past and present due to its ecosystem services, and the presence of 46 fish species has been mentioned in ichthyological studies conducted in the region (Deveciyan, 1915; Kosswig and Battalgil, 1943; Numann, 1958; Ladiges, 1960; Ongan, 1982; Rahe and Worthmann, 1986; Ergüven, 1989; Karabatak and Okgerman, 2002; Okgerman, 2008; Özuluğ et al., 2007; Tarkan, 2007; Tarkan et al., 2007, 2008; Saç and Özuluğ, 2015; Saç et al., 2019). However, the distribution of 20 species was reported in the last study on the fish fauna of the lake, which only included in-lake sampling (Okgerman, 2008). The lake environment is in a situation where the human population has increased significantly due to illegal construction and rapid urbanisation, and thus the pressure on the lake and its tributaries in terms of pollution and water balance has also increased (Akıner and Akıner, 2021).

The present study aims to determine the current status of the fish fauna and their distribution rates in Lake Sapanca and the streams flowing into the lake, which have a special position with their social and ecological functions. Another aim of the study is to reveal threats to the fish composition of the basin.

## MATERIALS AND METHODS

Field surveys were conducted in two different seasons, wet (May 2022) and dry (September 2022). Fish sampling was carried out using standard benthic and pelagic nets according to TS EN 14757 and 14011 Water Quality criteria in the lake and the SAMUS 725G electro-shocker in the streams. Sampling was carried out at 26 stations, 24 in the littoral parts of the lake with benthic nets and 2 in the deep parts with pelagic nets. Scoop nets and seine net were also used in the littoral areas of the lake. As for the streams, although the study plan provided for sampling in the lower, middle and upper sections of all the streams, due to the low flow rates and being relatively small size of the Değirmen, Maden and Keçi streams, sampling could only be carried out in the lower sections close to the lake. In the other streams, Balıkhane, Yanık, Mahmudiye, İstanbul and Kurtköy streams, sampling was carried out at two stations, one in the upper section and one in the lower section close to the lake, because of the presence of many physical obstacles that degrade the stream continuity (reversing dykes, reclamation benches, base belts, chutes, walls, dykes, stone fortifications, rip-raps, gabion mattresses, prefabricated pavements, industrial pavements, industrial reinforcements, culverts etc.) and prevent fish passage. Sampling was therefore carried out at 12 stations in 8 streams flowing into the lake (Figure 1). Threats to fish species and their habitats were recorded observationally during field surveys.

To determine fish abundance, catch per unit effort (CPUE) was calculated using the following equation: CPUE = (n/t/a) × 100 (n: number of samples, t: time (minute (min) for streams and hour (h) for lakes, a: sampling area) (Jordan & Willis, 2001; Mehner et al., 2005). For streams, the sampling area is the area sampled by electroshock, and for lakes, the sampling area is the area of the gillnet used to catch fish. The time spent on fishing effort was recorded in hours for the lakes and in minutes for the streams.

Alive fish samples were euthanised with pure (99.5%) phenoxyethanol (1 ml/L) and fixed in 4% formaldehyde. Species identification was made by detailed examination of the samples brought to the laboratory, and the number of individuals was determined according to the location where they were caught. Kuru (1980), Miller (1986), Geldiay and Balık (2007), Kottelat and Freyhof (2007), Özuluğ and Freyhof (2011), and Freyhof et al. (2018) were used for species identification.

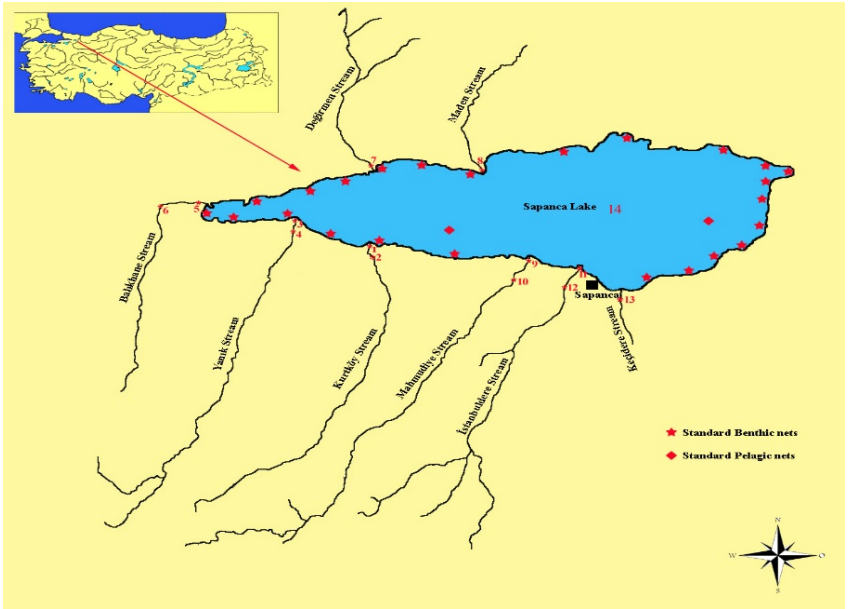


**Figure 1.** Sampling stations in Lake Sapanca and in the streams flowing into the lake

## RESULTS

As a result of the study, the existence of 26 species from 14 families was determined (Table 1). The identified species were described and classified according to Van der Laan et al. (2023). Among these species, seven species, *A. maeotica, C. cultiventris, C. carpio, S. erythrophthalmus, E. lucius, S. glanis,* and *S. abaster* were sampled only from the lake; five species, *G. sakaryaensis, P. borysthenicus, P. strandjae, S. pursakensis,* and *O. mykiss* were sampled only from the streams flowing into the lake (Table 1). *Atherina boyeri, R. amarus, C. emrei, A. istanbulensis, B. bjoerkna, L. delineatus, R. rutilus, V. vimba, T. tinca, G. holbrooki, B. gymnotrachelus, N. fluviatilis, N. melanostomus,* and *P. semilunaris,* and were found both in the lake and in the streams flowing into the lake (Table 1).

Based on field studies conducted during two different seasons at Lake Sapanca, the most abundant species in terms of CPUE values during the wet season were *R. amarus*, *B. bjoerkna*, *A. boyeri*, *C. cultriventris*, *R. rutilus*, *V. vimba*, and various gobiid species. In the dry season, *R. amarus* and *B. bjoerkna* remained dominant, followed by *S. erythrophthalmus*. Other species, represented by only a few individuals, exhibited lower CPUE values (Table 2).

Similarly, field studies conducted on the streams flowing into Lake Sapanca revealed that the most abundant species during the wet season were *P. strandjae*, *S. pursakensis*, *N. fluviatilis*, and *R. amarus*, respectively. During the dry season, the dominant species shifted slightly, with *R. amarus*, *S. pursakensis*, *P. strandjae*, and *P. semilunaris* being the most abundant (Table 3).

When analysing the distribution of the species in the lake, the species *R. amarus* and *B. bjoerkna* were obtained from 23 of the 26 stations studied. *Rutilus rutilus* was also sampled at 18 stations. Among the species of high commercial value in the lake, *E. lucius* was represented by eight individuals in six stations, *S. glanis* by four individuals in three stations and *C. carpio* by one individual in only one station. In addition, *T. tinca, L. delineatus,* and *S. abaster* were found at only one site each. The invasive species, *G. holbrooki*, which was sampled with a scoop net in the coastal area of the lake, was not found in the nets.

In the samplings carried out at 13 stations in 8 streams flowing into the lake, 19 species were identified (Table 1, 2). When the streams were analysed in terms of species diversity, Balıkhane, Yanık, and Kurtköy streams were the richest locations with 16, 15 and 11 species, respectively, while Maden and Keçi streams had only 4 species each (Table 2).

**Table 1.** Fish species caught from Lake Sapanca and in the streams flowing into the lake. + indicates the presence of fish species in the Sapanca Lake basin

| Ordo | Familia | Species | Lake | Streams |
|---|---|---|---|---|
| Atheriniformes | Atherinidae | *Atherina boyeri* | + | + |
| Clupeiformes | Clupeidae | *Alosa maeotica* | + | |
| | | *Clupeonella cultriventris* | + | |
| Cypriniformes | Acheilognathidae | *Rhodeus amarus* | + | + |
| | Cobitidae | *Cobitis emrei* | + | + |
| | Cyprinidae | *Cyprinus carpio* | + | |
| | Gobionidae | *Gobio sakaryensis* | | + |
| | Leuciscidae | *Alburnus istanbulensis* | + | + |
| | | *Blicca bjoerkna* | + | + |
| | | *Leucaspius delineatus* | + | + |
| | | *Petroleuciscus borysthenicus* | | + |
| | | *Phoxinus strandjae* | | + |
| | | *Rutilus rutilus* | + | + |
| | | *Scardinius erythrophthalmus* | + | |
| | | *Squalius pursakensis* | | + |
| | | *Vimba vimba* | + | + |
| | Tincidae | *Tinca tinca* | + | + |
| Cyprinodontiformes | Poeciliidae | *Gambusia holbrooki* | + | + |
| Esociformes | Esocidae | *Esox lucius* | + | |
| Gobiiformes | Gobiidae | *Babka gymnotrachelus* | + | + |
| | | *Neogobius fluviatilis* | + | + |
| | | *Neogobius melanostomus* | + | + |
| | | *Proterorhinus semilunaris* | + | + |
| Salmoniformes | Salmonidae | *Oncorhynchus mykiss* | | + |
| Siluriformes | Siluridae | *Silurus glanis* | + | |
| Syngnathiformes | Syngnathidae | *Syngnathus abaster* | + | |

**Table 2.** Distribution and CPUE values of the species caught in the Sapanca lake basin (1-Kurtköy Stream lower, Kurtköy Stream upper, 3-Yanık Stream-lower section, 4-Yanık Stream-upper section, 5-Balıkhane Stream-lower section, 6- Maşukiye Stream, 7-Değirmen Stream, 8-Maden Stream, 9-Mahmudiye Stream-lower section, 10-Mahmudiye Stream-upper section, 11-İstanbul Stream-lower section, 12-İstanbul Stream-upper section, 13-Keçi Stream, 14-Sapanca Lake; W: Wet period, D: Dry period, *: drying up)

| Species | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | | 8 | | 9 | | 10 | | 11 | | 12 | | 13 | | 14 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W | D | W | D | W | D | W | D | W | D | W | D | W | D | W | D | W | D | W | D | W | D | W | D | W | D | W | D |
| *A. boyeri* | 0.10 | - | - | - | 1.85 | - | - | - | 0.35 | - | - | - | - | - | - | * | - | - | - | - | - | - | - | - | - | - | 57.04 | 4.26 |
| *A. maeotica* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | * | - | - | - | - | - | - | - | - | - | - | 0.93 | 0.19 |
| *C. cultriventris* | - | - | - | - | - | - | - | - | 0.25 | - | - | - | - | - | - | * | - | - | - | - | - | - | - | - | - | - | 55.74 | 6.11 |
| *R. amarus* | 0.05 | 0.10 | - | - | 0.10 | 0.40 | - | - | 4.40 | 2.15 | - | 0.20 | - | 2.20 | 0.15 | * | - | 2.20 | - | - | - | 8.75 | - | - | - | - | 1114.07 | 381.67 |
| *C. emrei* | - | - | - | - | 0.25 | - | - | - | - | 0.05 | - | - | - | - | - | * | - | - | - | - | - | - | - | - | - | - | 0.56 | - |
| *C. carpio* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | * | - | - | - | - | - | - | - | - | - | - | - | 0.19 |
| *G. sakaryaensis* | - | - | - | - | 0.05 | - | - | - | - | - | - | - | - | - | - | * | - | - | - | - | - | - | - | - | - | - | - | - |
| *A. istanbulensis* | 0.25 | - | - | - | 0.10 | - | - | - | 0.35 | 0.15 | 0.10 | - | - | 2.00 | 0.10 | * | - | 0.10 | - | - | - | 0.10 | - | - | - | - | 0.74 | 0.18 |
| *B. bjoerkna* | - | - | - | - | - | - | - | - | 0.30 | - | - | - | - | - | - | * | - | - | - | - | - | - | - | - | - | - | 91.85 | 46.85 |
| *L. delineatus* | - | - | - | - | 0.15 | - | - | - | 3.70 | - | - | - | 0.05 | - | - | * | - | - | - | - | - | - | - | - | - | - | 1.11 | 0.56 |
| *P. borysthenicus* | - | 0.80 | - | - | - | 0.25 | - | - | 0.15 | 0.10 | - | - | 1.80 | 0.30 | 0.25 | * | 0.05 | - | - | - | - | - | - | - | - | - | - | - |
| *P. strandjae* | - | 0.20 | - | 0.20 | 0.05 | 0.10 | 2.25 | 2.10 | - | - | - | 0.05 | - | - | - | * | 2.10 | 1.30 | 2.10 | 1.25 | 0.10 | - | 0.85 | 3.00 | - | 0.55 | - | - |
| *R. rutilus* | - | - | - | - | - | - | - | - | 0.30 | - | - | - | - | - | - | * | - | - | - | - | - | - | - | - | - | - | 19.81 | 15.93 |
| *S. erythrophthalmus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | * | - | - | - | - | - | - | - | - | - | - | 1.85 | 30.37 |
| *S. pursakensis* | 1.00 | 1.30 | - | 0.85 | 0.60 | - | - | - | - | 0.10 | 0.45 | 0.10 | 0.10 | 0.20 | 0.20 | * | 1.90 | 1.50 | - | 3.65 | 0.70 | 2.15 | - | - | 0.65 | 1.35 | - | - |
| *V. vimba* | 0.05 | - | - | - | 0.05 | - | - | - | 0.10 | - | 0.40 | - | 0.10 | - | - | * | - | - | - | - | - | - | - | - | - | - | 10.19 | 4.26 |
| *T. tinca* | - | - | - | - | - | - | - | - | - | - | - | - | 0.05 | - | - | * | - | - | - | - | - | - | - | - | - | - | - | 0.19 |
| *G. holbrooki* | - | 0.40 | - | - | 3.00 | 0.50 | - | - | - | 0.75 | - | - | - | 0.45 | - | * | - | 2.10 | - | - | - | 0.90 | - | - | - | - | 0.19 | 7.04 |
| *E. lucius* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | * | - | - | - | - | - | - | - | - | - | - | 0.74 | 0.74 |
| *B. gymnotrachelus* | - | - | - | - | 2.10 | - | - | - | 0.05 | 0.35 | - | - | - | - | - | * | - | - | - | - | - | - | - | - | 0.05 | - | 8.33 | 0.37 |
| *N. fluviatilis* | 1.70 | - | - | - | 2.80 | - | - | - | 0.05 | 0.10 | 0.10 | - | - | - | - | * | 0.10 | - | - | - | - | 0.05 | - | - | 0.10 | - | 36.48 | 1.85 |
| *N. melanostomus* | - | - | - | - | 0.10 | - | - | - | - | - | - | - | - | - | - | * | - | - | - | - | - | - | - | - | - | - | 7.41 | - |
| *P. semilunaris* | 0.60 | 0.50 | - | - | 0.40 | - | - | - | 0.25 | 2.10 | - | 1.00 | - | 0.40 | - | * | 1.20 | 0.10 | - | - | - | 1.15 | - | - | - | - | 2.59 | 1.85 |
| *O. mykiss* | - | 0.05 | - | - | - | - | - | - | - | - | - | - | - | - | - | * | - | - | - | - | - | - | - | - | - | - | - | - |
| *S. glanis* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | * | - | - | - | - | - | - | - | - | - | - | 0.19 | 0.56 |
| *S. abaster* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | * | - | - | - | - | - | - | - | - | - | - | 0.37 | - |
| **Total** | **3.75** | **3.35** | **-** | **1.05** | **11.35** | **1.25** | **2.25** | **2.10** | **10.25** | **5.85** | **1.00** | **1.35** | **2.10** | **5.55** | **0.70** | * | **5.35** | **7.30** | **2.10** | **4.90** | **0.80** | **13.10** | **0.85** | **3.00** | **0.80** | **1.90** | **1410.19** | **504.44** |

**Table 3.** Total CPUE values of fish species collected from streams flowing into Lake Sapanca (W: Wet period, D: Dry period)

| Species | W | D | ∑ |
|---|---|---|---|
| *A. boyeri* | 2.3 | - | 2.3 |
| *A. maeotica* | - | - | - |
| *C. cultriventris* | 0.25 | - | 0.25 |
| *R. amarus* | 4.7 | 16 | 20.7 |
| *C. emrei* | - | 0.05 | 0.05 |
| *C. carpio* | - | - | - |
| *G. sakaryaensis* | 0.05 | - | 0.05 |
| *A. istanbulensis* | 0.9 | 2.35 | 3.25 |
| *B. bjoerkna* | 0.3 | - | 0.3 |
| *L. delineatus* | 3.9 | - | 3.9 |
| *P. borysthenicus* | 2.25 | 1.45 | 3.7 |
| *P. strandje* | 7.45 | 8.55 | 16 |
| *R. rutilus* | 0.3 | - | 0.3 |
| *S. erythrophthalmus* | - | - | - |
| *S. pursakensis* | 5.6 | 10.35 | 15.95 |
| *V. vimba* | 0.7 | - | 0.7 |
| *T. tinca* | 0.05 | - | 0.05 |
| *G. holbrooki* | 3 | 5.1 | 8.1 |
| *E. lucius* | - | - | - |
| *B. gymnotrachelus* | 2.2 | 0.35 | 2.55 |
| *N. fluviatilis* | 4.8 | 0.15 | 4.95 |
| *N. melanostomus* | 0.1 | - | 0.1 |
| *P. semilunaris* | 2.45 | 5.25 | 7.7 |
| *O. mykiss* | - | 0.05 | 0.05 |
| *S. glanis* | - | - | - |
| *S. abaster* | - | - | - |

## DISCUSSION

Although the first scientific data about the fish fauna of Sapanca Lake is found in Deveciyan (1915), the great Turkish traveller Evliya Çelebi, who lived in the 17th century, while talking about Sapanca Lake in his famous work, Book of Travels, states that the fishermen make a profit by catching 70-80 different species of fish living in the lake, such as trout, carp, pike and luna fish which are very delicious and nutritious (Danışman, 1969; 1970; 1971). In the following years, the presence of 41 different taxa was reported in the faunistic studies on the fishes of the lake (Kosswig and Battalgil, 1943; Numann, 1958; Ladiges, 1960; Ongan, 1982; Rahe and Worthmann, 1986; Okgerman, 2008) and in addition to these, Ergüven (1989) reported *Lampetra fluviatilis*, Tarkan (2007) *Lampetra* sp.; Özuluğ et al. (2007) *Phoxinus phoxinus* and *Gambusia holbrooki*; Tarkan et al. (2008) *Salmo trutta macrostigma*; Saç and Özuluğ (2015) *Phoxinus strandjae*; Saç et al. (2019) *Gobio sakaryaensis*, as well. Therefore, the distribution of 46 different fish species in Lake Sapanca has been reported in studies carried out between 1915 and the present day (Table 4). In the present study, 27 species belonging to 14 families were identified in the lake and its tributaries. Among these species, *L. delineatus* was identified for the first time from the lake basin and is the first record. Lake Sapanca is within the natural range of *L. delineatus*. The fact that it has not been reported in previous studies is probably due to the morphological similarity of this small-sized fish with the juveniles of some species such as *Squalius* and *Petroleuciscus*.

The eel, *A. anguilla*, which was last recorded from the lake in 1986 (Rahe and Worthmann, 1986), is a species whose range is shrinking due to habitat loss in many parts of Europe (Ağdamar et al., 2021). Lake Sapanca is connected to the Sakarya River by the Çark Stream and thus to the Black Sea. For this fish, which has to use this route for breeding migration, the control gates on the Çark Stream and the fact that part of the stream has been enclosed in a concrete canal can be considered as an obstacle. The species previously reported as *C. muhlisi* from the lake was found to be *C. cultriventris* through genetic and morphological studies (Aydoğan, 2018). In addition, the species *A. albidus* and *A. alburnus* reported in previous studies are considered to be a misidentification of the species *A. istanbulensis*. *Syngnathus nigrolineatus*, previously listed by Kosswig and Battalgil (1943) and Rahe and Worthmann (1986), is now recognised as a synonym of *S. abaster*. *Salmo* species prefer the trout zone of streams and it is thought that these fish were not caught because the upper zones of the streams present in the study could not be sampled.

Kosswig, who carried out the first important limnological study of the lake, compiled unpublished data on fish in 1958 and reported that there were 28 fish species living in the lake. There is no information on the species *Alvonus brunner*, and it is thought that this name included in the study as a typographical error. A similar situation applies to the species *Varicorhinus tri*, which has not been found in subsequent studies conducted in the lake or in other literature worldwide. Subsequently, Ladiges (1960) recorded 13 fish species from the lake. Among these species, *Chondrostoma knerrii* was then identified as *Chondrostoma nasus* in a study of *Chondrostoma* species in Türkiye by the same researcher (Ladiges, 1966). Since then, a single individual of this species was first identified in the lake in 2006 (Tarkan et al., 2007). Elvira (1987) gave the name *Chondrostoma nasus angorensis* to the form of this fish living in the Sakarya basin, and later the same researcher updated the scientific name of this fish to *Chondrostoma angorense* (Elvira, 1997). Examinations conducted on the single individual caught in the lake in 2006 confirmed that this fish was *Chondrostoma angorense* (Tarkan et al., 2007). The species *Alburnus albidus* recorded in Ladiges' study in 1960 has not been found in subsequent studies. *Alburnus albidus* is a fish native to Italy (Kottelat and Freyhof, 2007), but it was mistakenly reported to inhabit in Sapanca Lake. Many years later, in 1982, in the first study published by Ongan on the fish in the lake, 27 fish species were reported. In this study, three gobiid fish species were reported, namely *Neogobius fluviatilis*, *Pomatoschistus caucasicus kosswigi*, and *Proterorhinus marmoratus*, different from Numann (1958). Following this, Rahe and Worthmann (1986) reported 35 fish species from the lake in their study.

*Alburnoides bipunctatus*, *Atherina boyeri*, *Clupeonella abrau muhlisi*, *Neogobius syrman*, *Oncorhynchus mykiss*, *Syngnathus nigrolineatus*, *Syngnathus tenuirostris*, and *Vimba vimba tenella* are species that have been added to the lists

**Table 4.** Species identified in Lake Sapanca in the faunistic studies conducted to date (1- Deveciyan (1915), 2- Kosswig and Battalgil (1943), 3- Numann (1958), 4- Ladiges (1960), 5- Ongan (1982), 6- Rahe and Worthmann (1986), 7- Karabatak and Okgerman (2002), 8- Okgerman (2006), 9- Present study)

| Species | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| *Anguilla anguilla* | - | - | + | - | + | + | - | - | - |
| *Atherina boyeri* | - | + | + | - | + | + | - | + | + |
| *Alosa maeotica* | - | + | + | - | + | + | + | + | + |
| *Clupeonella cultriventris* | - | - | - | - | - | + | - | + | + |
| *Cobitis emrei* | - | - | + | - | + | + | - | + | + |
| *Abramis brama* | - | - | + | + | + | + | - | - | - |
| *Alburnoides bipunctatus* | - | - | - | - | - | + | - | - | - |
| *Alburnus albidus* | - | + | - | + | - | - | - | - | - |
| *Alburnus alburnus* | - | - | + | - | + | + | - | - | - |
| *Alburnus istanbulensis* | - | + | + | + | + | + | - | + | + |
| *Alvonus brunner* | - | - | + | - | - | - | - | - | - |
| *Blicca bjoerkna* | - | + | + | + | + | + | + | + | + |
| *Carassius carassius* | - | - | + | + | + | + | + | - | - |
| *Carassius gibelio* | - | - | - | - | - | - | - | + | - |
| *Chondrostoma angorense* | - | - | - | + | - | - | - | - | - |
| *Cyprinus carpio* | - | + | + | + | + | + | + | + | + |
| *Gobio sakaryaensis* | - | - | - | - | - | - | - | - | + |
| *Leuciscus aspius* | - | + | + | + | + | + | + | - | - |
| *Petroleuciscus borysthenicus* | - | + | + | + | + | + | - | - | + |
| *Phoxinus strandjae* | - | - | - | - | - | - | - | - | + |
| *Rhodeus amarus* | - | + | + | + | + | + | + | + | + |
| *Rutilus rutilus* | + | + | + | + | + | + | + | + | + |
| *Scardinius erythrophthalmus* | + | + | + | + | + | + | + | + | + |
| *Squalius pursakensis* | - | - | + | - | + | + | + | + | + |
| *Tinca tinca* | + | - | - | - | - | + | + | + | + |
| *Varicorhinus tri* | - | - | + | - | - | - | - | - | - |
| *Vimba vimba* | - | + | + | + | + | + | + | + | + |
| *Esox lucius* | + | + | + | - | + | + | + | + | + |
| *Babka gymnotrachelus* | - | + | + | - | + | + | - | + | + |
| *Knipowitschia caucasica* | - | + | - | - | + | + | - | - | - |
| *Neogobius fluviatilis* | - | + | + | - | + | - | - | + | + |
| *Neogobius melanostomus* | - | + | + | - | + | + | - | + | + |
| *Ponticola syrman* | - | - | - | - | - | + | - | - | - |
| *Proterorhinus semilunaris* | - | + | - | - | + | + | - | - | + |
| *Oxynoemacheilus angorae* | - | - | + | - | + | + | - | - | - |
| *Perca fluviatilis* | + | + | + | - | + | + | - | - | - |
| *Lampetra lanceolata* | - | - | - | - | + | - | - | - | - |
| *Gambusia holbrooki* | - | - | - | - | - | - | - | - | + |
| *Oncorhynchus mykiss* | - | - | - | - | - | + | + | + | + |
| *Salmo labrax* | - | - | + | - | - | - | - | - | - |
| *Salmo* cf. *macrostigma* | - | + | - | - | - | - | - | - | - |
| *Silurus glanis* | + | - | + | - | + | + | + | + | + |
| *Syngnathus abaster* | - | - | + | - | + | + | - | - | + |
| *Syngnathus tenuirostris* | - | - | - | - | - | + | - | - | - |
| *Syngnathus nigrolineatus* | - | + | - | - | - | + | - | - | - |
| *Leucaspius delineatus* | - | - | - | - | - | - | - | - | + |
| **Number of species** | **6** | **21** | **28** | **13** | **27** | **33** | **14** | **20** | **26** |

provided by previous researchers. It is believed that the individuals of the species *Oncorhynchus mykiss* (rainbow trout) found in the wild are rare individuals that have escaped from trout farms established on streams flowing into the lake, that do not have the ability to reproduce on their own, and are therefore unable to form a population. Indeed, all the studies carried out on this species to date have found their numbers to be very low. The species *Atherina mochon* and *Atherina boyeri* (sand smelt) listed in the fish lists of Kosswig and Battalgil (1943) and Numann (1958) are actually the same species and synonyms. Therefore, these two sands smelt records should actually be considered as a single species, namely the valid species *Atherina boyeri*. Therefore, in the studies by Kosswig and Battalgil (1943), Numann (1958), and Rahe and Worthmann (1986), only one species of sand smelt, *Atherina boyeri*, is mentioned. In the study conducted by Karabatak and Okgerman (2002), following Rahe and Worthmann (1986), this species is also given as *Atherina mochon*. Similarly, the species *Vimba vimba tenella* and *Vimba vimba*; *Syngnathus nigrolineatus* and *Syngnathus abaster* are synonyms, and these fish are now accepted as *Vimba vimba* and *Syngnathus abaster*. Therefore, considering them as separate species in the species list provided by Rahe and Worthmann (1986) will contribute incorrect information to the literature.

After the results of Rahe and Worthmann's study were published in 1986, there was no study on the fish composition for a long time, until Ergüven (1989) reported a new record of *Lampetra fluviatilis* (European river lamprey) for the lake in 1989. In this study, it was reported that *L. fluviatilis* was caught in the Kurtköy and Yanık streams, which flow into Lake Sapanca. However, the distribution areas of *L. fluviatilis* reported by Ergüven (1989) does not include the Black Sea coast and more southern latitudes (Kottelat and Freyhof, 2007). The first detailed research results after Rahe and Worthmann (1986) were published in 2002, and 15 fish species were reported in the list. Later, according to the more comprehensive results of Okgerman et al. (2006), there are 20 fish species in the lake, and two invasive fish species (*Carassius gibelio* and *Lepomis gibbosus*) were also identified. The species reported in this study, with the exception of the two invasive species, are species known to have previously occurred in the lake. However, in the study conducted by Okgerman et al. (2006) between 2000-2004, the species *Abramis brama*, *Alburnus alburnus*, *Alburnoides bipunctatus*, *Anguilla anguilla*, *Lampetra fluviatilis*, *Neogobius syrman*, *Nemacheilus angorae*, *Perca fluviatilis*, *Petroleuciscus borysthenicus*, *Pomatoschistus caucasicus kosswigi*, *Proterorhinus marmoratus*, *Syngnathus abaster*, which were previously known to occur in the lake, were not found. The last study on the fish fauna of Lake Sapanca was conducted in 2007, and no comprehensive ichthyofauna study has been conducted since then (Tarkan, 2007; Özuluğ et al., 2007). In this study, the fish fauna of the streams flowing into the lake was examined, and 12 species were identified (Tarkan, 2007). Among these species, *Phoxinus phoxinus* and *Gambusia holbrooki* are new records for the lake basin (Özuluğ et al., 2007).

Later, it was reported that the new record of *P. phoxinus* in Sapanca Lake was *Phoxinus strandjae* (Saç and Özuluğ, 2015). In addition, an individual belonging to the genus *Lampetra* was identified from Yanık Stream in 2007 for the first time by Ergüven (1989) and after Özuluğ et al. (2007). However, it was reported that the juvenile individuals obtained could not be used for species determination because adult individuals are very important for species determination of fishes belonging to this genus. But, recent molecular-based studies have revealed that the species living in Sapanca Lake and recorded as *Lampetra fluviatilis* is actually *Lampetra lanceolata* (Geiger et al. 2014).

Among the fish caught during the study, *G. holbrooki* and *O. mykiss* are exotic fishes to the lake and its tributary. The invasive *G. holbrooki* was found to be dense in the littoral region of the lake and especially in the lower parts of the streams. It is an undesirable fish species due to its predatory and aggressive behaviour on the eggs and larvae of native fish and amphibians, and because it can compete with them for food and habitat. The *O. mykiss* fish caught in the Kurtköy Stream is believed to be one of the fish that escaped from trout farms and settled in the wild. *Carassius carassius* was first reported from the lake by Numann (1958) and caught by other researchers in the following years. The species *C. gibelio*, which is difficult to distinguish morphologically, was only reported by Okgerman (2008). The fact that this invasive species was not caught in the current study is very positive for the biodiversity of the lake.

Among the fish species found in the lake basin are species endemic to Turkish inland waters such as *C. emrei*, *G. sakaryaensis*, *A. istanbulensis,* and *S. pursakensis*. In addition, *E. lucius*, *S. glanis*, and *C. carpio*, which are commercially valuable and preferred for sport fishing, and *V. vimba* and *S. erythrophthalmus*, which are consumed with pleasure by the local population, are important elements of the fauna. However, an important result of the study is that very few individuals of the species *S. glanis, E. lucius,* and *C. carpio*, which are among the species with high commercial value in the lake, were found. This situation is thought to be the result of intense sport fishing and poaching, despite the fact that the lake is closed to commercial fishing. Therefore, in addition to protecting the lake itself, it is important to protect the biodiversity it contains in order to ensure its sustainable use.

When analysing the temporal and spatial distribution of the fishes, it was found that the abundance (CPUE values) of some fishes were higher in the lake and lower sections of the streams, especially during the wet season. It is thought that this may be related to the reproductive behaviour of the fishes; many species such as *A. boyeri, C. cultriventris, R. amarus, B. bjoerkna, A. istanbulensis* and *V. vimba* come to the littoral areas mainly firstly to breed and also to feed after surviving the harsh winter conditions in the deeper parts of the lake. In addition, it has been observed that the fish composition in the lake has changed over the years. Karabatak and Okgerman (2002) determined that *S. erythrophthalmus, B. bjoerkna,* and *R. rutilus* were the dominant fishes in the lake about 20 years ago, followed by *V. vimba, E. lucius,* and *A. maoetica*. The fishing gear they use for their monthly surveys throughout the year is gill nets with mesh sizes ranging from 22 to 50 mm. In the present study, the dominant species was *R. amarus*, with small species such as *A. boyeri* and *C. cultriventris* also present with high CPUE values. This difference between the two studies may be mainly related to the mesh size used. It is also thought that continued fishing pressure on commercial fish such as *E. lucius* and *C. carpio*, which have had high catch rates in recent years (Karabatak and Okgerman, 2002), is responsible for their low abundance today.

When the factors that threaten the sustainable use of Lake Sapanca are examined, despite it being a drinking water basin, the following risk factors stand out: i) domestic waste due to construction on the shoreline almost all around the lake, ii) fertiliser and pesticide waste from intensive farming around the lake, iii) pollution from highways and railways along the northern and southern shores of the lake, iv) numerous water bottling plants around the lake, and v) pollution caused by intense tourism activities around the lake. Besides,

constructions such as dams, reclamation benches, base belts, chutes, walls, dykes, stone fortifications, rip-raps, gabion mattresses, prefabricated pavements, industrial pavements, industrial reinforcements, culverts are another factor that prevents fish from migrating to the upper reaches of streams for reproduction. The negative effects of these structures can be seen in the distribution of fish in the streams. While the lower sections of the streams close to the lake are rich in biodiversity, the lack of biodiversity in the upper sections is due to these physical barriers that restrict the migratory mobility of fish in almost all streams.

## CONCLUSION

Sapanca is the smallest district of the city Sakarya, but its population increased to 46 080, 26% in the last 23 years (TUİK, 2024). In addition, its population can be three folded in summers because of the native and foreign tourists (Yılmazer, 2022). The tourism activities in the town is clearly seen from the number of bungalovs increased up to 4000 nowadays (Çağlar, 2023). This faunistic study, carried out in a lake basin, which is subject to population growth and therefore urbanisation pressure, has provided current information on the species present and their population densities. The distribution of fish species in the lake and its streams was determined and species reported in previous studies but not caught in this study were interpreted. In the face of threats that are thought to be limiting the ecosystem functioning of the lake basin, it is recommended that monitoring studies are carried out, particularly for fish, which are thought to respond rapidly to water balance and pollution. A further recommendation is to provide urgent solutions to structures that prevent fish from breeding and feeding in streams.

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## AUTHORSHIP CONTRIBUTIONS

Ali İlhan: Design of the study, sampling and laboratory studies, writing draft. Gülşah Saç: Sampling and laboratory studies, writing draft. Özcan Gaygusuz: Desing of the study, sampling and laboratory studies, writing draft. Sencer Akalın: Sampling and laboratory studies. Esat Tarık Topkara: Sampling and laboratory studies. Dilek İlhan: Laboratory studies. Çiğdem Gürsoy Gaygusuz: Laboratory studies., Hasan Musa Sarı: Laboratory studies.

## CONFLICT OF INTEREST

The authors state that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## ETHICS APPROVAL

The care and use of experimental animals, sampling and analysis techniques used in this work are approved by “Ege University Animal Experiments Ethics Committee” with decree no “2021/078”.

## DATA AVAILABILITY

All relevant data is in the article.

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