

Current fish community structure of an anthropogenically pressured system: the case of the Küçükçekmece Lagoon (NW Türkiye)

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Abstract

This study offers the first detailed investigation of the ichthyofauna of the Küçükçekmece Lagoon (İstanbul, Türkiye) in nearly 30 years, with the aim of characterizing the current structure of the fish community in this anthropogenically pressured lagoon. Seasonal samplings were conducted between September 2023 and August 2024, and fishing was conducted at five different stations within the lagoon using multimesh gillnets and at two coastal sites using a seine net. A total of 18 fish species belonging to 12 families were identified. Only five species (*Atherina pontica*, *Engraulis encrasicolus*, *Chelon auratus*, *Chelon ramada*, and *Mugil cephalus*) were captured using gillnets. On the other hand, 17 species were recorded with a seine net in areas close to the lagoon's connection with the Sea of Marmara. *Atherina pontica* was the most abundant species in both fishing methods, while *Salaria pavo*, *Belone belone*, *Neogobius fluviatilis*, *Gobius niger*, and *Sparus aurata* were each represented by a single specimen. The current species composition indicates a community dominated by euryhaline species, which differs from historical records that included freshwater taxa. The absence of freshwater species in the catch coincides with the observed salinity levels (up to 14.12). Except for a few resident species (e.g., *A. pontica* and *E. encrasicolus*), the lagoon is predominantly inhabited by euryhaline species, especially during spring and summer. Serving as a structured baseline, this study documents the current ecological status of fish assemblages in the lagoon following long-term environmental change.

Keywords: *Atherina pontica*; abundance; brackish water; fish fauna; salinity.

Introduction

The biodiversity of a given ecosystem is important for the sustainability of the ecosystem services it provides, as well as for the continuity of human social and economic life. The pressure on natural resources to meet the growing needs of the world's population is increasing every day, and this pressure is causing an irreparable loss of biodiversity (Keck *et al.*, 2025). Inland surface waters (i.e., lakes, reservoirs, rivers, and wetlands) are ecologically valuable systems of major importance for global biodiversity. However, as they lie at the center of human settlement and activity, they are especially vulnerable to the pressures of urbanization and industrialization. In recent years, the importance of biodiversity has been recognized worldwide, and there is growing concern about the disruption of ecosystem services due to biodiversity loss and species extinction. Due to its geographical location, Türkiye lies at the crossroads of three of the world's

designated biodiversity hotspots (Caucasus, Irano-Anatolian, and Mediterranean) and is home to a high level of biodiversity in terms of both endemic and cosmopolitan species (Şekercioğlu *et al.*, 2011; Kaya *et al.*, 2025). In this geography, which is home to many ecosystems with different characteristics from each other, biodiversity detection and monitoring studies have been conducted extensively in recent years. Lagoons, one of these special systems, are important ecosystems of great ecological and economic importance, with high primary production due to nutrients carried by rivers (Rodrigues-Filho *et al.*, 2023). Globally, coastal lagoons in urbanized areas are among the most threatened ecosystems, often experiencing severe biodiversity loss and functional degradation (Kennish, 2002; Lotze *et al.*, 2006). At the same time, they are considered areas of high fish production that support both freshwater and marine species by serving as nurseries and feeding grounds, particularly in the early stages of their life cycles (Pérez-Ruzafa *et al.*, 2024).

The Küçükçekmece Lagoon is an ecosystem under severe pressure from uncontrolled urban growth, inadequate infrastructure/untreated sewage, and industrialization within the Istanbul metropolitan area. It is known that for many years, industrial activities such as paint, chemical metallurgy and textiles were carried out around the lagoon without satisfactory water treatment facilities. In addition to heavy metals, the lagoon was polluted by nutrients from municipal and agricultural activities (Altun *et al.*, 2009). The lagoon has shown some symptoms of eutrophication, such as an increase in toxic cyanobacteria and a deterioration in water quality from late spring to mid-autumn (Albay *et al.*, 2005; Gürevin *et al.*, 2017). Due to unplanned urbanization, heavy nutrient inputs, and untreated industrial waste around the lagoon, the problem of pollution has become more severe (Polge *et al.*, 2010; Gürevin *et al.*, 2017; Yılmaz *et al.*, 2021), and problems such as mass fish mortality events have become more frequent (Albay *et al.*, 2005; Memiş *et al.*, 2024). The fish community of the lagoon comprises both marine and freshwater species. The earliest record of fishes inhabiting the lagoon dates to Ninni (1923), who reported the presence of the freshwater perch *Perca fluviatilis*. Although several studies documented the lagoon's fish fauna prior to 1996 (Devedjian, 1926; Kosswig & Battalgil, 1943; Acara & Gözenalp, 1959; Meriç, 1980), the first comprehensive survey was conducted by Meriç (1986), who recorded 31 species belonging to 18 families, including both freshwater and marine taxa.

In the 1990s, a dam lacking fish passage was constructed on the Sazlı Stream, one of the main freshwaters inputs to the lagoon. Fishermen operating in the area reported that this impeded the seasonal migration of some fish species (*Alburnus derjugini*, *Vimba vimba*, etc.) between the lagoon and the stream. Freshwater inflow into the lagoon has been further restricted by the collectors constructed on the Nakkaş and Eşkinöz streams. Consequently, the lagoon's capacity for renewal through freshwater input appears to have declined over time, with seawater entering through the sea channel exerting increasing influence during certain periods. Over the past three decades, the environmental conditions in and around the lagoon have undergone significant transformation as urban expansion has accelerated and the pressure of urbanization has increased (Coskun *et al.*, 2008; Sönmez & Sivri, 2022). However, the extent to which the lagoon's fish fauna has been affected has not yet been investigated. In 2020, the deterioration of the lagoon's water quality had an impact on the discovery of two dead sturgeons, which were thought to have entered the lagoon to spawn (Memiş *et al.*, 2024). The main reasons for the decline or loss of species in an ecosystem are anthropogenic factors, such as pollution and habitat destruction, changes in genetic structure, and the introduction of invasive species into the habitat (Owens & Bennett, 2000; Shukla *et al.*, 2013). We hypothesized that the lagoon's fish fauna may have undergone changes in community structure and composition over the last three decades, likely influenced by escalating anthropogenic pressures, particularly increased urbanization, pollution, and hydrological alterations. The

primary aim of this study was to obtain updated data on the fish fauna of the Küçükçekmece Lagoon, which is subject to various environmental pressures, and to present the distribution and stock densities of the species. Another aim of the study was to determine some environmental factors such as oxygen, salinity, and depth affecting fish composition in the lagoon and to reveal their relationship with fish.

Materials and Methods

The Küçükçekmece Lagoon (41.00556° N, 28.74694° E) is a semi-enclosed and brackish coastal water body located on the European shore of the Sea of Marmara, within the metropolitan area of Istanbul, Türkiye. The lagoon covers a surface area of approximately 15.2 km² with a maximum depth of 20 m and is connected to the Sea of Marmara via a narrow channel that regulates hydrodynamic exchange (Polge *et al.*, 2010; Yılmaz *et al.*, 2021).

Seasonal sampling was conducted between September 2023 and August 2024. Fishing was conducted at five different sites (four on the shore; Eşkinöz - Site 1, Sazlı - St. 2, Nakkaş - St. 3, and Menekşe - St. 4; and one in the middle of the lagoon - St. 5) using scientific gillnets and at two sites (Menekşe - St. 6 and Paşaeli - St. 7) using a seine net (Fig. 1). The selection of two different gear types – multimesh gillnets and a seine net – was intentionally made to sample complementary components of the lagoon's fish community. The purpose of using the seine net is to detect fish thought to enter the lagoon for feeding or breeding purposes in certain periods, especially from the channel connecting with the sea. Standard benthic and pelagic nets with varying mesh sizes were used in accordance with TS EN 14757 Water Quality, in line with the European Water Framework Directive (CEN, 2015). Standard benthic nets (30 m long and 1.5 m height), represented by 12 different mesh sizes ranging from 5 to 55 mm, were used at the shore sites (mean 4 m depth). The pelagic net (27.5 m long and 6.0 m height), represented by 11 different mesh sizes ranging from 6.25 to 55 mm, was used in the middle of the lagoon, where the depth increased to 20 m. The seine net (15 m in length, 1.2 m in height, with a mesh size of 5 mm in the wings and 1 mm in the cod end) was deployed at the coastal sites, with a minimum of three replicates per sampling event. Despite the recognized selectivity biases of gillnets and seine nets, these gears were employed to preserve comparability with historical surveys of the lagoon because they continue to represent standard methods for assessing fish assemblages in such environments. Fish captured alive during sampling were rapidly removed from the nets and euthanized with an overdose of clove oil solution (100 mg/L).

Fish were transferred to the laboratory (Istanbul University, Faculty of Science, Environmental Biology and Ecology Laboratory) under cold conditions and separated according to species. The total length (TL, cm) of each individual was measured to the nearest 0.1 mm, and the body mass (W, g) was measured to the nearest 0.01 g on

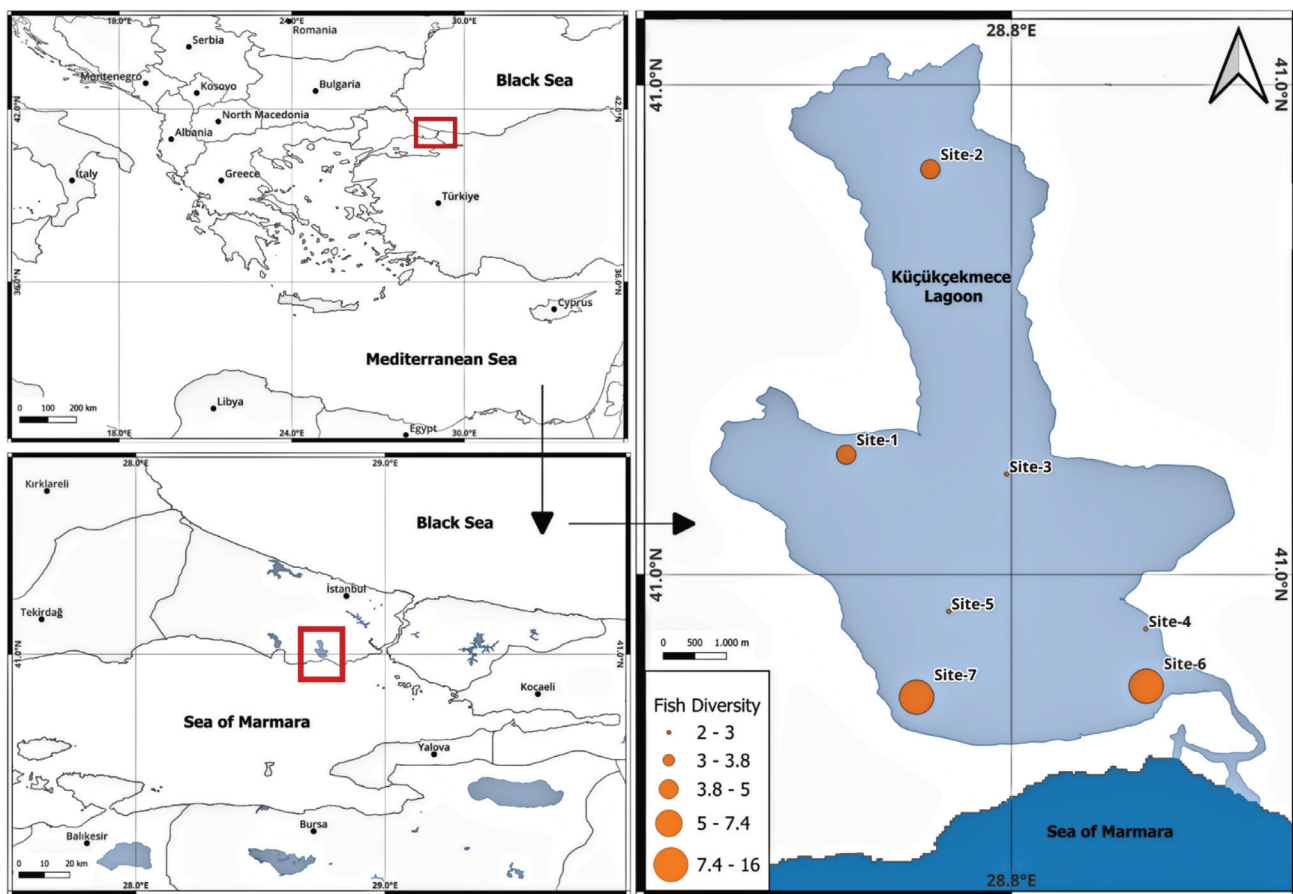


Fig. 1: The study area (the Küçükçekmece Lagoon) and the distribution of species diversity according to the sites in the lagoon.

a digital balance. For fish abundance caught with gillnets, the catch per unit effort (CPUE) was calculated using the following equation: $CPUE = (n/(t \cdot a)) \times 100$, where n is the number of individuals, t is the fishing duration (h), and a is the gillnet area (m^2) (Jordan & Willis, 2001; Mehner *et al.*, 2005). For fish abundance caught with a seine net, CPUE was computed as $(n/t) \times 100$ by dividing the number of individuals (n) per trip (t) since the seine fishing area was kept constant. The map of the study sites and fish diversity was generated using QGIS 3.32.1.

In parallel with fish sampling, water temperature ($^{\circ}C$, WT), pH, salinity (S), conductivity ($\mu S\ cm^{-1}$, EC), and dissolved oxygen ($mg\ L^{-1}$, DO) were measured *in situ* using a Eutech portable multiparametric analyzer, and the water depth was recorded at each site. A Secchi disk was used to measure water transparency, and the euphotic depth (Zeu) was calculated as 2.5 times the SD depth (SDD, m).

To investigate the effect of environmental variables on fish distribution within the lagoon, CPUE values that varied according to station and season were used. This evaluation was based solely on data obtained from gillnet sampling. Prior to analysis, data normality was assessed using the Shapiro–Wilk test. Because all variables showed significant deviations from normality ($p < 0.05$), non-parametric methods were employed for subsequent statistical analyses. To identify the environmental drivers of species distributions, we conducted a Canonical Correspondence Analysis (CCA) using the *vegan* package. CCA was performed using two data matrices: seasonal

fish abundance (biological data; number of individuals of fish species captured with multimesh gillnets) and seasonal environmental variables (explanatory data; DO, pH, WT, EC, S, D, and SDD). Two-dimensional biplots were generated to visualize species–environment relationships. The statistical significance of the overall model, individual axes, and predictors was assessed via permutation-based ANOVA (999 permutations). All analyses were performed using R software version 4.2.3 (R Core Team, 2022).

Results

A total of 18 fish species belonging to 12 families were identified in the Küçükçekmece Lagoon. Information on the number of individuals, location, and type of fishing gear used for each species caught in the lagoon is given in Suppl. Data. S1. Accordingly, only five fish species (*Atherina pontica*, *Engraulis encrasicolus*, *Chelon auratus*, *Chelon ramada*, and *Mugil cephalus*) were caught with gillnets at the five sites in the lagoon. On the other hand, 17 species were caught with seine nets at two sites near the lagoon’s connection to the Sea of Marmara. *Atherina pontica*, *E. encrasicolus*, and *C. auratus* were the three common fish species caught with both fishing gears at almost every site. In contrast, *Salaria pavo*, *Belone belone*, *Neogobius fluviatilis*, *Gobius niger*, and *Sparus aurata* caught in seine net were represented only by one individual. Figure 1 illustrates the study area and

the distribution of species diversity across the sampling sites in the lagoon.

The CPUE values of the fish species were calculated separately for both types of fishing equipment. *Atherina pontica* and *E. encrasicolus* were represented with the highest CPUE values in all seasons, whereas those mullet species gave very low values according to the catches made with multimesh nets within the lagoon (Suppl. Data. S2). The distribution of fish in the lagoon also varied between these two dominant species: *E. encrasicolus* dominance was observed in all seasons at the mid-lagoon station, the deepest station where pelagic multimesh nets were used. On the other hand, at the coastal stations where benthic multimesh nets were used, *A. pontica* was the dominant species in almost all seasons (Suppl. Data S2, Fig. 2, 3). No fish specimens were captured during winter sampling using a seine net (Fig. 3).

Atherina pontica was again the dominant species with high CPUE values because of the seine-net fishing carried out at two sites of the lagoon close to the sea connection and favorable for fishing. When the seasonal variation of the CPUE values of the species was examined, most of the fish species were encountered in the lagoon only in spring and summer, whereas the values of *A. pontica*, *E. encrasicolus*, and the mullet species, which are present in the lagoon in all seasons, decreased significantly in the autumn and winter months. *Salaria pavo*, *G. aculeatus*, *N. fluviatilis*, *G. niger*, *Pomatoschistus adriaticus*, *S. aurata*, *S. abaster*, *S. typhle*, and *B. belone* were only captured in spring and summer samplings with low CPUE values (<1.0 ind./t). *Neogobius melanostomus* caught in all seasons except winter had the highest CPUE value (13.67 ind./t) among all fish caught, and this was observed at the Menekşe (St. 6) station in spring.

Table 1 shows the seasonal averages and ranges (minimum-maximum) of the environmental parameters measured separately at each station in the lagoon. Accordingly, dissolved oxygen was highest in winter (11.43 mg L⁻¹), coinciding with the lowest recorded water temperature (12.10°C). pH values ranged from 6.65 to 8.46, with the highest values observed in summer. Conductivity and salinity also peaked in autumn, reaching 21.65 µS cm⁻¹ and 13.65, respectively. Similarly, Secchi depth was highest in autumn (3.78 m) and lowest in summer (1.90 m).

Canonical Correspondence Analysis revealed that the variation in fish species composition was significantly explained by the measured environmental variables ($p = 0.002$). Among the environmental factors, WT ($p = 0.003$), S ($p = 0.019$) and D ($p = 0.003$) had statistically significant effects on the species distribution. The first axis of the CCA was significant ($p = 0.001$) and captured the main gradient of variation across sites, whereas subsequent axes were not significant ($p > 0.05$). The biplot showed clear patterns of association between species and environmental gradients. *Chelon auratus* was strongly correlated with WT, whereas *M. cephalus* was closely associated with DO and pH. *Engraulis encrasicolus* exhibited a positive relationship with EC and S. In contrast, *A. pontica* and *C. ramada* showed weak correlations with pH and SDD and negative associations with WT and D (Suppl. Data. S3; Fig. 4).

Discussion

Although lagoons are naturally dynamic systems characterized by temporal fluctuations (Kjerfve, 1994; Elliott & Quintino, 2007), the significant changes in fish assem-

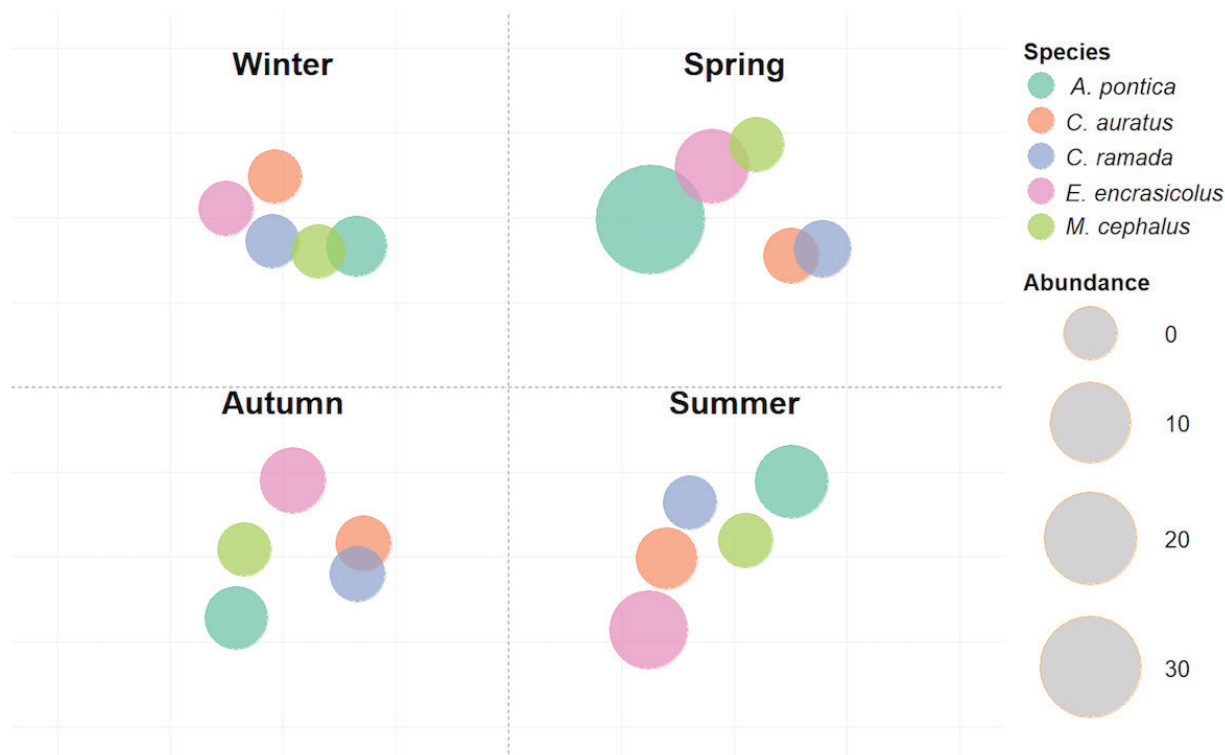


Fig. 2: Seasonal distribution of fish composition in the Küçükçekmece Lagoon with multimesh gillnets.

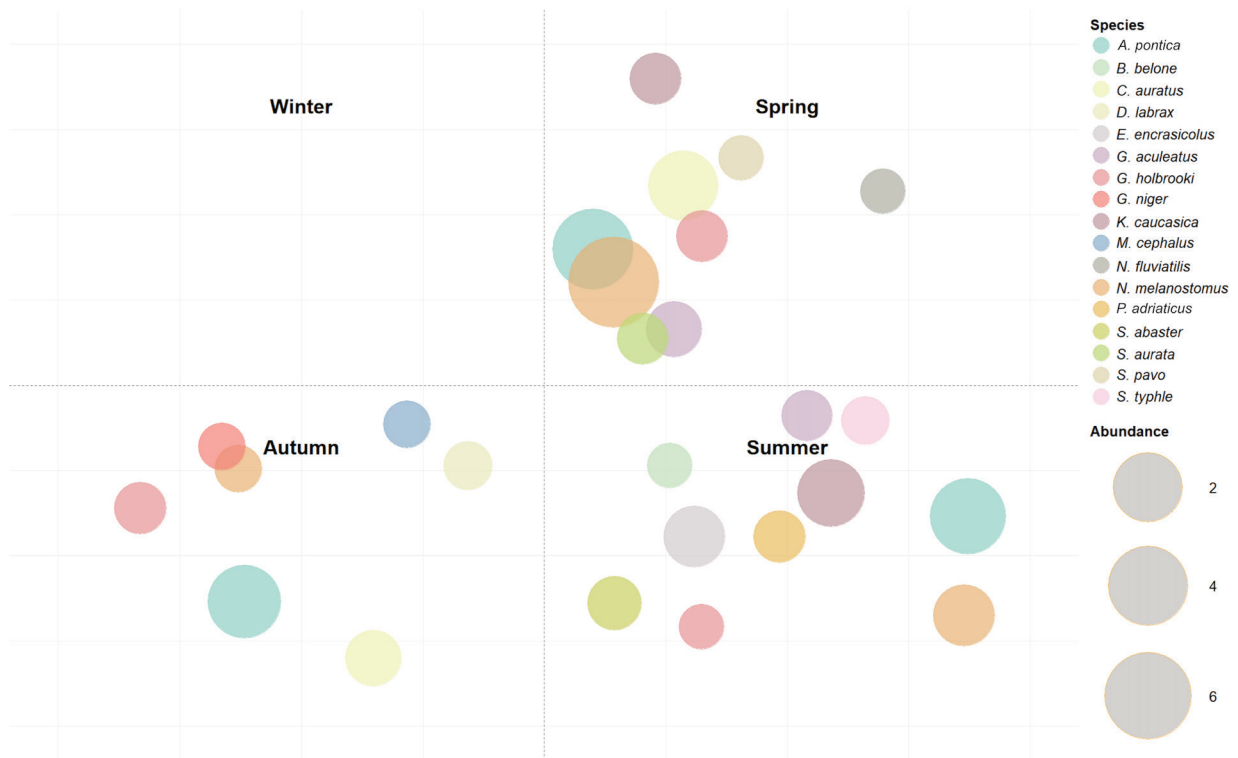


Fig. 3: Seasonal distribution of fish composition captured in the Küçükçekmece Lagoon with a seine net.

Table 1. Seasonal variation of environmental parameters in the Küçükçekmece Lagoon during the study period (DO: dissolved oxygen; WT: water temperature; EC: conductivity; S: salinity; D: depth; SDD: Euphotic zone).

Environmental parameters		Autumn	Winter	Spring	Summer
DO (mg/L)	mean	9.31	11.43	10.45	10.33
	min.-max.	7.49 – 10.10	9.55 – 12.41	9.71 – 10.65	9.48 – 14.11
pH	mean	7.13	6.65	8.27	8.49
	min.-max.	6.81 – 7.94	6.61 – 6.70	8.07 – 8.42	8.25 – 8.71
WT (°C)	mean	19.86	12.10	20.43	27.93
	min.-max.	19.5 – 20.4	11.5 – 12.8	19.2 – 22.5	27.4 – 28.9
EC (µS cm ⁻¹)	mean	21.65	19.67	17.02	18.02
	min.-max.	19.73 – 22.47	19.62 – 20.36	16.89 – 17.18	17.49 – 18.27
S	mean	13.65	12.42	10.87	11.23
	min.-max.	12.73 – 14.12	11.78 – 12.99	10.76 – 11.09	10.70 – 11.48
D (m)	mean	6.40	6.22	5.52	6.16
	min.-max.	2.5 – 18.6	2.4 – 18.4	1.7 – 18.7	2.2 – 18.3
SDD (m)	mean	3.78	3.40	2.32	1.90
	min.-max.	2.5 – 6.4	2.4 – 4.8	1.7 – 3.0	1.7 – 2.1

blages observed in the Küçükçekmece Lagoon coincide with a period of intense anthropogenic activity. The transformation in the community structure over the past three decades suggests that local stressors, such as urbanization and pollution, may be acting synergistically with natural variability, potentially contributing to a biotic homogenization process. While the lagoon historically supported a diverse assemblage of both freshwater and marine

species (Devedjian, 1926; Meriç, 1986), this balance has significantly shifted toward euryhaline dominance, in parallel with rising salinity levels and a marked decline in freshwater inflow. The significant increase in salinity (up to 14.12) during the study period is directly linked to the limited river input, primarily due to the construction of reservoirs on the Sazlı Stream and collector systems on the Eşkinöz and Nakkaş streams. Similar hydrologi-

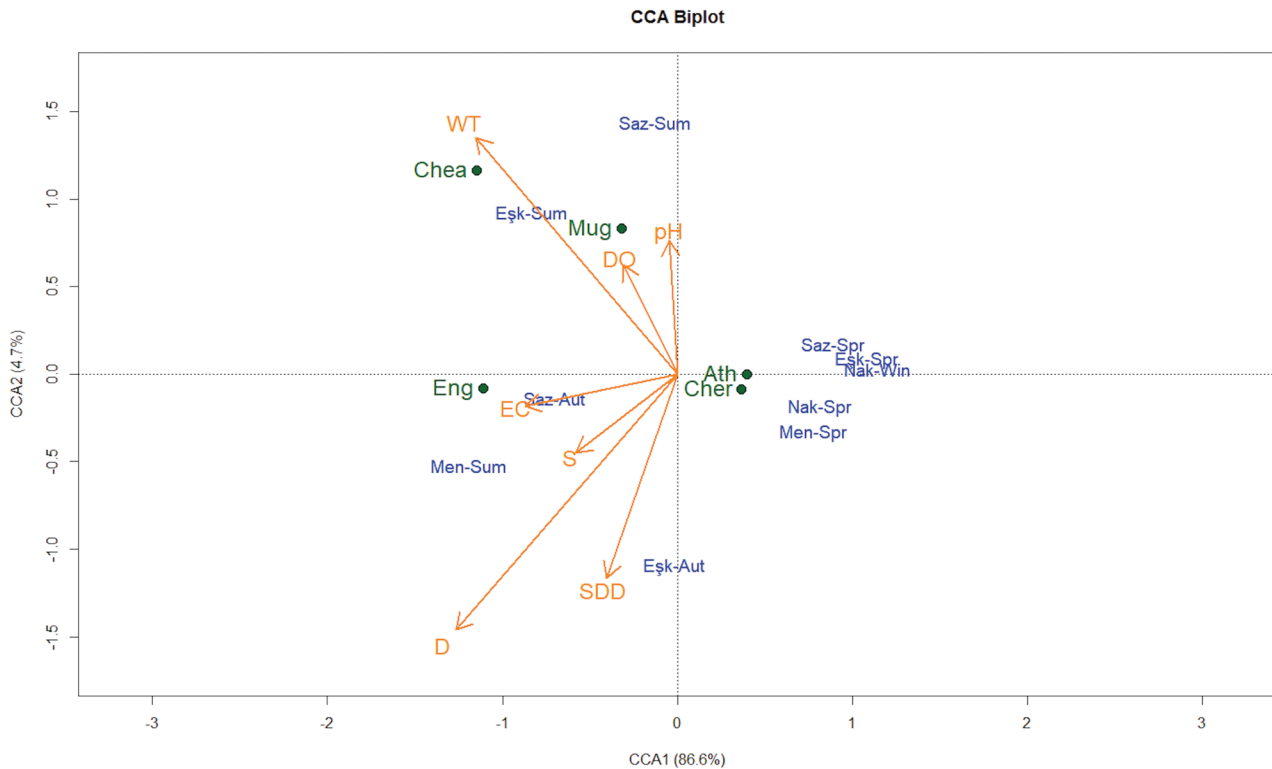


Fig. 4: Canonical Correspondence Analysis (CCA) ordination diagram of fish taxa and environmental variables. Abbreviations for fish: Ath: *Atherina pontica*; Chea: *Chelon auratus*; Cher: *Chelon ramada*; Eng: *Engraulis encrasicolus*; Mug: *Mugil cephalus*. Vectors of the variables were considered (environmental factors) with the ordination of study sites and seasons.

cal disruptions have been shown to generate long-term ecological consequences in other Mediterranean coastal lagoons, where increased salinity has reshaped species composition and food-web structure (Prado *et al.*, 2014; Maneas *et al.*, 2019; Ligorini *et al.*, 2023). In fact, none of the freshwater fish species previously recorded (*Esox lucius*, *Alburnus derjugini*, *Vimba vimba*, etc.) were encountered in the lagoon during the present study. *Rutilus rutilus*, *S. erythrophthalmus*, and *P. borysthenticus*, which formerly inhabited the lagoon, were found to persist in the Sazlıdere and Sazlıbosna reservoirs, both located on the Sazlı Stream (Özuluğ & Saç, 2019). Furthermore, in addition to the marine species that used the lagoon in the past, the present study documented, for the first time, the occurrence of *D. labrax*, *G. niger*, *P. adriaticus*, *S. aurata*, *S. pavo*, and *S. typhle*.

The decline or complete disappearance of freshwater species, such as *K. caucasica* and *P. fluviatilis*, previously recorded in the lagoon (Kosswig & Battalgil, 1943; Meriç, 1986), is likely attributable to increasing eutrophic conditions, particularly during the summer and autumn months, as well as a progressive rise in salinity. Earlier studies have documented several symptoms of eutrophication in the Küçükçekmece Lagoon, including intensified cyanobacterial blooms, nutrient release from sediments, and oxygen depletion (Albay *et al.*, 2005; Gürevin *et al.*, 2017; Köker *et al.*, 2021). These conditions contribute to habitat degradation, resulting in an increase in observed or reported fish mortality (Albay *et al.*, 2005; Memiş *et al.*, 2024). Taken together, these findings suggest that the Küçükçekmece Lagoon is undergoing

biotic homogenization, where tolerant and opportunistic species flourish while sensitive or habitat-specialist taxa decline or vanish. This ecological transition reflects a substantial loss of ecological integrity and resilience, which mirrors patterns observed in other heavily modified aquatic ecosystems (Rahel, 2002; Olden *et al.*, 2004; Feng *et al.*, 2023). The resulting shift toward a community dominated by a few tolerant generalist species at the expense of ecological specialists represents a classic case of biotic homogenization, a common consequence of intense anthropogenic disturbance in aquatic ecosystems.

The observed fish species composition was influenced by the selectivity of the fishing gears, sampling locations, and seasonal timing. The use of multimesh gillnets facilitated the sampling of diverse size classes across different vertical zones of the lagoon; pelagic gillnets were particularly efficient in the deepest site of the lagoon, selectively targeting pelagic species, for example, *E. encrasicolus*, as expected. On the other hand, benthic gillnets deployed in the littoral zones effectively captured benthopelagic species of various sizes, such as *A. pontica* and *C. auratus*. Furthermore, the seine net, with its smaller mesh size and active operation in shallow waters near the sea inlet, yielded the highest species diversity by capturing smaller benthic and benthopelagic taxa (e.g., *N. melanostomus*, *G. aculeatus*, *S. abaster*; and *K. caucasica*), as well as less common species such as *B. belone*, *G. niger*, and *S. pavo*. Therefore, the combination of these complementary fishing gears provided a comprehensive inventory covering the pelagic, demersal, and shallow-littoral habitats of the lagoon. Our results confirm previous observations that

combining different sampling gears is necessary to adequately assess fish assemblages with varying size structures and habitat preferences (Pierce *et al.*, 1990; Weaver *et al.*, 1993; Franco *et al.*, 2012).

Both species diversity and CPUE showed marked increases during spring and summer, especially at sites under stronger marine influence. This increase likely reflects the seasonal entry of euryhaline species into the lagoon for feeding or breeding, in parallel with increased primary productivity. Such a pattern is typical of Mediterranean lagoons, where fish exploit the system opportunistically in response to environmental factors such as temperature, salinity, and food availability (Franco *et al.*, 2006; Pérez-Ruzafa *et al.*, 2024). The marked decline in fish abundance during the colder months, specifically among resident species, suggests a reduction in the lagoon's carrying capacity and potentially increased physiological stress due to fluctuating water quality conditions.

The overwhelming dominance of *A. pontica* in both gillnet and seine net surveys is consistent with previous studies indicating its broad tolerance to salinity fluctuations and diverse environmental conditions (Henderson & Bamber, 1987; Andreu-Soler *et al.*, 2003; Maci & Basset, 2010). The remarkable success of *A. pontica* can be attributed to its exceptional tolerance to environmental stressors, including wide salinity fluctuations and eutrophic conditions. These adaptations allow it to dominate a degraded habitat from which more sensitive native species have been extirpated. Unlike many marine species that periodically prefer the lagoon (e.g., *B. belone*, *S. aurata*, and *D. labrax*), *E. encrasicolus* and several mullet species (*C. auratus*, *C. ramada*, and *M. cephalus*) also persisted across seasons, although in relatively low numbers. *Neogobius melanostomus* was the second most abundant species in the seine net catches, following *A. pontica*. The high abundance of *N. melanostomus* during the spring may be related to predation on the eggs or larvae of spring-spawning species (Henseler *et al.*, 2020) or the seasonal migration into deeper waters during the colder months (Rakauskas *et al.*, 2013). Contrary to expectations, *G. holbrooki*, a non-native species to Turkish waters, was caught at low densities despite its known tolerance to a wide salinity range (Nordlie & Minardi, 1996; Ruiz-Navarro *et al.*, 2011). This may be due to the relatively high salinity of the lagoon, which has been shown to influence the population density and life history traits of mosquitofish (Alcaraz & García-Berthou, 2007), potentially preventing it from becoming overabundant and competitively excluding native species. Although present in low abundance, the occurrence of such non-native species raises concerns about biological invasions and their potential impacts on native biodiversity and ecosystem functioning.

Regarding environmental variables, the lagoon is currently characterized by higher salinity and oxygen levels than previous years. In earlier periods, when the salinity was lower, eutrophic conditions were frequently reported, often triggered by cyanobacterial blooms in response to nutrient enrichment (Köker *et al.*, 2021). Additionally, mass fish mortality events were more common-

ly observed at low oxygen levels (Albay *et al.*, 2005). Canonical Correspondence Analysis results indicate that the fish species composition within the lagoon is strongly influenced by environmental gradients, particularly salinity, water temperature, and depth. Among these, salinity (S) emerged as the most critical role in structuring the fish assemblage. These findings indicate that rising salinity levels have reshaped the assemblage structure by restricting the habitat of freshwater residents while facilitating the dominance of euryhaline opportunists. *Engraulis encrasicolus*, for instance, exhibited a clear preference for areas with higher salinity and greater depth, which reflects its physiological tolerance and potential adaptation to marine-influenced zones within the lagoon. In this context, depth (D) likely influences species composition directly by determining habitat availability and indirectly through its effects on other physicochemical parameters, such as temperature, oxygen concentration, and light penetration. These findings align with the known euryhaline nature of *E. encrasicolus* and its frequent occurrence in the pelagic zones of estuarine and semi-enclosed coastal ecosystems (Zarrad *et al.*, 2018). The consistent high abundance recorded across all seasons also suggests that *E. encrasicolus* is a resident species in the lagoon rather than a seasonal migrant. Notably, *A. pontica*, the most dominant species in the lagoon, did not exhibit a significant positive correlation with any individual environmental gradient, which is interpreted as evidence of its broad ecological tolerance. Furthermore, the positive correlation observed between water temperature and the abundance of some mullet species and *E. encrasicolus* corresponds with higher CPUE values during warmer periods, when feeding activity and reproductive behavior are typically stimulated. This seasonal pattern is documented in other Mediterranean coastal lagoons, where Mugilidae species typically exhibit peak abundance during warmer months, driven by trophic migrations and recruitment events (Koutrakis *et al.*, 2000; Franco *et al.*, 2006; Katselis *et al.*, 2007). These findings corroborate the role of temperature as a key driver of mullet dynamics in the region.

The comparison of current findings with historical records suggests that the Küçükçekmece Lagoon is increasingly influenced by marine conditions, shifting away from its historically freshwater-dominated character. This shift could have implications for local biodiversity and ecosystem resilience, particularly considering the lagoon's role as a nursery habitat. To address these environmental changes, management strategies might benefit from focusing on potential hydrological restoration and the management of nutrient and pollutant inputs. Additionally, future research efforts incorporating functional traits analysis, trophic interactions, and long-term population dynamics would help improve our understanding of the lagoon's response to environmental stressors. Finally, acknowledging the limitations inherent in the sampling methodology employed in this study, future monitoring could be enhanced by integrating complementary techniques, such as environmental DNA metabarcoding and hydroacoustic methods, to provide a more comprehen-

sive assessment of the lagoon's ichthyofauna.

In conclusion, this study provides an update on the ichthyofauna of the Küçükçekmece Lagoon after nearly three decades, indicating observable shifts in species composition and community structure. The lagoon, which once supported both freshwater and marine species, is now predominantly inhabited by a few euryhaline and marine-tolerant species. These observed shifts may be plausibly linked to the dynamic nature of lagoon ecosystems, particularly the changes in salinity regimes resulting from the reduction of freshwater inflows. The dominance of *A. pontica* and the disappearance of previously recorded freshwater taxa illustrate a trend toward biotic simplification and reduced biodiversity. Seasonal variations, especially the higher species diversity observed during spring and summer, suggest that the lagoon still serves as a temporary habitat for certain migratory or opportunistic species. To mitigate further biodiversity loss and restore the lagoon's ecological integrity, immediate and targeted conservation actions are essential. These include the regulation of urban wastewater discharge, the re-establishment of freshwater inflows, and the implementation of long-term monitoring programs. The Küçükçekmece Lagoon will remain an ecologically valuable system with potential for recovery, but only if anthropogenic pressures are effectively managed and conservation priorities are properly addressed. Moreover, in the event of future interventions that may lead to structural or ecological modifications in the lagoon, the findings of this study will serve as an essential reference point, reflecting the lagoon's condition during the final stage of its retention of lagoonal characteristics. Continuous and long-term ecological monitoring is indispensable for evaluating both the trajectory of ecological change and the effectiveness of restoration efforts over time.

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Supplementary Data

The following supplementary information is available online for the article:

- 1-Individual numbers of fish species caught in the Küçükçekmece Lagoon and their distribution according to the type of fishing gear (BG: Benthic gillnet, PG: Pelagic gillnet, SN: Seine net).
- 2- Seasonal CPUE, total length (TL, cm) and mass (W, g) distribution of fish species caught from Küçükçekmece Lagoon (* estimated using gillnet data; ** estimated using seine net data).
- 3- 1. Shapiro–Wilk Normality Test. 2. Canonical Correspondence Analysis (CCA) Significance Tests.