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Fish Assemblage Structure and Waterbird Occurrence in Keddara Reservoir (Northern Algeria): Baseline Information for Biodiversity Monitoring

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ABSTRACT

Aims: This study provides the first checklist of waterbird species recorded in Keddara Reservoir (KR), updates the inventory of its fish fauna, and characterizes the structure of the fish assemblage.

Materials & Methods: Fish and waterbird surveys were conducted between January and December 2025. Fish were sampled using gill nets, traps, and fishing rods, while waterbirds were recorded through direct field observations. Fish community structure was assessed using relative abundance, diversity indices, and rank-abundance analysis, whereas waterbird assemblage patterns were evaluated using frequency of occurrence (FO).

Findings: Seven fish species and seven waterbird species were recorded during the study period. All fish species were non-native taxa. The fish assemblage showed moderate diversity ($H' = 1.574$; $1-D = 0.767$) and was dominated by three introduced species (*Alburnus alburnus*, *Carassius gibelio*, and *Micropterus salmoides)*. Comparison with historical records indicated changes in fish community composition, including the absence of previously reported native barbels and the detection of *Abramis brama*, not previously recorded in the reservoir. The waterbird community comprised seven species, with marked differences in their occurrence frequencies. *Larus michahellis* showed the highest FO, followed by *Anas platyrhynchos*, whereas the remaining species exhibited lower values.

Conclusion: This study provides baseline information for monitoring fish community changes, the status of historically reported native species, and waterbird occurrence patterns in KR. The results highlight the dominance of introduced fishes and the need for long-term surveys better to understand temporal changes in this artificial freshwater ecosystem.

Keywords: Artificial Reservoir; Biodiversity Inventory; Freshwater Fish; Keddara Reservoir; Waterbirds.

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Introduction

Artificial reservoirs are among the most widespread anthropogenic freshwater ecosystems worldwide and constitute important components of modern aquatic landscapes [1]. In Mediterranean areas, where natural wetlands have been extensively degraded, reservoirs can partially compensate for the loss of these habitats by supporting the diversity of species that depend on wetlands [2]. Reservoirs can provide a wide range of habitats for the development of biologically diverse systems and are of key importance in sustaining food chains and ecological functions. Specifically, fish communities are considered essential components of aquatic ecosystems, as drivers of food-web structures and processes [3]. At the same time, artificial water bodies can provide habitat for waterbirds, offer feeding and roosting areas, and serve as shelter during migration and wintering periods [4]. Reservoirs created by dams are particularly susceptible to biological invasions owing to frequent fish stocking. Introduced fishes could impact native communities through a variety of mechanisms, ranging from competition to invasions, predation, and interference with natural processes [5,6]. Therefore, it is critical to periodically census fish assemblages, which may indicate the status of native species and provide an understanding of long-term trends in artificial ecosystems.

There are more than 80 dams in Algeria, located in different climatic zones and habitats. Previous studies have demonstrated the significance of dams for fisheries production, freshwater biodiversity, and waterbird communities [7–10]. Nevertheless, there is still a lack of knowledge concerning the biodiversity present in Algeria's reservoirs, particularly concerning multiple vertebrate taxa.

The Keddara Reservoir is one of the essential freshwater sources, providing drinking water for the region. However, the knowledge about the biodiversity of this area is limited. Previous research focused on the assessment of physicochemical parameters of water masses and some aspects of fish bioecology [11-15]. In addition, no study thus far has attempted to analyze the diversity of waterbirds in Keddara, whereas information on the fish fauna is also scarce.

Therefore, it is necessary to investigate fish and waterbird biodiversity to determine baseline values. Thus, the current study (i) provides the first checklist of waterbirds and analyzes their occurrence patterns, (ii) updates the inventory of fish species and evaluates the assemblage structure based on biodiversity and abundance, and (iii) compares the fish community with previous findings.

Materials & Methods

Study Area

Keddara Reservoir (KR) is located in northern Algeria (Figure 1), on Oued Boudouaou, approximately 35 km east of Algiers, within Boumerdes Province. The reservoir was constructed primarily for drinking-water supply and was put into operation in 1987. It represents one of the largest freshwater storage systems in the region, with a storage capacity of approximately 146.5×10^6 m^3, a surface area of about 5.2 km^2, and a maximum depth of approximately 150 m. Recent assessments based on water quality indices indicated that the KR currently exhibits generally good raw water quality. However, some parameters such as turbidity and salinity showed higher values than those considered desirable for drinking-water purposes [12]. Three main sources supply the reservoir: inflows from Oued Keddara, Oued El Haad, and Oued Isser; transfers of surplus water from Hamiz Reservoir; and pumped transfers from Beni-Amrane Reservoir [14]. A partial view of the reservoir and its surrounding landscape is presented in Figure 2. The KR is situated within the sub-humid bioclimatic stage characterized by a temperate winter [15]. The reservoir is surrounded by Mediterranean vegetation dominated by Aleppo pine (*Pinus halepensis*), eucalyptus (*Eucalyptus* spp.), pistachio (*Pistacia* spp.), and carob (*Ceratonia siliqua*). The presence of different human activities also characterizes the study area. During the

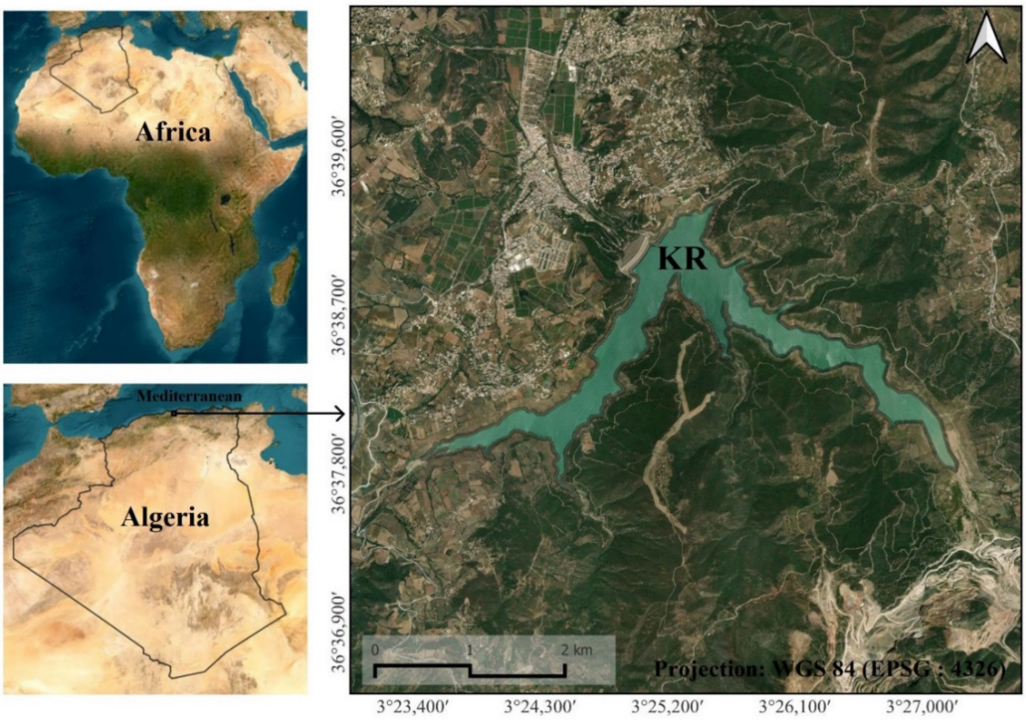

Figure 1) Geographic Location Of Keddara Reservoir (KR) In Northern Algeria (Map Generated Using QGIS Version 3.40.14).

Figure 2) Partial View Of Keddara Reservoir (Northern Algeria) During The 2025 Field Survey.

field survey, both commercial and sport fishing were observed. Notably, apart from the concessionary fishery, visitors were seen catching fish as they used the reservoir as a recreational facility. In addition, the field survey revealed that livestock animals such as sheep were grazed at the margins of the reservoir.

Field Data Collection and Analytical Methods

Field data on fish and waterbirds were collected during twenty visits to Keddara Reservoir between January and December 2025.

Fish Sampling Procedures and Community Structure Analysis

Fish surveys were conducted in both littoral and offshore habitats using a combination of gill nets with different mesh sizes, traps, and fishing rods to maximize species detection across a wide range of ecological niches and size classes. All captured fish were identified to species level based on external morphological characters, including body shape, meristic counts, coloration patterns, fin morphology, as well as other diagnostic taxonomic features.

Fish community structure was assessed from the cumulative number of individuals of each species recorded across the 20 sampling occasions. Species composition, relative abundance, and diversity metrics were subsequently calculated to characterize the fish assemblage. The relative abundance (p_i) of each species was calculated as the proportion of individuals of each species relative to the total number of captured individuals using Eq. (1):

$$p_i = \frac{n_i}{N} \qquad \text{Eq. (1)}$$

where ni is the number of individuals of species i and N is the total number of individuals recorded during the study period.

The Shannon–Wiener diversity index (H') measures the uncertainty in predicting the species identity of a randomly selected individual and incorporates both species richness and the proportional abundance of species [16]. H' was calculated using Eq. (2):

$$H' = -\sum_{i=1}^{S} p_i \ln p_i \qquad \text{Eq. (2)}$$

where pi is the proportional abundance of species i and S is the total number of recorded species.

Simpson's diversity index (1−D) measures the probability that two individuals randomly selected from the assemblage belong to different species [17]. The index was calculated using Eq. (3):

$$1-D = 1-\sum_{i=1}^{S} p_i^2 \qquad \text{Eq. (3)}$$

Pielou's evenness index (J') was used to assess the evenness of the distribution of individuals among species. Values range from 0 to 1, with values approaching 1 indicating that individuals are more evenly distributed among species [18]. J' was calculated using Eq. (4):

$$J' = \frac{H'}{\ln S} \qquad \text{Eq. (4)}$$

where H′ is the Shannon–Wiener diversity index and S is the total number of recorded species. All diversity indices were calculated in RStudio (version 2025.05.0+496). To visualize species dominance patterns within the fish assemblage, a rank–abundance [19] curve was constructed by ranking species according to their relative abundance in decreasing order.

Waterbird Survey Methods and Occurrence Frequency Assessment

Waterbird surveys were conducted

through direct visual observations from fixed vantage points strategically selected to provide optimal coverage of open-water areas and surrounding habitats. Observations were carried out during the morning, generally between 07:00 and 11:00, when bird activity was highest. Each survey lasted approximately 4 hours, depending on field conditions and the extent of the surveyed area. Birds were observed using 10 × 42 binoculars, allowing accurate detection and identification at varying distances.

Species identification was based on external morphological characteristics, including plumage features, body shape, coloration patterns, and other diagnostic field characters. Scientific names followed current accepted nomenclature.

The occurrence frequency (FO, %) of each waterbird species was calculated according to Eq. (5):

$$FO(\%)=\frac{N_i}{N_t}\times 100 \qquad \text{Eq. (5)}$$

where N_i represents the number of surveys in which species i was recorded and N_t represents the total number of surveys conducted. Higher FO values indicate that a species was detected in a larger proportion of surveys and therefore occurred more consistently during the study period.

Findings

Composition and Diversity of the Fish Assemblage

A total of seven fish species belonging to four families were recorded during the survey period, representing a cumulative catch of 525 individuals (Table 1). Leuciscidae was the most species-rich family (three species), followed by Cyprinidae (two species), whereas Centrarchidae and Xenocyprididae were each represented by a single species.

Relative abundance analysis showed that *Alburnus alburnus* was the dominant species, accounting for 30.9% of all captured individuals, followed by *Micropterus salmoides* (25.1%) and *Carassius gibelio* (24.0%). Together, these three introduced species represented approximately 80% of the total fish assemblage. In contrast, *Hypophthalmichthys molitrix* (0.6%) and *Rutilus rutilus* (1.3%) showed very low relative abundances.

The rank–abundance curve revealed a clear dominance pattern within the fish assemblage, with similar abundance levels among the three highest-ranked species (*A. alburnus*, *M. salmoides*, and *C. gibelio*), followed by a marked decline in abundance towards the remaining species (Figure 3). The fish assemblage exhibited a Shannon–Wiener diversity index of 1.574, a Simpson diversity index of 0.767, and a Pielou's evenness index of 0.809 (Table 2).

According to the International Union for Conservation of Nature (IUCN) Red List, six recorded species are classified as Least Concern, whereas *H. molitrix* is listed as Near Threatened.

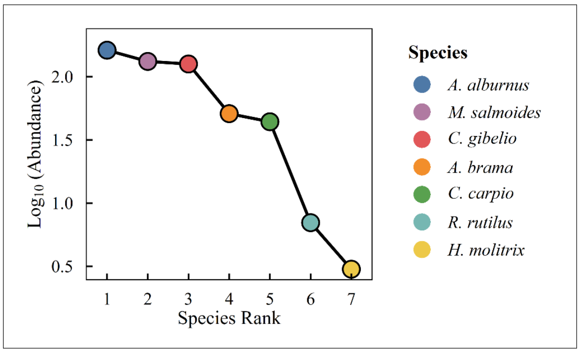

Figure 3) Whittaker Rank–Abundance Curve Of The Fish Assemblage Recorded In Keddara Reservoir During The 2025 Survey.

Table 1) Fish Species Recorded In Keddara Reservoir During The 2025 Survey, Including Taxonomic Information, IUCN Status, Number Of Captured Individuals (n) And Relative Abundance.

Species		Family	IUCN Status	N	Relative Abundance (%)
Scientific Name	Common Name				
Alburnus alburnus (Linnaeus, 1758)	Bleak	Leuciscidae	LC	162	30.9
Abramis brama (Linnaeus, 1758)	Common Bream	Leuciscidae	LC	51	9.7
Cyprinus carpio (Linnaeus, 1758)	Common Carp	Cyprinidae	LC	44	8.4
Carassius gibelio (Bloch, 1782)	Prussian Carp	Cyprinidae	LC	126	24.0
Hypophthalmichthys molitrix (Valenciennes, 1844)	Silver Carp	Xenocyprididae	NT	3	0.6
Micropterus salmoides (Lacépède, 1802)	Largemouth Bass	Centrarchidae	LC	132	25.1
Rutilus rutilus (Linnaeus, 1758)	Common Roach	Leuciscidae	LC	7	1.3

Note: IUCN status: LC = Least Concern; NT = Near Threatened.

Table 2) Diversity Indices Calculated For The Fish Assemblage Recorded In Keddara Reservoir During The 2025 Survey.

Diversity Indices	Value
Shannon–Wiener Diversity Index (H′)	1.574
Simpson Diversity Index (1–D)	0.767
Pielou's Evenness Index (J′)	0.809

Composition and Occurrence of the Waterbird Community

A total of seven waterbird species belonging to five families were recorded during the survey period (Table 3). Ardeidae and Podicipedidae were the most represented families, each including two species. The remaining families (Anatidae, Laridae, and Phalacrocoracidae) were each represented by a single species.

FO varied considerably among species. *Larus michahellis* exhibited the highest occurrence frequency (95%). *Anas platyrhynchos* was also frequently observed, with an FO of 70%. Intermediate occurrence frequencies were recorded for *Phalacrocorax carbo* (40%), *Egretta garzetta* (35%), *Ardea cinerea* (30%), and *Tachybaptus ruficollis* (25%). *Podiceps cristatus* showed the lowest occurrence frequency (15%), being detected during only three surveys.

Discussion

The fish assemblage recorded in KR consisted exclusively of species previously reported as introduced in Algerian inland waters [9,14]. This pattern is consistent with observations from several Algerian reservoirs, where freshwater fish communities are frequently

dominated by non-native taxa [20–23].
R. rutilus, H. molitrix, M. salmoides, and *A. alburnus* were previously reported from KR [15,24], and their detection in the present survey indicates their current occurrence in the reservoir. In contrast, native cyprinid taxa such as *Barbus setivimensis* and *Barbus antinorii,* which were previously reported as the most abundant species in KR [25], were not detected during the present survey. The apparent shift from native to introduced fish dominance represents one of the most important ecological changes observed in KR.
Although the absence of these native barbels during the present survey should be interpreted cautiously because of possible imperfect detection, several mechanisms may explain the current dominance of non-native fishes. First, repeated fish stocking and hydrological connections between reservoirs have probably facilitated the establishment of non-native species in KR. Second, if introduced, they may prove to be an ecological success due to their ability to reproduce rapidly, thrive in a wide range of environments, and possess competitive advantages over native species, which can lead to their dominance in the ecosystem through competition for resources, modifying the habitats, or preying on the native fishes. For example, a previous study demonstrated that the decline of *B. setivimensis* following the establishment of *A. alburnus* in KR involved competitive and/or predatory interactions [15]. Similar declines of native freshwater fishes associated with the increasing dominance of introduced species have also been reported in other Algerian reservoirs [26]. However, this hypothesis needs further ecological studies. Complementary approaches, including environmental DNA (eDNA) analyses, are therefore needed to determine the current status of native barbel populations and to assess ongoing changes in the fish community structure of KR. *Abramis brama* was recorded in the present study but was not reported in previous studies. Together, these differences suggest temporal changes in the fish community structure.
The relatively low Shannon diversity

Table 3) Waterbird Species Recorded In Keddara Reservoir During The 2025 Survey, Including Taxonomic Information, IUCN Status, Number Of Surveys In Which Each Species Was Recorded (N), And Frequency Of Occurrence (FO).

Species		Family	IUCN Status	N	FO (%)
Scientific Name	Common Name				
Anas platyrhynchos (Linnaeus, 1758)	Mallard	Anatidae	LC	14	70
Ardea cinerea (Linnaeus, 1758)	Grey Heron	Ardeidae	LC	6	30
Egretta garzetta (Linnaeus, 1766)	Little Egret	Ardeidae	LC	7	35
Larus michahellis (Naumann, 1840)	Yellow-Legged Gull	Laridae	LC	19	95
Tachybaptus ruficollis (Pallas, 1764)	Little Grebe	Podicipedidae	LC	5	25
Phalacrocorax carbo (Linnaeus, 1758)	Great Cormorant	Phalacrocoracidae	LC	8	40
Podiceps cristatus (Linnaeus, 1758)	Great Crested Grebe	Podicipedidae	LC	3	15

Note: IUCN status: LC = Least Concern.

recorded in KR is consistent with patterns reported for Mediterranean reservoirs, where fish assemblages are often characterized by low species richness and a high proportion of introduced species [27,28]. In contrast, substantially higher Shannon diversity values have been reported from reservoirs in Burkina Faso and India, reflecting fish assemblages composed of a considerably larger number of species [29-32]. Among the recorded species, *A. alburnus, C. gibelio* and *M. salmoides* were the most abundant. Consistent with this pattern, the diversity indices and the rank–abundance curve indicate a fish assemblage of moderate diversity and relatively high evenness, with a small number of abundant species and a few rare taxa.

The observed abundance pattern is consistent with the ecological characteristics of these three species, which are known for their broad ecological tolerance. *A. alburnus* has colonized numerous reservoirs and lakes throughout Europe and the Mediterranean region owing to its high reproductive capacity and ecological plasticity [33]. In Algeria, the species was accidentally introduced in 2006 into Hamiz Reservoir through fish stocking operations involving carp species imported from Hungary. It was subsequently detected in KR in 2008, most likely through the Hamiz–Keddara water transfer system connecting the two reservoirs [34]. Its high relative abundance in the present survey is consistent with successful establishment within KR, although population trends over time cannot be inferred from the present dataset alone. Similarly, *C. gibelio* is considered one of the most successful freshwater invaders worldwide and is characterized by rapid population growth, high environmental tolerance, and the ability to exploit a wide range of ecological conditions. Its establishment has been associated with the decline of native fish populations in several invaded ecosystems, mainly through competition and alterations of fish community structure [35–36]. The abundance of *M. salmoides* is also noteworthy. This species is regarded as one of the world's most invasive freshwater predators [37].

The waterbird community recorded during the study showed relatively low species richness when compared with other reservoirs in northern Algeria [7,8,38]. However, the observed species richness should be considered as a baseline estimate rather than a complete assessment of waterbird diversity, since additional species may be detected through longer-term monitoring. The high occurrence frequency of *L. michahellis* is consistent with observations from numerous anthropogenic aquatic habitats throughout the Mediterranean Basin. This species has undergone substantial population growth during recent decades and frequently exploits reservoirs, landfills, ports, and other human-modified environments owing to its marked ecological adaptability and opportunistic feeding behavior [39,40]. The relatively high FO of *A. platyrhynchos* indicates that this species regularly used KR during the study period. The other recorded waterbird species showed more variable occurrence patterns throughout the annual cycle. These observations suggest differences in the temporal presence of waterbird species within the reservoir.

Although species richness was relatively low, the assemblage included representatives of several ecological guilds, including diving birds (*P. cristatus* and *T. ruficollis*), piscivorous birds (*P. carbo*), wading birds (*A. cinerea* and *E. garzetta*), and waterfowl

(*A. platyrhynchos*). The presence of these different ecological groups suggests that KR provides a variety of habitat conditions and potential feeding opportunities. However, habitat-use patterns were not directly assessed in this study. The co-occurrence of abundant fish populations and piscivorous birds such as *P. carbo* may indicate potential ecological interactions between the two assemblages. However, these relationships remain to be tested using approaches such as diet analysis, stable isotope analysis, or other trophic investigations.

The present study nevertheless has several limitations that should be considered when interpreting these results. Although surveys covered an entire annual cycle, the inventory was based on a single year of sampling using gill nets, traps, and fishing rods, which may not detect all species present, particularly rare or low-density taxa. Likewise, waterbird observations were based on occurrence frequency rather than standardized abundance estimates. Consequently, the present inventory should be regarded as an updated baseline rather than a comprehensive assessment of the reservoir's biodiversity.

The establishment of introduced fishes in KR may also have management implications because the reservoir is connected to other water bodies through transfer systems. These hydrological connections may facilitate the spread and establishment of non-native species. Regular biodiversity monitoring, appropriate biosecurity measures, and careful management of fish stocking and water-transfer activities are therefore needed to limit further introductions and spread of non-native fishes.

This study highlights two directions for future research: the first is to clarify the current status of native barbel populations using targeted survey methods. The second is to monitor changes in the abundance and dominance of introduced fishes within the reservoir and the connected water system over time. Such information would improve our understanding of biodiversity changes and provide a scientific basis for the conservation and management of this freshwater ecosystem.

Conclusion

This study provides a first checklist of waterbird species and an updated inventory of fish fauna in Keddara Reservoir. The fish assemblage was entirely composed of introduced species, while widespread Mediterranean wetland species dominated the waterbird community. By updating previous records and documenting the current occurrence of fish and waterbird species, this study provides an updated overview of vertebrate biodiversity in the KR. Although the inventory is not exhaustive, it establishes a useful reference for future surveys. Further monitoring, including additional taxonomic groups and complementary methods such as environmental DNA (eDNA), would help detect species that may have been overlooked and improve our understanding of biodiversity changes over time in this reservoir.

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Ethical Permission: Fish and waterbird surveys were conducted under authorization from the Algerian National Agency of Dams and Transfers (ANBT) within a doctoral research framework. All recorded species are not subject to specific protection restrictions under the applicable national regulations; therefore, no additional ethical approval was required.

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Conflict of Interest: The authors declare that there is no conflict of interest regarding the publication of this manuscript.

AI Use Declaration: Artificial intelligence (ChatGPT, 2026) tools were used for improving the language and readability of the initial draft. However, the authors conducted all scientific content and interpretation of results, and the scientific accuracy of the material was reviewed and approved by them. Artificial intelligence played no role in data generation or scientific decision-making.

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