REPORT ON THE SPECIES DIVERSITY OF FISH IN ALBANIA'S MAJOR LAKES

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ABSTRACT

Lake Shkodra, between Albania and Montenegro; Lake Ohrid, between Albania and North Macedonia; and the two Prespa Lakes that span the borders of Albania, North Macedonia and Greece, together form the largest lake complex in Europe in terms of habitats, species and genetic diversity. This paper presents the unique characteristics that sustain the stable and resilient condition of each lake, as well as one of their most important features: the diversity of their fish populations.

Keywords: fish; genetic diversity; Lake Shkodra; Lake Ohrid; Prespa Lakes; species diversity

Introduction

The hydrological complex formed by the Drin and Buna rivers and associated lakes (Shkodra, Ohrid, Great Prespa, and Small Prespa), is on the Balkan Peninsula, in a region characterized by active tectonic, hydrographic, geomorphological, biogeographical and evolutionary processes. This complex is in part of the Adriatic Sea Basin, which is one of the most ecologically and scientifically intriguing in the Mediterranean area, as the water in the South Adriatic–Ionian zoogeographic region is noted for its distinct features (Dhora 2017).

Although the four lakes are hydrologically interconnected each has unique characteristics that determine their ecological individuality and importance.

Among the most important features of these lakes is the genetics and species diversity of their fish populations. Genetic diversity refers to the genes in each population of a species varying and diversity of the variety of species present and their relative abundance (Biba et al. 2013).

This article outlines, for each lake, the key characteristics that sustain the ecological stability and resilience of the ecosystem, as well as the genetic and species diversity of their ichthyofauna.

Materials and Methods

The characteristics of the lakes were mainly obtained from Dhora (2016, 2017), Dhora et al. (2016) and Group authors (2015). These characteristics were revised and adapted according to two main aspects: the stable condition of the lakes and the genetics and species diversity of their fish.

The updated list of fish in Albania's major lakes is based on Talevski et al. (2009), Crivelli and Catsadorakis (2012), Barbieri et al. (2015), Marić (2018) and Dhora (2020).

Species diversity was based on comparing data for each lake on the number of species of fish, the number of species of Cyprinidae, the number of species of Salmonidae, the number of species migrating to the sea, the number of introduced species and the number of endemic species.

The genetic diversity of the fish is based on data presented in Dhora (2024) and several aspects of the species of salmon in the Moraça River, three species of salmon in Lake Ohrid, *Alosa agone* in Lake Shkodra, two species of *Rutilus* in Lakes Shkodra and Ohrid, and the indigenous common carp in Lake Shkodra, which are in genetic equilibrium (Biba et al. 2013).

Results and Discussion

Characteristics of each lake

Below are the characteristics of Albania's major lakes that support the stable and resilient condition in these ecosystems, as well as the genetic and species diversity of their fish populations.

Lake Shkodra

Lake Shkodra is one of the biggest lakes in the world (100–10,000 km²) and is the largest lake on the Balkan Peninsula in terms of surface area.

The subsiding movement of the plate on which Lake Shkodra lies began at the end of the Paleogene and the beginning of the Neogene. It is believed that this downward movement has been offset by the deposition of sediment from inflowing rivers, an important geological factor contributing to the lake's long-term stability.

Karst modelling revealed hydrographic features, lake morphology and high catchment potential.

Approximately 44.3% of the lake's minimum surface area lies below sea level. This feature classifies the lake as a crypto depression, which is a rare phenomenon in Europe and globally. This aspect contributes to its classifi-

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cation as a stereotypical lake, with unique natural values, regenerative capacity and longevity.

Lake Shkodra is a lowland lake, yet it is supplied with rainwater from high-altitude areas in its extensive catchment basin.

The lake functions as a hydrological stabilizer. When the flow of water in the Drin River is low, Lake Shkodra discharges water into the Buna River, but when the flow is high it impedes the normal outflow of the Buna and blocks the discharge from the lake. As a result, the water level, surface area and volume of the lake increase.

Historically, Lake Shkodra is described as both a riverine system (lotic system) in which the lake is the potamic segment of the Morača-Buna River, and a marsh system (lentic, palustrine) along the lowland stretch of the river. Currently, Lake Shkodra is a lake (lentic, lacustrine), with a large, permanent water surface, which distinguishes it from marshland.

As the lake's water temperature very rarely drops below 0 °C its thermal regime is subtropical. It contains more water during the wet seasons and less in the summer months.

There are significant seasonal fluctuations in water level of this lake, which can reach up to 5 meters. These fluctuations are important ecologically as during the warm seasons when the water level is low, aquatic macrophytes flourish and reproduction and migration occur.

As autumn approaches, macrophytes die back and decompose in the lakebed sediments, some of which are carried via the Buna River to the sea, which results in the natural cleansing of the lake.

In the cold seasons, when water levels are at their maximum, the lake undergoes a reversal in ecological dynamics. The number of habitats decreases, and the fauna seeks shelter for overwintering.

Lake Shkodra is a littoral-type environment as its shallowness and fluctuations in water level prevent the development of a well-defined vertical zonation within the lake.

The lake is characterized by clear, oligotrophic waters with a low phytoplankton biomass. The feedback mechanisms that maintain water quality include: the nutrient concentrations in the water versus humic production in wetlands; nutrient levels versus the productivity of riparian forest habitats; and food web structures that transfer phosphorus from littoral to pelagic zones versus biogeochemical processes that inhibit phosphorus recycling from sediments.

There are three main habitats in Lake Shkodra:

- The lacustrine system, which includes limnetic and littoral habitats.
- The palustrine system, consisting of habitats that vary in vegetation and the presence or absence of standing water,
- The riverine system, which includes both permanently and seasonally flooded habitats.

Aquatic macrophytes are the most characteristic feature of the littoral zone and, to a certain extent, the entire Lake Shkodra ecosystem.

The lake is notable for its high species diversity. It also has significant ornithological value at a regional scale. In and around Lake Shkodra and its catchment area, a total of 283 species of birds are recorded, 168 of which are associated with aquatic habitats.

Lake Ohrid

Lake Ohrid is situated at an altitude of 693 metres above sea level, nestled between the Mokra Mountains to the west and Galicica Mountains to the east.

This lake is listed among the nine most ancient lakes worldwide and is considered the oldest in Europe.

It is one of the largest lakes in the world and with an average depth of 167 metres and a maximum depth of 288.7 metres, it is one of the deepest in Europe and second in terms of average depth and volume the largest in the Balkans.

Lake Ohrid and Lake Prespa are part of the Dessaret basin group, formed by a geotectonic depression during the Pliocene

Uniquely Lake Ohrid is primarily spring-fed. Approximately 50% of its inflow originates from underground sources coming from Lake Prespa, which lies about 10 km to the southeast and is roughly 150 meters higher in altitude

There are three thermal zones in this lake:

- The epilimnion, the uppermost water layer, extends to a depth of about 20 meters and can reach temperatures of 24–27 °C.
- The metalimnion lies beneath the above, where temperature decreases by approximately 0.5 °C per metre of depth.
- The hypolimnion is the deepest, coldest layer, which does not receive heat from sunlight or oxygen from the atmosphere. At 150 metres depth, the temperature is about 6 °C.

The open waters in this lake are oligotrophic, whereas the nearshore zones are considered mesotrophic.

Lake Ohrid has an outstanding biodiversity, including:

- Habitat diversity, often physically and/or ecologically isolated,
- Species diversity, particularly of endemic taxa,
- And genetic diversity in several biological groups.

The lake's biota is unique, not only because of its physical isolation, but also because its biocenosis is homogeneous, stable and a product of long-term evolutionary processes.

Lake Ohrid has the highest density of endemic species per surface area of any lake in the world.

The presence of cold, oxygen-rich underwater springs, combined with both horizontal and vertical isolation, are the main reasons for the lake's unique evolutionary pathways, high level of endemism and ecological stability.

Lake Ohrid is often described as a "museum of relict species" or a "repository of living fossils," as many of the species there that were once widespread millions of years ago and are now extinct elsewhere, but survived in this lake. The most notable relict groups include Diatoms, Gastropods and Salmonids, with the benthic community being among the most interesting.

Zooplankton plays a vital role in the lake's food web, serving as the primary food source for small fish, which in turn sustain predatory fish, including trout.

A total of 270 bird species is recorded in Lake Ohrid and its surrounding catchment.

The Prespa Lakes

The Prespa Lakes**,** both Great and Small, form part of the Dessaret basin group, which originated from a geotectonic depression during the Pliocene. Great Prespa Lake is included on the list of the 21 oldest lakes in the world.

Located at altitudes ranging from 844 to 852 metres above sea level, they are the highest tectonic lakes in the Balkans.

Great Prespa Lake

This Lake is among the largest globally (100–10,000 km^2). It receives water primarily via surface inflows, while its outflows are subterranean, passing through the karstic systems beneath Mount Galicica and Mount Mali i Thate, and emerging as springs in Tushemisht and Saint Naum, which subsequently feed Lake Ohrid.

The lake has a maximum depth of 52 metres. Over the past few decades, the water level has dropped by approximately 8 meters, which is most likely due to changes in the underground karstic water flow, or other natural or anthropogenic reasons.

Unlike Lake Ohrid, thermal stratification in Great Prespa Lake is less distinct, although a general layering does exist.

For most of the year, the open waters of Great Prespa are oligotrophic, shifting towards mesotrophic during the summer months.

Ecological stability of this lake is attributed to its clean water and two primary production systems: phytoplankton, which thrives in the surface thermal layer and rooted macrophytes in the littoral zone.

Small Prespa Lake

Small Prespa Lake is shallow, with a maximum depth of only 7.7 meters and is eutrophic due to high concentrations of phosphorus. It is rich in emergent vegetation and wetland habitats, making it especially important for birdlife.

Landscape and Biodiversity

There are many habitats in the surroundings of this lake, scenic bays, and islands such as Golem Grad, Maligrad, Agios Achillios and Vidronisi, which, together with the pristine nature and clear waters, contribute to the lakes' beauty and ecological value.

The habitat diversity, species richness, and presence of endemic taxa, particularly in terms of gastropods and fish, means this lake should have priority for conservation. In total, over 200 bird species are recorded there and recently the overwintering water-bird populations have reached up to 50,000 individuals.

In terms of biogeographical classification, this lake is generally grouped in the Adriatic–Ionian lake system, which also includes Lake Ohrid. However, it can also be considered ecologically distinct from Lake Ohrid and the broader Eastern Lake Group, which includes two Balkan and three Anatolian lakes.

To date, 28 species of aquatic macrophytes are recorded there along with over 200 species of birds. In the past two decades, the maximum number of waterbird individuals counted during the winter period has approached 50,000.

Genetics and species diversity of fish

Genetic diversity of fish

Salmo obtusirostris is a complex species, which includes *Salmo zetensis* in the Zeta River, which some authors regard as a subspecies of *S. obtusirostris*. Two other species, *Salmo montenigrinus* Karaman 1933 in the Morača River, is considered by some authors as a synonym of *S. obtusirostris*, and *Salmo taleri* Karaman, 1933 in the upper course of the Zeta River that morphologically resembles *S. cf. farioides*, has so far been recorded only at a single locality. Therefore, the *Salmo* species in the Morača River basin, which includes the Zeta and Cem tributaries, are still not well known, although six species are reported. It is important to accurately determine these species or subspecies, using genetic analyses.

A thorough study of the non-migratory *Alosa agone* population in Lake Shkodra is needed, which should also determine whether migration to the sea occurs. For years, a portion of individuals older than three years may not have migrated and over time, a non-migratory population may have formed, adapted to life along the northeastern shore of the Albanian part of this lake, and possibly reproducing there. Individuals in this population are smaller than the migratory ones, have smaller heads and fewer spots on both sides of the body (Kottelat and Freyhof 2007). This long-established population is *Alosa agone*, living in sympatry with *Alosa fallax* (Rakaj and Crivelli 2001). The above is also discussed in Dhora (2024).

The common carp (*Cyprinus carpio*) was introduced into Albania by the Romans, who cultivated it. Considering its adaptive capacity, the carp population in Lake Shkoder can be regarded as an autochthonous species. Microsatellites have been used as molecular markers to assess genetic variability at the DNA level in carp populations of Lake Shkodra and Lake Ohrid. This study re-

vealed that only the carp population in Lake Shkodra is at genetic equilibrium (Biba et al. 2013). The conservation of the native common carp in Lake Ohrid, and possibly also in the Prespa Lakes, should be ensured by careful stock enhancement based on selected individuals.

Rutilus karamani and *Rutilus ohridanus*, previously considered distinct species in Lake Shkodra, are regarded by Bianco and Ketmaier (2014) as synonyms of a single species, *Leucos basak* Heckel, 1843 and were once classified as subspecies: *karamani* the yellow roach and *ohridanus* the white roach (Dhora et al. 2008). Dhora (2024) suggests that this variation may represent intraspecific diversity, possibly in terms of colour morphs adapted to particular aquatic habitats.

Equally important are the trout, particularly the species in Lake Ohrid: *Salmo aphelios* Kottelat, 1997; *Salmo balcanicus* Karaman, 1927; *Salmo lumi* Poljakov, Filipi and Basho, 1958, and *Salmo ohridanus* Steindachner, 1892. In many cases, trout populations are on the brink of collapse due to pollution, declining water levels and unregulated fishing.

Species diversity of fish

The list of freshwater fish in Albania, according to Dhora (2020), comprises 100 species. The two most significant families in terms of species are Cyprinidae with 40 species and Salmonidae with 15 species. The table below provides, for each lake, the following data: the number of species, the number of species of Cyprinidae, the number of species of Salmonidae, the number of migratory species, number of introduced species and number of endemic species.

As shown in Table 1, Lake Shkodra has the highest number of species with 45, followed by Great Prespa Lake with 30 species, then Lake Ohrid with 28 species and finally Small Prespa Lake with 18 species.

The number of species in the family Cyprinidae is as follows: Lake Shkodra has 26 species, Great Prespa Lake 19 species, Lake Ohrid 15 species and Small Prespa Lake 14 species. The total number of species and those of the Cyprinidae family is greatest in Lake Shkodra due to its subtropical characteristics, large surface area, and shallowness over most of its extent. After Lake Shkodra, Great Prespa Lake follows with considerable fewer species and Cyprinidae species. This is because it is shallower and more eutrophic, especially along the gently sloping shores with abundant vegetation. The difference becomes more pronounced in the other lakes.

Lake Shkodra also has the greatest number of species of Salmonidae, as this count includes the trout in the Morača River, which flows into the lake and contributes over 60% of the lake's total water inflow. Lake Ohrid is deep and the water comes from both surface and subterranean springs, which favours salmonids.

Due to its close proximity and connection to the Adriatic Sea via the Buna River, Lake Shkodra also hosts numerous migratory species.

Both Lake Shkodra and Large Prespa Lake have many introduced species, numbering 16 and 14 respectively. Many of these species were introduced to increase fish production for human consumption. By contrast, Lake Ohrid has 4 introduced species, while Small Prespa Lake has 8. The latter is a shallow and eutrophic.

Each lake hosts endemic species. The endemic species in the two Prespa lakes are almost identical due to their close hydrological connection. Lake Shkodra shares some endemic species with the Morača River. Whereas, Lake Ohrid's endemic species have developed within the lake itself, primarily due to geographical and ecological isolation.

Conclusion

Many of the features of these lakes are unique. Lake Shkodra, is a rare cryptodepression in Europe and worldwide. Lake Ohrid is primarily fed by springs and is the richest lake in terms of endemic species relative to its surface area. The Prespa Lakes are at an altitude of 852 meters and are the highest lakes in the Balkans. Water enters these lakes via surface flow, disappears beneath Mount Galicica and Mount Thate, re-emerging as springs at Tushemisht and Saint Naum, which feed Lake Ohrid.

In terms of management the main characteristics of Albania's large lakes are particularly important as the endemic species are threatened by pollution and unregulated fishing.

The high species diversity of fish in these lakes needs to be recognized. The three supposed endemic species of trout in Lake Ohrid need to be genetically confirmed as distinct species. In the case of the six species of trout in the Morača River, there is a need for genetic studies

Table 1 Numbers of species that belong to different taxonomic groups in different lakes.

Lake	Species					
	Total no. of species	Cyprinidae	Salmonidae	Migratory species	Introduced	Endemic
Lake Shkodra	45	26	7	8	16	6
Lake Ohrid	28	15	6	2	4	5
Great Prespa lake	30	19	3	1	14	7
Small Prespa lake	18	14	?	1	8	7

aimed at differentiating species and subspecies. A comprehensive study of the non-migratory *Alosa* population in Lake Shkodra is required, including morphological, genetic, embryological, ecological and evolutionary analyses. *Rutilus karamani* and *Rutilus ohridanus* are currently thought to be one species; however, further population and genetic studies are needed in both Lake Shkodra and Lake Ohrid to clarify whether they are subspecies or distinct forms.

Lake Shkodra, Lake Ohrid and the Prespa Lakes are protected areas in their respective countries. In the future, the entire hydrological complex and its catchment basin should be declared a protected area. This would involve an integrated approach by five countries if the management is to be successful.

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