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CHANGES IN THE DIVERSITY AND ABUNDANCE OF MACROPHYTES IN THE LOCALITY EZERANI - LAKE PRESPA

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ABSTRACT

Macrophytes represent one of the key biological elements used in evaluating the ecological status of freshwater ecosystems, as their qualitative composition and abundance reflect long-term environmental conditions. Recent surveys of Lake Prespa indicate a substantial decline in macrophyte diversity and population density, signalling notable ecological degradation. To assess the current state of the lake's littoral vegetation, this study compares the findings from the most recent field investigation (September–October 2024) with data collected 13 years earlier from the same locality at Ezerani. Macrophyte material was collected following standard limnological procedures, and species abundance was assessed using a five-degree ordinal scale. The 2024 survey documented only three macrophyte species, whereas ten species had been recorded previously. This substantial reduction in richness and abundance points to moderate to severe ecological disturbance, attributed to increased anthropogenic pressure, nutrient enrichment, and the accelerated withdrawal of lake water that has exposed and desiccated former vegetated zones. The observed changes highlight a critical environmental situation in Lake Prespa and underline the urgent need for strengthened conservation actions. Effective management—integrating nutrient reduction, improved wastewater control, littoral restoration, and systematic monitoring—is essential to halt further degradation and preserve the remaining macrophyte communities.

Keywords: macrophytes; species diversity; abundance; ecological status; Ezerani; Lake Prespa

INTRODUCTION

Macrophytes, as relatively long-lived and structurally complex aquatic plants, are one of the core biological quality elements used—together with phytoplankton, macrozoobenthos, and fish—in evaluating the ecological status of lake ecosystems (Solimini et al. 2006). Their ecological relevance stems from their ability to integrate environmental changes over extended periods, making them particularly effective indicators of long-term ecological conditions. Because macrophytes respond slowly and progressively to variations in nutrient

concentrations, hydromorphological changes, and water transparency, they are widely recognised as reliable limnological indicators of both improvement and degradation in aquatic ecosystems (Melzer 1999).

Across Europe, several macrophyte-based indices have been developed to assess nutrient pollution and trophic state in both lakes and running waters (Melzer 1999; Schneider, Krumpholz, and Melzer 2000; Schneider and Melzer 2003). These tools offer critical insight into the ecological dynamics of freshwater bodies, helping to identify early signs of eutrophication, shifts in macrophyte communities, and broader alterations in aquatic habitat structure. Such indices have become increasingly important in regions experiencing intensified anthropogenic pressures, land-use changes, and hydrological disturbances.

Lake Prespa, the second largest lake in North Macedonia and an internationally recognised transboundary ecosystem, has undergone substantial ecological change over recent decades. Increasing nutrient inflow from agriculture, changes in hydrology, untreated wastewater inputs, and intensified human activities have collectively driven the lake toward a more eutrophic state. These pressures have altered water quality, reduced water transparency, and accelerated habitat modification along the littoral zone. Macrophyte communities, particularly those inhabiting shallow, nearshore environments, have responded to these changes with notable shifts in their composition, spatial distribution, and abundance patterns.

Given these documented environmental challenges, the purpose of this study is to identify and evaluate changes in the diversity and abundance of macrophytes in the Ezerani locality of Lake Prespa. By comparing the findings from the 2024 field survey with data collected 13 years earlier at the same transects, this research aims to provide a clearer and more comprehensive understanding of long-term ecological trends. Such comparative analyses are essential for determining the extent of macrophyte decline, assessing ongoing environmental stressors, and guiding future conservation and management strategies within this ecologically sensitive and internationally significant lake system.

LITERATURE REVIEW

Previous studies on the macrophyte vegetation of Lake Prespa have primarily concentrated on documenting the qualitative and quantitative composition of macrophyte communities across various littoral localities, while also assessing lake trophicity through macrophyte-based ecological indices (Trajanovska et al. 2019; Taleska et al. 2022; Trajanovska, Taleska, and Veljanovska Sarafiloska 2022; Taleska and Trajanovska 2023; Trajanovska et al. 2024). These investigations consistently demonstrate that macrophytes in Prespa are highly sensitive to environmental alterations, particularly nutrient enrichment, sedimentation, and hydrological fluctuations. As a result, macrophyte assemblages have long served as reliable indicators of ecological change within the lake's littoral zone.

Research conducted over the last decade has identified several concerning trends. First, there is evidence of increasing eutrophication, driven by agricultural runoff, untreated wastewater, and internal nutrient loading. These pressures have altered the species composition and abundance of submerged macrophytes, leading to a decline in taxa associated with clear-water, low-nutrient conditions. Second, fluctuations in water levels—partly natural and partly influenced by anthropogenic water withdrawal—have contributed to habitat loss and shifts in macrophyte distribution. Studies by Trajanovska and colleagues highlight how these hydrological shifts have affected not only macrophyte communities but also broader ecological processes across Prespa's nearshore environment.

Despite the growing body of literature, there remains a significant gap in long-term comparative analyses that directly evaluate changes in macrophyte communities at identical sampling locations across extended time periods. Most existing studies investigate single-year or short-term dynamics, limiting the ability to assess long-term ecological trajectories.

Importantly, no previous study has systematically compared current macrophyte assemblages with those documented more than a decade earlier at the same transects within the Ezerani locality, one of the lake's most ecologically important littoral zones.

This absence of temporal comparison is critical, as it restricts our understanding of the rate, direction, and magnitude of vegetation change in Lake Prespa. Without long-term reference points, it becomes difficult to distinguish between natural variability, short-term fluctuations, and persistent ecological degradation driven by anthropogenic stressors. By filling this gap, the present study contributes essential new knowledge on macrophyte decline, habitat alteration, and the overall ecological condition of the Ezerani littoral zone. Comparing the 2024 dataset with data collected 13 years earlier provides valuable insights into the progressive loss of biodiversity, shifts in species dominance, and the long-term impacts of nutrient loading, hydrological stress, and environmental degradation in Lake Prespa.

METHODS

Field sampling of macrophytes in Lake Prespa was conducted between September and October 2024 at the Ezerani locality, along three predetermined transects (Ezerani 1, Ezerani 2, and Ezerani 3) selected to represent characteristic littoral habitats across a range of depth gradients (Figure 1). The transects were positioned to capture spatial variation in vegetation structure and to ensure comparability with earlier research conducted 13 years prior at the same locality.

Figure 1. Lake Prespa and locality Ezerani (1-3)

Standard limnological procedures were applied during the field campaign, following the methodological frameworks described by Wetzel (1975) and Lind (1985). Macrophyte material was collected from the onset of visible vegetative development until the end of the growth period to ensure full representation of both dominant and subdominant species. Sampling of submerged vegetation was performed using a Van Veen grab sampler (Figure 2), which enabled the consistent retrieval of plant material from multiple depth intervals along each transect.

Figure 2. Van-Veen grab for collecting the samples

All collected specimens were transported to the laboratory for detailed taxonomic identification. Species determination was carried out using regional floras and identification keys for vascular macrophytes, including the works of Hayek (1924–1933), Jordanov (1963–1970), Josifović (1970–1977), and Tutin et al. (1964–1980). At each depth zone within each transect, species presence or absence was recorded, and species abundance was assessed using a five-degree ordinal scale adapted from Tüxen and Preising (1942, cited in Melzer 1999), where 1 = very rare, 2 = infrequent, 3 = common, 4 = frequent, and 5 = predominant.

The collected data were organized into tables and graphical representations illustrating species composition and abundance at each transect. To evaluate long-term ecological change, the 2024 findings were systematically compared with results from the previous study conducted 13 years earlier in the same locality. This comparative approach enabled an assessment of temporal changes in macrophyte diversity, distribution, and overall littoral vegetation structure in Lake Prespa.

RESULTS

A total of three macrophyte species were recorded during the 2024 survey at the Ezerani locality: *Myriophyllum spicatum* L., *Ceratophyllum demersum* L., and *Ceratophyllum submersum* L. These species were observed across depths ranging from 0.5 to 5 m, displaying notable differences in abundance among the three transects and across the sampled depth gradient (Tables 1–3).

Among all recorded taxa, *Myriophyllum spicatum* consistently exhibited the highest abundance values. At 0.5 m in each transect, the species reached the maximum observed abundance value (5) on the five-degree ordinal scale, indicating dominant coverage in the shallow littoral zone. In contrast, *Ceratophyllum submersum* showed the lowest overall abundance and a more patchy distribution, typically ranking between 1 and 3 across transects.

Tab.1. Qualitative composition and abundance of macrophyte species in Ezerani 1(autumn)

Depth (m)	Macrophyte species (Ezerani 1)	Abundance
0.5	*Myriophyllum spicatum* L.	5
1.5	*Myriophyllum spicatum* L.	3
2	*Myriophyllum spicatum* L.	3
	Ceratophyllum demersum L.	3
	Ceratophyllum submersum L	1
3	*Ceratophyllum demersum* L.	1
4	*Ceratophyllum demersum* L.	3

5	*Ceratophyllum demersum* L.	2

Tab.2. Qualitative composition and abundance of macrophyte species in Ezerani 2 (autumn)

Depth (m)	Macrophyte species (Ezerani 2)	Abundance
0.5	*Myriophyllum spicatum* L.	5
1.5	*Myriophyllum spicatum* L.	3
2	*Myriophyllum spicatum* L.	3
	Ceratophyllum demersum L.	1
	Ceratophyllum submersum L	1
3	*Myriophyllum spicatum* L.	2
	Ceratophyllum demersum L.	1
	Ceratophyllum submersum L	1
4	*Myriophyllum spicatum* L.	2
	Ceratophyllum demersum L.	3
	Ceratophyllum submersum L	1
5	*Ceratophyllum demersum* L.	1

Tab.3. Qualitative composition and abundance of macrophyte species in Ezerani 3 (autumn)

Depth (m)	Macrophyte species (Ezerani 3)	Abundance
0.5	*Myriophyllum spicatum* L.	5
1.5	*Myriophyllum spicatum* L.	4
2	*Myriophyllum spicatum* L.	4
	Ceratophyllum demersum L.	1
3	*Ceratophyllum demersum* L.	1
4	*Ceratophyllum submersum* L	3
5	*Ceratophyllum demersum* L.	4

Overall, macrophytes were distributed throughout the entire sampled depth range (0.5–5 m). *Myriophyllum spicatum* dominated all transects and depths, confirming its competitive advantage under the current environmental conditions in Lake Prespa. Conversely, *Ceratophyllum submersum* was consistently the least abundant species, indicating a narrower ecological tolerance or reduced suitability of recent environmental conditions.

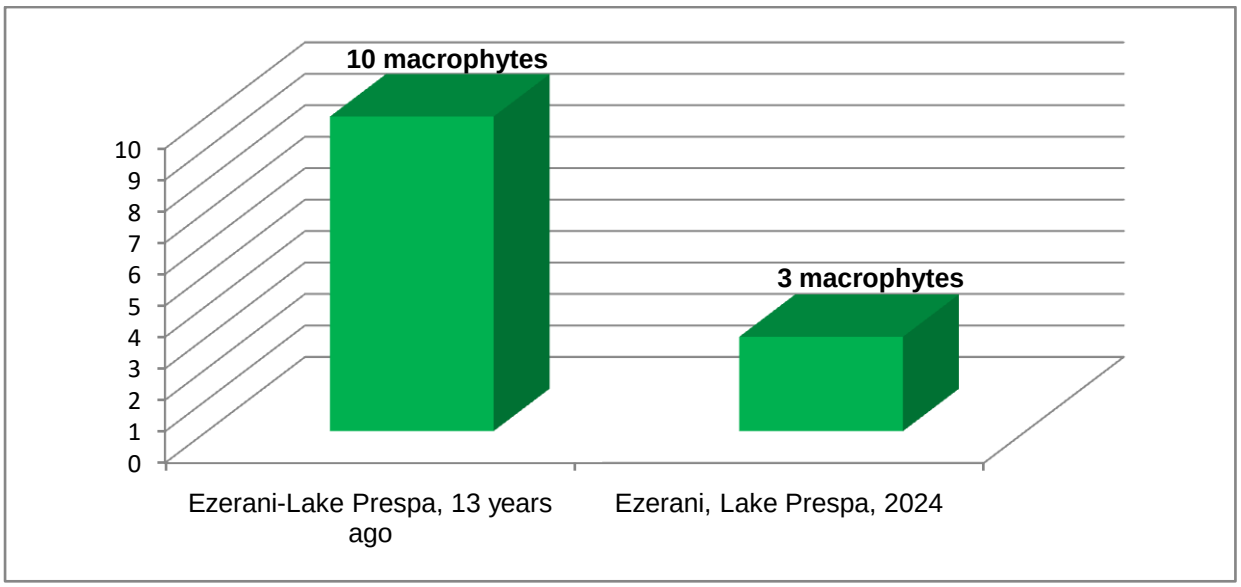

Figure 3. Comparison of the qualitative composition of macrophytes over a period of 13 years

Figure 3 illustrates a clear and significant decline in macrophyte diversity over the 13-year period examined. In 2024, only three species—*Myriophyllum spicatum*, *Ceratophyllum demersum*, and *Ceratophyllum submersum*—were recorded, whereas ten species were documented during the earlier study. Historically, the Ezerani littoral zone supported a substantially richer macrophyte community, including emergent species such as *Phragmites australis* and *Typha angustifolia*, as well as submerged taxa such as *Potamogeton pusillus*, *Potamogeton perfoliatus*, *Potamogeton lucens*, *Stuckenia pectinata*, *Najas marina*, and *Zannichellia palustris*.

The disappearance of these taxa—particularly the Phragmites, Potamogeton and Najas species—indicates pronounced degradation of littoral vegetation, consistent with increased eutrophication, hydrological alteration, and sedimentation pressures affecting Lake Prespa. This marked loss of structural and taxonomic diversity reflects long-term ecological decline and stresses the urgency of ecosystem management interventions.

DISCUSSION

The results of this study demonstrate a substantial and ecologically significant decline in the diversity and abundance of macrophytes in the Ezerani locality of Lake Prespa. The ecological condition of the littoral zone is shaped by interrelated environmental factors such as substrate composition, water depth, light penetration, hydrological dynamics, and nutrient availability (Trajanovska et al. 2014, 2019). The marked reduction in species richness and the contraction of macrophyte coverage indicate heightened ecological stress, most likely driven by nutrient enrichment, altered hydrological regimes, and the cumulative influence of long-term anthropogenic pressures. The persistent dominance of *Myriophyllum spicatum*, a species known for its tolerance to elevated nutrient conditions, coupled with the continued but diminished presence of Ceratophyllum species, suggests a shift toward a simplified macrophyte community structured around a small number of stress-tolerant taxa.

A comparison with historical studies highlights the severity of this shift. Thirteen years ago, the macrophyte assemblage in the Ezerani littoral zone was considerably richer and structurally more complex. Emergent species such as *Phragmites australis*, *Typha angustifolia*, and *Typha latifolia* formed discontinuous yet ecologically important belts along the shoreline. Submerged taxa—including *Potamogeton pusillus*, *Potamogeton perfoliatus*,

Potamogeton lucens, *Stuckenia pectinata*, *Najas marina*, and *Zannichellia palustris*—were also present and often abundant (Trajanovska et al. 2019). These species collectively contributed to habitat heterogeneity, nutrient cycling, and the provision of spawning and refuge habitats for fauna. The complete absence of these emergent and submerged genera in the 2024 dataset represents a dramatic ecological shift and aligns with broader evidence of trophic deterioration, loss of habitat complexity, and hydromorphological alteration throughout Lake Prespa (Trajanovska et al. 2019; Trajanovska et al. 2024).

Despite the methodological strengths of this study, several limitations must be acknowledged. First, the comparison is based on two discrete time points, which may not fully account for interannual variability or extreme seasonal fluctuations in macrophyte development. Second, the pronounced decline in water level observed in recent years has reshaped the littoral zone, potentially confounding direct comparisons by reducing the availability of suitable macrophyte habitat rather than strictly reflecting ecological degradation. This hydrological factor may have contributed to the exclusion of emergent and shallow-water taxa now left stranded along the exposed shoreline. Third, the study did not include winter or early spring sampling, which may have captured additional species or early-stage growth forms that were not visible during the autumn sampling period.

Future research should aim to establish a multi-year monitoring programme that incorporates seasonal surveys, hydrological measurements, and annual macrophyte assessments. Such an approach would provide more robust insights into temporal dynamics and distinguish long-term ecological trends from short-term variability. Integrating nutrient analyses, sediment composition studies, and hydrological modelling would also strengthen our understanding of the drivers behind macrophyte decline. Furthermore, expanding sampling efforts to include multiple littoral sites across Lake Prespa would clarify whether the observed changes in Ezerani reflect a localized disturbance or a lake-wide pattern of ecological degradation. These integrated methods would contribute to more effective conservation planning, early detection of ecosystem stress, and the design of targeted restoration interventions.

CONCLUSION

The 2024 survey conducted at the Ezerani locality recorded only three macrophyte species, representing a dramatic decline from the ten species documented 13 years earlier. This pronounced reduction in species richness and abundance reflects moderate to severe ecological degradation, driven by nutrient enrichment, elevated anthropogenic pressures, and the accelerated withdrawal of water that has exposed and desiccated former vegetated zones. The complete disappearance of several emergent and submerged taxa—particularly species within the genera Potamogeton, Stuckenia, Typha, and Najas—signals a major shift in the functional structure and ecological resilience of Lake Prespa's littoral zone.

These findings underscore the urgent need for comprehensive and coordinated conservation measures. Priority actions include reducing nutrient inflow and agricultural runoff, improving wastewater treatment infrastructure, restoring degraded littoral and wetland habitats, and implementing systematic year-round ecological monitoring. Strengthened public awareness initiatives and cross-border collaboration are essential given Lake Prespa's transboundary nature and shared ecological responsibilities. Ultimately, the protection and restoration of macrophyte communities are critical not only for maintaining the ecological integrity of Lake Prespa but also for preserving the biodiversity, ecosystem services, and environmental stability of one of the Balkan region's most important freshwater ecosystems.

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