

LONG-TERM SHIFTS AND RECENT PATTERNS IN LAKE OHRID'S ROTIFER COMMUNITY

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Abstract: Pelagic rotifers are sensitive components of freshwater zooplankton and can provide useful evidence of ecological change. Lake Ohrid, an ancient and oligotrophic lake, offers an unusually long record for examining temporal variability in its pelagic rotifer assemblage. This study reconstructs the available evidence from published investigations conducted between 2000 and 2010, the 2019 monogonont checklist, and contemporary Hydrobiological Institute monitoring from summer 2025 to spring 2026. The historical 2000–2008 monthly series recorded 13 pelagic taxa and showed pronounced seasonal and interannual variability. Mean annual rotifer density ranged from 22,544 ind. m⁻³ in 2000 to 6,988 ind. m⁻³ in 2008, while *Kellicottia longispina* and *Keratella cochlearis* were the principal abundant taxa. The largest proportion of the rotifer population was repeatedly associated with the 20–40 m zone. The 2004–2006 investigations confirmed low abundance typical of the oligotrophic pelagial, whereas the 2010 survey identified eight rotifer taxa within a 16-species zooplankton assemblage and highlighted the ecological importance of the metalimnion. The 2019 checklist recognized 12 pelagic monogonont taxa. Recent monitoring again documented *K. longispina* and recurrent *C. hippocrepis*, together with strong seasonal restructuring of the zooplankton community. The combined evidence indicates persistence of a characteristic core assemblage rather than a simple long-term increase or decline. Because historical and contemporary datasets differ in sampling design, depth coverage and reporting units, direct regression across all periods is not statistically defensible. The most robust current signal is therefore taxonomic continuity combined with marked seasonal and interannual variability. Continued standardized monitoring of abundance, composition and vertical distribution, linked to temperature, oxygen, nutrients and phytoplankton variables, is required to determine whether recent changes represent normal variability or an emerging ecological shift.

Keywords: zooplankton, abundance variability, vertical zonation, ecological monitoring

1. INTRODUCTION

Rotifers are among the most responsive components of freshwater zooplankton. Their short generation times, high reproductive potential and sensitivity to temperature, food availability and trophic conditions make them useful for detecting ecological variation at relatively short temporal scales. Recent work further shows that rotifer communities can respond differently among genera to warming, trophic enrichment and changes in water colour, reinforcing the value of species-level or genus-level information rather than total abundance alone (Devkota et al., 2025; Estlander et al., 2024; Kuczyńska-Kippen et al., 2025).

Lake Ohrid is an ancient, tectonic and oligotrophic lake characterized by strong vertical gradients and pronounced seasonal structuring of the pelagic food web. Its low nutrient availability is reflected in comparatively low zooplankton abundance, while the metalimnion represents an important zone of biological production and interaction among trophic levels (Tasevska et al., 2017). Long-term observations of the lake are therefore particularly valuable because they allow natural variability to be distinguished, at least partially, from persistent ecological change.

Systematic investigations by Tasevska and collaborators provide the principal historical basis for pelagic Rotifera in Lake Ohrid. Monthly observations during 2000–2008 documented 13 pelagic taxa, strong seasonal dynamics and a concentration of much of the rotifer population at 20–40 m, with *Kellicottia longispina* and *Keratella cochlearis* among the principal abundant taxa (Tasevska et al., 2008). Comparative observations from 2004–2006 showed the low rotifer abundance characteristic of Lake Ohrid relative to the more productive Lake Dojran and highlighted *Gastropus stylifer* and *K. cochlearis* as important taxa (Tasevska et al., 2012b).

The 2010 investigation subsequently demonstrated strong vertical and seasonal organization of the entire zooplankton assemblage, recording 16 pelagic species, including eight rotifers, and identifying the metalimnion as the most productive environment (Tasevska et al., 2017). The later checklist of monogonont rotifers recognized 73 species in the lake, but only 12 as pelagic, emphasizing the need to distinguish the relatively small pelagic fauna from the much richer littoral assemblage (Tasevska et al., 2019).

Recent ecological literature supports this interpretation of rotifers as responsive indicators. Rotifer-based indices can track trophic state, while functional traits and feeding guilds may provide additional information on environmental conditions (Kolarova & Napiórkowski, 2024; Karpowicz et al., 2025; Kuczyńska-Kippen et al., 2025). Long-term lake studies also show that changes in zooplankton composition can integrate the effects of warming and trophic change, but separating these drivers requires consistent sampling and environmental covariates (Caroni et al., 2025).

The objective of the present study was to reconstruct the long-term evidence for pelagic Rotifera in Lake Ohrid and to place the 2025–2026 monitoring results in a historical context. Specifically, the study aimed to evaluate continuity and turnover in species composition, compare source-specific abundance patterns, assess seasonal and vertical structuring, and determine whether the available evidence supports a directional long-term change.

2. MATERIALS AND METHODS

Study area and source material

Lake Ohrid is a deep ancient lake situated on the border of North Macedonia and Albania, with a surface area of approximately 358 km² and a maximum depth close to 289 m. The pelagial is characterized by seasonal thermal stratification and strong vertical gradients in temperature, oxygen and biological production. The present reconstruction used published studies covering 2000–2010, the 2019 taxonomic checklist, and the Hydrobiological Institute/Ministry of Education and Science monitoring report for summer–autumn 2025 and winter–spring 2026.

Historical and contemporary datasets

The 2000–2008 series represents the principal quantitative historical baseline. Monthly samples were collected at multiple depths from the pelagial, including 0, 10, 20, 30, 40, 50, 75, 100 and 150 m, using a Ruttner sampler and preserved material for quantitative analysis. The 2004–2006 comparison provided additional abundance and dominance information. The 2010 survey contributed evidence on seasonal and vertical distribution and environmental relationships. The 2019 checklist was treated as a taxonomic reference point rather than as a single-year field survey.

Contemporary monitoring was conducted at a central pelagic station reaching 150 m depth, with sampling at 0, 10, 20, 30, 40, 50, 100 and 150 m. The report covered summer and autumn 2025 and winter and spring 2026. Qualitative occurrence and explicit quantitative values were treated separately. A taxon not appearing in a quantitative table was not interpreted as absent unless absence was explicitly established.

Data harmonization and evidence classification

Because the historical sources differ in sampling design, temporal coverage and reporting units, abundance values were retained in their original units and were not pooled into a single regression. The reconstruction therefore emphasizes persistence, turnover, dominance and source-specific abundance. For the evidence matrix, C denotes a confirmed record, O an occasional record, and NR a taxon not reported in the available source. NR does not imply biological absence. This conservative approach is necessary because differences in sampling intensity and taxonomic resolution can generate apparent turnover even when taxa remain present.

3. RESULTS

Historical composition and abundance

The 2000–2008 investigation recorded 13 pelagic rotifer taxa. Eight were described as common through much of the series: *K. longispina*, *K. cochlearis*, *Polyarthra vulgaris*, *Filinia terminalis*, *Trichocerca capucina*, *G. stylifer*, *Asplanchna priodonta* and *Ploesoma truncatum*. *Brachionus angularis* occurred only in selected years, whereas *Synchaeta pectinata* and *C. hippocrepis* were occasional. *K. quadrata* was first recorded in the pelagic zone in June 2004 and subsequently occurred repeatedly (Tasevska et al., 2008).

Mean annual rotifer density varied strongly, from 22,544 ind. m⁻³ in 2000 to 6,988 ind. m⁻³ in 2008. In 2000, *K. longispina* averaged 16,371 ind. m⁻³ and represented approximately 73% of total rotifer density. The large difference between annual means demonstrates the magnitude of interannual variability, but the historical series itself does not establish a monotonic decline. Seasonal maxima generally occurred in summer and autumn, and the largest proportion of the population was concentrated at approximately 20–40 m (Tasevska et al., 2008).

2004–2006 And 2010 Evidence

The 2004–2006 comparison confirmed low pelagic rotifer abundance in Lake Ohrid. Total rotifer density ranged from 0.67 ind. L⁻¹ in June 2006 to 8.2 ind. L⁻¹ in July 2004, with *G. stylifer* and *K. cochlearis* among the most abundant taxa. These values were substantially lower than those of the more eutrophic Lake Dojran, consistent with the oligotrophic character of Lake Ohrid (Tasevska et al., 2012b).

The 2010 survey recorded 16 pelagic zooplankton species, including eight rotifers. *K. longispina* was the most abundant rotifer, at approximately 7 ind. L⁻¹. The metalimnion was identified as the most productive zone, with phytoplankton biomass and zooplankton abundance reaching maxima there (Tasevska et al., 2017). This provides independent support for the ecological importance of the 20–40 m zone identified in the earlier Rotifera series.

Contemporary monitoring, 2025–2026

The recent monitoring again documented a broad qualitative pelagic assemblage. In summer 2025, *K. longispina* and *C. hippocrepis* were quantitatively represented. In winter 2026, *K. longispina* was reported at 1,500 units in the source table. In spring 2026, both *K. longispina* and *C. hippocrepis* were present with depth-specific records. The monitoring report also documented marked seasonal restructuring of the overall zooplankton assemblage,

with lower taxonomic representation in winter and increased qualitative diversity in spring (Hydrobiological Institute Ohrid & Ministry of Education and Science, 2026).

The contemporary observations are therefore consistent with continued occurrence of the characteristic pelagic core. They do not justify interpreting the absence of individual taxa from particular quantitative tables as disappearance, because the reporting resolution differs among seasons. The recurrence of *C. hippocrepis* is of particular interest because the taxon was historically occasional and was included in the 2019 pelagic checklist (Tasevska et al., 2019).

Persistence and turnover

K. longispina provides the strongest continuity signal, being documented in the 2000–2008 series, the 2004–2006 studies, the 2010 survey, the 2019 checklist and all three contemporary seasonal datasets. *C. hippocrepis* shows an intermittent-to-recurrent pattern. *K. quadrata* illustrates a taxon first recognized in the pelagic series during the historical monitoring period, whereas *B. angularis* and *S. pectinata* show more restricted occurrence.

Table 1. Reconstructed occurrence of principal pelagic Rotifera in Lake Ohrid across historical and contemporary evidence periods

Taxon	2000–08	2004–06	2010	2019 checklist	Summer 2025	Winter 2026	Spring 2026
<i>Kellicottia longispina</i>	C	C	C	C	C	C	C
<i>Keratella cochlearis</i>	C	C	NR	C	NR	NR	NR
<i>Gastropus stylifer</i>	C	C	NR	C	NR	NR	NR
<i>Polyarthra vulgaris</i>	C	NR	NR	C	NR	NR	NR
<i>Polyarthra major</i>	NR	NR	NR	C	NR	NR	C
<i>Filinia terminalis</i>	C	C	NR	C	NR	NR	NR
<i>Trichocerca capucina</i>	C	C	C	C	NR	NR	NR
<i>Asplanchna priodonta</i>	C	C	NR	C	NR	NR	NR
<i>Ploesoma truncatum</i>	C	NR	NR	C	NR	NR	NR
<i>Conochilus hippocrepis</i>	O	C	NR	C	C	NR	C
<i>Keratella quadrata</i>	C	C	NR	C	NR	NR	NR
<i>Synchaeta stylata</i>	NR	C	NR	C	NR	NR	NR
<i>Brachionus angularis</i>	O	NR	NR	NR	NR	NR	NR
<i>Synchaeta pectinata</i>	O	NR	NR	NR	NR	NR	NR

C = confirmed; *O* = occasional; *NR* = not reported. *NR* does not imply biological absence.

Source: Prepared by the author based on the study data (O. Tasevska)

4. DISCUSSION

Persistence is stronger than quantitative stability

The central result of the reconstruction is that taxonomic continuity is greater than quantitative stability. The historical 2000–2008 record contains strong fluctuations in total density and in the dominance of individual taxa, but the principal pelagic assemblage remains recognizable across later investigations. This pattern is ecologically plausible for an oligotrophic lake in which food supply, thermal structure and vertical gradients vary seasonally.

The persistence of *K. longispina* is particularly notable. Its repeated dominance in the historical series and its continued detection in 2010 and 2025–2026 indicate that it remains a fundamental component of the pelagic rotifer assemblage. At the same time, recent experimental evidence shows that warming can affect *Kellicottia* differently from *Keratella* and *Polyarthra*, demonstrating that total rotifer abundance alone may conceal taxon-

specific responses (Devkota et al., 2025). This supports the value of retaining species-level monitoring in Lake Ohrid.

Seasonal and vertical restructuring

The repeated importance of the 20–40 m zone is one of the clearest spatial signals in the available record. Historical Rotifera concentrations and the later identification of the metalimnion as the most productive zone point to persistent coupling between plankton distribution and vertical environmental gradients (Tasevska et al., 2008, 2017). The recent monitoring should therefore be interpreted not only through total abundance but also through the depth of the abundance maximum.

Seasonal restructuring is similarly important. The historical series showed higher rotifer abundance during summer–autumn, while the recent monitoring showed reduced quantitative representation during winter and renewed occurrence in spring. Such seasonality is not unexpected: temperature, phytoplankton biomass and microbial food pathways influence rotifer population dynamics, while interactions with crustacean zooplankton can alter relative dominance. Comparable long-term studies elsewhere demonstrate that climate and trophic changes may shift the timing and magnitude of zooplankton peaks (Caroni et al., 2025).

Implications for ecological assessment

Rotifer abundance, composition and functional structure have increasingly been used as indicators of trophic and ecological conditions. Recent studies demonstrate relationships between rotifer metrics and trophic-state indices and show that functional traits can improve interpretation of environmental change (Kolarova & Napiórkowski, 2024; Karpowicz et al., 2025; Kuczyńska-Kippen et al., 2025). Functional approaches have also been proposed for detecting lake browning and changes in food-web conditions (Estlander et al., 2024). These approaches are relevant to Lake Ohrid because future monitoring can move beyond species lists toward integrating abundance, feeding guilds and environmental drivers.

The recent North Macedonian evidence from Strežovo Reservoir also demonstrates the usefulness of seasonal and vertical zooplankton sampling for ecological assessment and provides a regional methodological context for interpreting Lake Ohrid data (Tomljanović et al., 2025). However, Lake Ohrid should not be evaluated against eutrophic systems using absolute rotifer abundance alone, because its oligotrophic baseline is fundamentally different.

Can a long-term directional trend be inferred?

The decrease from 22,544 ind. m⁻³ in 2000 to 6,988 ind. m⁻³ in 2008 is a real historical signal, but it cannot be extrapolated to 2026 as evidence of a continuous decline. The later studies use different abundance units, sampling designs and reporting resolutions. A statistically defensible trend analysis would require harmonized raw counts, comparable sampled volumes, fixed depths and consistent seasonal coverage. The present synthesis therefore supports a conclusion of strong variability superimposed on persistence, rather than a statistically demonstrated directional change.

5. CONCLUSIONS

The integrated historical and contemporary evidence indicates that the pelagic rotifer community of Lake Ohrid has remained taxonomically recognizable over more than two decades while showing substantial fluctuations in abundance, dominance and seasonal representation. The 2000–2008 series demonstrates strong interannual variability, including a marked difference between annual mean densities in 2000 and 2008, but does not establish a monotonic long-term decline.

K. longispina is the strongest indicator of continuity, occurring across the historical and contemporary evidence periods. The repeated importance of the 20–40 m zone and the metalimnion further suggests persistence of a characteristic vertical habitat structure. Contemporary monitoring adds an important baseline and confirms that seasonal restructuring remains a major feature of the pelagic community.

The present evidence therefore supports the interpretation of persistent community structure combined with strong seasonal and interannual variability, rather than a demonstrated long-term increase or decline. Continued standardized monitoring is essential for determining whether future deviations from this baseline represent natural variability or an emerging ecological shift.

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