UKLO Proceedings: A Multidisciplinary Approach to Sustainable Development Goals • Vol. 2, No. 1, 2026
Published by the University "St. Kliment Ohridski" – Bitola

(*) Corresponding author
Original research article
DOI: https://doi.org/10.20544/uklop.2026.628
Received: 28.11.2025 • Accepted after revision: 30.12.2025 • Published: 09.05.2026

COMPARATIVE ANALYSIS OF ROTIFER COMMUNITIES IN NATURAL LAKES AND RESERVOIRS OF NORTH MACEDONIA

Orhideja Tasevska*
PSI Hydrobiological Institute, Ohrid, North Macedonia
ORCID: https://orcid.org/0000-0003-3976-0616
orhidejat@hio.edu.mk

ABSTRACT

Rotifers are widely recognized as effective bioindicators of freshwater ecosystems because of their sensitivity to environmental changes, rapid life cycles, and central role in aquatic food webs. In North Macedonia, natural lakes such as Ohrid, Prespa, and Dojran, alongside numerous artificial reservoirs, represent key aquatic habitats with contrasting ecological dynamics. Understanding differences in rotifer communities between natural and artificial systems is crucial for evaluating ecosystem health and the impacts of anthropogenic pressures. This study compares rotifer assemblages in natural lakes and reservoirs of North Macedonia, focusing on community structure, diversity, and responses to environmental drivers. The analysis is based on published studies and long-term monitoring programs. Results demonstrate higher diversity and stability in natural lakes, dominated by oligotrophic and mesotrophic taxa, while reservoirs exhibit lower species richness, stronger fluctuations, and dominance of opportunistic taxa associated with nutrient enrichment. These findings highlight the role of rotifers as indicators of hydrological and trophic stability, and emphasize the importance of continued ecological monitoring in the face of climate and land-use changes.

Keywords: rotifers, lakes, reservoirs, community structure, bioindicators, North Macedonia

1. INTRODUCTION

Rotifers represent a key component of freshwater plankton, contributing significantly to nutrient cycling and serving as an important food source for higher trophic levels(Gilbert 2022). Their rapid reproductive cycles and ecological sensitivity make them valuable indicators of environmental change (Ejsmont-Karabin et al. 2020a). Research in North Macedonia has shown that rotifer communities respond strongly to variations in trophic status, hydrodynamics, and anthropogenic pressures, making them useful for ecosystem assessment.

The country's freshwater network includes three ancient natural lakes (Ohrid, Prespa, and Dojran) and numerous reservoirs constructed primarily for hydropower, drinking water supply, and irrigation. These systems differ markedly in origin, age, hydrology, and nutrient dynamics, offering a natural contrast for assessing how environmental stability shapes plankton communities.

2. LITERATURE REVIEW

Previous investigations by Tasevska and collaborators (2008, 2012a, 2012b, 2015, 2017a, 2017b, 2019, 2024) provide comprehensive insight into rotifer diversity and structure across these contrasting habitats. This manuscript integrates these findings to elucidate how habitat origin, trophic state, and hydrological regime shape rotifer communities in Macedonian inland waters.

3. METHODS

This comparative analysis is based on a synthesis of existing published research and long-term monitoring data:

1. Published works by Tasevska and colleagues on zooplankton dynamics in:
    - Ancient lakes (Ohrid, Prespa): Characterized by stability, great age, and unique biodiversity (endemism). Lake Ohrid is notably oligotrophic (nutrient-scarce), while Lake Prespa shows signs of mesotrophy and ongoing eutrophication.
    - Shallow/Impacted lakes (Dojran): Highly eutrophic, reflecting significant anthropogenic and climatic pressures.
    - Reservoirs: Typically characterized by high hydrological fluctuations, rapid nutrient cycling, and high vulnerability to land-use impacts (e.g., Špilje, Konče 1, and Konče 3 reservoirs).
2. Long-term monitoring data from the Hydrobiological Institute – Ohrid (Guseška et al. 2012, 2014; Kostoski et al. 2024).
3. Secondary literature on trophic indicators and freshwater rotifer ecology (Sládeček 1983; Segers 2008;Estlander 2024).

Rotifer community characteristics were evaluated based on:

- Species richness and abundance.
- Dominant taxa and seasonal succession patterns.
- Functional feeding groups.
- Trophic state indicators.
- Environmental drivers including Total Nitrogen (TN), Total Phosphorus (TP), Secchi depth, and hydrological regime.

Comparisons were made between natural and artificial systems by trophic status (oligotrophic $\rightarrow$ eutrophic) and by hydrological stability (stable $\rightarrow$ regulated).

4. RESULTS

4.1. Comparative summary of rotifer assemblages

A comparative overview of the rotifer communities across the studied natural lakes and reservoirs is presented in Table 1, structured along the observed trophic gradient.

Table 1. The rotifer communities across the studied lakes

Habitat (Trophic Status)	**Species Richness (Approx.)**	**Mean Abundance (Ind L^{-1})**	**Dominant Taxa**	**Ecological Signature**
Lake Ohrid (Oligotrophic, Natural)	73 taxa (Tasevska 2019)	Low (5–10)	*Keratella cochlearis, Kellicottia longispina*	**High stability**, oligotrophic conditions, stenothermic species.
Lake Prespa (Mesotrophic/Eutrophic, Natural)	44 species (Tasevska et al. 2015)	Moderate/Variable	*Brachionus angularis, Trichocerca* spp.	Signs of **enrichment** and mesotrophic status, high littoral diversity.
Lake Dojran (Eutrophic, Natural/Shallow)	55 species (Tasevska et al. 2012)	High (> 120)	*Brachionus calyciflorus, B. plicatilis, Asplanchna priodonta*	**Eutrophic stress**, unstable dominance, fast-reproducing species.
Špilje Reservoir (Oligotrophic/Regulated)	10 taxa (Tasevska et al. 2017)	Low (mean 2.9 ± 4.1)	*Kellicottia longispina* (47%)	**Lower diversity** than natural counterpart, but still reflects low nutrients.
Konče Reservoirs (Eutrophic/Regulated)	13 taxa (Tasevska et al. 2017)	Very High (mean 50 ± 7.8)	*Brachionus falcatus, B. angularis, Hexarthra mira*	**High abundance**, extreme variability, dominance of opportunistic taxa.

4.2. Natural lakes

Natural lakes exhibited higher species richness and taxonomic diversity overall, with stable seasonal succession patterns.

- Lake Ohrid showed particularly persistent oligotrophic signals (Tasevska 2019). The low mean abundance (5–10 ind L^{-1}) reflects oligotrophic conditions and strong predation control by copepods and cladocerans. Diéguez et al. (2002) and Conde-Porcuna and Declerck (1998) have shown that predation by copepods can suppress rotifer populations, while experimental and field studies indicate that large filter-feeding cladocerans outcompete and reduce rotifer densities (MacIsaac and Gilbert 1989; Arcifa et al. 2020). The community is characterized by a balanced mix of microphagous filter feeders and raptorial species, indicating stable food-web interactions (Obertegger and Manca 2011; Horppila 2019).
- Lake Prespa, characterized by mesotrophic to eutrophic tendencies, displayed higher seasonal variability, linked to agricultural runoff and water-level fluctuations, with periodic dominance of *Brachionus angularis* and *Trichocerca* spp. during summer (Tasevska et al. 2015). This indicates a mesotrophic regime with clear signs of enrichment due to catchment eutrophication.
- Lake Dojran, the most eutrophic, showed the highest total abundance but also the greatest seasonal fluctuations. Elevated phosphorus levels (TP > 60 µg L^{-1}) promote opportunistic fast-reproducing species species like *Brachionus calyciflorus* (Tasevska et al. 2012a).

4.3. Reservoirs

Reservoirs were characterized by lower species richness compared to natural lakes and higher total abundance fluctuations. The communities were generally dominated by opportunistic taxa (Tasevska et al. 2017).

- Eutrophic reservoirs (Konče 1 and 3) recorded very high mean densities (up to 50,049 ind L^{-1}), with dominant species like *Brachionus falcatus* and *B. angularis*. This pattern is driven by nutrient-rich and hydrological instability, favouring species with fast reproductive rates (r-strategists) (Galir Balkić et al. 2018).
- Even oligotrophic reservoirs (Špilje), while having low abundance, showed significantly lower diversity (only 10 taxa recorded), emphasizing the impact of hydrological regulation on diversity, regardless of nutrient concentration.

5. DISCUSSION

The observed patterns underline fundamental ecological differences between natural lakes and reservoirs in North Macedonia. Long-term stability in natural lakes supports diverse and structured rotifer assemblages (Shurin et al. 2010). Reservoirs, in contrast, are driven by external nutrient pulses and artificial water level changes that favour opportunistic and r-strategist taxa (Seong-Ki et al. 2020).

Rotifer diversity and community structure in North Macedonian waters mirror a clear ecological gradient:

- Trophic transition: The gradient moves from oligotrophic stability (Ohrid, Špilje) → to mesotrophic fluctuation (Prespa) → to eutrophic instability (Dojran, Konče reservoirs).
- Species shift: Species composition transitions from cold-adapted and slow-reproducing (e.g., *Kellicottia*, *Keratella*) to warm-tolerant, opportunistic taxa (e.g., *Brachionus*, *Filinia*).
- Bioindicator confirmation: These findings align with the global pattern where *Brachionus* and *Hexarthra* serve as indicators of eutrophic, unstable habitats. Studies have shown that *Brachionus* frequently dominates rotifer assemblages in eutrophic or human-impacted waters, while shifts in nutrient loading and trophic state are often mirrored by changes in rotifer community composition, with opportunistic taxa flourishing under disturbed conditions (e.g. Kim et al. 2020; Ejsmont-Karabin et al. 2020b; Phan et al. 2021; Kuczyńska-Kippen et al. 2025), whereas *Kellicottia* and *Keratella* reflect oligotrophic stability. Species such as *Kellicottia longispina* and *Keratella* spp. are frequently associated with oligotrophic, stable lake conditions and constitute dominant microphagous components of low-productivity plankton communities (Tasevska 2017b; Wærvågen and Andersen 2017). Reservoirs, despite sometimes having comparable nutrient levels to natural lakes, are more affected by hydrological regulation, short retention times, and frequent mixing, all of which intensify community instability and suppress diversity (Gabaldón et al. 2017; Seong-Ki et al. 2020; Tomljanović et al. 2025; Li et al. 2025).

This pattern demonstrates how rotifers integrate physical and chemical signals of ecosystem change, functioning as a biological “mirror” of freshwater health. The Macedonian data thus fit broader global findings that rotifer assemblage metrics can serve as sensitive indicators of trophic evolution and anthropogenic disturbance.

Future research should focus on:

- The impacts of climate-driven hydrological changes on Prespa and Dojran Lakes.
- The effects of land-use intensification in reservoir catchments.

- Assessing the success of restoration efforts and controlled nutrient management strategies.

6. CONCLUSION

Rotifer communities in North Macedonia show distinct biogeographical and ecological responses shaped by habitat origin, stability, and nutrient dynamics. Natural lakes support stable, diverse communities adapted to long-established conditions, whereas reservoirs host more variable and opportunistic assemblages. Rotifers therefore represent a valuable tool for assessing trophic state and disturbance, supporting freshwater management and conservation planning in the region.

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