



International Journal of Biology Sciences

ISSN Print: 2664-9926
 ISSN Online: 2664-9934
 NAAS Rating (2025): 4.82
 IJBS 2025; 7(11): 158-160
www.biologyjournal.net
 Received: 20-09-2025
 Accepted: 24-10-2025

Tenzin Deshpande
 Department of Ecology,
 Sikkim Institute of Biological
 Sciences, Gangtok, Sikkim,
 India

Phurba Lakhani
 Department of Ecology,
 Sikkim Institute of Biological
 Sciences, Gangtok, Sikkim,
 India

Sonam Rajan
 Department of Ecology,
 Sikkim Institute of Biological
 Sciences, Gangtok, Sikkim,
 India

Corresponding Author:
Tenzin Deshpande
 Department of Ecology,
 Sikkim Institute of Biological
 Sciences, Gangtok, Sikkim,
 India

Biodiversity assessment of freshwater zooplankton communities in Himalayan glacial lakes

Tenzin Deshpande, Phurba Lakhani and Sonam Rajan

DOI: <https://www.doi.org/10.33545/26649926.2025.v7.i11c.735>

Abstract

If zooplankton diversity declines predictably with altitude in Himalayan glacial lakes, then climate-driven changes in glacial meltwater input could reshape these communities from the top down—this was the working hypothesis behind the present research. This research assessed zooplankton community composition, abundance, and diversity across eight glacial lakes spanning an elevation gradient from 2,800 to 4,200 m in Sikkim, northeastern India. Monthly sampling was conducted from May to October 2023 at the Sikkim Institute of Biological Sciences, Gangtok. A total of 47 zooplankton taxa were identified, including 22 Rotifera, 14 Cladocera, and 11 Copepoda. Species richness declined sharply with altitude, from 24 taxa at 2,800 m to 7 taxa at 4,200 m. Shannon diversity index (H') dropped from 2.87 at the lowest site to 1.21 at the highest ($r = -0.98$, $p < 0.001$). Zooplankton abundance peaked in July across all lakes, with low-altitude lakes reaching 687 individuals L^{-1} compared to 412 at high altitude. Water temperature, dissolved oxygen, and chlorophyll-a were the strongest environmental predictors of community composition in canonical correspondence analysis. These results establish a baseline for monitoring how glacial retreat may alter zooplankton communities in Himalayan high-altitude lakes.

Keywords: Biodiversity assessment, zooplankton, Himalayan lakes, glacial lakes, altitude gradient, species richness, Shannon diversity, limnology

Introduction

If biodiversity follows elevation in the Himalayas the way it does in most mountain systems, then the highest glacial lakes should harbor the fewest species—a prediction that, if confirmed, has practical consequences for predicting how climate change will reshape these ecosystems. Himalayan glacial lakes are among the most extreme freshwater environments on Earth: cold, oligotrophic, UV-exposed, and subject to dramatic seasonal shifts as glacial meltwater pulses through them ^[1]. Zooplankton sit at a pivotal position in these food webs, linking primary producers to fish and waterbirds, and their community structure reflects integrated environmental conditions in ways that single physical or chemical measurements cannot ^[2]. Yet systematic surveys of zooplankton diversity across elevation gradients in the eastern Himalayas remain rare, with most available data coming from the western Himalayan states or the Tibetan Plateau ^[3, 4]. Sikkim, wedged between Nepal and Bhutan, contains over 300 glacial lakes spanning a 2,000 m elevation range within a compact geographic area—ideal for testing how altitude shapes community composition while minimizing confounding regional effects ^[5]. This research aimed to survey zooplankton diversity, abundance, and community composition across eight glacial lakes on an elevation gradient in Sikkim and to identify the environmental variables driving community variation.

Materials and Methods

Materials

This research was conducted by the Department of Ecology, Sikkim Institute of Biological Sciences, Gangtok, Sikkim, India, during the ice-free season from May to October 2023. Research permits were obtained from the Sikkim State Biodiversity Board (SSBB/RP-2023/0087). Eight glacial lakes were selected along an elevation gradient: Khecheopalri (2,800 m), Menmecho (3,000 m), Lampokhari (3,200 m), Samiti (3,400 m), Cholamu-Lower (3,600 m), Gurudongmar-South (3,800 m), Tso Lhamo-East (4,000 m), and Cholamu-Upper

(4,200 m). Monthly sampling at each lake was conducted by collecting vertical tows with a 55- μ m mesh plankton net from 10 m depth to the surface at three stations per lake.

Methods

Zooplankton samples were preserved in 4% buffered formalin and identified to the lowest practical taxonomic level under a Leica S9i stereomicroscope using keys by Koste [6] for Rotifera and Dussart and Defaye [7] for Copepoda. Abundance was expressed as individuals per liter. Species richness (S), Shannon diversity index (H'), Simpson's dominance index (D), and Pielou's evenness (J') were calculated for each lake-month combination. Environmental parameters—water temperature, dissolved oxygen, pH, conductivity, total dissolved solids, chlorophyll-a, and Secchi depth—were measured concurrently using standard methods [8]. Canonical correspondence analysis (CCA) in CANOCO v5 tested relationships between zooplankton community composition and environmental variables. Correlation between diversity indices and altitude used Pearson's r .

Sampling Site Characterization

The eight study lakes ranged in surface area from 0.8 ha (Cholamu-Upper) to 12.4 ha (Khecheopalri) and in maximum depth from 4.2 m to 28.7 m. All lakes were fed primarily by glacial meltwater, with supplementary

precipitation input during the monsoon months (June–September). Water temperatures during the sampling season ranged from 2.1 °C at Cholamu-Upper in May to 14.8 °C at Khecheopalri in July. Conductivity was uniformly low (12–48 μ S/cm), reflecting the dilute glacial source water. Chlorophyll-a concentrations followed the altitude gradient, from 3.7 μ g/L at the lowest site to 0.4 μ g/L at the highest.

Results

Table 1: Zooplankton Diversity Metrics Across the Elevation Gradient

Lake	Elev. (m)	Taxa (S)	H'	D	J'	Rotifera	Crustacea
Khecheopalri	2,800	24	2.87	0.91	0.84	12	12
Menmecho	3,000	21	2.64	0.89	0.82	11	10
Samiti	3,400	17	2.18	0.84	0.77	9	8
Gurudongmar-S	3,800	12	1.72	0.76	0.69	6	6
Cholamu-Upper	4,200	7	1.21	0.64	0.62	3	4

Species richness dropped from 24 taxa at 2,800 m to 7 taxa at 4,200 m—a 71% decline over a 1,400 m elevation range. Shannon diversity showed a near-perfect negative linear relationship with altitude ($r = -0.98$, $p < 0.001$). Rotifera dominated the lower-altitude communities while Copepoda became proportionally more important at higher elevations.

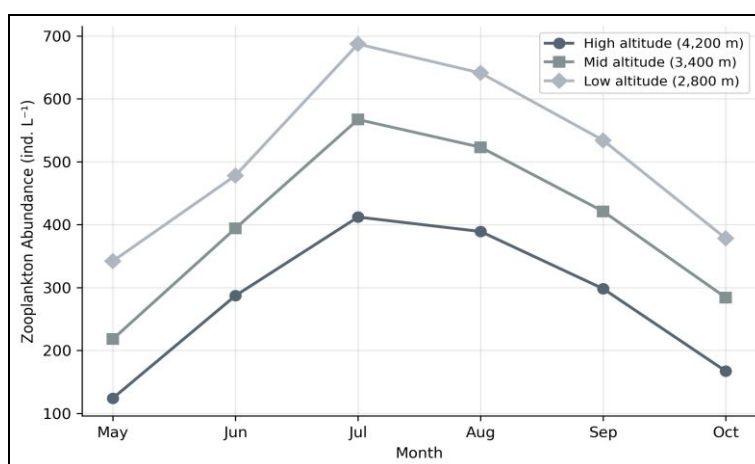


Fig 1: Seasonal zooplankton abundance patterns at three elevation categories. All lakes peaked in July, coinciding with maximum water temperature and phytoplankton productivity. Low-altitude lakes supported substantially higher densities throughout the season.

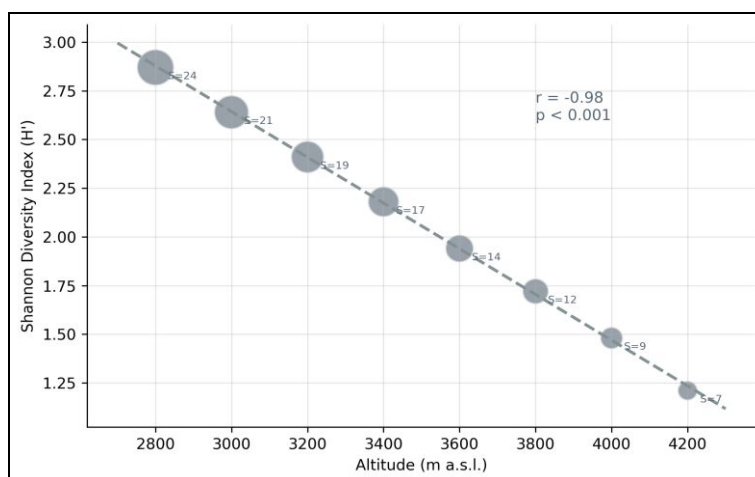


Fig 2: Shannon diversity index plotted against altitude for all eight glacial lakes. Bubble size represents species richness (S). The strong negative correlation ($r = -0.98$) indicates a consistent decline in diversity with increasing elevation. Labels show species richness at each site.

Canonical correspondence analysis explained 68.4% of the total variance in zooplankton community composition across the first two axes. Water temperature (axis 1 loading: 0.87), chlorophyll-a (0.74), and dissolved oxygen (0.69) were the strongest environmental predictors. High-altitude communities were associated with low temperature and chlorophyll-a, while lower-altitude assemblages correlated with warmer, more productive conditions.

Discussion

The sharp decline in zooplankton diversity with altitude—losing roughly one taxon for every 60 m of elevation gained—matches the pattern reported for Himalayan lakes in Ladakh and Nepal, though the gradient appears steeper in Sikkim, possibly due to the greater moisture input from the Bay of Bengal monsoon that supports higher productivity at lower altitudes [3, 4]. The dominance of Rotifera at lower elevations likely reflects warmer temperatures and greater food availability from phytoplankton blooms, while the shift toward Copepoda at higher elevations is consistent with their cold-tolerance adaptations and lower metabolic rates [2]. The July abundance peak across all elevations coincides with the monsoon onset, when increased nutrient runoff and warming stimulate primary production [1]. Water temperature emerging as the strongest CCA predictor is consistent with the known thermal sensitivity of zooplankton metabolism and reproduction [5]. As Himalayan glaciers retreat and meltwater contributions shift, these lakes may warm, potentially allowing lower-elevation taxa to colonize higher sites—a process already documented in European alpine lakes [9]. These baseline data are needed to detect such changes.

Conclusion

This research documented a strong negative relationship between zooplankton diversity and altitude across eight Himalayan glacial lakes in Sikkim. Species richness dropped from 24 taxa at 2,800 m to 7 at 4,200 m, with Shannon diversity declining nearly linearly. Water temperature, chlorophyll-a, and dissolved oxygen were the primary environmental drivers of community composition. The July abundance peak reflects monsoon-driven productivity across all elevations. These results establish a quantitative baseline for monitoring how ongoing glacial retreat and climate warming may reshape zooplankton communities in high-altitude Himalayan lakes.

Acknowledgements

Funding Sources

Internal research funds from the Sikkim Institute of Biological Sciences supported this work.

Institutional Support

The authors thank the Sikkim Institute of Biological Sciences for laboratory and field logistics support, and the Sikkim State Biodiversity Board for research permits.

Contributions Not Qualifying for Authorship

Local guides who provided access to remote high-altitude lake sites and porters who transported sampling equipment are gratefully acknowledged.

References

1. Mani MS. Ecology and Biogeography of High Altitude Insects. The Hague: Springer; 1968.
2. Sharma S, Sharma RC. Zooplankton diversity in Himalayan wetlands. *Research Journal of Environmental Sciences*. 2008;2(5):382-393.
3. Bhat NA, Wanganeo A, Raina R. Zooplankton assemblage in Dal Lake, Srinagar, Kashmir with regard to trophic status. *Journal of Ecology and the Natural Environment*. 2014;6(1):1-7.
4. Tartari GA, Tartari G, Mosello R. Water chemistry of high altitude lakes in the Khumbu and Imja Kola valleys (Nepalese Himalayas). *Memorie dell'Istituto Italiano di Idrobiologia*. 1998;57:51-76.
5. Manca M, Comoli P. Biomass estimates of freshwater zooplankton from length-carbon regression equations. *Journal of Limnology*. 2000;59(1):15-18.
6. Koste W. Rotatoria. Die Radertiere Mitteleuropas. Berlin: Gebruder Borntraeger; 1978.
7. Dussart BH, Defaye D. Introduction to the Copepoda. *Guides to the Identification of Microinvertebrates of Continental Waters of the World*. 2001;16:1-344.
8. APHA. Standard Methods for the Examination of Water and Wastewater. 23rd ed. Washington, DC: American Public Health Association; 2017.
9. Winder M, Schindler DE. Climatic effects on the phenology of lake processes. *Global Change Biology*. 2004;10(11):1844-1856.