Asian Journal of Environment & Ecology

Volume 23, Issue 9, Page 43-49, 2024; Article no.AJEE.122364
ISSN: 2456-690X

Diversity and Environmental Significance of Moss-Dwelling Testate Amoebae in Various Biotopes Around Nainital Lake, Uttarakhand

Bindu. L [a*] and V.M. Sathish Kumar [b]

[a] Western Ghat Regional Centre, Zoological Survey of India, Kozhikode-673006, India.
[b] Gangetic Plains Regional Centre, Zoological Survey of India, Patna, India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ajee/2024/v23i9596

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/122364

Original Research Article

Received: 12/06/2024
Accepted: 23/08/2024
Published: 28/08/2024

ABSTRACT

The present research aims to record the diversity of testate amoebae occurring in different biotopes around Nainital Lake, Uttarakhand, concerning distribution. Free-living, testate amoebae are single-celled protists with external shells and acting excellent bio-indicators of environmental changes. Collection of Tree, Rock and wall Moss samples was done at different locations around the Nainital Lake area from both the littoral zones and the terrestrial regions. The results show an impressive number of species of testate amoebae; 39 species of testate amoebae span over 11 genera and 8 families that all are new for the region and stress the role of some species in biomonitoring and evaluation of the condition of the environment in these peculiar biotopes. This study not only increases researcher's knowledge on the testate amoebae species distribution in Nainital Lake but

**Corresponding author: E-mail: bindulajapathi40@gmail.com;*

Cite as: *L, Bindu., and V.M. Sathish Kumar. 2024. "Diversity and Environmental Significance of Moss-Dwelling Testate Amoebae in Various Biotopes Around Nainital Lake, Uttarakhand". Asian Journal of Environment & Ecology 23 (9):43-49. https://doi.org/10.9734/ajee/2024/v23i9596.*

also contributes to the body of knowledge that would be useful for the ecological and environmental status of the area in the future. The outcomes of the research confirm the need for the conservation of the habitats in the area surrounding Nainital Lake to sustain the biodiversity and ecosystems of the region.

Keywords: Testate amoebae; protozoa; moss, Nainital; pollution indicator.

1. INTRODUCTION

Nainital is a hill station in the state of Uttarakhand located in the Kumaon region, often referred to as the “Lake District of India”. It is well-known for its picturesque beauty, calm waters of lakes and prosperity in bio-diversity. Locationally, Nainital stands at about 2,084 meters above sea level and is located in the Kumaon Hills, a part of the lesser Himalayas. The town is set around the Nainital Lake, a natural freshwater lake that covers approximately 48 hectares and with a maximum depth of 29 meters [1].

Geographically and climatically, the region is very peculiar with exciting flora and fauna and is especially important for ecological and environmental research. Various plant and animal life pertain to the habitats of Nainital which includes aquatic and terrestrial species [2]. This diversity is complemented by the presence of forests, alpine meadows, and various mosses and ferns, which creates suitable conditions for research on various microfauna, especially the testate amoebae.

Environmental conservation factors of Nainital are not restricted to its biological importance; it also has hydrological and climatological importance to the region. In actuality, the lake and its associated catchment area serve as a water supply for the water requirements of the town and nearby region, along with they control the micro-climate through evapotranspiration [3]. Based on these factors, Nainital is a significant natural laboratory for ecological and environmental studies concerning the need to conserve and manage Nainital’s natural resources sustainably. Moss-dwelling testate amoebae, a unique group of protists characterized by shell-like tests, are pivotal indicators of environmental conditions and play significant roles in microbial food webs and nutrient cycling [4]. These microorganisms are particularly abundant and diverse in mosses, where they utilizes the microhabitats provided by the dense mat of moss leaves and the associated microclimate [5]. The biotopes around Nainital Lake present a unique mosaic of habitats ranging from aquatic to terrestrial, creating ideal conditions for studying these amoebae. A comprehensive account of the moss-dwelling testate amoebae from this region remains sparse. So, this study aims to fill this gap by providing an account of the testate amoebae inhabiting various biotopes around Nainital Lake. The findings will contribute to the understanding of the biodiversity and ecology of testate amoebae in this region and offer insights into their potential as bioindicators for environmental monitoring and conservation efforts.

2. LITERATURE REVIEW

2.1 Testate Amoebae as Bioindicators

Testate amoebae, a diverse group within the phyla Tubulinea and Cercozoa, have shells called tests made of silicon oxide, chitin, or calcium carbonate [6,7]. Biochemical research has found that there are around seven hundred known species all over the world and the discovery is still added to the list day by day [8,9]. The available research on testate amoebae diversity in India has shown that the species of this group are diverse in various habitats, ranging from the freshwater ponds to the forest soils [10]. These organisms have essential functions in nutrient turnover and microbial networks of consumers, with their abundance and species richness varying with the local environment, the water content, acidity and nutrient concentrations [11].

Shelled protozoa such as testate amoebae can be met in various aquatic and terrestrial habitats and have been revealed to be useful in reflecting the conditions of an environment, especially in peatland, freshwater environments, and soils [12]. Due to their high degree sensitivity of moisture, pH, and other environmental changes, they can be used as an indicator of ecological changes [13]. Testate amoebae are of sensitivity to water quality, pollution and climate change parameters and is therefore used in paleo

reconstructions of water characteristics as well as in the current ecological state [14]. The existence, absence and variety of testate amoebae can indicate alterations in the conditions of the habitat, for instance hydrological characteristics or in the pollution level. For example, some species are adapted to acidic conditions while others to near neutral conditions hence the use of the species to deduce changes in pH and moisture levels over the years [15].

Free-living amoebae are known to have significant applications as bioindicators to show changes in the environment, especially as regards to the pollution status of water and land. These organisms, which are usually microscopic and have shelllike structures made of organic materials are known to be very sensitive to changes in water chemistry, nutrients and organic pollution [4,15]. For example, some species of *Arcella* genus can live well in water with low nutrient concentration but are affected by polluted water due to high heavy metals and organic pollutants [11]. Furthermore, the *Difflugia* species exhibited changes in community about eutrophication and change of sediment related to anthropogenic influence [16]. Such findings depict testate amoebae as bioindicators that could effectively show environmental alterations caused by pollution, hence being relevant in monitoring ecosystems and helping in the conservation of ecosystems. Besides being helpful in presentday environmental analysis, testate amoebae are also helpful in paleoecology. Fossils preserve their physical bodies, allowing their remains can be used to help study past conditions and thus long term changes in the climate and its effects on the ecological systems [17].

2.2 Global Diversity

The global distribution of testate amoebae is more than 675 species under 104 genera and 22 families including records from polar regions.

2.3 Diversity in India

In India 209 species belong to 37 genera under two classes and two orders of testate amoebae were recorded.

3. MATERIALS AND METHODS

The moss samples for the present study were collected from various biotopes around Nainital Lake (Fig.1) as part of the survey of the Western Himalaya by the Zoological Survey of India in October 2019. The samples were obtained from various biotopes like rocks, trees and walls around the lake (29° 23’ 02.94’’ N and 079° 27’ 21.42’’ E., Alt. 1940 m.) by scraping with a spatula into polythene bags and brought to the laboratory for further processing. The processing of samples followed the non-flooded petri dish method outlined by Foissner [18]. Subsequently, prepared permanent slide mounts from each sample and examined them

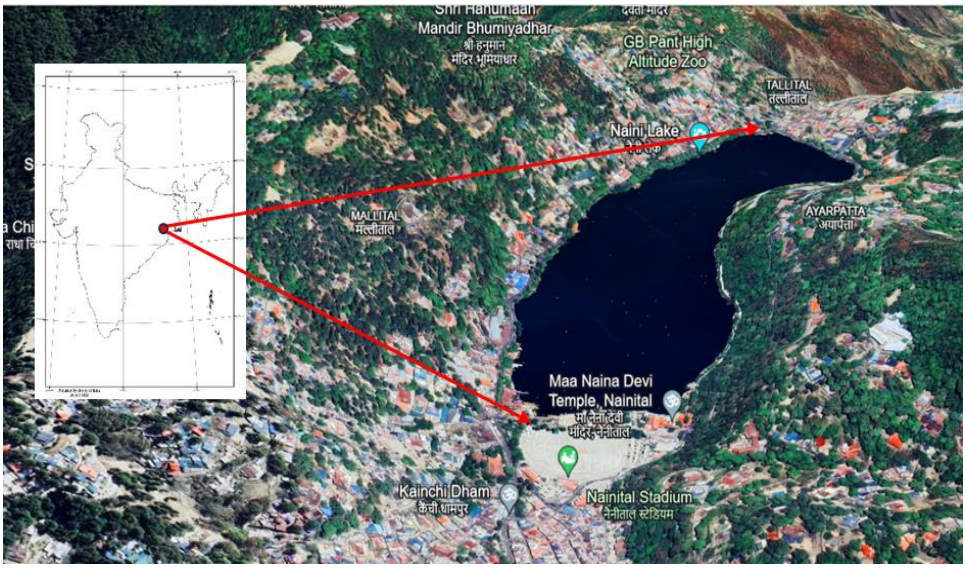

Fig. 1. Map of Nainital Lake: The Study Area (Source: Modified from Google Earth & SOI)

using compound microscopes equipped with a camera attachment for image capturing and species-level identification. All the registered permanent slides were deposited in the National Zoological collections of Marine Biology Regional Centre, Zoological Survey of India, Chennai.

4. RESULTS

The study yielded the records of 39 species of testate amoebae spaning over 11 genera and 8 families from various biotopes of mosses viz., tree, rock and wall (Fig.2). It is found that the maximum diversity of species was observed in Tree moss and the least diversity was in rock moss. Tree mosses hold most moisture content and the moisture regime of the habitat has a significant influence on the activity of the testate amoebae fauna and its population fluctuation [19].

4.1 Systematic list of Testate Amoebae around Nainital Lake: Findings from the Present Study (Classification as per Adl *et al*., 2019) [20]

Phylum Tubulinea Smirnov *et al*., 2005
Class Elardia Kang *et al*., 2017
Order Arcellinida Kent, 1880

Family Arcellidae Ehrenberg, 1843

1. *Galeripora catinus* (Penard, 1890) González-Miguéns *et al*., 2021

Family Netzeliidae Kosakyan et al., 2016

2. *Cyclopyxis arcelloides* (Penard, 1902) Deflandre, 1929
3. *Cyclopyxis arcelloides gibbosa* Van Oye, 1949
4. *Cyclopyxis eurystoma* Deflandre, 1929
5. *Cyclopyxis kahli* Deflandre, 1929 tree, wall

Incertae sedis

6. *Trigonopyxis arcula* Penard 1912

Family Difflugiidae Wallich, 1864

7. *Difflugia globulosa* (Dujardin, 1837) Penard, 1902
8. *Difflugia levanderi* Playfair, 1918

Family Centropyxidae Jung, 1942

9. *Centropyxis aculeata* (Ehrenberg, 1838) Stein, 1859
10. *Centropyxis aculeata grandis* Deflandre, 1929
11. *Centropyxis aculeata oblonga* Deflandre, 1929
12. *Centropyxis aerophila* Deflandre, 1929
13. *Centropyxis aerophila sphagnicola* Deflandre, 1929
14. *Centropyxis cassis* (Wallich, 1864) Deflandre, 1929
15. *Centropyxis constricta* (Ehrenberg, 1841) Penard, 1890
16. *Centropyxis laevigata* Penard, 1890
17. *Centropyxis minuta* Deflandre, 1929
18. *Centropyxis orbicularis* Deflandre, 1929
19. *Centropyxis platystoma* (Penard, 1890) Deflandre, 1929

***Incertae sedis* Arcellinida**

20. *Awerintzewia cyclostoma* Schouteden, 1906

Phylum Cercozoa Cavalier-Smith, 2018
Class Silicofilosea Adl *et al*., 2012
Order Euglyphida Cavalier-Smith, 1997
Family Assulinidae Lara *et al*., 2007

21. *Assulina muscorum* Greeff, 1888
22. *Assulina seminulum* (Ehrenberg, 1848)

Family Euglyphidae Lara *et al*., 2007

23. *Euglypha capsiosa* Coûteaux, 1978
24. *Euglypha ciliata* (Ehrenberg, 1848)
25. *Euglypha compressa* Carter, 1864
26. *Euglypha filifera* Penard, 1890
27. *Euglypha laevis* (Ehrenberg, 1845)
28. *Euglypha rotunda* (Ehrenberg, 1845)
29. *Euglypha simplex* Decloitre, 1965
30. *Euglypha strigosa* (Ehrenberg, 1848) Leidy, 1878
31. *Euglypha tuberculata* Dujardin, 1841

Family Trinematidae Adl *et al*., 2012

32. *Corythion asperulum* Schonborn, 1988
33. *Corythion dubium* Taranek, 1871
34. *Trinema complanatum* Penard, 1890
35. *Trinema enchelys* (Ehrenberg, 1838)
36. *Trinema grandis* (Chardez, 1960) Golemansky, 1963
37. *Trinema lineare* Penard, 1890
38. *Trinema penardi* Thomas & Chardez, 1958

Family Cyphoderiidae Saedeleer, 1934

39. *Cyphoderia ampulla* (Ehrenberg, 1840)

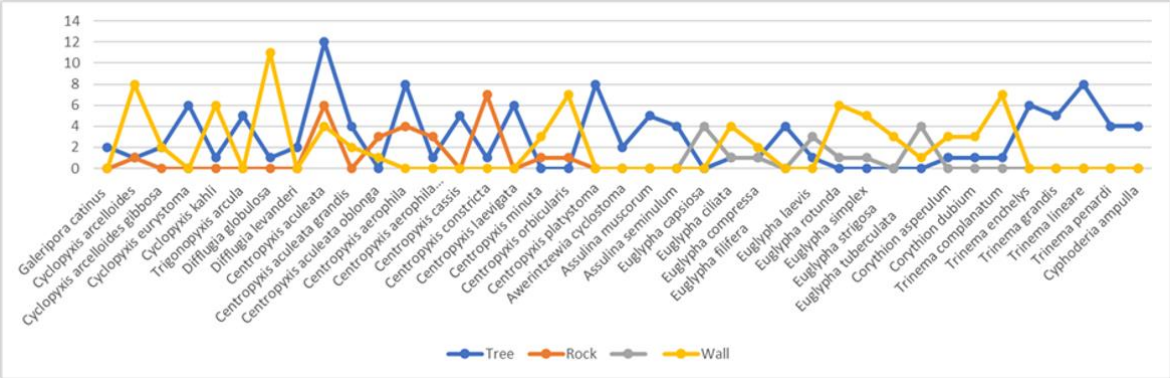

Fig. 2. Line chart showing moss dwelling testate amoebae from various biotopes around Nainital lake, Uttarakhand

5. CONCLUSION

In conclusion, by showcasing the beauty of the location marked by the Naini Lake and the nature around it, Nainital has undoubtedly benefitted the region's economy. This popularity also comes with increased environmental impacts to the extent that it is hard to sustain. The town's dependence on Naini Lake for both entertainment and domestic water requirements highlights the necessity to manage the problem of water pollution and water quality by controlling the impact of the pollutants generated by urbanization and modern agriculture.

The continued environmental impacts in Nainital are air pollution due to vehicle emission and industrial discharge, water pollution through untreated sewage discharge, and soil pollution through improper waste disposal which are threats to wildlife and human beings. Such problems require prompt and efficient steps to combat pollution and introduce rational management practices.

In this connection, the presence of testate amoebae dwelling in mosses offers a good chance of observing changes concerning the state of the environment. These microorganisms are susceptible to the changes in their environment, so they are widely used in signaling pollution and ecological changes [21]. Field studies have demonstrated that species in the genera, *Arcella* and *Difflugia* perform to changes in water chemistry and nutrient concentrations [21-23], which is an indication of overall environmental conditions. In the present study, the abundance of *Centropyxis aculeata* in tree moss indicates higher level of organic pollution in the lake area which supports the studies of Olivia [24].

Further research should be conducted on testate amoebae to develop more precise site-specific research concerning the function of these organisms in ecological assessment, especially in disturbed habitats influenced by people. Therefore, by incorporating such microhabitat-specific studies, it will be possible to understand better the environmental processes of such delicate mountain ecosystems as Nainital Lake and improve the chances of their protection and further use.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (Chat GPT, COPILOT etc.) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENTS

The authors are thankful to the Director, Zoological Survey of India, Kolkata for approving the project for the present study and also grateful to the officials of Uttarakhand Forest Department for granting permission to collect the moss samples for the study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Joshi JC, Joshi DR, Dani DD. Kumaun Himalaya: A geographic perspective on

resource development. The University of Michigan. Gyanodaya Prakashan. 1983;324.
2. Semwal, R.L. and Mehta, J.P. Ecology of forest fires in Chir pine (Pinus roxburghii Sarg.) forest of Garhwal Himalaya.1996; *Current Science*, 70(6): 426-427.
3. Rajput V, Jong TF, NEGI RK, Hydrological study of Naini lake (Nainital), India. J.Flora and Fauna. 2009;15(1):83-86.
4. Mitchell EAD, Charman DJ, Warner BG, Wilmshurst JM. Testate amoebae as environmental and climate indicators in peatland studies. In: Mitchell, EAD, Charman DJ. (Eds.), Testate Amoebae in Peatlands: Past and Present. Developments in Earth Surface Processes. 2008;11: 1-30.
5. Baynes L, Chardez D. An annotated list of testate amoebae observed in the Arctic between the longitudes 27° E and 169° W. Archiv für Protistenkunde.1995;146(3-4): 219-233.
6. Lara E, Heger TJ, Mitchell EAD. Recent progress in the taxonomy of testate amoebae (order Arcellinida Kent, 1880) (Protista): new scales from Venezuela. European Journal of Protistology. 2007;43(1):37-52.
7. Kosakyan A, Heger TJ, Leander BS, Todorov M, Mitchell EAD, Lara E. COI barcoding of neotropical freshwater testate amoebae (Arcellinida): diversity assessment and insights into the genetic structure of Arcellinida. Protist. 2016;167(6):523-536.
8. Bobrov A, Mazei Y, Lahr DJG. The new family Paramphitrematidae nov.fam. and two new species of amphitrematid testate amoebae (Arcellinida, Tubulicorythida) from Russia and Scotland. *Protistology*. 2017;11(3):148-160.
9. Mitchell EAD, Charman DJ, Warner BG. Testate amoebae analysis inecological and paleoecological studies of wetlands: past, present and future. Biodiversity and Conservation. 2015;17(2):211-230.
10. Bobrov A, Todorov M, Kosakyan A, Mitchell EAD. The diversity anddistribution of testate amoebae in the Eastern Ghats of India. European Journal of Protistology.2018;64:69-80.
11. Heger TJ, Mitchell EAD, Overpeck JT. Climatic and environmental controls on testate amoebae in tropical South America over the Last Glacial-Interglacial Transition. Quaternary Science Reviews. 2018;188:161-175.
12. Charman DJ. Biostratigraphic and paleoecological applications of testate amoebae. *Quaternary* Science Reviews. 2001;20(16):1753-1764.
13. Anna Simova, Martin jirousek, patricia singh, petra hajkova and michal hajek. ecology of testate amoebae along an environmental gradient from bogs to calcareous fens in east-central Europe: development of transfer functions for palaeoenvironmental reconstructions, Palaeogeography, *Palaeoclimatology,* Palaeoecology. 2022;60:111-145. ISSN 0031-0182 Available:https://doi.org/10.1016/j.palaeo.111145.
14. Bobrov A, Charman DJ, Warner BG. Ecology of testate amoebae (Protozoa: Rhizopoda) on peatlands in western russia with special attention to niche separation inclosely related taxa. Protist.1999;150(2):125-136.
15. Jassey VE, Signarbieux C, Hättenschwiler S, Bragazza L, Buttler A, Delarue F, Mitchell EAD. An unexpected role for mixotrophs in the response of peatland carbon cycling to climate warming. Scientific Reports.2 013;3:23-54.
16. Wilkinson DM, Mitchell EAD, Wilkinson GM, Richards K. The response of testate amoeba communities to changes in land use and vegetation over the past 500years. Journal of Biogeography. 2019;46(7):1362-1375.
17. McCarthy FMG, Collins ES, McAndrews JH, Kerr HAA Comparison of postglacial arcellacean (Thecamoebian) and pollen succession in Atlantic Canada, illustrating the potential of arcellaceans for paleoclimatic reconstruction. Journal of Paleontology. 1995;69(5):980-993.
18. Foissner W. Estimating the species richness of soil protozoa using non-flooded petridish method. In protocols in protozoology. Lee, J.J and Soldo,A.T.(eds), Allen Press; 1992.
19. Smith HG. Distribution and ecology of the testate rhizopod fauna in continental Antarctic zone. Polar Biol. 1992;12:629-634.
20. Adl SM, Bass D, Lane CE, Lukes J, Schoch CL, Smirnov A. Revisions to the classification, nomenclature, and diversity

of eukaryotes. Journal of Eukaryotic Microbiology. 2019;66: 4–119.

21. Patterson RT, Kumar A. A review of current testate rhizopod (thecamoebian)research in Canada. Palaeogeography, palaeoclimatology, palaeoecology. 2002; 180(1-3):225-251. Available:https://doi.org/10.1016/S0031-0182(01)00430-8.
22. Yang J, Zhang W, Shen Y. Response of testate amoebae (Difflugia: oblonga) to different levels of pollution in freshwater ecosystems. Environmental Pollution. 2010;158(2):287-294. Available:https://doi.org/10.1016/j.envpol.2009.08.026
23. Mitchell EAD, Gilbert D. Vertical micro-distribution and response to nitrogen deposition of testate amoebae in Sphagnum. Journal of Eukaryotic Microbiology. 2004;51(4):480-490. Available:https://doi.org/10.1111/j.1550-7408.2004.tb00400.x
24. Olivia Kuuri-Riutta, Minna Valiranta, Eeva-Stiina Tuittila.Literature review on testateamoebae as environmental indicators and as a functional part of the microbial community in northern peatlands, Mires and Peat. 2022;28:Article 28:16. Available:http://www.mires-and-peat.net/, ISSN 1819-754X, International Mire Conservation Group and International Peatland Society, DOI: 10.19189/MaP.2022.OMB.StA.2412

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/122364