



# Microfauna Hidden in Moss: First Report of Testate Amoebae from Bhimbandh Wildlife Sanctuary, Bihar, India

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## Authors' contributions

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

Moss associated testate amoebae of Bhimbandh Wildlife Sanctuary in Bihar are yet to be reported from the literature. Therefore, this article serves as the initial attempt to document and evaluate the state of species richness of testate amoebae in this sanctuary. Testate amoebae belong to the single celled organisms classified under protist fauna characterized by developing complex covering of outer chitin shells; they are renowned as bio indicators owing to their high reactivity to any changes in the environment. In September 2024, moss samples were taken from the sanctuary in a faunal survey to assess the diversity of testate amoebae in moss environments. Upon

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analysing these samples 17 species of testate amoebae span over 6 genera and 6 families were found during this preliminary investigation. These findings constitute new records for Bhimbandh Wildlife Sanctuary in Bihar and highlight the importance of moss as a critical habitat for these species.

**Keywords:** *Testate amoebae; protozoa; moss; Bhimbandh wildlife sanctuary; pollution indicator.*

## 1. INTRODUCTION

The worlds of microscopic organisms living in moss ecosystems are explored in this article. Testate amoebae, unicellular protozoans enclosed in protective shells are valuable bioindicators of environmental conditions. This study documents for the first time this microfauna in Bhimbandh Wildlife Sanctuary, a part of the rich biodiversity of Bihar, India. The research examines moss samples from a variety of microhabitats to determine the diversity and ecological importance of testate amoebae, providing a new view of the biological heritage of the sanctuary's lesser-known organisms.

Bhimbandh Wildlife Sanctuary (BWS) is in the Munger district in Bihar, India and covers an area of 681.99<sup>2</sup> kms. It is located within the geographical position of 24°50 'to 25°10 'north latitude and 86°15 'to 86°30 'eastern longitude. The task of creating this sanctuary was initiated in the year 1976 and is considered as an important bio diverse region located in the Rajgir hills of Kharagpur range [1].

BWS is popular for its diverse vegetation and wildlife, it is most famous for its hot springs and numerous tracts of ecosystems that host many species of mammals, birds and reptiles besides many groups of Insects. BWS has a significant role in wildlife protection and is a very crucial wildlife avenue that links other forests in Bihar. As a sanctuary, it has an inherent ecological value for both conservation and ecotourism purposes, which has been recognised by the Ministry of Environment, Forest and Climate Change, Government of India. The contrasting environmental conditions in India ranging from alpine to tropical forest provide a suitable background for the study of testate amoebae in different habitats throughout India. But scientific studies on testate amoebae in many wildlife sanctuaries of India are still limited or unexplored. Majority of works have focused on areas of moderate or high altitude, for example the Western Ghats or the Himalayas, whereas tropical areas like those present in BWS, Bihar, remain poorly investigated in terms of testate amoebae diversity.

While the diversity of testate amoebae has been documented in various states and eco-regions across India, only a few preliminary studies have been conducted in Bihar [2] leaving significant gaps in understanding their distribution and ecological roles in the region. Particularly, their presence and diversity within the wildlife sanctuaries and national parks of Bihar remain largely unexplored, highlighting the need for focused research in these ecologically significant areas.

Shelled protozoa specifically testate amoebae are the species that occupy large numbers of habitats. They are very susceptible to ecological alterations [3] and are therefore good biomarkers to ecological variations because of their short generation intervals [4,5,6]. These organisms are found in different parts of the world and from tropical to polar regions and from land to sea water environments. Due to their ability to respond to changes in moisture, pH, and other factors in the environment they are used as indicators of ecological change [7]. Testate amoebae also depend on the water quality, pollution, and climate change parameters and therefore are applied for paleo- reconstructions of past water conditions and contemporary ecological status [8,9,10,11]. A diverse group of shelled protozoa (testate amoebae) are essential to ecosystem functioning, especially in soil and aquatic microhabitats. Because of their sensitivity to changes in the environment, these protists are also important as bioindicators and play an essential role in nutrient cycling and decomposition of organic material [12]. There has been a well documented association of testate amoebae with mosses, as moss microhabitats provide moist, nutrient rich environments in which they can survive and reproduce. Besides enriching the microfauna diversity, these moss layers also create microecosystems that support complex food webs, that way microbial communities are linked with higher trophic levels [13].

This study is the first to report the diversity of testate amoebae within BWS within the moss-dominated microhabitats. By documenting these

protozoan species, this research enhances our understanding of testate amoebae distribution in tropical ecosystems and underscores their ecological roles within moss communities [3]. Furthermore, insights into their diversity contribute to the broader biogeographical understanding of protozoa across India's varied landscapes, highlighting the importance of conserving microhabitats in tropical sanctuaries. Therefore, this work is an attempt to carry out preliminary assessment of testate amoebae in BWS as they are ecologically important. Thus, the faunal diversity of the given area has been expanded by studying 17 species, 6 genera, and 6 families. Furthermore, given the high level of pollution in Bihar, it should also be mentioned that testate amoebae are considered to be sensitive organisms that can reflect the changes in the environment that is why they can be used as bioindicators of the ecological state of the area. Future work on the protozoan taxonomy could be very useful in monitoring and management of the environment in the state.

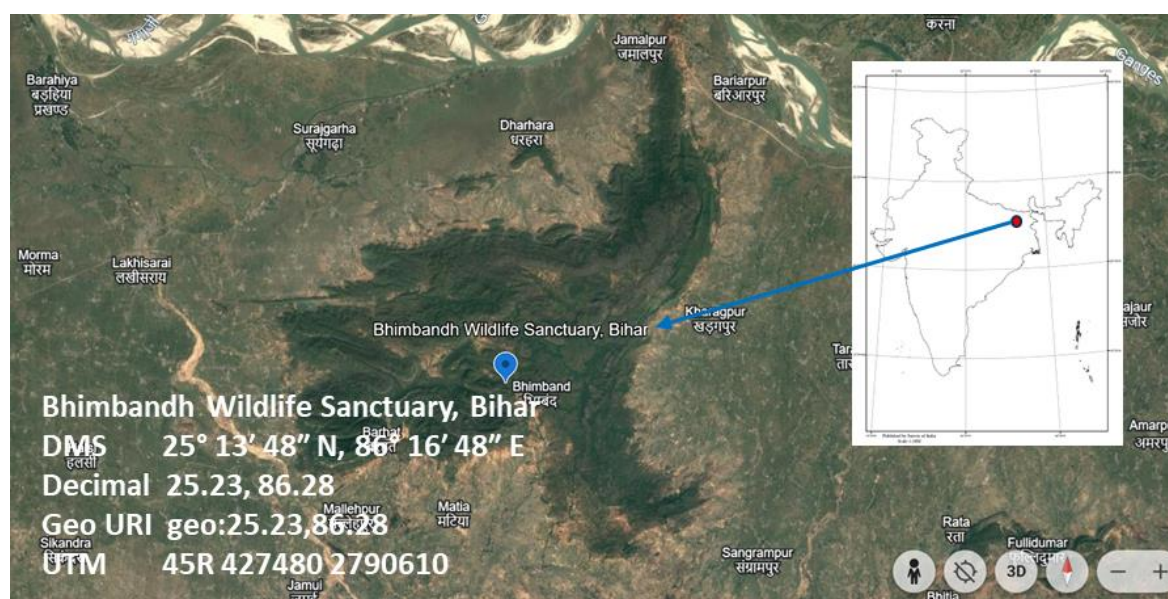
## 2. GLOBAL AND INDIAN DIVERSITY OF TESTATE AMOEBAE

Free living amoebae also show a high degree of world distribution with 675 plus species belonging to 104 genera and 22 families and with records from the polar areas. In India this diversity is reflected in the distribution of 209 species belonging to 37 genera classified under two classes and two orders [14]. This wide

dispersal underlines the versatility of testate amoebae and these organisms' role as bioindicators, as they are found in polar ice and other places in India as well as other environments.

## 3. MATERIALS AND METHODS

The moss samples for the present study were collected on 28<sup>th</sup> September 2024 as part of a faunal survey program within the BWS in Bihar. The samples were obtained from soil (Map. 1; 25.01.109° N and 86.42.022° E) 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 [15]. A portion of the moss sample collected from soil is placed in a Petri dish, spread out in a thin layer. A small amount of distilled water is added to moisten the sample without flooding it, ensuring the water only saturates the material and mimics natural microhabitats. The sample is then incubated at room temperature for a few hours or overnight, allowing microorganisms to become active. Subsequently, permanent slide mounts were prepared from each sample and examined using Labomed (Lx 400) microscopes equipped with a Sony CMOS camera attachment for image capturing and species-level identification. All the registered permanent slides were deposited in the National Zoological collections of Gangetic Plains Regional Centre, Zoological Survey of India, Patna.



Map 1. Study area, Bhimbandh Wildlife Sanctuary (BWS) in Bihar (Source: SOI & Google Earth)

#### 4. RESULTS AND DISCUSSION

The study yielded the following new records to Bhimbandh Wildlife Sanctuary, Bihar belonging to 17 species of testate amoebae span over 6 genera and 6 families during this preliminary investigation.

Systematic list of Testate Amoebae from BWS, Bihar: Findings from the present study (Plate 1) (Classification as per Adl et al., 2019) [16,17]  
Domain Amorphea Adl et al., 2012  
Supergroup Amoebozoa Lühe, 1913, sensu Cavalier-Smith, 1998  
Phylum Tubulinea Smirnov et al., 2005  
Class Elardia Kang et al., 2017  
Order Arcellinida Kent, 1880  
Family Netzeiliidae Kosakyan et al., 2016

##### 1. *Cyclopyxis arcelloides* (Penard, 1902) Deflandre, 1929

1902. *Centropyxis arcelloides* Penard, *Faune Rhizopodique du bassin du Léman*, Geneve, p. 309.

1929. *Centropyxis* (*Cyclopyxis*) *arcelloides* Deflandre, *Arch. Protistenkd.*, 67, p.367.

*Distribution*: India: Andhra Pradesh, Arunachal Pradesh, Himachal Pradesh, Kerala, Manipur, Meghalaya, Mizoram, Odisha, Sikkim, Tamil Nadu, Uttar Pradesh, Uttarakhand, West Bengal, Chandigarh, Punjab, Bihar

*Remarks*: Present record from BWS, Bihar

##### 2. *Cyclopyxis eurystoma* Deflandre, 1929

1929. *Centropyxis* (*Cyclopyxis*) *eurystoma* Deflandre, *Arch. Protistenkd.*, 67: 370.

*Distribution*: India: Arunachal Pradesh, Assam, Himachal Pradesh, Kerala, Maharashtra, Nagaland, Tamil Nadu, Telangana, Uttarakhand, West Bengal, Punjab, Bihar

*Remarks*: Present record from BWS, Bihar

##### 3. *Cyclopyxis kahli* Deflandre, 1929

1929. *Centropyxis* (*Cyclopyxis*) *kahli* Deflandre, *Arch. Protistenkd.*, 67:371.

*Distribution*: India: Himachal Pradesh, Kerala, Tamil Nadu, Uttarakhand, Bihar

*Remarks*: Present record from BWS, Bihar  
Family Phryganellidae Jung, 1942

##### 4. *Phryganella acropodia* (Hertwig & Lesser, 1874)

1909. *Phryganella acropodia* Hopkinson, *The British Freshwater Rhizopoda and Heliozoa*, 2: 74, pl.20, Figs.13-14.

*Distribution*: India: Himachal Pradesh, Sikkim, Tamil Nadu, Telangana, Uttarakhand, Punjab, Bihar

*Remarks*: Present record from BWS, Bihar  
Family Diffugiidae Wallich, 1864

##### 5. *Diffugia globulosa* (Dujardin, 1837) Penard, 1902

1837. *Diffugia globulosa* Dujardin, *Ann. Sci. nat. Zool.* (2) 8: 310, pl. 9. Fig. 1.

1902. *Diffugia globulosa* Penard, *Faune Rhizopodique du Bassin de Leman*. Geneve: Kundig, pp.714.

*Distribution*: India: Andhra Pradesh, Assam, Himachal Pradesh, Meghalaya, Odisha, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, Punjab, Bihar

*Remarks*: Present record from BWS, Bihar  
Family Centropyxidae Jung, 1942

##### 6. *Centropyxis aerophila* Deflandre, 1929

1929. *Centropyxis aerophila* Deflandre *Arch. Protistenkd.*, 67:330.

*Distribution*: India: Andhra Pradesh, Arunachal Pradesh, Himachal Pradesh, Kerala, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Sikkim, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, Uttarakhand, West Bengal, Chandigarh, Punjab, Bihar

*Remarks*: Present record from BWS, Bihar

##### 7. *Centropyxis aculeata* (Ehrenberg, 1838) Stein, 1859

1958. *Centropyxis aculeata minima* Van Oye, *Etude sur les Rhizopodes des marais du-ouest d'Uvira (Congo-belge)*, *Hydrobiologia*, 10:85-137.

*Distribution* : India : Andhra Pradesh, Arunachal Pradesh, Assam, Himachal Pradesh, Kerala, Maharashtra, Meghalaya, Mizoram, Nagaland, Odisha, Rajasthan, Sikkim, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, Uttarakhand, West Bengal, Chandigarh, Bihar

*Remarks*: Present record from BWS, Bihar

##### 8. *Centropyxis ecornis* (Ehrenberg, 1841)

1841. *Arcella ecornis* Ehrenberg, *Abh. Akad. Wiss. Berlin*, p. 368.

1879. *Centropyxis ecornis* Leidy, *Freshwater Rhizopods of North America*, pl.30, Figs. 20-24.

*Distribution*: India: Andhra Pradesh, Arunachal Pradesh, Assam, Himachal Pradesh, Kerala, Maharashtra, Meghalaya, Nagaland, Odisha, Sikkim, Tamil Nadu, Telangana, Uttar pradesh, Uttarakhand, West Bengal, Punjab, Bihar

*Remarks*: Present record from BWS, Bihar

##### 9. *Centropyxis kurakchayensis* Snegovaya and Alekperov, 2005

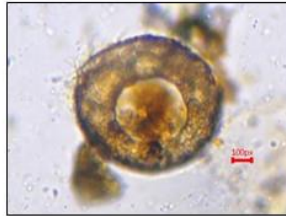
2005. *Centropyxis kurakchayensis* Snegovaya Alekperov, *Protistology* 4(2) : 149-183.

*Distribution*: India: Kerala, Bihar

*Remarks*: Present record from BWS, Bihar

##### 10. *Centropyxis platystoma* (Penard, 1890) Deflandre, 1929

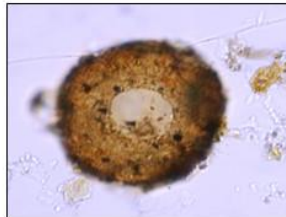
1929. *Centropyxis platystoma* Defalndre, *Arch. Protistenkd.*, 67: 338.



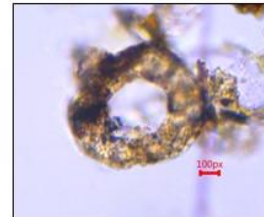
1. *Cyclopyxis arcelloides*  
(Penard, 1902) Deflandre, 1929



2. *Cyclopyxis eurystoma*  
Deflandre, 1929



3. *Cyclopyxis kahli*  
Deflandre, 1929



4. *Phryganella acropodia*  
(Hertwig & Lesser, 1874)  
Hopkinson, 1909



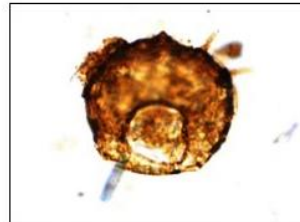
5. *Diffugia globulosa*  
(Dujardin, 1837) Penard, 1902



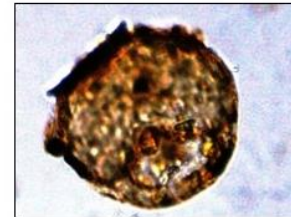
6. *Centropyxis aerophila*  
Deflandre, 1929

**Plate 1a**





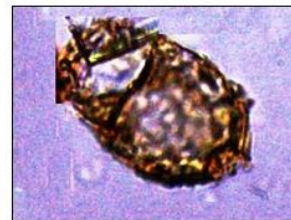
7. *Centropyxis aculeata*  
(Ehrenberg, 1838) Stein, 1859



8. *Centropyxis ecornis*  
(Ehrenberg, 1841)



9. *Centropyxis kurakchayensis*  
Snegovaya and Alekperov, 2005



10. *Centropyxis platystoma*  
(Penard, 1890) Deflandre, 1929



11. *Euglypha capsiosa*  
Coûteaux, 1978

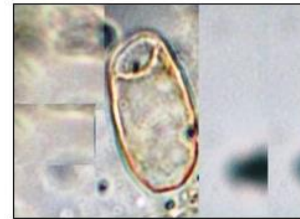


12. *Euglypha rotunda*  
(Ehrenberg, 1845)

Plate 1b



13. *Euglypha laevis* (Ehrenberg, 1845)



14. *Trinema enchelys* (Ehrenberg, 1838)



15. *Trinema lineare*  
Penard, 1890



16. *Trinema complanatum*  
Penard, 1890



17. *Trinema galeata* Jung, 1942

**Plate 1c**

**Plate 1. a, b & c Microphotographs of Testate Amoebae from BWS, Bihar**

**Distribution:** India: Andhra Pradesh, Arunachal Pradesh, Assam, Himachal Pradesh, Kerala, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal, Chandigarh, Punjab, Bihar

**Remarks:** Present record from BWS, Bihar  
Phylum Cercozoa Cavalier-Smith, 2018  
Class Silicofilosea Adl et al., 2012  
Order Euglyphida Cavalier-Smith, 1997  
Family Euglyphidae Lara et al., 2007

#### **11. *Euglypha capsiosa* Coûteaux, 1978**

1978. *Euglypha capsiosa* Coûteaux, *Journal of protozoology*, 25: 50A

**Distribution :** India: Kerala, Tamil Nadu, Bihar

**Remarks:** Present record from BWS, Bihar

#### **12. *Euglypha rotunda* (Ehrenberg, 1845)**

1911. *Euglypha rotunda* Wailes and Penard, *Proc. R. Irish Acad.*, 31: 60-62.

**Distribution:** India: Himachal Pradesh, Kerala, Maharashtra, Odisha, Telangana, Tripura, Uttarpradesh, Uttarakhand, Punjab, Bihar

**Remarks:** Present record from BWS, Bihar

#### **13. *Euglypha laevis* (Ehrenberg, 1845)**

1845. *Euglypha laevis* Ehrenberg, *Ber. Akad., Berlin*, p. 307.

1849. *Euglypha laevis* Perty, *Mitth. nat. Ges. Bern.*, p. 163

**Distribution:** India: Himachal Pradesh, Kerala, Maharashtra, Odisha, Telangana, Uttar Pradesh, Uttarakhand, Bihar

**Remarks:** Present record from BWS, Bihar  
Family Trinematidae Adl et al., 2012

#### **14. *Trinema enchelys* (Ehrenberg, 1838)**

1890. *Trinema lineare* Penard, *Mem. Soc. Geneve*, 31: 187, pl. 11. Figs. 5-17.

1915. *Trinema lineare* Cash, Wailes and Hopkinson, *Ray. Soc. Publ. London*, 3: 91, pl. 47, Figs. 11-21.

**Distribution:** India: Andhra Pradesh, Assam, Himachal Pradesh, Kerala, Maharashtra, Odisha, Sikkim, West Bengal, Bihar

**Remarks:** Present record from BWS, Bihar

#### **15. *Trinema lineare* Penard, 1890**

1890. *Trinema lineare* Penard, *Mem. Soc. Geneve*, 31: 187, pl. 11. Figs. 5-17.

1915. *Trinema lineare* Cash, Wailes and Hopkinson, *Ray. Soc. Publ. London*, 3: 91, pl. 47, Figs. 11-21.

**Distribution:** India: Andhra Pradesh, Arunachal Pradesh, Assam, Himachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Tripura, Uttarpradesh, Uttarakhand, Chandigarh, Punjab, Bihar

**Remarks:** Present record from BWS, Bihar

#### **16. *Trinema complanatum* Penard, 1890**

1890. *Trinema complanatum* Penard, *Mem. Soc. Geneve*, 31: 187, pl.10, Figs. 1-4.

**Distribution:** India: Andhra Pradesh, Arunachal Pradesh, Himachal Pradesh, Kerala, Meghalaya, Mizoram, Nagaland, Sikkim, Uttar Pradesh, Uttarakhand, Punjab, Bihar

**Remarks:** Present record from BWS, Bihar

#### **17. *Trinema galeata* Jung, 1942**

1942. *Corythion constricta* Jung, *Archv für Protistenkunde*, 95 (3): 253-356.

**Distribution :** India: Himachal Pradesh, Meghalaya, Bihar

**Remarks:** Present record from BWS, Bihar

## **5. CONCLUSION**

Moss-associated testate amoebae are most helpful for studying changes to the environment because mosses tend to grow in wet or in moist habitats. They also adapt quickly to changes in their environment, and hence are ideal as pollution and other ecological changes as biomarkers [18,19]. This makes their study invaluable especially in these un-investigated ecosystems like wildlife sanctuaries and national parks in Bihar. It is therefore critical to gain knowledge of the distribution and spacial heterogeneity of protozoans, especially testate amoebae, in these ecosystems due to rising effects of climate change and human activities. Commensurate with the responses they give to communities of these small organisms, they give prime data on major environmental issues, as such constituting significant importance in the field of biodiversity and ecosystems.

In the present study, it proposed to evaluate the health and overall states of ecosystems in Bihar and other regions through the species richness of testate amoebae. These organisms, which are now well documented to inhabit both terrestrial and aquatic environments, serve as baseline biomarkers, providing essential information for the assessments and inventory of ecosystems while also contribute new distributional records of species.

Therefore, on the basis of the current state of knowledge about testate amoebae present within the Bhimbandh Wildlife Sanctuary and other protected regions of Bihar, targeted, extensive site-specific research are required. Such inquiries should address their function on overseeing of ecological condition, equitable in areas that have felt the influence of human beings. Thus, the microhabitat-centered studies



will contribute to improving our understanding of the ecological mechanisms, approximating efficiency of the protected area network, and providing directions for the sustainable use of these unique environments.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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