ГІДРОЕКОЛОГІЧНІ ДОСЛІДЖЕННЯ

UDK 574

A. Farooqui

FRESH WATER THECAMOEBIANS: ECOLOGICAL INDICATORS OF SEASONALLY INDUCED HYDROLOGICAL CHANGES IN LAKES

Birbal Sahni Institute of Palaeobotany, India

The data available for thecamoebians as environmental indicators in ecological perspective is scarce from India. The sediment collected from five lakes in the outskirts of Lucknow city, India was studied for thecamoebian response to winter (November) and summer (May) climatic conditions. About 11 species were recovered from these lakes and could be segregated into Type-I and Type-II. During winters Type-I shows dominance of *Centropyxis aculeata, C. arcelloides, Arcella vulgaris, A. discoides, Difflugia oblonga, Difflugia gramen* which are adapted to high dissolved oxygen (DO), normal pH and low salinity in November along with the aquatic weed *Lemna* in its exponential phase of growth. The above thecamoebians succumb to hydrological changes during May when the air temperature increases to about 46° Celsius, pH and salinity also increase and DO of water decreases to as low as 5 mg/l. Subsequently, the growth of *Lemna* ceases during this period and the weed detritus settles in the lake. Under such conditions the dominance of Type-II comprised of *Difflugia protaeiformis, Trigonopyxis arcula, Amphitrema flavum, A. stenostoma and Trinema* spp. increase in number indicating its tolerance and adaptability. It is suggested that these species are detrivorous and DO plays a major role in defining the susceptibility and tolerance of *Centropyxis aculeata* and *Amphitrema stenostoma.* While Type-I are the indicators of high DO, the Type-II are useful microbes that help in cleaning the aquatic detritus essential for maintaining the trophic level of natural lakes.

Keywords: ecology, lake, thecamoebians, Lucknow, India.

А. Фарооки

Институт палеоботаники Бирбал Сахни, Индия

АМЕБЫ СЕМЕЙСТВА *THECAMOEBIDAE*, ЖИВУЩИЕ В ПРЕСНОЙ ВОДЕ, КАК ЭКОЛОГИЧЕСКИЕ ИНДИКАТОРЫ ПРИ ИЗУЧЕНИИ СЕЗОННЫХ ГИДРОЛОГИЧЕСКИХ ИЗМЕНЕНИЙ ОЗЕР

Исследования амеб семейства *Thecamoebidae* в качестве индикаторов окружающей среды до сих пор не получали широкого распространения в Индии. Данная работа является одной из первых, посвященных этому подходу. В качестве исходных данных взяты пробы осадков пяти озер, расположенных вблизи города Лакнау (Индия). Целью изучения стала активность амеб, живущих в отобранных образцах, в зимнее и летнее время (ноябрь и май). В ходе работ было установлено 11 видов амеб, которые условно разделили на два типа – 1-й и 2-й. К представителям 1-го типа относятся *Centropyxis aculeata, C. arcelloides, Arcella vulgaris, A. discoides, Difflugia oblonga, Difflugia grame*, а также водоросли *Lemna*, к представителям 2-го типа – *Difflugia protaeiformis, Trigonopyxis arcula, Amphitrema flavum, A. stenostoma* и *Trinema*. Результаты исследований показали, что амебы 1-го типа могут служить индикаторами уровня растворенного кислорода, а амебы 2-го типа – использоваться для борьбы с детритами и соответственно для поддержания трофического уровня естественных озер.

Ключевые слова: экология, озера, амебы семейства Thecamoebidae, Лакнау, Индия.

А. Фароокі

Інститут палеоботаніки Бірбал Сахні, Індія

АМЕБИ РОДИНИ *THECAMOEBIDAE*, ЯКІ МЕШКАЮТЬ У ПРІСНІЙ ВОДІ, ЯК ЕКОЛОГІЧНІ ІНДИКАТОРИ ПРИ ВИВЧЕННІ СЕЗОННИХ ГІДРОЛОГІЧНИХ ЗМІН ОЗЕР

Дослідження амеб родини *Thecamoebidae* як індикаторів навколишнього середовища до цього часу не отримали широкого розповсюдження в Індії. Дана робота є однією з перших, присвячених цьому підходу. Як вихідні дані прийнято проби осадів п'яти озер, які розташовані поблизу міста Лакнау (Індія). Метою дослідження стала активність амеб, які знаходилися в одібраних зразках, у зимовий та літній час (листопад та травень). У холі роботи було встановлено 11 видів амеб, які умовно поділили на два типи – 1-й та 2-й. До представників 1-го типу належать *Centropyxis aculeata, C. arcelloides, Arcella vulgaris, A. discoides, Difflugia oblonga, Difflugia grame*, а також водорості *Lemna*, до представників 2-го типу – *Difflugia protaeiformis, Trigonopyxis arcula, Amphitrema flavum, A. stenostoma* та *Trinema*. Результати досліджень показали, що амеби 1-го типу можуть слугувати індикаторами рівня розчиненого кисню, а амеби 2-го типу – використовуватися для боротьби з детритами і відповідно для підтримання трофічного рівня природних озер.

Ключові слова: екологія, озера, амеби родини Thecamoebidae, Лакнау, Індія.

Thecamoebians (testate amoeba) are a diverse group of testate rhizopods living in aquatic to moist habitats and occur commonly worldwide in a variety of freshwater, slightly brackish environments and salt marshes (Medioli and Scott, 1988; Patterson and Kumar, 2002; Charman et al., 2002). Studies of testate amoebae are reported from Canada, Europe, Africa and China etc. (Kumar and Dalby,1998; Yang, Shen, 2005; Lahr and Lopes, 2006), South America (Vucetich, 1978), Brazil (Lansac-Toha et al., 2001). Environmental tolerances of testate amoeba in different regions have been studied (Booth and Zygmunt 2005). Very few records of past and present testate amoebae are available from India (Rao, H.S.M. 1928; Nair, & Mukherjee, 1968; Mishra and Saksena, 1990; Das and Chattopadhyay, 2003; Farooqui & Gaur, 2007). The knowledge of testate amoeba ecology is limited from India where the fresh water ecosystems are seasonally subjected to limnological changes induced by extreme conditions of temperature, humidity and precipitation in the central and north-central part. The present work documents the seasonal fluctuation of thecamoebians responding to dissolved oxygen, pH and salinity in Lake Ecosystem.

DESCRIPTION OF THE STUDY SITE

The study area is located in nearby Lucknow city which falls in the north-central alluvial plains of India (Fig. 1). The area is subjected to three extreme seasonal conditions such as summer, rainy and winter characterized by maximum 46°C in summers and minimum 6°C in winters. The average atmospheric temperature in rainy seasons remain ~28°C. All the five lakes were shallow with water level not exceeding more than a meter in the centre covering an area of about 300 to 400 square meters in November (average atmospheric temperature- 18°C). However, the lakes shrinked to about half a diameter in May (average atm. temp. 34°C and low precipitation-100-150mm). During July and August (average atm. temp. 28°C) due to maximum precipitation (350-400mm) the lake area increases and the nutrients drain into it from nearby areas (sodic and agriculture land

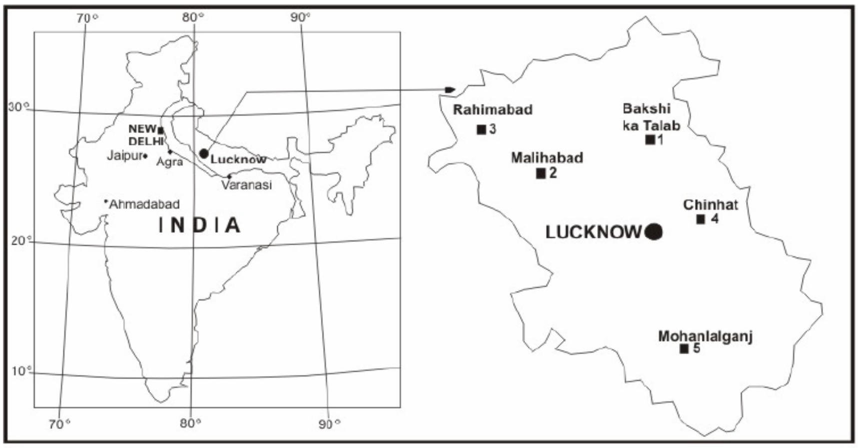

Fig.1: Location Map of lucknow and nearby studied lakes (1-5)

including anthropogenic input). During the rainy season (July-Aug-September) begins the onset of exponential growth phase of *Lemna* (duckweed) which continues until January showing its maximum cover in the lake surface during November and December. From January onwards, probably, due to exhaustion of lake nutrients the propagation of *Lemna* fronds start declining. Gradually, the brownish *Lemna* fronds appear on the surface of the lake and by February, March all the detritus settles in the lake bed. Subsequently, the summer season sets in and the increase in atmospheric temperature results into rapid evaporation of lake water.

MATERIALS AND METHOD

The sediment-water interface samples were collected from the periphery of 5 lakes by Veen-Van grab sampler and stored in polythene bottles. The aqueous soil solution was analyzed for pH, salinity and dissolved oxygen (DO) within 40 minutes of collection by portable 'Thermo-Orion, U.S.A' electrode analyzer at standardized 25° Celsius temperature. The results given in figures are the average value of 6 samples from each lake. Testate amoebae were isolated from soil samples in laboratory. Samples were boiled in distilled water for 10 minutes and passed through 250 mesh size. Thereafter, the samples were treated in series with glacial and anhydrous acetic acid in order to reduce the opacity of the thecamoebians to study it under high power transmitted light microscope (Olympus BX-52). The material was subsequently caught in the 600 mesh size and was stored in glycerol. Slides were prepared, and all testate amoebae were identified and counted in the processed 10g samples. The results of the thecamoebian count is the average value of 6 samples from each lake.

RESULTS

In both the seasons the pH in all the water bodies ranged between 7 and 8 except in lake-3 which increased to 9 during May (Fig.2). The salinity ranged between 0.1 to 0.4 ppt in November and between 0.3 to 1 in May. The dissolved oxygen in water was low in May which ranged between 5 and 6 mg/l. However, the dissolved oxygen remained high during November which ranged between 7-11 mg/l.

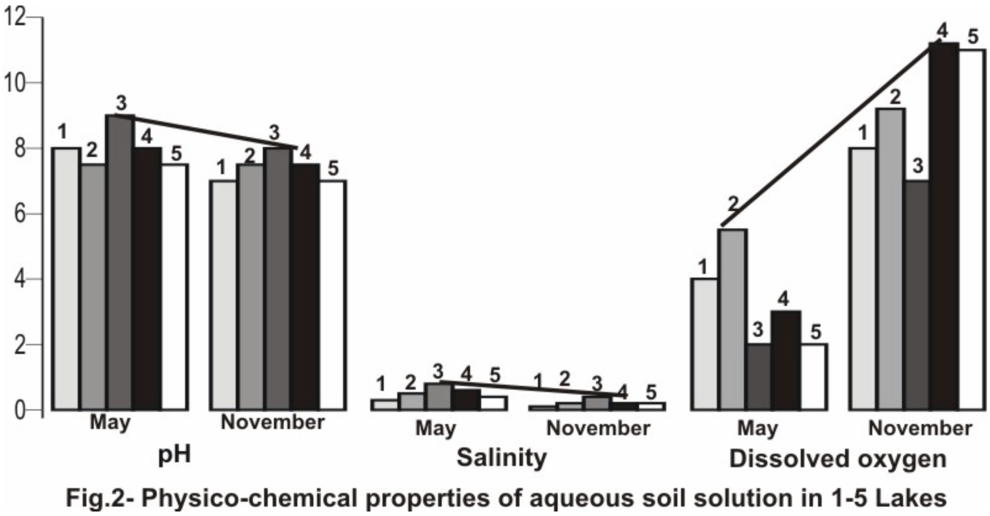

Fig.2- Physico-chemical properties of aqueous soil solution in 1-5 Lakes

Two types of thecamoebians were identified on the basis of percentage count in summers and winters. These are Type-I comprising of dominant species in winters (November) and Type-II which show comparative dominance in summers (May).

Type-I thecamoebians show dominance in the total count comprising *Centropyxis aculeata* (max. 42 % & min. 31 % in Lake [L] -5 & L-2, respectively) followed by *Arcella discoides, Difflugia gramen, D.oblonga, A. vulgaris* and *Centropyxis arcelloides* (Fig.3). However, in May the Type-II species dominated comprising 30.7% of *Amphitrema* *stenostoma* (max.34 % and min. 26% in L -1,2 and L-5, respectively) followed by *A. flavum, Difflugia protaeformis*, *Trigonopyxis arcula* and *Trinema* type. Thus, the percentage of the average total count of thecamoebians in all the lakes in May shows highest percentage of *Amphitrema stenostoma* (30.7%), followed by *A. flavum* (18.8%), *Trigonopyxis arcula* type (10.1%), *Trinema* and *Centropyxis aculeata* (5.1 & 5.2%), *Difflugia oblonga, Centropyxis arcelloides, D. gramen, A. discoides* and *A. vulgaris* (4.4, 4.1, 3.8 and 2.5, respectively). However, the percentage of the average total count in November was highest for *Centropyxis aculeata* (35.9) followed by Difflugia gramen (11.1%), Arcella vulgaris (10.4%), A. discoides (10.7), D. oblonga (8.9%) and Centropyxis arcelloides (8.2%). The standard deviation is highest for *Centropyxis aculeata* by ±3.7 in November and highest for *Amphitrema stenostoma* by ±6.4. Results indicate that these two species are very sensitive and indicator species of seasonally induced hydrological fluctuations in shallow lake system.

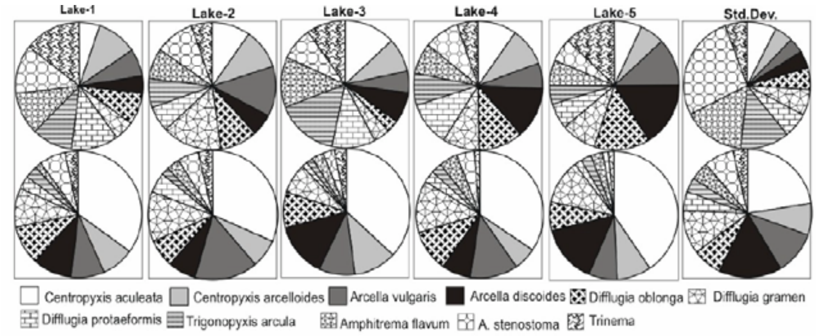

Fig.3- Pie Diagram showing percentage of average total count (6 samples per lake) and standard deviation (between 5 lakes) of thecamoebians in May (top row) and November (bottom row)

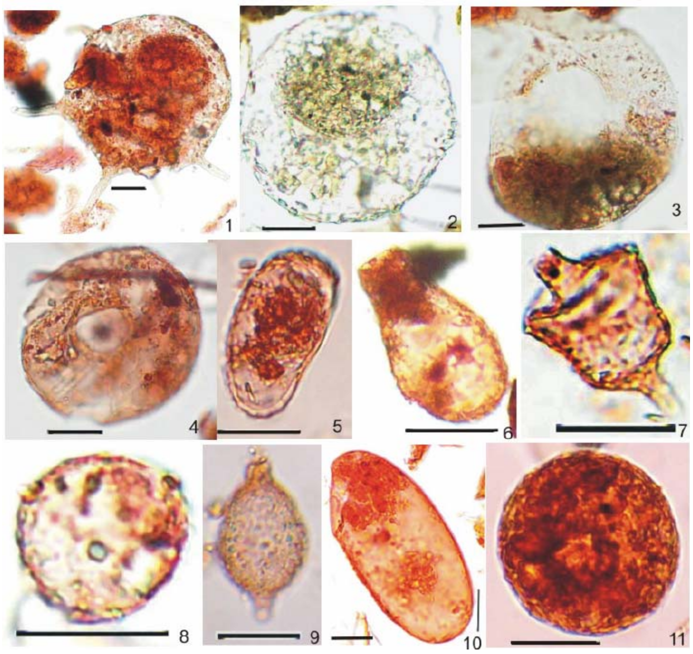

Fig. 4. **Light Microscopic photomicrographs. All scale = 20 µm:**
1 – *Centropyxis aculeata* (Ehrenberg); 2 – *Centropyxis arcelloides* (Penard);
3 – *A. vulgaris* (Ehrenberg); 4 – *A.discoides* (Ehrenberg); 5 – *Trinema enchelys* type (Ehrenberg);
6 – *Difflugia oblonga* (Ehrenberg); 7 – *D. protaeiformis* (Lamarck); 8 – Difflugia gramen (Leclerc);
9 – *Amphitrema stenostoma* (Nüsslin); 10 – *A. flavum* (Archer); 11 – *Trigonopyxis arcula* (Penard)

All the lakes show similar results with respect to general increase in Type-I species in November and Type-II species in May. However, Lake-3 shows highest pH (9) with lowest DO (5 mg/l) and lake-3 and 4 shows high salinity (0.8 to 1 ppt) in May as compared to other lakes. Despite the change in the abiotic factors within the studied 5 lakes, the trend in thecamoebian dominance of Type-I and II species did not change in significantly in both the seasons. While pH and salinity varied in both seasons by ±0.6 and ±0.3, respectively, the DO in water show wide variation of ± 2.1 Standard Deviation. Probably, the parameters like DO play a major role in defining the susceptibility and tolerance of *Centropyxis aculeata* and *Amphitrema stenostoma* (as compared to other species) along with pH towards alkalinity and high salinity in the present study. Therefore, it is apparent that Type-I thecamoebians in general show adaptability to aquatic ecosystem having normal to high DO but are sensitive to low DO and succumb to adverse summer conditions. On the other hand, Type-II species are adapted to low DO and are detritus loving enabling the natural ecosystems to get rid of organic detritus.

DISCUSSION

The aim of the study was to present the relationships between species composition of thecamoebians and seasonally induced hydrological conditions in lakes mostly subjected to extreme climatic conditions. The study shows that testate amoebae respond to main habitat parameters, i.e. pH, salinity and dissolved oxygen (DO). Particular amoebae species occurrence may be more strongly correlated with DO than with the pH and salinity, that would suggest that DO has important influence on the formation of amoebae communities. In the analysed case, the physico-chemical properties of the lake water shows increase in pH and salinity during summer season because the salts are drained from agricultural land and nearby municipal waste mainly during the rainy season. During this period due to increased nutrient and shallow depth in the lake, the propagation of *Lemna* fronds dominate. Profuse propagation of *Lemna* fronds and low temperature during winter months perhaps resulted into oxygenation of the water and therefore, high Dissolved Oxygen (DO) was recorded during the exponential growth phase during winters. As the atmospheric temperature increases to maximum of 46°C in summer season, high rate of evaporation from the lake surface is expected which is likely to leave behind salts and therefore, increase in salinity is obvious. The increase in pH may have been due to municipal wastes, washing and bathing activity that generally add detergents in the water body. The *Lemna* fronds decline propagation and settle in the lake bed during summers perhaps due to stressed conditions of high pH and salinity coupled with nutrient exhaustion. The degradation of the weed detritus and other organic waste input in the lakes may have increased the Biological Oxygen Demand (BOD) which resulted into low DO during summers. As compared to all the lakes the pH and salinity was highest in lake-3 which may be due to vast area covered by sodic land in the vicinity. It was observed that even during November the pH was 7.5 and salinity was 0.4 ppt in some of the studied lakes as compared to in May, but the DO of lake water showed a drastic change both in November and May. Therefore, it is suggested that the dominance of Type-I and Type-II thecamoebians are sensitive to increase and decrease in DO but may have adaptability to fluctuating pH and salinity which may help in biomonitoring trophic status of the lakes.

It has been reported earlier that *Difflugia protaeiformis,* is often abundant in pH of 6.5–7.5, and in higher pH and highly contaminated lakes in Canada (Reinhardt et al., 1998; Kumar and Patterson, 2000). Dominance of *D. protaeiformis* strains in an assemblage has generally been related to either polluted or stressed environments in northern Ontario and Italy (Asioli et al., 1996). Centropyxids are known to be opportunistic, and they dominate stressed environments. The present study shows that all the lakes are under stressed conditions in most months of the year and therefore, high percentage of *Centropyxis* species is likely to be present but interestingly, it has been observed here that these are highly sensitive to DO irrespective of either pH or salinity and are indirectly sensitive to high atmospheric temperature inducing hydrological changes in the water body.

Species of *Amphitrema, D.protaeiformis, Trigonopyxis and Trinema* increase in May but were also recorded in low number in November. It is suggested that these are detrivorous thecamoebians and therefore, show its dominance when the weed detritus settles in the lake during May. *Trigonopyxis arcula*, is a taxon indicative of relatively dry conditions and are known to be good indicators of soil moisture levels in soils and acidity in lakes (Charman et al., 2000; Mieczan, 2007). In the present study its abundance in dry season and sub-optimal conditions of high salinity and low DO indicate that *Trigonopyxis* is tolerant to stressed conditions which may be either acidic or alkaline /saline. Earlier records also show that the fluctuation in its population is attributed to the moisture content of their habitat (Smith, 1982; Mitchell et al., 1999). Other factors like pH (Costan and Planas, 1986; Ellison, 1995), eutrophication (Schonborn, 1962), temperature (Medioli and Scott, 1988), light, oxygen and food availability (Charman et al., 2000) control the testacean community structure.

Our results indicate that change in abiotic factors particularly pH, salinity and DO induced by extreme climatic conditions in tropics and sub-tropics play a more important role in defining thecamoebian community in an ecosystem. It is interesting to monitor quantitatively and qualitatively the susceptibility and tolerances of individual testate species in the geographic space like north-central part of India where extreme seasonality induced changes in the abiotic factors of the aquatic ecosystem. Thus, testate amoebae have several strengths relevant for monitoring and studying high resolution palaeoecology and paleoenvironment to infer hydroperiods, climate and temperature variability.

ACKNOWLEDGMENT

Thanks are due to Director, Birbal Sahni Institute of Palaeobotany for providing necessary facilities to accomplish this work. I am grateful to Dr. Arun Kumar, Centre for Petroleum and Minerals Research Institute, Saudi Arabia, for his valuable suggestions and encouragement.

REFERENCES

Asioli, A., Medioli, E.S, Patterson, R.T. 1996 Thecamoebians as a tool for reconstruction of paleoenvironments in some Italian lakes in the foothills of the Southern Alps (Grta, Varese and Candia). *J. Foraminifer. Res*., 26: 248-263.

Booth, R., Zygmunt, J. 2005. Biogeography and comparative ecology of testate amoebae inhabiting *Sphagnum* dominated peatlands in the Great Lakes and Rocky Mountain regions of North America. *Diversity Distributions,* 11, 577-590.

Charman, D., Roe, H.M., Gehrels, W.R. 2002. Modern distribution of saltmarsh testate amoebae: regional variability of zonation and response to environmental variables: *Journal of Quat. Sci.* 17 (5–6), 387-409.

Das, **A.K and Chattopadhyay**, **P** 2003. Morphology, Morphometry, and Ecology of Moss Dwelling Testate Amoebae (Protozoa :Rhizopoda) of North and North-East India: Rhizopoda) of North and North-East India. *Memoirs, Zoological Survey of India* viii, 530.

Farooqui, A and Gaur, A.S. 2007. Arcellaceans and pollen/spores of a late Harappan settlement near Porbandar, west coast of India: Implications for palaeoecology and environmental monitoring. *Current Science* 92 (7), 992-998.

Kumar, A., Dalby, A.P. 1998. Identification key for Holocene lacustrine Arcellacean (thecamoebian) taxa. *Palaeontologia Electronica*: 1-39.

Kumar, A., Patterson, R. 2000. Arcellaceans (Thecamoebians): New tools for monitoring long and short term changes in lake bottom acidity. *Environmental Geology 39*, 689-697.

Lahr, D.J.G., Sônia, G.B.C., Lopes, S. 2006. Morphology, Biometry, Ecology and Biogeography of Five Species of *Difflugia* Leclerc, 1815 (Arcellinida: Difflugiidae), from Tiete River, Brazil. *Acta Protozoologica* 45, 77-90.

Lansac-Tôha, F.A., Velho, L.F.M., Zimmermann-Callegari, M.C., Bonecker, C.C., Takahashi, E.M. 2001. On the occurrence of testate amoebae (Protozoa, Amoebozoa, Rhizopoda) in Brazillian inland waters. III. Family Difflugiidae: Genus *Difflugia*. *Acta Scientiarum* 23, 305-321.

Medioli, F and Scott, D. 1988. Lacustrine thecamoebians (mainly Arcellaceans) as potential tools for paleolimnological interpretations. *Palaeogeo. Palaeoclim., Palaeoeco.* 62, 361-386.

Mishra, S.R., Saksena, D.N. 1990. Seasonal abundance of the zooplankton of wastewater from the industrial complex at Birla Nagar (Gwalior), India: *Acta-Hydrochim.-Hydrobiol.* 18, 215-220.

Nair, K.N., Mukherjee, R.N 1968. On some testacean rhizopods (Protozoa: Sarcodina) of the ground and tree mosses from Calcutta and its environs. *Proc. National Academy of Sciences of India* 38B, 185-193.

Patterson, R.T., Kumar, A. A review of current testate rhizopod (thecamoebian) research in Canada. *Palaeogeo. Palaeoclim., Palaeoeco.* 180, 225-251, (2002).

Rao, H.S.M: Studies on Soil Protozoa. Part I, Protozoan Fauna of some Mysore soils. *Journal of Indian Institute of Science,* 11, 111-116, (1928).

Reinhardt, E., Dalby, A., Kumar, A., Patterson, R. Arcellaceans as pollution indicators in mine tailing contaminated lakes near Cobalt, Ontario. *Micropaleontology* 44, 131-148, (1998).

Vucetich, M.C. Nuevos aportes al conocimiento de los tecamebianos del dominio subtropical. *Neotropica* 24, 79-90, (1978).

Yang, J and Shen, Y. Morphology, biometry and distribution of *Difflugia biwae* Kawamura, 1918 (Protozoa: Rhizopoda). *Acta Protozoologica.* 44,103-111, (2005).

Charman, D., Hendon, D., Woodland, W. The identification of peatland testate amoebae: *Quaternary Research Association Technical Guide* no. 9, London, 147, (2000).

Mieczan, T. Epiphitic protozoa (testate amoebae and ciliates) associated with *Sphagnum*in peatbogs: relationship to chemical parameters– *Pol. J. Ecol.,* 55 (1), 79-90, (2007).

Smith, H.G. The terrestrial protozoan fauna of South Georgia. *Polar Biology*, 1, 173-179, (1982).

Mitchell, E., Buttler, A., Warner, B. Ecology of testate amoebae (Protozoa: Rhizopoda) in *Sphagnum* peatlands in the Jura Mountains, Switzerland and France. *Ecoscience* 6, 565-576, (1999).

Costan, G and Planas, D. Effects of a short-term experimental acidification on a microinvertebrate community (Rhizopoda, Testacea). *Can. J. Zool*., 64, 1224-1230, (1986).

Ellison, R. Paleolimnological analysis of Ullswater using testate amoebae. *Journal of Paleolimnol.* 13, 51-63, (1995).

Schönborn, W. Zur Ökologie des sphagnikolen, bryokolen und terrikolen *Testaceen Limnologica* 1, 231-254, (1962).

Надійшла до редколегії 12.05.09