

## SUBFOSSIL ORIBATID MITES IN THE PEAT DEPOSITS OF THE EUTROPHIC MIRE: SOUTHERN TAIGA OF WESTERN SIBERIA

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**ABSTRACT:** The remains of subfossil oribatid mites have been investigated in nine peat layers of the eutrophic mire, located in the southern taiga ecological zone of Western Siberia. In total, 17 taxa have been revealed. Hydrophilic mites *Limnozetes* sp. and *Hydrozetes* sp. dominated all assemblages, which reflects an increased surface wetness of the mire during the entire period of its development (8,850 yr). Fluctuations in the surface wetness are expressed through changes in both the species composition and the relative abundances of species of oribatid mites. Decreases of surface wetness are accompanied by a decrease in the proportion of *Hydrozetes* sp., an increase in the proportion of *Limnozetes* sp. and in the number of species in the assemblage.

**KEY WORDS:** Reconstruction, paleoenvironment, Oribatida, Holocene, bioindicators.

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### INTRODUCTION

Oribatid mites belong to one of the few groups of soil organisms, the remains of which can be preserved for a long time in peat deposits of mires. Therefore, they can be used as indicators in paleoecological studies. In particular, due to the high level of species diversity and differences in their ecological preferences, oribatid mites often play the role of bioindicators in paleoenvironmental reconstructions. There are few paleoecological studies that rely on acarological analyses. Such studies have been carried out in peat deposits of bogs (Krivolutsky and Laskova 1979; Druk 1986; Krivolutsky *et al.* 1990), in minerotrophic mires (Karpinen and Koponen 1973; Krivolutsky *et al.* 1995; Krivolutsky and Sidorchuk 2005; Schelvis *et al.* 2005), as well as in lake (Solhøy and Solhøy 2000) and stream sediments (Coetzee and Brink 2003). The results of these studies indicate that mites reflect mainly local hydrological conditions and other characteristics of the upper horizon of the soil profile.

Paleoenvironmental reconstruction requires information on the ecology of the oribatid mite species that inhabit the mires presently. According to the data from different authors, 20 to 48 species of oribatid mites are found in bogs (Laskova 1980; Druk 1982; Druk and Vilkamaa 1988), while 7 to 43 species are found in minerotrophic mires (Druk 1982; Sidorchuk 2008; Mordkovich *et al.* 2014). A comparative analysis of mite assemblages from modern oligotrophic and minerotrophic mire habitats detected differences in their species com-

position (Sidorchuk 2008). In addition, oribatid assemblages have significant differences within a single mire ecosystem, depending on the moisture and the trophic status of a given microbiotope (Laskova 1988; Sidorchuk 2008). These factors point to a high value of oribatid mites as indicators in paleoecological studies.

In Western Siberia, several studies have been devoted to the study of oribatids in mires under modern conditions (Druk 1986; Mordkovich *et al.* 2003; Andrievskii 2003, 2007; Mikheeva 2008; Mordkovich *et al.* 2014). The results of paleoecological studies of mites in peat bogs have been published by Druk (1986) and Krivolutsky *et al.* (1990).

Our research is designed to evaluate the prospects for the application of acarological analysis in paleoenvironmental reconstructions that concern minerotrophic mires. This study aims to determine the diversity of oribatid mite assemblages in the peat deposits of a eutrophic mire. These data are then used to reconstruct the paleoenvironmental conditions of the peat formation during the Holocene.

### STUDY AREA

The research area is located within the southern taiga subzone of Western Siberia, on the Ob–Irtysh interfluvial plain. The climate is moderately continental (Kremenetski *et al.* 2003). We have selected a typical eutrophic mire, located on the first floodplain terrace of the left gently sloping bank of the

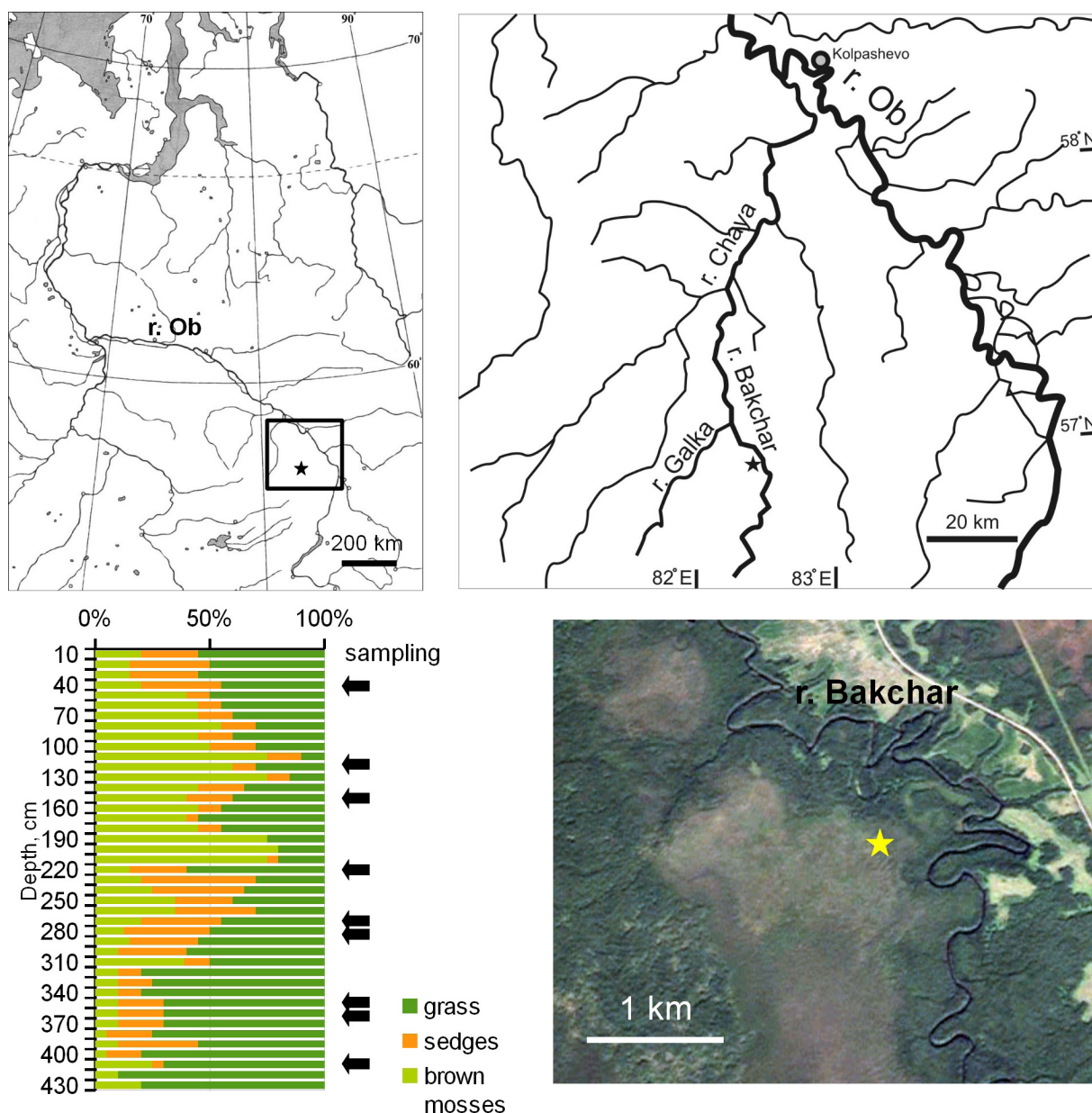


Fig 1. Geographic location of the study area and macrofossils composition of the peat; the star marks the peat core selection place.

Bakchar River (Fig. 1; 56°55' N, 82°30' E). It is an open, heavily waterlogged mire, covering an area of about 120 hectares and occupied by shrubs, brown mosses and sedges. The peat core was placed 200 m from the edge of the mire, in a place where a few 5–10 m high pines and birches grew (marked with a star in the Fig. 1). The thickness of the peat deposit at this place was 430 cm. Peat was underlain by carbonate loam and clay.

## MATERIAL AND METHODS

Sampling of peat for analysis was carried out by the Russian manual peat corer (the shuttle 50 cm in length, 5 cm in diameter) with an interval of 10 cm in September 2010.

Radiocarbon dating of peat samples was performed in the laboratory of Cenozoic geology and paleoclimatology at the Institute of Geology and Mineralogy of the Siberian Branch of the Russian Academy of Sciences (SB RAS) by L.A. Orlova and in the laboratory of bioinformational technologies of the Institute of Monitoring of Climatic and Ecological Systems of the SB RAS by G.V. Simonova on Quantulus 1220 (Table 1). The received dates were calibrated using the CALIB 7.1 program. (Stuiver *et al.* 2017). In the text of the article, calibrated age data are presented using the BP system (Before Present time). Based on the dates obtained, the age of each peat layer in the peat core was calculated.

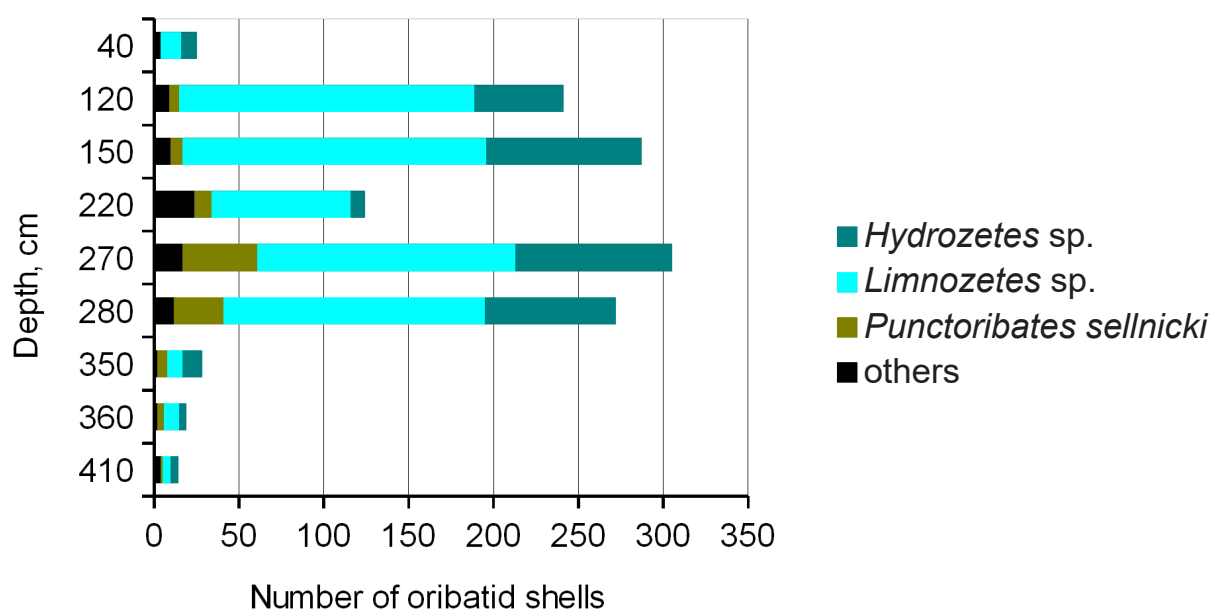


Fig 2. Density of fossil mites in the peat core from the studied eutrophic mire.

Macrofossil analysis of peat was carried out by E.M. Volkova (Tula State University) in accordance with the guidelines (Katz *et al.* 1977; Tyuremnov *et al.* 1977).

Peat samples for acarological analysis had a fixed volume of 50 ml of raw peat. Subfossil mites were removed from the peat by the method of paraffin flotation (Sidorchuk 2003). Then, the mites were enclosed in Berlese mounting medium for the subsequent identification. A total of 1,315 remains of adult oribatids were analyzed. In addition, there was a significant amount of skins, as well as of individual specimens of larvae and nymphs in the peat, which indicates the autochthonous formation of oribatid taphocoenosis.

**Description of the peat core.** The investigated peat core was composed of eutrophic peat, which consisted of residues of different grass species, sedges and brown mosses. Oribatid mite assemblages were analyzed in the selected nine layers of peat, which has formed under contrasting environmental conditions (Table 2). The selection of peat layers was made on the basis of synchronization with regional paleoclimatic curves, obtained as a result of a palynological analysis of peat deposits from a mire located 180 km to the northeast of the study area, in the southern taiga of Western Siberia (58°20' N, 84°00' E) (Blyakharchuk 2009). Paleoclimatic reconstructions relied on the information statistic method of Klimanov (1985). The first paleoclimatic curve reflects the reconstructed annual precipitation. It is most likely that during the periods of the greatest and the lowest humidity in

the Holocene climate, the study mire responded to climatic changes by a consequent increase or decrease in the surface wetness. The second paleoclimatic curve reflects the average annual air temperature (Table 2).

## RESULTS

A total of 17 taxa of oribatid mites were identified in the peat core (Table 3). All taxa were found in modern conditions: in the Ob basin, in the northern and middle taiga of Western Siberia (Andrievskii 2007; Mikheeva 2008).

A number of features of the oribatid mite assemblages have been revealed (Fig. 2), as presented below.

1. 410–400 cm (8,500–8,350 cal yr)—only 14 oribatid remains were found. Among them the species from the genera *Hydrozetes*, *Limnozetes* and *Ceratozetes* prevailed. *Punctoribates sellnicki* and *Suctobelbella* sp. were represented by single specimens.

2. 360–350 cm (7,400–7,100 cal yr)—the species composition of the assemblage was similar to the previous one, except that the relative abundance of *Limnozetes* sp. has increased slightly.

3. 350–340 cm (7,100–6,800 cal yr)—the species composition, similar to that of the assemblage outlined above, was observed. The relative abundance of *Hydrozetes* sp. has increased to a considerable degree.

4. 280–270 cm (5,900–5,750 cal yr)—the density of oribatid remains sharply increased in the peat (from 29 to 272). The remains of *Limnozetes*



sp. prevailed in total. *Hydrozetes* sp. and *Punctoribates sellnicki* took the position of subdominants. The remains of *Tectocephus velatus*, *Suctobelbella* sp., *Carabodes* sp. were encountered singly.

5. 270–260 cm (5,750–5,600 cal yr)—the assemblage was also dominated by a species from the genus *Limnozetes*. The relative abundance of subdominants *Hydrozetes* sp. and *Punctoribates sellnicki* increased slightly. The species composition of the assemblage was similar to the previous one.

6. 220–210 cm (4,900–4,650 cal yr)—this assemblage differed from the previous two in a lower content of the oribatid remains and a higher species diversity. The greatest species number was found: 13 oribatid taxa. The dominant species was *Limnozetes* sp., while species *Hydrozetes* sp. and *Punctoribates sellnicki* were subdominants. The remains of the other taxa occurred singly (Table 3).

7. 150–140 cm (3,000–2,750 cal yr)—the number of *Limnozetes* sp., which predominated in the assemblage, increased. *Hydrozetes* sp. was subdominant. The remaining species were single. A noteworthy feature of the assemblage was the presence of *Micreremus brevipes*—a species that dwell on trees.

8. 120–110 cm (2,200–2,000 cal yr)—a species structure, similar to the one above, was observed in this assemblage. However, species that live on trees were absent.

9. 40–30 cm (800–650 cal yr)—very few remains of oribatids were found. Among them, the remains of *Limnozetes* sp. and *Hydrozetes* sp. prevailed. Taxa *Tectocephus velatus*, *Suctobelbella* sp., *Eupelops* sp. were encountered only singly.

The number of oribatid remains in peat samples ranged from 14 to 305, averaging  $146 \pm 129$  (arithmetic mean and standard deviation). The lowest number of remains was observed in the peat samples from the deepest and the uppermost layers of the peat deposit (Fig. 2). It is important to note that the preservation quality of shells in all the peat layers under study was relatively similar (Fig. 3). According to the classification by Erickson (1988), oribatid remains mainly belong to class 2 and 3 types of preservation: inflated intact exoskeletons with most setae missing, with leg segments lost, usually with genital and anal plates. So, at the moment, it is difficult to argue that there is a relationship between the degree of preservation of mite remains and their number in the studied peat samples.

In general, all the oribatid assemblages studied in the peat core were dominated by hydrophilic mites from the genera *Limnozetes* and *Hydrozetes*.

The main differences between the assemblages were observed in the relative abundance of different species and in the composition of the accompanying species. It has been observed that during the highest surface wetness of the mire, the ratio of the remains of the dominants of *Hydrozetes* sp. to *Limnozetes* sp. was on the average 0.8. With a decrease in the surface wetness of the mire, this ratio decreased to 0.5–0.4.

Three groups of peat samples, which formed under different sets of conditions, were distinguished: 1) high humidity of the climate (wet conditions); 2) humidity conditions close to the modern; and 3) low humidity (dry conditions; Table 4). Our data showed that the relative abundance of some species of oribatids (*Astegistes pilosus*, *Limnozetes* sp., *Eupelops* sp.) tended to increase gradually along with a decrease in climate humidity. Other species (*Hydrozetes* sp., *Suctobelbella* sp., *Punctoribates sellnicki*), displayed an opposite tendency, i.e., their relative abundance has decreased. There was also a trend towards an increase in the species number of mites with a decrease in climate humidity (Table 4). Some species (*Micreremus brevipes*, *Banksinoma* sp., *Latilamellobates* sp., *Achipteria* sp.) were found only during the periods of the least surface wetness of the mire.

## DISCUSSION

The comparison of our results with the data of other authors on the oribatid mites, was complicated by the difficulty in identifying the subfossil mites. Only four species of oribatids were confidently identified to the species level. Meanwhile, different species of the same genus have different ecological preferences. Therefore, identification to the genus weakens the chances of reconstructing the paleoenvironment of the mire.

Nevertheless, our results have shown that the studied assemblages consist of specific mire oribatids (*Limnozetes* sp., *Hydrozetes* sp. and *Punctoribates sellnicki*), as well as of species that occur in a wide range of habitats (*Astegistes pilosus*, *Tectocephus velatus*, *Micreremus brevipes*), according to the overview (Mumladze *et al.* 2013). A large proportion of oribatid species with a broad ecological plasticity characteristic in mires has already been noted in another study (Druk and Vilkamaa 1988).

When compared to the paleoecological data of other authors (Solhøy and Solhøy 2000; Schelvis *et al.* 2005), the studied peat core stands out due to

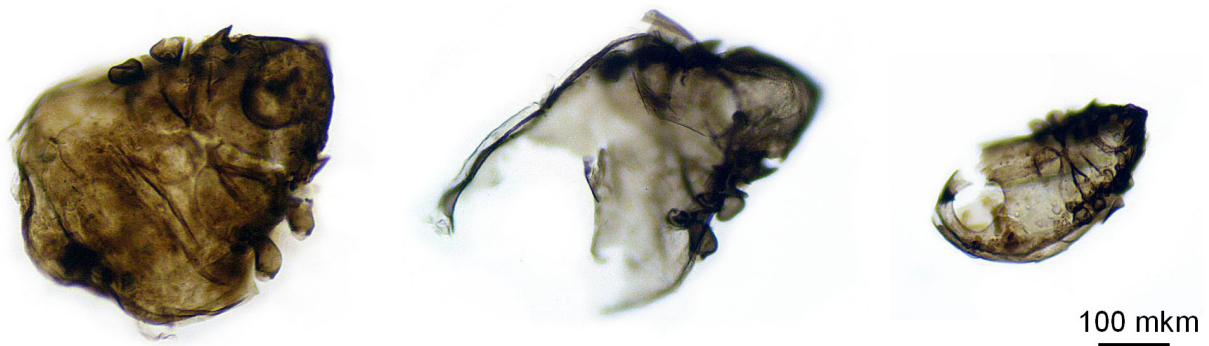


Fig 3. Photomicrographs of most common subfossil mites in studied peat layers.

the poor species composition of oribatids, as well as the dominance of specific hydrophilic species in all assemblages. The species structure of the assemblages from the studied peat is very similar to the species structure of modern oribatid assemblages from highly watered mire microbiotopes. Such species structures are characterized by a small number of specific hydrophilic species and a sharp predominance of one of them over the others in relative abundance (Druk and Vilkamaa 1988; Laskova 1988).

Similar assemblages, with the dominance of *Hydrozetes lemnae*, followed by *Limnozetes ciliatus* and with the single presence of *Punctoribates sellnicki*, *Tectocepheus velatus*, *Suctobelbella palustris*, *Scheloribates* cf. *pallidulus*, *Eupelops* cf. *ureaceus*, *Achipteria coleoptrata*, *Galumna lanceata* were associated with the initial stages of development of a swamp in Turkey (Schelvis *et al.* 2005). Also, Krivolutsky *et al.* (1995), in a review of various paleoecological studies, note that the dominance of hydrophilic oribatid species from the genera *Hydrozetes* and *Limnozetes* is characteristic of the subfossil mite assemblages at the initial stages of mire formation. This feature is also observed in later paleoecological studies (Solhøy and Solhøy 2000; Krivolutsky and Sidorchuk 2005). In our work, such assemblages have been identified not only in the bottom layers of peat, but along the entire depth of the peat core. All of this indicates a high level of mire surface wetness during the entire period of its development.

Despite the constantly high surface wetness of the mire, the differences in the species composition and the relative species abundance among the subfossil mite assemblages indicate some fluctuations in the surface wetness of the mire during its development. This means that oribatid assemblages can respond to even minor changes in the paleoenvironment. Thus, subfossil mites from the peat potentially allow for a precise reconstruction

of a very wide range of variations in hydrological conditions of the mire.

Variations in the density of oribatid remains in peat can be caused by the gradual destruction of the remains during conservation. It is, therefore, not surprising that in the deepest layers of the studied peat, the least amount of oribatid remains was found. However, even in the upper layers of the peat, there were few remains of mites (at the depths of 40–30, 220–210 cm; Fig. 2). The causes of the decrease in the density of oribatids are not completely clear to us. It is possible that in these periods, initially, there were few mites in the mire due to unfavorable habitat conditions, the precise nature of which is unknown to us.

According to the acarological data, the following history of the mire development emerges. At the first stages of the formation of the peat deposit, the mire was heavily watered and, perhaps, characterized by flowing moistening (410–350 cm, 8,500–6,800 yr ago). The density of mite remains was low. Two hydrophilic taxa (*Hydrozetes* sp. and *Limnozetes* sp.) prevailed, with approximately equal shares of relative abundance in the assemblages. It is interesting to note that according to the data from Krivolutsky *et al.* (1995), mites from the genus *Hydrozetes* do not tolerate stagnant moistening. It is, therefore, probable that during this period the mire was regularly flooded with river water.

At depths of 280–260 cm (5,900–5,600 yr ago), the species composition of the oribatid assemblages remained approximately the same. However, the relative abundance of *Limnozetes* sp. has increased substantially, while the relative abundance of *Hydrozetes* sp. has decreased. Most likely, the wetting of the mire surface had ceased to be flowing, while a high level of its surface wetness was preserved. We think that the flooding of the mire surface with river water became less frequent. This could be due to the level of the growing

peat deposit rising higher than the level of the floods. Alternatively, this could be due to the river water level decreasing due to a decrease in the climate humidity.

The significant changes in the mite assemblage at the depth of 220–210 cm (4,900–4,650 yr ago) indicate a change in the local environment in the mire. The appearance of mite species with various ecological preferences was a consequence of a decrease in the surface wetness of the mire. Since the majority of oribatid mites are aerobiont soil organisms, a decrease of the surface wetness of a mire leads to an increase in the diversity of its habitats. The greatest species number of oribatid taxa in this layer of peat indicates that the drying of the mire surface during this period was most significant. However, it seems that this drying was relative, and the mire surface wetness was high enough to allow the development of hydrophilic species. Thus, *Limnozetes* sp. predominated, although their relative abundance had greatly decreased.

At depths of 150–140 cm (3,000–2,750 yr ago), only seven oribatid taxa were found. Species number in comparison with the previous assemblage had decreased. The dominance of *Limnozetes* sp. pointed to the high humidity of the environment in the mire. However, the presence of *Micreremus brevipes*, which lived on the bark and branches of trees, indicated the presence of trees at the mire. The development of trees meant a relative decrease in the surface wetness.

At the depth of 120–110 cm (2,200–2,000 yr ago), the remains of the hydrophilic *Limnozetes* sp. still predominated. Species that lived on trees were not found. Although there were many remains of mites in the peat, the species composition was relatively poor, i.e. only six oribatid taxa were identified. All of this indicated an increase in the surface wetness of the mire.

At the depth of 40–30 cm (800–650 yr ago), very few oribatid remains were found. Perhaps, this is due to the mire conditions being unfavorable for their habitation. According to the paleoclimatic curve of the air temperature, the climate cooled down during this period. The predominance of hydrophilic taxa among the oribatid mites reflected a high level of the mire surface wetness.

## CONCLUSION

Our results indicate good preservation of oribatids in a minerotrophic peat. In particular, in the studied peat core, 1,315 remains of subfossil oriba-

tid mites have been recovered. This number is significant for a paleoenvironmental reconstruction. A total of 17 oribatid taxa were identified in nine peat samples, including species with different ecological preferences. Dominance of *Hydrozetes* sp. and *Limnozetes* sp. in the oribatid assemblages indicates a high surface wetness of the mire during the entire period of peat formation. During the periods of a slight decrease in the surface wetness, an increase in both the relative abundance of *Limnozetes* sp., as well as the species number of oribatid mites was observed. It is known that the number and ratio of mite remains from the genera *Hydrozetes* spp. and *Limnozetes* spp. can indicate the differences in the mire hydrological conditions. This is due to the significant differences in the ecological preferences of these genera in regards to hydrophilicity. In particular, unlike *Limnozetes* spp., *Hydrozetes* spp. demand open water and good aeration.

The revealed features of subfossil oribatid mite assemblages testify to the high sensitivity of these bioindicators to changes in the paleoenvironmental conditions in mires. Our findings illustrate a potential for reconstructing a wide range of grades of mire surface wetness.

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Table 1

Radiocarbon dates of the peat core from the eutrophic mire

Lab. No.	Dated material	Depth (cm)	Age $^{14}\text{C}$ yr BP	Age cal yr BP (1 $\sigma$ )	Probability
IMCES-14C283	peat	40–50	1,048 $\pm$ 80	984 (906–1,062)	0.92
IMCES 74	peat	110–120	2,210 $\pm$ 40	2,182 (2,154–2,210)	0.47
IMCES 89	peat	190–200	3,940 $\pm$ 40	4,394 (4,349–4,438)	0.70
IMCES 81	peat	220–230	4,515 $\pm$ 40	5,123 (5,059–5,186)	0.75
COAN-7895	peat	330–340	5,960 $\pm$ 110	6,802 (6,668–6,936)	1.00
IMCES 87	peat	370–380	7,240 $\pm$ 40	8,029 (8,001–8,057)	0.57
COAN-7880	peat	420–430	8,000 $\pm$ 130	8,848 (8,682–9,013)	0.93

Table 2

Characteristics of the studied peat layers

Depth (cm)	Age cal yr BP	Climatic humidity*	Thermal climate regime*
40–30	800–650	similar to modern conditions	cold
120–110	2,200–2,000	similar to modern conditions	similar to modern conditions
150–140	3,000–2,750	very dry	cold
220–210	4,900–4,650	dry	similar to modern conditions
270–260	5,750–5,600	similar to modern conditions	cold
280–270	5,900–5,750	similar to modern conditions	warm
350–340	7,100–6,800	very wet	similar to modern conditions
360–350	7,400–7,100	wet	cold
410–400	8,500–8,350	similar to modern conditions	similar to modern conditions

\*—data from reconstructed regional paleoclimatic fluctuations are used (Blyakharchuk 2009).

Table 3

Total abundance of oribatid mite species in the studied peat layers

Oribatid mite species	Depth, cm								
	410	360	350	280	270	220	150	120	40
<i>Astegistes pilosus</i> (Koch, 1841)	—	—	—	—	—	2	1	1	—
<i>Carabodes</i> sp.	—	—	—	1	—	—	—	—	—
<i>Tectocephus velatus</i> (Michael, 1880)	—	—	—	8	8	2	2	—	1
<i>Hydrozetes</i> sp.	4	4	11	77	92	8	91	52	9
<i>Micreremus brevipes</i> (Michael, 1888)	—	—	—	—	—	—	2	—	—
<i>Limnozetes</i> sp.	5	9	9	154	152	82	179	174	12
<i>Suctobelbella</i> sp.	1	1	1	3	8	4	5	7	2
<i>Banksinoma</i> sp.	—	—	—	—	—	1	—	—	—
<i>Ceratozetes</i> sp.	3	—	—	—	—	—	—	—	—
<i>Latilamellobates</i> sp.	—	—	—	—	—	4	—	—	—
<i>Punctoribates sellnicki</i> Willmann, 1928	1	4	6	29	44	10	7	6	—
Ceratozetidae gen sp	—	1	1	—	1	4	—	—	—



# Subfossil oribatid mites in peat deposits

<i>Eupelops</i> sp.	—	—	—	—	—	2	—	—	1
<i>Achipteria</i> sp.	—	—	—	—	—	3	—	—	—
<i>Scheloribates</i> sp.	—	—	—	—	—	—	—	1	—
<i>Liebstadia</i> sp.	—	—	—	—	—	1	—	—	—
Galumnidae gen sp	—	—	—	—	—	1	—	—	—
Total number of oribatid remains	14	19	28	272	305	124	287	241	25

Table 4

Total relative abundance of oribatid mite species in the studied peat layers, which were formed under different hydroclimatic conditions

Oribatid mite species	Wet conditions	Similar to modern conditions	Dry conditions
<i>Astegistes pilosus</i>	—	0.1%	0.7%
<i>Carabodes</i> sp.	—	0.1%	—
<i>Tectocephus velatus</i>	—	2.0%	1.0%
<i>Hydrozetes</i> sp.	31.9%	27.3%	24.1%
<i>Micreremus brevipes</i>	—	—	0.5%
<i>Limnozetes</i> sp.	38.3%	58.0%	63.5%
<i>Suctobelbella</i> sp.	4.3%	2.5%	2.2%
<i>Banksinoma</i> sp.	—	—	0.2%
<i>Ceratozetes</i> sp.	—	0.4%	—
<i>Latilamellobates</i> sp.	—	—	1.0%
<i>Punctoribates sellnicki</i>	21.3%	9.3%	4.1%
Ceratozetidae gen sp	4.3%	0.1%	1.0%
<i>Eupelops</i> sp.	—	0.1%	0.5%
<i>Achipteria</i> sp.	—	—	0.7%
<i>Scheloribates</i> sp.	—	0.1%	—
<i>Liebstadia</i> sp.	—	—	0.2%
Galumnidae gen sp	—	—	0.2%
Total number of oribatid remains (number of peat samples)	47 (2)	857 (5)	411 (2)