Analysis of surface wetness changes in the Maly Labysh mire in south of Western Siberia during the last two millennia

I V Kurina and T A Blyakharchuk
Laboratory of Monitoring of Forest Ecosystems, Institute of Monitoring of Climatic and Ecological Systems, Siberian Branch of the Russian Academy of Sciences, 10/3 Academichesky avenue, 634055, Tomsk, Russia
E-mails: irina.kuryina@yandex.ru; blyakharchuk@mail.ru

Abstract. In this study we investigate peat deposits of a transitional sedge-Sphagnum mire by using a testate amoeba analysis to reconstruct the paleohydrology of the mire for the last two millennia. The Maly Labysh mire is located in a river floodplain in low mountains in the south of Western Siberia. The goal of our research is to evaluate the water table depth changes in the mire due to regional and continental climate changes in the late Holocene. Two short-term dryings of the mire surface in 2100-1900 and 1600-1400 yr BP have been revealed. Afterwards, an unusual shift in the oligotrophic conditions on the mire surface is documented between 1400-1100 yr BP. This indicates some weakening of the influence of the nearby river likely due to a decrease in the precipitation. Then, starting at ca. 900 yr BP the mire gradually came back to transitional conditions again, and its surface moisture remained moderately high without notable fluctuations. The close consistency of the thus revealed periods of short drying with similar events in the development of other lake and bog sediments in the south of Western Siberia indicates the fact of predominant influence of westerlies on the formation of the regional climate.

1. Introduction
Analysis of past climate change is a fundamental basis for modeling and forecasting the future climate change. Along with global trends in climate fluctuations on a continental scale, there are various aspects of the regional climate, in which global climate changes are transformed through the interaction with local features of the water balance of the territory, relief, vegetation cover, and movement of air masses, determining the picture of climatic fluctuations in each given region.

The information about past climatic changes is preserved in various natural objects, including peat deposits of mires. Analysis of different bioindicators from peat makes it possible to extract information about the environmental conditions that existed during the historical development of a mire, including palaeoclimate change. Among such bioindicators is analysis of testate amoebae, which provides a quantitative reconstruction of the depth to the water table and the surface wetness of the mire during its development.

The aim of our research is a reconstruction of the depth to the water table in a mire located in an insufficiently studied region of low-mountain Shoria in the south of Western Siberia in the context of regional and global climatic fluctuations of the Late Holocene.
2. Materials and methods

The research object chosen was a transitional Sphagnum-sedges fen Maly Labysh located in the floodplain of the Kondoma river (52.6306° N 88.0829° E, 490 m a.s.l.) [1]. The study area is located at the western macro-slope of the low Kuznetsk Alatau mountains covered with taiga forests and belongs to the territory of the Shorsky National Park in the south of Kemerovo region (Figure 1).

The peat thickness is 240 cm at the coring place in the fen. The taken core was cut into 5-cm thick continuous slices. Among them five peat samples along the peat core were selected for radiocarbon dating. The age at a depth of 200 cm was 2200 cal yr BP. The radiocarbon dates obtained were calibrated using an IntCal13 calibration curve [2] in a software application Bacon 2.2 [3] based on R [4]. Further in the text the data of the calibrated age are given BP (Before Present, years ago from 1950).

![Figure 1](image_url)

**Figure 1.** Geographical location of the Maly Labysh mire (1) and other palaeoecological records: 2 – Lake Shira [11]; 3 – peat bog [3].

Testate amoeba analysis was performed in 43 peat samples throughout the core, except for peat samples taken for radiocarbon dating. The sample preparation was carried out according to the standard method with minor modifications [5]. Subsamples of raw peat with a volume of 1–2 cubic centimeters were taken from the middle of each peat slice, washed through the sieve (mesh size: 0.355 μm) to remove large plant macrofossils, and then concentrated by sedimentation to a volume of 10 ml. Testate amoebae were identified and counted using a light microscope at ×200–×400 magnification and several guides [6, 7]. Quantitative reconstruction of the depth to the water table (DWT) was calculated using a transfer function model published earlier and based on a training set of modern testate amoebae assemblages inhabiting minerotrophic mires in the southern taiga of Western Siberia [5]. The model is based on a transfer function WA-inv tol (weighed averaging with downweighting tolerance and inverse deshrinking) and has RMSEP = 6.6 cm and R² = 0.82 performance characteristics estimated by bootstrapping (n cycles = 1000) [5]. All calculations were performed using R 4.0.1 [4] and package rioja 0.9–21 [8]. The distribution diagram of the testate amoebae in the peat core was constructed using the program TGView 2.0.2 [9].
3. Results

High quantity of testate amoeba shells (from 26 to 992 in each sample) was revealed throughout the studied peat core, which was sufficient for reliable DWT reconstruction. The main dominant taxa in the peat core were wet-related *Hyalosophenia papilio, Archerella flavum, Centropyxis constricta v. minima* and two taxa from *Diffugia* (*Diffugia* sp.1 and *Diffugia* sp.2); and dry-related *Trinema lineare, Euglypha rotunda, Corythion pulchellum*. Three main stages in the mire development were identified based on cluster analysis of the fossil testate amoeba assemblages (Figure 2).

![Figure 2. Distribution of the percentages of the main testate amoeba taxa along the peat core Maly Labysh and reconstructed depth to water table (root mean square error of prediction is estimated by bootstrapping (n cycles = 1000) and marked with thin black lines on both sides of the curve).](image)

1. 240-135 cm: in the bottom layers of the peat deposit (240-220 cm) specific testate amoeba assemblages have preserved, with prevalence of taxa from *Centropyxis* (*C. constricta v. minima, C. elongata, C. minuta, C. sylvatica v. minor*), *Diffugia* and *Plagiopyxis* indicating conditions of a rich minerotrophic peat. Next, they were replaced by assemblages with prevalence of *Trinema lineare* and *Diffugia* sp. (220-135 cm) indicating a gradual increase in the surface wetness in the mire with a growth of the peat deposit (mean DWT = 10 cm) it is likely that the water table was slightly below the mire surface.

2. 135-105 cm: hydrophilic *Archerella flavum* and *Hyalosophenia papilio* typical for oligotrophic bogs dominated at this stage. The reconstructed DWT value (mean DWT = -1 cm) indicated high surface wetness in the mire; the water table was likely to be close to or even above the mire surface. However, in this case it is important to note that a sharp increase in the relative abundance of oligotrophic testate amoeba taxa rather diagnoses the oligotrophic conditions of the environment on the mire surface than an increase in its surface wetness.

3. 105-0 cm: this stage was characterized by the prevalence of *Trinema lineare, Euglypha rotunda,* and *Corythion pulchellum* indicating the return of transitional mesotrophic conditions on the mire surface and moderately high surface wetness (mean DWT = 15 cm) the water table was likely slightly below the mire surface.

4. Discussion

The results of the DWT reconstruction based on the testate amoeba data indicate, in general, a high level of surface wetness in the mire during the entire history of its development, and the fossil testate amoeba assemblages indicate the environmental conditions of a transitional poor minerotrophic fen. Against this background, during the first stage (240-135 cm, 2200-1400 cal yr BP) two short-term
Dryings of the mire surface stand out at 2100-1900 and 1600-1400 cal yr BP (Figure 3). Similarly, short-term dry periods are documented by testate amoeba data in 2200, 2000, 1600, and 1500 cal yr BP on the surface of the bog located in the subtaiga subzone 750 km northwestwards (Fig. 1) [10]. Furthermore, drier climate conditions by pollen data were registered at 2150-1950, 1800-1750, and 1550-1500 cal yr BP in Lake Shira located 250 km northeastwards [11] from the studied mire (Figure 1). Apparently, these dry events in the region of the south of Western Siberia are driven by short-term climate fluctuations.

Figure 3. Reconstructed depth to water table (DWT) during the history of development of the Maly Labysh mire. Negative DWT values indicate water table above the mire surface. Root mean square error of DWT prediction is estimated by bootstrapping (n cycles = 1000) and marked with whiskers. Periods of drier climate conditions are marked with grey bands. Period with oligotrophic conditions in the mire surface is marked with the dotted frame.

After that, in the period 1400-1100 cal yr BP (the second stage of mire development, 105-135 cm) the prevalence of typical oligotrophic taxa, *Hyalosphenia papilio* and *Archerella flavum*, is observed in the fossil testate amoeba assemblages (Figures 2 and 3), most likely suggesting weakening of the fluvial activity of the nearby river followed by the absence of regular flooding of the mire surface and the consequent stagnant water regime in the mire and its acidification. We assume that the decline of the fluvial activity in this period was driven by the climate change and caused by decreased precipitation, although the reconstructed DWT value indicated high surface wetness in the mire at this time. This period coincides with the beginning of the well-documented Medieval Climate Anomaly (1250-800 cal yr BP [10]), which is characterized by drier climate conditions in 1250-1200 and 1100-1050 cal yr BP in [10] and in 1350-1100 cal yr BP in [11].

Then, starting from 900 cal yr BP, the Maly Labysh mire gradually came back to the transitional mesotrophic conditions on its surface, and the surface wetness remained moderately high (DWT is 15 cm below the mire surface) without notable fluctuations. The return to mesotrophic conditions indirectly indicates the resumption of regular flooding of the mire surface by river waters, which is probably caused by an increase in precipitation.
5. Conclusions
Centennial scale climate fluctuations have obviously influenced the changes in the surface wetness of the Maly Labysh mire during the last two millennia. The good consistency between the above-revealed short-term dry periods in the studied mire and similar dry events registered in the other regional lake and peat sediments located in the south of Western Siberia acknowledges the fact of predominant influence of the western transfer of humid air masses from the North Atlantic on the formation of the regional climate.

6. Acknowledgements
This research was supported by the Russian Foundation for Basic Research (project no. 20-55-53015/GFEN_a).

References
[1] Chernova N A, Blyakharchuk T A and Blyakharchuk P A 2014 Proc. Russian Conf. Man and nature - interaction in specially protected natural areas ed L A Trilikauskas (Gorno-Altaisk: Gorno-Altaisk State University press) pp 173–179
[2] Reimer P J et al 2013 Radiocarbon 55 1869–87
[3] Blaauw M and Christen J A 2011 Bayesian Analysis 6 457–474
[4] R Core Team 2012 R: A language and environment for statistical computing. R Foundation for Statistical Computing Vienna Austria. URL: https://www.r-project.org/
[5] Kurina I V and Li H 2019 Microbial Ecology 77 37–55
[6] Geltzer Y G, Korganova G A and Alekseev D A 1985 A practical guide to the identification of soil testate amoebae (Moscow: Moscow State University press)
[7] Mazei Y A and Tsyganov A N 2006 Freshwater testate amoebae (Moscow: KMK press)
[8] Juggins S 2017 rioja: Analysis of quaternary science data, R package version 0.9-21. URL: https://CRAN.R-project.org/package=rioja
[9] Grimm E C 2004 TGView Version 2.0.2. (Illinois: Illinois State Museum, Springfield)
[10] Willis K S, Beilman D, Booth R K, Amesbury M, Holmquist J and MacDonald G 2015 The Holocene 25 (9) 1425–36
[11] Hildebrandt S, Müller S, Kalugin I A, Dar’ in A V, Wagner M, Rogozin D Y and Tarasov P E 2015 Palaeogeogr. Palaeoclim. Palaeoecol 426 75–84