Catena 126 (2015) 1–10

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

The response of a shallow lake and its catchment to Late Glacial climate changes — A case study from eastern Poland

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ARTICLE INFO

Article history:
Received 28 May 2014
Received in revised form 7 October 2014
Accepted 13 October 2014
Available online 19 November 2014

Keywords:
Catchment development
Lake sediments
Multi-proxy analysis
Subfossil Cladocera
Late Glacial
East European Plain

ABSTRACT

In this study we investigate how climate fluctuation in the Late Glacial period influenced the development of a lake and its catchment located in the East European Plain. We analyzed the sediments of the lake for pollen, subfossil Cladocera, macrofossils and chemical composition. We aimed at disentangling: (1) the climate changes and their limno-ecological responses, (2) temperature dynamics with the use of Cladocera-based transfer function (MJT) and macrofossil-based reconstruction of mean minimum July temperature (MMJT), (3) timing of the response of different proxies to environmental changes. The results of multiproxy analyses explicitly suggest that the main driver for changes in aquatic and terrestrial ecosystems as well as geomorphological processes in the catchment was climate. Reconstructed temperatures generally follow the known trends showing the increase at the beginning of the Allerød and decrease at the beginning of the Younger Dryas. However, there are some discrepancies between the two reconstructions as well as between the generally accepted temperature trends in Late Glacial. The timing of the proxy response to climate change differs, the aquatic proxies responding first.

1. Introduction

Climate is the main environmental factor that affects lake ecosystems, directly through temperature and precipitation changes, and indirectly influencing the lake surroundings (Cohen, 2003; O'Sullivan and Reynolds, 2005). For example, air temperature regulates surface water temperatures, whereas temperature and precipitation together determine lake depth and control plant cover development in the catchment area. Vegetation type and density, in turn, influence the intensity of erosion, whereas the input of terrestrial material into the lake affects the whole aquatic ecosystem.

At the end of the last glaciation, there was a general climate warming trend although it included fluctuations such as warmer Allerød or cooler Younger Dryas, which are well recorded in the Greenland ice core NGRIP δ18O (%) results (Rasmussen et al., 2006). These fluctuations had a major impact on the environment (Bakke et al., 2009; Mayewski et al., 1993) and terrestrial archives (Brauer et al., 1999; Goslar et al., 1999; Neugebauer et al., 2012; Ralska-Jasiewiczowa et al., 1998; Wulf et al., 2013).

The main aim of this article is to investigate how major climate shifts in the Late Glacial period (Litt et al., 2001) influenced lake and catchment development. We investigated sediments of Lake Łukie located in eastern Poland (Fig. 1). This region was not glaciated during the Vistulian glaciation and therefore we expected that the lake ecosystem dynamics were different from those of the lakes located more to the north of Europe. In order to reconstruct climatic fluctuations and their limno-ecological responses, we analyzed the sediments of the lake using multi-proxy approach, including pollen, subfossil Cladocera, macrofossils and chemical composition of the sediment with special attention to the time of reaction of each proxy. We also attempted to quantify air temperature dynamics with the use of subfossil Cladocera assemblages and plant macrofossil remains. The method to use Cladocera remains for reconstruction of past environment parameters, with modern training data-sets was recognized to have "enormous potential" (Korhola and Rautio, 2001). Here we present the first Cladocera

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http://dx.doi.org/10.1016/j.catena.2014.10.007
0341-8162/

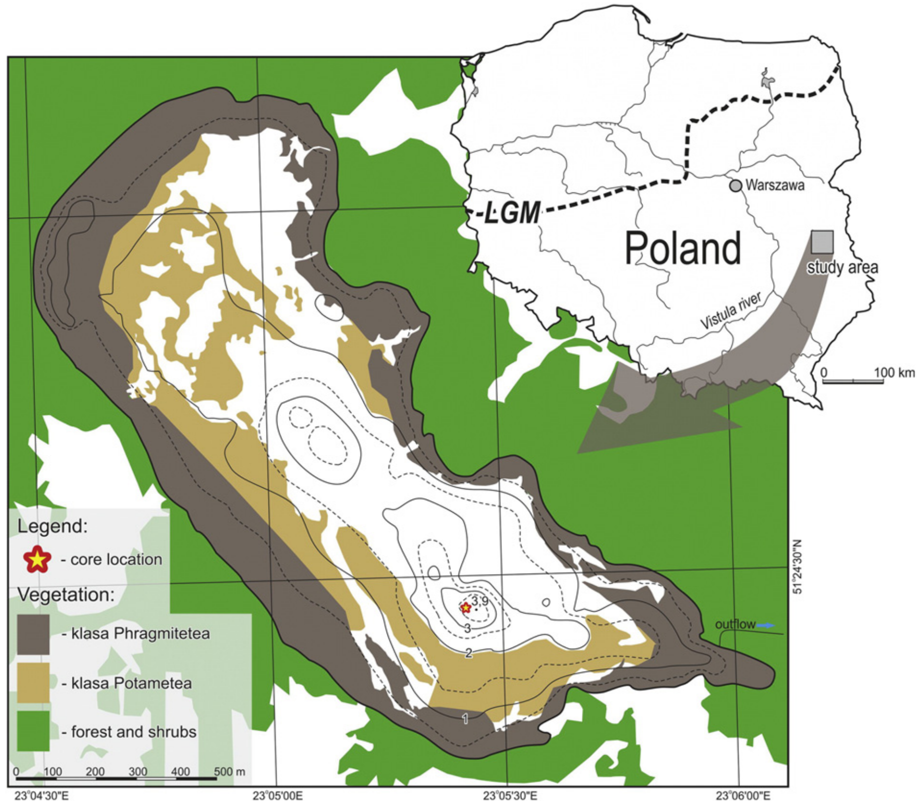

Fig. 1. Location of Lake Łukie on the map of Poland, with marked maximum extent of Vistulian glaciation (LGM), lake bathymetry (m), vegetation type and core location.

based reconstruction from Central Europe. We also pointed out the different timing of the response of proxies to climate changes.

2. Study site

Lake Łukie is located in the East European Plain, within the Łęczna-Włodawa Lake District. The lake is one of four lakes located in Polesie National Park, which is also a biosphere reserve designated by the UNESCO in 2002. The lake is eutrophic, its area is 136.7 ha and maximum depth 3.9 m. Lake Łukie is located beyond the reach of the last glaciation (Fig. 1) (Kondracki, 2001), and therefore the relief of its surroundings is monotonous. Pleistocene deposits, mostly sands, form hills (Harasimiuk et al., 2002) separated by depressions filled with organic sediments (peat, gyttja), often located in the deepest part of the lake. The climate of this region is temperate with strong continental features. The mean annual temperature is 7.3 °C and the amplitude of temperature is high, 22 °C, when comparing mean temperatures of January and July, or 70 °C when comparing extreme temperatures. The mean annual precipitation is 575 mm (Kaszewski, 2002). Lake Łukie is surrounded by peatlands dominated by *Ribo nigri–Alnetum* and *Betuletum pubescentis* plant associations. Most of the shallow area of the lake is covered by "water pineapple" (*Stratiotes aloides*). The pilot research done on Cladocera fauna in 2008 by Rybak revealed, that 5 species lived in the pelagic zone, *Diaphanosoma brachyurum* being dominant.

3. Materials and methods

3.1. Sampling

A 10-m core of sediments was retrieved from the deepest part of Lake Łukie (3.5 m) in November 2009, using a floating platform and a Więckowski piston corer with chamber diameter of 50 mm (Więckowski, 1959). The core was sampled at a 10-cm resolution, 1 cm^3 was taken for pollen, subfossil Cladocera, and chemical analysis at exactly the same depth. Larger samples 40–75 cm^3, 5 cm thick, were taken for macrofossil analysis. There were 30–40 samples prepared and analyzed for each of the proxies.

3.2. Chronology of the core

The chronology of Lake Łukie sediments was determined on the basis of AMS ^{14}C dates (Table 1) and pollen biostratigraphy. The results of the pollen analysis were compared with the already published pollen diagram of Lake Perespilno, located 30 km east. Lake Perespilno has a unique feature, its Younger Dryas sediments are varved and sediment sequence is dated with the ^{14}C method, therefore aside from pollen based biostratigraphy it also has good chronology. We assumed that given the geographic proximity of both lakes, their pollen diagrams reflect regional changes that were synchronous. We closely examined the curves for major trees and NAP for both lakes and accepted, that the beginning of the main Late Glacial chronozones must have happened at the same time in both lakes.

3.3. Pollen analysis

Sediment samples for pollen analysis were prepared according to Berglund and Ralska-Jasiewiczowa (1986). All sporomorphs were identified and counted until a minimum of 500 pollen grains of trees and shrubs (arboreal pollen, AP) were counted. Pollen grains of all herbaceous species (except the local aquatic and telmatic plants) were counted as non-arborescent pollen (NAP), and the sum of AP and NAP was considered as 100%. The zonation of the palynological sequence was constructed through CONISS (Grimm, 1987) and allowed us to distinguish three pollen zones within the Late Glacial sequence of the sediment. The CONISS dendrogram and diagram illustrating pollen distribution (Fig. 2) were drawn with Tilia2 and Tilia-Graph (Grimm, 1992).