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# Cladocera record from Budzewo (Skaliska Basin, north-eastern Poland)

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ABSTRACT. The sediment sequence from Budzewo (Skaliska Basin, north-eastern Poland) contains cladoceran records beginning from the early Holocene. A total of 33 Cladocera taxa were identified in the entire sequence. The cladoceran fauna of the initial stage of palaeolake history in the Preboreal shows high similarity to early Holocene Estonian and Scandinavian records. Benthic *Alonella nana* was dominant at that time. After that, probably during the Boreal and early Atlantic periods, Cladocera species diversity increased and planktonic forms (bosminas) became dominant, pointing to a rise of water level. The species composition indicates that the lake was meso- to eutrophic. The lake began to shallow during the middle Atlantic. The process was completed in the Subboreal and the lake transformed into a bog. The fall in water level and finally the terrestrialization of the lake is correlated with similar processes recorded in other sediment sequences in northern Poland, suggesting that this event may have been driven by regional factors such as lower precipitation.

KEYWORDS: Cladocera remains, Holocene, shallow lake, terrestrialization

## INTRODUCTION

Cladocerans form a major component of the zooplankton in freshwater lakes. Cladocera taxa can live in various part of a lake; some are planktoners and active swimmers, and others are benthic organisms dwelling on different substrates (e.g. plants, mud, sand). Since their exoskeleton is well preserved in sediments, Cladocera remains have been studied for decades (Frey 1958, Goulden 1964) and used as a good indicator of past and temporal changes in trophic states (Manca et al. 2007), acidification (Sienkiewicz et al. 2006, Gąsiorowski & Sienkiewicz 2010a), climate (Gąsiorowski & Sienkiewicz 2010b, Szeroczyńska & Zawisza 2011), food web structure (Alexander & Hotchkiss 2010, Skov et al. 2010), and human impacts on lake ecosystems (Gąsiorowski & Hercman 2005, Gąsiorowski 2008).

Holocene Cladocera records have been studied in a few localities in north-eastern Poland (Czeczuga & Kossacka 1977, Szeroczyńska 1985, Zawisza & Szeroczyńska 2007, Gąsiorowski & Kupryjanowicz 2009). There are many lakes in the region but little is known about changes in the history of Cladocera in that part of Poland. The aim of this study was to characterize the cladoceran assemblages in a sediment sequence in Budzewo (western part of Skaliska Basin) and to reconstruct the changes in lake ecosystems as reflected in the variation of cladoceran species composition. In this paper a special attation was paid to the process of transformation the palaeolake into a peat-bog. The changes in Cladocera species composition during the lake-peat transformation has been compared with similar processes described from the other sites (Korponai et al. 2010).

## MATERIAL AND METHOD

Core W4 from Budzewo in the Skaliska Basin (Pochocka-Szwarc 2013) was subsampled for Cladocera every 15–40 cm (Fig. 1). Cladocerans were analysed from detrital gyttja and peat sediments in the 995–200 cm depth interval (Kołaczek et al. 2013).

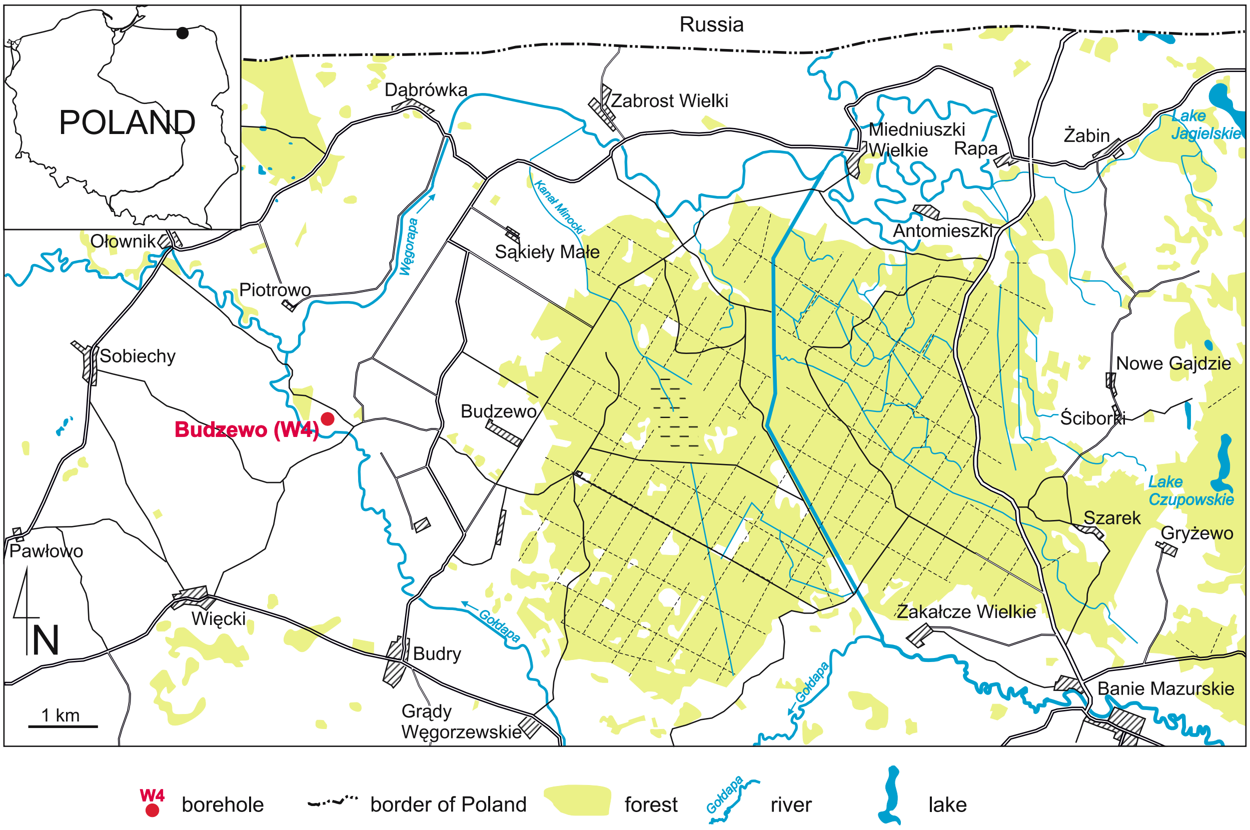


**Fig. 1**. Location of studied sediment sequence

The methodology follows that described by Korhola and Rautio (2001). Samples for cladoceran analysis (1 cm$^3$ of wet sediment) were heated at 80°C with 8% KOH with magnetic stirring to deflocculate the material. Then the sample was sieved through 33 μm mesh and diluted in 10 cm$^3$ distilled water. A slide was prepared from 0.1 ml of each sample and studied with a biological microscope at ×100, ×200, and ×400. Two to six slides were scanned from each sample, depending on the total concentration of cladoceran remains in the sediment. In all samples except those from horizons 995 cm and 980 cm, 350–400 cladoceran remains were counted (headshields, shells, postabdomen, postabdominal claws). For each species the most abundant body part was chosen to represent the number of specimens, and percentages of the sum of specimens were calculated. Identification of cladoceran remains was based on keys by Flössner (2000) and Szeroczyńska and Sarmaja-Korjonen (2007). The results are presented as percentage diagrams in depth scale. Cladocerans were grouped according to their ecological preferences, as described by Whiteside (1970) and Duigan (1992). Planktonic/littoral (P/L) ratios were calculated as described by Gąsiorowski and Hercman (2005). The studied sediment sequence was divided into four Cladocera phases based on cluster analysis. The CONSLINK algorithm was used for clustering samples into groups (Gordon & Birks 1972).

## RESULTS

From 200–995 cm depth, 37 samples were studied for Cladocera species composition in the Budzewo W4 core. The remains of 33 taxa belong to 5 families: 27 taxa belong to Chydoridae, 1 to Sididae, 3 to Bosminidae, 1 to Daphniidae, and 1 to Leptodoridae. Based on changes in species composition, 4 phases of Cladocera succession were described (Fig. 2) and assigned to chronozones based on pollen stratigraphy (Kołaczek et al. 2013).

### Phase I (995–895 cm), Preboreal

Only a few remains of *Alonella nana* and *Alona quadrangularis* were found in the deepest sample (995 cm horizon). Higher in the sequence, *Alonella nana* and *Bosmina longirostris* are dominants. Other benthic species occurred in this phase and the P/L ratio is low. The total sum of cladoceran specimens per 1 cm$^3$ increased to almost 10 000.

### Phase II (895–550 cm), Boreal – Early Atlantic

Pelagial species developed and the genus *Bosmina* was dominant group of Cladocera.

The pelagial predator *Leptodora kindtii* also is represented in this phase. Benthic species are numerous but their percentages are low. The total concentration of Cladocera remains reached 13 000 specimens per 1 cm$^3$. The P/L ratio increased significantly and reached maximal value in the sample from the 675 cm horizon, but the concentration of cladoceran remains was relatively low (3500 specimens · cm$^{-3}$).

Phase III (550–310 cm), Middle – Late Atlantic

Planktonic taxa declined and benthonic forms began to dominate the cladoceran assemblages, related mainly to muddy and sandy bottom (e.g. *Alona quadrangularis*, *Leydigia* spp., *Disparalona rostrata*). P/L ratio decreased and the total concentration of remains was low (1500–5000 specimens · cm$^{-3}$).

Phase IV (310–200 cm), Subboreal

*Bosmina longirostris* and *Chydorus sphaericus* reflect an increase in trophic state. Plant-related taxa increased (*Acroperus harpae*, *Graptoleberis testudinaria*) indicating lower water level. The P/L ratio value was still very low, but the total concentration of Cladocera increased and reached maximal value (16 800 ind. cm$^{-3}$) in the uppermost sample. This phase documents the final overgrowing of the lake. No Cladocera remains were found above the 200 cm horizon.

## DISCUSSION

Cladoceran phase I represents the initial stage of lake history. At that time there was a shallow lake with cool water and the bottom was gradually colonized by macrophytes. The species composition (i.e. domination of *Alonella nana*) in this phase is specific for Budzewo, differing from the initial stage in other Polish lowland lakes, where the cladoceran assemblages during initial stages were dominated by so-called 'Arctic species' such as *Acroperus harpae*, *Alona affinis*, and *Chydorus sphaericus* (Zawisza & Szeroczyńska 2007). The species composition from the basal part of the

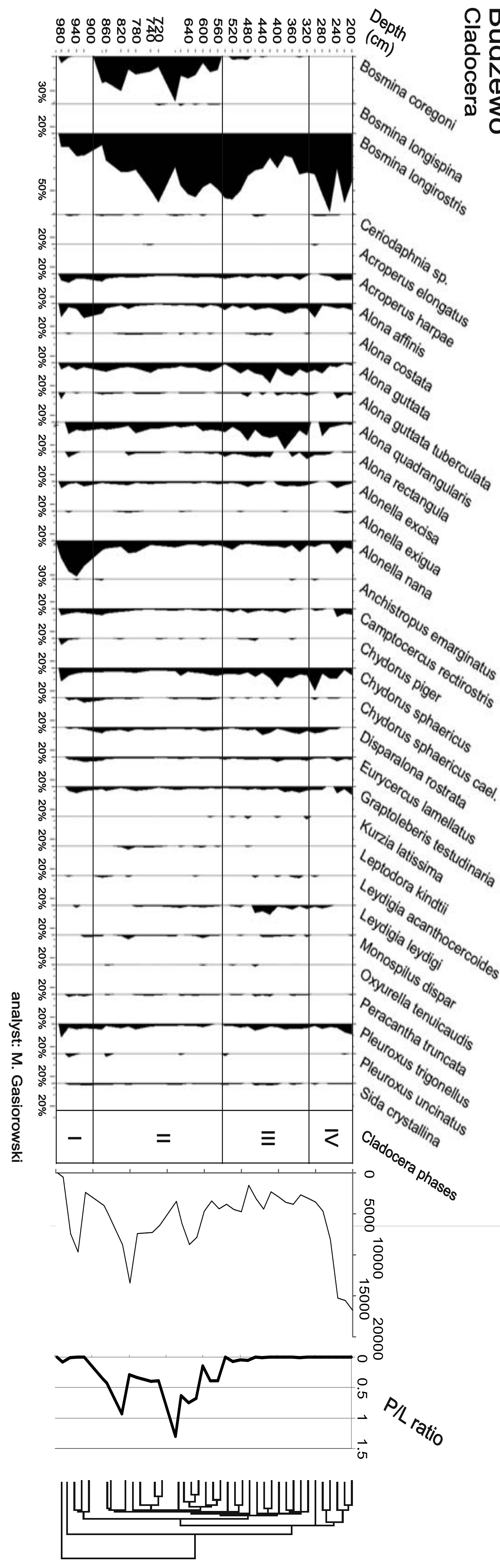


**Fig. 2**. Relative percentages, fauna phases, total concentration per 1 cm$^3$, planktonic:littoral ratio and cluster analysis (CONSLINK) dendrogram based on results of Cladocera analysis from core W4 in Budzewo

Budzewo sediment sequence is more similar to that recorded in some postglacial sediment sequences in Estonia and Finland (Sarmaja-Korjonen et al. 2003). In fact, even now the climate of north-eastern Poland is more continental than in other parts of Poland and corresponds to the climate of north-eastern Europe. Radiocarbon dating and pollen stratigraphy indicates that phase I comprises sediments deposited from the beginning of the Holocene, during the Preboreal (Kołaczek et al. 2013). Besides climate warming during this chronozone, Cladocera data supported by the stable isotope composition of lacustrine carbonates (Mirosław-Grabowska 2013), that is, relatively low values of $\delta^{18}O_{carbonates}$, indicate inflow of cold water into the lake, possibly from melting dead-ice.

The lake became significantly deeper in the Boreal period (cladoceran phase II). Planktonic cladoceran taxa began to dominate and the planktonic/littoral ratio reached its maximal value 1.3 in the 675 cm horizon (Fig. 2). The high proportion of *Bosmina coregoni* suggests the existence of an extended limnetic zone. A rise of water level at that time is also confirmed by diatom flora (Sienkiewicz 2013), namely the domination of planktonic taxa. The absence of *Daphnia* may suggest intensive fish predation, but other large species such as *Leptodora kindtii* and *Eurycercus lamellatus* were present in this phase. Thus the lack of daphnias might be explained by high food competition from small planktoners (e.g. bosminas) or other factors. Littoral taxa were numerous, and the species composition of benthic chydorids points to the presence of a habitat mosaic at the bottom of the lake: patches of macrophytes, and muddy and sandy bed. Trophic state was probably on the level meso/eutrophy. Symptoms of water level decline and increased trophy were observed from the beginning of the middle Atlantic (phase III). *Bosmina coregoni* declined and finally disappeared, with a simultaneous increase of benthic species. Similar changes were recorded in diatom species composition (Sienkiewicz 2013) by an increase of benthic and epiphytic taxa. The isotopic record (Mirosław-Grabowska 2013) also indicates changes in the precipitation/evaporation ratio and, indirectly, shallowing. The increase of green algae *Botryococcus* (Kołaczek et al. 2013) points to eutrophication, confirmed by the high proportion of *B. longirostris* and *Chydorus sphaericus*. A specific increase of species related to open-bed was observed in the middle part of this cladoceran phase. Benthic species living on sandy (e.g. *Chydorus piger*, *Monospilus dispar*) and muddy (*Disparalona rostrata*, *Leydigia leydigi*) bottom may indicate increased erosion in the palaeolake's catchment and higher input of detrital material into the basin. However, they also disappeared in the uppermost sample and this coincided with an increase of plant-related taxa (e.g. *Camptocercus rectirostris*, *Graptoleberis testudinaria*). Therefore, terrestrialization of the palaeolake at Budzewo was caused more probably by overgrowth with limnic and telmatic plants (see Kołaczek et al. 2013) than by infilling with clastic sediments. Moreover, the simultaneous increase of *Alona guttata* var. *tuberculata* and *Alonella excisa* suggests a slightly more acidic environment or the presence of peatland in the vicinity of the coring site.

The palaeolake at Budzewo probably was overgrown with macrophytes at the beginning of the Subboreal. Besides the low water level, Cladocera were relatively abundant. This stands in contrast to observations by Korponai et al. (2010) from the Kis-Balaton Basin. In the Skaliska Basin, however, terrestrialization of the lake was relatively rapid, without a transitional stage between lake and bog (Gąsiorowski & Kupryjanowicz 2009). Overgrowing of the lake in the Skaliska Basin was synchronous with similar events at other sites in northern Poland (Ralska-Jasiewiczowa & Starkel 1988, Gąsiorowski & Kupryjanowicz 2009). The supraregional nature of that event implies climate as a controlling factor. However, it is hard to determined the nature of this factor (lower precipitation, increase of temperature, or other).

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