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DEVELOPMENT OF THE KUBŁOWO PALAEOLAKE, CENTRAL POLAND, DURING THE EEMIAN INTERGLACIAL AS AGAINST SUBFOSSIL CLADOCERA ANALYSIS – PRELIMINARY RESULTS

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Abstract
The results of analysis of Cladocera occurrence in lacustrine sediments from the Kubłowo site have been presented. Lacustrine and peat deposits found there have been previously analyzed for pollen content (depth of 11.1–3.8 m) and represent a longest continuous Eemian–Vistulian succession in central Poland (Roman and Balwierz, 2010). Cladocera analysis was carried out on 25 samples from the depth of 9.20–10.5 m of an Eemian age section. The section consists of fine organic sand, silt with organic matter and gyttja. Identified were 19 species of subfossil Cladocera and five zones of fauna development were distinguished. In the early and mid-Eemian low frequency zooplankton in the palaeolake has been found. Best conditions for zooplankton development occurred in the late Eemian (R PAZ E6, E7). At the end of the Eemian a significant change of climate in a deterioration of environmental conditions and decreased presence of zooplankton has been noted. Cladocera results and the pollen data enable a reconstruction of the climatic and environmental changes in the Kubłowo palaeolake.

Key words: Cladocera analysis, Eemian Interglacial, palaeoenvironment, central Poland.

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INTRODUCTION

Numerous localities with lacustrine deposits of Eemian Interglacial age have been found in central Poland, particularly in the Płock Lobe area and its surroundings (Fig. 1). The area, was a wide lakeland during the Eemian. Lake sediments of that age have well been documented in palynology. At some sites (Ruszkówek, Kaliska and Studzieniec) a succession of Cladocera has also been recorded (Mirosław-Grabowska and Niska, 2007a; Mirosław-Grabowska and Niska, 2007b; Mirosław-Grabowska *et al.*, 2009; Niska, 2008).

Generally, Cladocera an organisms group dominant within zooplankton and their subfossil remains are well preserved in sediments (*cf.* Szeroczyńska, 2002). Small size of Cladocera, their aptitude to produce ephippia which may be transported by birds to colonize new water bodies, and ability to reproduce by parthenogenesis, caused Cladocera much more expansive and mobile than larger aquatic fauna. Thus, their response to climatic and environmental changes may be faster and more radical than in the case of larger organisms.

Subfossil Cladocera have been studied for almost 90 years. In Poland, first studies were conducted in the 1980s and 1990s (Czeczuga *et al.* 1970, Mikulski, 1976, Szeroczyńska, 1984, 1985, 1991, 1998; Bińka *et al.* 1991). The high usefulness of Cladocera in reconstruction of environmental conditions has led to a considerable interest in its potential applicability in studies of older sediments preceding the last glaciation. Frey (1962) initiated investigations of Cladocera from Eemian deposits. Since 2001 similar studies have been taken up in Poland by Niska (Kupryjanowicz, 2005; Mirosław-Grabowska and Niska, 2005; Niska, 2002, 2003). Cladocera subfossils deposited during the Eemian Interglacial, compared to those from the Holocene sediments, are thinner, have a more damaged structure and often lack characteristic features enabling species determination. subfossil Cladocera remains examined in the Eemian sediments did not exhibit substantial differences in appearance and size compared to the present-day remains. Despite the substantial destruction of the Cladocera remains, the obtained results are fully credible and may be used in the reconstruction of environmental conditions from the period preceding the last glaciation

The aim of the article is to present results of Cladocera analysis and zooplankton succession, emphasizing the palaeolake environmental changes during the Eemian Interglacial at Kubłowo.

STUDY SITE

The Kubłowo site is located in the northern part of the Kłodawa Plateau within the area of the Warta Stadial, the final stadial of the Odranian (Late Saalian) Glaciation (for-

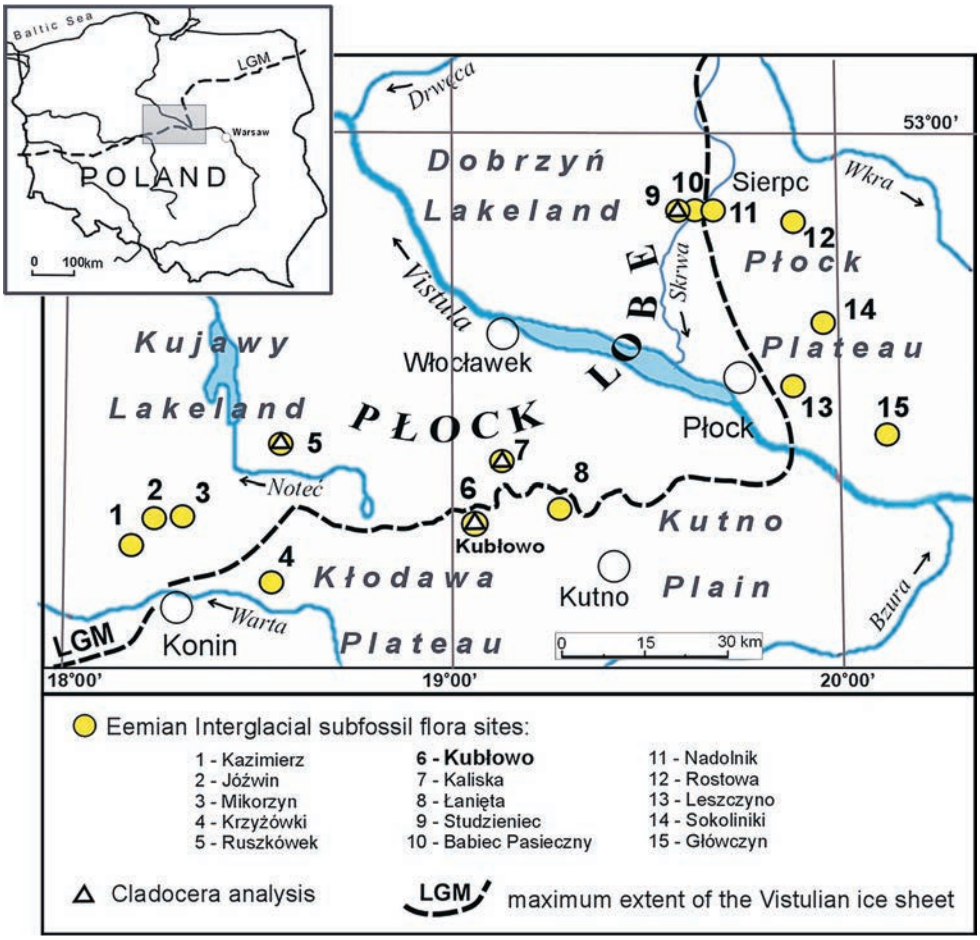

Fig. 1. Location of Eemian subfossil flora sites in Central Poland.

merly Wartanian Glaciation) (Lindner, 2005; Ber *et al.*, 2007) and slightly to the south of the maximum limit of the Vistulian (Weichselian) Glaciation ice sheet (Fig. 1). The Kłodawa Plateau is a monotonous morainic plain at 120–130 m a.s.l., mainly composed of till. There are no postglacial lakes, however, in fossil depressions at Kubłowo can be found biogenic deposits which accumulated throughout the Eemian Interglacial and the older part of the Vistulian, and were subsequently covered by glaciofluvial sediments during the last ice sheet advance (Roman and Balwierz, 2010). The organic deposits at Kubłowo have been found to be associated with marginal forms of the maximum extend of the Vistulian Glaciation ice sheet in the Płock ice lobe (Roman 2007, 2010). Lacustrine and peat deposits found there have been analyzed for their pollen content (depth of 11,1 – 3,8 m) and represent a longest continuous Eemian–Vistulian succession in central Poland (Roman and Balwierz, 2010). The presently examinated deposits from 10.50 to 9.20 m do not contain carbonates and their lithology is shown below:

Depth (m)	
9.20–9.40	laminated silt and silty clay, gray to brownish-gray,–HCl
9.40–10.10	gyttja, highly compressed, dark gray, –HCl
10.10–10.35	silt with organic matter, dark gray, –HCl
10.35–10.50	very fine organic sand, light gray, –HCl

METHODS

The Cladocera analysis was carried out on 25 samples from the depth of 9.20 to 10.50 m. The samples of $1 cm^3$ were prepared according to the standard procedure (Frey, 1986), slightly modified. After removal of carbonates using 10% HCl, each sample was heated to 80°C in 10% KOH for 20 minutes. After washing with distilled water, the residue was sieved through a 40-μm mesh. The fine material was transferred into a polycarbone test-tube. Before counting, the remains were coloured with safranine. A minimum number of 200 remains of Cladocera (3–5 slides) were examined in each sample. All the remains from each slide were counted (headshield, shell, postabdomen, postabdominal claws, antennules and other), and next, the cladoceran specimens were assembled. Identification and ecological interpretation of the Cladocera remains were carried out according to Duigan (1992), Frey (1958, 1962), Goulden (1964), Hofmann (1986, 2000), Korhola (1990), Flössner (2000) Szeroczyńska (1985), and Szeroczyńska and Sarmaja-Korjonen (2007). Results of the quantitative and qualitative analysis are shown in the concentration diagram, and the total number of Cladocera specimens in $1 cm^3$ of deposits and the species diversity was assessed according to the Shannon-Wiener Biodiversity Index to see on Figure 2, 3 (PolPal computer program, Walanus and Nalepka, 1999) .

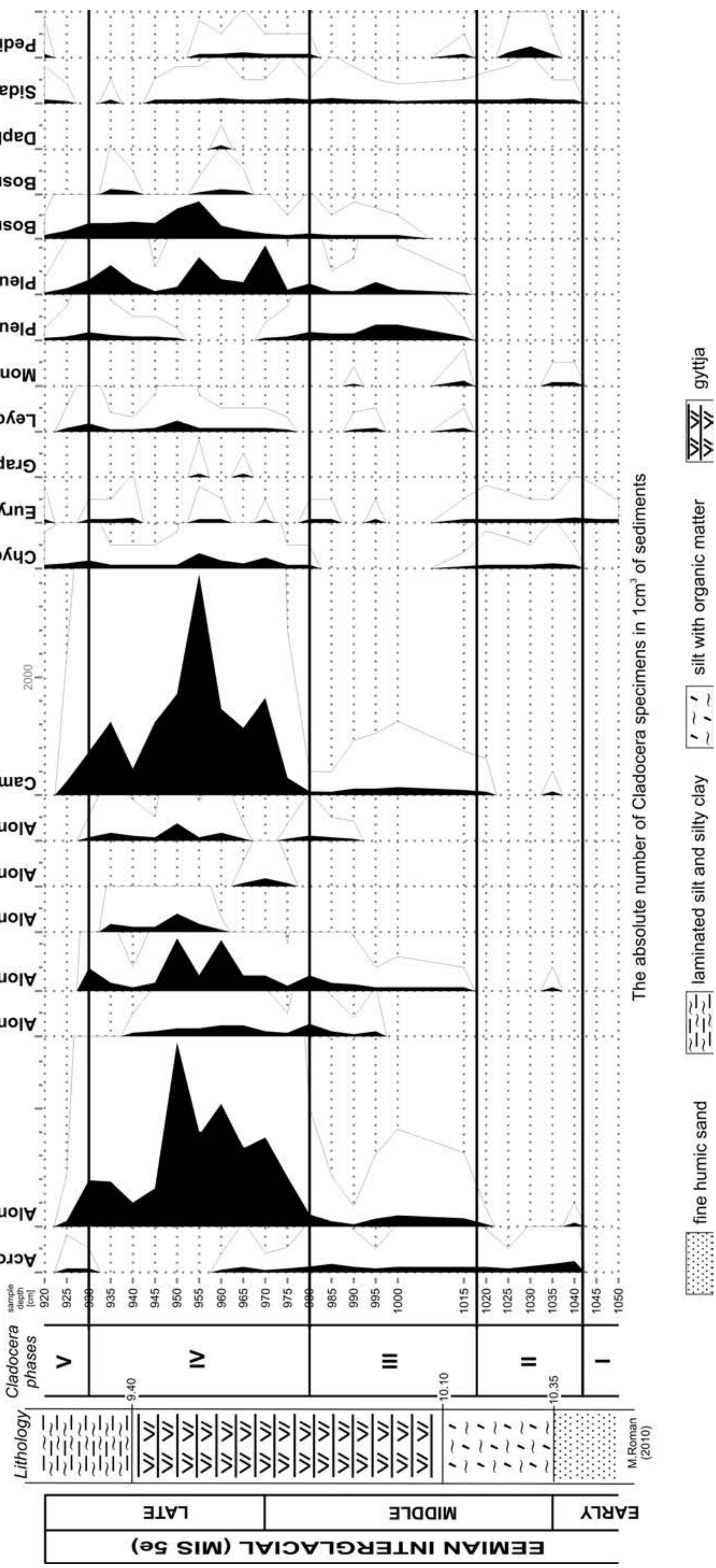

Fig. 2. Diagram of the absolute number of Cladocera individuals in the sediments of Kubłowo profile.

RESULTS

Subfossil cladoceran fauna from the Kubłowo palaeolake is represented by 19 species belonging to four families: Bosminidae, Chydoridae, Sididae, Daphnidae. Most of the remains are of the Chydoridae and Bosminidae families. Dominant were two species of Chydoridae – Alona affinis and Camptocercus rectirostris belonging to a group inhabiting the littoral zone in clear and calm water, depending on the presence of aquatic plants (Flössner, 1972). Considering the age of the remains from over 100 ka BP (128,000–118,000 years BP, Shackleton, Opdyke 1976), they are well preserved and came in large numbers. The quantitative and qualitative composition of fauna has enabled to distinguish five phases of the Cladocera development (Fig. 2).

Phase I (10.50 m – 10.42 m): at that phase only one species has been identified, namely, *Eurycercus lamellatus* which was tolerant to low water temperatures (Poulsen, 1944) and inhabs the littoral zone in clear waters. *E. lamellatus* suggests the existence of macrophytes (Flössner, 1972).

Phase II (10.42 m – 10.17 m): at that phase occurred species preferring water with low content of nutrients and tolerant of cold water, such as *Acroperus harpae*, *Eurycercus lamellatus*, *Sida crystalina*, *Alona affinis*, (Whiteside, 1970) and eurybiont – *Chydorus sphaericus* (Alhonen, 1970). Throughout this phase the presence of eight species of Cladocera was noted (above 400 specimens/1 cm^3 in the sediments, Fig. 3). Within the duration of this phase occurred *Monospilus dispar*, a species connected with sand in the bottom. The occurrence of the *Camptocercus rectirostris* suggested a little warmer water conditions (Poulsen, 1944). At that phase there are species characteristic for a littoral zone and the absence of species from the open water was noted.

Phase III (10.17 m – 9.80 m): at that phase species tolerant to cooler water (*Eurycercus lamellatus*) give way to species preferring water of higher temperature. In the lake found were *Camptocercus rectirostris* – preferring warmer, clean and calm water, dwelling in the macrophyte zone, and *Pleuroxus uncinatus* and *Pleuroxus trigonellus* – preferring water that is warmer and richer in nutrients (Frey, 1958). This may indicate a rise in water temperature and an increase in nutrients in the lake. Improvement of living conditions in the lake caused a greater biodiversity, 14 species occurred (above 1500 specimens/1cm^3 of sediments, Fig. 3).

Phase IV (9.80 m – 9.30 m): the beginning of phase IV was expressed by an increase of both diversity of taxa (18 species) and frequency of Cladocera remains up to 8000 specimens/cm^3 of a deposit. It indicates an improvement of the environmental conditions (warmer water, more nutrients) in the lake. The conviction of the warm conditions in this palaeolake is supported by the presence of *Camptocercus rectirostris*, *Pleuroxus trigonellus*, *Pleuroxus uncinatus* and *Graptoleberis testudinaria*. Higher attendance of the *Leydigia acanthocercoides*, *Alona rectangula*, *Pleuroxus uncinatus* species suggests a higher content of nutrients in the water (Korhola, 1990). The appearance of *Graptoleberis testudinaria* may indicate nutrient-rich water (Duigan, 1992). In the middle of that phase there was an increased presence of species preferring open water: *Bosmina coregoni*, *Bosmina longirostris* and *Daphnia pulex*-group. This may suggest a rise of the water level in the lake. In the middle of that phase (9.50 m) *Alonella excisa* have been reported, species that can be related to the decrease of pH of the water in the lake (Krause-Dellin and Steinberg, 1986). That phase ends the period of favorable conditions for the development of Cladocera. During that phase, two short periods of lower Cladocera frequency were recorded (9,65 m and 9.40 m). This could be due to the fluctuations in thermal conditions in the reservoir and the occurrence of short cold climate periods.

Phase V (9.30 m – 9.20 m): at the beginning of that phase 12 species of Cladocera were identified in sediments. The significant decrease in the presence of Cladocera individuals of all species (max 3000 individuals/1cm^3) along with lowering number of species was observed. In the palaeolake *Acroperus harpae* species reappeared. In that phase presented were species with diverse condition preferences but a decrease in concentration of remains in the sediment may indicate deteriorating living conditions in the lake probably connected with water lowering and climate cooling.

DEVELOPMENT OF THE KUBŁOWO PALAEOLAKE

The stratigraphy of the sediments of the Kubłowo palaeolake was determined on the basis of the distinguished pollen zones. According to the pollen data, the lacustrine deposits from 11.00m to 9.20m were accumulated during the Eemian Interglacial (Roman and Balwierz, 2010).

Early Eemian, Pollen zone K1 – *Pinus-Artemisia-Juniperus;* K2 – *Pinus–Betula-Quercus*

Sedimentation of organic deposits at Kubłowo commenced when in the neighborhood were open pine forests with a distinct birch share (L PAZ K1), while scarce open terrains were grassy (Roman and Balwierz, 2010). The amelioration of the climate led to a visible reduction in heliothytes, replaced by dense birch-pine forests (L PAZ K2) (Roman and Balwierz, 2010). At the begining of the period correlated with L PAZ K2 in the lake appeared cladocerans represented by a single species tolerating cold water (Cladocera Phase I). The water level was probably low. At the bottom of the lake sand was deposited. The conditions in the lake were not favorable for the development of zooplankton.

Eemian optimum, Pollen zone K3 – *Quercus*, K4 – *Corylus-Tilia-Almus*, K5 – *Carpinus-Alnus-Corylus-Tilia*

The interglacial climatic optimum began with oak forests and some elm and ash (L PAZ K3). At that time in the lake dominated species preferring water with a low content of nutrients and tolerant to cold water. In the zone the Cladocera species preferring warmer water appeared for the first time, which suggested slightly warmer water conditions (Cladocera phases II). At that zone predominated species from the littoral zone. The progressing warming resulted in changes in the dominant tree stands. The dominant species – oak, elm and ash trees were replaced by multi-species deciduous forests with hazel and linden trees, as well as alders (L PAZ K4), prevailing in wet habitats. With time, hornbeams began to spread and at the end of L PAZ K5 they became

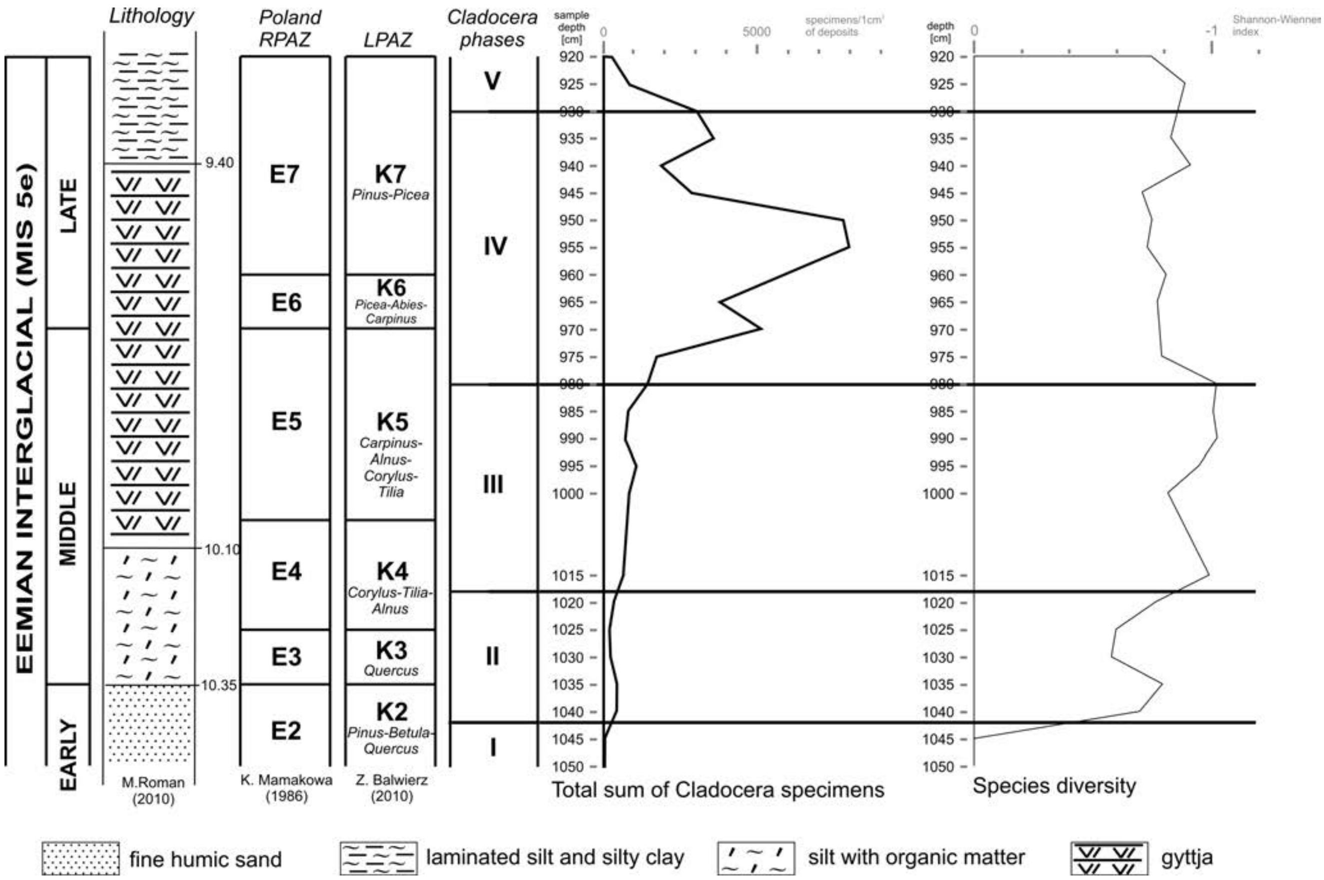

Fig. 3. Diagram of the total number of Cladocera specimens and species diversit at the Kubłowo profile.

dominant (Roman and Balwierz, 2010). In the lake from L PAZ E4 (Cladocera Phase III) there was an increased frequency of species preferring warmer water richer in nutrients. Improvement of living conditions in the lake caused a greater diversity of species. From the beginning of the K5 zone the water level in the reservoir became slightly higher.

Eemian post-optimum, Pollen zone K6 – *Picea-Abies-Carpinus*, K7 – *Pinus-Picea*

The decline of the climatic optimum was marked by the pre-eminence of horn beam forest. The gradual cooling of the climate led to a recession of thermophilous trees and the appearance of spruce, fir and yew (L PAZ K6). Despite the progressing cooling, the fauna inhabiting the lake reached its maximum development. The climatic conditions occurring in the L PAZ K6 and at the beginning of the K7 zone were optimal for the development of zooplankton, which resulted in the increase of the Cladocera species and respective individuals, including thermophilic species (Cladocera phase IV). A larger number of species preferring more fertile water as well as a presence of organic matter were noted. At the beginning of L PAZ K7 the increased number of species preferring open water suggests rising of the water level in the lake. Then, *Alonella excise* was reported. This may indicate the decrease of pH. The sediments changed into silt. At the end of L PAZ K7 there was a decrement in both the number of the Cladocera species and the number of specimens of particular species (Cladocera phase V). At that time the spread of pine trees with some spruce and initially also fir (L PAZ K7) marked the decline of the Eemian Interglacial (Roman and Balwierz, 2010). In the lake the most unfavorable conditions for the development of zooplankton occurred probably due to the progressing cooling of the climate.

During the late Eemian Interglacial there were recorded short periods of lower frequency of Cladocera (9.65m, 9.40m – Cladocera phase IV), which could have been due to fluctuations in the thermal conditions in the lake and the occurrence of short cooling periods.

DISCUSSION

The reconstruction of the Cladocera succession during the Eemian Interglacial at Kubłowo is comparable with the records from the adjacent Eemian sites: Ruszkówek (Janczyk-Kopikowa, 1997; Mirosław-Grabowska and Niska, 2007b) and Kaliska (Janczyk-Kopikowa, 1965, Mirosław-Grabowska and Niska, 2007b). These palaeolakes are located no further than 40 km from each other. The closest to Kubłowo is the Kaliska palaeolake. The Cladocera succession in the Kaliska palaeolake began with the outstart of the hazel zone (R PAZ E4). However, in the Ruszkówek palaeolake an individual Cladocera species appeared at the turn of R PAZ E2/E3 like in the Kubłowo palaeolake. The Cladocera species occurring during the early Eemian Interglacial belong to the so-called *arctic species* (*Alona affinis*, *Acroperus* *harpae*), tolerant of cold water with a low content of organic matter (*Eurycercus lamellatus)*.

During the period correlating with R PAZ E4 (Corylus) in the palaeolakes of Ruszkówek and Kubłowo fauna development and increased amount of thermophilic species were recorded. However, at the end of the hazel zone (E4) and in the hornbeam zone (E5) at two sites – Kaliska and Ruszkówek an absence of faunal remains was observed. The explanation of that phenomenon is difficult. One reason could have been the high content of $CaCO_3$ in those sediments. The carbonate might have accelerated the decay of chitin shells, which have not preserved till now. The second reason could have been a shortage in nutrients and/or unfavourable conditions in the reservoir connected with a higher water level (Mirosław-Grabowska and Niska, 2007b). There is no significant drop in Cladocera fauna frequency in the profile of Kubłowo probably due to lack of calcium carbonate in the sediments. This resulted in a continuous succession of Cladocera in the middle of the Eemian. In the palaeolakes the beginning of the late Eemian was associated with the development of the Cladocera fauna. Especially clearly marked was the increase in the frequency of fauna in the profiles of Kaliska and Kubłowo.

In the palaeolakes species from the littoral zone dominated. *Bosmina longirostris* was a common migrant species which, with increasing trophy, could move between open water and the littoral zone (Frey, 1986). Only from Kubłowo the presence of the *Bosmina coregoni*, the species connected with open water zone was repoted, which may indicate greater depth in the Kubłowo palaeolake than in the others lakes.

The end of the Eemian Interglacial is connected with a strong drop in frequency of Cladocera in the studied palaeolakes. The gradual cooling resulted in an inhibition of life in all the lakes.

In the neighboring palaeolakes, there was a similar development of the Cladocera succession resulting from regional climate changes taking place in the Eemian Interglacial. The differences in the development of the fauna between lakes are the result of differences in the local conditions under which lakes existed and of their origin, characteristics and the location of the lake basin.

The studies of the Kubłowo palaeolake will be continued for the purpose of tracing the Cladocera succession and lake development throughout the Vistulian. The research will also be supplemented by determination of stable isotopes in the sediments.

CONCLUSION

1. In the Kubłowo palaeolake most dominant and most diverse group of species was the littoral group – the Chydoridae family.

2. The development of zooplankton in the reservoir began as in other reservoirs in the region before the L PAZ K3 (R PAZ E3).

3. The environmental conditions in the palaeolake during the early Eemian Interglacial have not provided favorable conditions for the development of zooplankton, which could be associated with a low content of nutrients in the water.

4. Increase water fertility occurred in the middle of Eemian Interglacial (Cladocera Phase III).

5. Based on the increase in the number of Cladocera found that the most favorable environmental conditions for the fauna development present in the end of the middle Eemian Interglacial and the beginning of the late Eemian Interglacjal.

6. The highest frequency of the Cladocera remains in the sediments occurred at the end of the Eemian Interglacial (K6 and K7 L PAZ) similarly to other sites, the Kaliska and the Ruszkówek.

7. The Cladocera species found in the examined palaeolake correspond to the present-day species inhabiting the area of Poland and Europe.

8. Cladocera subfossils deposited during the Eemian Interglacial, compared to those from the Holocene sediments, were thinner, had a more damaged structure and they often lacked characteristic features enabling species determination.

9. Cladocera phases show a good correlation with the local pollen assemblages zones distinguished by Balwierz (Roman and Balwierz, 2010).

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