

SUBFOSSIL CLADOCERAN FAUNA OF THREE SMALL HARD-WATER LAKES OF DIFFERENT TROPHIC STATUS

Magdalena Suchora, Anna Kaczorowska, Wojciech Pęczuła

Department of Hydrobiology, University of Life Sciences in Lublin
B. Dobrzańskiego str. 37, 20-262 Lublin, magda.suchora@up.lublin.pl



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Summary. The analysis of subfossil Cladocera remains in surface sediments from central and littoral sites was carried out in three, closely located, small lakes belonging to the Łęczna-Włodawa Lake Group. The species composition, total abundance and biodiversity measures (species richness and species diversity) were used to characterize subfossil Cladocera fauna. The highest specimens abundance and the lowest biodiversity values were observed in a hypertrophic lake, Lake Syczyńskie, whereas the lower abundance and highest diversity were typical, for the lake representing the lowest trophy, Lake Stone. Cluster grouping indicates a high intra-lake similarity of samples, regardless of provenance. Between the lakes, the most similar assemblages were those of lakes Syczyńskie and Pniówno which, again, reflect the trophic gradient.

Key words: subfossil Cladocera, small water bodies, palaeolimnology, trophic state index TSI, Chełm Hills

INTRODUCTION

Despite its important ecological role and the multiple anthropogenic threats, a high share of small lakes are often left behind in the main course of limnological research. This concern also zooplankton studies. Cladocera, as a significant component of lacustrine zooplankton, play an important role in freshwater ecosystems. Due to their intermediate position in the aquatic food webs, they actively participate

in shaping the water quality [Carpenter *et al.* 1987]. As a result of the small number of faunistic investigations, the knowledge on distribution of freshwater Cladocera is scarce [Dziuba *et al.* 2013]. An effective, in terms of effort, approach towards faunistic research, lacustrine monitoring and assessment of ecosystem condition, is the palaeolimnological method [Nevalainen 2010]. Lake sediments are powerful archives of information on the lake ecosystem and its direct vicinity, and, due to the integrative character, a single sampling can provide a share of information [Cohen 2003]. Chitinous remains of Cladocera preserve well, and can be identified to the species level, therefore, keeping in mind a few well known constraints of subfossil cladocera analysis [for details see Korhola and Rautio 2001], we can successfully utilize this method in limnological studies.

The three lakes selected to this study – Syczyńskie, Słone and Pniówno – are marginally located among the Łęczna-Włodawa Lake Group, within the Chełm Hills Region (Lublin Upland, SE Poland). As far as Cladocera are concerned, little is known about the composition of the zooplankton in this group of lakes, except in Lake Syczyńskie [De Eyto *et al.* 2003, Adamczuk and Kornijów 2011]. Since the studies of Kowalczyk [1977, 1978], no data were published on Cladocera composition of these waterbodies. Information about the composition of cladoceran fauna may be helpful in assessing the ecological quality of lakes. Although nowadays the use of Cladocera in lake quality assessment is underexploited, yet the vast potential of this group is widely pointed out [Jeppesen *et al.* 2011, Luoto *et al.* 2013].

The aim of the study was to: (1) provide an information about the composition of subfossil Cladocera of three small, hard-water lakes, (2) compare their Cladocera assemblages, (3) survey the diversity of remains in sediments from shallow and deep parts of the explored lakes.

STUDY SITE

The study was conducted in three small, hard-water lakes: Syczyńskie, Słone and Pniówno, located in the border zone of the Polish Lowlands and the Lublin Upland, included by Wilgat [1954] within the Łęczna-Włodawa Lake Group. These lakes, together with Lake Tarnowskie (not included in this study), stand out as a sub-group, mainly due to the chemical properties of their water [Dawidek *et al.* 1998]. The lakes are classified as similar also due to their morphology – comparable area, regular, round basin shape, high Ohle Index, as well as the character of the catchment with the cretaceous bedrock and the predominance of agriculture [Tab. 1; Dawidek *et al.*, 2000; Pęczuła *et al.* 2014]. What is more, all of the studied lakes have flow-through character, with short (less than 1 year) water residence time [Ferencz and Dawidek 2014].

Table 1. Characteristics of studied lakes

Specification	Stone	Pniówno	Syczyńskie
Geographic coordinates	N 51°18'17" E 23°21'55"	N 51°14'47" E 23°20'32"	N 51°17'12" E 23°14'17"
Max depth, m	8.0	3.0	2.9
Area, ha	3.4	3.2	5.6
Ohle index	211.0	81.0	80.2
Dominant form of land use in the catchment	agriculture	agriculture and rural settlement	agriculture and rural settlement
Category according to alternative stable state theory [Scheffer 1990]	macrophyte-phytoplankton dominated	phytoplankton-macrophyte dominated	phytoplankton dominated
TSI	51.0 ⁽¹⁾ (eutrophy)	59.2 ⁽²⁾ (eutrophy)	79.5 ⁽¹⁾ (hypertrophy)

⁽¹⁾ After Pęczuła *et al.* 2014 (mean for 2009 summer months).

⁽²⁾ After Sugier *et al.* 2010 (mean for summer season 2005–2007).

MATERIAL AND METHODS

Sediment sampling was performed during 2009 winter season. The cores of undisturbed lake sediments were collected with a Uwitec gravity corer, with a 6 cm inner diameter of the sampler. In all lakes, samples were collected from central (deepest) and littoral (water depth 1–1.5 m) parts of the basin. Directly after sampling the sediments were cut into 1 cm slices, packed in plastic and kept at 4°C until the laboratory work was undertaken. For the purpose of this study, only the uppermost sub-samples representing 0–1 cm depth were analyzed.

The laboratory preparation of cladoceran remains followed the procedure set out by Szeroczyńska and Sarmaja-Korjonen [2007]. Volumetric samples – 1 cm³ of wet sediments – were treated with 10% HCl to eliminate carbonates, and, subsequently, boiled in 10% KOH for 15 minutes to remove organic matter. After each stage of chemical preparation, the residue was washed through 33 µm mesh sieve with distilled water. A measured volume of 10 ml of the final residue was stained with safranin and quantitatively sub-sampled for microscope slides. For each slide, a 0.1 ml of well-stirred sample was taken. Depending on frequency of remains, from 4 to 5 slides were prepared from each sample. All identifiable body parts of Cladocera were counted – shells, headshields, postabdomens, postabdominal claws and ephippia. The identification of remains followed Szeroczyńska and Sarmaja-Korjonen [2007]. The most numerous body part was chosen for each species to represent the number of individuals. Total Cladocera abundance was expressed as the number of individuals per 1 cm³ of fresh sediments. The diagram of percentage share of Cladocera species was prepared with Tilia

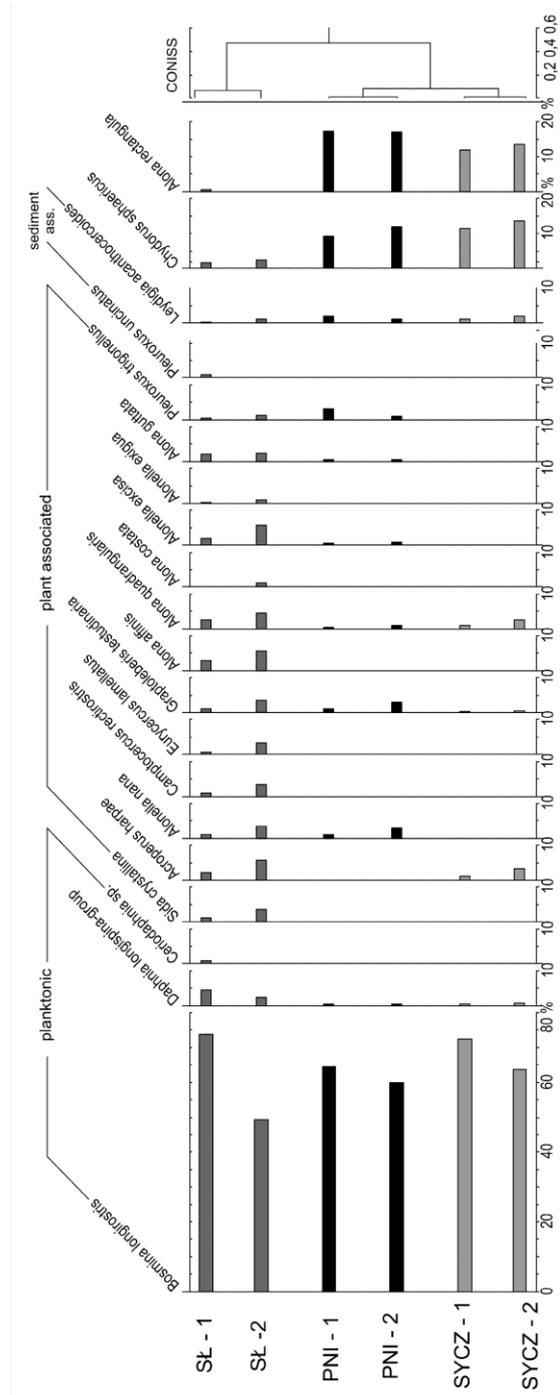


Fig. 1. Percentage Cladocera composition. Site abbreviation: SL – Lake Stone, PNI – Lake Pniówno, SYCZ – Lake Syczyńskie, 1 – sample from the center of the lake basin, 2 – littoral sample

software [Grimm 1991], and the biotic indexes: species richness (n), Shannon's diversity (H'), and dominance (D) were calculated and plotted with PAST [Hammer *et al.* 2009]. Clustering were performed by way of CONISS method [Grimm 1991].

RESULTS AND DISCUSSION

The total abundance of Cladocera in six examined sedimentary samples was diverse, with lower values noted in littoral samples. In the samples from the central parts of the lakes ranged from 4 900 spec·cm⁻³ in Lake Słone, to 11 700 spec·cm⁻³ in Lake Syczyńskie, whereas in littoral samples, it varied from 1 750, to 3 700 spec·cm⁻³, respectively (Fig. 1). The highest species richness was noted in sediments originating from Lake Słone – in two sampling sites, a total of 20 taxa were encountered. Much lower species richness was found in lakes Pniówno (11 species) and Syczyńskie (8 species). The number of species discovered in these lakes is rather low in comparison to the samples from other eutrophic Łęczna-Włodawa lakes [Kowalewski *et al.* 2012, Suchora unpublished]. Comparing the samples from littoral and pelagic provenances of lakes Pniówno and Syczyńskie, the species richness was the same, whereas in Lake Słone, the number of taxa was higher in the sediments derived from the central part of the basin (19), in comparison to the littoral sample (17). Species diversity revealed a maximum value in Lake Słone and lower values in Pniówno and Syczyńskie (Fig. 2).

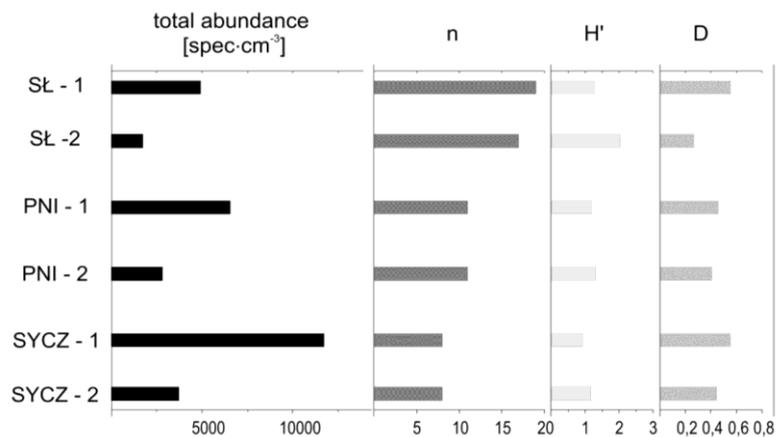


Fig. 2. Total Cladocera abundance, species richness (n), Shannon diversity (H') and dominance (D)

In all lakes, *Bosmina longirostris* was a dominating species, with share ranging from 65 to 75%. In lakes Pniówno and Syczyńskie, *Alona rectangularis* and *Chydorus sphaericus* also have a high share. The dominance of these three

species is interpreted as symptomatic of severe anthropogenic eutrophication [Hofmann 1987]. This is in accordance with the monitoring data – the Trophic State Index TSI [Carlson 1977] calculated for lakes Pniówno and Syczyńskie indicate more advanced eutrophication than in Lake Słone (Tab. 1). Also, Lake Słone solely represents the macrophyte-dominated state [Pęczuła *et al.* 2014].

Beside the abovementioned, other common, however, less frequent, chydorid species found in all lakes were *Graptoleberis testudinaria*, *Alona quadrangularis* and *Leydigia acanthocercoides*. These are indicated as typically occurring in eutrophic, turbid or high conductivity waters [Szeroczyńska 1998, Bjerring *et al.* 2009], however, *G. testudinaria* requires the presence of macrophytes [Bjerring *et al.* 2009].

The upper layer of lake sediment is known to represent the most recent record of lake history – typically the last few years. Among all studied lakes, Lake Syczyńskie's data alone is useful for comparing the fossil and aquatic cladoceran community, as this is the only data concerning Cladocera net-samples. A study performed in 2001 reported the steady dominance of *Bosmina longirostris* in all seasons [Adamczuk and Kornijów 2011], which is in accordance with the sediment record.

In the past studies of Lake Syczyńskie no representatives of family Chydoridae were found [De Eyto *et al.* 2003, Adamczuk and Kornijów 2011], whereas in the present study, we found in the sediment several species: *Chydorus sphaericus*, *Alona rectangula*, *Acroperus harpae*, *Graptoleberis testudinaria*, *Alona quadrangularis* and *Leydigia acanthocercoides*. The higher (comparing to sampling from water column) taxonomic richness of sedimentary Cladocera is an often mentioned phenomenon [Nevalainen 2010, Blanco *et al.* 2013], as the sediment typically represents several years of lake history. Moreover, the traditional sampling methods are of low efficiency in the case of benthic Cladocera (mostly chydorids), which are the best represented and the most indicative group in palaeolimnological studies.

On the other hand, the serious constraint in the comparison of water and sediment assemblages is the underrepresentation in sediments of planktonic taxa. Their poor preservation results from the greater delicacy of chitinous remains. This should be considered when the composition of cladoceran fauna is interpreted based on a subfossil record. In context of this study, the potentially underrepresented groups may be mainly the *Daphnia* and *Ceriodaphnia*, found previously by Kowalczyk [1977, 1978].

In all studied lakes the taxa were uniformly represented among functional lake zones. Only the plant-associated species *Alona costata* was present exclusively in littoral sediments of Lake Słone. Its absence in the profundal sample might be explained by its low abundance in the lake, as well as its ecological preferences. The species *A. costata* is often found in association with *Chara* [Duigan 1992], and dense beds of this plant in the littoral zone may be the factor

limiting the transport of remains to the central part of the basin. This may be the case also with respect to some other chydorid species. Nevertheless, it is evident, that the more numerous chydorid taxa are well represented in the sediments from both functional zones of lake.

CONCLUSIONS

This study has shown that: (1) the sedimentary Cladocera species composition confirms the advanced eutrophic status of the studied lakes, (2) the total abundance of Cladocera was higher in more eutrophic, phytoplankton- and macrophyte-phytoplankton dominated lakes than in a macrophyte-dominated lake of lower trophic, (3) the Cladocera taxa composition in shallower, non-stratified lakes Pniówno and Syczyńskie was similar at both sampling sites, whereas in deeper, seasonally stratified Lake Słone, the differences in composition between the sampling sites were more profound, however still minor. The conclusion on representativeness of the samples from the shallower part of the basin may have implication for further palaeolimnological research of small, shallow highly eutrophicated lakes, (4) the sediment versus net-sampling results obtained for Lake Syczyńskie suggest that analysis of surface sediments is an effective method in studies of Cladocera taxonomic richness.

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SUBFOSYLNA FAUNA CLADOCERA TRZECH MAŁYCH JEZIOR TWARDOWODNYCH O ZRÓŻNICOWANEJ TROFII

Streszczenie. W pracy przedstawiono wyniki analizy subfosylnych szczątków wioślarek (Cladocera) w osadach trzech jezior twardowodnych, należących do najmniejszych w grupie jezior łączyńsko-włodawskich. W próbach pochodzących z centralnych partii jezior oraz strefy litoralu analizowano skład gatunkowy, liczebność i bioróżnorodność wioślarek. Skład subfosylnej fauny Cladocera porównano w układzie międzystrefowym jak również pomiędzy badanymi obiektami. Największą liczebność osobników i najmniejszą różnorodność gatunkową stwierdzono w najsilniej zeutrofizowanym Jeziorze Syczyńskim, natomiast najmniejsza liczebność i duża różnorodność wystąpiły w reprezentującym niższą trofiję wód Jeziorze Słonym. Największe podobieństwo pod względem składu fauny wioślarek wykazują jeziora Syczyńskie i Pniówno, co jest odzwierciedleniem gradientu trofii wód.

Słowa kluczowe: subfosylne szczątki Cladocera, drobne zbiorniki wodne, paleolimnologia, indeks stanu trofii TSI, Pagóry Chełmskie