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SUBFOSSIL REMAINS OF CHIRONOMIDAE FROM TWO SHALLOW LAKES REPRESENTING EXTREME ALTERNATIVE STATES

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Abstract

The remains of Chironomidae in the recent sediments of macrophyte-dominated Lake Rotcze and phytoplankton-dominated Lake Syczyńskie (Polesie Region) were analyzed in order to check their suitability for diagnosing the lake status according to the alternative equilibria concept and thus also the development of submerged vegetation. In both lakes chironomid capsules were predominated by phytophilous taxa but their relative abundance was higher in the phytoplankton-dominated lake. The percentage of pelophilous taxa in the lakes did not exceed 10%. The taxa richness of both phytophilous and pelophilous assemblages was higher in the macrophyte-dominated lake. Therefore I conclude that the presence of phytophilous forms, and even their prevailing contribution in the total chironomid numbers can not be sufficient to prove the existence of a macrophytic state of a lake. In order to put a proper diagnosis on the development of vegetation in the past, the detailed analyses of the qualitative and quantitative structure of both ecological assemblages is needed.

Key words: lakes, subfossil Chironomidae, macrophytes, alternative states

INTRODUCTION

Family Chironomidae is commonly used for the estimation of ecological conditions in freshwater ecosystems. It is so because this group of insects is the richest in taxa amongst invertebrates, the most widespread and, often, also the most numerously represented in various types of surface waters (Cranston 1995).

Chironomidae are also one of the best tools in paleolimnological studies since their chitinous head capsules (originating from successive larval stages) are well preserved in the bottom sediments and can be relatively easily identified. Their remains provide data on processes undergoing in lakes and allow the reconstruction of various disturbances in watersheds and climate changes (Hofmann 1988, Walker 1993, 1995). For these reasons chironomid remains have been frequently used for evaluating the present and past trophic status of water bodies (Devai & Moldovan 1983, Brodersen & Lindegaard 1997).

Many chironomids are plant associated, other are typical mud dwellers (Kornijów & Gulati 1992a, b). Therefore, it seems to be possible, based on remains of chironomids and their analyzes, to infer historical development of macrophytes, playing a crucial role in shallow ecosystems (Jeppesen *et al.* 1998). This would help to diagnose the lake status according to "alternative equilibria hypothesis" (Scheffer *et al.* 1993). Such an attempt was undertaken in this study. The subfossil remains of chironomid larvae from two lakes representing two extreme alternative states were analyzed and the validity of the results obtained were verified by comparing them with those obtained earlier by standard limnological methods. Until now there have been virtually no attempts to check the lake equilibria state based on chironomid remains (Little & Smol 2000).

STUDY AREA, MATERIAL AND METHODS

The lakes studied are located in the eastern part of Poland, called Polesie (Fig. 1). They differ in water chemistry and development of vegetation (Tab. 1). According to the concept of alternative stable states (Scheffer *et al.* 1993) the lakes belong to two extreme types: Lake Rotcze to macrophyte-dominated and Lake Syczyńskie to phytoplankton-dominated (Kornijów *et. al*. 2002a).

The densely growing emergent vegetation formed a belt in both lakes and consisted mainly of *Phragmites australis* and *Typha* sp. Submerged vegetation in Lake Rotcze covered the bottom surface almost entirely. It represents 15 associations with 17 species. They were predominated by: *Elodea canadensis*, *Ceratophyllum demersum* and *Chara fragilis* (Sugier & Lorens 2002). In Lake Syczyńskie submerged vegetation almost did not exist and was represented solely by some very small patches of *Ceratophyllum demersum* (Kornijów *et al.* 2002b).

Surface sediment samples from the middle parts of the lakes were collected in March 2004. From each lake five

Fig. 1. Location of the studied area.

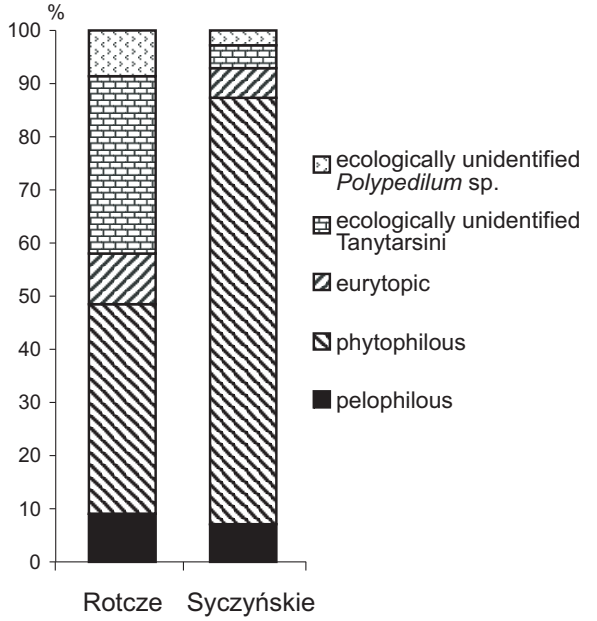

Fig. 2. Ecological assemblages within subfossil Chironomidae in the recent sediments of lakes Rotcze and Syczyńskie.

samples of the uppermost 2 cm sediments were taken by means of an Uwitec corer sampler of the surface of 28.3 cm^2. Samples were stored in the temperature of about 4°C. From each sample the volume of 20 cm^3 was taken for further analysis following the procedure of Hofmann (1986). In addition, the sediments from Lake Syczyńskie, because of high content of carbon calcium, were initially treated with 10% HCl. The head capsules were identified mainly according to Wiederholm (1983), Chernovskij (1949) and Walker & Brodersen (1997).

Amongst the taxa found the following ecological assemblages were distinguished: phytophilous, pelophilous and eurytopic, based on the papers by Kornijów (1982) and Kornijów & Gulati (1992a, b). Some of the taxa, named as ecologically unidentified Tanytarsini and *Polypedilum* sp., were not qualified to any of the above groups because of the too low level of identification. The genera of *Cricotopus* and *Glyptotendipes*, of which some species might occur in the zooobenthos (*e.g. C. bicinctus* and *G.* f.l. *polytomus*) have been qualified as epiphytic since the earlier studies of zoobenthos did not reveal their presence in the bottom sediments (*e.g.* Kornijów 1982, 1988, Tarkowska-Kukuryk 2004).

RESULTS

Qualitative composition of subfossil Chironomidae

The total number of 29 taxa of chironomids were identified in the collected material (Table 2). The number of taxa found in macrophyte-dominated Lake Rotcze (24) was much higher than in phytoplankton-dominated Lake Syczyńskie (16). As many as 11 taxa occurred in both lakes. *Cryptochironomus* sp., *Einfeldia* sp. (B group), *Phaenopsectra* sp., *Stempellina* sp., *Corynocera* sp., *Corynoneura* sp., *Parakiefferiella* sp., *Psectrocladius* sp. (semicirculatus and sordidellus gr.), *Ablabesmyia* sp. and *Procladius* sp. were found only in Lake Rotcze, while *Cladopelma* sp. occurred exclusively in Lake Syczyńskie. In lakes Rotcze and Syczyńskie the following number of taxa were found within the assemblages distinguished: phytophilous – 15 and 8, pelophilous – 8 and 3, and eurytopic – 3 and 2, respectively. The mean absolute number of head capsules in Lake Rotcze amounted to 239 ind./100cm^3 sediment. The most numerous were Tanytarsini and *Polypedilum* sp.

In Lake Syczyńskie the number of head capsules was over 3 times lower (76 ind./100cm^3 sediment), with the highest contribution of *Cricotopus* sp. and *Glyptotendipes* sp.

The ecological structure of Chironomidae

In both lakes the chironomids were predominated by phytophilous larvae, that constituted *ca*. 40 % of all the larvae in macrophyte-dominated Lake Rotcze and as much as 70%

Table 1

Morphometric (acc. to Michalczyk & Wilgat 1998), physico-chemical and biotic characteristics of the studied lakes

Lake	Area [ha]	Max depth [m]	Mean depth [m]	Total P[b] [µg/L]	Electr.conduc.[b] [µS /cm]	pH[b]	Secchi disc[b] [m]	Chlorophyll-*a*[c] [µg /L]	PVI[d] [%]
Rotcze	43	4.3	1.9	32.4	173	8.6	2.5	12.4	31.2
Syczyńskie	5.6a	2.9a	0.9[a]	238.9	514	8.8	0.2	330.8	0.0

[a] – after Dawidek *et al.* (2000); [b] – after Smal *et al.* (in press); [c] – according to W. Pęczuła (unpublished); [d] – PVI (the volume of water occupied by submerged vegetation) after Kornijów *et al.* (2002a)

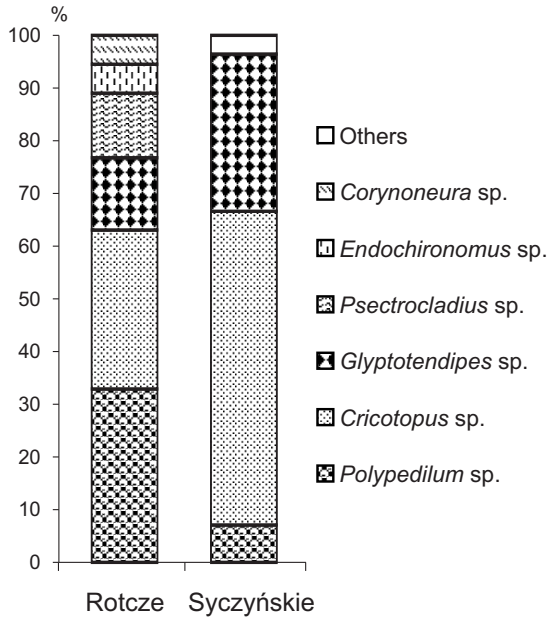

Fig. 3 Dominance structure of phytophilous subfossil Chironomidae in the recent sediments of lakes Rotcze and Syczyńskie.

in phytoplankton-dominated Lake Syczyńskie (Fig. 2). The share of pelophilous and eurytopic groups was similar in both lakes, neither of them exceeding 10%. In Lake Rotcze a considerable percentage of individuals accounted for ecologically unidentified Tanytarsini (30%) and *Polypedilum* sp. (10%).

The dominance structure of phytophilous and pelophilous chironomid assemblages

The common dominants amongst phytophilous midges for both lakes were *Cricotopus* sp. and *Glyptotendipes* sp. (Fig. 3). Moreover, *Psectrocladius* sp. achieved quite high percentage in Lake Rotcze (Fig. 3). The pelophilous taxa were predominated by big and haemoglobin possessing *Chironomus* sp. in Lake Syczyńskie, and by predatory *Procladius* sp. in Lake Rotcze (Fig. 4)

DISCUSSION

The qualitative richness of all chironomids as well as the taxa number of the ecological assemblages distinguished, clearly indicate contrasting habitat conditions in both lakes. Much lower taxa number in phytoplankton-dominated Lake Syczyńskie can suggest habitat homogenization, a phenomenon occurring in lakes undergoing high rate of eutrophication (Kornijów 1988). This is usually accompanied by deterioration of oxygen conditions, which may be reflected by almost 60% contribution of resistant to oxygen depletion *Chironomus* sp. in pelophilous group in this highly fertile lake.

The high taxonomic richness of phytophilous taxa found in Lake Rotcze mirrors luxuriantly developed flora (Sugier & Lorens 2002). This is in agreement with the finding by Kornijów (1989), that many plant associated taxa prefer particular groups of elodeids, which in consequence reflects the species composition and richness of the fauna.

Table 2

The composition and mean absolute numbers of subfossil Chironomidae (number of head capsules/100 cm^3 sediment) in macrophyte-dominated Lake Rotcze and phytoplankton-dominated Lake Syczyńskie

Taxa	Lake Rotcze	Lake Syczyńskie
Chironominae		
Cladopelma sp. (*laccophila* gr.)	0	10
Chironomus sp.	3	3
Cryptochironomus sp. (*defectus* gr.)	2	0
Cryptochironomus sp.	1	0
Dicrotendipes sp.	16	2
Einfeldia sp. (B gr.)	2	0
Einfeldia sp.	1	0
Endochironomus sp.	4	1
Glyptotendipes sp. (A gr.)	0	9
Glyptotendipes sp.	10	8
Microtendipes sp. (pedellus gr.)	0	1
Microtendipes sp.	1	0
Parachironomus sp.(*arcuatus* gr.)	0	1
Parachironomus sp.	1	0
Phaenopsectra sp.	2	0
Polypedilum sp. (*Pentapedilum*)? *sordens*	21	4
Polypedilum (*convictum* gr.)	3	0
Polypedilum (*nubeculosum* gr.)	2	0
Polypedilum sp.	17	2
Stempellina sp.	1	0
Corynocera sp.	2	0
Tanytarsus sp.	5	2
Tanytarsini n.det.	66	3
Chironominae n.det.	1	1
Orthocladiinae		
Corynoneura sp.	4	0
Cricotopus sp. (*sylvestris* gr.)	10	13
Cricotopus sp.	12	21
Parakiefferiella sp.	2	0
Psectrocladius sp. (*semicerculatus* gr.)	5	0
Psectrocladius sp. (*sordidellus* gr.)	4	0
Psectrocladius sp.	2	0
Orthocladinae n.det.	7	3
Tanypodinae		
Ablabesmyia sp.	13	0
Procladius sp. (Holotanypus)	3	0
Procladius sp.	5	0
Tanypodinae n.det.	1	1
Chironomidae n.det.	10	0
Total number	239	76
Sum of taxa	29	16

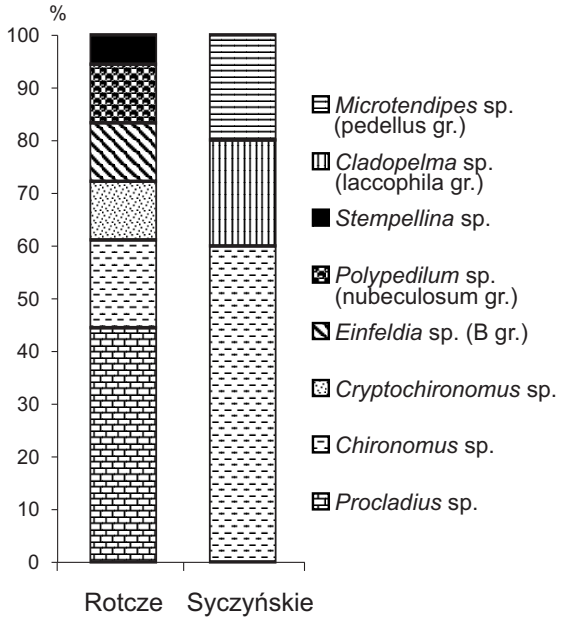

Fig. 4. Dominance structure of pelophilous subfossil Chironomidae in the recent sediments of lakes Rotcze and Syczyńskie.

In spite of well developed flora in Lake Rotcze the chironomid remains recorded twice lower percentage of phytophilous forms than in phytoplankton-dominated Lake Syczyńskie. This was a surprising and unexpected result. Providing that the unidentified ecologically and very numerous Tanytarsini and *Polypedilum* sp. in Lake Rotcze are plant associated (which is very likely), the contribution of all phytophilous chironomids would not be higher than in Lake Syczyńskie. The question arises how it is possible that in lakes of so contrasting development of submerged and floating leaved vegetation, the percentage of phytophilous forms is comparable. Presumably the reason for this is the origin of the fauna and proportions between numbers (productivity) of phyto- and pelophilous larvae. In Lake Syczyńskie the density of zoobenthos is very low and its occurrence is restricted to near shore zone due to oxygen deficits in deeper places (Kornijów *et al.* 2002b). However, densely growing emergent macrophytes are abundantly inhabited by epiphytic chironomids such as *Cricotopus* sp. and *Glyptotendipes* sp., the remains of which were the most numerously represented in the bottom sediments in the middle lake zone. They would derive there through resuspension, since the lake is very shallow, but also being transported by fish during defecation. This would explain the high contribution of phytophilous larvae remains in the collection. A more complicated case represents Lake Rotcze in which density of living zoobenthos in the middle lake zone is very low, density of epiphytic fauna very high (Kornijów *et al.* in prep), but the proportions of the remains are opposite.

The above points to the fact that the encountering the presence of the phytophilous forms or even their predomination in the fauna can not exclude the existence of phytoplankton-dominated state of a lake, as suggested by Little & Smol (2000): " ... our paleolimnological data suggest that the lake has not experienced a phytoplankton-dominated, turbid state in the last two centuries, as taxa often associated with macrophytes (*e.g. Glyptotendipes, Cricotopus, Psectrocladius, and Polypedilum*) have remained abundant throughout the core". The taxa listed by them from a macrophyte-dominated lake, except for *Psectrocladius*, predominated also in phytoplankton-dominated Lake Syczyńskie of the present study.

It seems therefore, that in order to diagnose the lake status it is necessary to analyze the whole chironomid community, including benthic forms, their taxonomic richness, species composition, presence of species typical of particular bottom susbtrates (sand, mud, *etc*.), and species of indicatory value pointing to specific habitat conditions, *e.g.* taxa susceptible to oxygen depletion or *vice versa*.

Additional and complementary analyses, *e.g.* the remains of macrophytes, cladocerans and chlorophyll-*a* might be very helpful.

In Lake Rotcze the absolute number of head capsules was 3 times higher than in Lake Syczyńskie. This finding can reflect higher sedimentation rate in the latter, in which primary production is extremely high as suggested by huge concentrations of chlorophyll-*a* (Tab. 1).

CONCLUSIONS

Presence of phytophilous forms, and even their prevailing contribution in the total chironomid numbers can not be sufficient to prove an existence of a macrophytic state of a lake. In order to put a proper diagnosis on the development of vegetation in the past, the detailed analyses of the qualitative and quantitative structure of both: phytophilous and pelophilous assemblages is needed.

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