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Letter to Editor

Limnological Study of a Lake Formed in Limestone Quarry (Kraków, Poland). I. Zooplankton Community

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Abstract

The zooplankton of a meromictic lake, in a former limestone quarry situated in southern Poland, was studied monthly in the years 2000-2001. A low density and diversity of zooplankton assemblage was noted. Individuals of the dominant species *Daphnia longispina* represented all body size classes and were present during the whole study period; the maximum number of *Daphnia* females carrying the eggs was noted in May. The normal dial vertical migration of *Daphnia*, studied in June, was observed.

Keywords: meromictic lake, zooplankton, *Daphnia longispina,* dial vertical migration

Introduction

Several post-exploration lakes are present in various parts of Poland and their character depends on material which was previously exploited from the quarry or the age of the given water body [1]. The fauna of such strip-mine lakes has not been investigated very often [2, 3, 4, 5]. No biological studies have been conducted on Zakrzówek lake, formed in 1991 in a former limestone quarry. In this study the first results of the zooplankton community structure, body size distribution of *Daphnia longispina* and this species dial vertical migrations in the Zakrzówek lake are presented.

Study Area and Methods

Zakrzówek lake in a former limestone quarry, has an area of 21 ha with the maximum depth of 32 m (Fig. 1). This is a meromictic lake located in a karstic formation, Kraków (Poland), which shows high chloride content and conductivity values of its water resulting from the substantial influence of the Vistula River, which flows 600 m west from the quarry. Information on lake water chemistry and chlorophyll *a* content, based on samples taken at the same times as those of the present study, can be found in an accompanying paper of Galas [6].

Zooplankton samples were taken monthly from April 2000 till March 2001 (except for February when the lake was partially frozen) from the whole water column by vertical net hauls from 20 m depth (below this depth H_2S was detected all year) to the surface, during daytime. Two nets were used with mesh size of 200 µm and 40 µm. Collected animals were preserved in a formaldehyde solution. Abundance, composition of the main zooplankton groups (cladocerans, copepods and rotifers) and body length of the dominant species *Daphnia longispina* were determined. Results are shown as the number of individuals per L (ind. L^{-1}) of water. In July, two times within 24 hours (during the day and night) zooplankton samples were taken from the lake surface to the depth of 21 m, every 3 m. Specimen density was counted and *D. longispina* number in each body length class in each water layer was determined. Water for chlorophyll *a* analyses was filtrated through the 50 µm net to determine only its part available for zooplankton in the studied lake [6].

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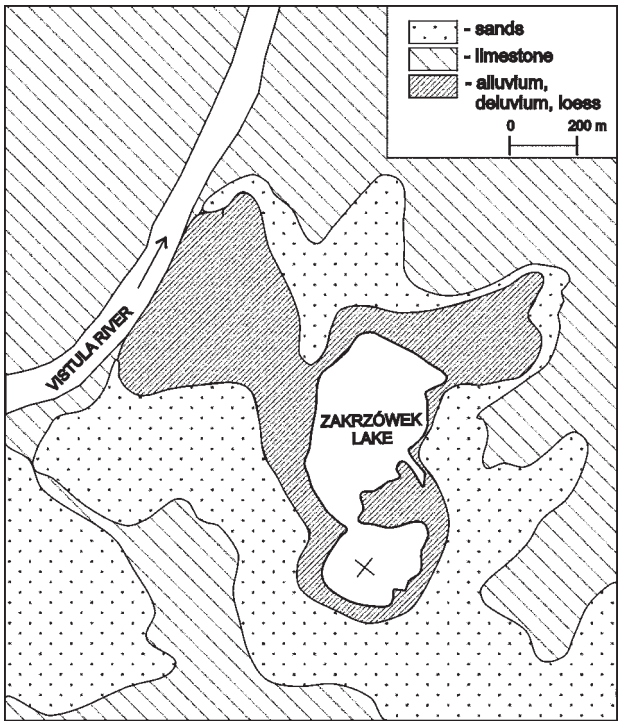

Fig. 1. Map of lake Zakrzówek, the sampling point is indicated by x.

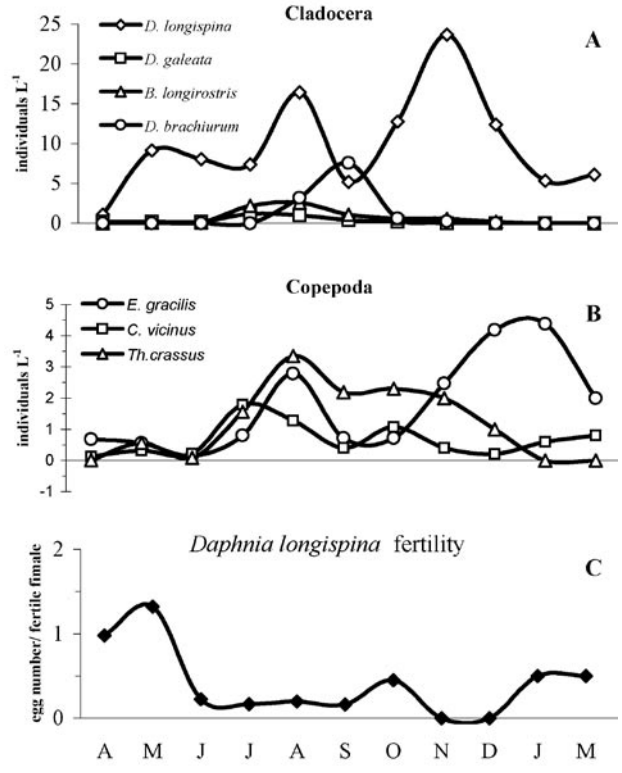

Fig. 2. Seasonal density changes of Cladocera (A) and Copepoda (B) and fertility of *Daphnia longispina* (C) in Zakrzówek lake.

Results

The lake is relatively poor in zooplankton. Five species of Cladocera: *Daphnia longispina*, *D. galeata, Bosmina longirostris, Diaphanosoma brachiurum,* and *Polyphemus pediculus;* four taxa of Copepoda: *Eudiaptomus gracilis, Cyclops vicinus, Thermocyclops crassus*, and Harpacticoida non det.; three species of Rotifera: *Keratella cochlearis, K. quadrata,* and *Filinia longiseta* were found. One spe-

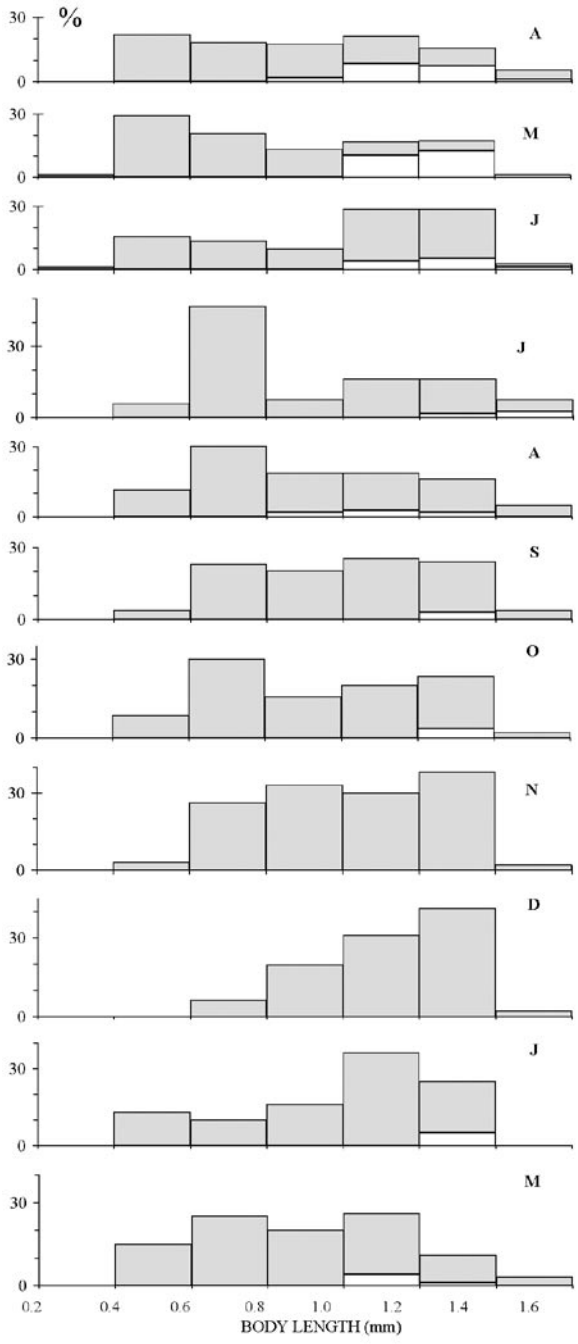

Fig. 3. Body size distribution in the *Daphnia longispina* population in Zakrzówek lake, shadow boxes - all females, white boxes - females carrying eggs.

cies of Diptera: *Chaoborus flavicans* was also noted in Zakrzówek lake.

The maximum Cladocera density was 25 ind. L^{-1} while for Copepoda this was only 5 ind. L^{-1}. *Daphnia longispina*, the dominant species was observed in all the studied months (Fig. 2A). The other Cladocera species played a negligible role in determining total zooplankton density.

Among Copepoda the lack of dominant species was observed (Fig. 2B). In spring population density of all species found in the lake was low (0.5 ind. L^{-1}) while in the summer *Eudiaptomus gracilis, Cyclops vicinus* and *Thermocyclops crassus* were observed more often (3 ind. L^{-1}). In autumn and winter the number of *Eudiaptomus gracilis* was the highest (4.5 ind.L^{-1}) while the number of two other Copepoda species was low.

During the whole year (except for November and December) egg-bearing females were observed. The females of *Daphnia longispina* grow and reproduce at body lengths of 0.8 mm. Their fertility (number of eggs per one fertile female) was low, averaging 0.2 eggs. In May the females produced the maximal number of eggs (1.5 eggs per female) (Fig. 2C).

The dominant *Daphnia longispina* individuals belonging to all body size classes were present during the whole study period (0.4 to 1.6 mm) (Fig. 3). In spring, the percentage share of each size class was almost equal 20%. Higher share of bigger individuals (>0.6 mm) was observed since July, together with a decrease in the number of smaller individuals.

The results concerning dial vertical migration of *Daphnia longispina* in June are shown in Fig. 4. During the day *Daphnia* individuals were present in deeper waters in the lower part of the lake, just over the H_2S layer. Approximately 0,3 ind. L^{-1} in the three deepest layers (12-15m, 15-18m, 18-21 m) were noted. At night, most of the individuals moved towards the water surface; approximately 0,2 individuals L^{-1} in two upper layers (0-3 m, 3-6 m) were observed. Only the smallest (youngest) specimens were observed during the day in the surface waters whereas there were no medium or large animals (Fig. 5). Within the lake depth varying number of the biggest specimens was found. At night in the surface layers small and medium individuals were observed, while the biggest ones were very scarce. The diversity of percentage share of *Daphnia* size classes at different lake depths was not so significant at night as during the day.

Discussion

The zooplankton species identified in the Zakrzówek lake appear to be frequent inhabitants of natural lakes and artificial impoundment [2, 3, 5, 7]. However, this community is poor in terms of number of species, their density and body size. It may be the result of food limitation connected with the very low concentration of chlorophyll *a* (0.59 µg L^{-1}) [6] and therefore scarce phytoplankton was found in the studied lake. Algae stated in Zakrzówek lake (*Mougeotia* sp., *Spirogyra* sp., *Cladophora glomerata, Cosmarium* sp., *Westella* sp., *Chlamydomonas* sp. *Pseudanabaena* sp., *Phormidium* sp. - Bucka pers. comm.) are hardly available for zooplankton animals, because they consume only smaller cells [8].

Boronat and Miracle [9] have shown that some species of Daphnia size may be smaller under low food conditions. Small body size of *D. longispina* (0.2 - 0.6 mm) as compared with 2 times larger individuals in the meromictic, limestone lake in Spain with higher chlorophyll *a* content [10] is also the result of food limitation in Zakrzówek lake. This also does not favour fertility of females and leads to the lowering of *Daphnia longispina* population abundance. However, females of this species produce eggs and off-spring all the year but their density

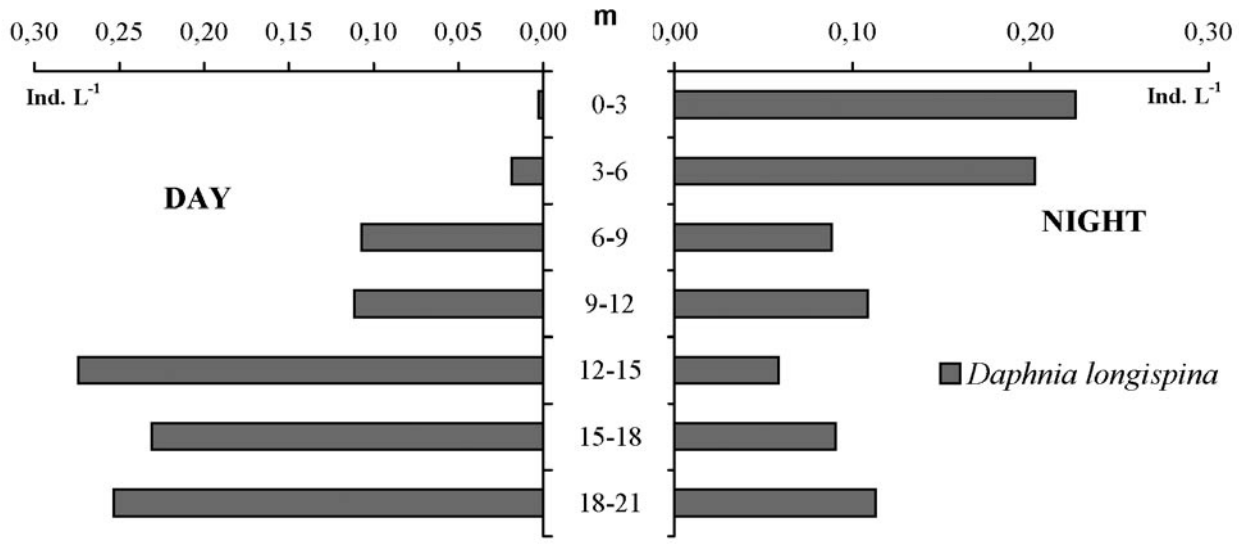

Fig. 4. Dial vertical migration of *Daphnia longispina* in Zakrzówek lake.

is not very high (25 ind. L^{-1}). It is much higher than the density of *D. pulicaria* (1 ind. L^{-1}) in an ultraoligotrophic, high mountain lake [11].

According to Ejsmont-Karabin [5] colonisation of new reservoirs by zooplankton takes place several years after their creation. Poor animal community structure

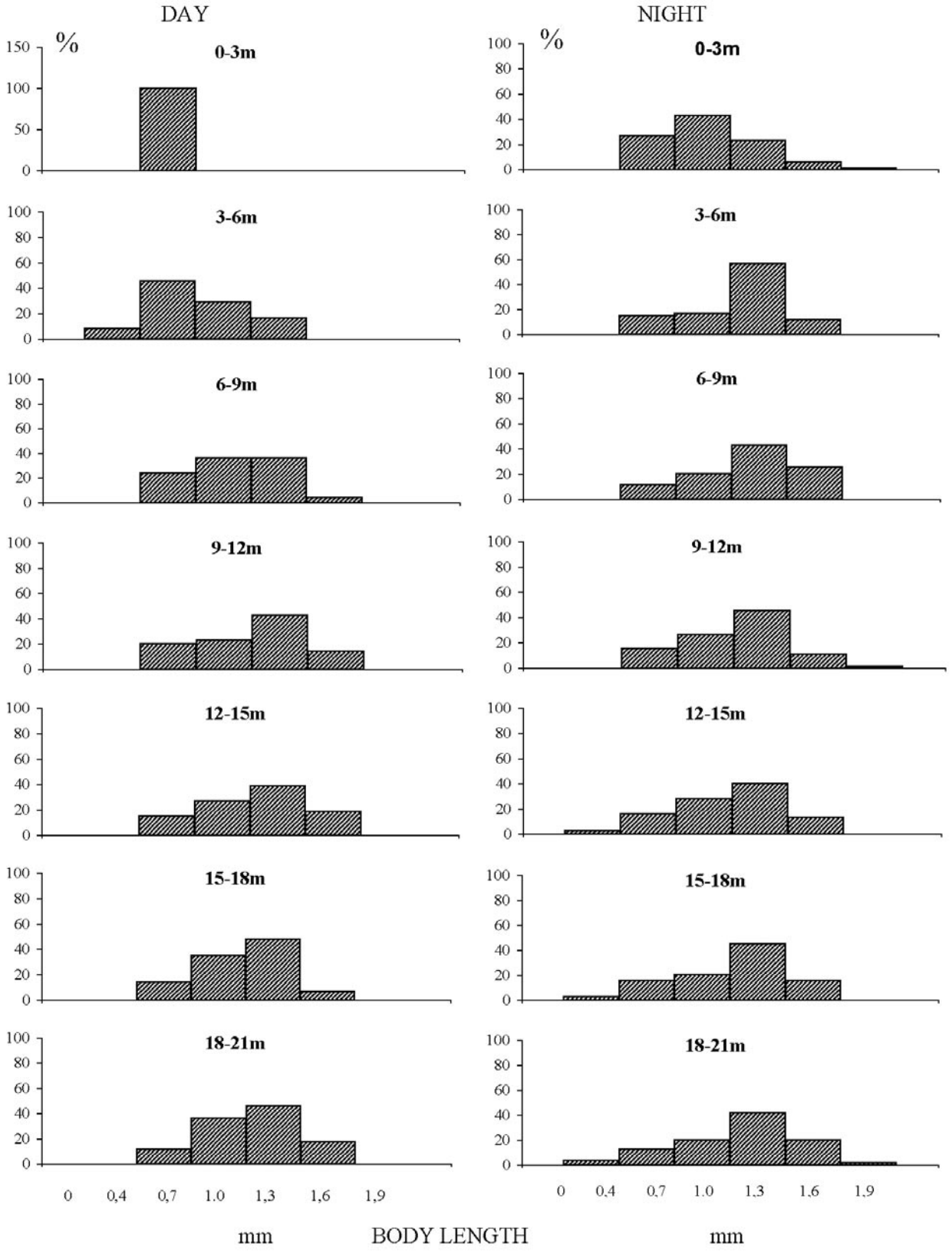

Fig. 5. Body size distribution of the *Daphnia longispina* during the dial vertical migration.

colonising post-exploitation lakes may be the effect of environmental stress and young age of the lake [12], but even in a 70-year-old lake in a former limestone quarry (also a meromictic and oligotrophic one), only 10 Cladocera and 8 Copepoda species were identified [3].

Dial vertical migration (DVM) of zooplankton is a very common behaviour in a water environment [13, 14, 15]. In Zakrzówek lake *Daphnia longispina* showed typical DVM: it finds a daily refuge in the deeper parts of the lake as a response to the presence of visually hunting predators – mostly planktivorous fish and *Chaoborus* larvae, not very common in Zakrzówek. During the day only juveniles occurred in the upper waters, because they are small, have light colour, and are almost invisible for fish. Large and pigmented females carrying eggs move to the deeper parts of the lake, avoiding hunting predators [14]. Here, fish predation influenced typical size structure of *Daphnia* populations along the vertical profile as observed in other meromictic lakes [9, 10]. Unfortunately, we have only indirect information (Piotr S., pers. comm.) on fish population in Zakrzówek lake. Further studies on the relationship between fish-zooplankton are needed.

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