

ABIOTIC FACTORS RELATING TO CRUSTACEAN
ABUNDANCE IN SOME SHALLOW LAKES
IN ŁĘCZYŃSKO-WŁODAWSKIE LAKES DISTRICT
(EASTERN POLAND)

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Co-financed by National Fund
for Environmental Protection
and Water Management

Summary. Investigations on density of crustacean plankton in relation to physico-chemical parameters were carried out in 5 shallow lakes located in Łęczyńsko-Włodawskie Lakes District. The studied lakes showed extreme abundances of Cladocera and Copepoda, with the lowest density in Lake Czarne Sosnowickie and the highest one in Lake Dratów. The environmental variables that significantly correlated to the density of Crustacea were temperature, conductivity, pH, and total suspension for Cladocera, and temperature and total suspended solids for Copepoda. The study contribute to more insight the nature of constrains associated with tolerance of crustacean zooplankton communities for changes in their environments in an advanced stage of global eutrophication of waterbodies.

Key words: Cladocera, Copepoda, density

INTRODUCTION

Crustacean zooplankton is a key component of freshwater ecosystems, mediating the energy flow between nanno- and picoplankton communities and higher trophic levels, such as fish, in pelagic habitats. The capacity of zooplankton to utilize primary producers and their suitability as food for fish determines the effectiveness of the lake food web. Crustacean plankton show a very various

options in patterns of occurrence in lakes both in world-wide and local scale. The causes of different community dynamics of zooplankton is not clear, however, it has been suspected that environmental parameters shape their abundance [Wang *et al.* 2012]. Nevertheless, the role of environmental parameters in community dynamics of Crustacea still remains unsolved problem. The same species usually inhabit a wide range of lakes, although in different abundances, and the major environmental requirements for many species are almost the same [Pinel-Alloul *et al.* 2013] suggesting they are ecologically flexible. On the other hand, it has been shown in some studies that crustaceans are sensitive to many physical, chemical and ecological factors [Nevalainen *et al.* 2011, Parveen and Mola 2013]. Many papers have indicated zooplankton as possibly useful to estimate water quality, but they often have arrived at contrary conclusions [eg. Jeppesen *et al.* 2000 versus Haberman 1996, 1998]. As a result, that group was not included as an obligatory biological quality element in the EU Water Framework Directive (WFD) [Caroni and Irvine 2010, Jeppesen *et al.* 2011]. That prompted many hydrobiologists to study relations among abiotic factors and abundance of Crustacea to elaborate effective monitoring methods based on crustacean indices [Haberman and Laugaste 2003, Carpenter *et al.* 2006, Ejsmond-Karabin and Karabin 2013, Haberman and Haldna 2014]. The detail aims of this study were to examine the community structure of crustaceans in 5 lakes differing in environmental conditions, as well as to assess the influence of those conditions on the crustacean communities, and this would contribute to better understanding the role of environmental factors in community dynamics of planktonic crustaceans and thus revitalise the use of Crustacea as bioindicators in lakes.

STUDY AREA, MATERIAL AND METHODS

The lakes selected to conduct the study are eutrophic reservoirs situated in the area of Łęczna-Włodawa Lake District (Eastern Poland): Lake Dratów (51°20'26"N, 22°56'45"E), Lake Krzcień (51°23'59"N, 22°56'01"E), Lake Domaszne (51°28'13"N, 23°0'10"E), Lake Czarne Sosnowickie (51°30'56"N, 23°01'40"E), and Lake Białe Sosnowickie (51°31'56"N, 23°02'39"E). Crustaceans (cladocerans and copepods) were examined in the open water zone of each lake. The samples were taken from April to October 2012. Collected data were presented in three seasons: spring (April), summer (July) and autumn (October). At each of the sites, double samples were collected with the use of a 5-litre Bernatowicz sampler. Samples were sieved through in a 40 µm mesh net and fixed with formalin-glycerine solution. In the laboratory, the classification and counts of crustaceans were made with the use of the Sedgewick-Rafter cell to calculate abundance expressed as a number of individuals per 1 dm³.

Simultaneously to biological studies, chemical analyses were taken. Temperature, conductivity, pH and dissolved oxygen (DO) were determined *in situ* with a multiparametric probe, total organic carbon (TOC) was determined using the spectrophotometer PASTEL UV and the remaining factors (TP – total phosphorus, P-PO₄, N-NH₄, N-NO₃, chlorophyll *a* were analysed in the laboratory [Golterman 1969].

The differences of physical and chemical water parameters among studied habitats were analysed by means of one-way ANOVA. Detrended Correspondence Analysis (DCA) was used to measure and illustrate the variability gradients indicated by Cladocera. Due to the length of the gradient with a range > 4 standard deviations (SD) Canonical Correspondence Analysis (CCA) was applied, in order to determine the relationships between crustaceans and environment parameters. Automatic forward selection of environmental variables, Monte Carlo permutation test was used to determine the most important variables. Variables which level of significance exceeded 0.05 were plotted passively on the diagrams. On the resultant plot, the arrows representing the physico-chemical variables indicate the direction of maximum change of that variable, and the length of each arrow is proportional to the rate of change. The proportion of variance explained by environmental variables was quantified using variance partitioning. The ordination analyses were performed by means of CANOCO 4.5 for Windows.

RESULTS

The chemical properties of water differed significantly between lakes (ANOVA, $F = 19.3\text{--}33.7$, $P = 0.001\text{--}0.039$). Lake Dratów was characterised by the lowest values of temperature. In Lake Krzcień, the lowest values of Secchi disc visibility, conductivity, N-NO₃, and the highest values of pH, total solids, total phosphorus and chlorophyll-*a* were found. Lake Domaszne showed the lowest values of pH, N-NH₄, total phosphorus and total organic carbon. Lake Czarne Sosnowickie showed the highest values of water temperature, N-NH₄, N-NO₃ and P-PO₄ and total organic carbon. In Lake Białe Sosnowickie, the highest values of conductivity and the lowest values of P-PO₄ were found (Fig. 1).

The density of Cladocera in the studied lakes ranged from 22 ± 16 ind. dm⁻³ in Lake Czarne Sosnowickie to 557 ± 668 ind. dm⁻³ in Lake Dratów. Cladocerans were constrained in the ordination space of PCA seasonally (Fig. 2a). *Daphnia longispina*, *Chydorus sphaericus* and *Bosmina longirostris* were more numerous in spring and autumn samples, whereas in summer samples the species *Diaphanosoma brachyurum*, *Daphnia cucullata*, *Bosmina coregoni* and *Ceriodaphnia quadrangula* prevailed. All variables altogether explained 54.5% of total variance in the density of Cladocera. The results of Monte Carlo Permutation test showed the significant influence of three variables: temperature ($\lambda = 0.46$, $F = 4.27$,

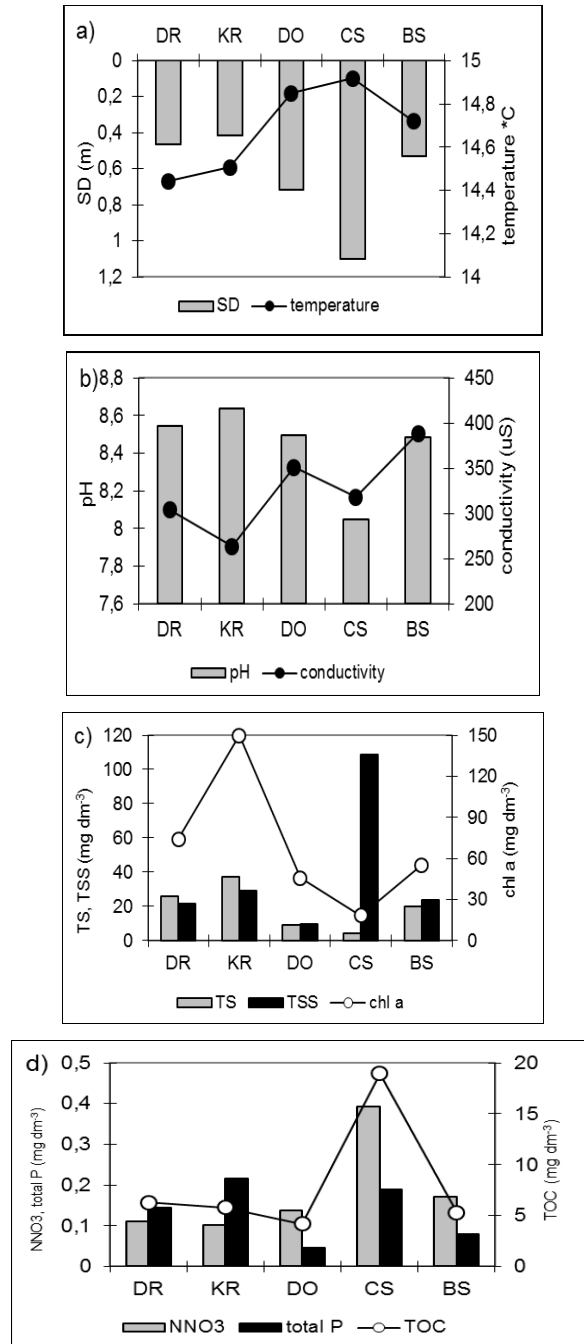


Fig. 1. Physical and chemical characteristics of water in the investigated lakes (average values for the period April – October 2012). DR – Dratów, KR – Krzczeń, DO – Domaszne, CS – Czarne Sosnowickie, BS – Białe Sosnowickie

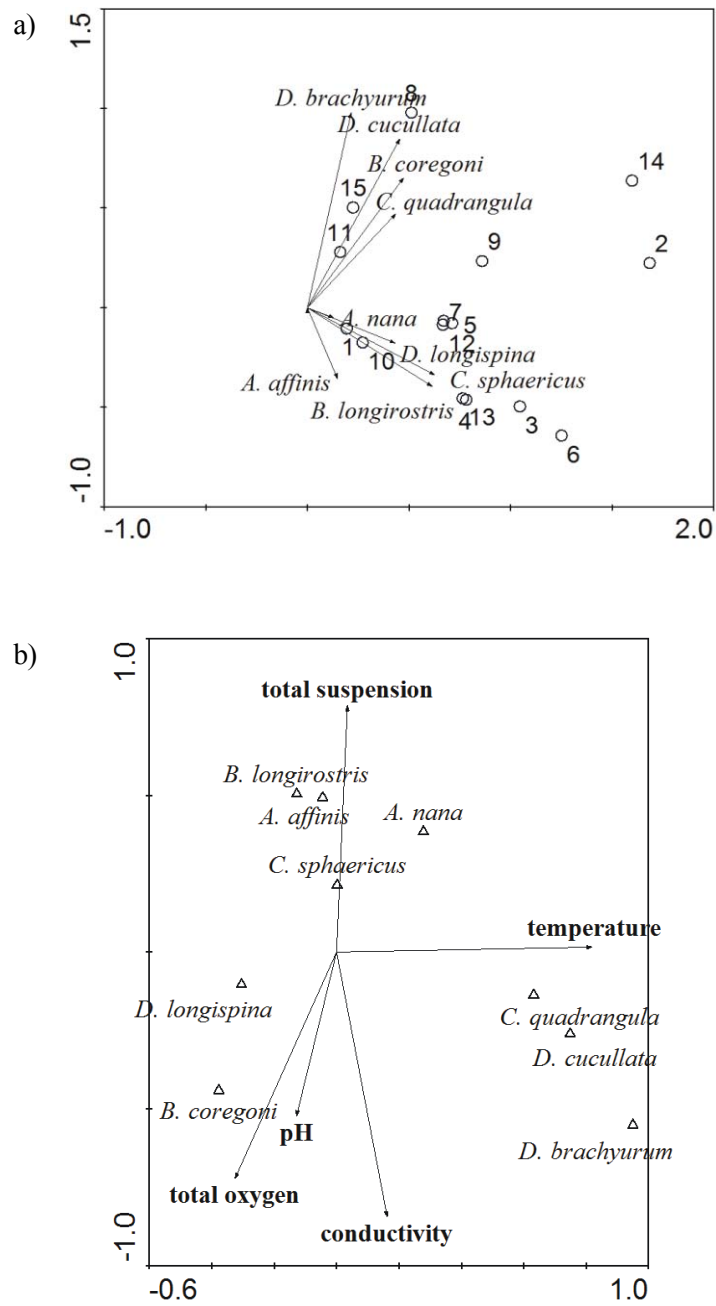


Fig. 2. Biplots of PCA (a) and CCA (b) for Cladocera assemblages showing species and samples (a) or environmental variables (b). Samples collected are marked with numerals: 1–3 Dratów, 3–6 Krzcień, 7–9 Domaszne, 10–12 Czarne Sosnowickie, 13–15 Białe Sosnowickie

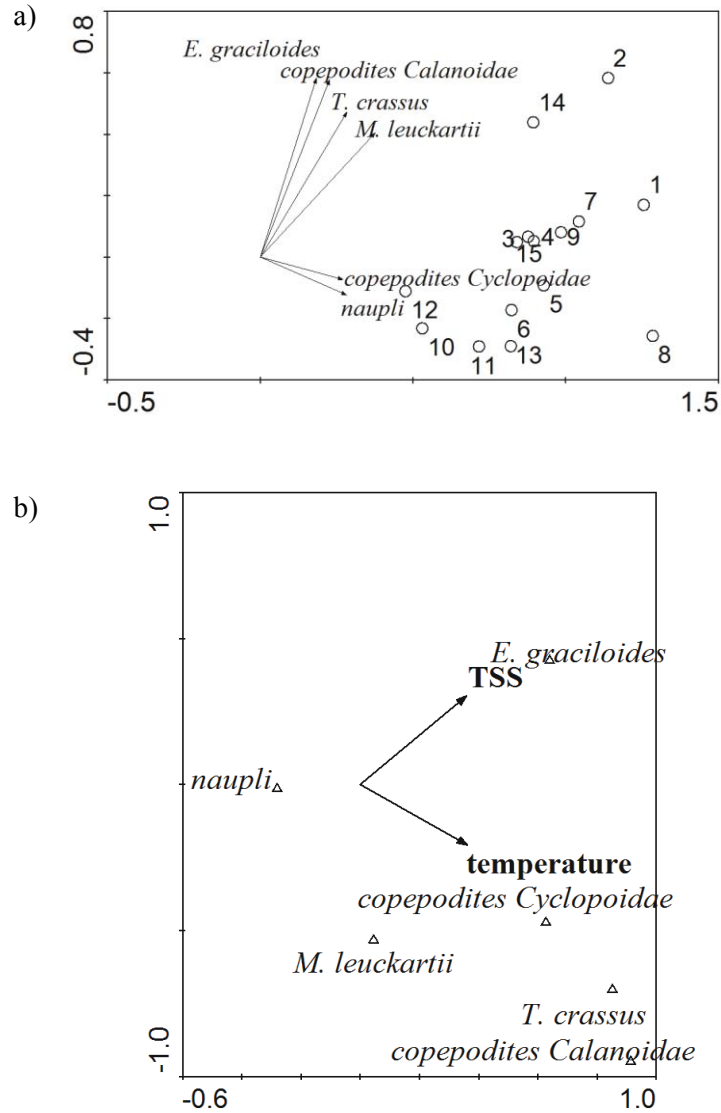


Fig. 3. Biplots of PCA (a) and CCA (b) for Copepoda assemblages showing species and samples (a) or environmental variables (b). Samples collected are marked with numerals: 1–3 Dratów, 3–6 Krzcień, 7–9 Domaszne, 10–12 Czarne Sosnowickie, 13–15 Białe Sosnowickie

$P = 0.002$), conductivity ($\lambda = 0.44$, $F = 5.42$, $P = 0.004$), pH ($\lambda = 0.26$, $F = 4.09$, $P = 0.007$) and total suspension ($\lambda = 0.19$, $F = 3.47$, $P = 0.014$). On the ordination plot, *B. longirostris*, *A. affinis*, *A. nana*, and *C. sphaericus* were related to rising gradient of total suspension, *D. longispina*, and *B. coregoni* were related to rising gradients of pH and conductivity, whereas temperature had an effect on each cladoceran species (Fig. 2b).

The lowest density (121 ± 25 ind. dm^{-3}) of Copepoda was found in Lake Krzcień, and the highest (255 ± 166 ind. dm^{-3}) in Lake Dratów. Copepods were constrained in the ordination space of DCA seasonally and the samples were apparently split into two groups, namely spring and autumn samples with dominant larvae and immature individuals, and summer samples with dominant cyclopoids *Mesocyclops leuckartii* and *Thermocyclops crassus* as well as calanoid *Eudiaptomus graciloides*, including mature and immature individuals (Fig. 3a). All variables together explained 40.8% of total variance in the density of Copepoda. However, the results of Monte Carlo Permutation test showed the significant influence of two variables: temperature ($\lambda = 0.3$, $F = 4.57$, $P = 0.034$) and total suspended solids (TSS) ($\lambda = 0.06$, $F = 3.42$, $P = 0.042$). *M. leuckartii*, *T. crassus* and copepodites showed the relation with rising gradient of temperature, whereas the abundance of *E. graciloides* was influenced mostly by rising gradient of TSS (Fig. 3b).

DISCUSSION

The studied lakes showed extreme abundances of Cladocera and Copepoda, with the lowest values in Lake Czarne Sosnowickie and 25-times higher density in Lake Dratów. Densities of cladocerans and copepods in early spring showed different patterns, for in all the studied lakes, spring community structure was represented mainly by Copepoda. Such pattern results from different evolutionary strategies of adapting to a seasonally variable habitat: the time to develop is much longer for cladocerans than for copepods as cladocerans overwinter as resting eggs in the sediments [Dodson *et al.* 2010], while copepods overwinter as immature stages in the water column and sediments [Thorp and Covich 2009]. PCA ordination analyses showed that distinct species of both Cladocera and Copepoda showed seasonal succession. Among cladocerans, *D. longispina*, *C. sphaericus* and *B. longirostris* prevailed in spring and autumn, whereas in summer they were replaced by *D. cucullata*, *D. brachyurum*, *B. coregoni* and *C. quadrangula*. Among copepods, adults predominated only in summer season, whereas in spring and autumn immature individuals prevailed. The present study showed that some environmental factors occurred to be important in the community development of Crustacea. These factors were temperature, conductivity, pH and total suspension (TS) for Cladocera, and temperature and total suspended solids (TSS) for Copepoda. In both cases, the temperature occurred to be a very important factor. Water temperature is known to directly interacts in reducing or enhancing metabolism and reproduce rates. Furthermore, temperature primarily controls the seasonal succession of crustaceans' reproductive models [Jiménez *et al.* 2012]; under favourable temperature crustacean populations can multiply rapidly or reproduce only a few generations under low tem-

peratures [Ismail *et al.* 2011]. The role of pH in developing cladoceran communities is well known, as that parameter has been most extensively examined as a variable influencing Cladocera [Nevalainen *et al.* 2011, Korosi and Smol 2012]. Conductivity that turned out to be an important parameter affecting the density of Cladocera, has been repeatedly reported as decisive factor in the distribution of cladocerans both in geographical and whole-lake scale [Geraldés and Boavida 2007], although the mechanism of its influence on cladocerans is not clear. As the aforementioned factors affect metabolic processes of Cladocera, total suspension (TS) probably influences their community dynamics in pretty other way. The densities of some cladocerans (*B. longirostris*, *C. sphaericus*, *A. nana*, *A. affinis*) increased along with increased gradient of TS. Presence of a large concentration of macroscopic particles can create „visual clutter” that can be used by some cladocera species as refuges to constrain harmful effect of predators [Wright and Shapiro 1990]. That explanation of influence of TS on Cladocera is supported by the fact that factor influenced mainly small cladocerans that are not able to utilise total suspension as food resources. However, abiotic variables better explained the abundance of Cladocera than Copepoda. For copepods, environmental conditions considered in the study explained less than 50% of total variance in their density suggesting that the main role in their development have some factors not included in the study. Next to temperature, the factor significant for the density of Copepoda was TSS. TSS occurred to be important for herbivorous *E. graciloides*. In general, suspended solids refers to concentration of inorganic and organic matter with a diameter of less than 62 μm [Billota and Brazier 2008], and are correlated positively with total phosphorus [Jones and Knowlton 2005] suggesting their relation to components of organic seston. Thus, it cannot be excluded that TSS was used by *E. graciloides* as important food sources. Startlingly, the lack of significant correlation between crustacean density and chlorophyll a suggest that there was little control of phytoplankton biomass by planktonic crustaceans in those lakes.

CONCLUSIONS

The obtained results showed significant relations of crustacean density in the studied lakes and some environmental parameters. The lakes showed extreme values in abundances of Cladocera and Copepoda. The environmental variables explained 54.5% of total variance in the density of Cladocera, and 40.8% of total variance in the density of Copepoda. Density of Cladocera was correlated to temperature, conductivity, pH, and total suspension. Density of Copepoda was correlated to temperature and total suspended solids. The results imply that density of Crustacea may give indications on ecological quality of lake ecosystems. The study contribute to more insight the nature of constrains

associated with tolerance of crustacean zooplankton communities for changes in their environments (which is still unsolved because of a large number of unknowns) in an advanced stage of global eutrophication of waterbodies.

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CZYNNIKI ABIOTYCZNE WPŁYWAJĄCE NA LICZEBNOŚĆ PLANKTONU
SKORUPIAKOWEGO W PŁYTKICH JEZIORACH
NA POJEZIERZU ŁĘCZYŃSKO-WŁODAWSKIM (WSCHODNIA POLSKA)

Streszczenie. Celem pracy było określenie wpływu czynników fizycznych i chemicznych wody na kształtowanie się struktury planktonu skorupiakowego w 5 płytkich jeziorach położonych na Pojezierzu Łęczyńsko-Włodawskim. Badane jeziora charakteryzowały się istotnymi różnicami w liczebnościach planktonowych Cladocera i Copepoda. Jezioro Czarne Sosnowickie charakteryzowało się najniższą liczebnością skorupiaków, zaś najwyższą liczebność stwierdzono w jeziorze Dratów. Liczebność Cladocera była kształtowana przez temperaturę, przewodność, pH i zawiesinę ogólną. Liczebność Copepoda była kształtowana przez temperaturę i zawiesinę rozproszoną. Badania przyczyniają się do lepszego zrozumienia wpływu zmian środowiskowych na liczebność planktonu skorupiakowego w warunkach globalnej eutrofizacji wód oraz nadchodzących zmian klimatycznych.

Słowa kluczowe: Cladocera, Copepoda, liczebność