

## CHANGES IN THE ZOOPLANKTON COMMUNITY OF PONDS AS A RESULT OF MACROPHYTE COVER TRANSFORMATION IN A PASTORAL WATER BODY

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**Summary.** This study was conducted in order to examine to what extent the macrophyte cover differs from year to year as a result of water level change and how these differences would affect the zooplankton structure of an investigated small water body. The research was carried out on a small pond, located within a pastoral catchment area in the north-western part of the Wielkopolska region, over two years, between 2002 and 2004. Zooplankton was sampled from eight stations altogether, four each year, including *Chara fragilis*, *Ceratophyllum* spp., *Potamogeton natans* and an open water area in the first year, as well as *Typha latifolia*, *Ceratophyllum* spp., *Potamogeton natans* and an open water area in the second year of the studies. In total 110 zooplankton species were identified, with only 53% common for both years of the study. Macrophyte stands of spatially complicated architecture were characterised by richer species diversity and higher zooplankton densities than the open water zone and macrophyte stands of sparse stem structure, which was a result of the greater mosaic of the densely vegetated habitats which created more ecological niches and provided the inhabiting organisms with better refuge conditions. Furthermore, the similarity indices of the zooplankton community confirmed the distinctiveness of the habitats created by morphologically diverse macrophytes and those of simple build. Additionally, the obtained results showed impoverishment of the zooplankton community structure caused by the rebuilding of the macrophyte cover, being a result of changes in the water level over the two years of the examination.

**Key words:** pond, zooplankton, species diversity, macrophyte cover rebuild, water level decrease

### INTRODUCTION

Ponds, which are small ecological systems, contribute to the enrichment of the local biodiversity since they create favourable life conditions for many organisms, both producers and consumers. They also play an important role in increasing local water retention, which is particularly essential in Poland, where water resources are restricted. The creation of ecotone zones is vital to the maintenance of small water bodies since these create typical buffer zones as well as optimise agricultural practices in the surrounding area. The buffering zones between the land area and the pond water reduce the rates of nutrient inflows into the water body. Moreover, the differentiated kinds of macrophyte cover, including rush, floating or submerged macrophyte species, contribute to the improvement of water quality.

Macrophytes in ponds are very important as they may intake great amounts of nutrients preventing accelerated algae growth, reflect a lot of the sunlight, and regulate

water temperature. They may also provide a nutritional source [Jones *et al.* 2000, Degans and De Meester 2002] and serve as refuge spots for numerous groups of animals. Both rotifers and crustaceans may use macrophytes as concealment against invertebrate and vertebrate predators [Diehl and Kornijów 1998] and the various architecture of plants provides organisms with a range of protective conditions within the complex conglomeration of macrophytes [Diehl 1992] with increasing protection among the more structurally complex plants [Warfe and Barmuta 2004].

Due to the small area and depth as well as to the related small water volume, parameters that increase the pond susceptibility to degradation, small water bodies often undergo changes in their trophic status. Even in the same pond the life conditions of aquatic plants may be affected by trophic status or changes in environmental conditions, including water level fluctuations [van der Valk and Davis 1976], which may easily be reflected in the macrophyte cover transformation. Water level changes often contribute to the impoverishment of vegetation cover and, in consequence, to the impoverishment of other organism communities that inhabit the differentiated habitats of a small water body. Zooplankton assemblages of ponds consist of typical pond-associated forms as well as forms characteristic for the littoral zone of lakes.

The main goal of this study was to review the progress of zooplankton transformation following the re-building of the macrophyte cover of the examined pond. Detailed analysis incorporates:

- analysis of the rotifer and crustacean structure in different vegetated stands and, comparatively, in the open water area with emphasis on the habitat preferences of particular species,
- comparison of the diversity index of the zooplankton community among the analysed stations,
- participation of eutrophic species of zooplankton within particular habitats,
- determination of the nutrient composition and physical features of the open water zone as well as among macrophyte stands.

## STUDY AREA, MATERIALS AND METHODS

The research was carried out on a small water body located in the north-western part of the Wielkopolska region, in the village of Piotrowo near Obrzycko, over two years, between 2002 and 2004. The pond was characterised by unequal beds and differentiated rush and water vegetation during the subsequent years of examination as a result of water level fluctuations. This is a typical anthropogenically modified pond situated within an agricultural area. There are only single trees surrounding the pond. The rush zone is created by a thick belt of mainly *Typha latifolia*. The composition of submerged macrophytes changes from year to year. In the first year of examination (2002) the elodeids were dominated by *Chara fragilis* with a lesser participation of *Ceratophyllum* spp., while in 2004 the presence of stoneworts was not recorded, however, common hornwort occurred in great amounts, filling most of the water column within the pond basin.

Water temperature, dissolved oxygen, pH and conductivity (Sension 156 Hach), as well as Secchi depth were measured directly at the sampling sites. Later the water sam-

ples were analysed in the laboratory to determine total phosphorus (TP) and ammonium ( $\text{NH}_4$ ) content (Tab. 1).

Table 1. Physical and chemical parameters in water samples collected in 2004 from particular stations of examined water body

Tabela 1. Fizyczne i chemiczne parametry próbek wody pobranych w 2004 r. z poszczególnych stanowisk

Stand – Stanowisko	Cond.	pH	O <sub>2</sub>	TP	N-NH <sub>4</sub> <sup>+</sup>	Chl <i>a</i>
Open water – Otwarta toń wodna	417	6.60	11.6	50	1820	20.3
<i>Potamogeton natans</i>	424	6.74	10.5	56	2360	19.25
<i>Ceratophyllum demersum</i>	393	7.37	8.6	75	1860	33.57
<i>Typha latifolia</i>	417	6.67	8.2	63	2010	4.5

cond. – conductivity –  $\mu\text{S cm}^{-1}$ , pH, O<sub>2</sub> – oxygen –  $\text{mg O}_2 \text{ l}^{-1}$ , TP – total phosphorus –  $\mu\text{g l}^{-1}$ , N-NH<sub>4</sub> – ammonium –  $\mu\text{g l}^{-1}$ , chl *a* – chlorophyll *a* –  $\mu\text{g l}^{-1}$

cond. – przewodnictwo –  $\mu\text{S cm}^{-1}$ , pH, O<sub>2</sub> – tlen –  $\text{mg O}_2 \text{ l}^{-1}$ , TP – fosfor ogólny –  $\mu\text{g l}^{-1}$ , N-NH<sub>4</sub><sup>+</sup> – amon –  $\mu\text{g l}^{-1}$ , chl *a* – chlorofil *a* –  $\mu\text{g l}^{-1}$

Zooplankton was sampled from eight stations altogether, four each year, including *Chara fragilis*, *Ceratophyllum* spp., *Potamogeton natans* and the open water area in the first year, as well as *Typha latifolia*, *Ceratophyllum* spp., *Potamogeton natans* and the open water area in the second year of the studies. Samples were collected in triplicate from each station, using a plexiglass core sampler (method for sampling in the littoral zone recommended by e.g. Schriver *et al.* 1995), thickened by means of a planktonic net (45  $\mu\text{m}$ ) and preserved with 4% formaldehyde.

To estimate the species diversity of rotifers inhabiting particular zones in the lake the Shannon and Weaver coefficient was applied [Margalef 1957]. The similarities between zooplankton communities in different habitats were compared using the Ward method and the Euclidean distance measure [Sokal 1961]. The graphic form of the similarity was presented using a tree-diagram [Krebs 1989].

The Mann-Whitney U-test was used in order to determine the effect of the pond on the distribution of plankton communities ( $N = 24$ ).

## RESULTS

The concentration of chlorophyll *a* differed between particular sampling stations, with the highest values at the hornwort bed and the lowest among the *Typha* stand. The analysis of chemical content revealed the highest values of total phosphorus within the *Ceratophyllum* stand and highest values of ammonium among the *Potamogeton* station (Tab. 1).

110 zooplankton species in total were identified (75 Rotifera, 25 Cladocera, 10 Copepoda). Only 53% of the taxonomical structure was common for both years of the study. Comparing both years of examination it was found that the species diversity decreased, from a total of 92 species in 2002 to 77 in 2004. The taxonomical structure differed between the sampling stations with the mean lowest in the zone of open water and the *Typha* bed and highest among the *Chara* stands (for rotifers and cladocerans) and the *Ceratophyllum* bed (for copepods) (Fig. 1).

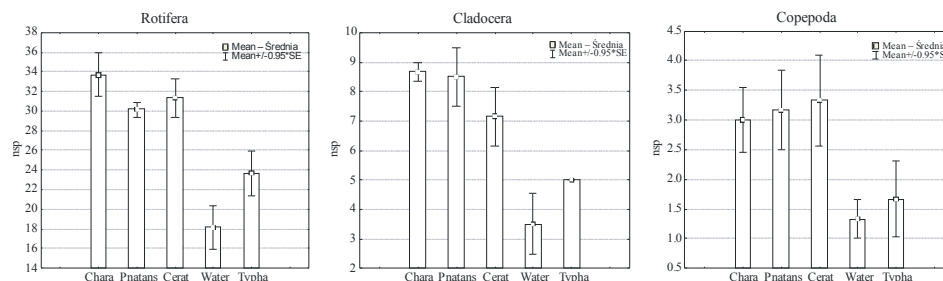


Fig. 1. Mean numbers of zooplankton species in the examined pond (Chara – *Chara fragilis*; Pnatans – *Potamogeton natans*; Cerat – *Ceratophyllum* spp., Water – open water zone; Typha – *Typha latifolia*)

Rys. 1. Średnia liczba gatunków zooplanktonu w badanym stawie (Chara – *Chara fragilis*; Pnatans – *Potamogeton natans*; Cerat – *Ceratophyllum* spp., Water – otwarta toń wodna; Typha – *Typha latifolia*)

The mean number of rotifer specimens per 1 litre reached the highest values within the stonewort bed, while crustaceans had their highest densities in the *Ceratophyllum* stand (Fig. 2).

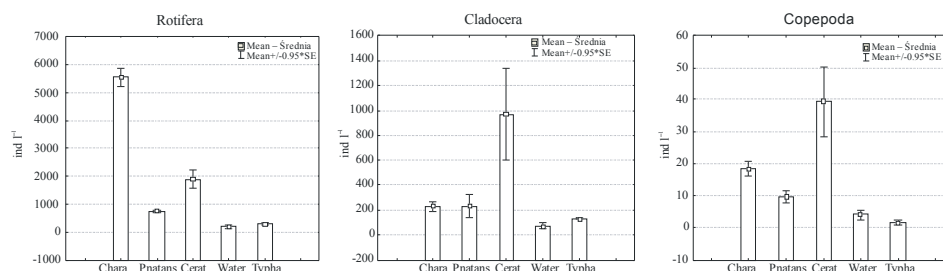


Fig. 2. Mean densities of zooplankton communities in the examined pond (Chara – *Chara fragilis*; Pnatans – *Potamogeton natans*; Cerat – *Ceratophyllum* spp., Water – open water zone; Typha – *Typha latifolia*)

Rys. 2. Średnia liczebność ugrupowań zooplanktonu w w badanym stawie (Chara – *Chara fragilis*; Pnatans – *Potamogeton natans*; Cerat – *Ceratophyllum* spp., Water – otwarta toń wodna; Typha – *Typha latifolia*)

Rotifers dominated over crustaceans in the first year of examination, while in the second year in the zones of open water and *Ceratophyllum* cladocerans reached higher numbers. In the case of rotifers ( $Z = 2.3238$ ,  $p < 0.05$ ) and copepods ( $Z = 2.0656$ ,  $p < 0.05$ ) the densities differed significantly between particular stations with the highest numbers of the first group within the stonewort bed and of the second group within the hornwort stand. Moreover, such differences ( $Z = 2.3238$ ,  $p < 0.05$ ) were also found for bdelloids, *Cephalodella gibba* (Ehrenberg), *Dissotrocha aculeata* (Ehrenberg), *Lecane closterocerca* (Schmarda), *L. lunaris* (Ehrenberg), *Lepadella triptera* Ehrenberg and *Pompholyx sulcata* (Hudson) which all prevailed in the *Chara* bed (Fig. 3). The mean densities of zooplankton communities differed between both years, reaching 794 ind l<sup>-1</sup> in the first year and 412 in the second year. Moreover, it was found that the mean abundance of rotifers decreased (from 2272 to 596 ind l<sup>-1</sup>), while that of cladocerans increased (from 97 to 620).

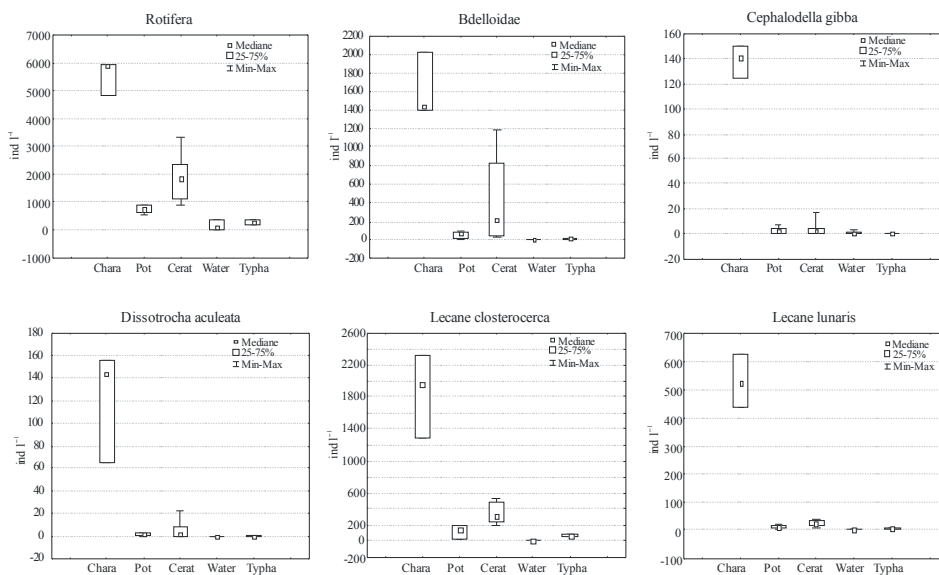


Fig. 3. Habitat preferences of particular zooplankton species in the examined pond (Chara – *Chara fragilis*; Pot – *Potamogeton natans*; Cerat – *Ceratophyllum* spp., Water – open water zone; Typha – *Typha latifolia*)

Rys. 3. Preferencje siedliskowe poszczególnych gatunków zooplanktonu w badanym stawie (Chara – *Chara fragilis*; Pot – *Potamogeton natans*; Cerat – *Ceratophyllum* spp., Water – otwarta toń wodna; Typha – *Typha latifolia*)

The mean Shannon-Weaver biodiversity index values ranged from 1.17 to 4.04, with the lowest values within the open water and the *Potamogeton natans* zones and the highest values in the *Chara* and *Ceratophyllum* beds (Fig. 4). Analysis of both years revealed that this index decreased from a mean of 2.96 in the first year to 2.26 in the second year.

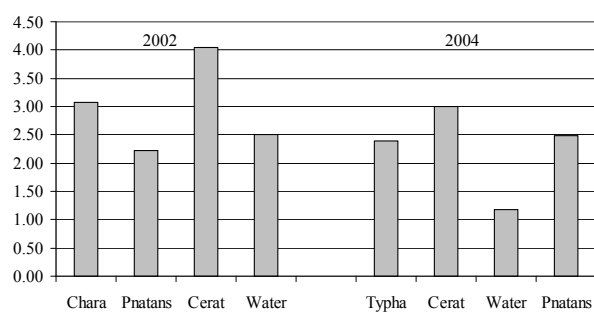


Fig. 4. Biodiversity index of zooplankton communities in the examined pond (Chara – *Chara fragilis*; Pnatans – *Potamogeton natans*; Cerat – *Ceratophyllum* spp., Water – open water zone; Typha – *Typha latifolia*)

Rys. 4. Wskaźnik różnorodności gatunkowej ugrupowań zooplanktonu w badanym stawie (Chara – *Chara fragilis*; Pnatans – *Potamogeton natans*; Cerat – *Ceratophyllum* spp., Water – otwarta toń wodna; Typha – *Typha latifolia*)

Analysis of the zooplankton communities among all the examined habitats within the studied pond revealed that the highest similarity, using the Ward method and Euclidean distance measure, was found among two pairs of habitats. The first group, of the strongest relationship, was noticed among the open water zone and the *Typha latifolia* stand with the adhering area of *Potamogeton natans*. The second group included two habitats – *Chara* and *Ceratophyllum* beds (Fig. 5).

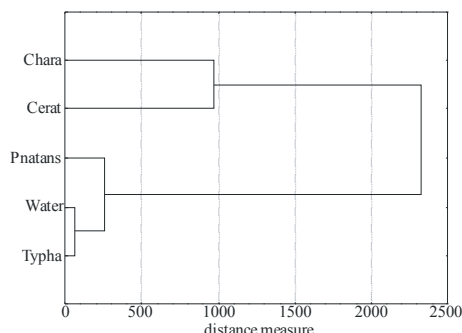


Fig. 5. Mean value of similarity of zooplankton communities (the Ward method and Euclidean distance measure) in the examined pond (Chara – *Chara fragilis*; Pnatans – *Potamogeton natans*; Cerat – *Ceratophyllum* spp., Water – open water zone; Typha – *Typha latifolia*)

Rys. 5. Średnia wartość podobieństwa ugrupowań zooplanktonu (Metoda Warda, odległość euklidesowa) w badanym stawie (Chara – *Chara fragilis*; Pnatans – *Potamogeton natans*; Cerat – *Ceratophyllum* spp., Water – otwarta toń wodna; Typha – *Typha latifolia*)

The participation of eutrophic species within the total zooplankton densities reached values between 9 and nearly 80%. The mean participation of such species was 36% in 2002 and 48% in 2004. In both years of investigation the highest values were found in the open water zone (69 and 79% of the total zooplankton abundance in two successive years, respectively), while macrophyte zones were characterised by much lower values (Fig. 6).

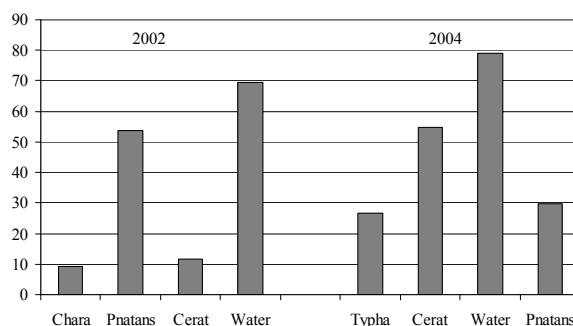


Fig. 6. Participation of eutrophic species in the total zooplankton densities in the examined pond (Chara – *Chara fragilis*; Pnatans – *Potamogeton natans*; Cerat – *Ceratophyllum* spp., Water – open water zone; Typha – *Typha latifolia*)

Ryc. 6. Udział gatunków eutroficznych w całkowitej liczebności ugrupowań zooplanktonu w badanym stawie (Chara – *Chara fragilis*; Pnatans – *Potamogeton natans*; Cerat – *Ceratophyllum* spp., Water – otwarta toń wodna; Typha – *Typha latifolia*)

## DISCUSSION

Small water bodies located in the pastoral catchment area are usually smaller than 1 ha, they are shallow and characterised by changeable water level, which can, as a consequence, cause variation in the life cycles and processes connected with their inhabitants and pond functioning. The transformation of life cycles and processes within the smaller ponds is the fastest, as these warm up a lot quicker than the larger and much deeper ponds.

Along with the rebuilding of the macrophyte cover the taxonomical structure of zooplankton changed. In the examined material only 53% of species were common for both years of the study. Moreover, the number of species decreased significantly, from 92 to 77, in the consecutive years. The species richness varied between the sampling stations, with the lowest values within the zone of open water and rush area and the highest among macrophyte stands (the maximum within *Chara* and *Ceratophyllum* beds). Aquatic vegetation of small water reservoirs may consist of different ecological groups which create a mosaic of habitat and the life conditions resemble the littoral zone of lakes [Ozimek and Rybak 1994] which is typically characterised by rich and diverse zooplankton communities [Gliwicz and Rybak 1976].

Rotifers showed a dominance over crustaceans in 2002, while in 2004 cladocerans dominated in the zones of open water and hornwort. Such a shift in the dominating structure of both groups of zooplankton may suggest changes in predation pressure in the examined water body caused by a sudden water level decrease. Rotifers had a statistically higher abundance in the stonewort bed while copepods in the hornwort stand. Additionally, bdelloids, *Cephalodella gibba*, *Dissotrocha aculeata*, *Lecane clostercerca*, *L. lunaris*, *Lepadella triptera* and *Pompholyx sulcata* prevailed in the *Chara* bed. Such a model of zooplankton distribution resembles the model for shallow lakes and ponds with fish predation present, where the highest densities of zooplankton are found among the thick and spatially more complex macrophyte stands during the day, as described by e.g. Timms and Moss [1984].

Furthermore, the mean Shannon-Weaver biodiversity index reached their lowest values levels within the open water zone and the *Potamogeton natans* stand, while the highest values appeared in the *Chara* and *Ceratophyllum* beds, both architecturally complex habitats, where inhabiting organisms find the more ecological niches and where the best refuge conditions are to be found [Jeppesen *et al.* 1997, Moss *et al.* 1998]. Moreover, the food conditions were better among dense macrophyte habitats since the bed of *Ceratophyllum* was characterised by the highest concentration of chlorophyll *a* and total phosphorus compared to the other stations. It was also observed that with the lowering of the water level of the studied pond the mean biodiversity index decreased by nearly one quarter.

A very high similarity of zooplankton communities was recorded for two pairs of habitats, differing in the level of space heterogeneity. The strongest similarity was obtained for the open water zone and the rush zone together with the floating-leaved pondweed stand, i.e. for both zones of simple and sparse spatial organisation. The second group comprised two architectonically complicated habitats of dense stem structure – the stonewort and hornwort beds. Similarly, Basu *et al.* [2000] described the positive relationship between morphological structure and macrophyte density with zooplankton.

In addition, the shift in macrophyte cover caused by water level fluctuations affected the participation of eutrophic species [Sládeček 1983, Karabin 1985] within the total zoo-

plankton numbers, which increased during the second year of the study by nearly 35% compared with the first year, which suggests a decrease in the water quality of this pond.

## CONCLUSION

The obtained results demonstrated that the rebuilding of the macrophyte cover of the investigated water body caused by changes in the water level over the two years of the examination affected the zooplankton assemblages with respect to species community structure, species diversity index, as well as participation of eutrophic species. Moreover, differences in the spatial and morphological structure among particular aquatic plant stands determined the structure of the rotifer and crustacean communities. Additionally, the similarity indices distinguished two groups of habitats, where the density and the stem spatial structure seemed to have a great impact on the zooplankton distribution between certain macrophyte stands of the investigated water body.

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#### ZMIANY W STRUKTURZE UGRUPOWAŃ ZOOPLANKTONU STAWÓW JAKO WYNIK TRANSFORMACJI POKRYWY MAKROFITOWEJ ŚRÓDPOLNEGO ZBIORNIKA WODNEGO

**Streszczenie.** Celem badań była ocena wpływu zmian w strukturze syntaksonomicznej zbiorowisk makrofitów w kolejnych dwóch latach badań, wynikająca z obniżenia się poziomu lustra wody, na strukturę ugrupowań zooplanktonu niewielkiego zbiornika wodnego. Badania prowadzono w dwóch latach – 2002 i 2004 na małym stawie zlokalizowanym w zlewni rolniczej, położonym w pn.-zach. części Wielkopolski. Stwierdzono łącznie obecność 110 gatunków zooplanktonu, przy czym zaledwie 53% było elementem wspólnym dla dwóch kolejnych lat badań. Wykazano, że stanowiska makrofitów o przestrzennie skomplikowanej architekturze charakteryzowały się bogatszą strukturą taksonomiczną i wyższymi liczebnościami zbiorowisk zooplanktonowych niż płaty makrofitów o luźnej strukturze pędów oraz stanowiska toni wodnej. Było to wynikiem większej heterogeniczności gęstszych płatów roślinnych, które były w stanie 'wykreować' dużą większą liczbę nisz ekologicznych, a także zapewniały lepsze warunki kryjówki dla przebywających tam organizmów. Dodatkowo wskaźnik podobieństwa gatunkowego potwierdził odrębność siedlisk zbudowanych przez płaty makrofitów o budowie skomplikowanej morfologicznie oraz o prostej budowie. Ponadto uzyskane wyniki wskazywały na zubożenie struktury ugrupowań zooplanktonu, wywołanej przebudową struktury roślinności makrofitowej analizowanego stawu w następstwie obniżenia się poziomu lustra wody.

**Słowa kluczowe:** staw, zooplankton, różnorodność gatunkowa, przebudowa pokrywy makrofitowej, obniżenie poziomu wody