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DYNAMICS OF ZOOPLANKTON STRUCTURE IN THREE SMALL WATER BODIES ON THE AREA OF AN AGRITOURISM FARM

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Summary. Analyses were conducted at three small natural water bodies (ponds) located on the area of an agritourism farm in Kierwiny, Warmia and Mazury Province (north-eastern Poland). Samples of zooplankton were collected once a month since May till October 2010. The analyzed ponds differed, mainly, in the type and intensity of feeding in particular seasons: pond no. 1 – a direct receiver of wastewater discharged from a stable; pond no. 2 – joined with an overflow with pond no. 1, the shallowest and periodically drying out; and pond no. 3 – a typical mid-field pond. Rotifers (77 taxa) were the most abundant and the most diverse zooplankton community in the investigated ponds. The zooplankton biomass was predominated by the crustacea (12 taxa). The prevailing species included: *Anuraeopsis fissa, Polyarthra longiremis*, *Keratella testudo, Proales sordida* and a juvenile stage of Copepoda – nauplius. The highest diversity and evenness of the identified taxa contribution in zooplankton abundance was noted in the astatic pond no. 2. The phenomenon of inter-species hybridization of water fleas from the *Daphnia* genus was observed in ponds no. 1 and 2. Zooplankton diversity structure and dynamics in the ponds were determined by environmental factors, basin character and feeding with biogenes and resulted, most of all, from the inter-species dependencies and interactions as well as high trophy of waters of the analyzed water bodies.

Key words: zooplankton, Rotifera, Crustacea, Protozoa, small water bodies, agritourism farm

INTRODUCTION

The functioning of small water bodies is affected by a variety of determinants that stem mainly from their genesis, intended purpose and further exploitation. Contemporarily, a man uses different types of natural and artificial land depressions filled with water in order to exploit its resources as well as for economic, touristic and recreational purposes. From this perspective, small reservoirs play a significant role in highly-industrialized areas and in urban agglomerations

[Jaguś and Rzętała 2008, Rzętała 2008]. It is also noteworthy that natural and transformed water regions serve a tremendous function in the natural environment in affecting the course of processes and preserving bio-diversity. In addition, they serve as corridors in the functioning of ecological networks in both the urban and rural landscape [Gorączko and Żytelewska 2005, Stolarska and Frątczak 2005].

Unfortunately, in the context of the role they play these ecosystems are simultaneously severely endangered. Small depth and water capacity as well as a large contact zone with the external environment (the so-called edge effect) are the main factors that influence their susceptibility. Small reservoirs are exposed to effects of the basin, anthropogenic activity or fluctuations in atmospheric conditions to a significantly greater extent than lakes do.

The reported hydrobiological study was conducted at three small water bodies characterized as ponds, located on the area of the agritourism farm and horse stud „Dom Trakeński" in Kierwiny (District Kiwity, Lidzbarski Community, Warmia and Mazury Province, north-eastern Poland). The rural landscape of the District includes naturally-valuable primitive enclaves, under legal protection: ornithological reserve „Mokradła Żegockie", Protected Landscape Area of the Lower Valley of Łyna River, Protected Landscape Area of Symsarna River Valley and ecological land „Bartniki" – a refuge of water and mud birds [Program Ochrony Środowiska …2004].

The aim of this study was to determine the structure and to observe the dynamics of changes proceeding in zoopolankton community of small water bodies at the area developed for agritouristic purposes.

MATERIALS AND METHODS

Samples of zooplankton were collected once a month, from May till October 2010, from each of the analyzed ponds. Morphometric parameters of all ponds were similar: depth of ca. 1–2 m, and surface area of < 0.2 ha. The riparian zone of all ponds included assemblages of grey willow, fragments of alder marshy meadow and low meadow vegetation.

Pond no. 1, located ca. 50 m away from a stable, is a receiver of wastewater from a station at which horses are cooled and washed in the summer period. These wastewaters are organic, but very diluted and very sporadically contain trace amounts of detergents. The reservoir is equipped in a wooden barrier used to regulate the water stage and becomes an overflow channel discharging the excess of water to pond no. 2 during heavy rainfalls or spring melts. Under natural conditions, the pond no. 2 is periodical in character. In turn, pond no. 3 is a typical mid-field pond, surrounded by meadows and arable lands.

For quantitative analyses, the samples (20 dm^3) were concentrated on a plankton net with a mesh diameter of 30 μm. The material was fixed with Lugol fluid and preserved in a formalin solution with the concentration of 4%.

The collected material was analyzed to determine the qualitative and quantitative composition and biomass of zooplankton. Taxonomic identification of zooplankton was carried out using works by: Flössner [1972], Sterble and Krauter [1978], Radwan *et al*. [2004], as well as Rybak and Błędzki [2010]. The nauplius and copepodite stages of copepods were not subjected to taxonomic identification. Plankton counts (ind. · dm^{-3}) were assayed using a method proposed by Hansen [Starmach 1955]. The individual biomass of rotifers was determined using weight standards [Radwan *et al*. 2004]. In the case of crustaceans and protozoa, individual organisms were measured under a microscope with an eyepiece with an accuracy of up to 0.01 mm. In order to quantify biomass, it was assumed that density of an individual zooplanktonic organism equaled 1, i.e. 1 mm^3 = 1 mg [Hernroth 1985].

Diversity of the qualitative structure of zooplankton was determined in terms of: general species diversity – Shannon-Weiner's diversity index [Shannon 1948], Margalef's species richness index [Margalef 1957], species dominance [Kasprzak and Niedbała 1981], Pielou's species evenness index [1966], and the Jackard's index of species similarity of communities [Marczewki and Steinhaus 1959].

Results were developed statistically following methods proposed by Sokal and Rohlf [1981] and Zar [1984] using a statistical package STATISTICA 10.0. Counts and biomass of zooplankton of high-rank taxonomic groups were compared with the use of correlation coefficients at the probability level of $p < 0.05$.

The significance of mean values of ecological indices was determined with the Mann-Whitney *U* test and Student *t* test. Mean values of zooplankton counts and biomass in particular ponds and sampling periods were compared with the Kruskal-Wallis ANOVA rank test.

RESULTS

A total of 97 taxa of zooplankton were identified in the analyzed ponds including: 82 taxa of rotifers, 8 species of water fleas, 3 taxa of copepods and 3 species of protozoa. The greatest taxonomic diversity was determined in pond no. 1 (76), whereas the lowest one (59) in pond no. 3. Differences in the mean values of this parameter noted between the ponds were statistically insignificant (*U* test, $p < 0.05$) (Fig. 1b). There was either no difference in mean values of species numbers between the compared sampling periods (*U* test, $p < 0.05$) (Fig. 1a).

Zooplankton of pond no. 2 was characterized by high diversity assessed based on Shannon's index (3.01) and Margalef's species richness index (9.28). In contrast, the lowest values of these indices were determined in pond no. 3, namely 1.5 and 6.09, respectively (Fig. 2b and d). Differences in the mean values of these parameters between particular ponds were statistically significant (test *t*, $p < 0.05$). The taxonomic diversity of zooplankton of the analyzed ponds was also significantly (*U* test, $p < 0.05$) determined by the season of the year (Fig. 2a and c).

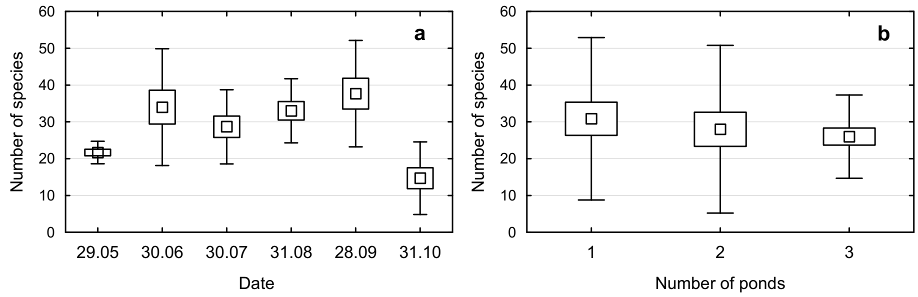


Fig. 1. Mean number of zooplankton species in particular ponds and sampling periods in 2010

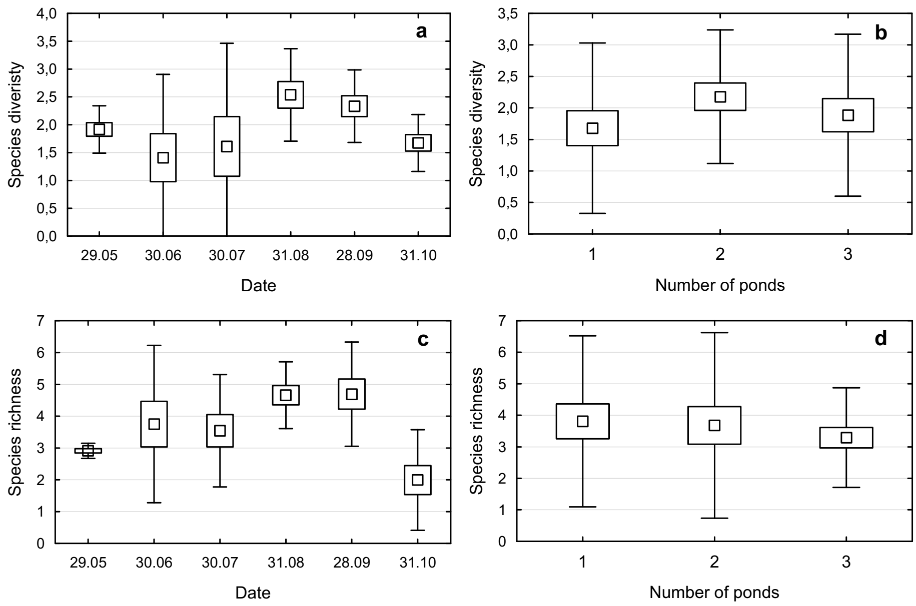


Fig. 2. Mean values of indices of zooplankton species biodiversity and abundance in particular ponds and sampling periods in 2010

The high diversity of zooplankton in pond no. 2 coupled with high values of the evenness index (Fig. 3b) point to the even distribution of the number of particular taxa in the biocenosis. In the other compared ponds zooplankton structure was characterized by the presence of one to three strongly dominant species, which was confirmed by significantly lower mean values of the discussed parameter, especially in June and July. Strong eudominants included the following Rotifera: *Anuraeopsis fissa*, *Polyarthra longiremis, Proales sordida* and *Keratella testudo*. Their maximum contribution in the total zooplankton abundance reached: 90.2% (pond no. 1), 48.3% (pond no. 1), 41.6 (pond no. 3), and 51.2% (pond no. 1), respectively. In the autumn season, the intensity of their prevalence in the zooplankton structure was observed to decrease, but its traits were preserved in individual phyla (Fig. 3a and b).

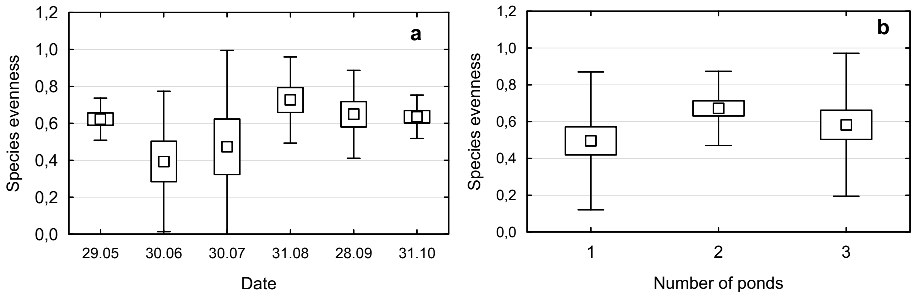


Fig. 3. Mean values of Pielou evenness index in particular ponds and sampling periods in 2010

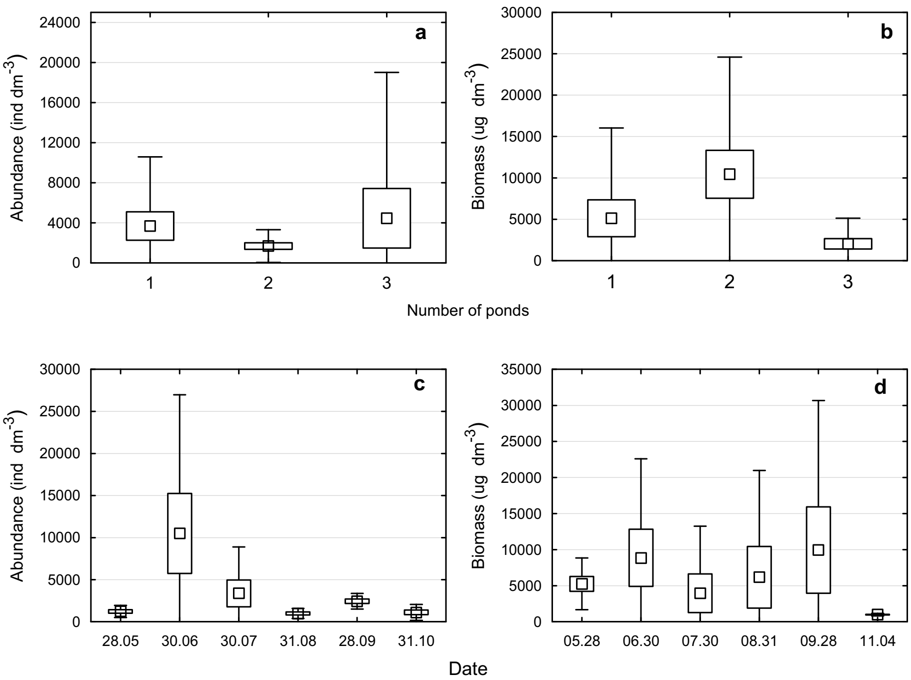


Fig. 4. Average abundance and biomass of zooplankton in each pond on different sampling days in 2010
Small square: average, rectangle: ± standard error, „swirls" : ± standard deviation

In the case of crustaceans, the highest frequency of occurrence and abundance were determined for the larval stages of copepods: nauplius and copepodite. The maximum contribution of these forms accounted for: 14% in pond no. 2 in June and 11% in pond no. 1 in May, respectively. The presence of water fleas in the zooplankton community was detected almost exclusively in ponds no. 1 and 2. The highest frequency of occurrence was noted for: *Chydorus sphaericus* (78%) and *Pleuroxus truncatus* (50%). The genus *Daphnia* was represented by *D. galeata* and *D. longispina,* and by hybrids of these species. Individuals with common traits constituted 49% of all

Table 1. Indices of species diversity and faunal similarity in the investigated ponds

Measure/indicator	Pond		
	1	2	3
Number of species	76	70	59
Species diversity	1.80	3.01	1.49
Species richness	0.91	0.93	0.61
Species evenness	0.42	0.71	0.37
	1–2	1–3	2–3
Faunal similarity	0.560	0.578	0.582

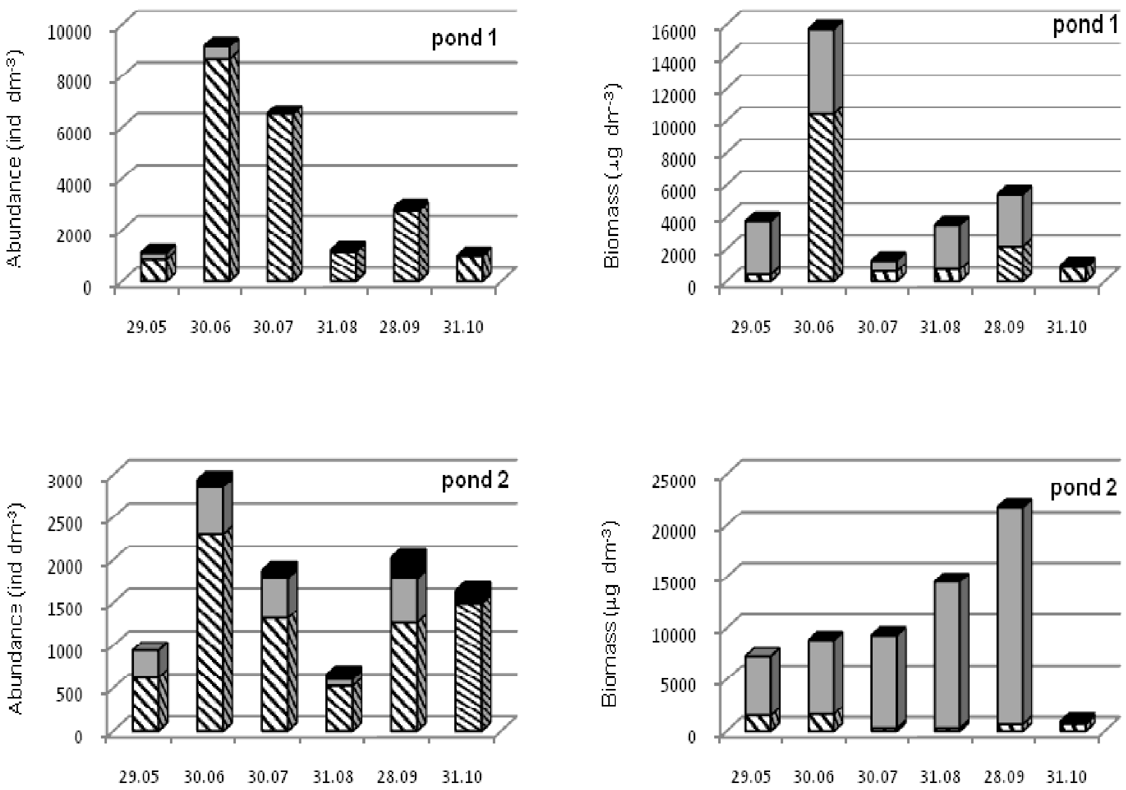
representatives of *Daphnia* genus observed throughout the study period in pond no. 1. In zooplankton of pond no. 2 the hybrid morphs constituted from 15% to 100% of the *Daphnia* genus in May and June, respectively.

The protozoa of the genus *Arcella* occurred in the entire analytical season in all ponds. Usually, in their case the highest count and contribution in the structure were noted in pond no. 3 with the maximum determined in September at 290 ind. · dm^{-3}, which constituted 12% of total zooplankton abundance.

The mean values of zooplankton count and biomass in particular ponds did not differ significantly (ANOVA, respectively $p = 0.7165$ and 0.0759). In pond no. 2, the mean count of zooplankton was the lowest (1680 ind. · dm^{-3}), however the mean value of biomass turned out to be the highest (10.443.1 mg · m^{-3}). In ponds no. 1 and 3 values of these parameters accounted for: 3682 and 4459 ind. · dm^{-3} as well as 5123.5 and 2038.7 mg · m^{-3}, respectively. The mean values of zooplankton count in the analyzed ponds were significantly differentiated by the sampling period (ANOVA $p = 0.0170$) (Fig. 4a and c). It was due to significant deviations from the mean counts noted in June and July. The maximum zooplankton count was determined in June in ponds no. 3 (19.280 ind. · dm^{-3}) and no. 1 (9255 ind. · dm^{-3}) (Fig. 5). In both cases, the values were affected by strong development of *Anuraeopsis fissa*, whose contribution reached 88 and 66.5%.

In all pounds, the count of zooplankton was determined by the population density of Rotifera ($r = 0.998$ with $p < 0.05$) (Fig. 5). The highest count of the rotifers and their contribution in total zooplankton density were observed throughout the study period in ponds no. 1 (868–8660 ind. · dm^{-3} and 77–94%) and no. 3 (690–18.560 ind. · dm^{-3}, and 96%). Aside the prevailing Rotifera, also Crustacea abundance was significant in the structure of zooplankton from pond no. 2 (12–33.5%) (Fig. 5).

In all analyzed ponds, the biomass of zooplankton was determined by the Cladocera ($r = 0.858$, $p < 0.05$). The maximum biomass value in September was due to the massive growth of *Chydorus sphaericus* and *Pleuroxus truncatus* reaching 100 and 300 ind. · dm^{-3}, which represented 4.9 and 14.8% of zooplankton structure in pond no. 2 (Fig. 5). This phenomenon elicited a significant increase in mean values of zooplankton biomass, however the differences between particular sampling periods were statistically insignificant (ANOVA, $p = 0.2163$) (Fig. 4b and d).



pond 1
Abundance (ind dm-3)
10000
8000
6000
4000
2000
0
29.05
30.06
30.07
31.08
28.09
31.10
pond 1
Biomass (µg dm-3)
16000
14000
12000
10000
8000
6000
4000
2000
0
pond 2
Abundance (ind dm-3)
3000
2500
2000
1500
1000
500
0
pond 2
Biomass (µg dm-3)
25000
20000
15000
10000
5000
0

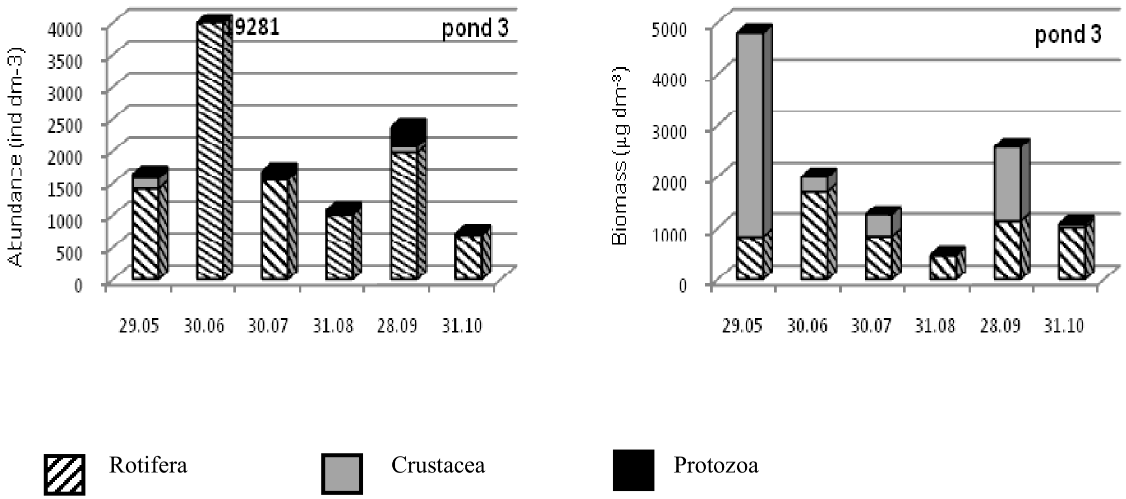


Fig. 5. Dynamics of seasonal changes in the count and biomass of zooplankton in particular ponds

DISCUSSION

The structure of zooplankton from the analyzed ponds was characterized by high diversity of the Rotifera phylum, 82 taxa of which were determined in the entire study period. A similar diversity was reported in the case of mid-field ponds by Kuczyńska-Kippen [2006]. In turn, considerably poorer (37 taxa) was the rotifer biocenosis of a small overgrown pond in the Wielkopolska region investigated by Kuczyńska-Kippen and Nagengast [2006a, b], and of six small reservoirs in Slovakia (39 Rotifera amongst 103 taxa) [Illová and Pastuchová 2012], where water fleas prevailed in the dominance structure. The lesser richness of the Rotifera community (41 taxa) was also demonstrated by Goździejewska and Tucholski [2010], during whole-season analysis of zaooplankton of fish culture ponds in Olsztynek (north-eastern Poland). Such a high taxonomic diversification of rotifers in our study might have resulted from a lack of consumers – including larval stages of fish, and from abundance of feed and a simultaneously low count of filtering Cladocera competing for the feed [Lampert and Sommer 2001].

The total number of taxa in the analyzed ponds was the highest and at a similar level in the period since June till September. The decrease in diversity indices noted in June and July was caused by disturbance of the even distribution of species contribution in the biocenosis with a strong dominance of: *Anuraeopsis fissa*, *Polyarthra longiremis, Filinia longiseta, Trichocerca pusilla,* and *Keratella cochlearis* var. *tecta* – species acknowledged as indicators of high water trophy [Radwan (ed.) 2004, Kuczyńska-Kippen *et al*. 2009].

In all ponds together, the periodical, mass appearance and eudominance (> 10%) referred to nice species of rotifers and one representative of water flea – *Pleuroxus truncatus*. Amongst the Rotifera, a species being typical to small water bodies and abundant at the beginning of the study period was *Keratella testudo*.

Apart from the above mentioned, a large community was constituted by psammonic-peryphytic rotifers [Bieniarz *et al*. 2003, Radwan *et al*. 2004], represented by small species of the following genera: *Lecane*, *Colurella*, *Euchlanis*, *Lepadella*, *Cephalodella*, *Mytilina,* and *Trichocerca*. They occurred in low counts and irregularly since June till September. A similar characteristics of the seasonal growth in populations of species that acc. to Wiszniewski [1937] are included to a group of psammophiles and herein were represented by: *Cephalodella gibba, Colurella obtusa, Lecane closterocerca*, *Lepadella patella*, and a psammoxenic species *Trichocerca weberi*, was described by Bielańska-Grajner [2004]. Many authors have emphasized the eurytopic character of the above taxa, identifying their presence both in stagnant waters of various trophy levels [Radwan *et al*. 2004], in different climatic zones [e.g., Altindaĝ 1999, Serafim *et al*. 2003], as well as in water-courses and dammed reservoirs [Endler *et al*. 2006].

The specific phenomonenon of zooplankton growth and functioning was observed in a shallow, astatic pond no. 2. It was characterized by the highest, out of all ponds examined, contribution of protozoa and crustaceans in the biocenosis. The generation and development of numerous populations of amoebas of the genus *Arcella* were stimulated by the varying level of the water table.

In turn, the maximum water filling of ponds no. 1 and 2 as well as the growth of vegetation in the first half of the study period assured optimal conditions for the growth of water fleas of the genus *Daphnia* and adult forms of copepods: *Eudiaptomus graciloides* and *Mesocyclops leuckarti*. Highly significant correlations between crustaceans population density and the growth of hydromacrophytes were reported by Kuczyńska-Kippen *et al*. [2009]. However, in the case of pond no. 2, apart from the spring season when the surface of water was densely covered with *Lemna* sp., no larger communities of submerged plants were observed. The bottom of the pond included residues of detritus and hums, which could be of benefit to the *Colurella uncinata* population, whose negative relationship with the presence of macrophytes was proved by the above authors.

In August and September the presence of water flea *Simocephalus vetulus* was noted in pond no. 2. The strong growth of this species population, till the maximum in September, proceeded at the concomitant decrease or even complete absence in the subsequent month of the juvenile forms of copepods. In the period of *S. vetulus* emergence, no increase was noted in the count of the adult forms of copepods till the end of the study period. This may be explained by results of laboratory analyses carried out by Parker [1960] on the competition between *Simocephalus vetulus* and *Cyclops viridis.* It was concluded that *S. vetulus* might affect diminished fertility of copepods. The presence of *S. vetulus* in pond no. 2 in the period of its drying out is consistent with findings of Kamiński [2009] who reported on the presence of this species in periodical forest ponds.

In ponds no. 1 and 2 analyses demonstrated the presence of *Daphnia cucullata, D. galeata,* and *D. longispina* species as well as their hybrids, identified as *Daphnia* sp., that possessed common traits of these species. The contribution of hybrids in both reservoirs constituted around a half of the count of *Daphnia* genus individuals, whereas periodical overflow of water from pond no. 1 to pond no. 2 could cause „commonality" of this phenomenon in those ponds. The periodical dominance of the hybrid forms may be due to seasonal changes in habitat conditions (in this case, to the discharge of wastewaters from a washing station for horses and to the astatic character of the reservoirs), as the inhabitants are more adaptable to these varying conditions than the representatives of water fleas of „pure" species. The hybrid individuals are less susceptible to changes in feed quality and show greater flexibility in habitat selection [Brzeziński 2010].

In summary, it may be concluded that the structure of zooplankton of small water bodies (ponds) on the area of the agritourism farm in Kierwiny is determined, most of all, by the effect of the immediate basin and seasonality of atmospheric factors including particularly intensity of precipitation. It is, additionally, influenced by trophic relationships and interspecies interactions.

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DYNAMIKA STRUKTURY ZOOPLANKTONU MAŁYCH ZBIORNIKÓW WODNYCH NA TERENIE GOSPODARSTWA AGROTURYSTYCZNEGO

Streszczenie. Analizą objęto trzy małe naturalne zbiorniki wodne na terenie gospodarstwa agroturystycznego w Kierwinach, woj. warmińsko-mazurskie. Próby zooplanktonu pobierane były raz w miesiącu, w okresie od maja do października w 2010 r. Badane zbiorniki różniły się przede wszystkim rodzajem i intensywnością zasilania w poszczególnych sezonach: staw nr 1 – bezpośredni odbiornik zanieczyszczeń dopływających ze stajni; staw nr 2 – połączony przelewem ze stawem nr 1, najpłytszy, okresowo przesychający; staw nr 3 – typowe oczko śródpolne. Najliczniejszym i najbardziej różnorodnie reprezentowanym zespołem zooplanktonu w stawach były Rotifera (77 taksonów). Biomasę zooplanktonu kształtowały skorupiaki (12 taksonów). Do gatunków dominujących należały: *Anuraeopsis fissa, Polyarthra longiremis*, *Keratella testudo, Proales sordida* oraz stadia młodociane Copepoda – nauplius. Największe zróżnicowanie i równomierność udziału zidentyfikowanych taksonów zooplanktonu stwierdzono w astatycznym zbiorniku nr 2. W stawach nr 1 i 2 obserwowano zjawisko hybrydyzacji międzygatunkowej wioślarek z rodzaju *Daphnia*. Struktura i dynamika zmienności zooplanktonu w stawach kształtowana była przez uwarunkowania środowiskowe, charakter zlewni, zasilanie w biogeny. Wynikała w największym stopniu z zależności i interakcji międzygatunkowych oraz z wysokiej trofii wód badanych zbiorników.

Słowa kluczowe: zooplankton, Rotifera, Crustacea, Protozoa, małe zbiorniki wodne, gospodarstwo agroturystyczne