COMPOSITION OF MOLLUSK COMMUNITIES AS A PROXY IN STUDIES ON SEASONAL DYNAMICS OF ASTATIC WATER BODIES

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Abstract: Astatic ponds are small, shallow and often isolated water bodies, characterized by distinct wet and dry cycles, leading to high variability of hydrodynamics and water chemistry. These unstable ecotonal ecosystems are crucial for supporting biodiversity, especially in agricultural landscape. In the presented research, we have explored species composition of mollusk communities in relation to size, water level dynamics, isolation and chemical characteristics of chosen astatic ponds, in order to assess its applicability as a proxy of seasonal dynamics of astatic water bodies. We have observed significant differences between mollusk communities in the temporary ponds and the neighboring Łuknajno Lake. These differences result from contrasting physical and chemical characteristics of these two types of habitat. According to presented research, the following mollusk species can be used as indicators of small ponds characterized by significant water level drop in summer: *Catascopia occulta*, *Galba truncatula*, *Gyralus* sp.

Key words: astatic ponds, mollusks, seasonal dynamics.
Słowa kluczowe: *zbiorniki astatyczne, mięczaki, dynamika sezonowa*.

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1. Introduction

Astatic ponds are small-sized, shallow and often isolated water bodies characterized by high variability of chemical, physical and hydrogeomorphic conditions. Though they remain flooded for sufficiently long time to allow development of aquatic and semi-aquatic vegetation and invertebrate communities, the astatic water bodies have a tendency to partially or completely dry out, which in some cases leads to distinct wet and dry cycles (Patzig et al. 2012; Tabosa et al. 2012; Lukacs et al. 2013).Therefore, the organisms inhabiting astatic ponds developed mechanisms which allow them to survive unstable physical and chemical conditions. Most of these organisms show diverse adaptations to the summer dry period. These adaptations vary from different forms of long-lasting dormancy, to life-form changes (from typically aquatic to terrestial). Other species are characterized by wide ecological amplitude and phenotypic plasticity, that enable them to survive even under dry conditions (Williams 2006; Zacharias et al. 2007; Lukacs et al. 2013; Tabosa et al. 2012).

While the depth of astatic ponds alters regularly during the season, the length of their flooding period depends on the long-term climatic changes and remains unperiodical on the short-time scale (Zacharias et al. 2007). Hence, the reliable proxies are needed to assess the dynamics of temporary water bodies. Taxonomic composition and abundance of freshwater mollusks, especially pulmonate snails (*Pulmonata*) and particular sphaerid bivalves (*Spahaeriidae)* seems to be an useful tool for such studies (Jurkiewicz-Karnkowska 2006; Dillon 2004; Nicolet et al. 2004).

In the presented research, we have explored species composition of mollusk communities in relation to size, water level dynamics, isolation and chemical characteristics of chosen astatic ponds, in order to assess its applicability as a proxy of seasonal dynamics of small water bodies.

Astatic ponds not only provide habitat to unique and diverse fauna and flora adapted to variable wet and dry conditions, but also function as ecotonal zones. As such they support biodiversity and heterogeneity of agricultural landscape, for example as refuge for rare plant and animal species (Williams 1998; Céréghino et al. 2008; Bilton et al. 2009; Kłosowski and Jabłońska 2009; Thiere et al. 2009; Gioria et al. 2010; Kirkman et al. 2012). Therefore, during our research we paid special attention to rare species of both gastropods and bivalves.

Tab. 1. Characteristics of studied ponds. Annual dynamics of water level is shown according to the 1–3 scale: (1) no significant water level changes during the year; (2) significant drop of water level in summer; (3) complete drying out of the pond in summer or freezing in winter. All presented data were collected by the authors of this study. Areas and distances given in the table were determined according to GPS measurements

Tab. 1. Charakterystyka badanych zbiorników. Ze względu na zmiany poziomu wody, zbiorniki podzielono na trzy klasy: (1) brak istotnych zmian poziomu wody w zbiorniku w ciągu roku; (2) wyraźny spadek poziomu wody w zbiorniku w lecie; (3) całkowite wysychanie zbiornika latem lub przemarzanie zimą. Dane prezentowane w tabeli zostały zebrane przez autorów artykułu. Powierzchnie zbiorników oraz ich odległości od jeziora zostały wyznaczone na podstawie pomiarów GPS

Pond *Zbiornik*	**Area [m^2]** *Powierzchnia [m^2]*	**Distance from the Łuknajno Lake [m]** *Odległość od Jeziora Łuknajno [m]*	**Annual water level dynamics** *Roczna dynamika poziomu wody*	**pH** *odczyn*	**Ca^{2+}[mg/dm^3]** *Ca^{2+} [mg/dm^3]*
1	39900	400	1	7,2	43,3
2	6040	500	1	6,9	48,0
3	8200	320	1	7,0	41,6
5	2000	570	2	6,9	28,4
6	1730	320	1	6,9	42,8
7	1000	270	2	6,8	46,8
8	700	220	2	6,9	47,6
9	600	210	2	7,4	17,0
10	1500	500	3	6,5	12,0
11	3700	590	1	6,7	31,2
12	15000	430	1	6,7	34,3
13	18000	150	2	6,9	26,7
14	16000	520	3	6,7	47,5
15	91900	480	1	6,9	41,6
16	2500	919	2	6,9	48,7
17	10130	2200	1	7,2	37,0
18	3500	2090	3	7,0	28,2
19	29550	1850	1	6,8	11,1
21	3700	2400	1	7,0	28,0
22	3620	620	2	6,9	48,0

2. Study site

All studied ponds are located in post-glacial landscape of Northeastern Poland (Masurian Landscape Park) in the surroundings of the Łuknajno Lake. This kettle lake covers 680 ha (average depth 0.6 m). The lake and fen communities developed on its shores are a UNESCO Biosphere Reserve (since 1972) and are also protected by Ramsar Convention (since 1977) (Jabłońska-Barna 2007; Guździoł 2008). In 2009 water retention program have been implemented in the Puszcza Piska Forest, resulting in major hydrological changes in the neighboring post-agricultural landscape. These changes were reinforced due to intensive beaver activity. As a result, on previously drained areas numerous small ponds have emerged lately, increasing heterogeneity of post-agricultural landscape.

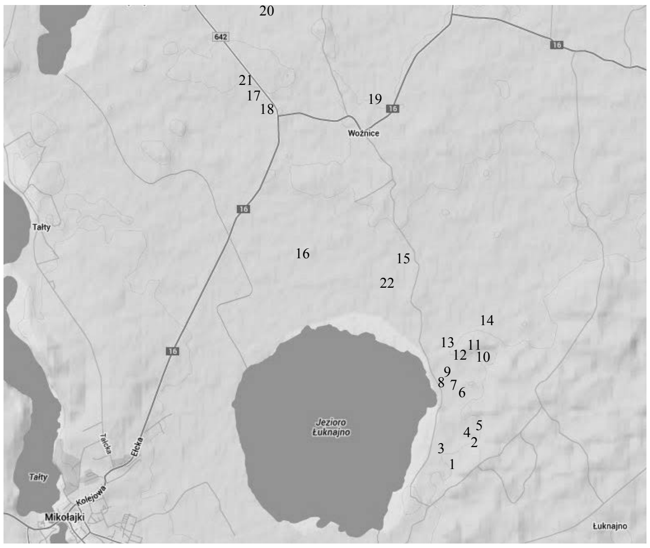

Fig. 1. Location of the Łuknajno Lake and neighboring temporary ponds

Ryc. 1. Położenie jeziora Łuknajno oraz sąsiadujących z nim drobnych zbiorników wodnych

For the purpose of this study 22 ponds were chosen. However, due to their physical and chemical distinctiveness, ponds number 4 and 20 were excluded from further inference. Chosen features of the ponds, with the exception of 4 and 20, are shown in the Table 1.

3. Materials and methods

Samples of the entire macroinvertebrate communities were taken in May and September 2010 in two different points of each pond. Adopted method of sampling was half-quantitative, with the use of round-shaped dip-net (22 cm in diameter, 1.5 mm mesh size). In each pond the dip-net was dragged 10 times, each time on the distance of 1.5 m. Acquired material was preserved with ethyl alcohol or formaldehyde. Total number of macroinvertebrates in each sample was estimated and the mollusks were identified according to the accessible keys (Piechocki 1979; Piechocki and Dyduch-Falniowska 1993; Kołodziejczyk and Koperski 2000). Research on mollusk communities comprised only a part of performed studies, which also included analyses of benthic communities. In future, further results will be presented in a separate article.

Chemical analyses were performed on fresh water samples according to the Polish Norms for water chemistry (numbers of method descriptions are listed in references): pH (using pH-meter), electrolytic conductivity (EC, using conductometer), carbonate hardness (CH, Warthy-Pfeifer method), concentration of calcium ions (using atomic absorption analyzer SOLAR 939). Last three parameters are strongly correlated, therefore concentration of calcium ions was chosen for further statistical analyses as a representative value.

All analyses were performed in the Laboratory of Environmental Chemistry in the University of Warsaw Biological and Chemical Research Centre (UW CBRC).

For the assessment of variation in composition and characteristics of mollusk communities in the studied ponds, and their relation to the chosen environmental factors, the following statistics were used:

1. Multidimensional Scaling (MDS) according to Timm (2002) for estimation of variability of mollusk communities in the studied ponds (Community Analysis Package 1.50 software, Pisces Inc.);
2. trend analysis (MS Office Excel 2007) and multiple regression (Statistica 10) for assessment of relations between mollusk communities and geographical features of the studied ponds;
3. Redundancy Analysis (RDA) for determination of relations between mollusk communities and chemical features of the studied ponds (CANOCO for Windows, Version 4.5) (Ter Braak and Simlauer, 1998).

4. Results

During our research we collected 10 344 individuals belonging to 14 species of mollusks. Detailed species composition of ponds is presented in the Table 2.

The average number of species per pond was 6 and fell into the range of 4 to 9 species. In the most cases

Tab. 2. Occurence of identified mollusk species in particular ponds (grey fields – species was observed in a pond)
Tab. 2. Występowanie poszczególnych gatunków mięczaków w badanych zbiornikach (szare pola – gatunek występował w zbiorniku)

Pond *Zbiornik*	***Anisus spirorbis***	***Anisus vortex***	***Catascopia occulta***	***Galba truncatula***	***Gyraulus sp.***	***Lymnaea stagnalis***	***Musculium lacustre***	***Pisidium sp.***	***Planorbarius corneus***	***Planorbis planorbis***	***Radix balthica***	***Segmentina nitida***	***Valvata cristata***	***Viviparus contectus***	**Number of species** *Liczba gatunków*
1	■	■				■				■	■	■			**6**
2		■				■	■				■	■			**5**
3	■	■				■		■	■	■	■	■			**8**
5		■		■						■		■			**4**
6		■			■						■	■			**4**
7		■		■				■				■			**4**
8		■		■	■	■				■		■			**6**
9		■			■	■						■			**4**
10		■				■		■		■		■	■		**6**
11		■			■	■	■			■	■	■			**7**
12		■				■		■		■	■	■	■		**7**
13	■	■	■			■			■	■	■				**7**
14															**0**
15		■	■		■	■			■	■	■	■		■	**9**
16		■			■	■				■	■	■			**6**
17	■	■				■				■	■	■			**6**
18		■				■	■			■	■	■			**6**
19		■			■	■		■		■	■	■			**7**
21		■			■	■				■	■	■			**6**
22		■		■	■	■				■		■			**6**
Frequency [%] *Frekwencja* [%]	**20**	**95**	**10**	**20**	**45**	**80**	**15**	**25**	**15**	**75**	**65**	**90**	**10**	**5**	**Total: 14 species** *Suma: 14 gatunków*

mollusks were an important component of the recorded macroinvertebrate community. According to our preliminary research, mollusk constituted on average about 40% of the total number of macroinvertebrates. However, in ponds number 6, 13, 15, 16 and 17 the participation of mollusks in macroinvertebrate community was significantly lower (around 20%). Most of the species observed in the ponds are common on the post-glacial areas in Poland. *Anisus vortex* (L.), *Segmentina nitida* O.F. Müller, *Lymnaea stagnalis* (L.), *Planorbis planorbis* (L.) and *Radix balthica* (L.) were present in more than half of the ponds, while *Viviparus contectus* (Millet) was recorded only in one pond (pond number 15), and *Catascopia occulta* Jackiewicz and *Valvata cristata* O.F. Müller were noticed in two ponds out of 20.

In order to assess variability of mollusk communities in the studied ponds, an ordination map was prepared with the use of values of Soerensen's similarity (Fig. 2.).

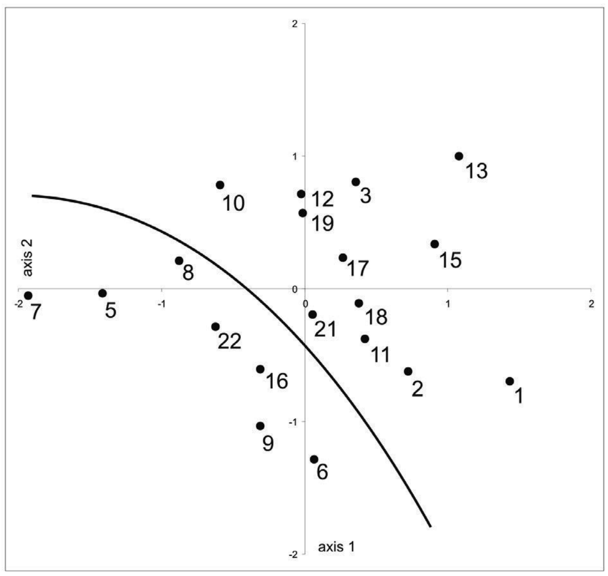

Fig. 2. Ordination map of the studied ponds with the use of Soerensen's similarity
Ryc. 2. Mapa ordynacyjna badanych zbiorników z wykorzystaniem wskaźnika podobieństwa Soerensena

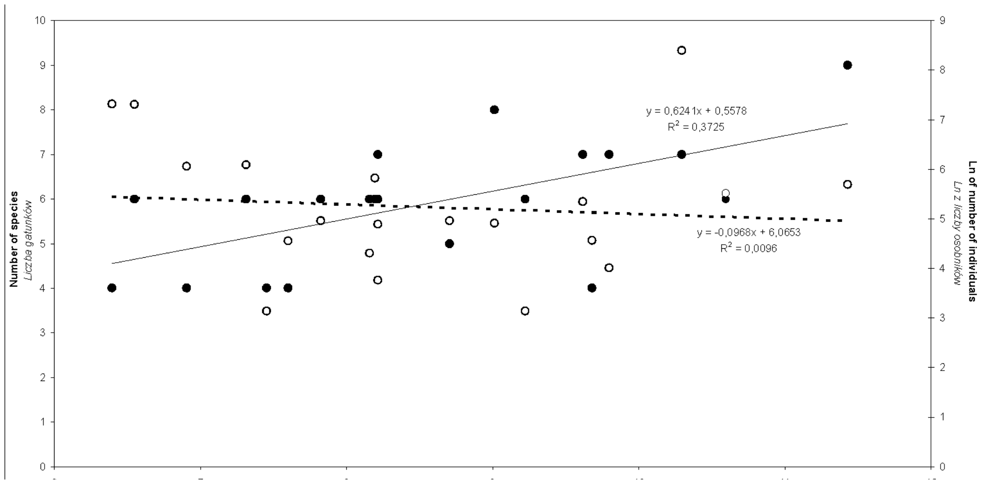

Fig. 3. Trend analysis showing relation between number and abundance of species, and size of the pond. Black points, solid line – number of species, white points, dotted line – logarithm of number of individuals
Ryc. 3. Analiza trendu pokazująca zależność między obserwowaną liczbą gatunków i osobników a wielkością zbiornika. Czarne punkty, linia ciągła – liczba gatunków, białe punkty, linia przerywana – logarytm z liczby osobników

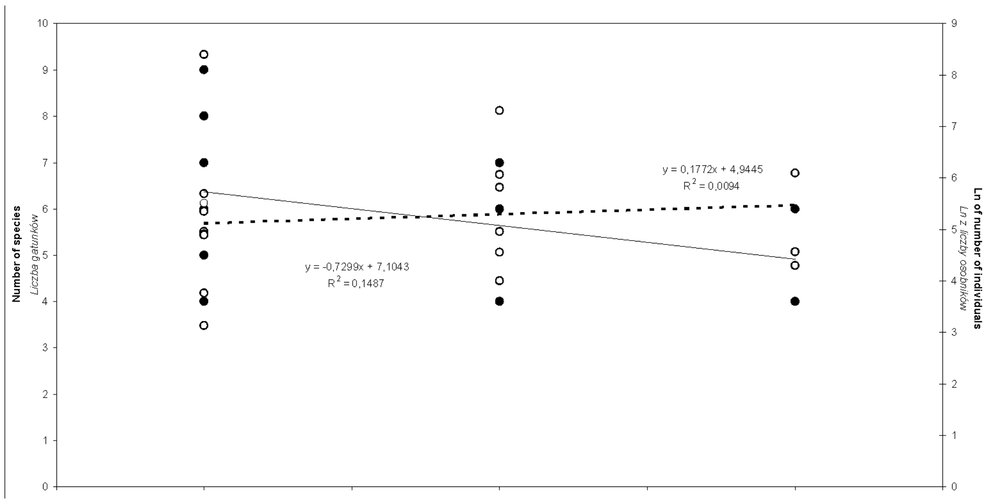

Fig. 4. Trend analysis showing relation between number and abundance of species, and water dynamics of the pond. Black points, solid line – number of species, white points, dotted line – logarithm of number of individuals
Ryc. 4. Analiza trendu pokazująca zależność między obserwowaną liczbą gatunków i osobników a roczną dynamiką poziomu wody w zbiorniku. Czarne punkty, linia ciągła – liczba gatunków, białe punkty, linia przerywana – logarytm z liczby osobników

The ponds characterized by a significant drop of water level in summer form a distinguished group in the lower left corner of the diagram (excluding pond number 6). Moreover, the neighboring ponds tend to be located near-by on the diagram (e.g. ponds number 17, 18, 19 and 21 or 5, 7 and 8), however this is not a general rule. There are also some irregularities (e.g. ponds number 2 and 3 separated on the diagram) that show that there are more factors influencing mollusk communities than only water dynamics and isolation of ponds.

In order to define these factors, further analyses were performed, including trend and multiple regression analyses. According to these calculations, there is a visible tendency that the observed number of species is higher in bigger ponds ($r^2 = 0.37$), while there is no such relation for the observed number of individuals ($r^2 = 0.01$) (Fig. 3).

Occurrence probability for *Radix balthica* and *Viviparus contectus* significantly increases with the size of the pond (according to multiple regression analysis for *R. balthica* β = 0.3966, B = 0.2513, p = 0.0320 and for *V. contectus* β = 0.5298, B = 1,6000, p = 0.0047), while *Anisus vortex* tends to occur more often in the smaller ponds (β = -0.2861, B = 0.3056, p = 0.0778).

As far as the dynamics of water level is concerned, higher numbers of species were observed in more stable ponds assigned to the 1st group in terms of water level changes ($r^2 = 0.15$). Again no such relation was recorded for the observed number of individuals ($r^2 = 0.01$) (Fig. 4).

Mollusk composition depends also on the distance between a particular pond and the Łuknajno Lake. Multiple regression shows that two species from the family *Planorbidae* are characterized by a contrasting behavior. *Planorbis planorbis i*s more common in ponds that are further from the lake ($\beta = 0.5439$, $B = 184.0630$, $p = 0.0308$), while *Planorbarius corneus* (L.) dominates in ponds in the direct surroundings of the Łuknajno Lake ($\beta = -0.5760$, $B = -227.0360$, $p = 0.0240$).

To summarize relations between the chosen environmental factors and the composition of mollusk communities, an RDA analysis was performed (Fig. 5). On the diagram only these parameters are shown, whose relation to mollusk communities was statistically important.

According to this analysis the size of ponds explains 23.9% of observed variance in the mollusk composition ($p = 0.002$), while pH and concentration of calcium ions explain 8.2% and 7.8% of observed variance ($p = 0.034$ and $p = 0.016$). Species located in the upper right part of the diagram are more frequent and abundant in bigger ponds. Species found in the upper part of the diagram tend to be more frequent and abundant in ponds characterized by lower pH and lower calcium ions concentration. The lower part of the diagram shows species that prefer more alkaline waters, richer in calcium ions.

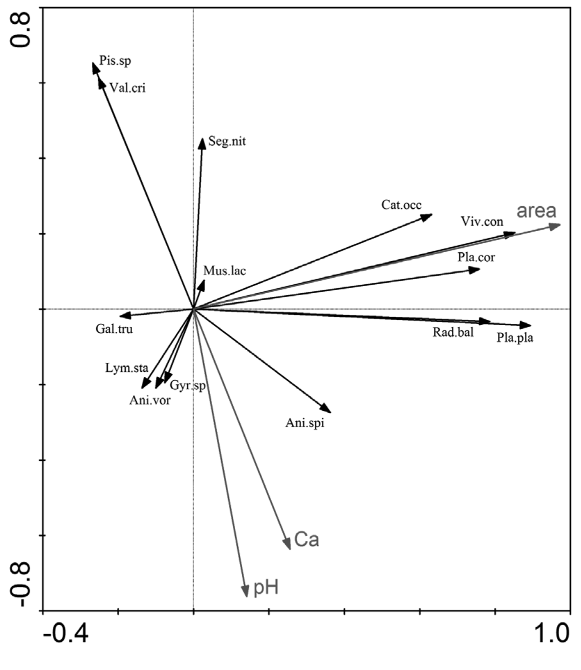

Fig. 5. RDA analysis of mollusk community composition in the studied ponds in relation to the chosen environmental factors. Particular values of the presented parameters are listed in the Tab. 1. Area – pond area [m^2]; pH – water pH in the ponds; Ca – concentration of calcium ions in the ponds [mg/dm^3]
Ryc. 5. Analiza RDA składu malakofauny w badanych zbiornikach w zależności od wybranych czynników środowiskowych. Wartości uwzględnionych parametrów zostały wyszczególnione w tab. 1. Area – powierzchnia zbiornika [m^2], pH – odczyn wody, Ca – zawartość jonów wapnia[mg/dm^3]

5. Discussion

All of the ponds studied are located in the vicinity of the Łuknajno Lake, which can be considered as a reservoir of invertebrate species colonizing the neighboring water bodies. In case of gastropods, most of the species observed in the ponds were also present in the lake (according to the study of mollusk communities in the lake by Guździoł 2008), with the exception of *Galba truncatula* and *Catascopia occulta*. There were also several species characteristic for the lake, that were absent in the ponds (*Acroloxus lacustris*, *Armiger crista*, *Bithynia leachi*, *Bithynia tentaculata* and *Physa fontinalis*) (Guździoł 2008). As far as specimens from the genus *Gyraulus* are concerned, they were preliminarily classified as *G. rosmaesslaeri* and *G. acronicus*, which is interestingly a glacial relic, nowadays rare in Poland. Yet, young specimens of the genus *Gyraulus* are difficult in identification. It is possible that the ones classified as *Gyraulus* sp. are in fact a mixture of a few species with *G. rosmaesslaeri*, *G. acronicus* and *G. albus*. Their detailed identification needs further activity.

As far as bivalves are concerned, though they were present in the ponds, Guździoł (2008) didn't observed them in the Łuknajno Lake. Yet, Guździoł (2008) focused on mollusk species living on macrophytes and used appropriate methods, which virtually excluded possibility of collecting bottom-concentrated bivalves. Nevertheless, studies performed by Jabłońska-Barna (2007) confirmed the presence of bivalves (namely *Pisidium casertanum* and *Anodonta cygnaea*) in the Łuknajno Lake.

Mollusk species dominating in the ponds, were mostly cosmopolitan and common in both stable and dynamic water bodies. Yet, there were observed significant differences in the structure of mollusk communities among the studied ponds. According to the presented statistical analyses (i.e. RDA on the Fig. 5), factors that explain this variability are size, distance from the pond to the lake, stability of the pond and also two parameters characterizing water chemistry – pH and concentration of calcium ions. We should also remember that intensity of predation as a factor determining composition of mollusks in small water bodies seems to be important (Vermeij and Covich 1978; Brönmark and Vermaat 1998), yet it was not taken into consideration in this research. Species composition and abundance observed in the ponds in this study differed also from the data for the Łuknajno Lake collected by Guździoł (2008).

Mollusk communities in the stable ponds, classified to the 1st group in the Tab. 1, resembled those form the Łuknajno Lake, described by Guździoł (2008). Bigger ponds were also characterized by the higher species richness, which follows the rule presented i.e. in Mackenzie et al. (2009) and Oertli et al. (2002), stating that the bigger the area, the more species can inhabit it, mostly because of the higher diversity of potential habitats. On the contrary, smaller ponds, classified to the 2nd group (Tab. 1), were characterized by lower diversity of mollusk communities and the presence of species typical for small water bodies, such as *Catascopia occulta*, *Galba truncatula* or *Gyraulus* sp. These species can be used as indicators of freshwater habitats distinguished by significant water level changes in summer, yet not completely drying out. Interestingly, in the samples collected form the ponds that dried out in summer (the 3rd group in the Tab. 1), no typical drought-resistant species were found, which may be a result of the random character of colonization processes on this area. Moreover, this was the first attempt of monitoring astatic ponds in this area, hence we do not have earlier data on their water level dynamics. For that reason, we cannot exclude possibility, that during our study period, these ponds dried out for the first time.

Though in the literature the distance from the species reservoir is regarded as a detrimental factor shaping species composition in the neighboring habitats (Angeler and Alvarez-Cobelas 2005; Kirkman et al. 2012), in our case only two species of mollusks present in the ponds showed relation to the distance from the Łuknajno Lake (*Planorbis planorbis* and *Planorbarius corneus*). It might result from the fact, that the distribution of ponds in the catchment of the Łuknajno Lake is rather dense, hence dispersion of species from the lake via other ponds is quick and relatively simple. Therefore, in this case for the proper interpretation of astatic ponds functioning, we should combine aspects of both island and metapopulation theories (Angeler and Alvarez-Cobelas 2005; Chase and Bengtsson 2010; Kirkman et al. 2012).

As far as the water chemistry of ponds is concerned, we analyzed pH and calcium ions content in water, since they are strongly limiting factors for mollusk communities (Kabisch and Hemmerling 1984). Moreover, we analyzed electrolytic conductivity and carbonate hardness as potentially important parameters, deriving form the first two. The RDA analysis showed small but statistically significant influence of pH and calcium ions content on the composition of mollusk communities. Such a small influence of the two most important factors might be a result of a limited diversity of these parameters that was encountered in the studied ponds.

6. Conclusions

During our studies, we have observed significant differences among mollusk communities in the studied astatic ponds. These differences result from divergent characteristics of such water bodies, as far as size, water level dynamics and variability of water chemistry are concerned. There are also several differences in composition and abundance of mollusk communities observed in the ponds in comparison to the accessible data for the Łuknajno Lake.

We suggest that the following mollusk species can be used as indicators of small ponds characterized by significant water level drop in summer: *Catascopia occulta*, *Galba truncatula*, and *Gyraulus* sp.

Astatic ponds are unique and dynamic habitats, being often refuges for rare species of plant and animals. In our study, in 9 ponds individuals belonging to the genus *Gyraulus* were found, some of them preliminarily classified as *Gyraulus acronicus*, which is a glacial relict, rare in Poland.

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BADANIA SKŁADU MALAKOFAUNY DROBNYCH ZBIORNIKÓW WODNYCH W OCENIE ICH SEZONOWEJ DYNAMIKI

Streszczenie

W niniejszym artykule przedstawiono badania prowadzone na 22 drobnych zbiornikach wodnych położonych w pobliżu Jeziora Łuknajno (Mazurski Park Krajobrazowy). Określono podstawowe parametry chemiczne zbiorników, ich sezonową dynamikę w odniesieniu do poziomu wody oraz skład malakofauny.

Celem prowadzonych badań było określenie przydatności malakofauny w ocenie dynamiki sezonowej drobnych zbiorników wodnych. Dodatkowo poszukiwano rzadkich gatunków mięczaków. Ogółem zebrano 10 344 osobniki należące do 14 gatunków. W poszczególnych zbiornikach rejestrowano od 4 do 6 gatunków mięczaków, z których większość to gatunki kosmopolityczne. Malakofauna badanych zbiorników przypominała składem zbiorowisko mięczaków opisane dla Jeziora Łuknajno (Guździoł 2008). Wyjątek stanowiły obecne jedynie w drobnych zbiornikach gatunki *Galba truncatula* i *Catascopia occulta* oraz obecne jedynie w jeziorze gatunki *Acroloxus lacustris*, *Armiger crista*, *Bithynia leachi*, *Bithynia tentaculata* i *Physa fontinalis*. Różnice jakościowe i ilościowe w składzie gatunkowym zbiorowisk mięczaków, pomimo potencjalnych możliwości dyspersji z jeziora do zbiorników, wskazują, że na występowanie mięczaków wpływają dodatkowo inne czynniki środowiskowe. Najważniejsze z nich to zróżnicowanie wielkości zbiorników, różnice w sezonowych zmianach poziomu wody, odległość od jeziora oraz chemizm wody. Duże, stabilne zbiorniki charakteryzują się większym bogactwem gatunkowym oraz występowaniem typowo jeziornych gatunków mięczaków. Małe, niestabilne zbiorniki wyróżniają się niższą różnorodnością gatunkową oraz występowaniem takich gatunków, jak *Catascopia occulta*, *Galba truncatula*, które należy uznać za gatunki wskaźnikowe tych siedlisk. Z odległością zbiorników od Jeziora Łuknajno związana była obecność dwóch gatunków mięczaków – *Planorbis planorbis* oraz *Planorbarius corneus*. Pierwszy z nich występował częściej w zbiornikach oddalonych od jeziora, drugi natomiast dominował w zbiornikach w bezpośrednim sąsiedztwie jeziora. Dla pozostałych gatunków nie zarejestrowano istotnych związków pomiędzy ich występowaniem a odległością zbiorników od jeziora. Małe znaczenie odległości siedlisk od rezerwuaru gatunków mogło być spowodowane gęstym rozmieszczeniem, a nawet czasowym łączeniem się zbiorników, co ułatwiało dyspersję badanych gatunków. Spośród badanych parametrów chemicznych zaobserwowano wpływ odczynu oraz twardości wody na występowanie poszczególnych gatunków mięczaków.