FOLIA MALACOLOGICA
Folia Malacol. 25(4): 257–265
ISSN 1506-7629 (print) • ISSN 2300-7125 (on-line)
The Association of Polish Malacologists
Faculty of Biology, Adam Mickiewicz University
Bogucki Wydawnictwo Naukowe
Poznań, December 2017
https://doi.org/10.12657/folmal.025.017

WATER BODIES OF A CITY PARK AS HABITATS OF RARE, PROTECTED AND ALIEN SPECIES OF MOLLUSCS

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ABSTRACT: Representatives of fifteen species of gastropods and ten taxa of bivalves were found in five small water bodies in Skaryszewski Park in Warsaw. They included *Sphaerium rivicola* (Lamarck) and *Anodonta cygnea* (Linnaeus) (empty shells only) which are very rare in Poland, as well as three alien species – *Dreissena polymorpha* (Pallas), *Physa acuta* Draparnaud and *Menetus dilatatus* (Gould). The first of the alien species may have been brought by humans and by waterfowl which is numerous in the Park, the second probably by birds alone. *Bithynia troschelii* (Paasch), recently elevated to species rank, was also recorded. Despite the similar water chemistry, the species composition and dominance structure of molluscs were greatly diversified both among the studied neighbouring ponds and within the largest of them – Lake Kamionkowskie. Two smallest ponds, emptied for winter, were inhabited only by snails. The diverse occurrence of molluscs might be an effect of different stability of particular water bodies and within Lake Kamionkowskie – of local accumulation of large amounts of organic matter (fallen leaves) on the bottom.

KEY WORDS: gastropods, bivalves, protected species, alien species, urban water bodies, biodiversity

INTRODUCTION

Mazowiecka Lowland lacks large natural water bodies. Warsaw, situated in its centre, has been almost completely deprived of its old network of watercourses and some of the small water bodies of the Vistula River floodplain have been, after regulation, cut off from the river and have undergone terrestrialisation. Some of oxbow lakes and side arms, however, have remained in city parks though no longer connected with the originally dense stream network. Numerous artificial reservoirs, mostly excavation pits, have appeared and have been included in park areas. It is estimated (KOŁODZIEJCZYK 1999) that over 100 variously transformed small water bodies of different age and origin can be found in Warsaw.

Water bodies of Warsaw attracted mainly the attention of ornithologists, less often of botanists and only sporadically of hydrobiologists. Aquatic vegetation of the left-bank and right-bank Warsaw was studied by GRYCZKA (1969) and POLESIAK (1970), respectively. KOŁODZIEJCZYK (1976) compared shore zones of four water bodies in Warsaw (including Lake Kamionkowskie).

The earliest studies on molluscs of Warsaw (ŚLÓSARSKI 1872, 1876a, b, 1877) were fragmentary. The first inventory of the Warsaw malacofauna was presented by JANKOWSKI (1933). FELIKSIAK (1933) analysed the malacofauna of the filter station and river pumping stations in Warsaw. KOŁODZIEJCZYK & DOŁĘGA (2004) compared the malacofauna of lakes Powsinkowskie, Wilanowskie and Czerniakowskie. LEWANDOWSKI (2013) described aquatic communities of the Warsaw district Bielany.

Urban water bodies may provide habitats for rare and protected animals, for example leeches (KOPERSKI 2010), and places suitable for alien species. The role of small artificial water bodies for al-

Ministry of Science and Higher Education
Republic of Poland

Folia Malacologica is funded by the Ministry of Science and Higher Education, Republic of Poland, under agreement no 747/P-DUN/2017 of May 19th, 2017 allocated to the activities for disseminating science:
Task 1: Preparation of English versions of publications (sum funded by DUN 9,000 PLN) and
Task 2: Digitalisation of publications and scientific monographs to enable their open access in the Internet (sum funded by DUN 7,000 PLN).

ien molluscs in industrial areas was demonstrated by LEWIN et al. (2015). Studies on all invertebrate macrofauna of water bodies were performed within a social project "Nature of Skaryszewski Park". The general characteristics of the fauna was presented by KOŁODZIEJCZYK & LEWANDOWSKI (2015a, 2016a). KOŁODZIEJCZYK & LEWANDOWSKI (2015b) recorded the American freshwater snail *Menetus dilatatus* in Lake Kamionkowskie. They also found *Bithynia troschelii*, until recently regarded as a conchological form or subspecies of *B. leachii* (Sheppard, 1823), in two small periodic park ponds (KOŁODZIEJCZYK & LEWANDOWSKI 2016b).

The aim of this study was a detailed analysis of the malacofauna of the water bodies in Skaryszewski Park which are subject to various forms of human impact. Particular attention was paid to the presence of rare, protected and alien species.

STUDY AREA AND METHODS

Studies were carried out in the water bodies of Skaryszewski Park in Warsaw: Lake Kamionkowskie (52°14'42"N, 21°03'14"E) with its southern shore adjacent to the Park, and four small interconnected ponds situated inside the park (Fig. 1). Lake Kamionkowskie is small and shallow (surface area 8 ha, maximum depth 2.1 m) of regular shoreline. In the 1920s and 1930s it lost its direct connection with the Praski Port and the Vistula River. Now there is only a small inflow to the lake through the Gocławski Canal and an outflow through an underground collector towards the Praski Port (SZYMKOWIAK & WIERZBICKA 2015). The shores are reinforced with fascine, the emergent vegetation is sparse; stones, cinder and brick chips abundantly cover the bottom on the other side of the park. Large patches of yellow water lilies *Nuphar lutea* (L.) Sibth. & Sm., accompanied by several sporadic submersed macrophytes and green algae, are found in various places of the lake (OZIMEK 2016).

The ponds inside the park are artificial water bodies formed at the beginning of the 20th century in wet areas of Saska Kępa (SZYMKOWIAK & WIERZBICKA 2015). They all have reinforced shores and are shallow. Pond A (52°14'30"N, 21°03'35"E), with its bottom and shores lined with concrete slabs and fed with drinking water from an artificial waterfall, is devoid of any macrophytes (various green algae are present). A few emergent macrophytes, one representative of submersed macrophytes (*Utricularia vulgaris* L.) and green algae are present in pond B (52°14'32"N, 21°03'34"E). Ponds C (52°14'30"N, 21°03'29"E) and D (52°14'36"N, 21°03'10"E) are inhabited (though not abundantly) by several species of emergent and submersed macrophytes, green algae and one floating-leaved species – *N. lutea* (OZIMEK 2016).

In winter, when water inflow is cut off, ponds A and B dry out and the water table in pond C slightly decreases. Numerous trees and shrubs along the

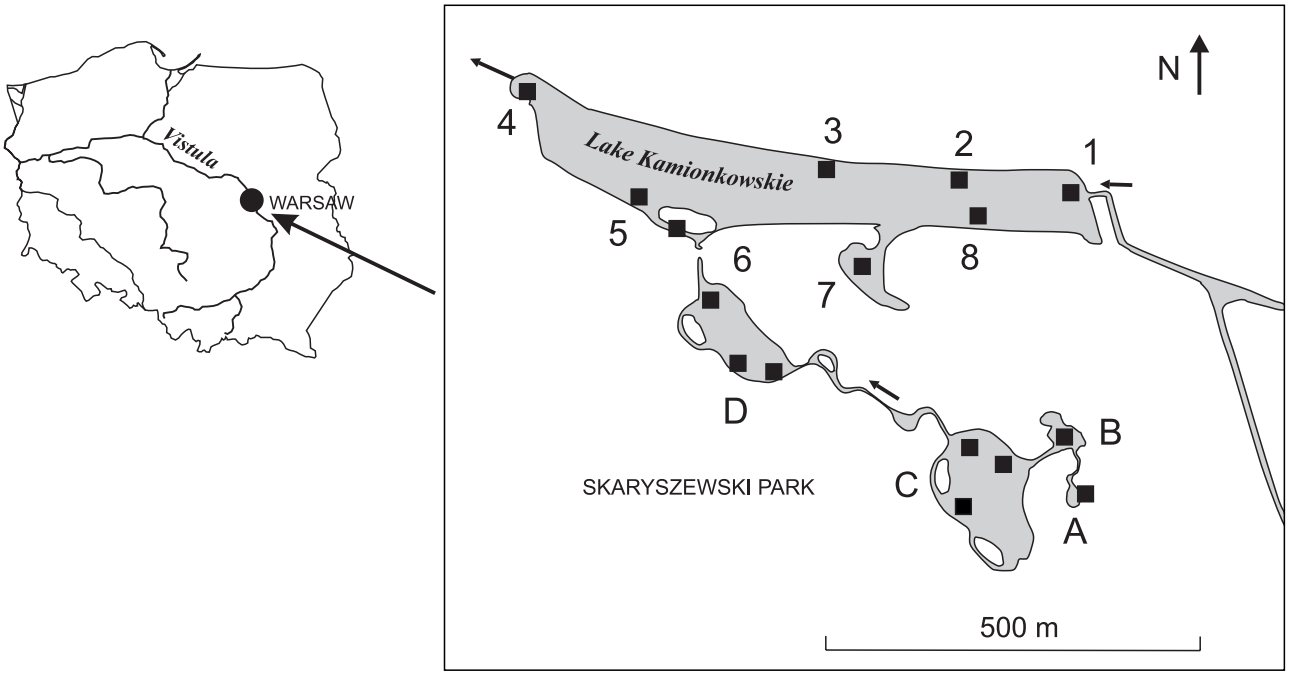

Fig. 1. Water bodies in Skaryszewski Park: A–D – ponds; 1–8 – sites in Lake Kamionkowskie; arrows indicate water flow direction

shores of all the studied water bodies provide fallen leaves, which locally accumulate on the bottom.

Standard water analyses were performed during sampling with WTW Multi 3430 SET G probe. Water pH in Lake Kamionkowskie was slightly alkaline (pH 7.6–8.1), electrolytic conductivity was very high (about 1,400 μS/cm in different sites), concentrations of dissolved oxygen in the surface water layer varied from 7.10 to 8.29 mg O_2/dm^3 and decreased with depth to 0.2 mg/dm^3 in the near-bottom layer. A similarly low oxygen concentration was noted in the near-shore zone above the layer of decomposing leaves on the bottom.

In the ponds, pH ranged from 7.8 to 8.4, electrolytic conductivity – from 1,220 to 1,300 μS/cm and oxygen concentration varied from ca. 9.3 mg O_2/dm^3 in ponds A and B to 6.0–7.8 mg O_2/dm^3 in pond C and to as much as 14.6 mg O_2/dm^3 in pond D (Ozimek 2016, and own data).

Molluscs were collected on 19.06.2014 in Lake Kamionkowskie (eight sites) and on 3.07.2014 in the ponds (1–3 sites in each) (Fig. 1). The number of sites was proportional to the size of the water body. Semi-quantitative samples (one per site) were taken from the depth of 0.3–0.5 m with a bottom scratch sampler (Zhadin 1966), side length 20 cm (D-frame; mesh size 0.2 mm), dragged along ca. 1 m of the bottom. The material was initially preserved in 4% formalin. In the laboratory the samples were washed on a sieve of 1 mm mesh size, segregated macroscopically and transferred to 70% alcohol. Both the preserved specimens and the empty shells were identified using the keys of Macan (1977), Piechocki (1979), Falniowski (1989), Piechocki & Dyduch-Falniowska (1993), Falniowski et al. (2004), Glöer et al. (2005), Welter-Schultes (2012), updating nomenclature after Piechocki & Wawrzyniak-Wydrowska (2016). The specimens were determined to species level, except the smallest bivalves of the genus *Pisidium*. The mollusc density (the resulting values were rounded to +/– 5 individuals/m^2), and the general diversity H (Shannon-Wiener index, $H = -\sum p_i \ln (p_i)$) were determined for each water body. The values of Shannon-Wiener index were analysed using Hutcheson's test (Hutcheson 1970, Scăunaşu et al. 2012). The faunal similarity between the water bodies was estimated with the species composition similarity index S according to Marczewski & Steinhaus (1959), and the similarity of dominance structure Re (%) – with Renkonen index (Trojan 1975).

The quantitative results were analysed using Statistica for Windows (version 12.0). The significance of differences in the density of molluscs among the water bodies was evaluated using a rank-based nonparametric ANOVA, Kruskal – Wallis and multiple comparisons tests. The faunal similarities of the freshwater mollusc communities in the ponds and Lake Kamionkowskie were estimated using cluster analysis method (Statistica Software, Ver. 12). Ward's method was used as the linkage rule and the Euclidean distances as the distance measure.

RESULTS

The total number of specimens found was 801, including 738 snails assigned to 15 species and 63 bivalves assigned to nine species and one genus (Table 1). In all the water bodies gastropods definitely prevailed over bivalves in terms of both the number of species and the number of individuals. The mollusc density was highest in pond A and pond B, smaller by an order of magnitude in Lake Kamionkowskie and in pond C and the smallest in pond D. Despite the fact that the density differed, Kruskal-Wallis test showed that the differences were statistically insignificant (H (df = 4 N = 16) = 8.184546, p = 0.0850). The total number of taxa varied from 5 (pond D) to 20 (Lake Kamionkowskie). Shannon-Wiener index ranged from 1.13 in pond A to 2.21 in Lake Kamionkowskie (Table 1). The value of this index for Lake Kamionkowskie was significantly higher than for all the other studied water bodies; it was also different for ponds A and B and ponds B and C (Table 2).

The dominance structure markedly differed among the studied water bodies (Fig. 2). *Radix balthica* in pond A constituted 47% of individuals, *Bithynia troschelii* and *Planorbarius corneus* also formed a large proportion. Pond B was dominated by *B. troschelii* (50%), followed by *Planorbis planorbis* and *Anisus vortex*. In pond C *Valvata piscinalis* constituted as much as 57% of all collected molluscs and *Bithynia tentaculata* – 28%. The genus *Pisidium* was represented by 7% of individuals. Only 12 individuals were found in pond D, most of them were *V. piscinalis*. The greatest proportion (25%) among all molluscs collected in Lake Kamionkowskie was formed by *V. piscinalis* (25%) and *Viviparus viviparus* (22%); *B. tentaculata*, *Physa acuta*, *Dreissena polymorpha* and *Radix auricularia* were also numerous.

The species composition of molluscs clearly differed among the studied water bodies (Table 3), particularly between ponds A and D (S = 0.01) and pond A and Lake Kamionkowskie (S = 0.02). A relatively high similarity index (0.63) was found only between ponds A and B. The similarity of dominance structure of molluscs (Table 3) was also very small, especially for pond A compared with ponds D (Re = 1%), C (Re = 4%) and Lake Kamionkowskie (Re = 7%). A high similarity of dominance structure was noted for the

Table 1. Molluscs collected in the studied water bodies in Skaryszewski Park (Warsaw, June–July 2014). LK – Lake Kamionkowskie

Taxa	Pond A	Pond B	Pond C	Pond D	LK
Gastropoda					
Viviparus viviparus (Linnaeus, 1758)					58
Valvata piscinalis (O. F. Müller, 1774)	3	4	43	5	66
Bithynia tentaculata (Linnaeus, 1758)		16	21	3	36
Bithynia troschelii (Paasch, 1842)	61	114			
Physa acuta Draparnaud, 1805	8				28
Radix balthica (Linnaeus, 1758)	101	7			5
Radix auricularia (Linnaeus, 1758)					14
Radix ampla (Hartmann, 1821)					3
Planorbis planorbis (Linnaeus, 1758)	5	30			
Anisus vortex (Linnaeus, 1758)	1	26			
Bathyomphalus contortus (Linnaeus, 1758)	2	9	1		
Gyraulus albus (O. F. Müller, 1774)			2		11
Planorbarius corneus (Linnaeus, 1758)	35	12	1		1
Menetus dilatatus (Gould, 1841)					2
Acroloxus lacustris (Linnaeus, 1758)					4
Bivalvia					
Unio pictorum (Linnaeus, 1758)				1	
Anodonta anatina (Linnaeus, 1758)				2	8
Dreissena polymorpha (Pallas, 1771)			1		18
Sphaerium corneum (Linnaeus, 1758)					5
Sphaerium rivicola (Lamarck, 1818)					3
Musculium lacustre (O. F. Müller, 1774)		9			2
Pisidium amnicum (O. F. Müller, 1774)					1
Pisidium henslowanum (Sheppard, 1823)			2		1
Pisidium subtruncatum Malm, 1855					1
Pisidium sp.		1	5	1	3
Number of specimens	216	228	76	12	270
Number of taxa	8	10	8	5	20
Mean density and range (ind./m²)	1.080	1.140	125 (15–235)	20 (5–45)	170 (10–490)
Shannon-Wiener index H	1.13	1.65	1.22	1.42	2.21
Index H_{max}	2.08	2.30	2.08	1.79	3.00
Var (H)	0.0035	0.0049	0.0139	0.0193	0.0037

malacofaunas of ponds C and D (73%) and a moderate similarity (42–45%) for those of ponds A and B and for Lake Kamionkowskie and ponds C and D.

The analysed water bodies were grouped based on the faunal similarity of their malacofauna (Fig. 3): ponds C and D were most similar in this respect, ponds A and B constituted another group clearly separated from the other three water bodies. Lake Kamionkowskie clearly differed from the ponds.

The number of both species and specimens differed among the sampling sites in Lake Kamionkowskie (from 2 to 10 and from 2 to 98, respectively – Table

Table 2. Values of Student's t test for comparison of indices H for two water bodies (above diagonal) and p-values (below diagonal). A–D – ponds; LK – Lake Kamionkowskie (Warsaw, June–July 2014)

Water body	A	B	C	D	LK
A	×	–3.43	0.95	–0.53	–10.74
B	0.001	×	3.21	1.46	–6.45
C	0.345	0.002	×	–1.10	–7.83
D	0.605	0.162	0.281	×	–5.30
LK	<0.001	<0.001	<0.001	<0.001	×

Table 3. Similarity of composition (Marczewski & Steinhaus index, S – above diagonal) and dominance structure (Renkonen index, Re % – below diagonal) in malacocoenoses of the studied water bodies. A–D – ponds; LK – Lake Kamionkowskie (Warsaw, June–July 2014)

Water body	A	B	C	D	LK
A	×	0.63	0.33	0.01	0.02
B	42	×	0.38	0.25	0.25
C	4	12	×	0.30	0.33
D	1	9	73	×	0.19
LK	7	11	45	42	×

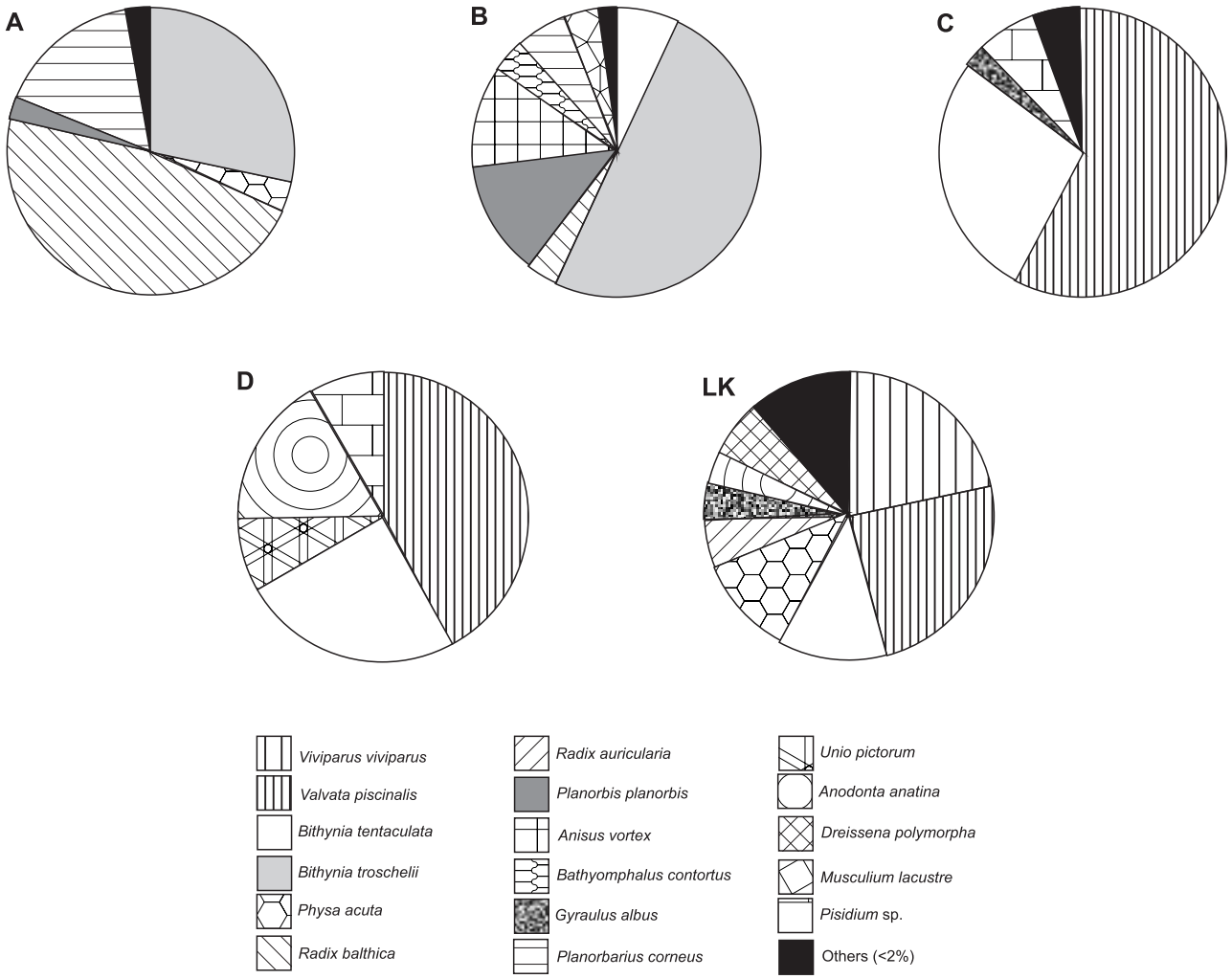

Fig. 2. Dominance structure of molluscs in water bodies of Skaryszewski Park: A–D – ponds, LK – Lake Kamionkowskie (Warsaw, June–July 2014)

4). Sites 6 and 7 were extremely poor, both quantitatively and qualitatively; site 1 was very poor quantitatively. Sites 4, 2, 5 and 8 were richest in terms of the number of species, and site 8 was the richest in specimens. The species composition differed markedly among the sites; the similarity index S varied from zero (for as many as seven pairs of sites) to 0.46 at the mean value of only 0.19.

Four species were represented exclusively by empty shells, found in sediments. They were *Valvata cristata* O. F. Müller, 1774 and *Hippeutis complanatus* (Linnaeus, 1758) in pond B and in Lake Kamionkowskie, *Anodonta cygnea* (Linnaeus, 1758) in pond C and in Lake Kamionkowskie and *Lymnaea stagnalis* (Linnaeus, 1758) in Lake Kamionkowskie. Eight other species, whose empty shells were found in sediments, were present as live individuals but in other water bodies. In pond D the number of species represented by empty shells (4) was almost equal to that of live individuals (5).

DISCUSSION

The number of recorded mollusc species (25) was high for small water bodies under strong human impact, like those in Skaryszewski Park. Moreover, the diversity of molluscs turned out to be higher compared to other invertebrate taxa (KOŁODZIEJCZYK & LEWANDOWSKI 2016b). This relatively great taxonomic diversity the malacofauna was observed within the relatively small area of the park, despite the generally similar water chemistry in the studied water bodies. The malacofauna of Lake Kamionkowskie was distinctly different from such faunas of the ponds (Fig. 3). The largest number of mollusc species and the high diversity in the lake (Table 1) most likely result from the combination of its size, its natural origin and its age.

It appears that the main local factor which may negatively affect molluscs in Lake Kamionkowskie is the large quantity of fallen leaves, particularly combined with the lack of water movement (site 6 between the shore and the island and site 7 in a shallow bay – Fig. 1, Table 4), which may lead to local oxygen deficit. Likewise, the hard, stony site (1) with large quantities of anthropogenic materials was poor in mollusc taxa. The scarcity of macrophytes in the studied habitats may also have a negative impact on the occurrence of molluscs.

The general scarcity of bivalves in the studied water bodies, particularly in the four ponds, might result from the character of their bottom (or artificial substratum like concrete or rubble) and from accumulation of allochthonous matter in the form of fallen leaves. The winter emptying of ponds A and B did not, however, negatively affect the snail fauna. Some species of the families Bithyniidae and Planorbidae are drought-resistant (KLEKOWSKI 1959, PIECHOCKI 1979). In the case of the smallest ponds A and B the lack of significant differences in mollusc density might result from too small a number of sampling sites (one site in each). On the other hand, the high value of Shannon-Wiener index for pond D (Table 1) is probably a result of the small number of collected animals.

From among protected species, Lake Kamionkowskie was inhabited by *Sphaerium rivicola*, a rare species in Poland; it is probably a relic of connection of the lake with the Vistula River, where the species was found by FELIKSIAK (1933) and JANKOWSKI (1933). *S. rivicola* has large oxygen demands and is very sensitive to water pollution. It avoids highly eutrophic waters (PIECHOCKI & DYDUCH-FALNIOWSKA 1993) and is now rare in the Vistula River catchment basin (LEWANDOWSKI 2004). Empty shells of *Anodonta cygnea* were also found; the species was recorded in the Vistula River near Warsaw by FELIKSIAK (1933) and JANKOWSKI (1933). Both species are now partly protected in Poland (DZIENNIK USTAW 2016; till 2014 they were strictly protected). *Bithynia troschelii*, found in two ponds, is included in the Polish red list of endangered animal species (PIECHOCKI 2002) as vulnerable. *Musculium lacustre* (DYDUCH-FALNIOWSKA & ZAJĄC 2002), found in pond B and in Lake Kamionkowskie, has the same status.

Anodonta anatina was found in Lake Kamionkowskie and in pond D; locally in the former at a density of about 25 ind./m^2. The shell length of *Unio pictorum* from pond D, of only 2.8 mm, may indicate its reproduction in this water body. The role of bivalves in various freshwater ecosystems and especially their filter-feeding behaviour which removes suspended matter from water (e.g. LEWANDOWSKI & STAŃCZYKOWSKA 1975, 1995, KRYGER & RIISGARD 1988, PUSCH et al. 2001) should be emphasised here.

The presence of several alien species in the studied water bodies is noteworthy. One of them was *Dreissena polymorpha*, observed (Table 1) not only in Lake Kamionkowskie but also in pond C. Its empty shells were found in pond D. Lake Kamionkowskie was also inhabited by the thermophilous *Physa acuta* and by *Menetus dilatatus* which is very rare in Poland. *D. polymorpha* appeared in Poland at least 200 years ago (STAŃCZYKOWSKA & LEWANDOWSKI 2011) and may have colonised Lake Kamionkowskie when it was still connected with the Vistula River. The spe-

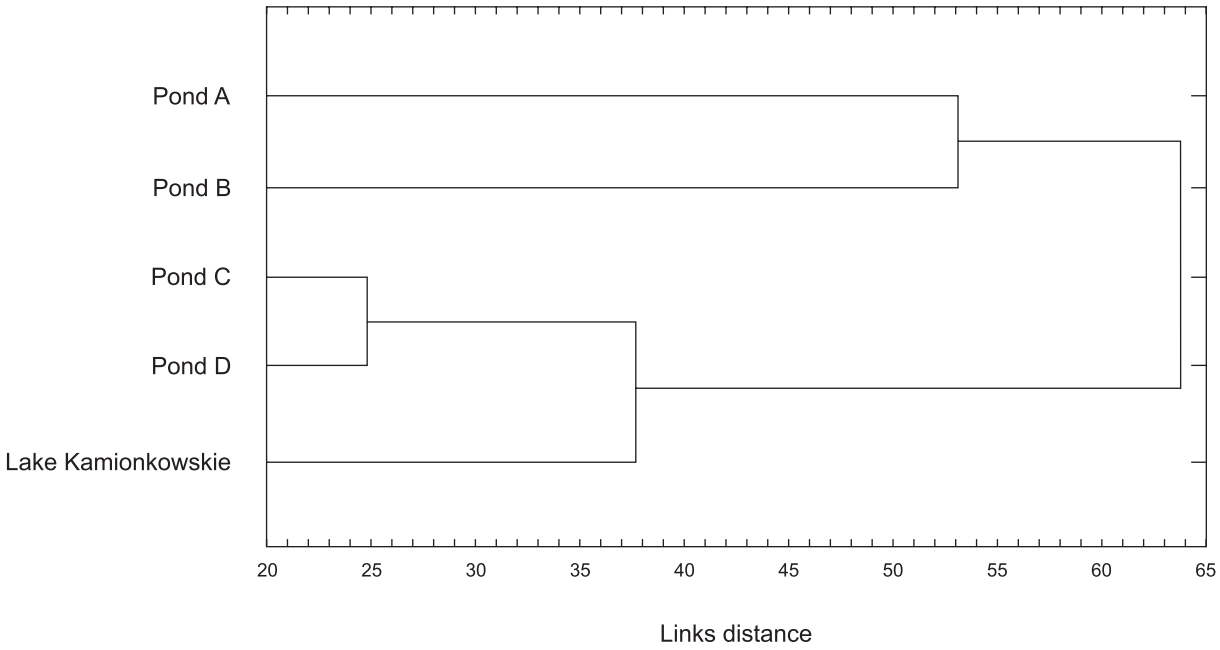

Fig. 3. Faunal similarity of malacocoenoses (Euclidean distance) in water bodies of Skaryszewski Park (Warsaw, June–July 2014)

Table 4. Molluscs in sampling sites in Lake Kamionkowskie (Warsaw, June 2014)

	Site no.							
	1	2	3	4	5	6	7	8
Number of taxa	3	9	7	10	9	2	3	9
Number of collected individuals	16	25	26	59	41	2	3	98
Density (ind./m²)	80	125	130	295	205	10	15	490

cies was already found in the river by Ślósarski (1872, 1876a, b, 1877), later by Feliksiak (1933) and Jankowski (1933), who also recorded it from the environs of Praski Port. *P. acuta* was present in Poland since the beginning of the 20th century, initially in artificially heated waters. In Warsaw it was first observed in reservoirs of the Botanical Garden in 1906 (Poliński 1917). Soszka & Soszka (1976) found the species in heated ponds of the Power Station "Siekierki". In the Vistula River *P. acuta* was first observed near Cracow, which was associated with the construction of electric power station in Skawina in 1958 (Zięba & Zaćwilichowska 1966, Alexandrowicz 1986). While Urbański (1947) was of the opinion that in Poland *P. acuta* occurred mainly in aquaria and greenhouse reservoirs, Strzelec (2011a) pointed to the possibility of colonisation of waters of natural thermal regime. The first stage of expansion at the beginning of the 20th century was facilitated by human activity (transfer with aquarium plants) but later the occupied area may have extended via water courses and transport in waterfowl plumage (Strzelec 2011a). *M. dilatatus* was brought in the middle of the 19th century from North America to Great Britain. It was known to occur in Poland since 1970, initially in heated Konin lakes (Berger & Dzięczkowski 1979, Strzelec 2011b) and, recently, in the Odra River at its junction with the Odra-Spree Canal (Piechocki & Szlauer-Łukaszewska 2013). Its presence in Lake Kamionkowskie may be associated with the abundance of water birds which are able to carry various invertebrate species in their plumage.

Transfer of various invertebrates, including small pulmonate gastropods, by birds was described by many authors (e.g. Boag 1986, Kappes & Haase 2012, Van Leeuwen & Van Der Velde 2012, Van Leeuwen et al. 2013). Warsaw water bodies are abundantly inhabited by waterfowl, mainly by *Anas platyrhynchos* L. The species is also numerous among the twelve waterfowl species in Skaryszewski Park (Kojtek et al. 2016). Due to the short distance covered by small pulmonates in birds' plumage, one may expect that small park water bodies, being "stops" for birds, may facilitate colonisation of even distant habitats by freshwater gastropods.

Bithynia troschelii was found in two of the studied water bodies. The snail was originally regarded as a subspecies or conchological form of *B. leachii* (Kołodziejczyk & Lewandowski 2016b), hence it was not listed separately in many papers. Consequently, not much is known of its occurrence in Poland. It is assumed, similarly as in the Czech Republic (Beran & Horsák 2009), to be a rare species. Therefore, information on its presence in the waters of Skaryszewski Park may be important for mapping of its distribution and for ascertaining its habitat requirements. It is possible that the two artificial water bodies are refuges for *B. troschelii* which was originally widespread in the right-bank Warsaw (Kołodziejczyk & Lewandowski (2016b)).

Compared with three Warsaw oxbows studied earlier (Kołodziejczyk & Dołęga 2004), the malacofauna of Lake Kamionkowskie does not differ in its species richness despite the fact that the lake is subject to a stronger human impact.

Urban water bodies show a relatively high species diversity of molluscs and may be both refuges for rare species and habitats for newly-arriving species of snails and bivalves. This is also true of other aquatic organisms. The crayfish *Orconectes limosus* (Rafinesque, 1817) (only one individual) and a representative of the fish family Gobiidae – *Neogobius gymnotrachelus* (Kessler, 1857) (Kołodziejczyk & Lewandowski 2016a and Wolnicki 2016, respectively) were observed in Lake Kamionkowskie. The turtle *Trachemys scripta elegans* (Wied-Neuwied, 1839) was also noted in the lake and in pond D (Olejniczak et al. 2016).

Human activity increasingly affects aquatic ecosystems leading to their transformation and to changes in the composition of aquatic communities. This is the effect of both unfavourable environmental changes which cause a decline of native species and the appearance of alien species. Such processes may change ecosystem's functions and often decrease (but sometimes increase) its biodiversity. The outcome will be particularly visible in small water bodies, including those in city parks.

ACKNOWLEDGEMENTS

We are grateful to Professor Maciej Luniak, who encouraged us to undertake studies in Skaryszewski Park. We are also indebted to Dr Ewa Rygielska-Szymańska for drawing of the figures. Prof. Maria Kozłowska and Dr Aneta Spyra provided a great input in statistical data processing. We thank the two anonymous reviewers for many specific remarks which we used in the final version of this paper.

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Received: March 17th, 2017
Revised: July 7th, 2017
Accepted: August 7th, 2017
Published on-line: September 25th, 2017