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Changes of malacofauna in a small lowland river in eastern Poland

Introduction

Molluscs are an important component of the biodiversity of freshwater invertebrate fauna (e.g. Jurkiewicz-Karnkowska, 2004; Królak, Korycińska, 2008; Piechocki, 2008). The malacofauna of large Polish rivers is well recognised (e.g. Piechocki, 1996; Jurkiewicz-Karnkowska, 2004; Lewandowski, 2004; Jurkiewicz-Karnkowska, Karnkowski, 2013; Piechocki, Szlauer-Łukaszewska, 2013; Lewin, 2014). Studies on the occurrence of molluscs in small lowland rivers in our climate zone, despite their long tradition, are fragmentary (e.g. Piechocki, 1969, 1972; Kasprzak, 1975; Kołodziejczyk, 1994; Jakubik, 2003, 2008; Jurkiewicz-Karnkowska, 2019). Areas less recognised for malacofauna include the Siedlce Upland – part of the South Podlasie Lowland (Kondracki, 2002).

Malacofauna of small watercourses in the Siedlce Upland is poorly understood. Some remarks on species present in the region were provided by Królak (1998), who described the results of her studies on the content of heavy metals in molluscs of the Siedlce Upland. Apart from papers by Jakubik (2003), Korycińska (2002) and Jurkiewicz-Karnkowska (2016, 2019), no detailed data on molluscs from this region can be found.

The Muchawka River is a left-bank tributary of the Liwiec River – the main river of the Siedlce Upland. Therefore, species composition of molluscs in the former may markedly affect taxonomic diversity in the latter. The Muchawka River drains mostly agricultural grounds and, thus, is not significantly polluted by domestic and/or industrial wastewaters. Until 1999, data about the river were limited to general faunistic and floristic characteristics and to annual assessment of water quality performed by the Environmental Protection Inspectorate based on physical, chemical and biological parameters (Bakiera et al., 1993). That is why detailed faunistic studies on molluscs in the river were undertaken in the years 1999–2000 (Jakubik, 2003). Sixteen years later, the assessment of taxonomic composition of molluscs in the Muchawka River, in relation to certain environmental factors, was repeated.

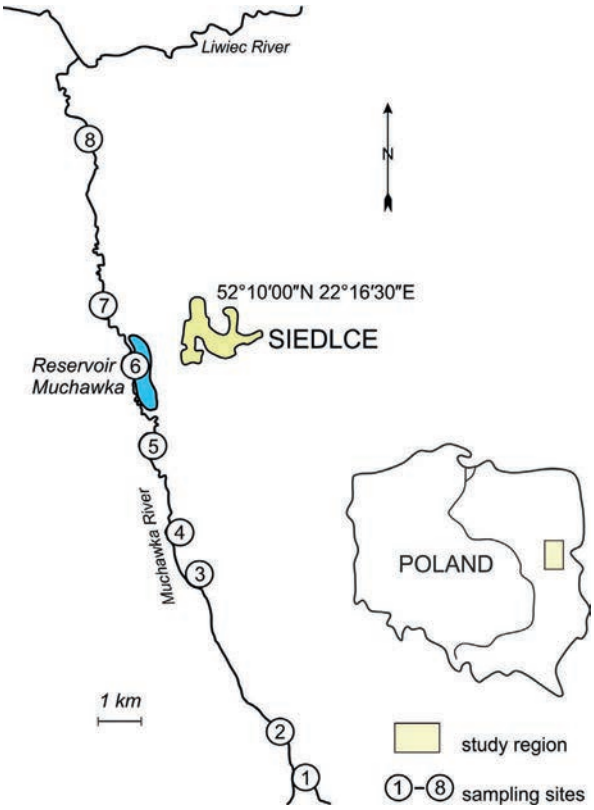

Fig.1. Location of the sampling sites (Jakubik, 2003)

Material and methods

Study area

Studies were carried out in the Muchawka River (52°12′35″N, 22°13′10″E) – a left-bank tributary of the Liwiec River. It springs about 2 km south of Daćbogi village and flows across the Siedlce Upland. The river is about 30 km long and its catchment area is 292 km^2.

The river forms a valley overgrown by periodically flooded meadows. The Muchawka River valley is floristically rich, especially in vascular plants. There are about 400 species of vascular plants dominated by the families Asteraceae, Poaceae and Fabaceae from meadow, aquatic and rush communities (Kot, Dombrowski, 2001). Waters of the Muchawka River feed a recreational dam reservoir in Siedlce. Eight sampling sites, the same as in Jakubik (2003), were selected along the course of the Muchawka River (Fig. 1, 2). Characteristics of the sampling sites are given in table 1.

Tab. 1. Characteristics of study sites; plant nomenclature according to Podbielkowski, Tomaszewicz (1996)

No. site	Type		Width the river [m]	Sampling depth [cm]	Vegetation
	bottom	river bank			
1	muddy	high, enforced with wooden stakes	2–3	50	*Acorus calamus* L., *Elodea canadensis* Michx, *Phragmites australis* (Cav.) Trin. ex Steud, *Sparganium ramosum* Curtis
2	sandy-stony	natural	2	20	*Sparganium ramosum* Curtis
3	stony-muddy		3	20	*Elodea canadensis* Michx, *Juncus effusus* L., *Nuphar lutea* L. Sibth & Sm, *Sagittaria sagittifolia* L.
4	sandy-stony	natural, gentle slope	5	30	*Elodea canadensis* Michx, *Nuphar lutea* L. Sibth & Sm, *Phragmites australis* (Cav.) Trin.ex Steud *Sagittaria sagittifolia* L.
5			6	80	*Elodea canadensis* Michx, *Nuphar lutea* L. Sibth & Sm, *Sagittaria sagittifolia* L., *Sparganium ramosum* Curtis
6	sandy-muddy		6	30	*Elodea canadensis* Michx, *Nuphar lutea* L. Sibth & Sm, *Sagittaria sagittifolia* L.
7			6	30	*Nuphar lutea* L. Sibth & Sm, *Sagittaria sagittifolia* L., *Sparganium ramosum* Curtis, *Typha latifolia* L.
8	muddy	natural, gently sloping, steep in some places	8	30	*Nuphar lutea* L. Sibth & Sm, *Phragmites australis* (Cav.) Trin.ex Steud, *Sagittaria sagittifolia* L., *Typha latifolia* L.

Methods

Water and molluscs were sampled in late spring (May to June) and in summer (July to the middle of September) 2016 in triplicate from every sampling site. Water for chemical analyses was collected in polyethylene containers and preserved with 2–3 cm^3 of chloroform per 1 dm^3 of water (Hermanowicz et al., 1999). Dissolved oxygen (measured with the oxygen probe EOT 196), temperature and electrolytic conductivity of water (conductivity meter CC-317) were determined in the field at each sampling site. Water pH (digital pH-meter CP-215), water hardness and concentrations of ammonium-nitrogen, nitrate-nitrogen, phosphates (field photometer LF-205) and chlorides (with the argentometric method as in Hermanowicz et al., 1999) were determined in the laboratory.

Based on physical and chemical parameters, water quality of the Muchawka River was estimated and compared with earlier data (Tab. 2).

Molluscs were sampled with a 20-cm-wide grab sampler (Jakubik, 2003). The sample was material collected from an area of one square meter. Bivalves of the family

Tab. 2. Water quality in the Muchawka River: A – data from 1999–2000 (Jakubik, 2003), B – data from 2016

Parameteres	Sites																Mean		Final water quality	
	1		2		3		4		5		6		7		8					
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Temperature [°C]	15.73	17.20	19.70	17.00	16.73	18.30	20.33	21.00	21.00	21.30	20.10	19.90	14.20	19.10	18.10	18.70	18.23	19.06	I	I
Acidity [pH]	7.53	7.61	7.66	7.90	7.66	7.58	7.86	7.54	7.86	7.65	7.53	7.71	7.40	7.63	7.37	7.57	7.61	7.64	I	II
Conductivity [mS/cm]	0.51	0.31	0.61	0.29	0.67	0.39	0.66	0.42	0.64	0.49	0.64	0.42	0.69	0.43	0.70	0.44	0.64	0.40	I	II
O_2 [mg/dm^3]	8.63	4.00	7.40	6.40	7.76	4.00	7.90	4.60	6.43	6.40	5.86	6.40	6.16	5.40	7.03	4.40	7.15	5.20	I	*
N – NO_3^- [mg/dm^3]	1.53	1.46	1.46	1.15	0.67	0.62	0.52	5.58	0.49	5.05	0.56	3.14	0.75	3.45	0.65	3.45	0.83	2.98	I	*
N – NH_4 [mg/dm^3]	0.62	0.03	0.28	0.04	0.34	0.10	0.20	0.26	0.25	1.08	0.19	0.03	0.20	0.12	0.12	0.03	0.28	0.21	I	II
PO_4^{3-} [mg/dm^3]	0.43	0.82	0.43	0.87	0.36	0.51	0.33	0.30	0.43	0.16	0.46	0.23	0.40	0.23	0.30	0.25	0.39	0.42	II	*
Cl^- [mg/dm^3]	4.99	16.00	5.94	16.00	5.77	14.00	5.77	21.00	5.66	30.00	5.66	21	6.27	22	6.22	25	5.78	20.60	I	II
Hardness [mg $CaCO_3$/dm^3]	255	176	331	180	364	242	362	228	341	244	347	234	370	242	373	242	345	224	I	I

Note: * does not fit in II

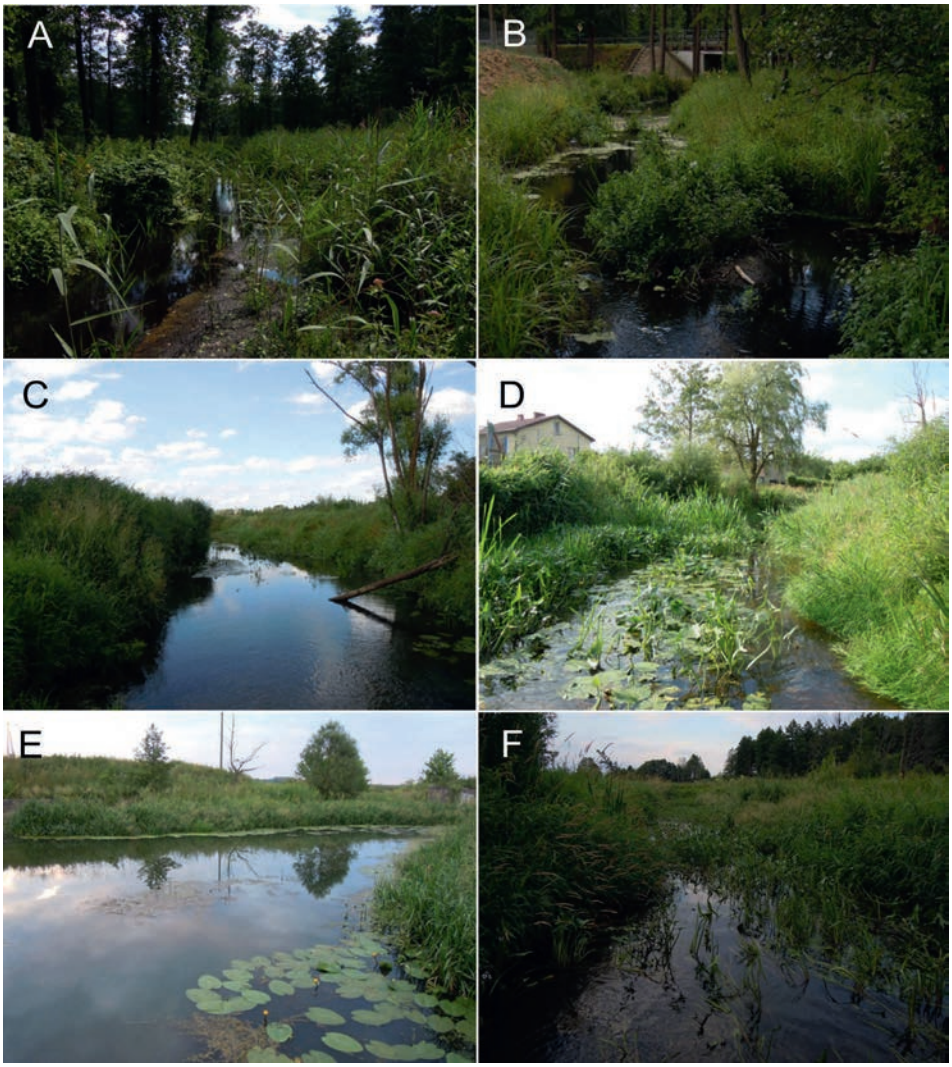

Fig. 2. A, B – sites (1–2) in the upper section of the river; C, D – sites (4–5) in the middle stretch; E, F – sites (7–8) in the lower river section (Photo. K. Lewandowski)

Unionidae were determined to the species level and then released back into the water. In the field, collected material was washed on a sieve of 0.5 mm mesh. In the laboratory, molluscs were preserved in 70% ethanol. Molluscs were identified to the species level based on their morphological and anatomical features according to Piechocki and Dyduch-Falniowska (1993), Jackiewicz (2000), Piechocki and Wawrzyniak-Wydrowska (2016). The species nomenclature follows Glöer (2002).

Statistical analysis

The following parameters were calculated (Górny, Grüm, 1981): (*1*) the total number of species (S); (*2*) density – expressed as the number of individuals per square metre; (*3*) domination according to the formula $D = 100 \times n_i/N$ where n_i is the number of individuals of the i-th species and N is the number of individuals of all species; the value of the domination, D, was divided into 5 classes: eudominants > 10.0%, dominants 5.1–10.0%, subdominants 2.1–5.0%, recedents 1.1–2.0% and subrecedents ≤ 1.0% of the sample; (*4*) the Shannon-Wiener index (H') (Hauer, Lamberti, 2007): $H' = -S\ P_i \ln P_i$ where $P_i = N_i/N$ – the share of individuals of the i-th species.

The significance of differences between the number of species and densities at particular sites visited in 1999–2000 and in 2016 were evaluated with the Tukey one-way ANOVA test (Statistica v. 10). The compared parameters had a normal distribution.

Results

Temperature and water hardness did not exceed standards established for the first class of water quality (*Rozporządzenie Ministra Środowiska*..., 2016). Water pH, electrolytic conductivity and concentrations of ammonium-nitrogen and chlorides corresponded to the second class of water quality. Only the concentrations of nitrate-nitrogen, phosphates and oxygen were higher than those typical for the second class of water quality (Tab. 2). Because of agricultural management of surrounding lands, the main source of phosphates delivered to the river is surface runoff from fields and meadows. Studies on malacofauna of the Muchawka River carried out in the years 1999–2000 revealed the presence of 12 mollusc species: five species of bivalves and seven species of snails (Tab. 3).

Tab. 3. Species composition of molluscs in the Muchawka River 1999–2000 (Jakubik, 2003) and the present study

No.	Species	1999–2000	2016
1.	*Anisus vortex* Linnaeus		×
2.	*Anodonta anatina* Linnaeus	×	×
3.	*A. cygnea* Linnaeus	×	
4.	*Bathyomphalus contortus* Linnaeus		×
5.	*Bithynia tentaculata* Linnaeus	×	×
6.	*Lymnaea stagnalis* Linnaeus	×	×
7.	*Physa acuta* Draparnaud		×
8.	*P. fontinalis* Linnaeus	×	×
9.	*Planorbarius corneus* Linnaeus		×
10.	*Planorbis carinatus* O.F.Müller		×

11.	*P. planorbis* Linnaeus	×	×
12.	*Pisidium amnicum* O.F.Müller	×	×
13.	*P. casertanum* Poli		×
14.	*P. henslowanum* Sheppard		×
15.	*P. nitidum* Jenyns		×
16.	*P. subtruncatum* Malm		×
17.	*Radix ampla* Hartmann	×	
18.	*R. auricularia* Linnaeus	×	
19.	*Sphaerium corneum* Linnaeus		×
20.	*S. rivicola* Lamarck	×	
21.	*Unio crassus* Philipsson		×
22.	*U. pictorum* Linnaeus	×	
23.	*Valvata cristata* O.F.Müller		×
24.	*Viviparus contectus* Millet	×	×
Total		12	19

In 2016, there were 19 species of molluscs in the river including 11 species of snails and 8 species of bivalves. Seven species of molluscs (5 species of snails and 2 species of bivalves) were recorded in both periods. Species invariably present in the river since 1999 were: *Anodonta anatina*, *Bithynia tentaculata*, *Lymnaea stagnalis*, *Physa fontinalis*, *Pisidium amnicum*, *Planorbis planorbis*, *Viviparus contectus*. Malacofauna showed both qualitative and quantitative diversity. In total, 390 individuals of molluscs were noted at all sites. *Pisidium casertanum* – one of eudominants – was present only at the last two sites (with densities of 153 individual × m^{-2} and 15 individual × m^{-2}, respectively) and constituted 43.1% of all molluscs (Tab. 4).

Tab. 4. Density (individual × m^{-2}) and dominance [D%] of the molluscs at the sampling sites in the Muchawka River (2016)

Species	Sites								N	D
	1	2	3	4	5	6	7	8		
Anisus vortex								1	1	0.3
Anodonta anatina						1			1	0.3
Bathyomphalus contortus	2	9							11	2.8
Bithynia tentaculata	2		12	2		1		4	21	5.4
Lymnaea stagnalis			3						3	0.8
Physa acuta						2			2	0.5
P. fontinalis			8						8	2.0
Pisidium amnicum			9			5		4	18	4.6
P. casertanum							153	15	168	43.1
P. henslowanum						1			1	0.3

P. nitidum	9								9	2.3
P. subtruncatum	75	12			2				89	22.8
Planorbarius corneus	1	2	1				1		5	1.3
Planorbis carinatus		2							2	0.5
P. planorbis			2						2	0.5
Sphaerium corneum			29		1	1	5	4	40	10.2
Unio crassus			2						2	0.5
Valvata cristata	1								1	0.3
Viviparus contectus			6						6	1.5
Total	90	25	72	2	3	11	159	28	390.0	100.0
Number of species	6	4	9	1	2	6	3	5	–	–

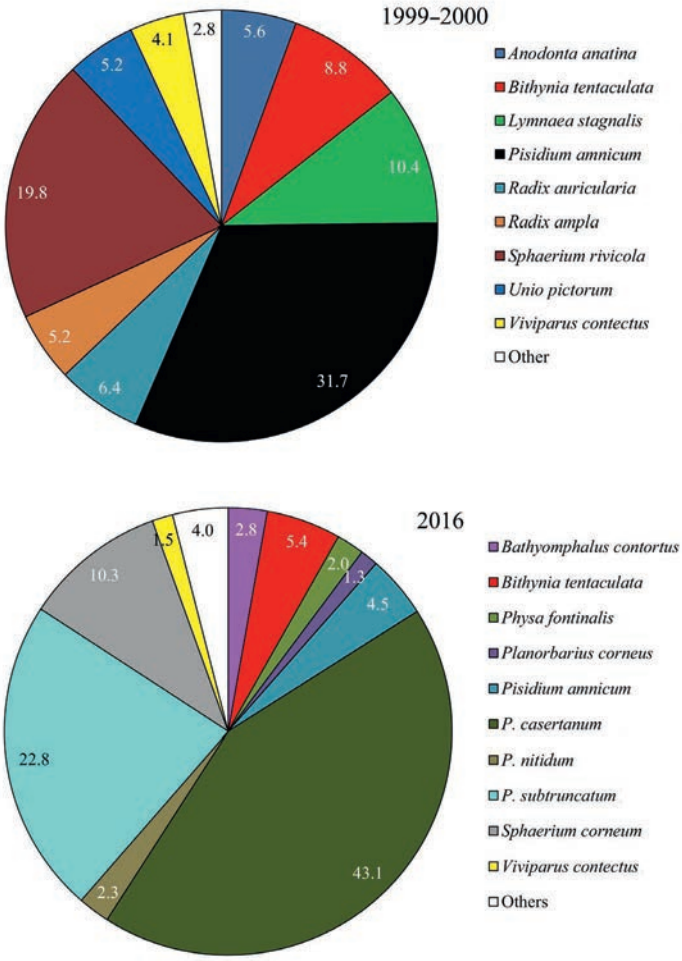

Fig. 3. Comparison of the domination [D%] of molluscs in the Muchawka River between 1999–2000 (Jakubik, 2003) and 2016

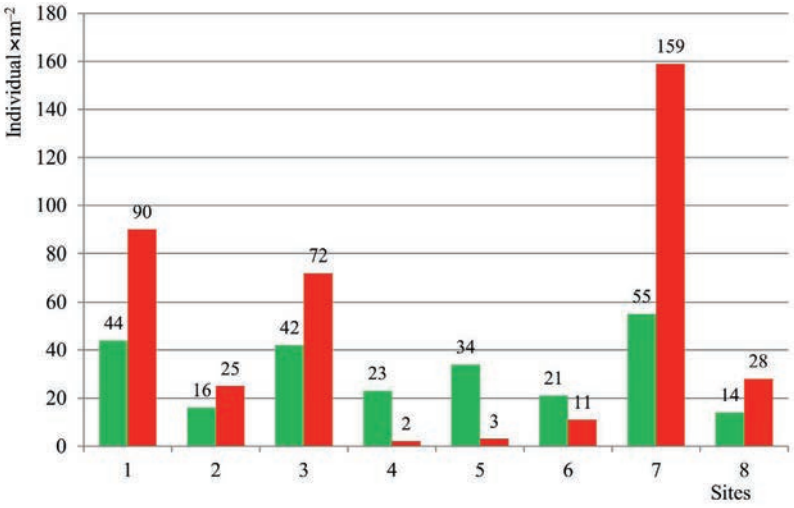

Fig. 4. Comparison of the density (individual × m^{-2}) of molluscs in the Muchawka River between 1999–2000 (Jakubik, 2003) – green and 2016 – red

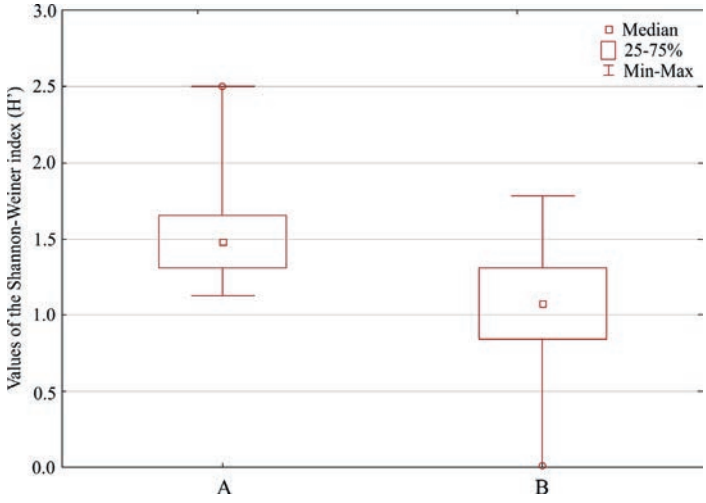

Fig. 5. Comparison of Shannon-Wiener indices H' of the molluscs in the Muchawka River between 1999–2000 – (A) (Jakubik, 2003) and 2016 – (B)

Two other species of bivalves of the family Sphaeriidae identified were also eudominants – *Pisidium subtruncatum* (22.8%) and *Sphaerium corneum* (10.3%) (Fig. 3).

Bivalves of the family Sphaeriidae constituted as many as 83.3% of all collected molluscs and, together with other bivalves (*Unio crassus* and *Anodonta anatina*), comprised 84.1%. Snails were mostly represented by the dominant *Bithynia tentaculata* (5.4% of all molluscs) and by subdominant *Bathyomphalus contortus* (2.8%).

Out of eight sites analysed, *Sphaerium corneum* and the snail *Bithynia tentaculata* were recorded in five sites. Most of the noted species were present in small densities in single sites. The highest number of mollusc species (9) was found at site 3 and the lowest numbers of species (1–2) were noted at sites within the city limits of Siedlce (sites 4 and 5). Noteworthy was the presence of a protected species, *Unio crassus*, at a density of 2 individual × m^{-2} in site 3. Apart from living molluscs, the empty shells of other species, such as *Valvata piscinalis* Müll., *Radix balthica* L. and *Acroloxus lacustris* L., were recorded.

Densities of molluscs in the year 2016 were markedly higher compared to those in the years 1999–2000 (Fig. 4). Significant differences were found in sites in the upper course of the river (sites 1, 2 and 3) and in sites (7 and 8) near its outlet (Tukey test, $p < 0.05$). The Shannon-Wiener index was lower in the year 2016 (Fig. 5).

Discussion

During the sixteen-year period since the first malacological analysis, the number of mollusc species in the Muchawka River increased from 12 to 19 and was comparable with that in the Skierniewka River (21 species) (Jurkiewicz-Karnkowska, 1989). The number of taxa was, however, lower than that found in the rivers Grabia and Pasłęka (Piechocki, 1969, 1972), Krutynia (Lewandowski, 1996; Jakubik et al., 2014) and Raba, Łubrzanka, Łośna, Biała Nida, Czarna Nida (Piechocki, 1981), Koprzywianka (Piechocki, 1987), Szeszupa (Lewandowski, 1990) and Wieprz (Piechocki, Łuczak, 1989; Piechocki, 1992). In each of the described habitats about 40 species of molluscs were noted.

Out of 19 species of molluscs found in the Muchawka River, 11 species were snails. The number is comparable with the 12 snail species recorded by Korycińska (2002) in the Liwiec River – the recipient of waters of the Muchawka. Later studies of molluscs carried out in the years 2013-2015 showed 26 species in the Liwiec River (Jurkiewicz-Karnkowska 2016, 2019). In the Muchawka River, among the taxa found by Jurkiewicz-Karnkowska in 2016, were noted all species with the exception of *Pisidium carinatus* and *Bathyomphalus contortus*.

Grużewski (2000) noted as many as 25 mollusc species including 15 species of snails and 10 species of bivalves in the Pęza River (right-bank tributary of the middle Narew River) which is much smaller than the Muchawka River. Studies from the same author (1996) in the Kamionka River in the Wigry National Park revealed 13 species of molluscs (10 of which were bivalves) – a number similar to that recorded in the Muchawka River in the first study period.

Malacofauna of the Muchawka River was dominated by bivalves of the genera *Pisidium* and *Sphaerium* – *Pisidium amnicum*, *Sphaerium rivicola,* in the first study pe-

riod and by *Pisidium casertanum* and *P. subtruncatum* in 2016. This phenomenon was confirmed by studies on molluscs by Jurkiewicz-Karnkowska (2016, 2019) who found a high frequency of bivalves of both genera in the middle stretch of the Liwiec River, i.e. near the inlet of the Muchawka River. According to Piechocki and Dyduch-Falniowska (1993), these bivalves mainly inhabit lowland rivers and prefer sandy or sandy-muddy largely overgrown substrata and clean or only slightly polluted water (Stadničenko, 1984). *Pisidium amnicum* is particularly sensitive to water pollution by domestic and industrial wastewaters and does not tolerate intensive eutrophication. The presence of bivalves of the family Unionidae in waters of the Muchawka River was evidence of high water quality, confirmed by physical and chemical analyses in the first study period. *Unio pictorum* was found in the years 1999–2000 at four sites (1, 2, 7 and 8) of the upper and outlet section of the river (Jakubik, 2003). In view of drastically decreasing numbers of Unionids in lakes and rivers of Poland, the presence of *Anodonta anatina*, *Unio pictorum*, *U. tumidus*, *U. crassus* (Królak, Korycińska, 2001) in the Liwiec River in the years 1996–1997 is noteworthy. In 2016, the situation for protected species changed, which might be associated with worsening water quality. Increased concentrations of nitrates and phosphates originated from agricultural management of the river drainage basin. *Anodonta cygnea*, *Sphaerium rivicola* and *Unio pictorum* disappeared from the river, while another protected species, *Unio crassus,* was noted. Studies by Jurkiewicz-Karnkowska (2016, 2019) also showed a lack of *Anodonta cygnea* and *Unio pictorum* in the middle stretch of the Liwiec River. Of particular importance was the presence of *Unio crassus* – a species whose occurrence in Poland's waters regularly diminishes due to proceeding eutrophication and degradation of river valleys (Abraszewska-Kowalczyk, 2002; Zając, 2004).

Regarding snails in the Muchawka River, a remarkable share were *Bithynia tentaculata,* while in the previous study period it was *Lymnaea stagnalis.* A similar change was reported by Jurkiewicz-Karnkowska (2016, 2019) for malacofauna of the Liwiec River. Both species prefer sandy-muddy substrates with some stones, which is characteristic of lowland rivers (Jackiewicz, 2000; Lewin, 2014).

The Shannon-Wiener index for data from 2016 was lower than in the years 1999–2000. The index increases with increasing number of species in a given community and with the evenness of their densities (Głowaciński, 1996). Despite an increased number of species in 2016, their densities were quite variable – from 2 individual × m^{-2} in the middle course of the river to 159 individuals × m^{-2} in the outlet.

Malacofauna of the Muchawka River reflects the natural character of a watercourse like this small lowland river (Wiśniewski et al., 1985; Jurkiewicz-Karnkowska, 1989, 2016; Raczyńska, 1999; Grużewski, 2000; Jakubik, 2008; Lewin, 2014). The present study is part of a larger project, which is scheduled to end in 2021.

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Conflict of interest

The author declares no conflict of interest related to this article.

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Abstract

In 2016, the species composition and the structure of the dominance of molluscs in the Muchawka River (left-bank tributary of the Liwiec River) were assessed. The occurrence of 19 species of molluscs were recorded, including 11 species of snails and 8 species of mussels. The eudominant was *Pisidium casertanum*, which, only in the last two sites, constituted 43.1% of all molluscs. Two other species of molluscs from the Sphaeriidae family were also eudominants – *Pisidium subtruncatum* (22.8%) and *Sphaerium corneum* (10.3%). Snails were most frequently represented by the dominant *Bithynia tentaculata*, constituting 5.4% of all molluscs, and the subdominant *Bathyomphalus contortus* at 2.8%. Sixteen years after the first malacological analysis, an increase in species richness and differences in the dominance of molluscs were found in the Muchawka River. Clams from the Sphaeriidae family invariably dominated but with a different species composition. The disappearance of the protected *Anodonta cygnea* and *Sphaerium rivicola* has been noted, and the occurrence of the protected *Unio crassus* has also been noted.

Key words: lowland river, molluscs, the Muchawka River

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Zmiany malakofauny w małej rzece nizinnej wschodniej Polski

Streszczenie

W 2016 roku dokonano oceny składu gatunkowego oraz struktury dominacji mięczaków rzeki Muchawki (lewobrzeżny dopływ Liwca). Odnotowano występowanie 19 gatunków mięczaków, a w tym 11 gatunków ślimaków i 8 gatunków małży. Eudominantem był małż *Pisidium casertanum*, który występując tylko na dwóch stanowiskach stanowił 43,1% wszystkich mięczaków. Eudominantami były także dwa inne gatunki małży z rodziny Sphaeriidae – *Pisidium subtruncatum* (22,8%) i *Sphaerium corneum* (10,3%). Ślimaki najliczniej reprezentował dominant *Bithynia tentaculata*, stanowiąc 5,4% wszystkich mięczaków oraz subdominant *Bathyomphalus contortus* – 2,8%. Po szesnastu latach od pierwszej analizy malakologicznej w rzece Muchawka stwierdzono wzrost bogactwa gatunkowego oraz różnice w dominacji mięczaków. Niezmiennie dominowały małże z rodziny Sphaeriidae, ale przy innym składzie gatunkowym. Odnotowano zanik chronionej *Anodonta cygnea* i *Sphaerium rivicola*, a pojawienie się również chronionej *Unio crassus*.

Słowa kluczowe: rzeka nizinna, mięczaki, rzeka Muchawka

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Ecology of molluscs in various types of aquatic habitats, studies on life strategies of molluscs in response to different habitat conditions using family Viviparidae as an example.

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