Teka Kom. Ochr. Kszt. Środ. Przyr. – OL PAN, 2013, 10, 132–142

MALACOFAUNA IN OXBOW LAKES OF THE BUG RIVER WITHIN THE NADBUŻAŃSKI LANDSCAPE PARK

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Co-financed by National Fund
for Environmental Protection
and Water Management

Summary. Malacofauna was studies in six oxbow lakes situated in the Nadbużański Landscape Park between the outlets of two confluents of the Bug River – the Liwiec and Nurzec. The water bodies are of different hydrological regime, from throughflow to isolated lakes. From 9 to 18 mollusc taxa were noted there. Oxbow lakes connected with the Bug had a higher species richness than those long ago permanently isolated from the river. Particularly large share in malacofauna of connected oxbow lakes had bivalves of the family Unionidae, *Dreissena polymorpha* and snails of the family Viviparidae. Protected species were found among studied molluscs. Studies carried out in two periods 2003–2004 and 2007–2011 showed small differences in species composition of malacofauna.

Key words: Nadbużański Landscape Park, oxbow lakes, molluscs

INTRODUCTION

The Nadbużański Landscape Park occupies a 120-km long part of natural valley of the Bug River, where a meandering river channel is accompanied by numerous oxbow lakes [Dombrowski *et al*. 2002]. Ecology of these oxbow lakes was poorly recognised though the interest in such water bodies has markedly increased recently. This pertains mainly to rivers of eastern Poland – the Bug and Narew [see e.g. Górniak 2001, Biesiadka and Pakulnicka 2004, Jurkiewicz-Karnkowska 2006, 2011, Lewandowski 2006, Strzałek 2006, Grużewski 2008].

Molluscs are the invertebrates that play an important role in the functioning of freshwater ecosystems. Their importance is associated with high densities and large biomasses they achieve in various water bodies [Stańczykowska and Lewandowski 1997, Dusoge *et al*. 1999]. Snails feeding on periphyton and detritus (less frequently on plants) and bivalves filtering seston from water may significantly modify matter cycling in an ecosystem [Stańczykowska *et al*. 1990, Molloy *et al*. 1997]. The occurrence of molluscs depends on many environmental factors like the type of substratum, plant cover, water flow, chemical composition of water and bottom sediments [Weigand and Stadler 2000, Strzelec and Serafiński 2004, Lewin 2006].

Six oxbow lakes of the lower Bug were analysed in the years 2003–2004 for macrobenthos including molluscs [Jakubik *et al*. 2006]. The aim of this study was to compare the occurrence of malacofauna in the years 2003–2004 with that in 2007–2011.

STUDY AREA AND METHODS

Six oxbow lakes (Fig. 1, Tab. 1) situated in the Nadbużanski Landscape Park between the outlets of the Liwiec and Nurzec Rivers were studied. The lakes are related to the Bug in various ways – from a throughflow lake near Szumin

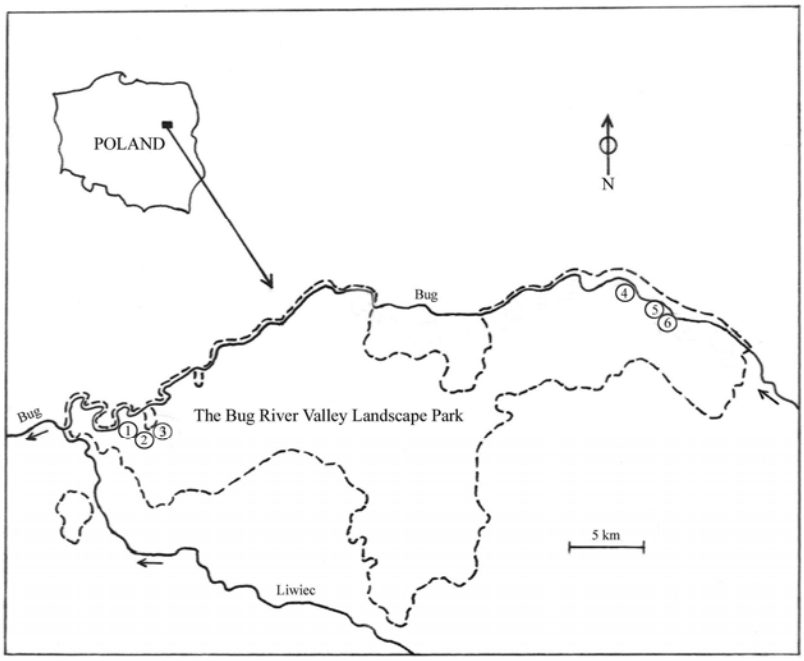

Fig. 1. Location of the studied oxbow lakes: 1 – Szumin, 2 – Wywłoka, western part, 3 – Wywłoka, eastern part, 4 – Wszebory, 5 – Przewóz Nurski, 6 – Lake Białe

Table 1. Characteristics of the studied ox-bow lakes [acc. to Jakubik *et al*. 2006, Jakubik 2012]

No.	Oxbow lake	Area, ha	Max. depth, m	N total, $mg \cdot dm^{-3}$	P total, $\mu g \cdot dm^{-3}$	Organic matter, % dry wt.	P, $mg \cdot g$ dry $wt.^{-1}$	N, $mg \cdot g$ dry $wt.^{-1}$
				in water		in bottom sediments		
1	Szumin	17.0	1.5	0.43–3.97	89–229	3.33 ±3.48	0.13 ±0.14	4.74 ±6.08
2	Wywłoka (western part)	23.0	3.5	0.23–3.51	26–122	1.77 ±1.76	0.15 ±0.15	4.05 ±3.98
3	Bużysko	25.0	2.0	0.07–2.76	155–1517	12.77 ±9.91	0.32 ±0.24	51.34 ±45.31
4	Wszebory	12.0	1.0	0.29–7.39	42–132	4.08 ±6.62	0.46 ±0.97	14.95 ±12.38
5	Przewóz Nurski	23.0	5.0	0.77–31.39	102–2215	2.81 ±2.51	0.13 ±0.08	7.89 ±2.85
6	Białe	1.5	2.0	0.30–7.56	23–146	24.37 ±19.36	0.35 ±0.18	60.30 ±36.80

to completely isolated (Lake Białe). From among other lakes Lake Wywłoka is permanently connected with the river while lakes Przewóz Nurski and Wszebory are connected with the river only at its high stages. A culvert under flood embankment divides Lake Wywłoka into eastern and western part. The first is a stagnant water body largely overgrown by the water soldier (*Stratiotes aloides*). In this study we dealt with the two parts as separate water bodies, former study was carried out in only western part. Surface area of studied lakes varied from 1.5 to 23 ha and their depth – from 1 to 5 m (Tab. 1).

Lake water pH ranged from 6.5 to 8.5. Mean concentrations of dissolved oxygen ranging from 5.1 to 10.7 mg · dm^{-3} indicated good aeration of analysed study sites. Calcium concentrations in all sites were rather low (from 60.1 to 79.3 mg · dm^{-3}) being typical of soft water lakes of the second water quality class.

Organic matter, phosphorus and nitrogen occurred in different concentrations in water and bottom sediments. Mean concentration of dissolved nitrogen varied from 0.23 to 31.39 mg · dm^{-3} and that of phosphorus – from 23 to 2215 μg · dm^{-3} (Lake Przewóz Nurski).

Mean concentration of organic matter in bottom sediments was from 1.77 to 24.37% of dry mass. Its highest concentration was found in Lake Białe; large part of organic matter was of terrestrial origin or from decomposing macrophytes. In other oxbow lakes the content of organic matter ranged from 1.77 to 4.08% of dry mass.

Mean concentrations of total phosphorus in bottom sediments were in the range of 0.13–0.46 mg · g^{-1} dry mass. Higher concentrations of total P were noted in isolated lakes, the highest in Lake Wszebory. Mean concentrations of total nitrogen varied between 4.05 and 60.30 mg · g^{-1} dry mass of bottom sediment and the highest concentration was found in isolated Lake Białe (Tab. 1).

Molluscs were studied in the years 2007–2011. In each of the oxbow lakes samples were collected in spring, summer and autumn from three to four sites. Molluscs were taken by hand from within a square frame of a side length of 0.5 m placed randomly four times at a depth of 0.5–1.0 m. Animal density and biomass were determined. Bivalves of the family Unionidae were analysed in the field (species, size, age) and released live to water (some species of Unionidae are protected). In this case biomass was estimated based on the size of individuals of particular species and on a large dataset from previous studies [Lewandowski and Stańczykowska 1975, Lewandowski 1990, 1996]. Domination structure and Shannon-Wiener diversity index were calculated according to Kasprzak and Niedbała [1981].

RESULTS

Twenty two molluscan taxa including 12 species of snails and 10 taxa of bivalves were found in all oxbow lakes in the years 2007–2011. Six snail species (*Viviparus viviparus*, *V. contectus*, *Bithynia tentaculata*, *Lymnaea stagnalis*, *Radix auricularia* and *Planorbarius corneus*) were found in all oxbow lakes. Equally

Table 2. Malacofauna in oxbow lakes of the Bug River (A – years 2003–2004 [acc. to Jakubik *et al.* 2006], B – years 2007–2011)

Taxon	Szumin		Wywłoka (western part)		Wywłoka (eastern part)	Wszebory		Przewóz Nurski		Białe	
	A	B	A	B	B	A	B	A	B	A	B
Gastropoda											
Theodoxus fluviatilis	+	+		+	+	+	+	+	+		
Viviparus viviparus	+	+	+	+	+		+	+	+	+	
Viviparus contectus	+	+	+	+	+	+			+	+	+
Bithynia tentaculata		+	+	+	+	+			+	+	+
Lymnaea stagnalis	+	+	+	+	+	+	+	+	+	+	+
Radix auricularia	+	+	+	+	+	+	+	+	+	+	+
Radix balthica		+		+	+		+				
Planorbarius corneus	+	+	+	+	+	+	+	+	+	+	+
Planorbis planorbis									+		+
Planorbis carinatus				+	+						
Anisus vortex	+		+					+	+	+	+
Hippeutis complanatus											+
Bivalvia											
Anodonta anatina	+	+	+	+	+	+	+	+	+		
Anodonta cygnea		+	+		+			+			
Pseudanodonta complanata		+			+						
Unio tumidus	+	+	+	+	+	+	+				
Unio pictorum	+	+	+	+	+	+	+	+			
Unio crassus	+	+									
Dreissena polymorpha	+	+	+	+	+						
Sphaerium rivicola	+	+	+	+	+				+	+	+
Musculium lacustre		+									
Pisidium sp.		+	+	+	+						
Total	13	18	14	15	17	9	9	9	11	8	9
Shannon-Wiener index	1.84	2.14	1.05	2.02	2.15	1.32	1.43	1.67	1.63	1.64	0.76
Combined number of taxa	19		17		17	11		13		10	

common and present in five oxbow lakes were four other species: a snail *Theodoxus fluviatilis* and three species of bivalves – *Anodonta anatina*, *Unio pictorum* and *Sphaerium rivicola* (Tab. 2). The least frequent species, noted in only one oxbow lake were *Hippeutis complanatus* found in Lake Białe and *Unio crassus* in Lake Szumin.

Four species of bivalves found in studied oxbow lakes were protected. Apart from already mentioned *U. crassus* and *S. rivicola*, *Anodonta cygnea* was found in four oxbow lakes and *Pseudanodonta complanata* in two.

The greatest species richness (15 to 18 species) was noted in two oxbow lakes (Lake Szumin and both parts of Lake Wywłoka) connected with the river and situated in the lowermost part of the Bug River catchment. Isolated oxbow lakes were inhabited by 9–11 species. Molluscs achieved also higher densities in connected than in isolated lakes. In Lake Szumin and in western part of Lake Wywłoka the density reached several hundred individuals per square metre. In isolated water bodies mean densities of molluscs were below 100 ind. · m^{-2} and their maxima did not exceed 200 ind. · m^{-2} (Tab. 3).

Table 3. Density and biomass of molluscs in the studied oxbow lakes (years 2007–2011)

Oxbow lake	Density, ind. · m^2		Biomass, g · m^2		Dominating species (% of mollusc density)
	mean	max.	mean	max.	
Szumin	280	540	2580	4800	*Anodonta anatina* (28) *Dreissena polymorpha* (27) *Unio pictorum* (12)
Wywłoka (western part)	340	660	5360	8750	*Unio pictorum* (35) *Unio tumidus* (16) *Bithynia tentaculata* (15)
Wywłoka (eastern part)	50	250	76	303	*Bithynia tentaculata* (42) *Viviparus viviparus* (23) *Viviparus contectus* (17)
Wszebory	48	165	102	190	*Radix auricularia* (37) *Lymnaea stagnalis* (33) *Planorbarius corneus* (18)
Przewóz Nurski	26	90	54	170	*Planorbarius corneus* (32) *Lymnaea stagnalis* (22) *Radix auricularia* (14)
Białe	50	200	70	90	*Sphaerium rivicola* (62) *Bithynia tentaculata* (19) *Viviparus contectus* (5)

The share of dominating species was different in each of the oxbow lakes. In oxbow lakes connected with the river the share of Unionidae bivalves was extremely high and their densities reached locally high values of 240 ind. · m^{-2} in Lake Szumin and 356 ind. m^{-2} · in western part of Lake Wywłoka. Large size achieved by these bivalves (maximum lengths of *Anodonta anatina*, *Unio pictorum* and *U. tumidus* were 104, 91 and 83 mm, respectively) and domination of large individuals (60–80 mm) translated into their big fresh biomass of several

kilograms per square metre (Tab. 3). Age of the oldest bivalves was 10 years in *U. pictorum* and 9 years in *U. tumidus* and *A. anatina*. A great share of *Dreissena polymorpha* among bivalves and of *Viviparus* snails was also noted in oxbow lakes connected with the river, particularly in Lake Szumin.

In other oxbow lakes bivalves of the family Unionidae contributed less and in Lake Białe they were absent. The latter water body was dominated by small bivalves *Sphaerium rivicola* and snails *Bithynia tentaculata*, hence low biomasses recorded there (Tab. 3).

DISCUSSION

Mean concentrations of phosphorus in oxbow lakes fell within the range noted in other water bodies, for example in shallow lakes in Florida [Olila and Reeddy 1993], in English lakes [Clarke and Wharton 2001] or in some Canadian lakes [Chambers and Prepas 1990]. Concentrations of total nitrogen, however, exceeded literature data several times [Kajak and Ławacz 1977, Chambers and Prepas 1990, Ligęza *et al*. 2007].

Differences in the occurrence of malacofauna were affected by environmental conditions, mainly by the content of organic matter, phosphorus and nitrogen in bottom sediments. The highest concentrations of these components were found in isolated Lake Białe indicating favourable food conditions in this habitat. However, in an isolated water body of high sediment organic matter content of terrestrial origin, conditions for filter-feeders are less favourable than those in a throughflow lake. This was manifested in a low number of species (9) and a low diversity index (0.76). Typical filter-feeders were represented there only by bivalve *Sphaerium rivicola*.

Oxbow lakes connected with the river were characterised by a higher species richness than lakes permanently isolated. Bivalves *Dreissena polymorpha*, *Pseudanodonta complanata*, *Unio crassus*, *Musculium lacustre* and species of the genus *Pisidium* were recorded only in the former lakes.

Throughflow lakes are flooded in spring by waters of the Bug River, which later transport part of delivered matter back to the river channel. Relatively small and shallow oxbow lakes may be compared with lake littoral which is the most diverse lake zone. Autochthonic organic matter and terrestrial matter delivered with surface runoff (detritus of riparian vegetation, inorganic substances) settles in an oxbow lake. Fertility of such a water body is affected by its connectivity with river, which carries organic and mineral substances from the catchment thus creating favourable food conditions for freshwater molluscs.

Studies carried out in the years 2007–2011 showed higher species richness and diversity than the study performed in 2003–2004 [Jakubik *et al*. 2006]. The differences were, however, small. Five more taxa were found only in Lake Szumin. In other oxbow lakes the differences amounted 1–2 taxa and in Lake

Wszebory the same number of species was found in both study periods although species composition of snails differed (Tab. 2).

Considering all taxa found in both study periods the highest species richness was found in oxbow lakes connected with the river: Lake Szumin (19 taxa) and both parts of Lake Wywłoka (17 taxa in each). Isolated oxbow lakes were inhabited by 10–13 taxa (Tab. 2). Connected oxbow lakes were also characterised by much higher densities and biomasses of molluscs compared with isolated lakes. This applied to both 2007–2011 and 2003–2004 study periods. Very high biomasses of molluscs in Lake Szumin and in western part of Lake Wywłoka resulted mainly from high densities of bivalves of the family Unionidae. Local densities of these bivalves that reached 240 ind. · m^{-2} in Lake Szumin and 360 ind. · m^{-2} in western part of Lake Wywloka are among the highest ever noted in the literature. In Lake Kortowskie (Masurian Lakeland) Widuto and Kompowski [1968] noted locally 256 Unionidae bivalves per 1 m^2 but the mean for the area of their occurrence in this lake was only 10 ind. · m^{-2}. In a small Szeszupa River flowing through several lakes (the Suwalski Landscape Park) densities of Unionidae exceeded 100 ind. · m^{-2} in some places and the highest density of over 350 ind. · m^{-2} and biomass (over 7 kg · m^{-2}) was found in a transitory zone between the river and a lake [Lewandowski 1990].

So high densities of bivalves are often associated with their clustering in beds for reproduction. Such a bed in the Grabia River was described in details by Piechocki [1969]. Usually, the densities of Unionidae in various habitats (rivers, lakes, dam reservoirs) are, however, much lower; often several ind. · m^{-2} [Őkland 1963, Negus 1966, Krzyżanek 1976, Kasprzak 1985, Abraszewska-Kowalczyk 2002].

Species richness of molluscs in studied oxbow lakes of the Bug River does not differ much from other Polish fresh water bodies. Hydrobiological literature shows examples of habitats rich [Piechocki 1969, Grużewski 2008, Jurkiewicz-Karnkowska 2009] and poor [Lewandowski 2005, Obolewski *et al*. 2009] in species. Lotic and lentic oxbow lakes may be a model of adaptation of life strategies of species to habitat conditions. The genus *Viviparus* living in all oxbow lakes and realizing two different life strategies may serve as an example. In isolated oxbow lakes young snails invest in growth and adults – in reproduction while in throughflow lakes the young invest in reproduction as do the adults. This way they increase a probability of population persistence in the habitat [Jakubik 2012].

Noteworthy is the presence of protected *Unio crassus* in Lake Szumin. The species is included in „The red list of threatened animals in Poland" and only Polish representative of Bivalvia mentioned in the Habitat Directive of the European Union [Głowaciński and Nowacki 2004]. It is a typically riverine species which may, however, penetrate oxbow lakes [Piechocki and Dyduch-Falniowska 1993, Piechocki 2002]. Other species protected in Poland: *Anodonta cygnea*, *Pseudanodonta complanata* and *Sphaerium rivicola* are also not rare in the studied oxbow lakes. Therefore, oxbow lakes may be quite valuable habitats that deserve protection like that provided by the Nadbużański Landscape Park.

CONCLUSIONS

1. Oxbow lakes of the Bug River are very differentiated mainly because of their connectivity with the river. The lakes may be divided into permanently connected with the river, periodically connected and permanently isolated.

2. The oxbow lakes differ in hydrology, morphometry, chemical parameters, taxonomic composition and abundance of molluscs.

3. Lakes connected with the Bug were characterised by a higher species diversity, higher densities and larger biomasses than the lakes long ago permanently isolated. The former were inhabited by dense populations of bivalves of the family Unionidae.

4. Oxbow lakes deserve protection due to the presence of rare and endangered species.

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MALAKOFAUNA STARORZECZY BUGU W NADBUŻAŃSKIM PARKU KRAJOBRAZOWYM

Streszczenie. Badaniami malakofauny objęto sześć starorzeczy położonych na terenie Nadbużańskiego Parku Krajobrazowego, między ujściami dwóch dopływów Bugu: Liwca i Nurca. Zbiorniki te są w różnym stopniu powiązane z Bugiem – od silnie przepływowych do całkowicie odciętych. Notowano w nich od 9 do 18 taksonów mięczaków. Starorzecza połączone z Bugiem charakteryzowały się większym bogactwem gatunkowym niż starorzecza dawno i trwale odcięte od rzeki. W zbiornikach połączonych z rzeką szczególnie duży udział w malakofaunie miały małże z rodziny Unionidae i *Dreissena polymorpha* oraz ślimaki z rodziny Viviparidae. Wśród mięczaków badanych starorzeczy występowały także gatunki chronione. Badania malakofauny prowadzone w dwóch okresach (2003–2004 i 2007–2011) wykazały niewielkie różnice w składzie gatunkowym.

Słowa kluczowe: Nadbużański Park Krajobrazowy, starorzecza, mięczaki