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DIVERSITY OF AQUATIC MALACOFAUNA OF TEMPORARY WATER BODIES WITHIN THE LOWER BUG RIVER FLOODPLAIN

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ABSTRACT: This study analyses the composition, species richness and diversity (H') of aquatic molluscan communities in temporary water bodies within the valley of the lower Bug River in eastern Poland. The investigations were carried out in 2007–2009 within the section of the valley located between 190th and 50th km of the river course in 50 water bodies. Relatively rich and diverse malacofauna was found in the investigated habitats: 32 snail species and 6 bivalve species. Species diversity (H') in individual water bodies ranged from 0.44 to 3.48. About 40% of all mollusc species showed frequencies of ≤10%. Dominance patterns varied much among the water bodies. Mollusc abundance ranged from 20 to over 1,800 indiv./m^2. Considerable species richness and diversity were found both within the active floodplain and the former one. This was probably related to the long duration of many of the investigated water bodies, as well as their periodical hydrological connectivity with permanent ones or river channel. From 9 to 12 samples should be enough to compile representative species list of molluscs inhabiting temporary water bodies, but as many as 28–40 samples would be necessary to obtain complete dataset.

KEY WORDS: molluscs, temporary water bodies, Bug river floodplain

INTRODUCTION

Aquatic molluscs, especially gastropods, are important components of macroinvertebrate fauna in many riparian environments (e.g. CASTELLA et al. 1984, 1991, RICHARDOT-COULET et al. 1987, FOECKLER et al. 1991, WEIGAND & STADLER 2000). Rich and diverse malacofaunas occur in permanent waters, but temporary water bodies are also important for biodiversity, because they often hold uncommon and rare species (CÉRÉGHINO et al. 2008). Such habitats support species either not found in any other habitat type or those which attain their greatest abundance in these waters. The distinctness of communities inhabiting temporary water bodies has been confirmed by some authors (e.g. OBRDLIK & GARCIA-LOZANO 1992, WILLIAMS 1998). In Poland the malacofauna of floodplain water bodies has been little studied (e.g. PIECHOCKi 1969, JURKIEWICZ-KARNKOWSKA 2006, 2008, 2009); this pertains especially to malacocoenoses of temporary water bodies.

Among floodplain water bodies of the lower Bug River there are numerous temporary ones, however only a fraction of these sites has been investigated (JURKIEWICZ-KARNKOWSKA 2009). The list of their malacofauna, based on 20 samples, is not complete, indicating a necessity of more intensive sampling of these habitats which are characterised by high spatial and temporal diversity. In order to determine the number of samples necessary to compile a complete malacofaunistic list of temporary water bodies located within a long section of the river valley, the number of sites was increased to 50, including sites investigated earlier (JURKIEWICZ-KARNKOWSKA 2009) and now re-sampled.

The aim of the present study was to analyse the composition, species richness, diversity (H') and abundance of aquatic mollusc communities in temporary water bodies within a large section of the lower Bug River valley (140 km) and to determine the number of samples necessary to compile a representative and complete species lists.

STUDY AREA AND METHODS

Samples were collected in 50 floodplain water bodies located within the lower Bug River valley, between 190th and 50th km of the river course (Fig. 1). The Bug River is the biggest tributary of the Narew River and one of the largest rivers in Poland (4th longest). It is 755 km long, with the basin area of 39,420.2 km^2. The mean long-term discharges (SSQ) recorded at Polish water gauge stations range from 41.2 to 153.9 m^3/s. The lower Bug covers 224.2 km of the river course (counting from the mouth) (DOJLIDO et al. 2003).

The active floodplain on the left-bank side of the valley is considerably constrained by flood control embankments (built mainly in the 1980s), except for short fragments (150th–146th, 58th–53rd and 9th–13th km of the river course) of natural floodplain. Desiccation of these areas can already be observed. Direct, though limited, connectivity of the cut off areas with the active floodplain occurs only in the places where culverts are present, but the sluices are opened only during lower water in the Bug River, when the only direction of drainage is from the floodplain to the river channel. In most cases there is only indirect connectivity through infiltration. The right-bank side of the valley has retained a relatively natural character.

The sites were located within fragments of natural floodplain, the 'active' floodplain sites being constrained by the embankment and the 'former' floodplain sites being situated outside the embankment. They differed in their location within the valley, size, depth, distance from the main river channel and permanent water bodies, hydroperiod length, successional stage, hydrological connectivity, abundance of macrophytes and canopy (Appendix). Both typical temporary water bodies and not completely drying ones (when a few percent of the area could remain wet) were included in the present study. Their geographical co-ordinates were measured with GPS.

Molluscs were sampled from May to September 2007–2009, using a pond net with the working side of 25 cm, mesh size of 0.5 mm and handle length of 2 m. Individual sites were investigated once or twice, taking 2–3 samples, depending on the water body size. Molluscs taken from the bottom (from the area of about 1.0 m^2) and macrophytes were washed on a sieve of 0.5 mm mesh and preserved with 75% ethyl alcohol. In the laboratory the animals were sorted, counted and identified using the keys of PIECHOCKI (1979) and PIECHOCKI & DYDUCH-FALNIOWSKA (1993). Species names were updated according to the "Checklist of species-group taxa of continental Mollusca living in Poland" (CLECOM, 2002) and "Catalogue of life" (CATALOGUE 2007).

Hydroperiod length was evaluated based on IMGW data at the gauge stations in Frankopol (163.2 km of the river course) and Wyszków (33.8 km of the river course).

Composition, species richness and dominance patterns of the malacocoenoses were described. Species diversity was estimated with Shannon-Weaver index (MARGALEF 1958). The frequency of individual species (% F) was expressed as percentage of samples containing the species to the total number of samples.

Sample-based rarefaction curve was developed using the software EstimateS, v. 8.0 (COLWELL 2004). Every site was treated as one sample. The samples were randomized without replacement. Estimates of

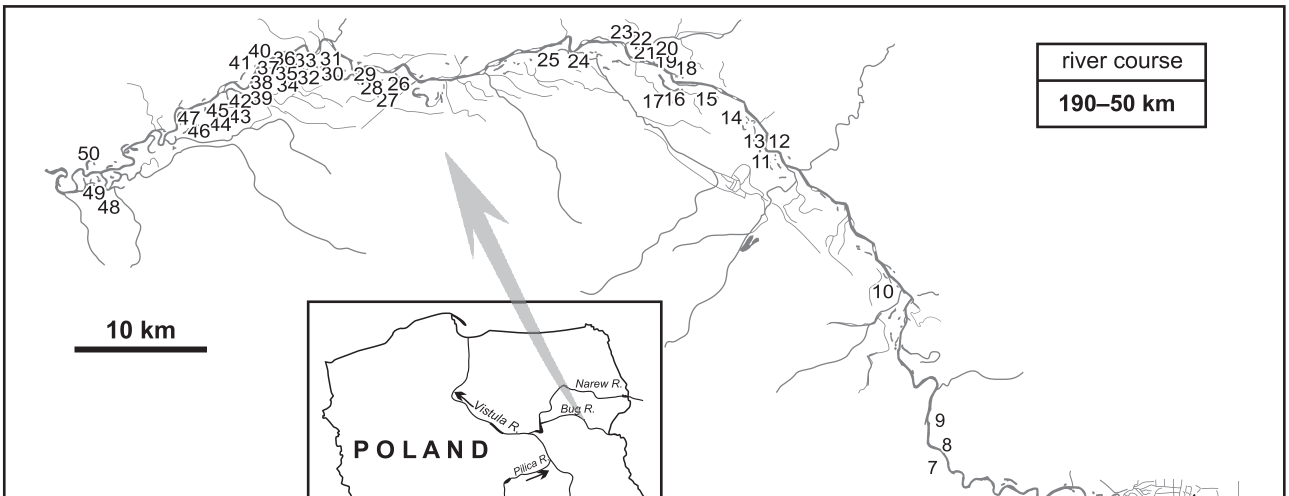

Fig. 1. Study area and location of the investigated water bodies (1–50). Main river channel – thick line, the network of thin lines – floodplain streams and drainage ditches

rarefied species richness (S_{MaoTau}) i. e. the expected species accumulation curve were based on the data of a resampled total observed species (S_{obs}) or sample-based rarefaction (COLWELL et al. 2004). The sample-based approach is recommended in the case of sample heterogeneity (i.e. patchiness) in the data (GOTELLI & COLWELL 2001). Sample-based rarefaction curve was used in the assessment of the sampling effort necessary to obtain representative datasets (i.e. ≥70% of the total number of expected species richness, according to MACKEY et al. 1984) and complete ones (i. e. ≥90% of the expected species richness, according to THOMPSON et al. 2007). The expected number of mollusc species was estimated using non-parametric abundance-based estimators Chao2 and Jackknife2 (COLWELL 2004).

Spearman's correlations between the number of species and abundance of malacocoenoses, as well as between the number of species, species diversity (H'), abundance and general environmental characteristics of the investigated habitats were computed with STATISTICA 6.0.

RESULTS

Thirty eight mollusc species were found: 32 snails (including 6 prosobranchs) and 6 bivalves (Table 1); individual sites held from 2 to 18 species (2 to 19 species, including molluscs identified on the basis of empty shells) (Fig. 2). The mean number of species per site (i. e. species density) was 8.94±4.45 (including molluscs identified on the basis of empty shells 9.66±4.41). Species diversity (H') in individual water bodies ranged from 0.44 to 3.48, in most of them it was relatively high (Fig. 2). The value of Shannon-Weaver's index exceeded 2 in 64% of all sites. Species richness and diversity (H') were positively correlated with the macrophyte abundance ($r=0.33$ and $r=0.30$, respectively; $p<0.05$), whereas a negative influence of the successional stage and the abundance of canopy on species diversity was found ($r=-0.30$ and $r=-0.34$, $p<0.05$).

The rarefaction curve showed an asymptote indicating a rather complete species list (Fig. 3). From 9 to 12 samples (depending on the estimator – Chao2 or Jackknife2) should be enough to complete a representative species list (i.e. ≥70% of the expected species number), but as many as 28–40 samples would be necessary to obtain a complete dataset (≥90% of the expected species number).

In the investigated habitats, planorbids dominated (*Planorbarius corneus*, *Planorbis. planorbis*, *Anisus leucostomus*, *A. septemgyratus*, *A. vortex*, *Segmentina nitida*, *Bathyomphalus contortus*) together with *Stagnicola palustris* and the prosobranchs *Valvata macrostoma* and *V. cristata* (Table 1). Dominance patterns were strongly differentiated among individual water bodies (Fig. 4). In most of them species resistant to drying dominated (*S. palustris*, *P. planorbis*, *P.*

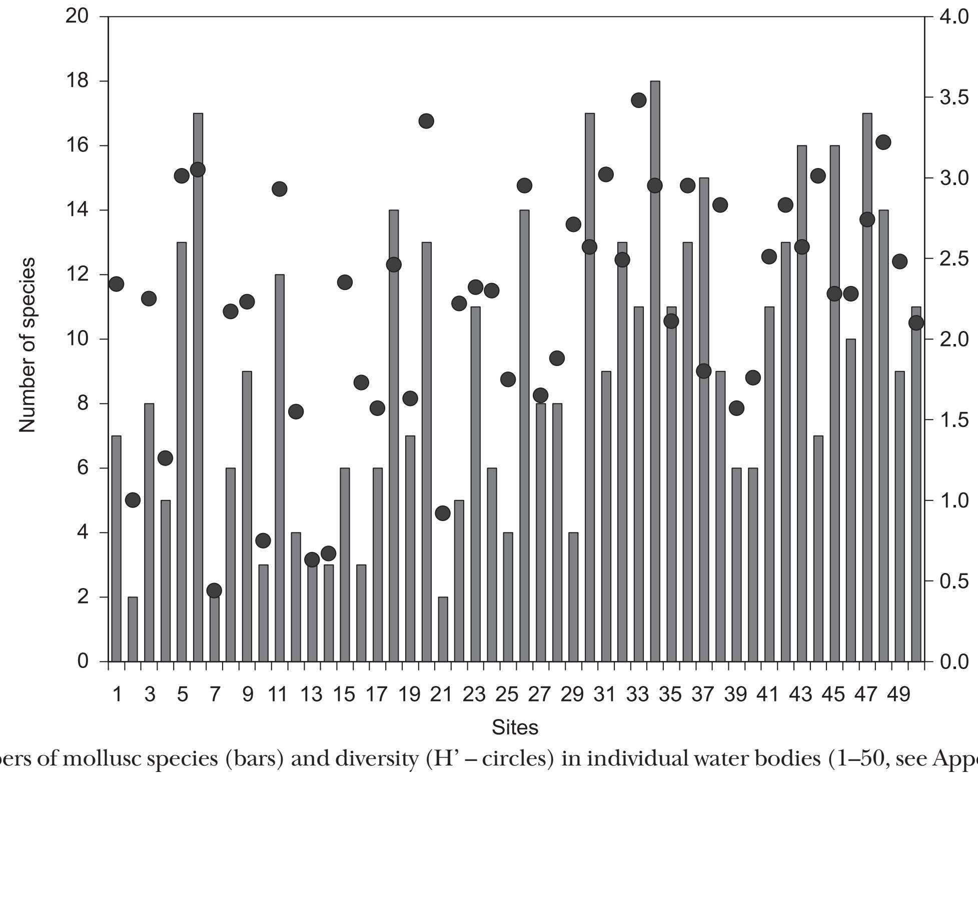

Fig. 2. Numbers of mollusc species (bars) and diversity (H' – circles) in individual water bodies (1–50, see Appendix and Fig. 1)

Table 1. The occurrence of molluscs: frequencies (% F) and relative abundances (percentages of individual species within the investigated water bodies). The values of % F given in parenthesis include also molluscs identified on the basis of empty shells

Species	Frequency of occurrence (% F)	Relative abundance (%)
Viviparus contectus (Millet)	30 (40)	0.40
Bithynia tentaculata (L.)	16 (18)	0.68
B. leachi (Sheppard)	24 (26)	0.74
Valvata piscinalis (O. F. Müller)	2 (2)	0,01
V. cristata (O. F. Müller)	42 (44)	3.91
V. macrostoma Mörch	34 (36)	6.82
Lymnaea stagnalis L.	44 (48)	1.55
Radix balthica (L.)	18 (20)	2.03
Stagnicola palustris (O. F. Müller)	66 (68)	5.76
S. corvus (Gmelin)	26 (26)	0.80
Catascopia occulta (Jackiewicz)	6 (6)	0.50
Galba truncatula (O. F. Müller)	12 (24)	0.09
Physa fontinalis (L.)	30 (32)	0.98
Aplexa hypnorum (L.)	10 (10)	1.10
Acroloxus lacustris (L.)	6 (6)	004
Planorbarius corneus (L.)	80 (84)	7.31
Planorbis planorbis (L.)	66 (66)	22.17
P. carinatus O. F. Müller	30 (34)	2.00
Anisus vortex (L.)	60 (62)	7.61
A. vorticulus (Troschel)	16 (18)	0.28
A. leucostomus (Millet)	36 (40)	8.08
A. septemgyratus (Rossmässler)	26 (26)	4.41
A. spirorbis (L.)	6 (8)	0.24
Gyraulus albus (O. F. Müller)	2 (2)	0.02
G. laevis (Alder)	4 (4)	0.05
G. rossmaessleri (Auerswald)	4 (4)	0.44
G. riparius (Westerlund)	8 (8)	0.44
G. crista (L.)	8 (8)	0.04
Bathyomphalus contortus (L.)	42 (46)	3.14
Segmentina nitida (O. F. Müller)	54 (60)	16.90
Hippeutis complanatus (L.)	14 (14)	0.18
Sphaerium corneum (L.)	14 (14)	0.74
Musculium lacustre (O. F. Müller)	6 (6)	0.13
Pisidium. nitidum Jenyns	2 (2)	0.01
P. casertanum (Poli)	8 (8)	0.11
P. milium Held	4 (4)	0.13
P. obtusale (Lamarck)	16 (18)	0.50
P. subtruncatum Malm	2 (2)	0.01

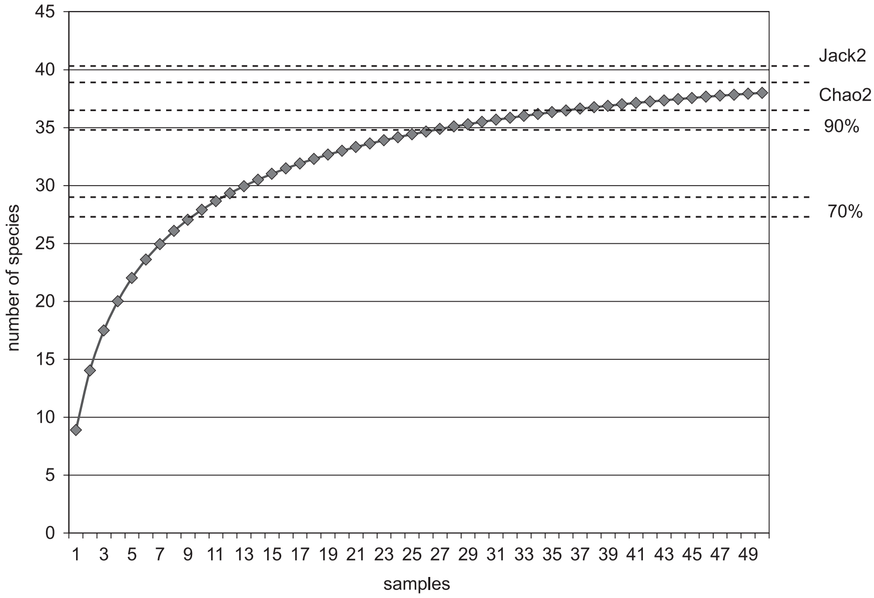

Fig. 3. Sample-based rarefaction curve of mollusc species richness (S_{MaoTau}) for the study area; successive dashed lines represent the following values: 70% of the expected species richness, 90% of the expected species richness; expected species richness calculated using Chao2 and Jackknife2 non-parametric estimators

corneus, *A. leucostomus*, *S. nitida*, *B. contortus*, *V. cristata*, *V. macrostoma*, *A. septemgyratus*), however in some sites, especially those periodically connected with the river or permanent water bodies, dominance of molluscs less resistant to desiccation was observed (e. g. *P. carinatus, Anisus vortex, L. stagnalis, P. fontinalis*, *V. contectus*).

Five species reached frequencies of ≥50% within the study area: *S. palustris*, *P. corneus*, *P. planorbis*, *A. vortex* and *S. nitida* (Table 1). About 40% of all mollusc species showed frequencies of ≤10%.

Mollusc abundance ranged from a few to over 1,800 indiv./m^2 (Fig. 5), maximum values were noted in two shallow water bodies located on meadows (sites 19 and 45, see Fig. 1), lacking surface connectivity with the river and with hydroperiod of up to 90 days, as well as in a small water body characterised by longer hydroperiod and temporary hydrological connectivity with the river water (site 32). High abundance in these habitats was related to great numbers of a few desiccation-resistant species: *V. macrostoma, V. cristata, P. planorbis, A. leucostomus* and *S. nitida.* However, considerable abundance (620 indiv./m^2) due to numerous occurrence of three species – *R. balthica, P. planorbis* and *A. vortex* - was observed also in a remnant of a larger water body located close to the river channel, with a thick layer of dark mud on the bottom and surface covered by *Lemna* spp. (site 9). The highest abun-

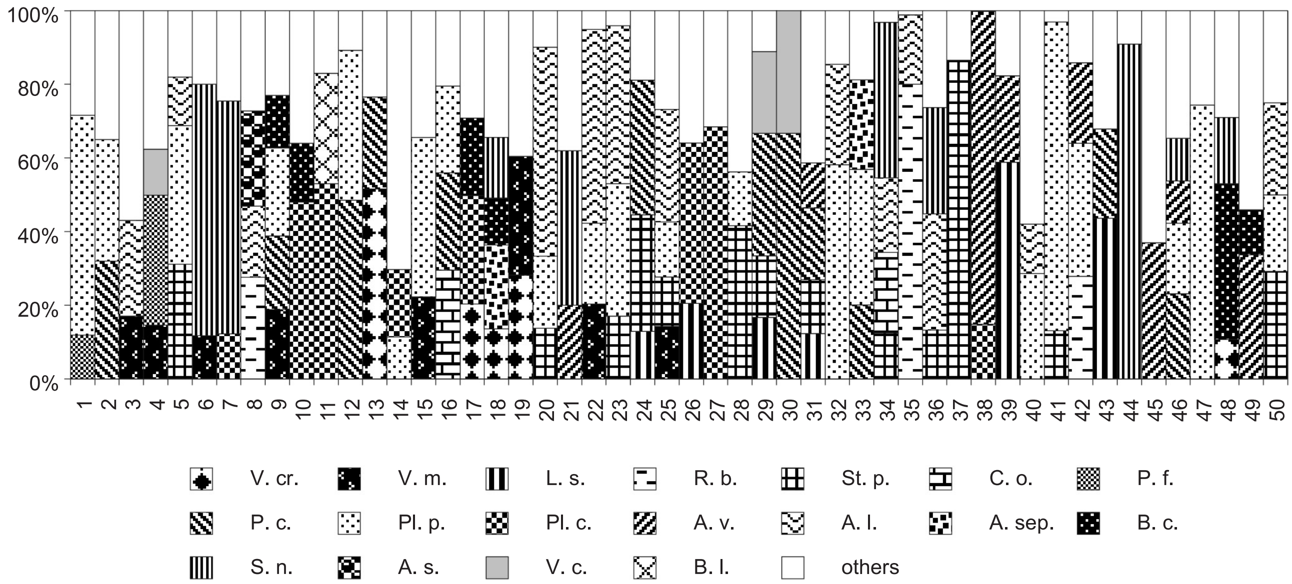

Fig. 4. Dominance relations in mollusc abundance in individual water bodies (1–50, see Appendix and Fig. 1). Full species names – see Table 1

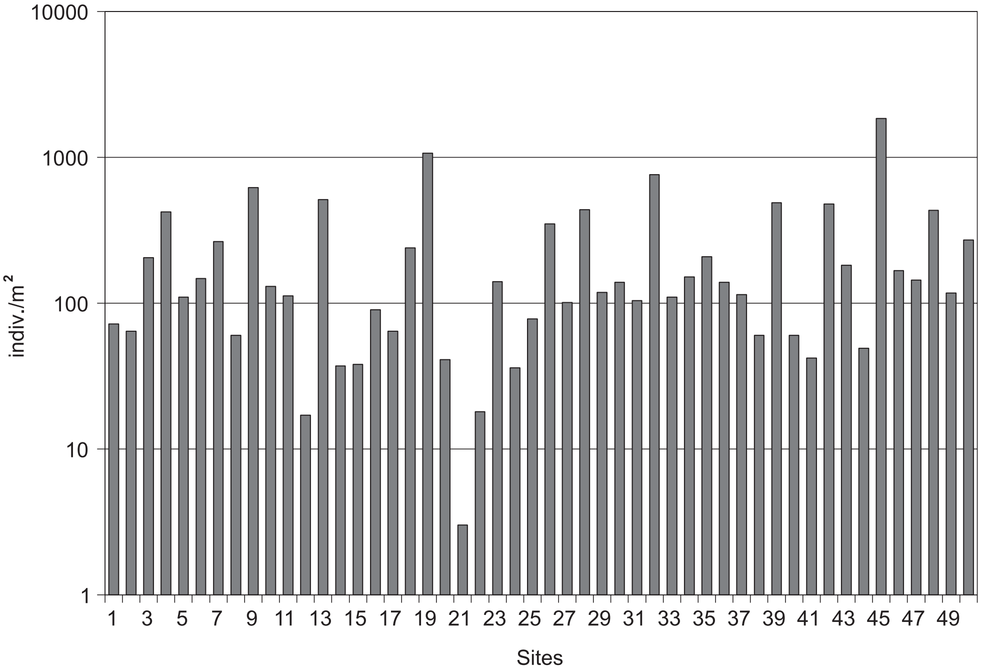

Fig. 5. Abundance of molluscs in individual water bodies (1–50, see Appendix and Fig. 1)

dance was reached mainly by snails resistant to drying. In the case of *S. nitida* the maximum density exceeded 1,300 indiv./m^2, for *P. planorbis* the respective value was over 600 indiv./m^2. Maximum densities of *V. cristata*, *V. macrostoma*, *P. corneus* and *A. leucostomus* were within the range of 200–300 indiv./m^2. For *S. palustris*, *A. hypnorum*, *A. septemgyratus* and *B. contortus* the respective values were up to 100 indiv./m^2. Some species, less resistant to drying out, also reached considerable abundance, e. g. *A. vortex* (over 400 indiv./m^2), or *R. balthica* (over 170 indiv./m^2). The abundance of bivalve species was rather low (1–49 indiv./m^2), the highest density was reached by *P. obtusale*. The mean abundance of molluscs in the investigated water bodies was 233.78±312.98 indiv./m^2. The abundance of molluscs was correlated with the number of species ($r=0.32$, $p<0.05$).

DISCUSSION

Mollusc communities inhabiting many temporary water bodies of the lower Bug River floodplain exhibited considerable species richness and diversity. It was partially consistent with the observations of OBRDLIK & FUCHS (1991), who reported the highest species richness from small water bodies within the active floodplain of the Rhine River. However, considerable species richness and diversity were found not only within the natural floodplain of the lower Bug River, but also in some habitats located within the active one, constrained by flood control embankment, as well as in the former one. They were probably related to the long duration of most of the investigated water bodies (up to 8–9 months and longer) and the presence of not only highly drought-resistant species, but also some other species, probably originating from permanent waters. Development of specialised drought-resistant communities (e.g. WIGGINS et al. 1980, SMITH & PEARSON 1987) takes place when the hydroperiod is short (3–4 months). The periodical hydrological connectivity with permanent water bodies or the river channel could enable dispersal of some species, thus increasing the species richness of temporary habitats.

The number of species found in the present study included six new species not recorded during the earlier investigations (JURKIEWICZ-KARNKOWSKA 2009): *G. albus*, *G. riparius*, *G. rossmaessleri*, *M. lacustre*, *P. subtruncatum* and *P. milium*. The occurrence of two species (*V. viviparus* and *P. hibernicum*), found earlier as single individuals, was not confirmed. These changes result from the increased number of investigated habitats and incidental occurrence of many species.

The habitats investigated in this study were mainly flooded meadows remaining at the relatively young stages of succession due to rejuvenation by alternative operation of flooding and desiccation. Some other habitats, representing remnants of old overgrowing water bodies, were mostly characterised by low diversity and species richness. A considerable effect of surface hydrological connectivity with permanent water bodies or river water on the species richness could be observed in a number of temporary habitats where less drought-resistant species constituted a significant part of the malacocoenoses (e.g. sites 2, 6, 8, 9, 12, 13, 21, 22, 24, 25, 34, 47, see Figs 1, 4).

The distinct character of the communities inhabiting temporary water bodies and the wide variation in their structure confirm the earlier observations, based on a smaller number of such habitats (JURKIEWICZ-KARNKOWSKA 2008, 2009) and the results of other authors (e.g. OBRDLIK & GARCIA-LOZANO 1992, WILLIAMS 1998, BILTON et al. 2009). Such habitats may be important biodiversity spots. The great contribution of temporary water bodies to the regional diversity is related both to the high habitat diversity determined by the variety of combinations of numerous factors and variability of faunal composition. About 40% of all mollusc species found in the temporary water bodies showed frequencies of ≤10%. Low frequencies may result from accidental colonisation of these habitats, where many dispersal and extinction events may have taken place (e. g. LASSEN 1975). The great variability of the structure and composition of the malacocoenoses may be related to dynamic changes of abiotic and biotic parameters. Among biotic factors, the quality and quantity of food may play an important role (e.g. FRÖMMING 1956). They change considerably during the year (BÄRLOCHER et al. 1978). Snails are the main components of malacofauna in small water bodies, especially temporary ones. They have unspecialised food requirements (e. g PIECHOCKI 1979) and this may be conducive to competition.

A relatively high number of samples (28–40 depending on the estimator used – Jackknife 2 or Chao2) would be necessary to attempt compiling a complete list (i. e. ≥90% of the expected number of species) of mollusc species within temporary and much drying water bodies in the lower Bug River valley. In the present study, including 50 water bodies, the investigated habitats were sampled with 92.5–97.5% completeness. In the previous investigations temporary habitats were inventoried with 70.9–80.2% completeness, with 20 samples (JURKIEWICZ-KARNKOWSKA 2009).

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Appendix

General characteristics of the 50 investigated water bodies (sites 1–50, see Fig. 1); location: 1 – natural floodplain, 2 – active floodplain constrained by the embankment, 3 – outside the embankment; successional stage: 1 – young, mainly flooded meadows, 2 – medium stages of succession, 3 – old, with advanced succession; hydrological connectivity: 1 – isolated water bodies, 2 – subsurface connectivity, 3 – temporary connectivity with permanent water bodies, 4 – possibility of temporary surface connectivity with the river water; hydroperiod length: 1 – <90 days, 2 – ≥90 days; macrophyte abundance: 1 – sparse occurrence, 2 – moderate occurrence, 3 – dense cover; canopy abundance: 1 – sparse occurrence, 2 – moderate occurrence, 3 – abundant occurrence

Number of site	Geographic co-ordinates		Location	Approximate size (m^2)	Depth (m)	Successional stage	Hydrological connectivity	Hydroperiod length	Macrophyte abundance	Vegetation abundance
1	N 52°21.672’	E 22°52.299’	1	200–500	<0.5	1	4	1	3	1
2	N 52°22.071’	E 22°52.172’	1	>500	<0.5	3	2	2	3	3
3	N 52°21.565’	E 22°52.139’	1	200–500	<0.5	3	2	2	3	3
4	N 52°22.255’	E 22°50.317’	1	200–500	<0.5	3	1	2	3	2
5	N 52°22.867’	E 22°42.863’	2	<200	<0.5	1	4	1	3	0
6	N 52°22.870’	E 22°42.835’	1	>500	≥0.5	2	4	2	3	0
7	N 52°23.128’	E 22°40.746’	1	<200	<0.5	1	1	1	3	0
8	N 52°24.662’	E 22°34.003’	1	<200	<0.5	1	3	2	2	1
9	N 52°24.801’	E 22°33.795’	1	200–500	<0.5	2	2	2	3	0
10	N 52°31.762’	E 22°30.728’	2	<200	<0.5	2	3	1	0	3
11	N 52°36.413’	E 22°23.965’	3	>500	≥0.5	1	2	2	3	0
12	N 52°37.294’	E 22°23.434’	1	>500	<0.5	2	4	2	3	0
13	N 52°37.318’	E 22°22.364’	2	>500	<0.5	1	4	1	3	0
14	N 52°39.237’	E 22°20.311’	3	<200	<0.5	2	3	1	3	2
15	N 52°39.617’	E 22°19.523’	3	<200	<0.5	3	1	1	2	3
16	N 52°39.860’	E 22°17.528’	2	>500	<0.5	1	1	1	3	0
17	N 52°39.849’	E 22°11.494’	3	200–500	<0.5	1	2	1	3	1
18	N 52°40.316’	E 22°16.913’	3	<200	≥0.5	2	1	2	3	0
19	N 52°40.963’	E 22°15.438’	3	200–500	<0.5	1	2	1	3	0
20	N 52°40.995’	E 22°15.336’	2	<200	≥0.5	2	4	2	3	0
21	N 52°41.023’	E 22°15.204’	2	<200	<0.5	1	4	1	3	0
22	N 52°41.048’	E 22°15.001’	3	<200	<0.5	1	2	1	3	0

Number of site	Geographic co-ordinates	Location	Approximate size (m^2)	Depth (m)	Succes-sional stage	Hydrological connectivity	Hydroperiod length	Macrophyte abundance	Vegetation abundance
23	N 52°41.066' E 22°.14.874'	3	<200	<0.5	1	2	1	3	0
24	N 52°41.318' E 22°09.524'	3	200–500	<0.5	1	3	1	3	0
25	N 52°41.458' E 22°06.573'	3	<200	<0.5	1	2	1	2	0
26	N 52°40.522' E 21°57.332'	3	<200	≥0.5	1	1	2	2	1
27	N 52°41.699' E 21°52.999'	3	<200	≥0.5	1	1	2	2	2
28	N 52°41.697' E 21°52.982'	2	<200	≥0.5	2	3	2	2	1
29	N 52°41.691' E 21°52.980'	2	200–500	≥0.5	2	3	2	3	0
30	N 52°41.432' E 21°52.911'	3	<200	≥0.5	1	1	1	2	1
31	N 52°41.133' E 21°52.826'	3	<200	<0.5	1	1	1	3	1
32	N 52°41.514' E 21°52.017'	1	200–500	≥0.5	3	2	2	3	3
33	N 52°.41.515' E 21°51.934'	1	<200	≥0.5	1	3	1	2	0
34	N 52°41.478' E 21°51.529'	1	<200	≥0.5	2	3	2	2	0
35	N 52°41.597' E 21°51.510'	1	200–500	≥0.5	2	3	2	2	0
36	N 52°41.617' E 21°51.490'	3	200–500	<0.5	3	1	1	3	2
37	N 52°.41.605' E 21°51.479'	2	<200	≥0.5	2	3	2	3	1
38	N 52°41.111' E 21°49.679'	3	>500	≥0.5	1	2	2	3	0
39	N 52°40.677' E 21°48.972'	1	200–500	<0.5	1	3	1	3	0
40	N 52°40.605' E 21°47.247'	1	<200	<0.5	1	1	1	3	0
41	N 52°40.600' E 21°47.350'	1	>500	<0.5	3	2	2	3	3
42	N 52°39.994' E 21°47.256'	1	>500	<0.5	3	1	2	3	2
43	N 52°40.059' E 21°47.136'	1	>500	<0.5	3	2	2	3	3
44	N 52°39.158' E 21°46.355'	1	>500	≥0.5	2	4	2	3	0
45	N 52°39.410' E 21°45.148'	1	<200	≥0.5	2	4	2	2	0
46	N 52°39.046' E 21°44.648'	1	<200	<0.5	1	4	1	3	0
47	N 52°39.111' E 21°44.029'	1	<200	<0.5	1	2	1	3	0
48	N 52°36.305' E 21°38.439'	3	<200	<0.5	1	1	1	2	0