



# EVOLUTION OF THE BUG RIVER VALLEY DURING THE HOLOCENE IN THE ENVIRONS OF JANÓW PODLASKI (EASTERN POLAND) IN THE LIGHT OF MALACOLOGICAL ANALYSIS OF OXBOW LAKE DEPOSITS

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**ABSTRACT:** The malacofauna of two profiles of deposits filling palaeomeanders of the Bug River Valley was studied. The first one (Zaczopki) represents an older phase of the valley development corresponding with the Early Holocene or even with the Late Glacial. Its assemblage contains numerous shells of cold-tolerant species. The second profile is situated near the village Woroblin. It represents a younger stage of the valley evolution (uppermost part of the Middle Holocene and Late Holocene). The mollusc fauna is typical of shallow and overgrown, stagnant water bodies. The sequences of mollusc assemblages from both profiles characterise the development of these reservoirs, corresponding with climatic changes and differences in fluvial activity of the Bug River during the Holocene.

**KEY WORDS:** malacofauna, molluscan assemblage, geological profile, alluvial palaeomeander, oxbow lake, Bug River

## INTRODUCTION

Oxbow lakes are typical components of the relief in the plains of alluvial meandering rivers. The oxbows emerge as a result of horizontal migration of the bed, occurring chiefly during floods, usually through the severing of meanders. The process leads to emergence of small, narrow and shallow bodies of stagnant water on the alluvial plain. They are usually quickly filled with river deposits and gradually vanish. The process normally lasts several hundred years. Oxbows develop at various distances from the main river channel and show diverse morphology. The deposits filling them are primarily phytogenic, mostly peats, and more rarely calcareous gyttjas. The substratum of these deposits is usually formed by river sands. Oxbows provide suitable habitats for animals, including communities of

snails and bivalves. The increased rate of oxbow formation in the Late Glacial and Holocene periods is associated with periods of intensive fluvial activity correlated with phases of humid climate. Generations of palaeomeanders of various ages can be found in many lowland river valleys in Poland (e.g. STARKEL 1977, GEBICA & STARKEL 1987, KALICKI & STARKEL 1987, KLIMEK 1987, RALSKA-JESIEWICZOWA & STARKEL 1988, HARASIMIUK & SZWAJGIER 2004). Oxbows provide suitable habitats for molluscs and are often inhabited by rich assemblages of aquatic fauna. Because of their small size, they are rapidly filled by deposits and are transformed into water-logged terrestrial habitats (bogs, moist meadows). The fillings of oxbows are mostly composed of peat. These sediments do not pro-

vide favourable conditions for the preservation of molluscan shells, primarily because of the considerable acidification of the environment. For this reason, and despite hundreds of studies carried out on palaeomeanders, subfossil mollusc shells were found only in few locations, where the sediments with a higher content of calcium carbonate were present (e.g. ALEXANDROWICZ et al. 1989, ALEXANDROWICZ & SANKO 1997, ALEXANDROWICZ 2004, GAIGALAS et al. 2007).

Studies on the extant fauna of oxbows of the lower Bug River valley have been carried out by JURKIEWICZ-KARNKOWSKA (2006, 2008). A rich malacofauna has been identified in several dozen of sites; it included 36 species of snails and 16 species of bivalves. However, information on the Holocene fauna of the Bug River valley is still very scanty. To date, only one profile in the Hrubieszów region has been described (ALEXANDROWICZ & DOLECKI 1991). The location represents the filling of a small palaeo-

meander. The rich malacofauna found in organic silts and sandy silts of Late Holocene age (the profile covers the period from 3,000 to 500 years B.P.) shows a clear prevalence of aquatic species in the bottom part of the profile. Toward the roof part, there is a marked increase in the number of terrestrial forms, which testifies to a gradual disappearance of the water body and the transformation of the oxbow into water-logged meadows.

The principal aim of this study was to reconstruct, based on malacological analysis, the evolution of small and relatively short-lived oxbow lakes which appear on river terraces as a result of cutting off of the meanders. The studies on the sequences of molluscan assemblages contained in the sediments of such lakes provide a rare opportunity to reconstruct the stages of their filling and disappearance. These stages show close connection with the climatic phases and the periods of changes in fluvial activity of rivers.

## GEOLOGICAL SETTING

The study area is situated in the middle part of the Bug River valley, ca. 5 km east of Janów Podlaski. The Bug river forms here a gorge marked by a distinct narrowing of the valley (down to ca. 1.5 km) and increased height of its slopes. The formation of the gorge is associated with the final stage of deglaciation of the Warta Glaciation (KUSZNERCZUK 2008, 2009). Fillings of two

palaeomeanders, developed on the low, left-bank terrace of the Bug, were analysed. The first site was situated ca. 500 m east of the centre of the village of Woroblin (Wb) (GPS: 52°11'25"N; 23°22'2"E), the second was slightly north of the village of Zaczopki (GPS: 52°10'4"N; 23°23'56"E) (Fig. 1).

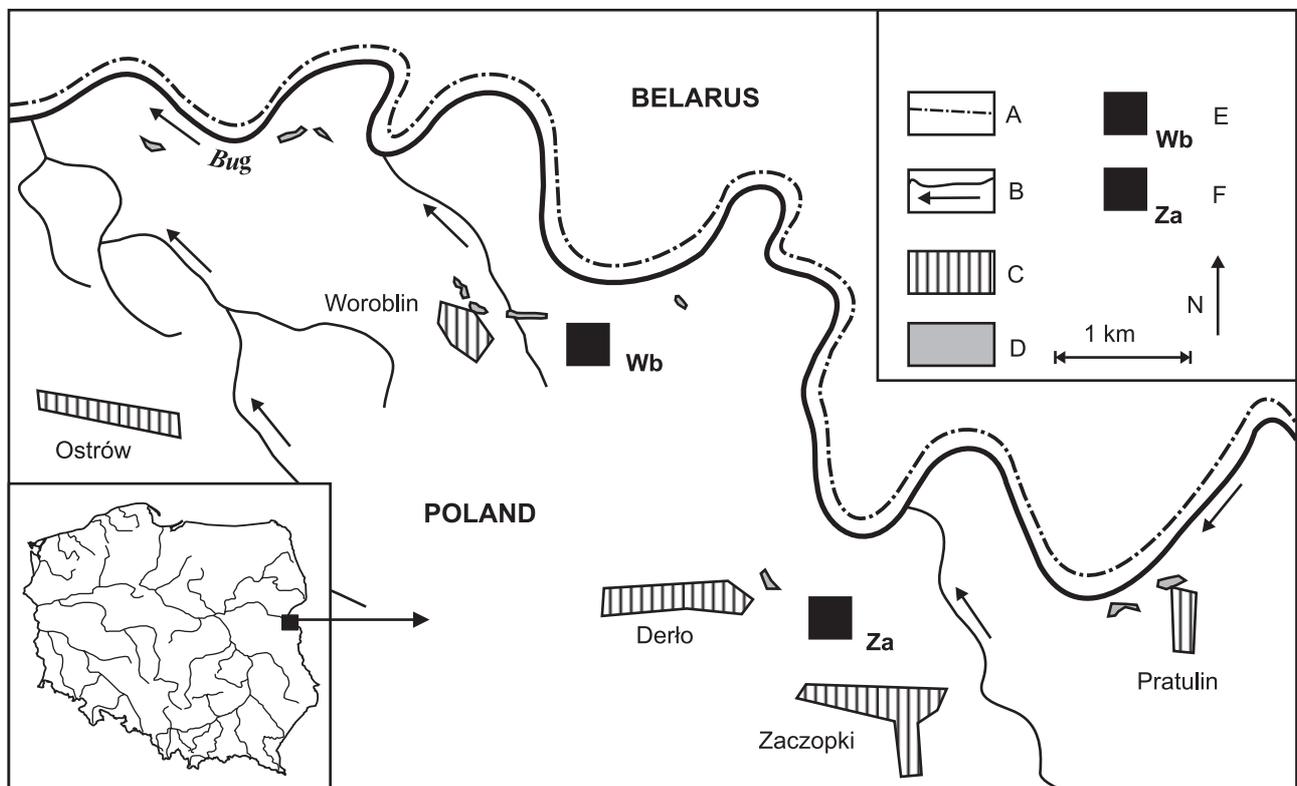


Fig. 1. Location of profiles Woroblin and Zaczopki: A – state boundary, B – rivers, C – villages, D – lakes, E – profile in Woroblin (Wb), F – profile in Zaczopki (Za)

The palaeomeander in Zaczopki represents the forms of an older generation. It is shaped as a multi-radial arc, more than 2 km long and reaching a radius of up to 850 m (KUSZNERCZUK 2008, 2009). The oxbow in Woroblin represents a younger, Holocene generation of forms; it is smaller, with a radius not exceeding 500 m.

The lithological profile of sediments filling the oxbow in Woroblin consists of limnic deposits in its lower part, while the upper interval is composed mainly of peat. The thickness of the sequence is 3.70 m (Fig. 2). Seven layers can be distinguished from bottom upward: 3.70–3.50 m – alluvial sand of channel facies (W-A); 2.80–3.50 m – fine-detritus calcareous gyttja with mollusc shells (W-B); 2.65–2.80 m – fine-detritus calcareous gyttja with well decomposed sedge-reed peat and mollusc shells (W-C); 2.50–2.65

m – clayed fine-detritus calcareous gyttja with mollusc shells (W-D); 2.20–2.50 m – sedge-moss peat with mollusc shells (W-E); 1.50–2.20 m – well decomposed sedge-moss peat with single fragments of mollusc shells (W-F); 0.00–1.50 m – sedge-moss peat (W-G).

The lithological profile of the oxbow in Zaczopki is composed mainly of peat. The total thickness of the section is 2.50 m (Fig. 2). Five layers can be distinguished from bottom upward: 2.50–2.30 m – alluvial sand of channel facies (Z-A); 2.00–2.30 m – peat with fragments of mollusc shells (Z-B); 1.55–2.30 m – well decomposed peat with sand admixture and numerous mollusc shells (Z-C); 0.55–1.55 m – sedge-moss peat with single mollusc shells in the lower part (Z-D); 0.00–0.55 m – well decomposed sedge-reed peat without mollusc shells (Z-E).

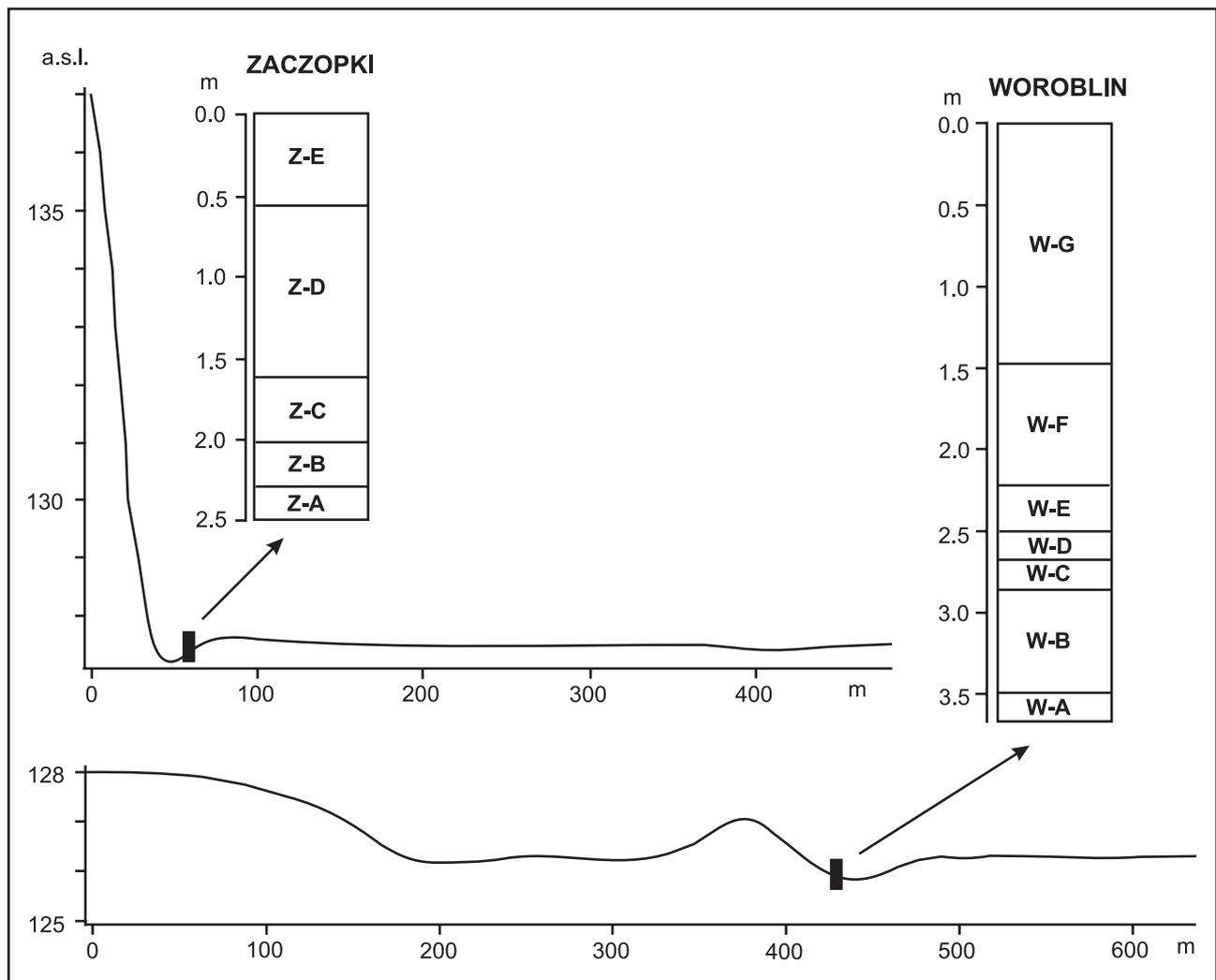


Fig. 2. Geomorphological position of profiles Woroblin and Zaczopki: W-A – W-G and Z-A – Z-E – layers described in the text

## MATERIAL AND METHODS

The malacological analyses included 33 samples taken from the Woroblin bore-hole at 5 cm intervals, covering a fragment of the profile at the depths of 1.5 to 3.5 m. Three of the samples contained only unidentifiable shell pieces. Because of the small volume of the samples and relatively poor malacofauna, the samples within the layers distinguished on the basis of the geological studies were pooled. The number of samples was therefore limited to nine. Each of them covered an interval of 10–30 cm, closely corresponding to the above-described lithological units (Fig. 2). Fifteen samples from the bore-hole at Zaczopki were collected from the 1.55–2.30 m interval. After pooling, on the basis of the principle described above, the malacological analysis covered eight samples (Fig. 2).

The malacological analysis employed standard methods described by LOŹEK (1964), ALEXANDROWICZ (1987) and ALEXANDROWICZ & ALEXAN-

DROWICZ (2011) which allowed to distinguish ecological groups characteristic of the analysed malacofauna. The proportion of species in particular samples enabled compilation of the malacological spectra for individuals, which provided a basis for interpretation. Additional data pertaining to the environmental conditions where deposits were formed, were obtained from two-component diagrams illustrating the relationship between the ecological groups, and also three-component diagrams presenting the various stages in the development and changes in the fauna. The *Bithynia*-index (Bi) (STEENBERG 1917, ALEXANDROWICZ 1987, 1999a, b, 2007) which represents the shell:opercula ratio of *Bithynia tentaculata* was also calculated. The shell predominance is characteristic of open littoral zones of lakes or other permanent water bodies, whereas the predominance of opercula is typical of reed bed zones.

## RESULTS

The mollusc assemblages of Woroblin and Zaczopki were relatively poor. The material included species of three ecological groups: H – terrestrial taxa typical of very moist and marshy habitats, T – aquatic species of temporary water bodies, and P – aquatic species typical of permanent water bodies. The latter group included lacustrine forms, species living in small, often densely overgrown water bodies as well as taxa of wide ecological tolerance. The malacofauna of Woroblin and Zaczopki was composed almost exclusively of aquatic molluscs. Nevertheless, there were essential differences between these profiles with regard to the composition and structure of the mollusc assemblages.

In the Woroblin profile the malacofauna was found in the lower interval, between the depths of 1.60 and 3.50 m. Twenty eight species – 18 snails and 10 bivalves – were found in the samples. Aquatic forms (27 taxa) predominated clearly over terrestrial ones (1 taxon) (Table 1). In total, the material included nearly 600 specimens. The number of species in individual samples ranged from 8 to 18, whereas the number of individuals varied from 17 to 222 (Fig. 3N). The malacofauna was definitely more diverse in the lower part of the profile (samples 5–9) and sparser in the middle part (samples 2–4). The uppermost part of the series contained only a few species, represented by few individuals (sample 1).

Table 1. Composition of molluscan fauna in Woroblin. E – ecological groups of molluscs (based on LOŹEK 1964, ALEXANDROWICZ 1987 and ALEXANDROWICZ & ALEXANDROWICZ 2011): H – hygrophiles, T – species of temporary water bodies, P – species of permanent water bodies

E	TAXON	Samples								
		1	2	3	4	5	6	7	8	9
H	<i>Succinea putris</i> (Linnaeus, 1758)	1				1				6
T	<i>Valvata macrostoma</i> Mörch, 1864	4	14			4	1	3	6	8
T	<i>Stagnicola</i> sp.			2	1	1				
T	<i>Planorbis planorbis</i> (Linnaeus, 1758)			1	1	1	2	1	1	7
T	<i>Segmentina nitida</i> (O. F. Müller, 1774)		6	1						
T	<i>Pisidium obtusale</i> (Lamarck, 1818)							1		
P	<i>Valvata cristata</i> O. F. Müller, 1774	4	7			4	5	4	4	26
P	<i>Valvata piscinalis</i> (O. F. Müller, 1774)		3		1	1	1	1	1	3
P	<i>Bithynia tentaculata</i> (Linnaeus, 1758) (+ operculum)	1	4 (+0)	2 (+0)	1 (+0)	5 (+3)	3 (+2)	9 (+2)	10 (+3)	30 (+61)



Table 1 continued

P	<i>Marstoniopsis scholtzi</i> (A. Schmidt, 1856)						1	4	4
P	<i>Physa fontinalis</i> (Linnaeus, 1758)			1	1				1
P	<i>Lymnaea stagnalis</i> (Linnaeus, 1758)	1							1 3
P	<i>Radix balthica</i> (Linnaeus, 1758)	3	12	10	4	8	6	20	6 16
P	<i>Anisus vorticulus</i> (Troschel, 1834)					1	1		1 1
P	<i>Gyraulus albus</i> (O. F. Müller, 1774)	2		2	2	8	2	8	7 4
P	<i>Armiger crista</i> (Linnaeus, 1758)	1	5	3	3	2		1	
P	<i>Hippeutis complanatus</i> (Linnaeus, 1758)								1
P	<i>Acroloxus lacustris</i> (Linnaeus, 1758)			1		2	2	5	3
P	<i>Planorbarius corneus</i> (Linnaeus, 1758)					1			
P	<i>Sphaerium corneum</i> (Linnaeus, 1758)						2	2	8
P	<i>Pisidium amnicum</i> (O. F. Müller, 1774)								1
P	<i>Pisidium henslowanum</i> (Scheppard, 1823)					6	3	2	2 4
P	<i>Pisidium milium</i> Held, 1836						1		1
P	<i>Pisidium pseudosphaerium</i> J. Favre, 1927							2	1
P	<i>Pisidium subtruncatum</i> Malm, 1855					2	4	5	6 13 20
P	<i>Pisidium pulchellum</i> Jenys, 1832							1	
P	<i>Pisidium crassum</i> Stelfox, 1918					1	2	1	1 2
P	<i>Pisidium casertanum</i> (Poli, 1791)			1	5	2	4	9	10 19
Total specimens		17	53	24	21	56	42	81	74 222
Total species		8	9	10	10	17	16	17	18 17

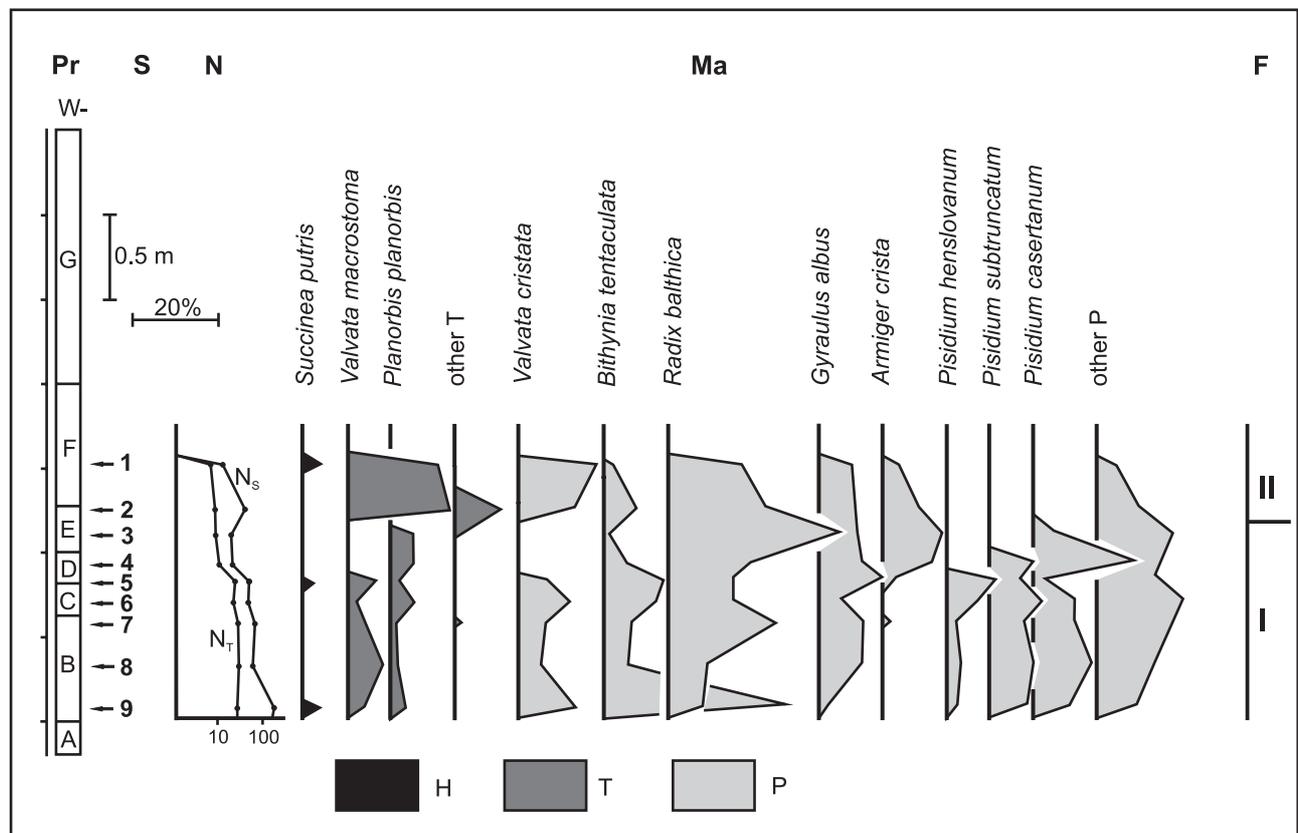


Fig. 3. Malacofauna of Woroblin. Pr – profile: A–G – layers described in the text, S – samples, N – number of taxa ( $N_t$ ) and specimens ( $N_s$ ), Ma – malacofauna; ecological groups of molluscs (based on LOŽEK 1964, ALEXANDROWICZ 1987 and ALEXANDROWICZ & ALEXANDROWICZ 2011): H – hygrophiles, T – species of temporary water bodies, P – species of permanent water bodies; F – phases of fauna development described in the text

Table 2. Composition of molluscan fauna in Zaczopki. Explanations as in Table 1

E	TAXON	Samples							
		1	2	3	4	5	6	7	8
T	<i>Valvata macrostoma</i> Mörch, 1864	4	17	21	13	8	5	22	20
T	<i>Stagnicola</i> sp.		39	21	5				
T	<i>Planorbis planorbis</i> (Linnaeus, 1758)	2							
T	<i>Anisus leucostoma</i> (Millet, 1813)	5	2						
T	<i>Segmentina nitida</i> (O. F. Müller, 1774)		1	1	1	4		2	7
T	<i>Pisidium obtusale</i> (Lamarck, 1818)			7		5		3	3
P	<i>Valvata cristata</i> O. F. Müller, 1774	3	30	38	26	20	14	33	31
P	<i>Valvata piscinalis</i> (O. F. Müller, 1774)	1		8	1				6
P	<i>Bithynia tentaculata</i> (Linnaeus, 1758) (+ operculum)	4 (+3)	9 (+11)	18 (+34)	6 (+15)	5 (+7)	1 (+4)	0 (+12)	2 (+7)
P	<i>Lymnaea stagnalis</i> (Linnaeus, 1758)			3					
P	<i>Radix balthica</i> (Linnaeus, 1758)	3	17	15	13	5	4	12	3
P	<i>Anisus vorticulus</i> (Troschel, 1834)								1
P	<i>Gyraulus albus</i> (O. F. Müller, 1774)		7						
P	<i>Gyraulus laevis</i> (Férussac, 1807)				1	2	2	1	7
P	<i>Armiger crista</i> (Linnaeus, 1758)		7	13	13	15	4	9	27
P	<i>Acroluxus lacustris</i> (Linnaeus, 1758)	1	3						
P	<i>Sphaerium corneum</i> (Linnaeus, 1758)				1	4			1
P	<i>Pisidium henslowanum</i> (Scheppard, 1823)			5					
P	<i>Pisidium subtruncatum</i> Malm, 1855			12	1				5
P	<i>Pisidium casertanum</i> (Poli, 1791)	2							
Total specimens		28	143	196	96	75	34	94	120
Total species		10	10	12	11	9	6	8	12

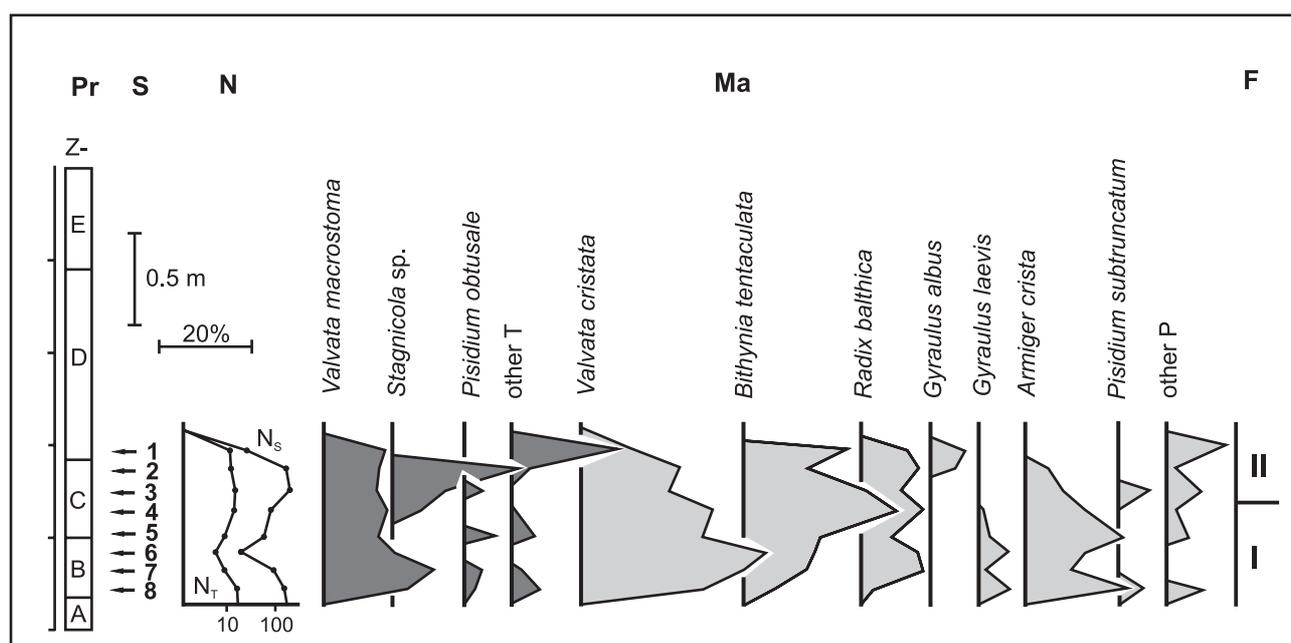


Fig. 4. Malacofauna of Zaczopki. For explanation see Fig. 3



Terrestrial species (ecological group H) were represented by few shells of *Succinea putris* appearing only in three samples. Taxa typical of shallow, temporary water bodies (ecological group T) occurred in great numbers. *Valvata macrostoma* was particularly common, especially in the upper part of the profile (samples 1 and 2, depth 1.95–2.30 m). *Planorbis planorbis*, *Segmentina nitida* and *Pisidium obtusale* (Fig. 3Ma) were less abundant. In the lower part of the studied sequence (samples 5–9, depth 2.30–3.50 m), there was a definite prevalence of species living in permanent water bodies (ecological group P). The fauna of this part of the profile was also the richest and most diversified. In addition, snails of remarkable ecological tolerance, such as *Bithynia tentaculata* and *Radix balthica*, living in both large open lakes and small, abundantly vegetated water bodies, were frequent. Euryoecious bivalves, such as *Pisidium casertanum* and *P. subtruncatum*, were also numerous. Other significant components of the assemblage were the taxa preferring shallow and considerably overgrown water bodies or littoral zones of large lakes, i.e. *Armiger crista*, *Gyraulus albus* and *Valvata cristata*. The remaining species occurred more rarely, and constituted an accessory component of the fauna (Fig. 3Ma, Table 1).

## DISCUSSION

Despite great similarities in the species composition of the two assemblages, there are also marked differences in the assemblage structure and the sequences of malacocoenoses.

In the Woroblin profile, two phases can be distinguished. The older phase is represented by samples 3–9 (depth range 2.30–3.50) and is characterised by the predominance of species typical of permanent water bodies (Figs 3F, 5D, F). In the lowest part of this interval (sample 9), the low values of Bi index indicate the presence of a shallow water body with reed-covered littoral (Fig. 5Bi). The high number of *V. cristata* is indicative of an abundant growth fraction of immersed vegetation. Also the occurrence of *S. putris* indicates the presence of a reed bed. *S. putris* is a hygrophile, often found on emerged vegetation near the shore. The increase in the Bi index in samples 3–8 (Fig. 5Bi), as well as the high frequency of euryoecious snails and bivalves, is indicative of the development of the water body and – probably – the increase in water level with a simultaneous reduction in the reed-covered area. In this interval, the fauna is the richest and the most diverse, thereby indicating favourable living conditions for molluscs (phase I; Figs 3F, 5D, F). A very rapid change in conditions, manifested as dramatic reductions in both abundance and diversity of species in the assemblage, is marked at the depth of 2.30 m (phase II; Figs 3F, 5D, F). The majority of species typical of permanent water bodies disap-

In Zaczopki mollusc shells were found in the lower part of the profile at depths of 1.55–2.30 m. The assemblage was slightly poorer than that found in Woroblin and included 20 species (15 snails and 5 bivalves), represented by nearly 800 specimens (Table 2). At this locality, only aquatic forms were found. The number of taxa per sample varied from 6 to 12, whereas the number of individuals ranged from 30 to 196 (Fig. 4N).

The species composition of the fauna resembled that described for the Woroblin locality, although the assemblage structure differed distinctly. Only two groups were represented in the Zaczopki profile. One consisted of species typical of temporary, very shallow and densely overgrown water bodies (ecological group T). Numerous specimens of *V. macrostoma* were found in all samples. In the upper part of the series, numerous, usually crushed shells of *Stagnicola* sp. appeared. Other taxa from group T appeared in much smaller numbers. Species of permanent water bodies (ecological group P) were represented chiefly by euryoecious *B. tentaculata*, *R. balthica* and by the taxa of small water bodies, such as *A. crista*, *G. albus* and *V. cristata*. The frequency of bivalves, markedly lower than in Woroblin, is noteworthy (Fig. 4Ma, Table 2).

pear here, and the forms typical of temporary water bodies begin to predominate. This interval (samples 1 and 2) may be associated with a period of rapid decline in water level, which may have resulted from either drainage or filling by deposits. The uppermost part of the profile, devoid of mollusc shells, represents the final stage in the development of the water body, and transformation of the oxbow into a peatbog or even into a wet meadow. The sequence of malacofaunas is presented on a projection triangle (Fig. 5). Two groups of samples are distinct. The projection points of samples 3–9 concentrate on the field which corresponds to the environment containing a permanent water body. The points of samples 1 and 2 show an evident shift towards the field containing temporary water bodies. This testifies to an essential reconstruction of the composition and structure of the malacocoenosis associated with a gradual filling of the lake and the disappearance of the oxbow (Fig. 5Tr).

The changes in the nature of habitats are much less marked in the Zaczopki locality. It is, however, still possible to distinguish two phases (Figs 4F, 5D, F). The older one (samples 4–8) is characterised by a significant proportion of species living in small permanent water bodies, overgrown by abundant vegetation: *A. crista*, *G. laevis* and *V. cristata*. The high frequency of *V. macrostoma* as well as very low values of the Bi index are other typical features of this interval (Figs 4, 5Bi). During this period, the water body was

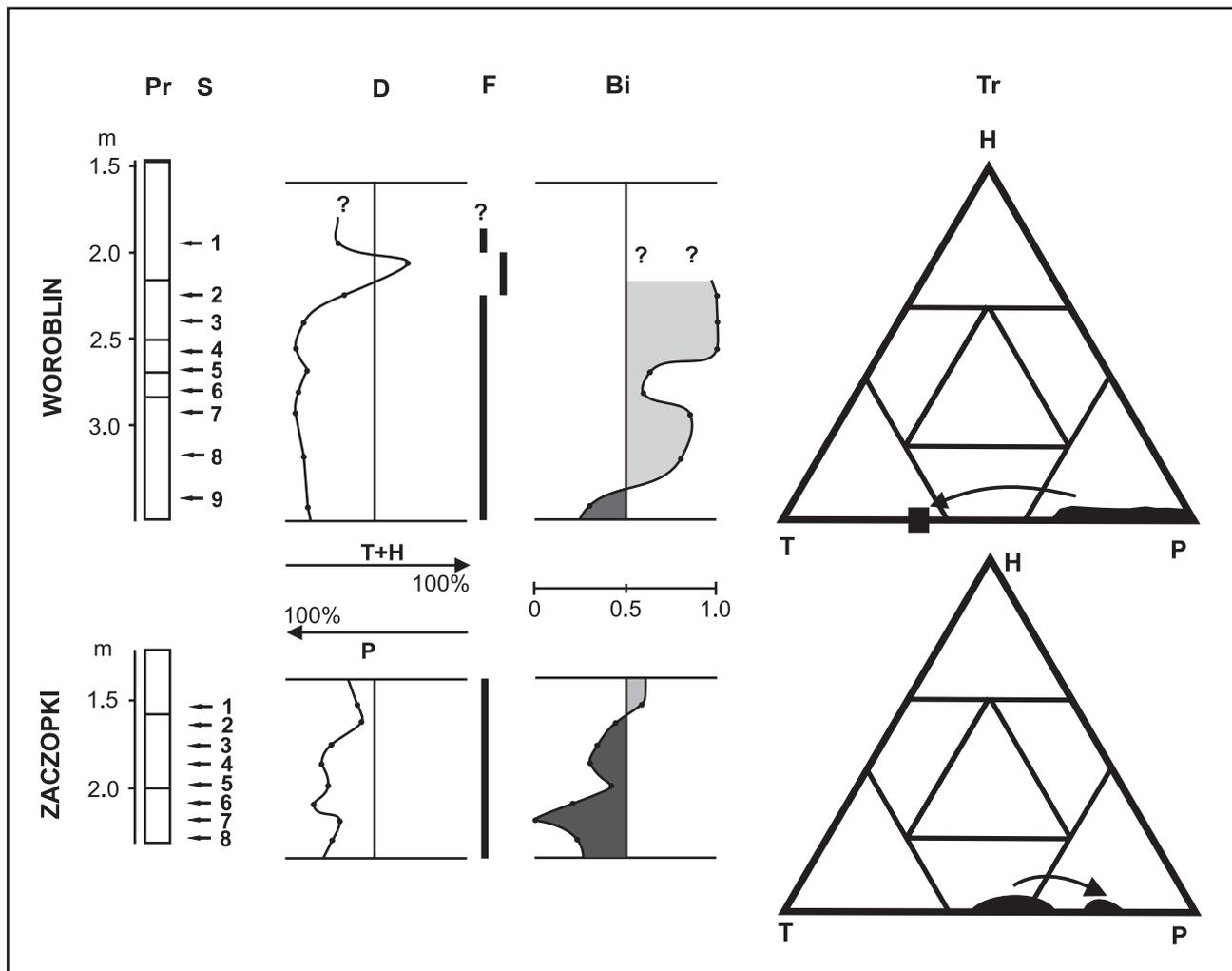


Fig. 5. Development of mollusc fauna in Woroblin and Zaczopki: Pr – profile, S – samples, D – two-component diagram, F – phases of fauna development described in the text. Bi – *Bithynia* index diagram, Tr – triangular diagram. For ecological groups of molluscs see caption to Fig. 3

very shallow and densely overgrown. This was probably the first stage in its development (Fig. 5D, F). The younger phase (samples 1–3) is characterised by a higher proportion of euryoecious forms and a marked increase in the Bi values (Figs 4, 5Bi, D, F). This might signify a small increase in the water level, as well as a reduction in the reed-covered area. The succession of molluscan communities is presented on a projection triangle. The diversity of the malaco-coenoses is less evident than in the Woroblin profile. The projection points of the samples from the lower part of the sequence are shifted towards the field of temporary water bodies, whereas the points corresponding to the samples from the upper interval lie in the field containing the permanent water bodies. This sequence is indicative of the gradual depth increase and development of the water body (Fig. 5Tr).

Both localities under study represent similar types of habitats; namely small, shallow and densely overgrown oxbows. The Zaczopki profile probably represents the first phase of the development of such

a water body, whereas the Woroblin locality pertains to the stage of gradual decline and transformation into a peatbog. The absence of any river (rheophile) species is indicative of the lack of currents within the water bodies studied. The two localities differ in age. Aquatic molluscs are much poorer stratigraphic indicators than terrestrial species. Most forms show a wide tolerance towards habitat and thermal conditions. Nevertheless there is a group of species that may be successfully used for stratigraphic purposes. Two such forms occur in the localities studied. The first is *B. tentaculata*. This species displays a wide ecological tolerance and occurs in various types of permanent water bodies, ranging from large lakes to small, densely overgrown ponds and oxbows (PIECHOCKI 1979). It is one of the most common components of the lacustrine chalk fauna (ALEXANDROWICZ 1980, 1989, 1999a, b, 2007). The above-mentioned form is, however, almost exclusively typical of deposits associated with the Holocene. Although it appears as early as the Preboreal Phase, it is practically absent in the



Late Glacial sediments (ALEXANDROWICZ 1980, 1989, 1999a, b, 2007). The numerous shells of *B. tentaculata* and opercula, occurring in the deposits of the Woroblin and Zaczopki profiles, indicate their Holocene age. The second form of stratigraphic importance is *G. laevis*. The species is typical of small overgrown water bodies (PIECHOCKI 1979). It is a cold-loving form, commonly occurring in Late Glacial lacustrine deposits and sometimes even in the Pleniglacial loess series accumulated in water bodies. In Holocene formations it still occurs in high numbers in the Preboreal Phase, but from the Boreal Phase on it is replaced by *G. albus* (ALEXANDROWICZ 1980, 1989, 1999a, 2007). A similar sequence can be observed in the Zaczopki profile. The profile corresponds with the Early Holocene (Preboreal and Boreal phases) and perhaps even with the end of the Late Glacial (Young Dryas). The Woroblin profile lacks both cold-tolerant elements and forms of high thermal requirements. In the age categories, the profile corresponds with the final stage of the Atlantic Phase, Subboreal Phase and/or the lower part of the Subatlantic Phase.

The palaeoecological and stratigraphic interpretations of the molluscan assemblages occurring in the Woroblin and Zaczopki localities correspond closely with the periods of intensified fluvial activity and the

phases when oxbows were formed. In terms of age, the Zaczopki locality probably corresponds to the phase of increasingly wet climate, falling within the period from 8,500 to 8,000 years B.P. This phase is well documented in many profiles of fluvial deposits throughout the territory of Poland (e.g. KOZARSKI & ROTNICKI 1977, SZUMAŃSKI 1983, STARKEL 1984, 1995, RALSKA-JASIEWICZOWA & STARKEL 1988). It is also a period of evident cooling of the climate and the expansion of glaciers in the Alps, where it is associated with the Venediger phase (PATZELT 1977, BORTENSCHLAGER 1982). The Woroblin profile corresponds with the uppermost part of the Middle Holocene and with the Late Holocene. In this period, several phases in the development of oxbows are marked, described in detail by a number of authors, e.g. KLIMEK (1974, 1987), STARKEL (1977, 1995), RALSKA-JASIEWICZOWA & STARKEL (1988), STARKEL et al. (1996). One of these phases is represented by the oxbow profile at Woroblin.

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