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MOLLUSC ASSEMBLAGES FROM SUBATLANTIC OXBOW LAKE DEPOSITS IN THE SZRENIAWA RIVER VALLEY NEAR SŁOMNIKI (MIECHÓW UPLAND, SOUTHERN POLAND)

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Abstract: A rich mollusc fauna was found in the sediments filling the ancient oxbow lake developed on the floodplain of the Szreniawa River in the environs of Miechów (near Topola village). The sediments represent the Subatlantic phase of the Holocene. Their stratigraphic position was confirmed by radiocarbon dates. The oxbow under study is filled with organic sediments (peats), organic-mineral (peaty muds), and carbonate deposits (calcareous muds) with the maximum thickness of 1.5 m. The variation in mollusc assemblages provided the basis for the reconstruction of environmental changes that took place over about 2,000 years, from the moment of oxbow emergence up to its complete filling. Within that sequence, it is possible to distinguish two principal intervals. The older interval corresponds to the period of a small water body functioning there. The malacofauna present in this interval shows the prevalence of aquatic and hygrophilous species. The younger phase corresponds to the period of accumulation of calcareous muds with predominance of open-country and xerophilous taxa. The collected materials also made it possible to determine the characteristics of the malacofauna diversification within the oxbow itself, and it showed the distinctiveness of environmental features in its central part and in marginal parts.

Key words: malacofauna, oxbow lake, environmental changes, Subatlantic Phase, Szreniawa River valley, Miechów Upland, southern Poland

INTRODUCTION

Oxbow lakes occurring within the floodplains are characteristic elements in the relief of river valleys. The development of those forms is associated with cutting off meanders, and the side migration of river beds, which is particularly intensive during floods. As a consequence of these changes, shallow, elongated bodies of stagnant water develop, usually with very abundant plant vegetation. The oxbow lakes are gradually filled with sediments and finally disappear. The development, evolution, and disappearance of oxbow lakes were the subject of a great number of studies. The long-term studies of those forms, conducted in the belt of Central Polish uplands, indicate the presence of several generations of oxbow lakes, which vary in terms of both morphology and age (e.g. Starkel 1997, Kalicki 2006, Starkel et al. 2013). Also noticeable is a clear-cut correlation between the emergence of the oxbow lakes, and the periods of humidified climate, showed by the increased frequency of floods (e.g. Kalicki & Krąpiec 1996, Starkel 2000, 2007, Starkel et al. 2007, Gębica 2011, Gębica et al. 2015). The oxbow lakes are most often filled by phytogenic sediments – peats or muds with great quantities of plant detritus, accompanied by mineral sediments (sands and silts, also often with plant detritus). Calcareous sediments: gyttjas, tufas and lacustrine chalks appear much more rarely. The presence of sediments with elevated content of calcium carbonate enables preservation of mollusc shells. The features of malacofauna assemblages, their species compositions, and the sequences in profiles provide data on both environmental changes

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and also about the age of sediment filling the oxbow lakes. Such analyses were the subject of a number of publications (e.g. ALEXANDROWICZ & SANKO 1997, GAIGALAS et al. 2007, 2013, SANKO et al. 2008, ALEXANDROWICZ & KUSZNIERCZUK 2012).

Like the marked part of Central Polish Uplands, the Szreniawa River valley was colonised by human groups relatively early. The appearance of agricultural cultures, particularly the period from 3,800 to 2,800 years BC, caused profound changes in the environment (e.g. KRUK et al. 1996, MOSKAL DEL-HOYO et al. 2018). Their main symptom was deforestation, not only of valleys, but also slopes and plateaus. As a consequence, on the one hand, there were the deep transformations of ecosystems; whereas, on the other hand, there were increases in the rate of denudation as well as in the frequency of floods (e.g. KALICKI & KRĄPIEC 1996, STARKEL 2000, 2007, STARKEL et al. 2007, GĘBICA 2011, GĘBICA et al. 2015).

The malacological studies of the sediments of the Vistulian (loesses) and the Holocene in the Szreniawa River catchment have been conducted over more than ten years. In the upper part of the valley, between Wolbrom and Miechów, three locations with Holocene calcareous tufas were identified and described (Sulisławice, Rzeuśnia, and Trzebienice) (PAZDUR 1987, ALEXANDROWICZ 2004, 2012). Several profiles of other deposits (loess, river and slope) were also studied (ALEXANDROWICZ et al. 1984, ALEXANDROWICZ 1995).

The principal objective of the presented study was to characterise the variability among the malacofauna assemblages occurring in the sediments filling the Szreniawa oxbow. These considerations constitute the basis for the reconstruction of environmental changes, taking into account short-term fluctuations, particularly the phases of climate drying and moisturising during the Late Holocene.

SITE DESCRIPTION

The Szreniawa River is a left-bank tributary of the Vistula River. The greater part of its catchment area is situated within the Miechów Upland, and the Proszowice Plateau (TYCZYŃSKA 1959, BAŚCIK & PARTYKA 2011, MICHNO 2016). The study area is situated in the central part of the valley, approx. 3 km east of the town of Słomniki, in the village of Topola (Fig. 1) (GPS 50°13'39"N, 20°09'26"E). In this section, the width of the Szreniawa River valley reaches approximately 1.7 km. The substrate of the study area is made of Upper Cretaceous marls covered by Quaternary sediments represented by Pleistocene sands with Scandinavian material, and by loesses associated with the last glacial cycle (GILEWSKA 1959, RUTKOWSKI 1965, MICHNO 2016). At the bottom of the valley, there are Holocene sediments, including sands, and loess deluvia. Peats and carbonate deposits (gyttjas, and calcareous tufas) occur locally (GILEWSKA 1959). In the aforementioned section, the Szreniawa is a meandering river, flowing in a flat-bottomed valley. On both sides of the river bed there is a flat and wide floodplain 1–1.5 m above the

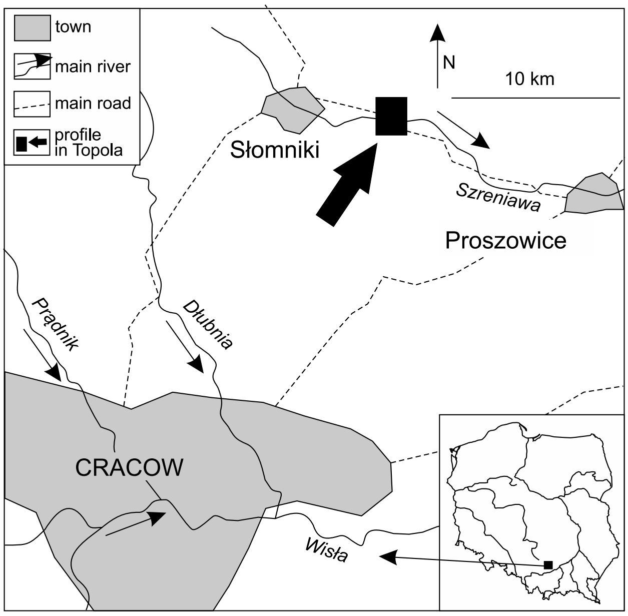

Fig. 1. General location of the oxbow lake near Topola Village

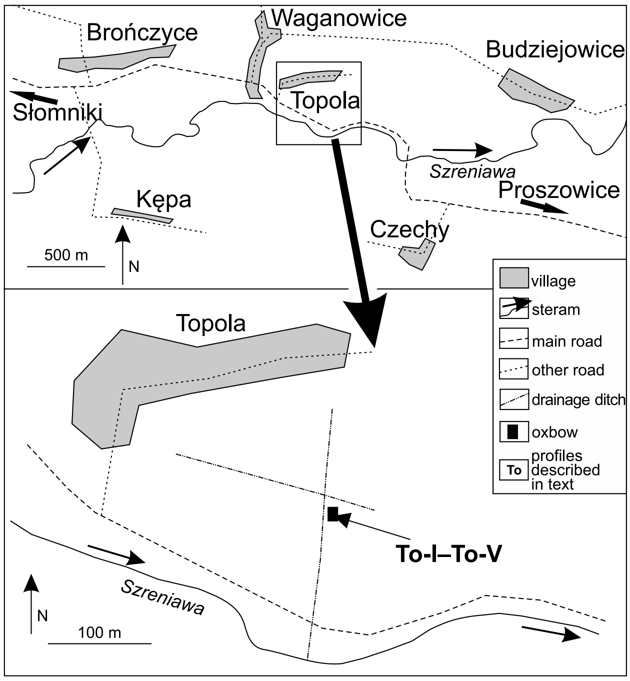

Fig. 2. Precise location of the oxbow lake near Topola Village

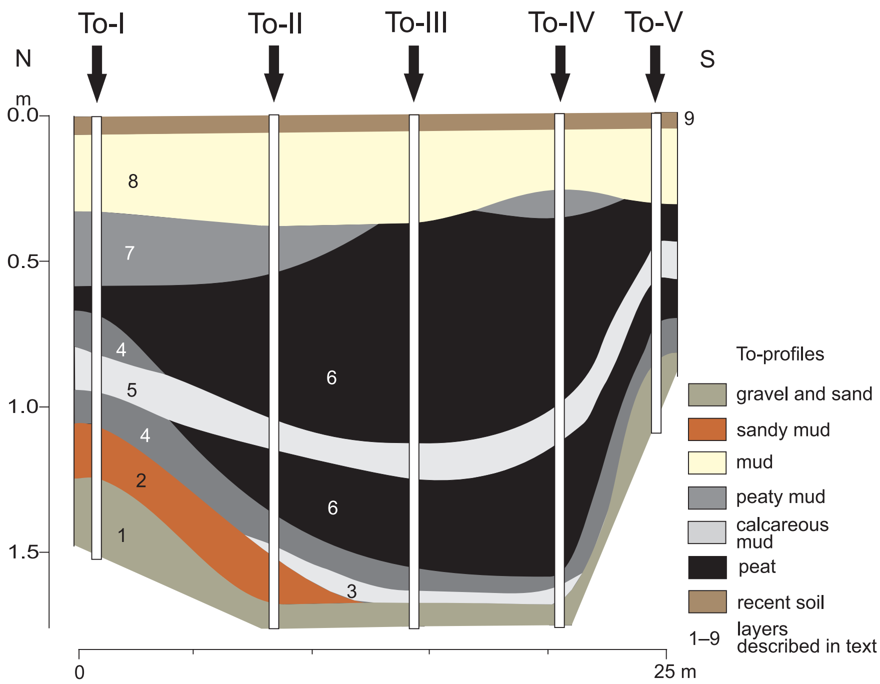

Fig. 3. Profiles and lithology of deposits filling the oxbow lake in Topola Village

river water level. In the area of the village of Topola, there were drainage ditches dug out where the profile of floodplain sediments, as well as the profile of sediments filling the oxbow lake were exposed (Fig. 2). The floodplain is composed of medium- and fine-grained sands containing few small blocks of the Upper Cretaceous marls, as well as much crushed fragments of shells of large bivalves of *Unio* (layer 1). The oxbow lake investigated in this study is approx. 25 m wide with a maximum depth of 1.5 m (Fig. 3). It is completely filled with sediments and cannot be seen from the surface of the floodplain. The material for malacological studies was collected from five profiles (To-I – To-V), along N–S cross section of oxbow lake (Figs 2, 3). In the central section of the oxbow lake, grey calcareous mud (layer 3) whose thickness reaches up to 10 cm overlie alluvial sands with gravels (layer 1) and/or sandy mud (layer 2). Above those, dark-grey peaty muds with very numerous plant remnants and abundant malacofauna occur (layer 4). Those are exposed in all profiles, and their thickness ranges between 15 and 25 cm. In the central part of the oxbow, black peats with no mollusc shells occur on the above-described muds (layer 5). They are a principal component of sediments filling the palaeomeander. In the northern part, their thickness is the lowest (approx. 10 cm), and, in the central and southern parts, it reaches 1 m. Within the peats, a characteristic layer of pale calcareous muds (layer 6) appears, with abundant and well-preserved shells. The thickness of the layer is similar throughout and amounts to 10–15 cm. On the peats, principally within the northern part, dark peaty muds with numerous plant remains and mollusc shells appear (layer 7). The aforementioned sediments are overlain by yellow muds with malacofauna (layer 8). Their thickness is 20–30 cm. The top is formed by a layer of recent soil (layer 9) (Fig. 3).

MATERIAL AND METHODS

Samples were taken for malacological analysis from the five profiles representing the cross-section through sediments filling the oxbow lake. The samples were taken at 5–15 cm intervals, depending on lithology of the sediments. In the laboratory, the samples were washed on a 0.5 mm sieve, and mollusc shells (both whole specimens and their fragments) were picked out. The identification was performed with the use of identification guides (Wiktor 2004, Welter-Schultes 2012, Piechocki & Wawrzyniak-Wydrowska 2016), and of comparative collections. In the samples, individuals of each taxon were counted. The broken fragments still identifiable to species were recalculated into the whole specimens in accordance with the formula developed by Ložek (1964). The further course of the analysis followed standard methods described by Ložek (1964) and Alexandrowicz & Alexandrowicz (2011). Individual taxa were allocated to ecological groups in accordance with the scheme presented by Alexandrowicz & Alexandrowicz (2011), and by Juřičková et al. (2014). In the studied materi-

Table 1. Composition of malacofauna in profiles To-I and To-II (samples 1–27). Symbols of ecological groups (E): F_B – species of sparse forests and bush zones, O_X – xerothermic species, O_O – open-country species, M_D – mesophilous species of dry habitats, M_I – mesophilous species, M_H – mesophilous species of humid habitats, H – hygrophilous species, W_T – species of temporary bodies of water, W_S – species of permanent bodies of water

E	Taxon	To-I																		To-II								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
F_B	*Fruticicola fruticum*			4		1				4	7							1						10	5	5	1	
O_X	*Cecilioides acicula*															24	18	16	29							12	28	34
	Helicopsis striata															3	2	3	5							1		
O_O	*Vallonia costata*	54	29	52	52	8		2	17	106	64	3	3		11	39	44	42	29	5	27	18	9	2	31	19	22	31
	Vallonia pulchella	298	45	163	128	83	6	69	871	501	357	118	163	34	76	78	94	65	89	23	39		56	30	438	98	79	101
	Pupilla muscorum	39	16	45	30	8	3	45	398	218	42	8	5	6	9	21	25	22	19	3	9		7	2	30	6	3	1
	Truncatellina cylindrica		4	8	7	1			1	8	4					3	5	1				2						
	Vertigo pygmaea	26		4	1	2	1	10	38	17	16	3	3		1	39	22	17	18		3	5			15	2		
M_D	*Cochlicopa lubricella*			3													3		4			14				6		
M_I	*Cochlicopa lubrica*	71		5	3	6	5	16	83	36	15	10	25	5	12	8	14	13	17	7	8		3	5	74	12	15	8
	Punctum pygmaeum	2																		3	2	1			8	2	1	8
	Euconulus fulvus															2	4			2		2		1		2		
	Perpolita hammonis				1								8	1	2	3	3	1	1	4	1	2	1		19	3	4	
	Limacidae	9	5	8	9	5		1	3	9	7	3	2	2	2	1		5		1	4		4	3	15	3		
M_H	*Carychium tridentatum*	3				4				2	7									5	10	2		2	1	1		
	Succinella oblonga	187		1	7	10	2	36	246	62	34	58	55	18	19	121	9	3	8	4	21	6	17	3	118	29	14	9
	Vertigo angustior	122	9	15	2	22		8	21	37	62	7	13	1	1	3				2	15		4	8	84	17	3	
	Perpolita petronella	18	2		2	4				7	7	1		1	1	2						1	4	4	2			
	Perforatella bidentata	5		1		4			4	3	4	35				3				1	7			1	17	6		
H	*Carychium minimum*	1		2		6		1		1	1	5	10		3	1	8	3		7	12	7	2	12	81	6	1	
	Succinea putris	151	1	2		4	16	36	14	1		68	30	12	24	3	1			12	15	12	38	12	126	4		
	Vallonia eniensis	13							6		3	1	4	3				1					9	11		2		
	Vertigo antivertigo	1		2				2			2	1				1				5	12	1			116			
	Zonitoides nitidus				1			3				10	5	2	2							1	3	2	3			
	Pseudotrichia rubiginosa	8				1	4	5	2	1			30	11	5					10	17	3	12	7	22			
W_T	*Valvata cristata*	5	4	5	1	1	12	27					2	4	13					25	7		5	1	7			
	Galba truncatula	34		2		5	25	36	6	3	1	5	4							17	12		1	1	6			
	Aplexa hypnorum																					6	1	1				
	Planorbis planorbis						4					6		3	7					4	3	3						
	Anisus leucostoma	11		2		1	21	44		1		4	3								2	1		1	8			
	Pisidium obtusale						8							1	4													
W_S	*Bithynia tentaculata*		1	11	15	3		15	1											3				1	1			
	Radix peregra				5	4	5	27												22	7	5	7		1			
	Anisus contortus					2	2	12												14	5	10	1					
	Planorbarius corneus						13	17															47					
	Pisidium subtruncatum	1			4	8	5	13												10	3		4		1			
	Pisidium casertanum						10													15	5			1				

al, the species of nine ecological groups appeared (F_B – species of sparse forests and bush zones, O_X – xerothermic species, O_O – open-country species, M_D – mesophilous species of dry habitats, M_I – mesophilous species, M_H – mesophilous species of humid habitats, H – hygrophilous species, W_T – species of temporary water bodies, W_S – species of permanent water bodies). The proportion of particular ecological groups provided the basis for the construction of malacological diagrams. The triangular diagrams were also constructed for particular profiles, presenting the sequences of fauna assemblages. The palaeoecological analysis was conducted based on the dendrogram of similarities (Morisita 1959) and enabled the identification of several ecological faunal associations. In constructing the dendrogram, the PAST statistical package was used (Hammer 2001). The data collected enabled reconstructing past environmental changes. The ages of the sediments were determined via three radiocarbon datings employing the use the OxCal software package (Bronk Ramsey 2003) and on the basis of the occurrence of characteristic species of molluscs.

Table 2. Composition of malacofauna in profiles To-III, To-IV and To-V (samples 28–45). For explanation see Table 1

E	Taxon	To-III							To-IV						To-V				
		28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
F_B	*Fruticicola fruticum*									5				17	4				
O_X	*Cecilioides acicula*						12	31						47				18	26
	Helicopsis striata							1						4				2	6
O_O	*Vallonia costata*	17	21	9	3	20	54	83	21	17	24	21	430	97	19	24	24	36	36
	Vallonia pulchella	24	14	26	1	476	124	117	31	35	31	33	542	111	28	38	35	46	57
	Pupilla muscorum	5	5			11	12	19	2					2	13	7	9	18	21
	Vertigo pygmaea	1	1			20	10	22					8	8	5	1	4	14	25
M_I	*Cochlicopa lubrica*	2	2	4		52	17	8	10	9	12	13	39	14	8	12	14	5	12
	Punctum pygmaeum		7			10	12	3	1	2	1		17	4	6	8	4	8	1
	Euconulus fulvus	1	2				2		1	3					2	1			
	Perpolita hammonis	10	8	5	1	14	22	7	3	8	14	13	63	8	2	9	8	12	3
	Limacidae		3	5		14	8	1	1	2	5	2	16	1	1	2	6	3	7
M_H	*Carychium tridentatum*	6				2	10	14	15	3	8	4	92	8	11	7	4	8	1
	Succinella oblonga	17	39	22	12	202	47	6	18	12	22	17	17	21	14	21	21	3	5
	Vertigo angustior	3	7	14	5	209	54	1	23	46	83	43	149	14	21	34	35	1	
	Perpolita petronella	2		2	1	2	3		1	1	1		28	4					
	Perforatella bidentata	1	8			25	7		3	39	33	12	31	7	7	9	7		
H	*Carychium minimum*	5	9	8	7	23	12	1	18	46	44	37	109	8	7	17	14	2	
	Succinea putris	22	21	22	19	35	31	5	14	24	39	28	13	5	6	29	22	1	
	Vallonia eniensis	15	14	3	2	17	3	1	11	32	29	33	29	1	5	22	19	8	
	Vertigo antivertigo	11	12		5	11	17	7	17	53	58	41	30	3	4	31	29	5	
	Zonitoides nitidus	4	7	1	8	3	8		2	17	14	13	10			8	7		
	Pseudotrichia rubiginosa	7	10	2		27	5		5	21	11	4	1			4	2		
W_T	*Valvata cristata*	21	4	31	29	6	3		24	8	33	21	12			5			
	Galba truncatula	17	12	29	19	6	12		34	17	39	29	7			7	2		
	Aplexa hypnorum	3		19	21						12								
	Planorbis planorbis	9		14	16				16	2	25		3			9			
	Anisus leucostoma	7	3	7	26	10	7		18	22	41	14				12	5		
	Pisidium obtusale	12		25	8		5		12	12	16	4	6			5	1		
W_S	*Bithynia tentaculata*	4		3	2	1			3		1	1	8						
	Radix peregra	16		15	7	3			22		13	14	3						
	Lymnaea stagnalis	3			2				1		2								
	Stagnicola palustris	3		21	22						12	3	2						
	Anisus contortus	6	4	17	29				12	1	5		2						
	Gyraulus albus	8		25	29				8		24	21							
	Planorbarius corneus	5		29	17														
	Pisidium subtruncatum	12		14	13	1			14		2	4	1						
	Pisidium casertanum	16		12	8				18		5	7	13						

RESULTS

Mollusc shells were found in 45 samples. In the remaining 46 samples, the malacofauna was not present or there were only single broken fragments usually excluding identification even to the level of genera. The malacofauna identified in the sediments filling the oxbow lake was rich and diversified. In total, 19,000 specimens representing 40 species (25 taxa of terrestrial snails, 12 species of water snails, and 3 species of bivalves) were identified. The number of taxa per sample ranged from 7 to 33, and the number of specimens ranged from 102 to 1,711 (Tables 1, 2).

The species of shaded and partly shaded habitats (ecological group F_B) were found only in a few samples and represented by single specimens of *Fruticicola fruticum* (Tables 1, 2, Figs 4–6). The open-country snails were present in all samples and often constituted the predominant component of the assemblage. Within the aforementioned group, both the xerophilous taxa, typical of the very dry habitats (ecological group O_X), and the species preferring more humid substratum (ecological group O_O) occurred. *Cecilioides acicula* – taxon very often living in agricultural areas and *Helicopsis striata* – a calciphilous form typical of very dry habitats should be allocated to the first group (O_X) (Tables 1, 2, Figs 4–6). The species of ecological group O_O, particularly *Vallonia pulchella*, occurred in very high numbers. That taxon was found in almost all samples and sometimes attained very high numbers. In total, nearly 6,000 shells of this species were identified (more than 30% of all specimens). *Vallonia costata* and *Pupilla muscorum* were less abundant (Tables 1, 2, Figs 4–6). Mesophilous snails, which are characteristic of dry habitats (M_D) and of moderately humid habitats (M_I), were relatively few, although their presence was found in all

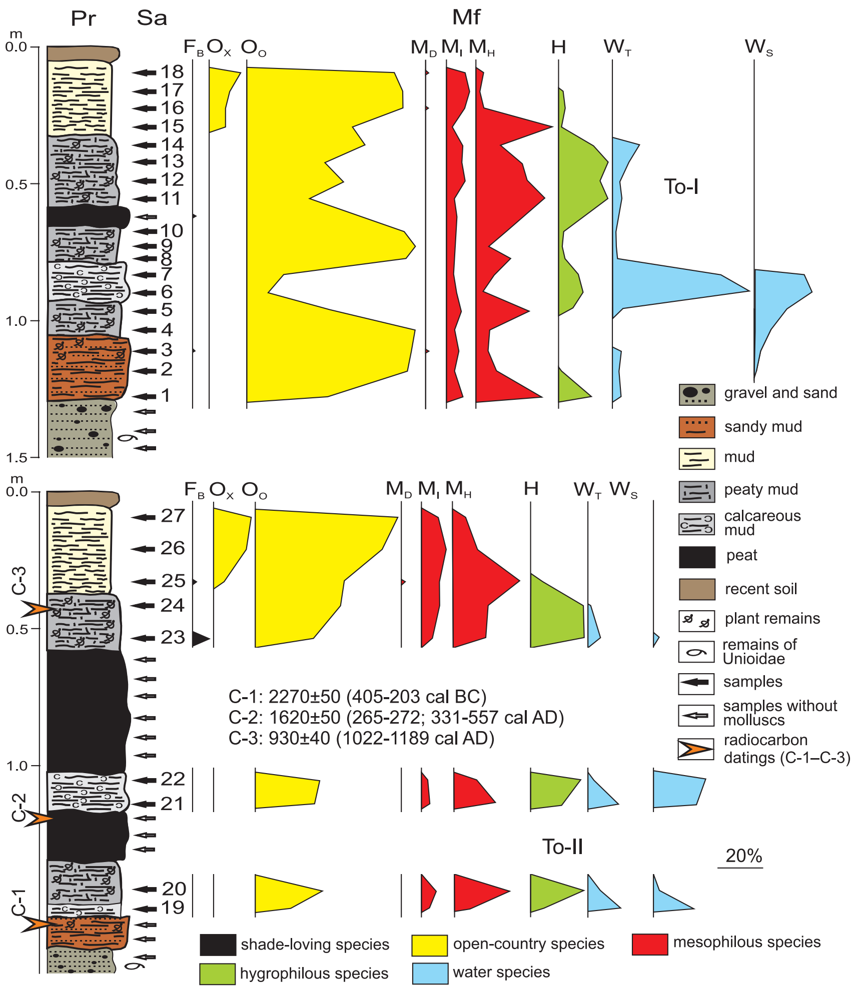

Fig. 4. Malacological percentage diagrams of profiles To-I and To-II. Pr – lithology of the profiles, Sa – samples, Mf – malacofauna (symbols of ecological groups: F_B – species of thin forests and bush zones, O_X – xerothermic species, O_O – open-country species, M_D – mesophilous species of dry habitats, M_I – mesophilous species, M_H – mesophilous species of humid habitats, H – hygrophilous species, W_T – species of temporary water bodies, W_S – species of permanent water bodies), C-1 – C-3 radiocarbon datings

samples. *Cochlicopa lubrica* and *Perpolita hammonis* are the most important representatives of the discussed groups. Mesophilous species typical of humid habitats (M_H) occur much more frequently. *Vertigo angustior* and *Succinella oblonga* appear particularly often. Both these forms inhabit moist, water-logged, open habitats (Tables 1, 2, Figs 4–6). Hygrophilous species (ecological group H) form an essential component of the fauna. They commonly appear in all profiles, except for their top sections. Sometimes they constitute a predominant component of the assemblage. The group also includes the taxa living in very humid terrestrial habitats, even those seasonally flooded. *Succinea putris* is a characteristic representative of

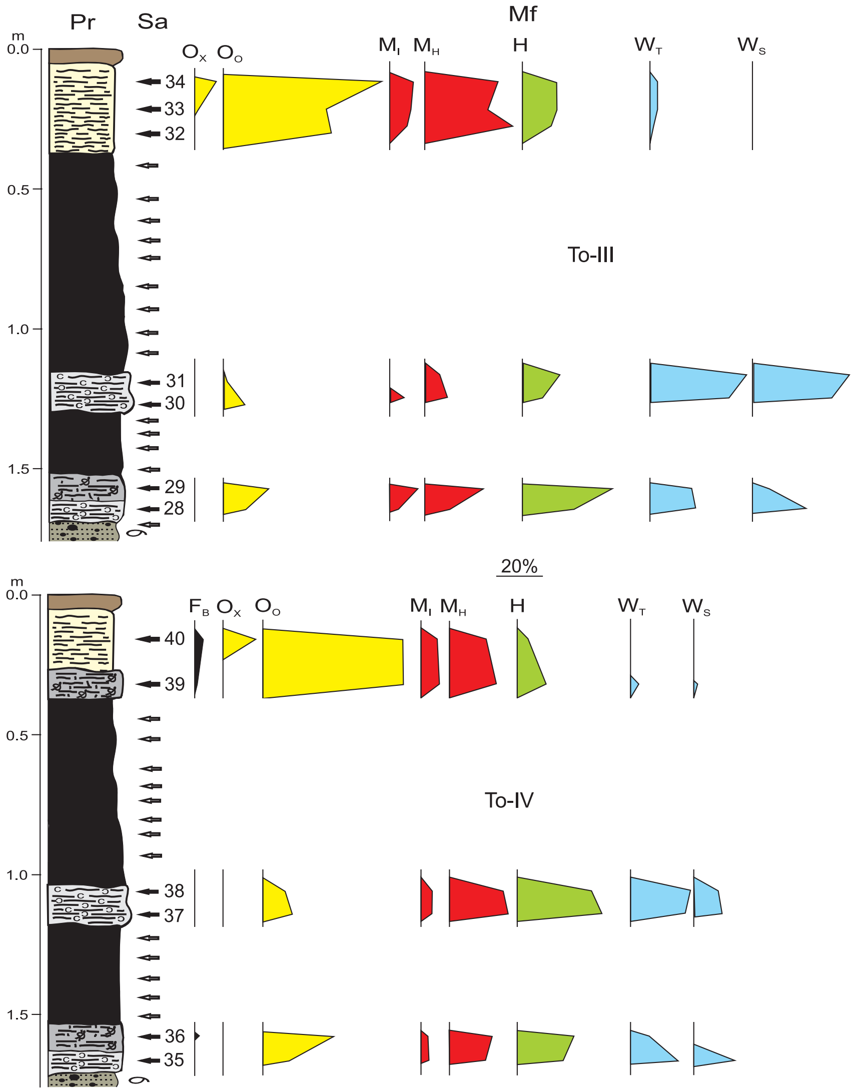

Fig. 5. Malacological percentage diagrams of profiles To-III and To-IV. For explanation see Fig. 4

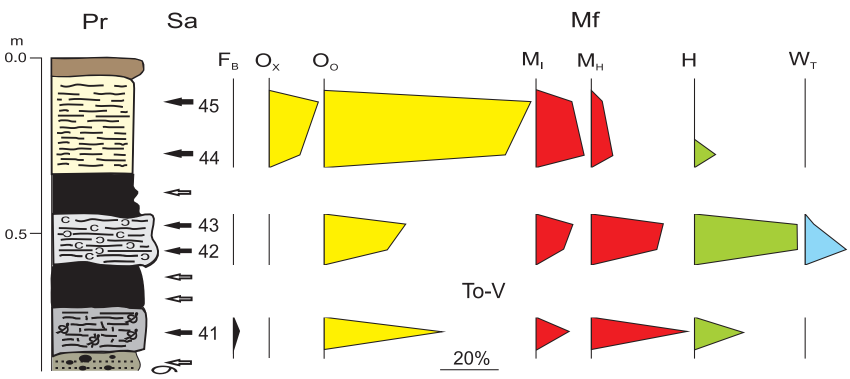

Fig. 6. Malacological percentage diagrams of profile To-V. For explanation see Fig. 4

that group. Moreover, *Vertigo antivertigo* and *Vallonia enniensis* are numerous (Tables 1, 2, Figs 4–6). From the viewpoint of the reconstruction of the oxbow's history, the aquatic species play a very important role. Here, the taxa typical of seasonal water bodies, well-enduring the episodes of drying-out and capable of surviving long periods in a very humid terrestrial habitats (ecological group W_T) should be taken into account. *Galba truncatula*, often accompanied by *Anisus leucostoma* and *Valvata cristata*, is a commonly occurring and the most typical representative of the group. The other group of water molluscs includes the species of shallow, permanent water bodies with abundant vegetation (ecological group W_S). The group includes the forms poorly capable of surviving drying-up phases: *Bithynia tentaculata*, *Pisidium subtruncatum*. These taxa appear in fair numbers, but only in some samples (Tables 1, 2, Figs 4–6).

DISCUSSION

The mollusc assemblages identified in the sediments filling the oxbow near the village of Topola show clear diversification in both vertical profile and horizontal section. The vertical section of the assemblages reflects the changes in environmental conditions during the process of filling the oxbow by sediments. The lateral variations show the differentiation of habitats within the oxbow lake.

FAUNISTIC ASSEMBLAGES

On the basis of projection triangles and dendrograms, it is possible to distinguish five types of faunal assemblages (Figs 7, 8).

Assemblage with water species (Wa). It shows high frequencies of aquatic forms whose proportion can exceed 50% of the whole assemblage. The analysis of the dendrogram allows the separation of two subtypes of fauna. The first (Wa-A) is characterised by a marked proportion of species whose survival of drying-up periods is poor. It corresponds to the phases of the continuous presence of a small body of stagnant water, with little depth, and abundant vegetation. The aforementioned malacoenosis appears exclusively in the central part of the oxbow lake, and it is associated with calcareous muds (Figs 4–8). The second subtype (Wa-B) is characterised by the predominance of species typical of seasonal water bodies. It corresponds to the periods of drying of the oxbow and a gradual transformation of a water body to terrestrial habitats with very high humidity. Although the assemblage with water species occurs in all profiles, it plays the most important role in the central part of the water body (profiles To-II – To-IV). In the marginal parts (profiles To-I and To-V), the aforementioned fauna is present only in short intervals (Figs 4–8).

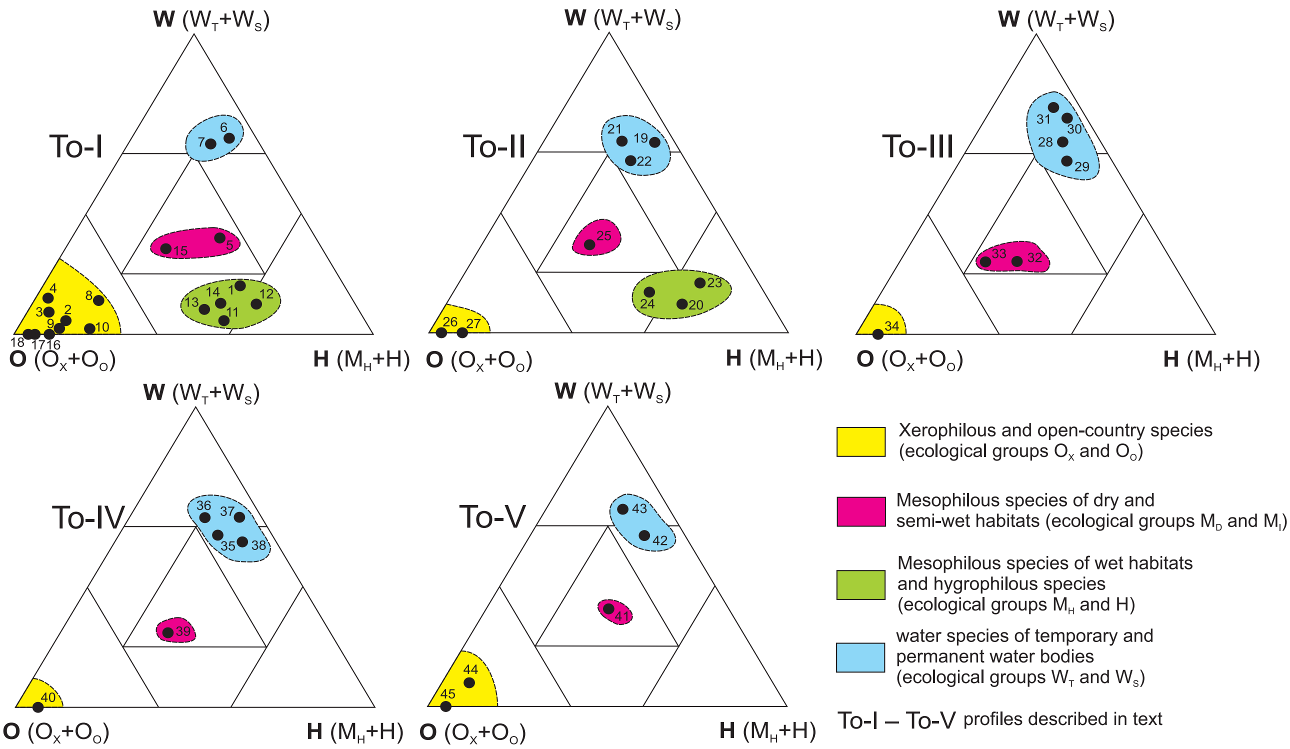

Fig. 7. Types of mollusc assamblages in particular profiles

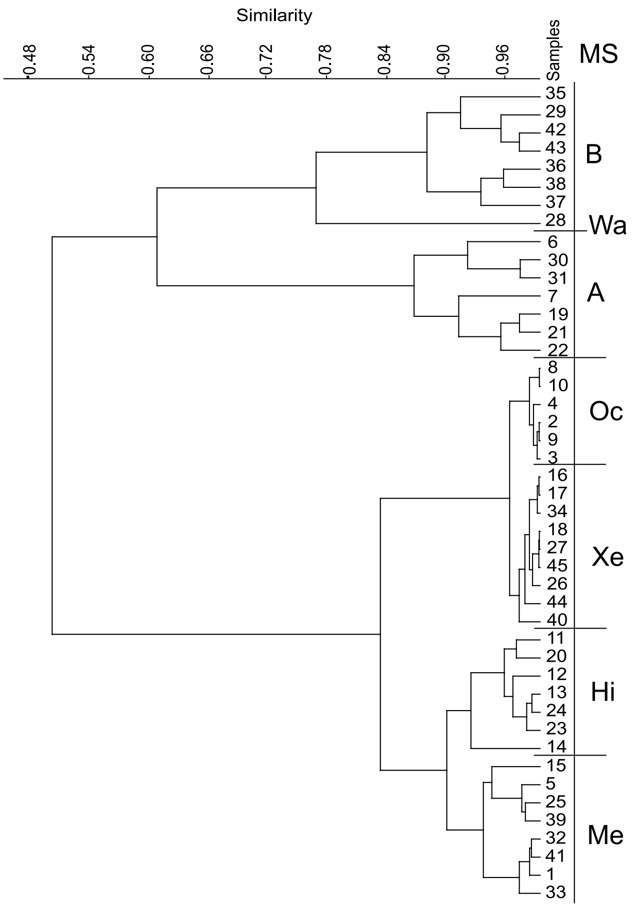

Fig. 8. Cluster analysis of the malacofauna from deposits filling the oxbow lake near Topola Village. MS – mollusc assemblages described in text

In the assemblage with hygrophilous species (H_I), the assemblage occurs only in profiles To-I and To-II. It appears in peaty silts in the higher part of the sequence (Figs 4, 7, 8). The principal component of the assemblage consists of species preferring water-logged, open habitats: *S. putris*, *Carychium minimum*, and *Zonitoides nitidus*. A relatively abundant occurrence of the rare species of *V. enniensis* is a faunistic curiosity here. Mesophilous taxa of humid habitats (*V. angustior*, *S. oblonga*) are usually abundant there. Aquatic species appear relatively rarely, and they include only the forms surviving well during the drying-up phases of water bodies. The snails of relatively dry open habitats, principally *V. pulchella* and *V. costata,* are again relatively rare. The discussed fauna corresponds to the phase of the disappearance of the oxbow and its transformation into a water-logged, open terrestrial environment. That could be linked with the final phase of oxbow filling.

In the assemblage with mesophilous species (M_I), although the assemblage appears in all profiles, it is represented only by single samples corresponding to short intervals (Figs 4–8). The great proportion of euryoecious terrestrial species (*Euconulus fulvus*, *Punctum pygmaeum*, and *P. hammonis)*, accompanied by snails of open-country and relatively dry habitats (*V. pulchella* and *V. costata*), is its characteristic feature. The proportion of forms typical of wet habitats is low. The aforementioned fauna is indicative of progressive drying of habitats at the site of the already filled oxbow.

In the assemblage with open-country species (O_O), the malacocoenosis was identified in the lower part of profile To-I (Figs 4, 7, 8). It is characterised by a very abundant occurrence of *Vallonia pulchella* and *Vallonia costata*. The open-country species constitute more than 60% of the assemblage. The mesophilous snails complement it. Hygrophilous or even aquatic species also occur there. The discussed fauna represents the marginal part of the oxbow and corresponds to the period of short-lived reduction of the extent of the water body.

The assemblage with xerophilous species (O_X) is the fauna typical of the top parts of all profiles (Figs 4–8). It is characterised by the predominance of open habitat species (*P. muscorum*, *V. pulchella* and *V. costata*). Its typical feature is the occurrence of *C. acicula*. It is a species living in soil and often associated with agricultural lands (Evans 1972, Alexandrowicz et al. 1997, Alexandrowicz 2004). The remaining ecological groups are of lesser significance. The aforementioned malacoenosis is characteristic of dry habitats that developed in the floodplain after the complete filling and drying of the oxbow.

DIVERSITY IN THE FAUNA ASSEMBLAGES WITHIN THE OXBOW

The Szreniawa Oxbow near the village of Topola is a small form feature not exceeding 25 m in width. Despite that, the succession of faunal assemblages and of sediments in particular profiles shows differences. In the central part of the oxbow (profiles To-II – To-IV), they are characterised by the presence of peats (layer 6) without mollusc shells. The thickness of these inserts is significantly reduced in the marginal parts (profiles To-I and To-V). In profile To-I, the peats are partly replaced by peaty muds (layer 7) with numerous remnants of vegetation and a malacofauna (Fig. 3). The significant differences between the central and marginal parts of the oxbow are also visible in the variability among mollusc assemblages. The assemblages with major proportions of water species and hygrophilous land forms predominate in the central part. The evident drying up of the habitats is marked only in the roof part of the sequence (Fig. 9). The malacofauna identified in the profiles representing the lakesides is characterised by a markedly lower proportion of aquatic forms which are replaced by hygro- and mesophilous as well as open-country forms which are more xerophilous (Fig. 9). These observations indicate that, in the central part of the

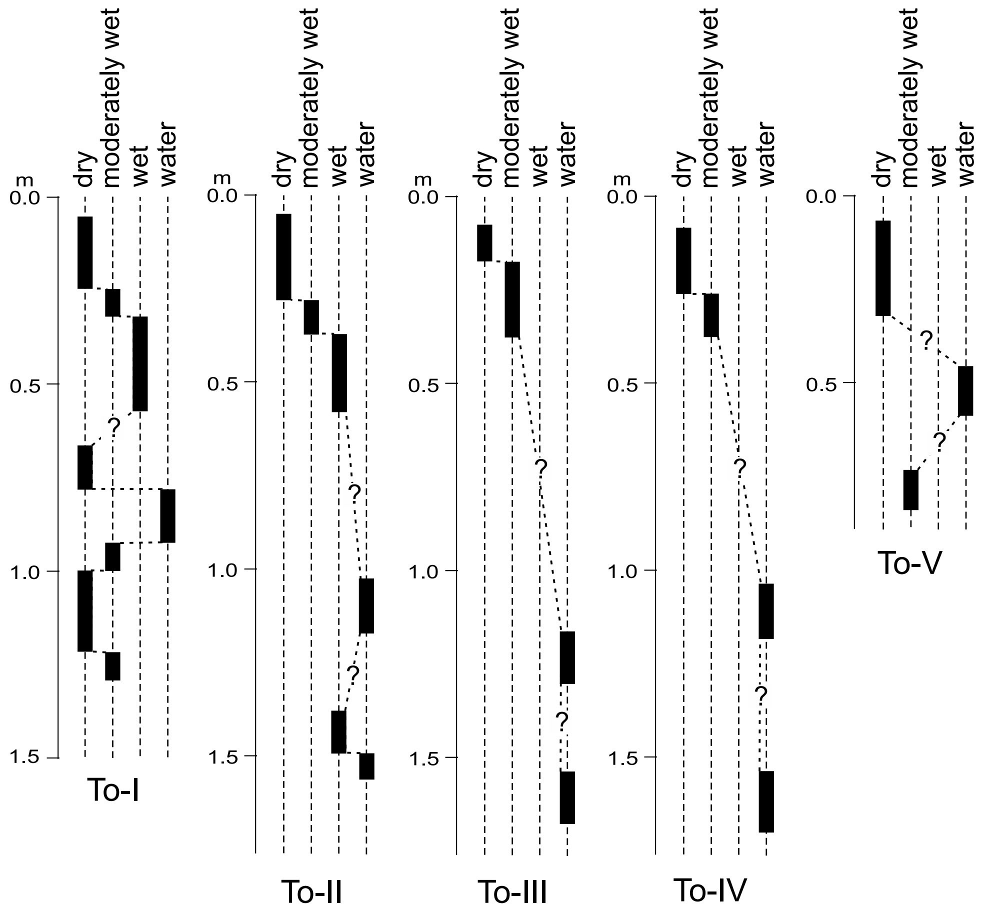

Fig. 9. Vertical differentiation of mollusc fauna within the oxbow lake near Topola Village

oxbow, throughout the whole period of its functioning, there was a shallow water body, occasionally drying up. In the marginal parts, terrestrial habitats with a high level of moisture predominated. These were more vulnerable to drying up and transforming to drier, open habitats. After the complete filling of the oxbow, the conditions became uniform throughout it, and the malacofauna became dominated by open-country and xerophilous species (Fig. 9).

EVOLUTION OF THE OXBOW

The diversity of the fauna, lithology of profiles and the results of radiocarbon analysis facilitate the distinction of several phases of the oxbow development and its age (Fig. 10).

Phase I represents the period preceding the emergence of the oxbow with medium- and fine-grained sands with gravel containing broken fragments of shells of large bivalves of the genus *Unio* (layer 1). These are sediments of running waters, probably of channel facies. In the top of layer 1, traces of erosion associated with the functioning river bed can be found. It is likely that the erosion processes led to washing out and removing sandy muds (layer 2) from the central part of the bed. They are preserved only in the northern part of the emerging oxbow. Such sediments were described in many profiles within the Szreniawa River valley (Michno 2016) as well as in other valleys within the Central Polish Uplands (Alexandrowicz et al. 1984, Alexandrowicz 1988, 1991, 1992) (Fig. 10).

Phase II was the period of initial channel infill. In its central part, a thin layer of calcareous muds (layer 3) contains a rich malacofauna with a great proportion of water species, indicative of the presence of a shallow, permanent body of stagnant water. In the northern part (profiles To-I and To-II), the aforementioned layer is replaced by peaty muds (layer 4) with admixture of fine-grained sands and plant remains. The radiocarbon dating of these remains gave the result of 2,270±50 years BP (405–203cal BC). This date marks the emergence of the oxbow. The presence of peaty muds in the marginal part of the oxbow is an indicator of its shallowing, and of the development of boggy habitats covered with abundant vegetation. It corresponds with the cold period of the late part of the Iron Age (e.g. Bond et al. 2001, Mayewski et al. 2004, Swindles et al. 2008). At that time, the phase of intensified fluvial actions of rivers and increased floods are marked in many valleys within the Central Polish Uplands and in the Carpathians (e.g. Kalicki & Krąpiec 1996, Starkel 2000, 2007, Starkel et al. 2007, Gębica 2011, Gębica et al. 2015). Presumably,

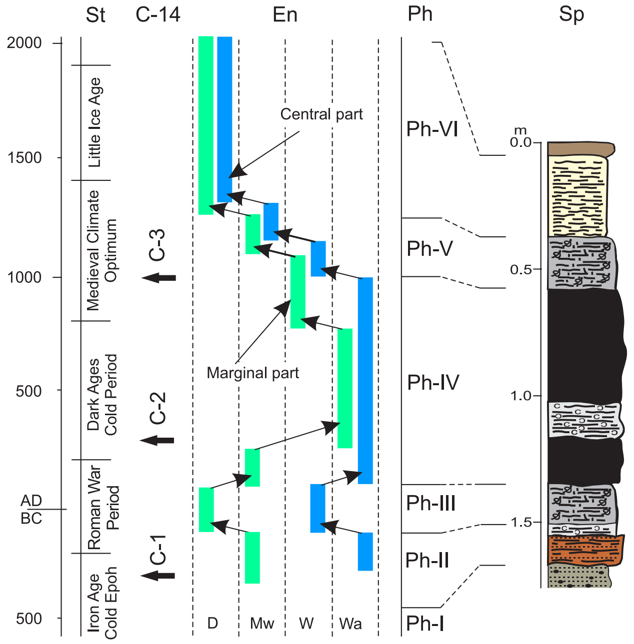

Fig. 10. Evolution of the oxbow lake near Topola Village during Late Holocene. St – stratigraphy, C-14 – radiocarbon datings, En – environmental changes; types of habitats: D – dry, Mw – moderately wet, W – wet, Wa – water, Ph –phases of development of the oxbow lake (described in text), Sp – synthetic lithological profile, La (1–9) – layers described in text

it is that period with which the shift of the Szreniawa River bed and cutting off its meander should be associated (Fig. 10).

Phase III represents a short period of the drying up of the oxbow. In the central part, the extensively waterlogged terrestrial habitats emerge. The disappearance of the species of permanent water bodies is observed, and these are replaced by the forms typical of episodic bodies of water, and by hygrophilous species. This drying-up effect is marked more clearly in the marginal part of the oxbow where the mesophilous and hygrophilous taxa, abundant in the previous phase, are replaced by snails of open habitats that prefer a relatively dry substrate. The nature of the sediments is also altered. In this section, the main role is played by dark peaty muds with numerous plant remains (layer 4). In terms of age, the aforementioned deposits can be linked to the climatic warming corresponding to the Roman Warm Period (Tinner et al. 2003, Davis et al. 2003, Mayewski et al. 2004) (Fig. 10).

Phase IV is the principal period of the filling of the oxbow. During that time, the entire depression is filled with water. It is supported by the presence of molluscs typical of permanent water bodies, noted in all profiles. The sediments representing the described section are primarily peats (layer 6). No mollusc shells were preserved there. Within the peats, there is a characteristic insert of pale calcareous muds, containing very many mollusc shells (layer 5). The floor of the insert was dated by the radiocarbon method at 1,620±50 years BP (265–272 and 331–557 cal AD). The date corresponds to the climatic cooling (Dark Ages) (Davis et al. 2003, Mayewski et al. 2004). In that period, there was the increase in the fluvial activities of rivers (e.g. Kalicki & Krąpiec 1996, Starkel 2000, 2007, Starkel et al. 2007, Gębica 2011, Gębica et al. 2015). The malacological record does not indicate any activation of the oxbow in the period. No traces of erosion and/or accumulation-related activities of fluvial waters are found in the sediments. Also, no rheophilous species of molluscs occur. The diversification of the fauna assemblages and the lithological variability seen in the section of the oxbow indicate that it was more stable in its central part. Here, it survived for the longest time. At the edges, its disappearance is marked near the end of the Dark Ages Cold Period, and, in the central part, its disappearance is as late as the Medieval Climate Optimum (e.g. Bradley 2000, Briffa 2000, Jones & Mann 2004) (Fig. 10).

Phase V has a lower limit determined by the end of peat deposition. The peats are replaced by dark peaty muds with abundant plant remains (layer 7). The beginning of their deposition was dated by the radiocarbon method at 930±40 lat BP (1,022–1,189 cal AD). Therefore, it corresponds to the warm phase of the Medieval Climate Optimum (e.g. Bradley 2000, Briffa 2000, Jones & Mann 2004). In that period, there are drying-up effects marked in both the central and marginal parts of the oxbow. They show as a gradual disappearance of aquatic molluscs being replaced by hygrophilous and mesophilous species. An increasing role is assumed by xerophilous species of open habitats. This phase represents the final stage of the oxbow development (Fig. 10).

Phase VI represents the period of deposition of yellow, calcareous muds (layer 8). Their emergence can be probably associated with the intensification of denudation on valley slopes and the increased supply of fine-grained material onto the floodplain. Within the aforementioned muds, the assemblage of small species diversity was identified, where xerophilous species typical of open habitats predominated. A very characteristic species present in the topmost parts of all profiles is *Cecilioides acicula*. That species is associated with farmlands (Evans 1972, Alexandrowicz et al. 1997, Alexandrowicz 2004). The intensified denudation on slopes can be linked to the phase of climatic cooling (Little Ice Age) (Bradley & Jones 1993, Bradley 2000, Briffa 2000, Jones & Mann 2004). Similar phenomena were described in a great number of profiles in the Central Polish Uplands, as well as in the area of the Carpathians and their foreland (e.g. Kalicki & Krąpiec 1996, Starkel 2000, 2007, Starkel et al. 2007, Gębica 2011, Gębica et al. 2015) (Fig. 10).

CONCLUSIONS

Oxbow lakes are typical of floodplains. The specific conditions prevailing in such water bodies can make them suitable for malacological studies. The malacoenoses contemporarily living in oxbow lakes have been described in many locations (e.g. Jurkiewicz-Karnkowska 2009, 2015, Lewin 2014). Older, infilled oxbows, are often no longer marked in the relief of floodplains. Their usually high content of plant remains leads to formation of sediments with acid reaction (primarily peats). Because of that, the calcareous shells of molluscs dissolve quickly, and they are not preserved in the sediments. In consequence, subfossil malacoenoses occurring in the fillings of oxbow lakes are only preserved in certain circumstances.

The mollusc assemblages identified in the channel infill near the village of Topola indicate the evolution of this form linked to climatic and environmental changes. The beginning of the aforementioned form falls in the wet period of the late part of the Iron Age. A small, shallow water body remained there for some 600–700 years, passing one phase of minor drying, probably falling in the Roman Warm Period. The disappearance and final drying of the oxbow can be linked to the Middle Ages. The intensified denudation during the Little Ice Age had led to the deposition of calcareous muds on which dry or even xerophilous habitats developed.

The discussed area of the Miechów Upland was subject to anthropogenic pressure relatively early. Its first essential symptom was extensive deforestation associated with the development of agricultural Neolithic cultures, principally the Funnel Beaker culture (e.g. Kruk et al. 1996, Moskal-del Hoyo et al. 2018). It is difficult to trace the indicators of anthropogenic pressure in the sediments filling the oxbow near the village of Topola. It may perhaps be linked to the adverse conditions, chiefly to the low position of the terrace, frequent floods, and the persisting high humidity of the substratum. After the oxbow was filled completely agricultural activity started in the area.

Oxbow lakes represent local habitats, usually small. The possibility to obtain large quantities of study material provides a chance to reconstruct the changes in the nature of habitats over time (in vertical profiles) as well as to consider the lateral diversification of malacoenoses within the oxbow itself. Such studies were conducted with respect to contemporary fauna (e.g. Jurkiewicz-Karnkowska 2009, 2015, Lewin 2014). In the cases of older fillings, usually only single profiles were analysed. Although such studies enabled the characterisation of the evolution of a given oxbow, they did not provide the possibility to describe the lateral diversification of malacoenoses developing in its various parts. In this respect, the location studied in this paper is unique to the whole of Poland.

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