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Malacofauna of the Holsteinian lake deposits at Hrud II (Eastern Poland) and its palaeoecological significance

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Mollusc-bearing deposits at Hrud II (Eastern Poland) accumulated in the western part of a palaeolake of Holsteinian age (MIS 11). The faunal assemblage is typical of freshwater environments and presumably represents a part of the interglacial climatic optimum (*Carpinus–Abies* Zone). On the basis of its varied composition, the evolution of the water body is described. Reinterpretation of the data from the eastern part of the lake (Hrud I) and combining of the results from both sites enable a wider palaeoecological reconstruction. Fluctuations in lake level, water dynamics and changes in the aquatic vegetation are inferred from quantitative relations between selected molluscs, especially *Lithoglyphus jahni*, *Valvata piscinalis* and *Bithynia tentaculata*, which prevail in the deposits investigated. A predominance of *Valvata piscinalis* indicates a rise in water level, whereas the communities with abundant *Bithynia* opercula are typical of a more shallow lake with rich reed fields. Amelioration of the trophic conditions between the pre-optimal and optimal part of the Holsteinian Interglacial can also be recognized.

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INTRODUCTION

Lacustrine deposits with molluscs were firstly described in the vicinity of Hrud near Biała Podlaska (Eastern Poland) at the beginning of the 1990s (Lindner *et al*., 1991). Their location, known as Hrud I, is connected with the eastern part of the depression between Ossówka and Hrud (Fig. 1), which is the shore zone of a palaeolake that existed in this area in the Holsteinian Interglacial (Lindner *et al*., 1991; Nitychoruk, 1994) corresponding to Marine Isotope Stage 11 (MIS 11; Nitychoruk *et al*., 2005, 2006). The lake was narrow (up to 1 km) and several kilometres long of a depth that reached over a dozen metres in the area of Hrud (Lindner and Marciniak, 1997; Nitychoruk, 2000, 2005). Carbonate gyttja and lake marl accumulated in its central part (Fig. 2). In the shore zone, silts, sandy silts as well as sands with fine gravel, abundant molluscs and locally with interbeds of gyttja were described and subjected to faunal and palaeobotanical analyses which confirmed their Holsteinian age (Lindner *et al*., 1991; Skompski, 1996; Krupiński, 2000). During further investigations mollusc-bearing deposits were also discovered in the western part of the lake and termed the Hrud II site, though molluscs were only briefly mentioned (Nitychoruk, 1994; Fig. 2). Although not as well studied as the eastern part of the lake, the preliminary results show distinct differences between the mollusc assemblages at Hrud I and II (Szymanek, 2011*a*, *b*). The clearest difference is a greater abundance of *Viviparus diluvianus* and fewer *Bithynia tentaculata* at Hrud II in comparison with Hrud I. The newly collected material is abundant, and the pollen as well as the snails *Viviparus diluvianus* and *Lithoglyphus jahni* are typical of the Holsteinian Interglacial in Poland (Szymanek, 2008*a*, 2011*a*).

The present paper describes in detail the molluscs from Hrud II and considers their environmental significance in relation to the palaeoecological interpretation made of the eastern part of the lake (Lindner *et al*., 1991). Palaeoecological conditions for the Hrud palaeolake, based on the molluscs, are reassessed.

MATERIAL AND METHODS

The well-preserved and numerous mollusc shells at Hrud II accumulated in fine-, medium- and vari-grained sands *ca*. 1.3 m thick covered by a thin layer of deluvial deposits. In this study eight samples at 10 cm intervals were taken for malacological analysis. They were collected from a small exca-

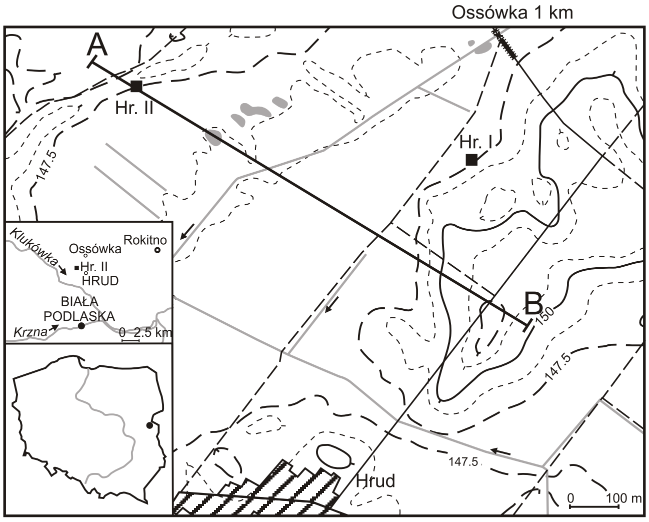

Fig. 1. Location sketch of the study area

vation in the depth interval 0.8–1.6 m. Approximately 3 litres of sediment per sample were wet-sieved using a 0.5 mm mesh. Mollusc shells and their fragments were then picked, identified and counted. Some incomplete specimens, especially thin-walled *Pisidium* bivalves were determined only to genus level. Standard malacological methods established by Ložek (1964), Alexandrowicz (1987) and Alexandrowicz and Alexandrowicz (2011) were applied. Firstly the molluscs were listed according to their environmental requirements (Table 1). Three ecological groups were distinguished at Hrud II: species of temporary water bodies – 10, species of permanent water bodies of stagnant waters – 11 and species of flowing waters – 12. During the interpretation supplementary classes after Ložek (1964, 1976, 1982) modified according to Körnig (1966), Piechocki (1979) and Skompski and Makowska (1989) were also considered (Table 1). In addition, for all samples, malacological spectra of species (MSS) and specimens (MSI; Fig. 3) as well as a simplified malacological diagram (Fig. 4) showing changes in the assemblage were constructed. Similar figures (Figs. 5 and 6) were drawn for the Hrud I site, to illustrate differences in mollusc composition and ecological changes in the water body. In this case the data of Lindner *et al*. (1991) and Skompski (1996) were used.

MOLLUSCS AND ENVIRONMENTAL CHANGES

HRUD II

The mollusc assemblage at Hrud II comprises 25 taxa – 9 species and 1 genus of snails as well as 13 species and 2 genera of bivalves, with a total of 19690 specimens (Table 1). The number of both taxa and specimens varies from 14 to 20 and from 1193 to 3766 per sample respectively. Despite some fluctuations it drops gradually towards the upper part of the section which may suggest a slight deterioration of the conditions. Only in sample 2 (0.9–1.0 m) was a distinct increase in number of specimens observed (Fig. 3).

All taxa recognised link the assemblage with freshwater environments (Table 1). Species characteristic of permanent water bodies of stagnant waters (ecological group 11) predominate but most of them can occur in both rivers and lakes.

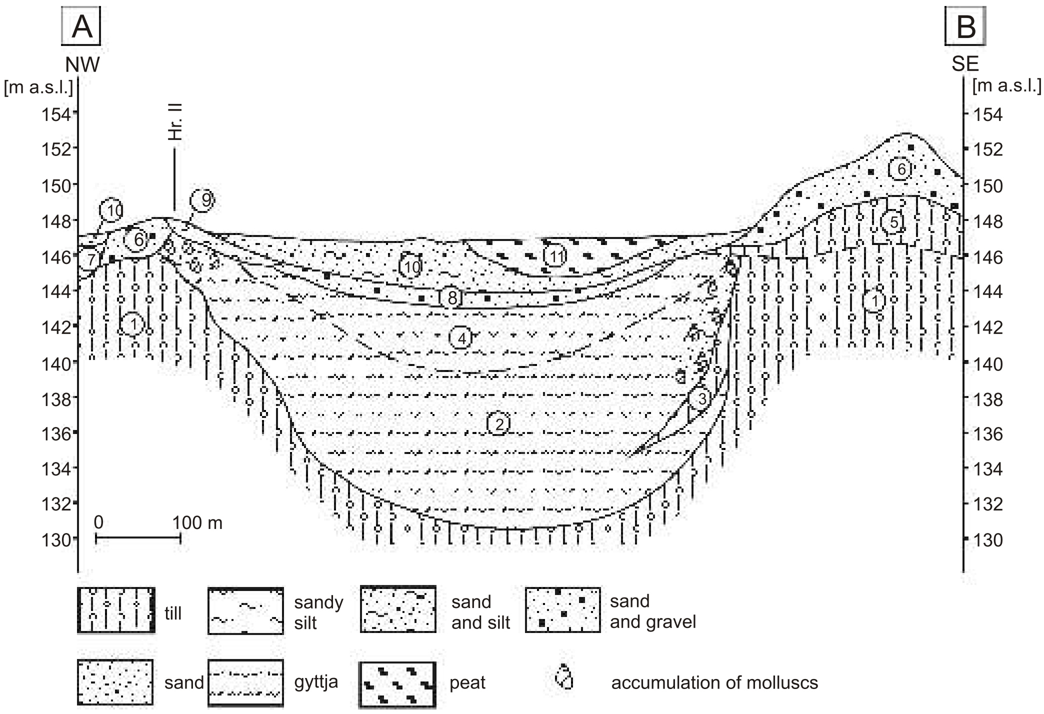

Fig. 2. Geological cross-section in the vicinity of Hrud II (after Nitychoruk, 1994, modified)

1 – Sanian 2 Glaciation; 2, 3 – Holsteinian Interglacial; 4–7 – Odranian Glaciation; 8 – Wartanian Glaciation; 9 – Vistulian Glaciation; 10, 11 – Holocene

Table 1

Malacofauna of the Hrud II site

I	II	Taxon	Samples							
			1	2	3	4	5	6	7	8
10	WP	*Pisidium obtusale* (Lamarck)								1
11	We	*Viviparus diluvianus* (Kunth)	5	5	5	5	5	6	5	4
11	We	*Valvata piscinalis* Müller	6	6	6	6	6	6	6	6
11	WL	*Valvata piscinalis* f. *antiqua* Sowerby	5	5	5	5	5	5	5	5
11	We	*Lithoglyphus jahni* Urbański	6	6	5	6	7	7	7	7
11	We	*Bithynia tentaculata* (Linnaeus) (+operculum)	1 3	1 4	1 2	1 2	2 2	1 1	1 1	 1
11	WL	*Lymnaea stagnalis* (Linnaeus)	1	1			1		1	
		Lymnaea sp.		1		1	1	1	k	1
11	We	*Gyraulus albus* Müller	1	3	1	1	1	2	1	
11	WL	*Armiger crista* f. *nautileus* (Linnaeus)								1
11	WL	*Acroloxus lacustris* (Linnaeus)		1			1	1	1	
11	We	*Pisidium henslowanum* (Sheppard)	1	2	1	1	1	1	1	3
11	We	*Pisidium milium* Held							1?	1
11	We	*Pisidium subtruncatum* Malm	3	4	1	1	2	2	2	4
11	WL	*Pisidium lilljeborgii* Clessin			1?					
11	We	*Pisidium casertanum* (Poli)	3	4	2	2	2	2	3	3
11	We	*Pisidium casertanum* f. *ponderosa* Stelfox	3	3	2	2	1	1	2	3
11	We	*Pisidium moitessierianum* Paladilhe	1	1		1	1	1	3	3
12	Wc	*Unio pictorum* (Linnaeus)					1			
12	We	*Unio tumidus* Philipsson					1		1	1
12		*Unio* sp.				1	1	k		1
12	Wc	*Pisidium amnicum* (Müller)	1		1	2	3	3	4	3
12	Wc	*Pisidium supinum* A. Schmidt							1?	
12	We	*Pisidium nitidum* Jenyns	3	4	2	2	2	2	3	4
		Pisidium sp.	3	4	2	3	3	3	3	4

I – ecological groups (after Ložek, 1964; Alexandrowicz, 1987): 10 – species of temporary water bodies, 11 – species of permanent water bodies of stagnant waters, 12 – species of flowing waters; II – supplementary ecological symbols (after Ložek, 1964, 1976, 1982; Körnig, 1966; Piechocki, 1979; Skompski and Makowska, 1989): Wc – species preferring flowing waters with weak currents, We – species present both in rivers and lakes, in stagnant and flowing waters, WL – species of permanent water bodies of various size, WP – molluscs of episodic, periodically drying out water bodies; number of specimens: **1** – 1–3, **2** – 4–9, **3** – 10–31, **4** – 32–99, **5** – 100–316, **6** – 317–999, **7** – more than 1000, k – a few fragments of shell

Among species of permanent water bodies of various size, abundant *Valvata piscinalis* f. *antiqua* was recorded as well as *Armiger crista* f. *nautileus*, *Acroloxus lacustris*, *Pisidium lilljeborgii* which are represented by single specimens. Molluscs which prefer flowing waters (ecological group 12) such as *Pisidium amnicum*, *Pisidium nitidum*, *Pisidium supinum* and *Unio pictorum* may attain 30% of all taxa (sample 5, 1.2–1.3 m) but in fact they appear in insignificant quantities (Table 1 and Fig. 3). They probably represent the wave affected zone in lacustrine environment. The latter is clearly evidenced by the lacustrine form *Valvata piscinalis* f. *antiqua* (Piechocki, 1979). However, occasional slowly flowing water is suggested by *Pisidium henslowanum* at Hrud II (*cf.* Piechocki and Dyduch-Falniowska, 1993).

The mollusc assemblage in the Hrud II section is dominated by three taxa – *Valvata piscinalis*, *Lithoglyphus jahni* and *Viviparus diluvianus*, although not evenly. In the lowest part of the profile (depth 1.3–1.6 m) *L. jahni* prevails and it is a main component of the fauna. *V. piscinalis*, *V. piscinalis* f. *antiqua* as well as *V. diluvianus* are abundant but only the first of these makes more than 10% of the association (Fig. 4). Generally numerous *P. amnicum* and *P. nitidum* point to rather strong wave action. The latter did not support aquatic vegetation as seen in a low content of species living on water plants. The restricted number of pulmonates together with a dominance of prosobranch gastropods indicates accumulation below 2 or 3 m water depth (Alexandrowicz, 1987).

Towards the upper part of the section predominance of *L. jahni* decreases (samples 2–5, Fig. 4). It is still a significant element of the community, but it is replaced by *V. piscinalis* and *V. piscinalis* f. *antiqua*, indicating somewhat deeper habitats (8–10 m). This is a typically zone with a muddy substratum and sparse vegetation (Piechocki, 1979; Alexandrowicz, 1987; Alexandrowicz, 2008). The association with *V. piscinalis* is accompanied by *V. diluvianus*. A scarcity of pulmonates is still observed, however, some changes in vegetation can be inferred from the proportions of opercula of *Bithynia tentaculata* which appears in the uppermost part of the succession in more significant amounts. Both the shells and opercula are often sorted in the littoral zone of water bodies and the ratios between them, expressed by the Bithynia-index (BIN) = (opercula – shells)/(opercula + shells), are a guide to sedimentary environ-

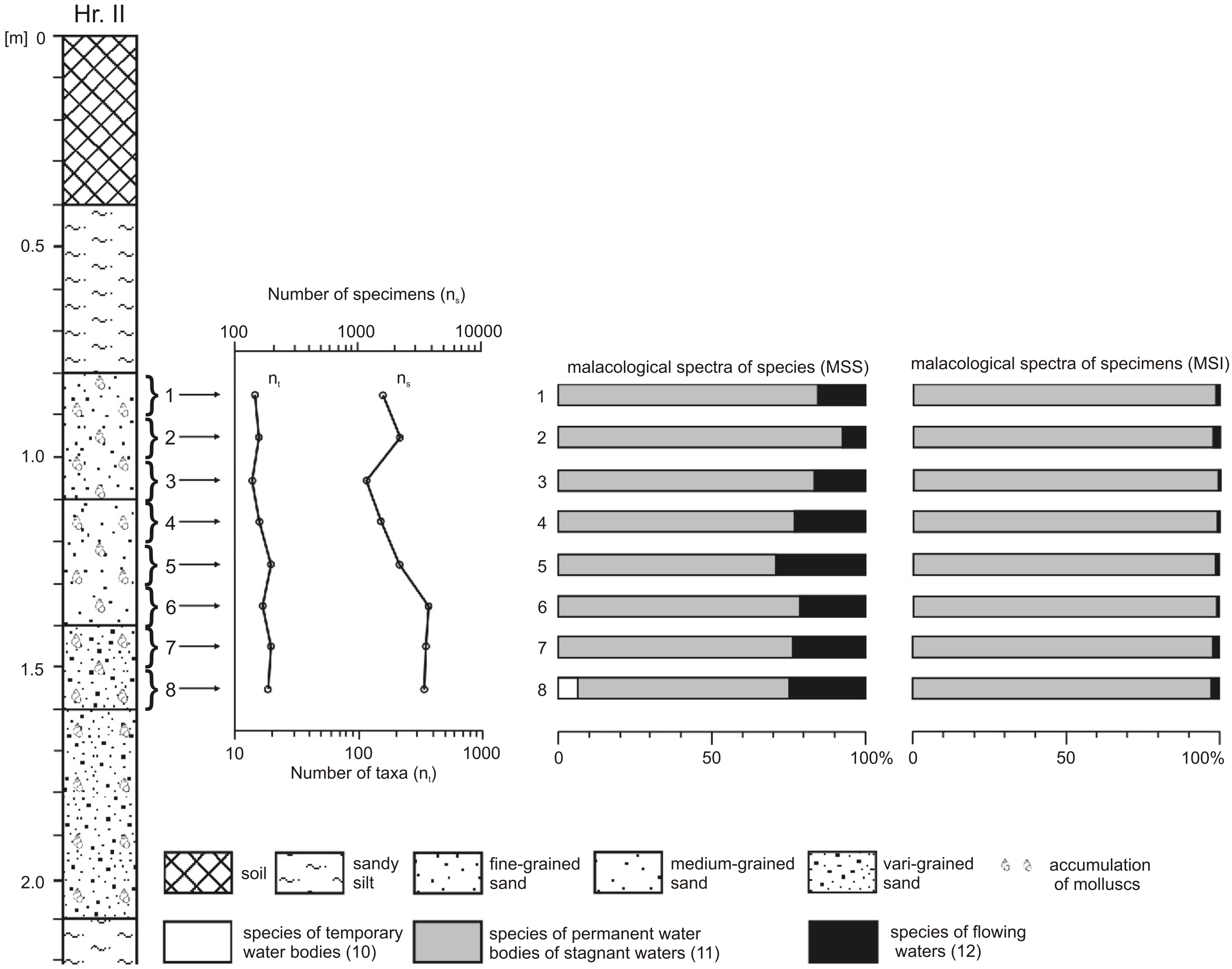

Fig. 3. Malacological composition of the Hrud II profile

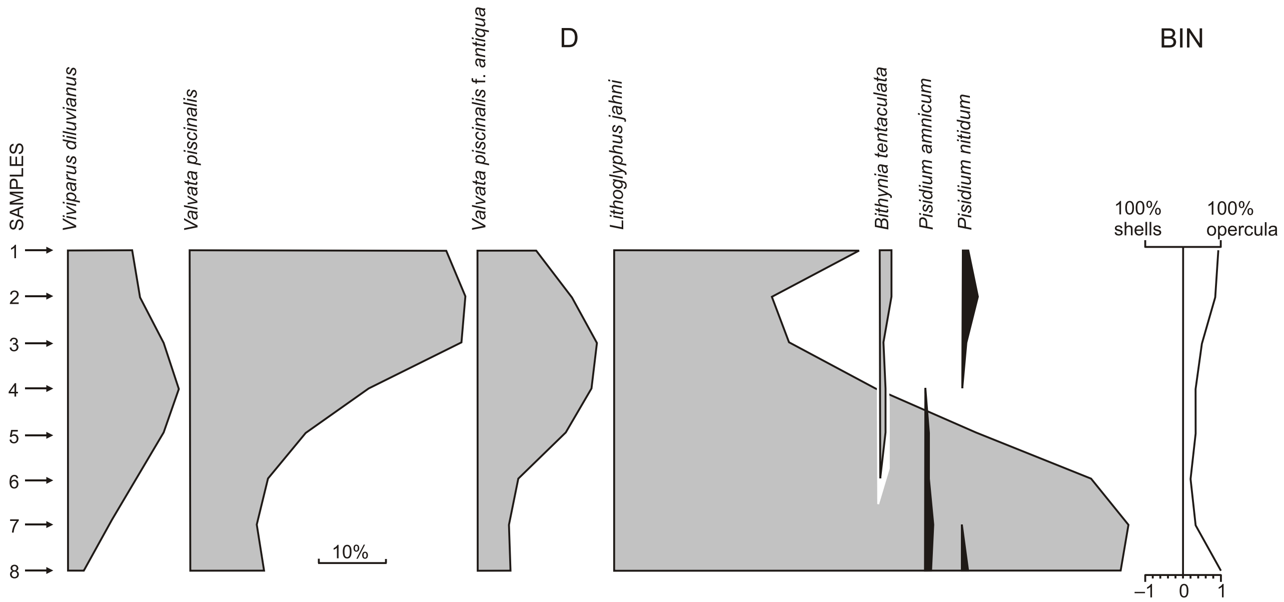

Fig. 4. Simplified malacological diagram (D) and changes of the Bithynia-index (BIN) at Hrud II

For explanations see Figure 3

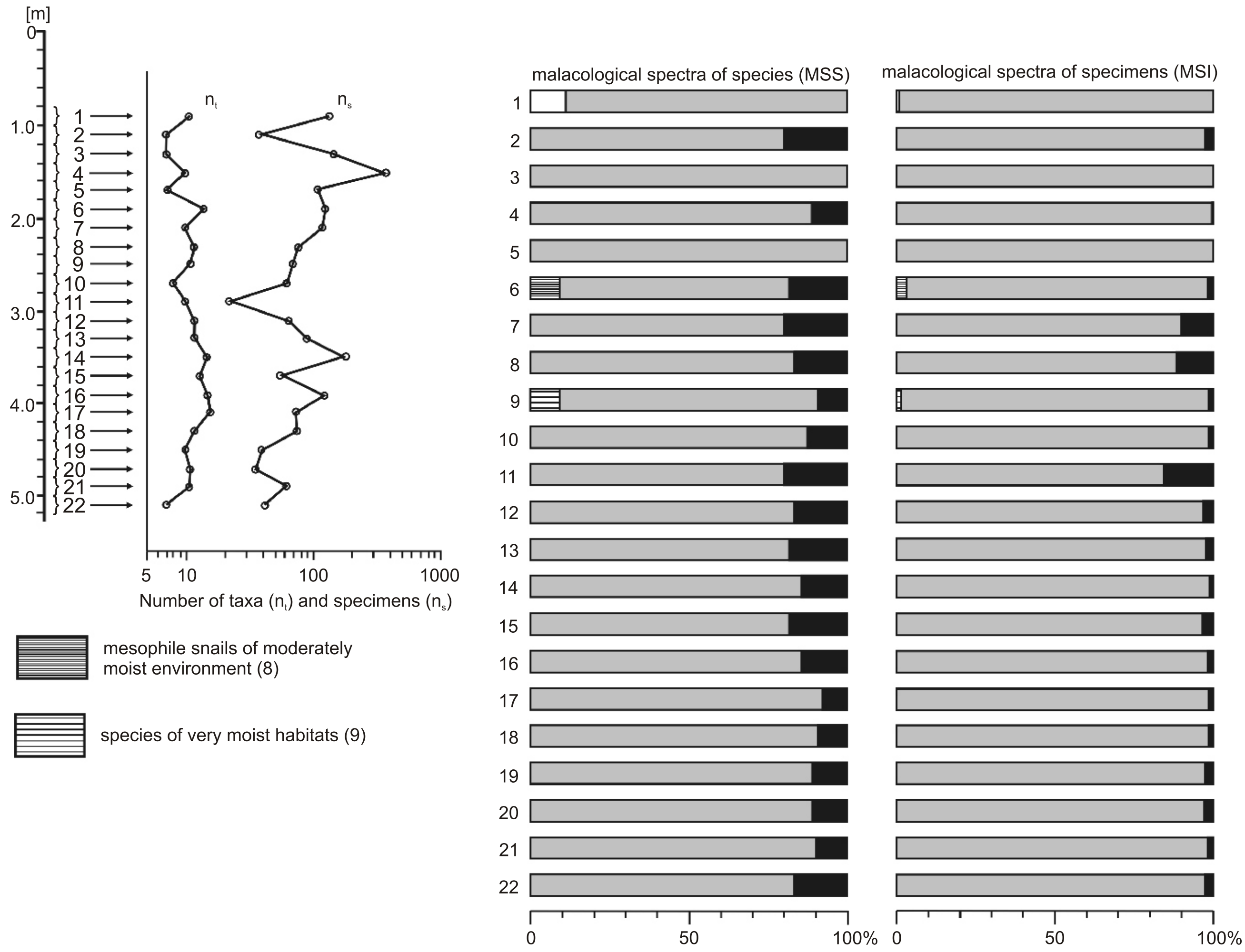

Fig. 5. Malacological composition of the Hrud I profile (based on data published by Lindner *et al*., 1991)

For explanations see Figure 3

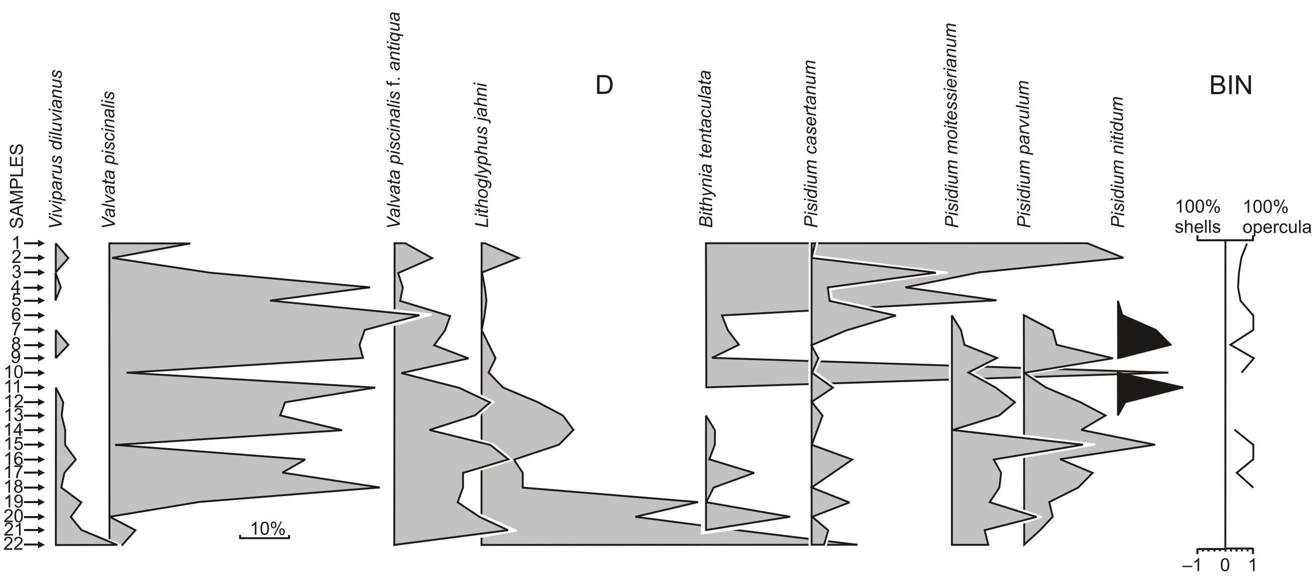

Fig. 6. Simplified malacological diagram (D) and changes of the Bithynia-index (BIN) at Hrud I (based on data published by Lindner *et al*., 1991)

For explanations see Figure 5

Table 2

Malacofauna of the Hrud I site (based on Lindner *et al*., 1991 – modified)

I	II	Taxon	Samples																					
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
8	MD	*Succinea oblonga* Draparnaud						2																
9	WD	*Succinea putris-elegans*									1													
10	WP	*Pisidium obtusale* (Lamarck)	1																					
11	We	*Viviparus diluvianus* (Kunth)		1		k				1d				1	1k	1k	1d	2d	1k	d	1d	1	1	2
11	We	*Valvata piscinalis* Müller	3		3	5	4	4	4	4	4	1	3	3	3	4		4	3	4	2		1	1
11	WL	*Valvata piscinalis* f. *antiqua* Sowerby	1	1d	1d	2d	1d	3	3	2	3	k	1k	3	3	3	3	3	3	3	2	2	3	
11	Wp	*Valvata cristata* Müller												1	1	1		1						
11	We	*Lithoglyphus jahni* Urbański	1	1		1	1	1		1	1	1	1	2	3d	4	2	2	2	2	3	3	4	3
11	We	*Bithynia tentaculata* (Linnaeus) (+operculum)	3 4	2 3	3 4	4 5	3 4	 2	 2	1 1	 1	3 4				1 1	 1	 1	1 2	 1		 2		
		Lymnaea (Radix)	2		1	3	1																	
		Lymnaea sp.						1											k					
11	Wp	*Anisus vorticulus* (Troschel)															k							
11	We	*Gyraulus albus* Müller	1													1	1	1	1	1	1		1	
11	WL	*Armiger crista* f. *nautileus* (Linnaeus)									1					2			1					
11		*Acroloxus* sp.												1	1	2	1	1	1	1		1	1	
11	We	*Sphaerium corneum* (Linnaeus)	d		d	k		d		k	k	k	k	k										
		Sphaerium sp.	d	d	d			d							k	k	k	k	k	k	d	k	k	
11	We	*Pisidium henslowanum* (Sheppard)																?	?			1?		
11	We	*Pisidium milium* Held											?							1?				
11	We	*Pisidium subtruncatum* Malm	1?			?	1	1	3	2				1										
11	WL	*Pisidium lilljeborgii* Clessin														1								
11	We	*Pisidium casertanum* (Poli)	1		4	3	2	3	2		1		1		1	1		3	1k		1		1	1
11	We	*Pisidium casertanum* f. *ponderosa* Stelfox						1	1	1		1												
11	We	*Pisidium moitessierianum* Paladilhe							1	1	2	1	1	2	2		3	3	2	2	1	2	2	1
11		*Pisidium parvulum* Clessin							2	2	3		1	2	3	3	3	2	3	2	1	1	1	
12		*Unio* sp.		k				k			k	k	k	k	d		d	d	k	d	d	d	d	k
12	Wc	*Pisidium amnicum* (Müller)														1								
12	Wc	*Pisidium supinum* A. Schmidt				1			1	1					1	?	?	?	?					
12	We	*Pisidium nitidum* Jenyns						1	2	2			1	1										
		Pisidium sulcatum (S. V. Wood)																						?
		Pisidium sp.		d				d									1					?		

8 – mesophile species of moderately moist environment; 9 – species of very moist habitats; MD – mesophile species of humid habitats, WD – snails of swamps, flooded meadows and shores of water bodies, Wp – molluscs of permanent, shallow, intensively overgrown water bodies; d – shell detritus; other explanations as in Table 1

ment. The opercula usually accumulate on the bottom in the reed zone and their domination is showed by the value of the index close to +1, while associations composed only of shells (BIN = –1) appear abundantly along the shores (Steenberg, 1917; S. W. Alexandrowicz, 1999). The community at Hrud II is clearly enriched in *Bithynia* opercula and the Bithynia-index rising from 0.33 to 0.93 indicates progressive overgrowing of the lake by reed and bullrush (Alexandrowicz and Sanko, 1997; W. P. Alexandrowicz, 1999, 2004, 2008). These changes, possibly connected with shallowing of the water body and/or amelioration of trophic conditions, are accompanied by a decrease in a content of *P. amnicum* which can barely tolerate such environment (Piechocki and Dyduch-Falniowska, 1993; Table 1 and Fig. 4).

The molluscs at Hrud II have a wide climatic tolerance, however, from occurrence of e.g., *Viviparus diluvianus*, *Lithoglyphus jahni*, *Acroloxus lacustris* and *Pisidium moitessierianum* a temperate climate may be deduced. This is in agreement with the results of pollen analysis, indicating the warm phase of the Holsteinian Interglacial, probably the *Carpinus–Abies* Zone, expressed in the section by high frequencies of oak, alder, fir, hazel and hornbeam (Szymanek, 2008*a*, 2011*a*).

HRUD I

Malacological investigations at Hrud I were conducted on 22 samples (depth 0.8–5.2 m) taken from the borehole HR-70 (Lindner *et al*., 1991; Skompski, 1996). The mollusc assemblage consists of 31 taxa – 14 of snails and 17 of bivalves, represented by over 2100 specimens. It is in general rich and diverse, however, many taxa appear as individual specimens. In many cases only a few fragments of shells or shell detritus are present, thus it is difficult to determine precisely the real abundance of specimens (Table 2). Presumably it changes from 23 to 366 per sample, whereas the number of taxa is between 7 and 16 with some distinct fluctuations observed in the profile (Fig. 5).

According to Skompski (Lindner *et al*., 1991; Skompski, 1996) the community is typical of a lake with possible overflow or of a littoral zone with wave action. The latter is suggested by the presence of *Pisidium parvulum*. The palaeoclimate has been described as mild (Lindner *et al*., 1991; Skompski, 1996). The gastropod fauna and the bivalves were interpreted separately. Two phases were distinguished in the development of snails. The first has a high content of *Lithoglyphus jahni* and *Viviparus diluvianus* (samples 12–22, depth 3.0–5.2 m) and the second is dominated by *Bithynia tentaculata* (samples 1–10, depth 0.8–2.8 m). Non-simultaneous occurrence of these species may be explained by changes of water acidity as *B. tentaculata* does not tolerate an acidic environment (Piechocki, 1979; Skompski, 1996). According to Skompski (1996) the chemical composition of the water, climate or other undetermined factors may also be responsible for the limited content of *V. diluvianus* in the upper part of the profile. Expansion of bivalves was characterized of a phase with *Pisidium moitessierianum*, *P. parvulum* and the more or less constant appearance of *Unio* sp. (samples 7–22, depth 2.0–5.2 m) as well as by a phase of *Pisidium casertanum* dominance (samples 1–6, depth 0.8–2.0 m; Lindner *et al*., 1991; Skompski, 1996).

As at the Hrud II site, species inhabiting both stagnant and flowing waters are present. Molluscs from ecological group 11 prevail. Reophile species (group 12) may attain 20% of the assemblage, although only in samples 7, 8, 11 (depth 2.0–2.2 m; 2.2–2.4 m; 2.8–3.0 m) do they occur in quite considerable amounts (10–15% of the assemblage), suggesting some water movement. In most cases they make no more than 3% of the community and are absent from samples 1 (0.8–1.0 m), 3 (1.2–1.4 m) and 5 (1.6–1.8 m) which points to a lack of the overflow and/or a very calm inshore zone of the lake (Fig. 5). The latter was probably quite densely overgrown by reeds as indicated by high values of the Bithynia-index (0.46–0.77; Fig. 6).

As mentioned above, *Bithynia tentaculata* is the main component of the fauna in the uppermost part of the section. The lower one is dominated by *Lithoglyphus jahni*. *Valvata piscinalis* is also very abundant; however, it disappears in some samples (Fig. 6). It is worth noting that decrease in its number usually coincides with greater amounts of *B. tentaculata* (Fig. 6), implying possible changes in water level. While *V. piscinalis* often inhabits deeper parts of the lake, for *B. tentaculata* a depth of 0.7–1.8 m is optimal (Piechocki, 1979; S. W. Alexandrowicz, 1987, 1999; Alexandrowicz, 2008). In the upper part of the section a bog bivalve *Pisidium obtusale* (ecological group 10) as well as a couple of species of land snails – *Succinea putris-elegans* and *Succinea oblonga* occur (Lindner *et al*., 1991). The first one represents ecological group 9, i.e. species of very moist habitats, the second is a mesophile snail of moderately moist environment (ecological group 8). However, they are insignificant components of the association (Table 2).

Other groups of animals (ostracods, fishes, rodents, insects) have also been described from Hrud I but as at Hrud II where fishes and rodents are present (Szymanek, 2008*a*) they do not in general strengthen the interpretation. Only the ostracod fauna indicates a few stages of development from a deeper to a relatively more shallow water body (Lindner *et al*., 1991).

No palaeobotanical analyses have been made in the HR-70 profile, however, Lindner *et al*. (1991) correlate the succession with those distinguished in the nearby HR-53 and HR-54 profiles (a few hundred metres to the SE), where pollen and diatoms were investigated. The correlation cannot be direct and unequivocal, but it may be assumed that the mollusc assemblage represents the older part of the Holsteinian Interglacial probably covering the interval of dominance of pine-birch forests with spruce and larch, of spruce forests and of the phase of yew-pine forests with spruce and alder. Unfortunately, based on the available material, more detailed interpretation is impossible. Diatoms indicate an oligo-mesotrophic lake, amelioration of the trophic conditions and lowering of the water level (Lindner *et al*., 1991; Lindner and Marciniak, 1997, 1998).

DISCUSSION

A water body of the Holsteinian age that existed in the vicinity of Hrud was inhabited by the rich mollusc fauna. It was differentiated into western (Hrud II section) and eastern (Hrud I profile) parts of the basin and evolved during its development. Changes in the assemblages may have been either synchronous and of local origin or they may reflect evolution of freshwater environments over a longer period. It should be noted, however, that some changes may not be connected with ecology but rather result from different sampling methods used at Hrud I and II, hindering the interpretation. Although the total volume of sample material derived from the borehole HR-70 is not given (Lindner *et al*., 1991) it was undoubtedly considerably smaller than that collected in the Hrud II excavation. This affects in particular the abundance of the assemblages, thus in correlation the percentage content of taxa and specimens should be emphasised instead of their numbers. Comment is also needed on the appearance of *Pisidium parvulum* Clessin, abundant at Hrud I and absent at Hrud II. According to Boettger (1961) this is a synonym of *Pisidium hibernicum* Westerlund, whereas Kuiper (1965) treats *P. parvulum* "as a composite species" synonymous with *P. obtusale* (Kuiper *et al*., 1989). In the literature also *P. parvulum* Woodward can be find and this name appears in synonomy of *Pisidium moitessierianum* (Piechocki, 1989). Basing on pictures presented by Skompski (1996) the presence of *P. hibernicum* at Hrud I can be inferred, but it is not certain. It seems, however, that an interval of abundance of that species was not recorded at Hrud II.

A few phases of the faunal development were distinguished in the profiles described, expressed mostly by various relations between *Lithoglyphus jahni*, *Valvata piscinalis* and *Bithynia tentaculata*. They show moderately dynamic changes in the mollusc communities which mainly reflect environmental conditions. Some climate influences cannot be excluded, but the wide climatic tolerance of most species limits the palaeoclimatic information that may be obtained. Although the populations share some similarities it appears that they existed at different times and record successive stages of the lake evolution as shown by the pollen data of the Hrud I (Lindner *et al*., 1991) and Hrud II sections (Szymanek, 2008*a*, 2011*a*).

The mollusc assemblage from the eastern part of the lake (Hrud I) is older and probably represents a longer period than the fauna found along its western bank (Hrud II). Initially it was dominated by *L. jahni*. Unfortunately, environmental interpretation is hindered here by the restricted data concerning the ecology of this species. It lived in lakes and rivers (Urbański, 1975; Skompski and Makowska, 1989) or only in rivers (Gittenberger *et al*., 2004; Kondrashov, 2007), but no detailed bathymetric data are presented. Nowadays *Lithoglyphus naticoides* (Pfeiffer) is most frequent in shallow depths (0.2–1.2 m), mainly in fluviatile environments, sometimes in lakes, and it avoids overgrown stagnant waters (Piechocki, 1979). It is hard to estimate how much in common had the fossil snail with these habitats; however, such an interpretation would be inconsistent with the information from ostracods, showing a relatively deep water body at that time (Lindner *et al*., 1991). The latter interpretation is supported by the succeeding community, dominated by *V. piscinalis*, which usually inhabits depths of *ca*. 8–10 m. The lake bathymetry was not constant. A periodic deepening and shallowing of the lake possibly occurred, as reflected in fluctuations of *V. piscinalis* and *B. tentaculata* contents. Decrease in the water level coincided with the growth of bullrush and reeds, whereas a deeper basin of wider extent favoured more intensive wave action, which restricted aquatic inshore vegetation. The most distinct drop in the water level and gradual overgrowing of the lake was noted in the uppermost part of the Hrud I profile (a phase of yew domination or later?). Very calm, totally stagnant and probably more eutrophic waters prevailed at that time.

A younger stage of the lake development is recorded in its western part; however, a hiatus between the Hrud I and II sections cannot be excluded. The molluscs from the Hrud II site existed during a phase of fir and hornbeam predominance in forest communities (Szymanek, 2008*a*, 2011*a*). According to Bińka (Bińka and Nitychoruk, 1995, 1996; Bińka *et al*., 1997) this is the climatic optimum of the Holsteinian Interglacial. The community was again dominated by *L. jahni*, which was subsequently replaced by *V. piscinalis*. The lake became deeper and some slight movements of the water appeared. Higher in the succession a drop in water level was combined with renewed growth of bullrush and reeds along the shore. Better trophic conditions can be also assumed. The part of the lake recorded at Hrud II was permanently inhabited by abundant *Viviparus diluvianus* which occurred in limited number at Hrud I. The warm and mild climate of the optimum was certainly favourable for this (Szymanek *et al*., 2005; Szymanek, 2008*a*, *b*, 2011*a*). The problem is that similar conditions prevailed during the *Taxus* (yew) zone of the Holsteinian. Thus, if correlation of malacological data with pollen spectra at Hrud I is correct, it appears that some non-climatic factors may have influenced the population of *V. diluvianus* at that site.

Variable relations between *Valvata piscinalis* and *Bithynia tentaculata* can be observed in the neighbouring Holsteinian sites at Ortel Królewski and Szymanowo (Szymanek, 2011*a*) as well as at Boczów in western and Zwierzyniec in north-central Poland (Skompski, 1989); however, detailed studies have not been conducted at those localities. A similar picture of evolution of water bodies is also known at many sites of the Eemian Interglacial (Alexandrowicz, 2008; Alexandrowicz and Alexandrowicz, 2010). Usually, the assemblages with *V. piscinalis* are connected with the early stage of the Eemian, whereas *B. tentaculata* is more abundant in higher parts of the successions. In addition fluctuations in content of these species appeared periodically during the pre-optimal and optimal phases of the interglacial, as noted for instance at Piła, Bogdanowo near Poznań or Rogaczewo and Kopaszewko in the vicinity of Leszno (Alexandrowicz, 2008; Alexandrowicz and Alexandrowicz, 2010). The assemblages with *V. piscinalis* and *B. tentaculata* are also used in environmental reconstructions of the Late Glacial and Early Holocene. *V. piscinalis* appeared earlier at the end of the Vistulian Glaciation and its abundance often points to the main phases of lake development, whereas *B. tentaculata* becomes more numerous in the Holocene and is typical both of more shallow water bodies and of zones with rich vegetation, where opercula predominate in the community (Alexandrowicz, 1987; W. P. Alexandrowicz, 1999, 2002, 2007).

CONCLUSIONS

The malacofauna at Hrud II differs from the assemblage described in the vicinity of Hrud by Lindner *et al*. (1991). It significantly elaborates the picture of environment evolution in this Holsteinian lake, recorded as changes of mollusc communities. This reflects variability of habitats and palaeoecology during the younger stage of lake development, during a part of the climatic optimum. Broader methods used for the Hrud I material facilitate the interpretation. A combination of the results from the eastern and western parts of the Hrud palaeolake provides considerable malacological data enabling more detailed environmental reconstruction. The problem of the unstable content of *Lithoglyphus jahni* in the deposits and its palaeoecological implications requires further investigation.

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