



Botanical composition of meadows and pastures and their role in the functioning of early medieval semi-artificial lake islands in Ziemia Lubuska (Lubusz land), western Poland

Karolina Maciejewska^{1,2} · Monika Badura² · Agnieszka M. Noryśkiewicz³

Received: 27 September 2021 / Accepted: 20 December 2021 / Published online: 20 May 2022
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Abstract

Continuation of archaeobotanical and palaeoecological research on three semi-artificial lake islands, Nowy Dworek, Chyčina and Lubniewice, has provided new information on the history, development and use of grasslands in Ziemia Lubuska (Lubusz land) in western Poland during the early Middle Ages. Pollen analysis reveals that the reduction in woodland and opening up of the regional landscape and the appearance of grassland communities there began around the 7th century AD, which preceded the construction of the islands in the lakes. The analysis of plant macroremains collected from the settlement layers on these islands, of pollen from cores in the lakes and studies of the phytosociological plant communities of recent vegetation have helped to describe the botanical composition of these past meadows and pastures. The results show strong similarities between the three sites, which suggests that the local populations were using the same grassland types, which were on soils ranging from damp to rather dry and sandy. The main grassland in the vicinity of the islands included the *Molinio-Arrhenatheretea* syntaxonomical class of communities, although *Festuco-Brometea* grasslands were also present. The presence of plant remains associated with various other types of meadows and pastures shows the diversity of habitats represented by the plant remains.

Keywords Western Poland · Early Middle Ages · Archaeobotany · Meadows and pastures · Semi-artificial lake islands

Introduction

The geographical, historical and cultural conditions in the Ziemia Lubuska (Lubusz land, western Poland), defined as an early medieval border area, make this microregion a very important place to study past settlement development. This is demonstrated by numerous publications on archaeological sites which provide data on the functioning of past local communities (Kurnatowska and Łosińska 1996; Kobyliński

2014; Kaczmarek 2019). Particularly interesting are some semi-artificial lake islands, which resemble crannogs, pre-historic island sites in the British Isles (Morrison 1985; Menotti 2012). In Poland, an interdisciplinary research project has studied the role of these unusual structures in the early medieval landscape of Ziemia Lubuska revealed by three islands in the lakes of Paklicko Wielkie, Lubiąż and Jezioro Długie (Fig. 1). Archaeological results have made it possible to define them as “central places” which were important centres of human activity for management, transport and even religious beliefs (Bleile 2010). One of the elements of this project involved recognising the environmental setting of these sites, with an emphasis on the use of plants on the islands. However, the issue of the botanical diversity of plant communities on the land around the lakes had not yet been studied in detail. The long list of taxa identified from the plant macroremains from the islands includes numerous plants which were components of natural and semi-natural plant communities as well as those connected with human activities, including meadows and pastures. The development and use of ancient grasslands poses

Communicated by K.-E. Behre.

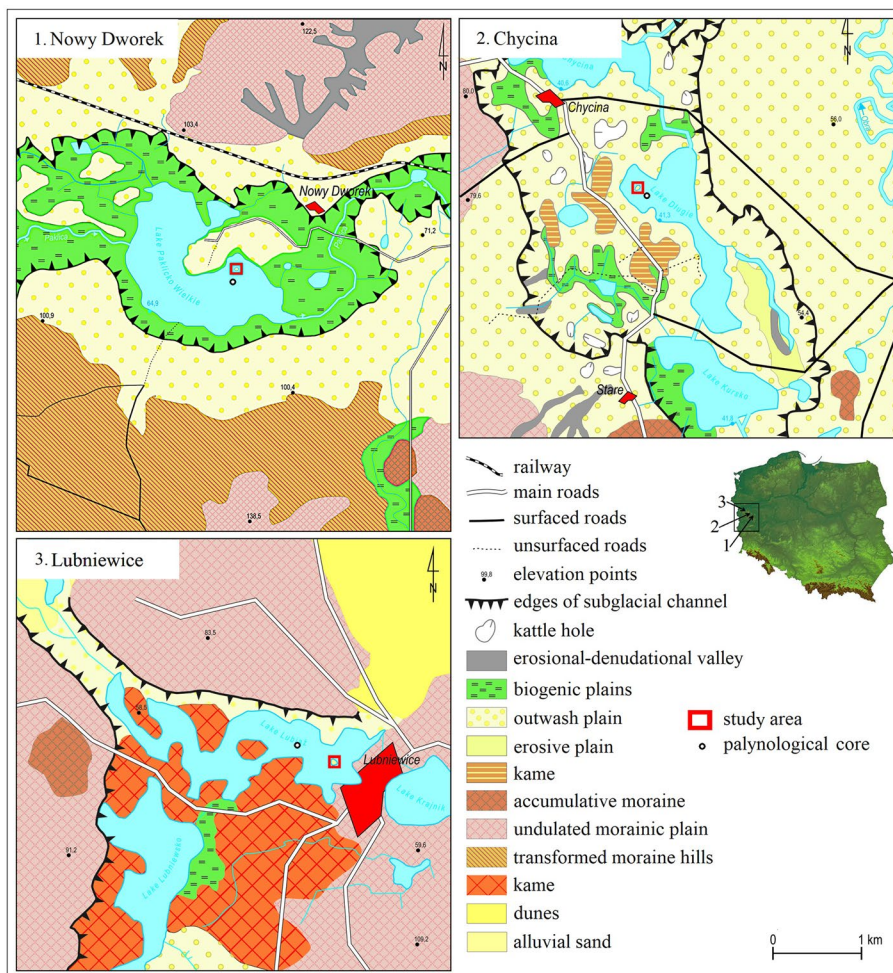
✉ Karolina Maciejewska
karolina.maciejewska.1@phdstud.ug.edu.pl

¹ Doctoral School of Natural Sciences, University of Gdańsk, ul. Wita Stwosza 63, 80-308 Gdańsk, Poland

² Laboratory of Palaeoecology and Archaeobotany, Department of Plant Ecology, Faculty of Biology, University of Gdańsk, ul. Wita Stwosza 59, 80-308 Gdańsk, Poland

³ Institute of Archaeology, Faculty of History, Nicolaus Copernicus University, Szosa Bydgoska 44/48, 87-100 Toruń, Poland

Fig. 1 Location of the sites (after Chudziak and Kaźmierczak 2020a, revised)



interesting questions for both botany and archaeology (Greig 1988; Behre and Jacomet 1991; Hodgson et al. 1999; Pini et al. 2021).

Grasslands are generally strongly connected with human activity. Farming, including grazing and mowing, has the greatest impact on their appearance in the landscape, development and botanical composition (Pärtel et al. 2005; Hejman et al. 2013; Boch et al. 2020). They are floristically rich communities which include plants from various taxonomic groups. The explanation of the role of meadows and pastures in the human landscape is rather complicated in the absence of good archaeobotanical evidence (Küster and Keenleyside 2009). The general history of meadows and pastures in Europe is known thanks to numerous pollen studies (such as Hjelle 1998; Ralska-Jasiewiczowa et al. 2006; Hejman et al. 2013; Kuneš et al. 2015; Qin et al. 2020). More detail has been provided by studies of ancient grasslands based on plant macroremains which have been done in Switzerland (Akeret et al. 2018), Germany (Knörzer 1975; Kreuz and Schäfer 2011) and the Czech Republic (Pokorný et al. 2006; Hájková et al. 2018). In Poland, the origins of these important plant communities have not yet been discussed in much detail. Most often, grasslands

are mentioned when other habitat groups are discussed, when they have been identified, for example in urban deposits (Wasylikowa 1978; Święta-Musznicka and Latałowa 2016), medieval ports (Latałowa 1999) or strongholds (Koszałka 2014). An outline of this topic was also presented in the study of materials from Żółte, another early medieval semi-artificial lake island in Pomorze Zachodnie (West Pomerania), Poland (Noryśkiewicz 2014; Pińska and Latałowa 2014).

The main objective of this article is to use the archaeobotanical data from the three islands to reconstruct the composition of the early medieval meadows and pastures which were located around the sites, and then to discuss the role of grassland communities in the local settlement system, also using the pollen data from the lake sediment.

Site description, materials and methods

The sites

The early medieval sites of Nowy Dworek, Lubniewice 10 (called Lubniewice in the following text) and Chycina

represent rare small semi-artificial islands in lakes located in Ziemia Lubuska (Lubusz land) in western Poland (Fig. 1). They were elements of the local settlements. The wooden structures of the islands were built in natural shallows in the lakes. Wooden bridges and a system of piers linked the islands with the mainland. The phases of use at the individual sites have been determined from the archaeological results, dendrochronology and radiocarbon dates. They represent successive stages of use, from construction to abandonment. Near every lake and island there were contemporary settlements on dry land (Chudziak and Kaźmierczak 2020a).

The site of Chycina is situated on a lake, Jezioro Długie (95.5 ha). It is a small area of 0.3 ha raised up to 0.4–0.5 m above the present lake level, now covered with shrubs and trees, with some rushes on the shore. There were three major phases of use. Phase I (from the last quarter of the 8th to the mid 9th century) includes remains of a quay and the central part of the island. Phase II (from the mid 9th to the 1st quarter of the 10th century) covers intensive use of the interior as well as temporary flooding of the island, and Phase III (from the 2nd quarter of the 10th to the early 11th century) represents the final period of use. Samples were collected from material connected with Phases I, II, II/III and III for our archaeobotanical studies (Table 1). Most of the waterlogged organic material was collected in the samples from Phase I. Samples from the later phases contained large amounts of mineral material.

The site of Lubniewice (0.2 ha), is located in the south-eastern part of Lubiąż lake (146 ha), ca. 135 m from the lake shore. Today, it is a flat area, reaching about 0.6 m above the water level. The island is covered with trees and shrubs, but there is no rush vegetation along the shore. The two main phases of occupation were distinguished by stratigraphy and archaeological finds. Phase I (the 4th quarter of the 8th to 1st

half of the 9th century) corresponds to intensive use of the entire island, the building of a wooden wharf and a bridge abutment after a rise in water level. Phase II covers resettlement after a short break of settlement in the 2nd to 3rd quarters of the 10th century. Unfortunately, sufficient material for archaeobotanical analysis was preserved only in the levels associated with Phase I, which consisted mostly of waterlogged material mixed with various amounts of minerals, mainly sand (Table 1).

The smallest of the islands is Nowy Dworek (0.02 ha), rising only 0.4 m above the lake level of Paklicko Wielkie (196 ha). Today, there are only isolated trees on the island and a wide strip of rushes around the edge. There are three phases of site use according to archaeological evidence. Phase I (from the last quarter of the 8th to the mid 9th century) represents the time when the bridge, embedded log structure and shore reinforcement were built. Phase II (from the mid 9th to the 1st quarter of the 10th century) covers remains from repairs and the building of a great superstructure to raise the surface of the island. In Phase III (from the 2nd quarter of the 10th to the early 11th century), although the bridge crossing ceased to operate, the island was still intensively used. The archaeobotanical samples consisted of perfectly preserved waterlogged organic material with a few charred seeds and some sand. However, it should be noted that the cultural layers in Phase I were present only in the form of thin inclusions among the pieces of wood. Phase II provided much more organic material, which may be because typical culture layers associated with the most recent settlement phase III could have been washed away as a result of rising water levels in the following periods (Table 1). For Phase III, no suitable material for archaeobotanical analysis was found.

Materials and methods

This study is based on the results from 45 bulk samples which represent the culture layers of the three islands (Table 1). The samples represent the material used for their construction and residues from activities there. Most samples were collected from Lubniewice (19) and Nowy Dworek (17), while Chycina provided only nine. All samples contained significant numbers of macroremains of meadow and pasture plants (Fig. 2). Most of them were waterlogged, but occasional specimens were charred. Mineralized remains were found only from Chycina.

The same procedures for macrofossil sample collection strategy and laboratory preparation and then analysis were applied to all the samples. The samples were taken from trenches on the islands and in shallow water. From every sample, a 300 cm³ subsample of sediment was selected, which was soaked for 24 h in KOH solution and wet sieved

Table 1 Archaeobotanical samples in relation to archaeological phases of use of the island

Phase	Chronology (century AD)	No. of samples
<i>Chycina</i>		
I	4th quarter of the 8th to 1st half of the 9th	6
II	2nd half of the 9th to 1st quarter of the 10th	1
II/III	2nd half of the 9th to beginning of the 11th	1
III	2nd quarter of the 10th to beginning of the 11th	1
<i>Lubniewice</i>		
I	4th quarter of the 8th to 1st half of the 9th	19
<i>Nowy Dworek</i>		
I	4th quarter of the 8th to 1st half of the 9th	4
II	2nd half of the 9th to 1st quarter of the 10th	13

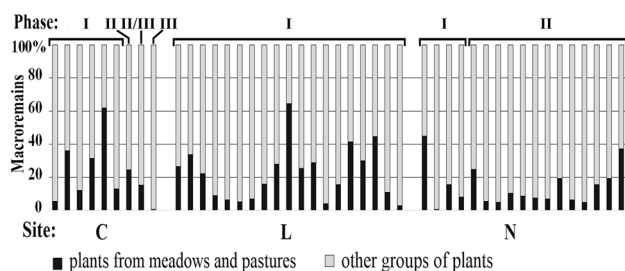


Fig. 2 Proportion of plant macroremains associated with meadows and pastures compared with other ecological and phytosociological groups in samples from the sites, by settlement phase. C, Chycina; L, Lubniewice; N, Nowy Dworek

with 2.0, 0.5 and 0.2 mm meshes. The remaining material was wet sieved only with a coarse sieve in order to obtain larger seeds which are normally under-represented in the main sample. Identification was made using the modern reference collection held at Laboratory of Palaeoecology and Archaeobotany, University of Gdańsk, as well as with reference to seed atlases and keys (Körber-Grohne 1991; Capers et al. 2006). Information on the qualitative and quantitative content of the botanical material is archived in the ARCHBOT-UGDA DATABASE at the Laboratory of Palaeoecology and Archaeobotany, University of Gdańsk. The identified taxa are named according to Mirek et al. (2002) and the arrangement of plant communities uses the phytosociological classification of Matuszkiewicz (2008) and Zarzycki et al. (2002). Ecological and habitat features follow Zarzycki et al. (2002), Roo-Zielińska (2014) and Ellenberg et al. (1992). The identified species have been assigned to a particular phytosociological rank within the grassland communities, while taxa less closely associated with grassland or with their optimum niche in meadows or pastures, but without being characteristic of any of the particular plant communities (syntaxons) discussed here, have been classed as "others". The species within the rush communities of class *Phragmitetea* were not included in the list. Some of these taxa may represent such communities around the islands and not on the lake shores. To illustrate the relationship between the botanical composition of the samples and the individual sites, detrended components analysis (DCA) in CANOCO 4.5 for Windows was done with square-root transformation of data sets for Phase I.

Pollen analysis of the sediments of all three lakes was done in order to study the extent of open unwooded areas in the early Middle Ages, including grasslands near the individual sites. Each profile of sediments was taken at maximum water depth and as close as possible to the islands (Fig. 1). Pollen analysis was done on the upper parts of the cores, which cover the record of environmental changes from the Migration Period (ca AD 375–568) to the present day. A total of 175 samples were analysed from the lakes, 40

from Jezioro Długie, 77 from Lubiąż and 58 from Paklicko Wielkie. Standard laboratory treatment was used for every sample (Berglund and Ralska-Jasiewiczowa 1986). During pollen analysis more than 500 AP or 1000 AP + NAP grains were counted per sample. Identification was made using the reference collection and the reference atlases (Beug 2004; Punt et al. 1976–2003) at the Institute of Archaeology, Nicolaus Copernicus University in Toruń. The resulting pollen counts were calculated and pollen diagrams drawn up and zoned using Polpal v. 2009 and later modifications (Walanus and Nalepka 1999). For every diagram, local pollen assemblage zones and the phases of more intensive levels of human activity (palynological settlement phases I–III) were identified. In view of the relatively vast lake areas, the pollen results reflect both local and regional vegetation around the individual sites (Sugita 1993; Sugita et al. 1999) and cover the land occupied by the groups of people who built and used the islands.

Results

General description of the material

The plant material contained over 90 grassland taxa from meadows and pastures, represented by over 12,200 remains (Table 2). The percentages of individual taxa differ from site to site and from phase to phase, although this may be related to the differences in the number of samples (Figs. 2, 3). The overall comparison of the results shows that grassland plants are better represented in Phase I in Chycina than II or III, whereas at Nowy Dworek both remains and taxa are better represented in Phase II than I. At Lubniewice, only Phase I has been preserved. The comparison of Phase I between the islands shows that grassland plants are better represented at Lubniewice than at Chycina or Nowy Dworek. DCA has demonstrated that the botanical composition of Phase I samples is similar from each island (pseudo- $F = 1.32$, $df = 2$, $p = 0$) (Fig. 4). On the right side of the diagram there are single samples containing mostly seeds of *Juncus* spp., while on the left are samples with mainly Poaceae remains.

Meadow and pasture communities

The phytosociological analysis of the plant communities represented by the macrofossils shows that the identified species relate to five of the currently distinguished classes of grassland communities (phytocoenoses) used as meadows and pastures (*Molinio-Arrhenatheretea*, *Festuco-Brometea*, *Nardo-Callunetea*, *Scheuchzerio-Caricetea* and *Koelerio glaucae-Corynephoretea canescentis*). They were represented in the plant remains from all three islands (Table 2), with small differences in the numbers of taxa and abundance

Table 2 List of plants from meadows and pastures with numbers of macroremains and their frequencies (in brackets) and by settlement phases and phytosociological groups. C, Chycina; L, Lubniewice; N, Nowy Dworek; W, soil moisture value; n, number of samples

Site	C				L		N		W
	I	II	II/III	III	I	I	II		
Phase									
Samples (n)	6	1	1	1	19	4	13		
Festuco-Brometea									
<i>Acinos arvensis</i>	16(4)				36(9)	42(2)	26(9)	1-2	
<i>Anthemis tinctoria</i>	6.5(2)				34.5(7)	1(1)	38(9)	2	
<i>Arabis hirsuta</i>					1(1)		2(2)	2	
cf. <i>Arabis hirsuta</i>	1(1)							2	
<i>Campanula glomerata</i>					2(1)	2(2)	6(3)	3	
<i>Centaurea scabiosa</i>					6.5(5)	1(1)	27(4)	2-3	
cf. <i>Centaurea scabiosa</i>						1(1)		2-3	
<i>Scabiosa columbaria</i>							1(1)	2	
cf. <i>Scabiosa columbaria</i>	1(1)							2	
<i>Stachys recta</i>							1(1)	2	
cf. <i>Stachys recta</i>	1(1)							2	
<i>Thalictrum simplex</i>							1(1)	3-2	
cf. <i>Thalictrum simplex</i>							1(1)	3-2	
<i>Hypericum perforatum</i>	7(3)				302.5(14)		45(4)	4	
cf. <i>Petrorhagia saxifraga</i>	1(1)							2	
<i>Petrorhagia prolifera</i>	3(1)				16.5(6)	7.5(2)	24(9)	2	
<i>Potentilla recta</i>					3(1)			2	
cf. <i>Senecio jacobaea</i>	1(1)							2-3	
Molinio-Arrhenatheretea									
<i>Achillea millefolium</i>	1(1)				9(3)			2-3	
cf. <i>Agrostis stolonifera</i>	3(2)				23(6)		2(1)	4	
<i>Angelica sylvestris</i>							1(1)	4	
<i>Bromus hordeaceus</i>					3(1)	5(1)		3	
cf. <i>Bromus hordeaceus</i>	1(1)							3	
<i>Caltha palustris</i>	1(1)						2(1)	5	
<i>Campanula patula</i>					12.5(2)			3	
<i>Carex hirta</i>						3(1)	12(7)	2-4	
<i>Carex panicea</i>							1(1)	4	
<i>Centaurea jacea</i>	2(1)				6(4)	1(1)	2(2)	2-3	
cf. <i>Centaurea jacea</i>					4(1)		6(1)	2-3	
<i>Cerastium holosteoides</i>	11(3)				66(13)	10(2)	40.5(6)	4-5	
<i>Cirsium oleraceum</i>					11(1)	1(1)		3-5	
<i>Daucus carota</i>	15(3)				70(13)	9(3)	22(6)	3	
<i>Epilobium palustre</i>	4(1)				5(3)			5	
<i>Filipendula ulmaria</i>	14.5(3)				135(12)	5.5(3)	56.5(9)	4-5	
cf. <i>Galium mollugo</i>					2(1)			3	
<i>Galium uliginosum</i>	5(1)				31(10)			4	
cf. <i>Geum rivale</i>					1(1)			4	
<i>Hypericum tetrapterum</i>					45(1)			4	
cf. <i>Hypericum tetrapterum</i>					1(1)			4	
<i>Juncus conglomeratus/effusus</i>	701(2)	45(1)			1209(6)	104(1)	123(3)	4-5	
<i>Juncus glaucus</i>		5(1)						4-5	
<i>Knautia arvensis</i>	3(1)				5.5(5)	2(2)	13(7)	3	
<i>Leontodon autumnalis</i>					2(2)			3	
<i>Linum catharticum</i>	20(4)				34(9)	1(1)	13(5)	2-4	
<i>Lychnis flos-cuculi</i>	3(3)				54(13)			4	
<i>Lythrum salicaria</i>	29(3)				399.5(15)	506(3)	794(7)	4-5	
<i>Molinia caerulea</i>					2(1)	1(1)	1(1)	4-5	
cf. <i>Molinia caerulea</i>							1(1)	4-5	
<i>Myosotis palustris</i>	1(1)				5(3)			4-5	
<i>Pastinaca sativa</i>	1(1)				45(11)	3(3)	15.5(8)	3	
<i>Plantago lanceolata</i>					5(4)			2-4	
<i>Plantago major</i>	55(4)				64(13)	1(1)	44(9)	3-4	
<i>Poa annua</i>	9(2)				7(2)		1(1)	3	
cf. <i>Poa annua</i>	5(3)				1(1)			3	
cf. <i>Poa pratensis</i>							2(1)	3	
<i>Potentilla reptans</i>	1(1)				17(9)		12(7)	3-4	
<i>Prunella vulgaris</i>	49(3)		1(1)		227(16)	30(2)	42.5(6)	3-4	
<i>Ranunculus acris</i>	31.5(4)				19.5(9)	14.5(2)	18(8)	3-4	
<i>Ranunculus repens</i>	28(4)		4(1)	4(1)	51.5(14)	13(3)	40.5(9)	4-3	
<i>Ranunculus sardous</i>	1(1)							4	

Table 2 (continued)

Site	C				L	N			W
	I	II	II/III	III		I	II		
Phase									
Samples (n)	6	1	1	1	19	4	13		
<i>Rhinanthus serotinus</i>					12(5)	1(1)	1(1)		4
cf. <i>Rhinanthus serotinus</i>					2(1)				3–4
<i>Rumex acetosa</i>					4(2)				3–4
<i>Rumex crispus</i>	21.5(4)				188.5(16)	8(3)	24.5(8)		3–4
<i>Scirpus sylvaticus</i>	83(4)				203(16)	24.5(3)	440(11)		4–5
<i>Stachys palustris</i>						1(1)	1(1)		4–5
<i>Taraxacum officinale</i>							1(1)		3
<i>Thalictrum flavum</i>							1(1)		4–5
<i>Trifolium pratense</i>	3(2)				2(2)	4(1)	1(1)		3
<i>Trifolium repens</i>	11(3)				5(5)				3–4
<i>Valeriana officinalis</i>					20(8)	16(3)	48(9)		4–3
<i>Odontites serotina</i>	1(1)				3(1)				3–4
<i>Potentilla norvegica</i>	3(1)				27.5(7)	3(2)	1(1)		3
<i>Stellaria graminea</i>	7(2)				45.5(11)	6(2)	7(4)		3
cf. <i>Stellaria graminea</i>						1(1)			3
<i>Thalictrum lucidum</i>					6(2)	1(1)	4(2)		4–5
<i>Veronica chamaedrys</i>	2(2)				18(8)	1(1)			3
Nardo-Callunetea									
<i>Ajuga pyramidalis</i>							2(1)		3
<i>Calluna vulgaris</i>	1(1)				251(11)		1(1)		2–4
<i>Hieracium lachenalii</i>	3(1)				2(2)		1(1)		3
<i>Hypericum maculatum</i>					25(2)				3–4
cf. <i>Hypericum maculatum</i>					1(1)		12(1)		3–4
<i>Luzula campestris</i>					1(1)				2–3
cf. <i>Luzula campestris</i>	2(1)								2–3
<i>Luzula campestris/multiflora</i>	9(4)				11(6)	2.5(2)	1(1)		2–3
cf. <i>Luzula multiflora</i>	5(1)								3
<i>Pimpinella saxifraga</i>							1(1)		2
cf. <i>Pimpinella saxifraga</i>							1(1)		2
<i>Potentilla erecta</i>	4(2)				13(6)	8(4)	41(10)		3–4
<i>Viola canina</i>							1(1)		3–5
Scheuchzerio-Caricetea									
<i>Carex nigra</i>							2(1)	5(4)	4–5
<i>Juncus articulatus</i>	275(2)				378(4)	26(1)	44(4)		4–5
<i>Juncus filiformis</i>					27(2)				5
<i>Menyanthes trifoliata</i>	2(2)								5–6
<i>Parnassia palustris</i>					1(1)				4–5
<i>Pedicularis palustris</i>							1(1)		4–5
cf. <i>Rhynchospora</i> sp.					2(1)				-
<i>Stellaria palustris</i>	3(3)				11(4)				4–5
cf. <i>Herniaria glabra</i>	1(1)								2
<i>Potentilla argentea</i>	6(3)				21.5(6)	4(1)	72(9)		2
cf. <i>Potentilla argentea</i>					2(1)				2
<i>Rumex acetosella</i>	390(6)	1(1)			236.5(16)	76.5(3)	305(13)		2
<i>Dianthus deltooides</i>					1(1)	4(2)	3(3)		2
cf. <i>Dianthus deltooides</i>					1(1)				2
Others									
<i>Agrostis</i> sp.	13(4)				65(8)		1(1)		2
<i>Agrostis</i> sp./ <i>Poa</i> sp.	1(1)				4(3)				2
<i>Centaurea jacea/scabiosa</i>						1(1)	3(2)		2–3
<i>Dianthus armeria</i>									2
cf. <i>Dianthus armeria</i>	1(1)								2
<i>Galium palustre</i>	3(2)				98(11)	1(1)			4–5
<i>Lysimachia thyrsiflora/vulgaris</i>							1(1)		-
<i>Phleum</i> sp.					2(2)				-
cf. <i>Phleum</i> sp.	2(1)								-
<i>Poa annua/Puccinellia distans</i>	1(1)								-
<i>Poa pratensis/nemoralis</i>	1(1)								-
<i>Poa</i> sp.	100(4)				221(10)	4(1)	45(4)		-
Poaceae indet.	44(5)	1(1)			1043(18)	476(4)	258(13)		-
<i>Puccinellia distans</i>	1(1)				1(1)				3–5
<i>Stellaria graminea/palustris</i>					1(1)	1(1)			-
<i>Trifolium</i> sp.	8(3)				7.5(5)		6(5)		-

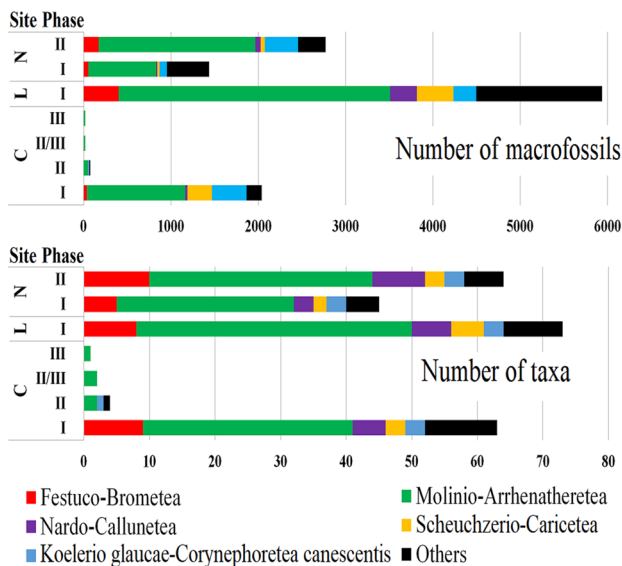


Fig. 3 The proportions of seed and taxa numbers in the archaeobotanical materials, by settlement phases and phytosociological groups; C, Chycina; L, Lubniewice; N, Nowy Dworek

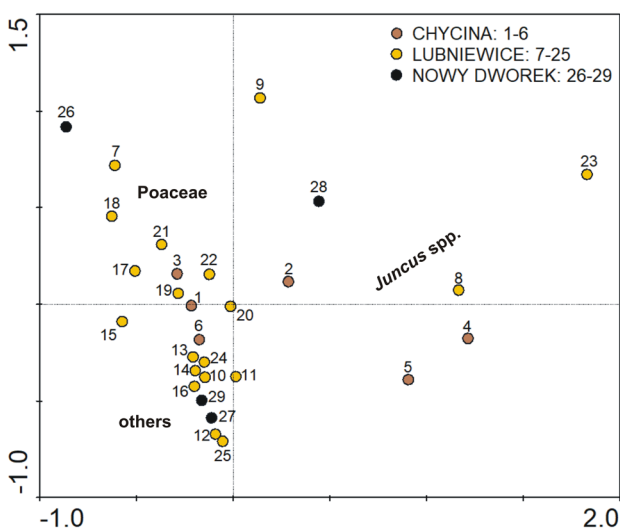


Fig. 4 Detrended components analysis (DCA) biplot of the botanical composition of Phase I samples from the individual islands

of macroremains (Fig. 2). The latter may result from the accumulation of remains of taxa such as *Juncus articulatus* and *J. conglomeratus/effusus*.

The botanical composition of the samples indicates that the most characteristic class of grassland growing near the islands was *Molinio-Arrhenatheretea*, which represents meso-eutrophic, semi-natural and managed meadows and pastures on soils of average richness and moisture content. This type of grassland is represented by almost 60% of all the macroremains from each island and over 50 species. The proportion of *Molinio-Arrhenatheretea*

species from every island is similar and high, over 50%. The Phase I remains from the islands are especially rich in these macroremains, with 1,216 from Chycina, 3,109 from Lubniewice and 776 from Nowy Dworek. However, these species are even better represented from Phase II at Nowy Dworek than Phase I, not only in terms of the number of remains (1,795), but also in terms of taxa (33) representing *Molinio-Arrhenatheretea* grassland. It is also worth noting that from Chycina in Phase II and III, only isolated remains of grassland plants were found, but almost all represent this class (Fig. 3). From every island, a similar set of taxa characteristic of *Molinio-Arrhenatheretea* was found. The greatest number of species was recorded from Lubniewice with 42 taxa, while there were 33 from Chycina and 37 from Nowy Dworek. Among 46 species found in the Phase I samples, 20 were found from all three islands. Among these are *Scirpus sylvaticus*, *Rumex crispus*, *Ranunculus repens*, *Prunella vulgaris*, *Lythrum salicaria*, *Daucus carota*, *Plantago major*, *Filipendula ulmaria*, *Cerastium holosteoides* and *Ranunculus acris*. At the same time, these were the most frequent species, with 15–23 remains in Phase I samples and also in the other phases. The great richness of *Molinio-Arrhenatheretea* taxa made it possible to sub-divide them into four phytosociological orders, which include *Molinieta lia caeruleae*, *Arrhenatheretalia*, *Plantagineta lia majoris* and *Trifolio fragiferae-Agrostietalia stoloniferae*. Of these, *Molinieta lia caeruleae* species were best represented from every island. The other orders were equally poorly represented from all islands. The order *Plantaginetea majoris* was hardly visible and from every island it was represented by isolated remains of only three taxa, *Plantago major*, *Poa annua* and *Polygonum calcatum*.

The next grassland class, *Festuco-Brometea*, a type of grassland growing on relatively dry soils, is the second best represented in terms of the number of taxa in the entire material, with a total of 13 species found, but only three of them, *Acinos arvensis*, *Anthemis tinctoria* and *Petrorhagia prolifera* occurred from all islands. Most of the taxa were represented by relatively few remains and only from Lubniewice. In 14 out of 19 Phase I samples, a fairly large number of *Hypericum perforatum* seeds were found (302.5). This was also found from Phase I at Chycina, and only from Phase II from Nowy Dworek. Two *Festuco-Brometea* species, *Anthemis tinctoria* and *Thalictrum simplex*, are characteristic of the order *Festucetalia valesiacae*, which is grassland of continental character growing on warm dry calcareous soils. *Anthemis tinctoria* was present from all sites, while *T. simplex* was found only from Nowy Dworek.

Class *Nardo-Callunetea* is represented by slightly fewer plants, with nine taxa. This represents semi-natural *Nardus* grasslands and seven of its species were found from Nowy Dworek, which were mostly from Phase II, while Chycina

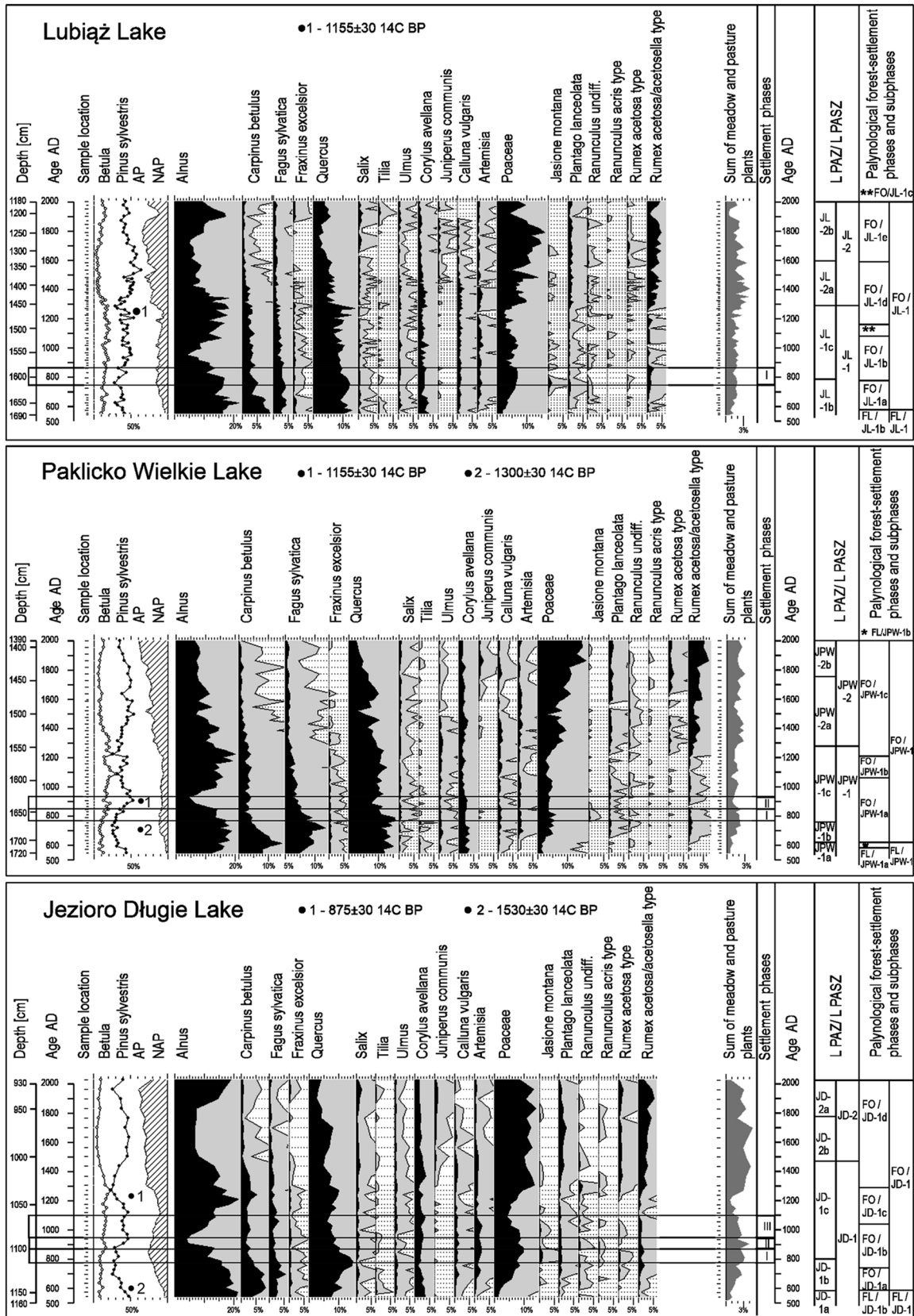


Fig. 5 Percentage pollen diagrams from the three lakes, Lubiąż, Paklicko Wielkie and Jezioro Długie, with selected curves of trees, shrubs and herbaceous plants. JL, Lubiąż; JPW, Paklicko Wielkie; JD, Jezioro Długie; FL, palynological wooded phase; FO, palynological settlement phase; LPAZ/LPASZ, Local Pollen Assemblage Zones/Local Pollen Assemblage Subzones; chronology of settlement phases as in Table 1

provided five species, only in Phase I, and another five from Lubniewice, where only Phase I was present. Almost all *Nardo-Callunetea* species were very poorly represented at each of the sites, except *Calluna vulgaris*, from which over 250 flowers and seeds were found from Lubniewice, and there were isolated finds from Chycina (Phase I) and Nowy Dworek (Phase II). Despite the relatively small number of *Nardo Callunetea* taxa, among them there were species characteristic of two orders, *Nardetalia* from Lubniewice and Nowy Dworek, and *Calluno-Ulicetalia* from all three islands.

Class *Scheuchzerio-Caricetea* grassland of marshy meadows and fens was distinguished on the basis of eight characteristic species which were mainly found in Phase I of all islands. With the exception of *Juncus articulatus*, other plants are represented by individual remains. The seeds of *J. articulatus* were abundant in the samples from Phase I in Chycina and Lubniewice (275 in two samples and 378 in four samples, respectively), but from Nowy Dworek there were far fewer remains from Phase I (26 in one sample) and Phase II (44 in four samples).

The final class, *Koelerio glaucae-Coryneporetea canescens*, which is a type of grassland growing on sandy soils and dunes, was represented by four species. It is worth noting that one of these, *Rumex acetosella*, was plentiful from all phases and islands, with over 350 remains from Chycina and Nowy Dworek and over 200 from Lubniewice.

Discussion

General picture of the early medieval landscape around the islands

Changes in the environment were the inevitable result of the growing amount of settlement in central Europe in the early medieval period. Woodland clearance as well as land management connected with animal husbandry gradually shaped not only ruderal plant communities, but also semi-natural meadows and pastures too, which became an integral part of the human landscape (Dutoit et al. 2009; Overland and Hjelle 2013; Kuneš et al. 2015), and this was no different in Lubusz land. Pollen results from the three lakes show a distinct wooded phase (FL) covering the Migration Period and the beginning of the early Middle Ages, followed by a settlement phase (FO) with varying degrees of human

pressure (Fig. 5). Before the development of local settlements and island enclosures there, the area was dominated by mixed deciduous woodland with a significant but variable proportion of *Carpinus*, *Fagus*, *Quercus* and some *Fraxinus*, *Tilia*, *Ulmus* and *Corylus*. Less fertile areas like glacial outwash plains must have been covered mainly by *Pinus* and *Quercus* woods and wet habitats by *Alnus* and riverside woods (Noryśkiewicz 2020).

There is evidence from the Jezioro Długie lake pollen results of early settlement at Chycina in the 7th century indicated by crops and grasslands. Cereal cultivation around Lubniewice and Nowy Dworek began in the mid 7th century, and meadows and pastures appeared there too. The pollen diagrams show increasing values of Poaceae, *Plantago lanceolata* and *Ranunculus* undiff., while *Calluna vulgaris*, *Juniperus* and *Jasione montana* appear sporadically. Importantly, the beginning of early medieval use of this area according to the pollen evidence started earlier than the construction of the timberwork of the islands. The mid 8th century marks an increase in the numbers and pollen values of herbaceous taxa connected with human activities (Fig. 5), which suggests that there was more intensive settlement when the islands were in use (Phase I). The pollen indicates growing numbers and pollen values of taxa characteristic of dry grasslands and pastures. Poaceae and *Calluna vulgaris* records increase, while *Jasione montana* forms a clear curve with a maximum above 1%. *Juniperus* is also sporadically present. This may suggest the development of dry grassland communities around the lakes and these are also in evidence from the macrofossil results. These grasslands may have spread as a result of heavy grazing by livestock on the light sandy soils around the sites. The results show not only the intensive development of agriculture with the cultivation of cereals, mainly *Triticum aestivum* and *Panicum miliaceum* as shown by the analysis of plant macroremains, but also of meadows and pastures. At the start of the 10th century, there was probably a change in the way the land was used, so that fields were cultivated further away from the islands, but meadows and pastures remained nearby. The widespread reduction in *Alnus* recorded by pollen diagrams, not only in northern Poland, but also in large areas of northern central Europe, occurred at the same time. The area of alder woods decreased around the 10th/11th centuries as a result of climate change (Stivrins et al. 2017; Latałowa et al. 2019) and this could coincide with Phase II of the islands. From the mid 11th century less settlement activity near the islands is shown by the pollen results, which is demonstrated by lower representation of meadow and pasture indicators and more alder (Fig. 5). A continuous rise of lake water level stables in the three lakes studied here was also observed (Chudziak et al. 2020).

Development and botanical composition of the meadows and pastures around Chycina, Nowy Dworek and Lubniewice

The archaeobotanical material from the islands is highly diversified, which represents a great variety of types of grassland which grew nearby. We should always remember that the recognition of past plant communities based on modern phytosociological classification is prone to inadequacies. These are mainly because of uncertainty about when the plant communities took their present form. It should also be remembered that there is no absolute phytosociological connection of a species to a particular plant community, which may be subject to modifications even today in different areas where the plants occur. A species may be recorded as growing within a vegetation community (phytocoenosis) which we might assign to a given syntaxonomic unit, such as an association, alliance, order or class, even though that community may not be its typical or associated unit (Zarzycki et al. 2002). Phytosociological systems also vary, and the species in the syntaxonomic units vary according to how the units are defined and what are the range limits of the individual syntaxa. If modern phytosociological classification is to be applied to ancient plant assemblages, it should be considered that it is not certain what past plant communities were like (Wasylikowa 1991). However, the use of phytosociology for archaeobotanical material can provide important clues for its interpretation. Assuming that the various plant communities in the past were at least similar to those of today, it is possible to arrange a long list of species into their probable communities and so describe the features of the past vegetation and the conditions of its occurrence (Rybniček and Rybničková 1995; Kalis et al. 2006; Karg 2008; Gao et al. 2018; Pini et al. 2021).

The development of settlement activity in the microregions within our study area was connected with the individual islands. The selection of places for settlement was not a matter of chance, but was related to local catchments (Chudziak and Kaźmierczak 2020b). There was a more favourable climate in the whole of Europe between the 7th and 9th century and this would have encouraged economic development in the region (Büntgen et al. 2011). The water levels in the lakes at the time of island construction seem to have been considerably lower than today. The quite similar archaeobotanical results for every island indicate that well developed *Molinio-Arrhenatheretea* grasslands grew on the dry land around all the lakes at the time. It is interesting that similar results were obtained from Żółte, another early medieval semi-artificial island in Pomorze Zachodnie (west Pomerania), Poland (Pińska and Latałowa 2014). Grasslands of this type are particularly strongly related to human activities such as using meadows to mow for hay or as pastures for grazing livestock (Klarzyńska and Kryszak 2016; Kulik

et al. 2016). Modern research shows that cattle, for example, prefer moist and productive habitats such as these grasslands provide (Putfarken et al. 2008). This is important, for archaeozoological results from this area indicate that cattle were important in the region in the early Middle Ages (Makowiecki 2020). They also show the presence of *Cervus elaphus* (red deer) and *Capreolus capreolus* (roe deer) there, which play a major part in the shaping of grassland communities (Bradshaw and Mitchell 1999; Schütz et al. 2003; Kuiters et al. 2005).

Another way in which these grassy areas near the islands may have been formed is by the clearance of deciduous woodlands from both dry and damp land (Pawłowski and Zarzycki 1977). The diversity of grassland species and the ample occurrence of *Molinio-Arrhenatheretea* plant remains suggest that this class developed rapidly and spread into various habitats. Moisture was undoubtedly the main diversifying factor, but the soil type must have been significant too (Table 2). A closer analysis of the species within the *Molinio-Arrhenatheretea* allows the taxa to be sub-divided into finer vegetational divisions, resulting in the identification of four orders and five associations. Since these plant communities must have developed at various distances from the wet ground near the lakes or watercourses, differences in the amount of soil moisture would have affected them too. The largest number of plants belong in the *Molinietalia caeruleae* order. It represents meadow and stream bank communities on moist or wet meso- and eutrophic soil (Maslovsky 2009; Grzegorzczak 2010; Zelnik and Čarni 2013). The presence of plants in this order may indicate the intensive use of this type of grassland near the islands. Within *Molinietalia caeruleae* are three related alliances, *Calthion palustris*, *Filipendulion ulmariae* and *Molinion caeruleae*. *Calthion palustris* today comprises nutrient rich, moist or wet meadows, on mineral soils which remain wet in these places even during droughts. These meadows are traditionally mown several times a year, and are of human origin. Species related to this alliance include *Epilobium palustre*, *Caltha palustris*, *Cirsium oleraceum* and *Myosotis palustris*. Another alliance, *Filipendulion ulmariae*, includes species such as *Stachys palustris*, *Valeriana officinalis*, *Filipendula ulmaria* and *Lythrum salicaria*, which may have grown in wet ground along the watercourses around the islands. *Molinion caeruleae* an alliance of nutrient poor grassland, mown annually, was also present near every lake and island as indicated by species including *Linum catharticum* and *Molinia caerulea*. Meadows and pastures of the order *Arrhenatheretalia elatioris* are also the outcome of intensive human activity. One of the conditions for their existence is traditional livestock grazing and these grasslands are now under protection (Chabuz et al. 2019). The presence of such types of grassland around the sites is shown by macrofossils of species such as *Daucus carota*, *Achillea*

millefolium and *Bromus hordeaceus*. They are found on slightly moist mineral soils, but can also grow by watercourses (Grzegorzczak 2010), which were plentiful around the islands. This set of species includes plants characteristic of lower syntaxonomic units. Four species (*Campanula patula*, *Galium mollugo*, *Knautia arvensis*, *Pastinaca sativa*) are now assigned to the alliance *Arrhenatherion elatioris*, which are meadows mown repeatedly. Another alliance, *Cynosurion*, which forms fertile pastures, was represented by three species, *Leontodon autumnalis*, *Ranunculus sardous* and *Trifolium repens*. Archaeobotanical studies indicate that this type of pasture appeared in Europe during the Roman period (Knörzer 1975). The other two orders within the *Molinio-Arrhenatheretea* may have only occurred locally or were of little use for the people there. The order *Trifolio fragiferae-Agrostietalia stoloniferae* develops as grasslands in places which are periodically flooded, but it is tolerant of trampling and it is indicated by species like *Potentilla reptans*, *Ranunculus repens*, *Agrostis stolonifera* and *Juncus glaucus*. There were also nitrophilous communities composed of species resistant to mechanical damage, such as modern blanket grasslands of the *Plantaginietalia majoris* order, of which only two species possibly connected with such communities have been found, *Plantago major* and *Poa annua*. What these two orders have in common is their resistance to intensive use, including trampling. The considerable presence of *Ranunculus repens*, *Rumex crispus* and *Plantago major* remains is noteworthy, and these plants can also spread into ruderal communities and even crops.

Unlike the *Molinio-Arrhenatheretea*, the other classes of grasslands from the dry land near every island are much less well represented. This may be because they were less useful or there were fewer suitable habitats for them, thus limiting their range.

Several species within class *Festuco-Brometea* represent thermophilous grasslands developing on rather dry soils, as shown by macroremains including *Acinos arvensis*, *Arabis hirsuta*, *Campanula glomerata*, *Centaurea scabiosa*, *Scabiosa columbaria* and *Stachys recta*. Although the origins of *Festuco-Brometea* communities are mainly due to environmental conditions, human activities, including keeping grazing livestock, are also important factors (Bała 2004; Dośtałek and Frantík 2008; Pokorný et al. 2015; Büchler et al. 2020). Plant remains from the islands indicate that there could have been such conditions on the dry land around every island, but these grasslands were only present during part of the period when the sites were in use. At Nowy Dworek, *Festuco-Brometea* is recorded in Phase I, while the number of both taxa and seed remains rises in the following phases. In the case of *Chycina*, the evidence of this type of community is only in Phase I.

Another grassland class which also seems to have been present in our study area is *Koelerio glaucae-Corynephoretea*

canescentis, which grows on sandy soil. The community is represented by only a few species. It is worth mentioning that in the pollen diagrams, the presence of occasional grains of *Jasione montana*, which is connected with this class, were recorded from horizons dating from before the formation of the islands. Numerous fruits of *Rumex acetosella* were found at each of the sites and it may have spread from this grassland to cultivated or ruderal habitats and arrived at the islands with the sediment which was brought there to strengthen the wooden structures (Badura et al. 2018).

Another important type of vegetation that must have developed near the islands includes communities such as the class *Nardo-Callunetea grasslands* and heath. They may have been formed from degraded *Molinio-Arrhenatheretea* grasslands, on disused and impoverished land or where woodlands had been cleared (Roo-Zielińska 2014). Macrofossils representing this class include *Luzula campestris*, *L. multiflora*, *Viola canina* and *Calluna vulgaris*. The latter, heather, grows on particularly poor soils, for instance sand, although sometimes also on nutrient-poor and acidic mires (Britton et al. 2003; Savukynienė et al. 2003). *Calluna* inflorescences and seeds were plentiful, especially at Lubniewice, which suggest that heather had been brought to the island on purpose (Badura and Noryskiewicz 2020).

The list of taxa includes species of the class *Scheuchzerio-Caricetea* which are characteristic of fens and transitional mires, but in small amounts, which may indicate that communities of this kind did not play a major part in the early medieval landscape around the lakes. Only in the case of Lubniewice were more remains found, suggesting that the people had more use for this plant material and brought it to the island. It should be remembered, on the other hand, that such wetlands are easily transformed into *Molinio-Arrhenatheretea* meadows on a peaty substrate (Osadowski et al. 2019).

In some papers on meadows (such as Grynja and Kryszak 2003; Maslovsky 2009; Wyłupek et al. 2019), the class *Phragmitetea*, formed by reeds, bulrushes and tall sedges, is also included with meadow and pasture communities. Although we have not listed taxa from this group, a considerable number of such remains have been identified in the material discussed here (Table 2). Some of them must have grown along the lake shores or local watercourses. When the water table was particularly low, such communities may have been colonised by plants of wet grassland. A reed belt, on the other hand, certainly formed around the islands and stabilised them.

The usefulness of meadows and pastures for the local human communities

In the past, meadows and pastures were the main source of grazing and fodder for livestock. Therefore, the emergence

of such grassland communities may be linked to animal husbandry (van Geel et al. 2003; Putfarken et al. 2008; Poschold et al. 2009; Florenzano 2019), although we have to remember that it would have been a gradual process. Archaeozoological data for the early Middle Ages in this area show that cattle, pigs, goats, sheep and horses were kept. At the same time, on the islands themselves, numerous fragments of animal bones were found, which were the post-consumption remains from food (Makowiecki 2020). Undoubtedly, livestock needed suitable sources of fodder from various plant communities, including grasslands. Naturally, the surrounding meadows and pastures may also have been influenced by wildlife such as deer (Gebert and Verheyden-Tixier 2001; DeVoe et al. 2019).

The plant remains from the islands include a number of important forage plants, which may indicate that herbaceous fodder such as hay was brought to the sites. These plants are mainly connected with the class *Molinio-Arrhenatheretea* and the order *Molinietalia caeruleae*. The legumes *Trifolium repens* and *T. pratense* were of particular nutritional value, as well as grasses such as *Poa pratensis* and *P. annua* (Miller and Thompson 2007; Komainda et al. 2019). Valuable grazing herbs like *Taraxacum officinale*, *Plantago lanceolata* and *Achillea millefolium* were also abundant. They made the fodder more nutritious (Putfarken et al. 2008; Pirhofer-Walzl et al. 2011; Supek et al. 2016). The accumulation of goat or sheep dung at Nowy Dworek (Phases I/II) is the only suggestion that live animals were kept on the islands. The pollen analysis of this dung showed that the goats or sheep had eaten tree leaves and inflorescences as well as herbaceous plants (Badura et al. 2018; Badura and Noryśkiewicz 2020). Some dung contained mostly pollen of herbaceous plants such as *Knautia arvensis*, *Plantago lanceolata*, *Rumex*, *Ranunculus* and Poaceae, which may represent associations within *Molinio-Arrhenatheretea*. Pollen of Apiaceae, Brassicaceae and Cichorioideae, possibly also from grassland plants, was also frequent in the goat or sheep dung, but in variable amounts.

The results include some plants with no special nutritional value, like *Bromus hordeaceus*, *Galium mollugo*, *Leontodon autumnalis* and *Angelica sylvestris*, which can be eaten by animals in small amounts or at certain stages of plant development. Some plants are unpleasant or poisonous (when fresh), such as *Ranunculus acris*, *R. repens* and *Caltha palustris* (Siminska et al. 2009; Grzegorzczak 2010; Nawara 2015).

The remains of *Campanula patula*, *C. glomerata*, *Centaurea jacea*, *C. scabiosa*, *Calluna vulgaris*, *Taraxacum officinale*, *Senecio jacobaea*, *Caltha palustris* and *Anthemis tinctoria* were also found, which are insect pollinated flowers, one of the features of traditional meadows and pastures (Steffan-Dewenter 2003; Meyer et al. 2017; Tonietto and Larkin 2018). Therefore, beekeeping may have developed

as a side effect of the formation of such communities around the islands. One of the ways in which plants adapt to entomophily is through bright, colourful flowers (McCall and Primack 1992; Gumbert et al. 1999; Hoyle et al. 2018). Showy purple or pink flowers are characteristic of species like *Campanula patula*, *C. glomerata*, *Centaurea jacea*, *C. scabiosa*, *Scabiosa columbaria* or *Calluna vulgaris* (Van Treuren et al. 1994; Steffan-Dewenter and Tschardt 2000; Denisow and Wrzesień 2015). Other species such as *Taraxacum officinale*, *Senecio jacobaea* and *Caltha palustris* have yellow-coloured flowers (Andersson 1996; Arnold et al. 2009; Lázaro and Totland 2010). Archaeologists suggest that the islands may have played a sacred role, so the plants mentioned above could have been used as decorations during the festivities held there. It may also be assumed that the nearby meadows and pastures were a source of medicinal plants for the local people. *Hypericum perforatum*, *Plantago major*, *Filipendula ulmaria*, *Centaurea scabiosa*, *Angelica sylvestris* or *Achillea millefolium* may have been gathered for this purpose (Grieve 1971).

Conclusions

The continuation of research on the samples obtained from the semi-artificial islands in the three lakes has provided new evidence of the presence and role of local grasslands in Ziemia Lubuska (Lubusz land) during the early Middle Ages. It may be assumed that in the 9th and 10th centuries these unusual sites were constructed near already well developed meadows and pastures. These particular types of grassland communities appeared around the 7th century with the clearance of woodland and establishment of local settlements. It seems that the grasslands were used by the people who built and used the islands at Nowy Dworek, Chycina and Lubniewice. The main types of grassland, according to the remains studied here, include meadows or pastures on slightly moist to wet soil. These, together with a significant number of species from other communities resilient to trampling and water level fluctuations, provide an image of strong economic uses of the areas around the lakes and related watercourses. Grasslands on drier, sandier, soil were also indicated by the plant remains, although these must have been located some distance away from the lakes themselves, but still within reach of the island users. The pastures would have been extensively grazed during spring and summer and haymaking cannot be excluded, either. Winter fodder was probably obtained from trees. The grasslands may have provided not only a source of fodder for farm animals, but also a source of medicinal and ornamental plants, as well as a grazing place for deer and other herbivores.

This study of the early medieval meadows and pastures represents only one part of the work on the natural history

of this area. Another aspect is the rich collection of remains of segetal and ruderal weeds that will allow us to study the changes that occurred in the landscape which was created by the people who built and used the islands.

Acknowledgements The paper has been written as part of the statutory research at the Department of Plant Ecology, University of Gdańsk (531-D040-D581-21) and financed by the Research Project of Young Scientists (Projekt Badawczy Młodych Naukowców), Faculty of Biology, University of Gdańsk (539-D040-B855-21). The field work has been carried out as part of the archaeological project of the Polish Ministry of Science and Higher Education 11H 12 0526 81. The authors wish to thank Wojciech Chudziak (archaeology) and Jacek Herbich (botany) for their helpful comments and suggestions. We would like to thank Julian Wiethold and one anonymous reviewer for their fruitful advice and encouraging comments on the manuscript.

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