

Changes of vegetation in Lake Perespilno environs (Lublin Polesie) in the Late Glacial and Holocene

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ABSTRACT. This paper focuses on the changes of vegetation cover in Lake Perespilno environs (Lublin Polesie) from ca. 12 800 years BP till the present time. Four pollen zones and 5 subzones were distinguished in the Late Glacial part of sediments, and 7 pollen zones and 19 subzones – in the Holocene part. The Late Glacial vegetation history is recorded in the sediments annually laminated. The two coolings clearly noticeable in the pollen diagrams were related to the Older and Younger Dryas but radiocarbon dating of the lower part of the lacustrine sediments from Lake Perespilno indicates the occurrence of an earlier cold phase corresponding to the pleniglacial decline. The occurrence of cooling between the Early Interstadial and Late Interstadial (Allerød) is questionable.

In the early Holocene the migration of trees occurred in the following order: *Ulmus*, *Corylus*, *Quercus*, *Fraxinus*, *Alnus*, and *Tilia*. From ca. 9000 years BP multispecies deciduous forests were forming. During the climatic optimum their composition was rather stable. The transformation of forest communities occurred at the beginning of the Subboreal chronozone. The proportion of thermophilous species decreased, and forests with *Carpinus* were developing. *Corylus* was retreating from ca. 4300 years BP, and the composition of forests became similar to that of modern ones.

The weak anthropogenic impact on the vegetation cover was associated with the migration of the Mesolithic tribes. The economic activities of the Neolithic people were more intensive but strong changes of vegetation cover under the influence of man have been recorded only since ca. 1700 years BP.

KEY WORDS: pollen analysis, history vegetation, Late Glacial and Holocene, Lublin Polesie, Poland

INTRODUCTION

Lake Perespilno is situated in the eastern part of the Łęczna-Włodawa Lake District, a subregion of the Lublin Polesie. The examined area is located in the central part of the “Western Polesie” protected zone, which extends from the Szack National Park in Ukraine to the Polesie National Park in Poland. The described site together with two neighbouring lakes (Wspólne and Koseniec) is protected as a nature reserve because the largest population of swamp turtles (*Emys orbicularis*) in Europe occurs there.

The palynological studies of Lake Perespilno sediments have been conducted for many

years. The Late Glacial laminated sediments render this site very interesting, which resulted in a range of related publications (Bałaga et al. 1998, Goslar et al. 1999). This paper aims to report the results of research on the Holocene sediments (the preliminary results were published by Bałaga et al. 2002). In addition, the vegetation succession during the Late Glacial will also be discussed, which is due to the fact that the latest results of radiocarbon dating (Goslar et al. 2000) of the laminated sediments have verified the former stratigraphic division of this deposit section (Ralska-Jasiewiczowa et al. 1999).

DESCRIPTION OF THE STUDY AREA GEOLOGICAL-HYDROLOGICAL CONDITIONS

The studied site is situated within the Włodawa depression (Fig. 1), which is a tectonic unit developed in the marginal part of the Precambrian East European platform. In the Breton phase this area was cut by the NE-SW faults, i.e. running sub-perpendicularly to the marginal dislocation zone of the platform. The resulting large block structures underwent vertical movements of different directions and amplitudes (Żelichowski 1984).

A diversified relief with relative heights reaching 30–50 m characterizes the surface of the sub-Quaternary basement, which is mainly composed of the Upper Cretaceous carbonate rocks susceptible to karstification, i.e. limestones, marls and chalk (Krassowska & Niemczycka 1984). Several ice-sheet advances largely removed the overlying Tertiary deposits. They are preserved in patches only locally, e.g. in

Włodawa environs (Mojski & Trembaczowski 1975). The origin of lakes in the Polesie region is closely related to geological structure and lithology of the sub-Quaternary basement (Wilgat 1954, 1994, Buraczyński & Wojtanowicz 1983, Wojtanowicz 1994, Bałaga et al. 1996).

The Quaternary deposits cover almost the whole studied area apart from the places where the Upper Cretaceous carbonate rocks are exposed. The Quaternary series is highly differentiated in respect of lithology and stratigraphy, and its thickness ranges from almost zero to 45 m. Its lithology is diversified both vertically and horizontally, probably because it was deposited during three glacial cycles (Harasimiuk & Wojtanowicz 1998).

This great variability of lithology, thickness and extent of the Quaternary deposits (forming several separate aquifers) determine water conditions in the studied region (Wilgat 1954, Michalczyk 1998). Shallow occurrence of poorly permeable deposits hinders the infil-

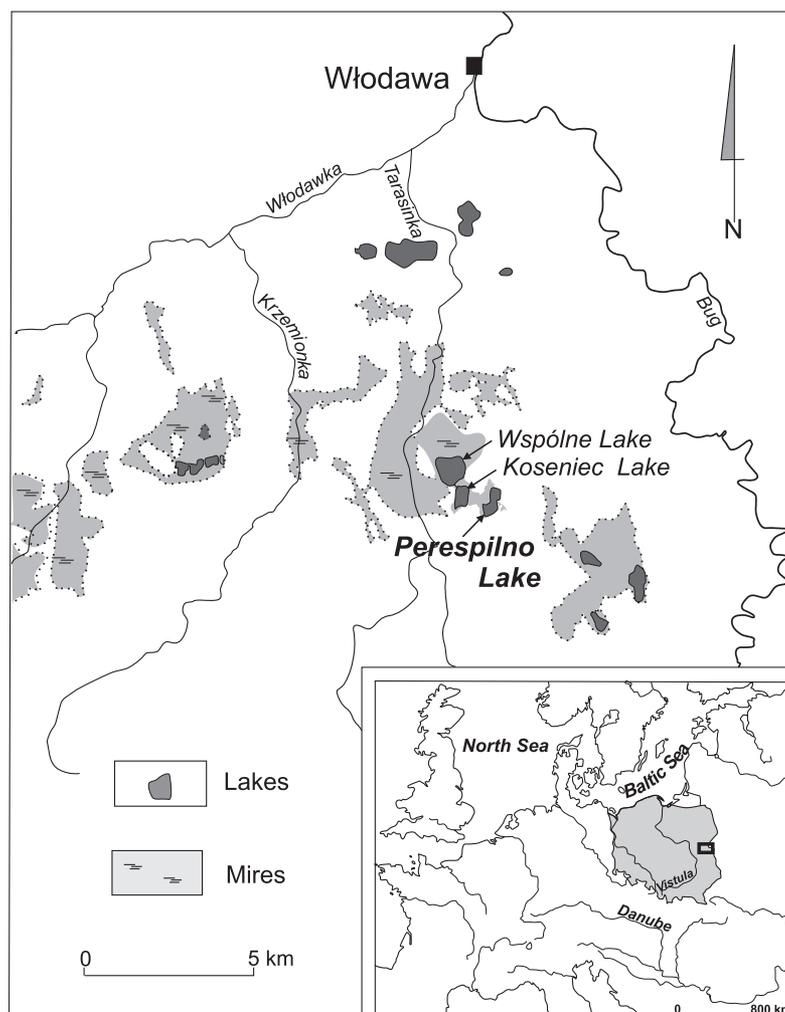


Fig. 1. Location map of the studied site

tration of water, which is collected in closed ground depressions. Weakly developed surface drainage network and shallow incision of rivers favour slow water flow. Tarasinka is the main river draining the examined area (Fig.1). Generally, shallow occurrence of groundwater and flat ground surface (relative relief reaches about 10 m) determine the characteristic features of the landscape with many swamps, mires and lakes. Shallow depressions create favourable conditions for peat development, which considerably enhances water storage of the area.

PRESENT-DAY VEGETATION

Forests cover over $\frac{3}{4}$ of the area of Lake Perespilno catchment, and over half of the neighbouring catchment of Lake Wspólne and Lake Koseniec (Fig. 2). Percentages of land use forms are presented in Table 1.

Alder carrs of *Alnetea glutinosae* class and various types of coniferous forests of *Vaccinio-Piceetea* class are predominant forest communities. Alder carrs develop in mesotrophic habitats where water stays on the ground surface during a considerable part of the year

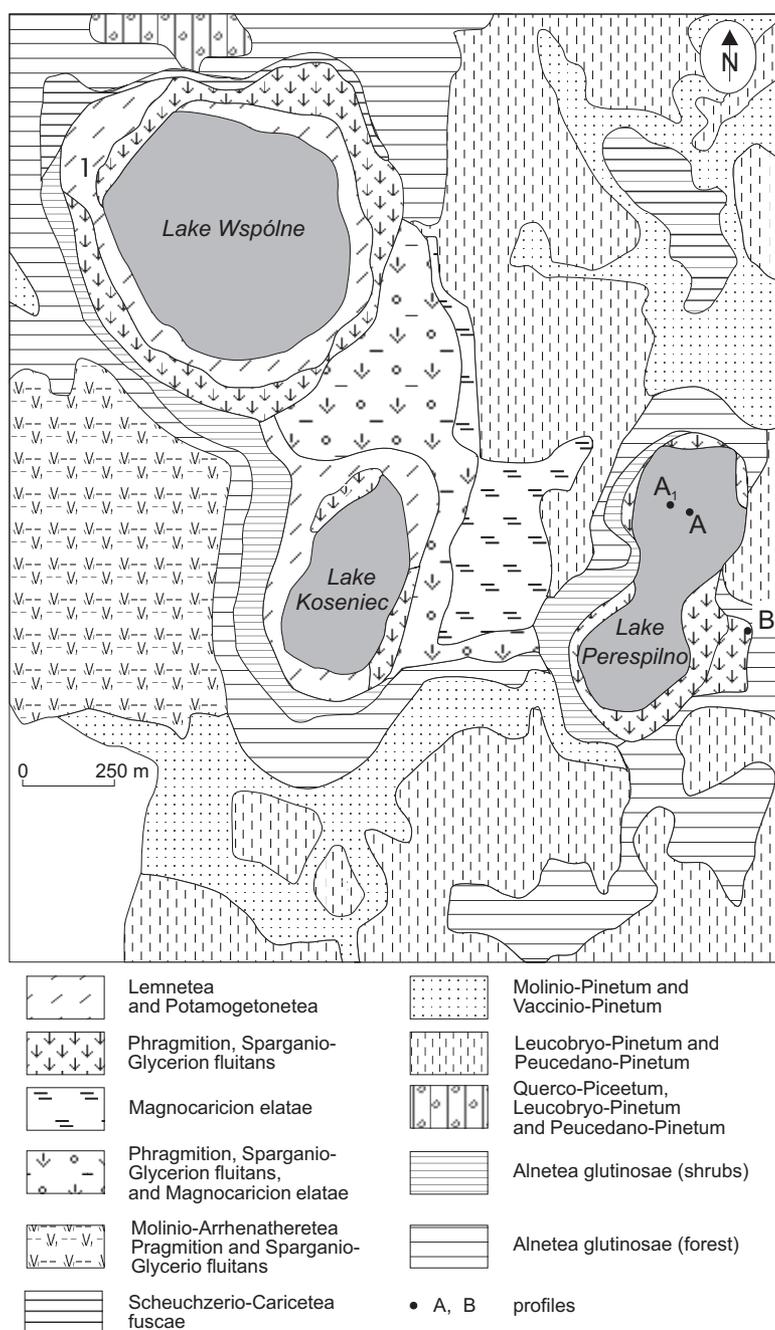


Fig. 2. Map of plant communities in Lake Perespilno environs after Fijałkowski et al. (1994), simplified

Table 1. Percentages of land use forms in lake catchments after Michalczyk et al. 1999, modified

Form of land use	Lakes	Forests	Shrubs and coppices	Swamps	Meadows and pastures	Arable land	Farm buildings
Catchment of Lake Perespilno %	9.47	77.54	9.25	3.39	0.22	0.08	0.00

due to high groundwater level. Willow shrubs (*Salicetum pentandro-cinereae* and *Betuleto-Salicetum repentis*) are often associated with alder carrs.

Coniferous forests near Lake Perespilno are considerably differentiated in respect of species composition and habitat conditions. Patches of *Quercus-Piceetum* and *Leucobryo-Pinetum* occupy rather fertile and wet habitats. In wetter habitats these associations are accompanied by *Ribo nigri-Alnetum*, and in drier habitats by *Peucedano-Pinetum* and *Festuco ovinae-Pinetum*. The coniferous forests (*Vaccinio uliginosi-Pinetum* and *Molinio-Pinetum*) occupy less fertile and wet habitats. Sedges occur on large swamps near the lake (Fijałkowski et al. 1994).

The land use in the catchment of Lake Perespilno has hardly changed for the last hundred years (Michalczyk et al. 1999).

DESCRIPTION OF STUDIED LAKE

Lake Perespilno consists of two basins (the northern one 6.4 m deep, and the southern one 4.5 m deep) with a total area of 24 ha. These basins are joined by a shallowing 2.7 m deep where gyttja reaches the thickness of 1.5 m (Wilgat 1954, 1994, Wilgat et al. 1991). During the last 170 years the area of Lake Perespilno has slightly changed; the data from topographic maps are presented in Table 2.

Lake Perespilno is classified as eutrophic and polymictic. Submerged water plants are represented by the association of *Ceratophylletum demersi*, which forms compact covers and penetrates water to a depth of 1.5 m in the south-western and north-eastern parts of the lake. The association of *Nupharo-Nymphaetum albae* occurs among reeds or in the margin of the compact reed belt. It is accompanied by the association of *Potamogetum natantis*, which is more abundant in the south-eastern

part of the lake. *Isoetes lacustris* occurs in the western part, together with the association of *Lemno-Utricularietum minoris*.

Reeds are mainly represented by the associations of *Phragmitetum communis* and *Scirpetum lacustris*, among which *Typha latifolia* and *Typha angustifolia* occur (more frequently near the north-western lakeshore). The proportions of the associations of *Equisetum limosi*, *Glycerietum maximae*, *Acoretum calami*, *Eleocharitetum palustri*, and *Sparganietum erecti* are considerably smaller (Fijałkowski 1960, Fijałkowski et al. 1994 and Fig. 2).

MATERIAL AND METHODS

The sediments for pollen analysis were collected by means of Więckowski's piston-corer from the central part (6.4 m deep) of the northern basin of Lake Perespilno in 1993 (profile A), and by means of Instorf borer from its shallower part (5.5 m deep) in 2001 (profile A-1). Profile A-1 was 9.5 m long, and a preliminary pollen analysis was carried out to correlate it with profile A in order to select fresh samples for radiocarbon dating. Instorf borer was also used to collect profile B about 400 m from the lakeshore, in the mire adjoining the lake basin from the southeast (Fig. 2).

The samples for pollen analysis were prepared with the Erdtman's acetolysis method (Faegri & Iversen 1989). Being preliminary treated with HCl and HF in order to carbonate and silica removal, respectively, they were boiled with KOH next. A modification with pellets containing *Lycopodium* spores was used for 1 cm³, two pellets for each sample, to count the pollen concentration (Stockmarr 1971, 1973). The obtained sporomorphes were stained with acid fuchsin and mounted in pure glycerine. Identification of pollen and spores was done using mainly keys inserted in Textbook of pollen analysis (Faegri & Iversen 1989) and in the book published by Moore et al. (1991). For critical determinations, modern reference material was used.

The percentages of individual taxa were calculated in the ratio of AP + NAP excluding telmatic plants, aquatic plants, and spores. The results of pollen analyses are presented as diagrams, which were made basing on the POLPAL program (Walanus & Nalepka 1996). The palynological data were correlated with the stratigraphic divisions based on the traditional method and numerical programme CONSLIK.

Dating was done in the Radiocarbon Laboratory of the Ukrainian National Academy of Sciences in Kiev and in the Poznań Radiocarbon Laboratory. The radiocarbon ages were obtained for gyttja from profile A-1, and for macrofossils from profiles A, A-1 and B.

Table 2. Changes of the Lake Perespilno area after Michalczyk et al. 1999

Year	1830	1887	1936	1960	1976
Area of Lake Perespilno (ha)	16.28	22.50	20.00	22.47	24.23

LITHOLOGY OF DEPOSITS

Profile A

Deposits description

0.0–640 cm	Water
640–1560 cm	Algae gyttja, black-brown, more compact downwards, with 42–50% of mineral material
1560–1980 cm	Algae gyttja, carbonate
1980–2248 cm	Algae gyttja, laminated*
2248–2263 cm	Algae gyttja, not laminated

* Characteristics of deposits is published by Bałaga et al. 1998, Goslar et al. 1999, and Goslar et al. 2000

Profile A-1

Deposits description

0.0–550 cm	Water
550–1500 cm	Algae gyttja, black-brown, more compact downwards

Profile B

Deposits description

0–80 cm	Sedge peat, black-brown, strongly decomposed
80–100 cm	Sedge peat, brown, strongly decomposed
100–165 cm	Sedge peat, brown, slightly decomposed, with many wood pieces (<i>Pinus</i>)
165–182 cm	Sedge peat, black-brown, strongly decomposed
182–189 cm	Clay, grey-brown, with dark organic interlayers
189–192 cm	Moss peat, brown, slightly decomposed
192–200 cm	Clay, grey-brown, with organic material

RADIOCARBON DATING

The results of radiocarbon dating of the late glacial laminated deposits (profile A) have been published by Goslar et al. (2000). The ages obtained for the Holocene part of the lake sediments (profile A-1) and the deposits of adjacent mire (profile B) are presented in Table 3, the ages of main vegetation changes – in Figure 3 and the relation between depth and age in Figure 4.

The deposits from the depths of 1295 and 1332.5 cm were radiocarbon dated at 6100 ± 90 and 6320 ± 90 , respectively. As these results seemed to be overestimated when compared to the pollen succession (Fig. 3), the macrofossils from the examined section of profile A-1 were also radiocarbon dated. In this case the obtained age (3900 ± 30) was much younger. In that controversial section all samples in which the content of macrofossils is sufficient for dating contain sand. Together with sand, macrofossils were probably “trapped in ice”,

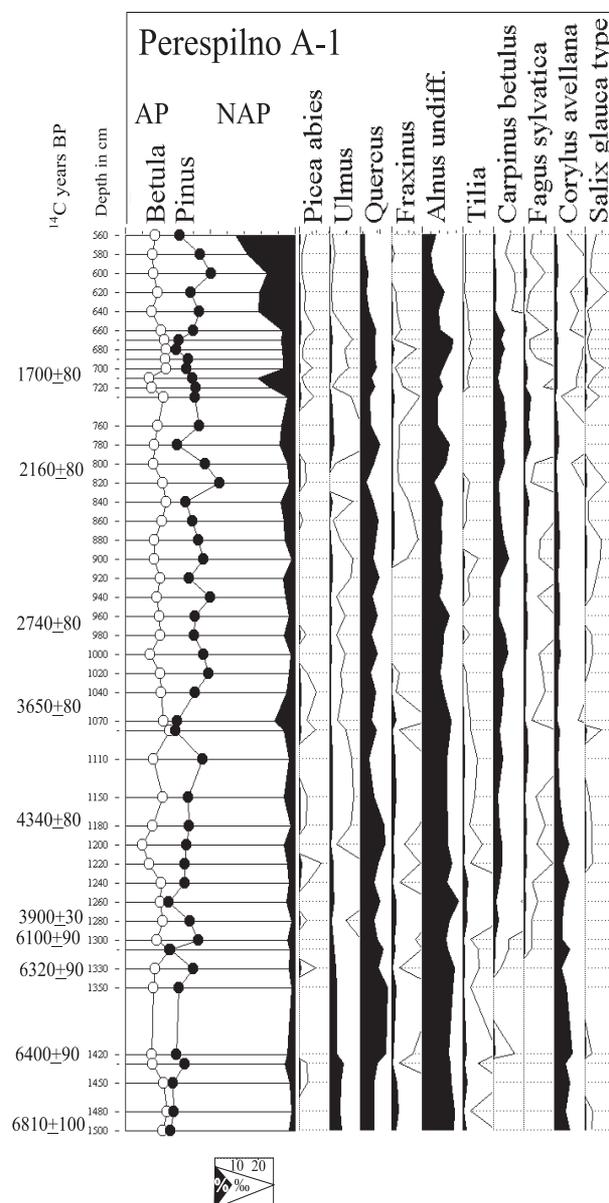


Fig. 3. Radiocarbon ages of main vegetation changes (profile A-1)

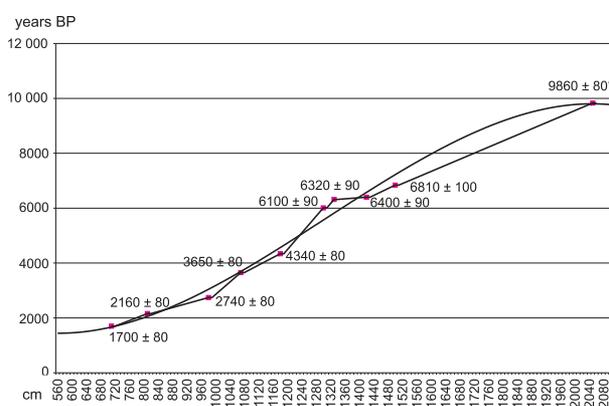


Fig. 4. Relation between depth and radiocarbon age of the Holocene sediments from Lake Perespilno,* after Goslar et al. (2000)

Table. 3. Radiocarbon ages of the lake and mire deposits

Perespilno A-1	No. Lab.	Material	Depth in cm	Age in years		
				BP	BC/AD	
					68.2% probability	95.4% probability
Ki-8632	gyttja	710–712.5	1700 ± 80	243–309 AD 313–425 AD	133–161 AD 169–197 AD 207–535 AD	
Ki-8633	gyttja	815–817.5	2160 ± 80	355–287 BC 259–245 BC 233–95 BC	389–41 BC 29–23 BC 9–1 BC	
Ki-8634	gyttja	975–977.5	2740 ± 80	973–957 BC 939–811 BC	1125–1117 BC 111–1097 BC 1087–1059 BC 1053–793 BC	
Ki-8635	gyttja	1065–1067.5	3650 ± 80	2137–2075 BC 2073–917 BC	2279–2253 BC 2231–2219 BC 2207–1861 BC 1843–1809 BC 1801–1773 BC	
Ki-8636	gyttja	1178–180.5	4340 ± 80	3091–3059 BC 3041–2881 BC	3335–3211 BC 3191–3155 BC 3135–2861 BC 2811–2755 BC 2721–2703 BC	
Poz-185	macrofossils	1293–1295	3900 ± 30	2470–2340 BC	2470–2290 BC	
Ki-8637	gyttja	1295–1297.5	6100 ± 90	5019–5017 BC 4999–4779 BC	5209–5171 BC 5143–5111 BC 5097–5093 BC 5081–4709 BC 4703–4691 BC	
Ki-8638	gyttja	1330–1332.5	6320 ± 90	5465–5447 BC 5419–5403 BC 5375–5227 BC 5225–5209 BC 5163–5145 BC	5475–5191 BC 5181–5061 BC	
Ki-8639	gyttja	1420–1422.5	6400 ± 90	5471–5431 BC 5425–5395 BC 5393–5315 BC 5311–5305 BC	5599–5595 BC 5529–5209 BC 5167–5143 BC 5109–5099 BC 5091–5083 BC	
Ki-8642	gyttja	1495–1500	6810 ± 100	5790–5625 BC	5960–5955 BC 5890–5530 BC	
Perespilno A	Poz-362	macrofossils	1633–1647	6130 ± 45	5210 BC (12.6%) 5170 BC 5140 BC (4.7%) 4950 BC	5260 BC (93.3%) 4910 BC 4880 BC (2.1%) 4850 BC
Perespilno B	Poz-217	peat	46.7–48.3	3820 ± 30	2310 BC (68.2%) 2370 BC	2400 BC (4.5%) 2370 BC 2350 BC (84.5%) 2190 BC 2180 BC (6.4%) 2140 BC
	Poz-183	peat	192–183	12 800 ± 60	13 800 BC (45.6%) 13 200 BC 12 800 BC (22.6%) 12 400 BC	13 900 BC (95.4%) 12 400 BC

and only then could such a heavy piece of ice sink into unconsolidated deposit. Such an interpretation can be assumed from the fact that the vertical streak of sand occurs only along one side of core A-1. The pollen spectra obtained from the middle part of the core did not include its sandy part, and as such couldn't reveal any noticeable changes in the pollen values (compare Fig. 3).

Macrofossils from the Holocene sediments occurring deeper than 15 m below lake water surface had to be taken from old (1993) core A, and the obtained age (6130 ± 45) is also underestimated when compared to a series of

previous radiocarbon ages and with pollen succession. Too long a storage time of core A may have influenced dating result in this case.

DESCRIPTION OF POLLEN ZONES

The diagrams (Figs 5–8) have been divided into local pollen assemblage zones (LP AZ), which correspond to periods of vegetation development dependent on climatic conditions. The pollen assemblage zones are also referred to as climatic-biostratigraphic zones sensu Blytt-Sernander (after Środoń 1972).

LATE GLACIAL

Description of local pollen assemblage zones belonging to the Late Glacial have been described

for Lake Perespilno, profile A and Perespilno mire, profile B (see Tab. 4, Figs 5, 6).

Table 4. Description of the pollen assemblage zones belonging to the Late Glacial (see Figs 5, 6)

Lake Perespilno, profile A	Perespilno mire, profile B
<p><i>Betula-Salix</i> LPAZ zone (varves 88–179) Characteristic taxa – <i>Betula</i> and <i>Salix</i>; <i>Hippophaë</i> and <i>Juniperus</i> present; high values of herbs with predominant Cyperaceae, Poaceae, and <i>Artemisia</i>. Two subzones are distinguished:</p> <p><i>Salix-NAP</i> subzone (varves 88–14) Characteristic high frequency of <i>Salix</i> and NAP (mainly Cyperaceae, Poaceae and Chenopodiaceae). Subzone limit: <i>Betula</i> increases, NAP decreases.</p> <p><i>Betula</i>-subzone (varves 14–179) Characteristic increase of <i>Betula</i>, and decrease of <i>Salix</i> and NAP; <i>Hippophaë</i> present; continuous <i>Juniperus</i> curve; <i>Typha latifolia</i>, <i>Sparganium</i>, <i>Menyanthes trifoliata</i> and <i>Nuphar luteum</i> appear; high values of <i>Equisetum</i> and <i>Pedicularis</i> sp. Subzone limit: decrease of <i>Betula</i>, <i>Salix</i>, NAP, increase of <i>Pinus</i>.</p>	<p><i>Betula-Salix-NAP</i> LPAZ zone (200–175 cm) Characteristic high values of <i>Betula</i>, <i>Salix</i> and NAP. Two subzones are distinguished:</p> <p>Cyperaceae-<i>Betula nana</i> subzone (200–195 cm) Cyperaceae dominant (59.5%); high values of <i>Betula nana</i> (3.5%), <i>Artemisia</i> (6.2%) and Chenopodiaceae (1%). Subzone limit: decrease of Cyperaceae, increase of <i>Betula</i>.</p> <p><i>Betula-Salix</i> subzone (195–175 cm) Characteristic increase of <i>Betula</i> (up to 37.5%); decrease of <i>Artemisia</i> (to 2.6%), Chenopodiaceae (to 0.2%), Cyperaceae (to 5.9%), <i>Equisetum</i> (to 22.6%); <i>Nuphar</i> and <i>Nymphaea alba</i> pollen, and Nymphaeaceae idioblasts present. Subzone limit: decrease of <i>Betula</i>.</p>
<p><i>Pinus-Betula</i> LPAZ zone (varves 179–747) Characteristic alternate domination of <i>Pinus</i> and <i>Betula</i>; characteristic taxa – <i>Juniperus</i>, <i>Thalictrum</i> and <i>Filipendula</i>. Three subzones are distinguished:</p> <p><i>Betula-Artemisia</i> subzone (varves 179–330) Characteristic increase of <i>Betula</i> and decrease of <i>Pinus</i>; still continuous curve of <i>Juniperus</i>; <i>Hippophaë</i> and <i>Nuphar luteum</i> present; rise of <i>Artemisia</i> and Chenopodiaceae; Subzone limit: <i>Pinus</i>, <i>Salix</i>, <i>Artemisia</i> and Chenopodiaceae decrease.</p> <p><i>Thalictrum</i> subzone (varve 330–589) <i>Artemisia</i> and Chenopodiaceae decrease; <i>Thalictrum</i> reaches its maximum values; <i>Nymphaea alba</i> appears. Subzone limit: <i>Pinus</i> and <i>Filipendula</i> increase.</p> <p><i>Filipendula-Artemisia</i> subzone (varves 589–747) Characteristic rise of <i>Filipendula</i> and <i>Artemisia</i>; decrease of <i>Pinus</i>; Subzone limit: <i>Artemisia</i> decreases.</p>	<p><i>Pinus-Betula</i> LPAZ zone (175–95 cm) Characteristic high values of <i>Pinus</i> and <i>Betula</i>; high and variable frequency of NAP. Three subzones are distinguished:</p> <p><i>Pinus</i> subzone (175–155 cm) Characteristic decrease of NAP, and increase of <i>Pinus</i> (up to 54.4%); high values of Cyperaceae (up to 17.6%); <i>Typha latifolia</i> and <i>Nymphaea alba</i> present.</p> <p><i>Artemisia-Chenopodiaceae</i> subzone (155–145 cm) Characteristic maximum values of <i>Artemisia</i> (6.2%), Chenopodiaceae (1.6%) and <i>Juniperus</i> (1.1%). Subzone limit: <i>Artemisia</i> decreases.</p>
<p><i>Pinus - Filipendula</i> LPAZ zone (varves 747–1189) Characteristic increase of <i>Pinus</i>; high values of <i>Filipendula</i> still: This zone is separated by hiatus. Zone limit: NAP increase</p>	<p><i>Pinus</i> subzone (145–95 cm) Characteristic high values of <i>Pinus</i> (up to 67.3%); frequency of NAP decrease (especially of <i>Artemisia</i> – to 1.5%, and Chenopodiaceae – to 0.25%). Subzone limit: <i>Artemisia</i> increases.</p>
<p><i>Artemisia-Chenopodiaceae</i> LPAZ zone (varves 1189–2358) High values of <i>Artemisia</i>, Poaceae, Cyperaceae, Chenopodiaceae; <i>Salix</i> and <i>Juniperus</i> increase; <i>Ephedra</i>, <i>Helianthemum</i>, <i>Gypsophila fastigiata</i>, <i>Pleurospermum austriacum</i> appear. Zone limit: NAP, Cyperaceae, <i>Artemisia</i> and Chenopodiaceae decrease.</p>	<p><i>Artemisia-Chenopodiaceae</i> subzone (95–85 cm) Cyperaceae dominant; <i>Artemisia</i> (6.3%) and Chenopodiaceae (1.3%) reach their maxima; <i>Juniperus</i> and <i>Ephedra</i> present. Zone limit: decrease of <i>Artemisia</i> and NAP, increase of AP.</p>

THE HOLOCENE

Lake Perespilno, Profile A, (Fig. 7)

***Betula-Pinus-Ulmus* LPAZ zone** (varves 2787–3113 and 1980–1905 cm)

Characteristic alternate rise of *Pinus* and *Betula*; beginning of continuous *Ulmus* and *Corylus* curves; pollen of other thermophilous

trees appear in low values (to 1%). Four subzones are distinguished:

Betula subzone (varves 2358–2778)

Betula dominant; beginning of continuous *Ulmus* curve; *Populus* present; sporadic pollen of other thermophilous species; *Artemisia* and Chenopodiaceae decrease; *Humulus* appears; *Filipendula*, *Urtica* and Filicales increase; *Nymphaea alba* and *Typha latifolia* present.

Subzone limit: *Betula*, *Salix* increase, *Pinus* decreases.

Betula-Salix subzone (varves 2787–3063)

Characteristic increased values of *Salix*; alternate domination of *Pinus* and *Betula*; beginning of continuous *Corylus* curve. Subzone limit: *Pinus*, *Corylus* rise, *Salix* falls.

Pinus subzone (varves 3063–3113 and 1980–1935 cm)

Pinus dominant (58.0–66.4%); increase of *Ulmus* (2.1–3.9%), *Corylus* (1.2–8.1%) and *Quercus* (up to 2.8%); pollen values of other thermophilous trees not exceeding 1%. Subzone limit: *Corylus*, *Quercus* increase.

Corylus subzone (1935–1915)

Rise of *Ulmus* (2.4–3.4%, with peak of 12.7% at a depth of 1910 cm), *Corylus* (5.8–9.7%), *Quercus* (up to 3.2%) and *Alnus* (up to 2.6%); decrease of *Pinus* (60.4–36.6%). Subzone limit: *Corylus* increases, *Pinus* decreases

***Corylus-Quercus-Alnus* LPAZ** zone (1915–1705 cm)

Distinct decrease of *Pinus*; pollen values of thermophilous trees increase (*Corylus* and *Alnus* dominant); characteristic occurrence of *Pteridium aquilinum*. Two subzones are distinguished:

Corylus subzone (1915–1820 cm)

Characteristic culmination of *Corylus* curve (up to 13.9%) followed by its gradual decrease to 8.1% and culmination of *Alnus* (15.9%); *Ulmus* ranges between 3.2 and 6.3%; slight rise of *Quercus* (2.3–3.7%) and *Fraxinus* (1.4–1.7%); values of *Tilia* about 1%. Subzone limit: *Corylus*, *Alnus* decrease, *Tilia* increases.

Pinus subzone (1820–1705 cm)

Pinus dominant (26.0–42.7%); *Alnus* (9.5–14.0%), *Quercus* (3.7–6.5%), *Ulmus* (4.2–5.9%) and *Tilia* (up to 1.1%) increase; values of *Corylus* (to 12.7%) somewhat lower than in the preceding subzone, with a distinct decrease (to 3.9%) in the late phase of the subzone. Subzone limit: *Pinus* decreases, *Alnus*, *Ulmus*, *Corylus* increase.

***Corylus-Quercus-Ulmus* LPAZ** zone (11 705–1363 cm)

Characteristic high values of *Ulmus*, *Quercus*, *Alnus*, *Corylus*, *Tilia*, and *Fraxinus*. Three subzones are distinguished.

Alnus subzone (1705–1565 cm)

Alnus dominant (18.0–24.6%); gradual rise of *Quercus* (5.0–8.5%), *Fraxinus* (2.1–3.4%) and *Tilia* (0.8–2.0%); curve of *Ulmus* slightly increases, then decreases and rises again; *Hedera helix* appears. Subzone limit: *Ulmus*, *Quercus* decrease, *Pinus* increases.

Pinus subzone (1565–1495 cm)

Increase of *Pinus* (22.7–35.0%), decrease of *Ulmus* (7.6–5.0%), *Alnus* (17.9–15.4%) and *Corylus* (9.3–8.0%). Subzone limit: *Pinus* decreases, *Corylus* increases.

Corylus subzone (1495–1265 cm)

Characteristic rise (up to 14.6%) and next decrease (to 8.1%) of *Corylus*; values of *Alnus* fluctuate (12.8–20.9%); decrease of *Ulmus* (4.1–3.9%) and *Quercus* (13.2–8.8%); frequency of *Tilia* and *Fraxinus* not exceeding 2.7%; *Artemisia* increases; first pollen grain of *Plantago lanceolata* appears. Subzone limit: *Corylus* decreases, *Pinus* increases.

***Corylus-Carpinus* LPAZ** zone (1365–1175 cm)

Values of thermophilous taxa (*Ulmus*, *Corylus*, *Tilia*, and *Fraxinus*) decrease; *Pinus* increases; continuous but low curves of *Carpinus* and *Fagus*. Three subzones are distinguished:

Ulmus subzone (1365–1290 cm)

Curve of *Ulmus* falls to 1.1%; *Alnus* decreases (18.8–13.1%); increase of *Pinus* (23.3–37.6%) and *Quercus* (9.7–12.1%); values of *Fraxinus* range from 0.8 to 2.8%, and those of *Tilia* from 1.2 to 1.4%; curves of *Carpinus* and *Fagus* are continuous but low (up to 1%); *Corylus* curve falls (3.7–4.2%) in the beginning of the subzone, and next it rises to 10.8%. Subzone limit: *Quercus*, *Fraxinus* decrease, *Carpinus* increases.

Corylus subzone (1290–1235 cm)

Corylus (6.7–12.3%), *Ulmus* (up to 1.7%), *Alnus* (up to 18.5%) and *Carpinus* (2.9–3.1%) increase; *Quercus* decreases (to 8.5%); slight rise of *Artemisia* and Cyperaceae; next pollen grain of *Plantago lanceolata* appears. Subzone limit: *Corylus* decreases, *Ulmus* increases.

Carpinus subzone (1235–1175cm)

Gradual increase of *Carpinus* (3.8–5.0%) and *Fagus* (0.8–1.3%); characteristic culminations of *Quercus* (up to 14.1%) and *Alnus* (up to 24.5%) in the last part of the subzone

are associated with decrease of *Pinus* (34.4–19.5%) and *Corylus* (9.1–3.4%); low frequency of *Ulmus* and *Fraxinus* (up to 1.6%), and *Tilia* (up to 0.9%); increase of *Artemisia* and NAP; *Plantago lanceolata*, *Urtica*, and *Rumex acetosella* present. Subzone limit: *Corylus* falls, *Pinus* rises.

***Pinus-Alnus-Quercus* LPAZ**
zone (1175–880 cm)

Characteristic high values of *Pinus*, *Quercus*, *Alnus*, and *Carpinus*. Five subzones are distinguished on the basis of the changes in the values of *Carpinus*, *Artemisia* and NAP.

***Pinus* subzone (1175–1070 cm)**

Characteristic decrease of *Carpinus* (4.9–3.2%); increase of *Pinus* (15.2–18.6%) and *Betula* (18.7–23.2%); decrease of *Alnus* (to 15.2%), *Quercus* (to 5.5%), *Corylus* (to 2.7%), *Tilia*, and *Fraxinus* (to 0.7%); low values of *Ulmus* (1.0–2.1%) and *Picea* (0.4–0.7%); increase of anthropogenic indicator. Subzone limit: *Carpinus* increases.

***Carpinus-a* subzone (1100–1070 cm)**

Characteristic small rise of *Carpinus* (4.4–6.8%), *Pinus* (34.1–34.3%), and *Alnus* (17.2–18.9%); Curves of *Quercus* (8.9–8.6%) and *Corylus* (2.3–2.8%) decrease; values of *Fagus*, *Ulmus*, *Tilia*, and *Picea* not exceeding 1%; slightly higher values of *Fraxinus* (to 1.2%). Subzone limit: *Carpinus* decreases.

NAP subzone (1015–1070 cm)

Characteristic increase of *Artemisia* and NAP; decrease of *Carpinus* (to 2.7%), *Quercus* (to 8.6%), *Pinus* (to 31.5%), and *Alnus* (to 15.6%); *Fagus* curve rises to 1.7% in the middle part of the zone; slight increase of *Betula* (19.9–27.1%). Subzone limit: *Carpinus* decreases

***Carpinus-b* subzone (1015–975 cm)**

Characteristic rise of *Carpinus* (5.0–6.5%), decrease of NAP and *Artemisia*; slight increase of *Alnus* (14.8–17.4%) and *Fagus* (up to 1.6%), decrease of *Pinus* (to 31.5%) and *Betula* (to 19.4%). Subzone limit: decrease of NAP, increase of *Quercus*, *Alnus*, and *Carpinus*.

***Pinus-NAP* subzone (975–880 cm)**

Characteristic decrease of *Carpinus* (to 3.5%); curves of *Alnus*, *Fraxinus* and *Ulmus* fall, and those of *Pinus* and *Betula* rise; anthropogenic indicators, among them Cere-

alia, increase. Subzone limit: increase of *Carpinus*, decrease of NAP.

***Pinus-Alnus-Abies* LPAZ zone (880–690 cm)**

Characteristic the highest values of *Carpinus* and the occurrence of *Abies*. Four subzones are distinguished on the basis of *Carpinus* and *Artemisia* frequency.

***Carpinus* subzone (880–815 cm)**

Characteristic the highest values of *Carpinus* (3.9–8.9%), and fall of NAP and *Artemisia*. Subzone limit: decrease of *Carpinus*, increase of NAP and *Salix*.

***Salix-NAP* subzone (815–755 cm)**

Characteristic increase of *Salix*, *Betula* (22.6–32.5%), NAP, *Artemisia*, *Pteridium*; *Carpinus* decreases (4.7–3.8%). Subzone limit: *Salix* falls, *Pinus*, *Carpinus*, and *Tilia* rise.

***Pinus* subzone (755–690 cm)**

Pinus increases (41.1–45.6%); *Alnus* decreases (13.2–10.6%); *Fagus* reaches its highest values (2.3%); *Carpinus* rather high (4.3–5.6%); values of *Tilia*, *Ulmus*, and *Corylus* not exceeding 1%.

LAKE PERESPILNO, PROFILE A-1
(Fig. 8)

***Pinus-NAP* LPAZ zone (710–560 cm)**

Characteristic high frequency of NAP, among them anthropogenic indicators rise. Three subzones were distinguished:

NAP subzone (720–705 cm)

Characteristic high values of NAP, Poaceae, *Rumex acetosella*, and *Secale cereale*. Subzone limit: decrease of NAP, increase of *Carpinus*.

***Carpinus* subzone (705–650 cm)**

Characteristic rise of *Carpinus* and fall of anthropogenic indicators. Subzone limit: increase of NAP, decrease of *Carpinus*, *Quercus*.

NAP-Cerealia subzone (650–560 cm)

Pollen of Cerealia reaches about 3.5%; values of all deciduous trees decrease, high values of *Humulus/Cannabis* type.

PERESPILNO MIRE, PROFILE B
(Fig. 6)

***Pinus-Betula-Ulmus-Alnus* zone (85–65 cm)**

Characteristic rise of *Pinus* and *Betula*; *Alnus*, *Corylus*, and *Ulmus* increase.

Quercus-Corylus-Ulmus-Tilia

zone (65–45 cm)

Increase of *Quercus*, *Tilia* and *Fraxinus*; *Carpinus* and *Fagus* appear.

Pinus-Alnus-Sphagnum zone (45–0 cm)

High values of *Pinus*; *Alnus* and *Sphagnum* increase; gradual decrease of *Corylus*, *Tilia*, and *Ulmus*.

CHANGES OF VEGETATION IN THE LATE GLACIAL

Betula-Salix LPAZ (Table 4, Figs 5, 6)

Pollen spectra of the oldest examined deposit layers (*Salix*-NAP and Cyperaceae-*Betula nana* subzone) with high pollen values of herbs indicate the occurrence of open landscape in Lake Perespilno environs at ca. 12 800 years BP (see also age cal BP in Fig. 5). Sedge communities developed in waterlogged habitats near the lake as evidenced by high values of Cyperaceae. Spores of *Selaginella selaginoides*, Musci and *Sphagnum* can indicate the occurrence of moss tundra communities. Shrub communities with various species of willows and birches (*Salix polaris* and *Betula nana* – profile B) were also an important component of the wet habitat landscape. Xerothermic grass-*Artemisia* communities, with different species of *Artemisia* and Chenopodiaceae as the main components, occurred on dry and sandy habitats. The subzone was earlier correlated (profile A) with the Older Dryas (Bałaga et al. 1998, Goslar et al. 1999). In this paper, a proposition of other scheme is accepted (Ralska-Jasiewiczowa et al. 1999), in which the subzone corresponds to the last part of the pleniglacial. The issues concerning of Late Glacial chronology are discussed among others by Menke (1985 in Litt et al. 1998), van Geel et al. (1989), Litt & Stebich (1999), Litt et al. (2003), and de Klerk (2004).

The increasing values of *Betula*, and the simultaneous decrease in NAP percentages in the *Betula* subzone provide evidence of the development of pioneer birch forests in Lake Perespilno environs. Light-demanding shrubs (*Juniperus communis* and *Hippophaë rhamnoides*) occupied dry and sandy habitats. *Myriophyllum spicatum* and *M. verticillatum* occurred in the lake, and *Sparganium*, *Typha latifolia*, *Polygonum amphibium*, *Equisetum*,

and *Menyanthes trifoliata* formed rush communities in the inshore zone. Algae of genus *Pediastrum* were abundant. Climate amelioration at that time is evidenced by moderately thermophilous species such as *Typha latifolia*, *Myriophyllum spicatum*, *M. verticillatum*, and *Nuphar luteum*. This subzone, distinguished in the profiles A and B, can be correlated with the early interstadial Meiendorf (Menke 1968, Usinger 1985, Litt & Stebich 1999, Litt et al. 2001) but it does not represent a complete succession (Ralska-Jasiewiczowa et al. 1999).

Pinus-Betula LPAZ (profile A and B)

The increasing values of *Pinus* in pollen spectra of *Pinus-Betula* zone point to the increasing proportion of pine in forest communities. Birch was still an important component of forests in the *Betula-Artemisia* subzone (Fig. 5). The continuing high values of NAP, rise in the pollen values of *Artemisia* and Chenopodiaceae, and the continuous curve of *Juniperus communis* indicate that forests were rather open. It should be stressed that the values of *Juniperus communis* in pollen spectra from Polesie are rather low (up to 1%) in comparison with those from other regions of Poland (Ralska-Jasiewiczowa 1989).

The occurrence of *Typha latifolia* and *Nuphar luteum*, and the gradually increasing percentages of *Pinus* pollen suggest amelioration of thermic conditions. The rise in the values of *Artemisia* and Chenopodiaceae provides evidence of drier climate favouring the expansion of steppe-like communities.

Pinus pollen predominates in pollen spectra of the *Thalictrum* subzone (profile A – Fig. 5). Its domination is associated with the decrease in the values of *Artemisia* and Chenopodiaceae, probably indicating the expansion of forest communities with predominant pine onto the habitats occupied by heliophilous communities. The decrease in the frequency of *Juniperus communis* may provide evidence of greater shading in the forests. The appearance of thermophilous *Nymphaea alba* in the lake indicates progressive climate amelioration.

Birch-pine forests were still present near the lake in the *Filipendula-Artemisia* subzone (profile A, Fig. 5). The rise in the values of *Artemisia* and Chenopodiaceae provide evidence of the spread of heliophilous communities. Thermophilous species, e.g. *Nymphaea alba*, were still present in the lake.

The three subzones distinguished in profile A (discussed above) were related to the early phase of the Allerød (Bałaga et al. 1998, Goslar et al. 1999), and defined as the late phase of the Early Interstadial – *Betula-Artemisia* subzone, and the Oscillation Period – *Thalictrum* and *Filipendula-Artemisia* subzone (Ralska-Jasiewiczowa et al. 1999). Phases of cooling and warming during the Oscillation Period were not distinct. Phases of cooling and/or decreased humidity can be probably evidenced by the rise in the values of *Artemisia* and Chenopodiaceae (*Betula-Artemisia* and *Artemisia-Filipendula* subzones in profile A, and *Artemisia-Chenopodiaceae* subzone in profile B). The ages of these phases do not correspond to those of the phases described by Litt et al. (2001).

***Pinus-Filipendula* LPAZ zone (profile A) & *Pinus* subzone (profile B)**

Pine (playing an increasingly important role) and birch were main components of forest communities. Pollen spectra provide evidence of open forests with ferns (Filicales), in which *Picea* and *Larix* probably occurred as an admixture. Pollen grains of these trees appear sporadically but even low values may indicate that they grew near the lake as their pollen spread at a rather short distance. The presence of *Larix* is evidenced by the occurrence of its macrofossils, i.e. needles found in the samples prepared for radiocarbon dating. The continuous curve of *Populus* may indicate the formation of aspen-willow communities, which resembled a modern association of *Salici-Populetum* occupying wet habitats near lakes and streams. A hiatus lasting about 670 years occurs in this zone.

Higher values of *Populus* and *Filipendula* (profile A), as well as the decrease in the frequency of *Thalictrum*, *Potentilla* type and *Juniperus* can indicate that the climate was not only warmer but also more humid during this zone. A strong development of *Nymphaea alba* and *Typha latifolia* in the lake are worth noting, as these plants indicate the average temperature of July of about 16°C. This zone corresponds to the late phase of the Oscillation Period and the younger phase of the Allerød.

***Artemisia-Chenopodiaceae* LPAZ (profile A – Fig. 5 and profile B – Fig. 6)**

The rise in the pollen values of herbs, and especially different species of *Artemisia* and

Chenopodiaceae, indicates the occurrence of open communities associated with very dry continental climate. This zone corresponds to the Younger Dryas. Herb communities with *Artemisia* and Chenopodiaceae were predominant at that time. Also, taxa typical of dry and cold climate, such as *Ephedra distachya*, *Helianthemum*, *Pleurospermum austriacum*, *Gypsophila fastigiata* type, occurred in these communities. Light-demanding *Juniperus* was again a characteristic component of the Late Glacial communities in the Lake District. Pine and birch together with spruce and larch (whose pollen appears more frequently in this zone) occurred as groups of trees in a park landscape. Goslar et al. (1999) published a detailed account of climatic conditions during this period and the preceding ones.

CHANGES OF VEGETATION IN THE EARLY AND MIDDLE HOLOCENE

***Betula-Pinus-Ulmus* LPAZ (profile A – Fig. 5 and profile B – Fig. 7)**

During this zone, corresponding to the Preboreal chronozone, denser woodlands with dominant birch developed. The proportion of herbs was still considerable (pollen values up to 15.7%). Previously numerous heliophytes (*Artemisia* and Chenopodiaceae) gradually retreated. Birch outnumbered other trees to the utmost degree, a situation would not happen during the subsequent vegetation history in Lake Perespilno environs. In the *Betula* subzone the pollen values of *Betula* (up to 35.4%) are at the level of their first maximum in the Late Glacial. Pine was also an important component of forests. The continuous and gradually rising curve of elm appears in the diagram. The early spread of elm was a characteristic phenomenon in the Lublin Polesie (Ralska-Jasiewiczowa 1983, Bałaga et al. 1983, 1995, Bałaga 1990). Isopollen maps reveal that elm migrated from the south-east, i.e. from the Eastern Carpathians (Huntley & Birks 1983, Bodnariuc et al. 2002). Assuming that the limiting values of elm local presence are 1.5–2%, it can be pointed out that elm was spreading from ca. 9900 years BP (interpolated age, see Fig. 4). Elm entered pine-birch forests in more fertile and wetter habitats. Willow and poplar were also impor-

tant in the landscape at that time. They occupied wetter places near the lake. *Humulus*, *Urtica*, and *Filipendula* occurred among herbaceous vegetation in these communities. The proportions of *Artemisia*, Poaceae, and *Pinus* increased during the formation of pine-birch-elm communities in the *Salix-Betula* subzone, probably evidencing changes in moisture and thermal conditions. The appearance of *Juniperus communis* and *Gypsophila fastigiata* pollen in this subzone can also indicate drier and cooler climate.

This domination of birch in forests lasted for about 380 years. In the course of time birch was retreating from birch-pine forests, pine becoming predominant (*Pinus* subzone) from ca. 9500 years BP (Fig. 4). A dynamic spread of hazel in pine-birch forests (*Corylus* subzone) started about 9300 years BP (Fig. 4) as evidenced by its pollen values over 2%, i.e. over the assumed limit value of hazel local presence. The appearance of pollen of other thermophilous trees (*Quercus*, *Fraxinus*, *Alnus*) indicates that these trees approached the examined area.

Nymphaea alba and *Typha latifolia* became again very abundant in the lake providing evidence for a considerable warming at the beginning of Holocene. The lamination of sediments declined.

***Corylus-Quercus-Alnus* LPAZ (Fig. 7)**

A transformation of pine-birch-elm forests with abundant hazel occurred about 9000 years BP (Fig. 4). Pine was gradually replaced by thermophilous species. Multispecies deciduous forests with oak, alder, ash, and then lime became dominant. Open forests created favourable condition for the development of shrub understorey with heliophilous hazel, which reached its first maximum values in this zone. *Pteridium aquilinum* more frequently appeared in herbaceous vegetation, with other ferns (Filicales) still being present.

Alder expanded on wet or waterlogged habitats, and reached its first maximum about 100 years later than hazel. Alder communities near the examined site encroached on moss mire with abundant *Scorpidium scorpioides* (Marek 1965). Palaeobotanical analyses of the alder mire situated near the south-eastern shore of Lake Perespilno reveal that the following succession took place: *Potametea-Phragmitetea-Alnetea*. From among three alder species

probably only *Alnus glutinosa* took part in the boreal expansion on the Polesie area. Alder forests near Lake Perespilno occurred usually in closed depressions, near-shore zone, and along streams. The proportion of alder increased in the younger part of the *Corylus* subzone as is evidenced by its pollen values of 15.9%.

Quercus and *Fraxinus excelsior* were next components appearing in multispecies deciduous forests on fertile habitats. Oak, the pollen values of which gradually rise to 6.5%, could also have occurred on less fertile habitats in mixed coniferous forests of *Pino-Quercetum* type. *Fraxinus excelsior* belongs to the species of low productivity and spread of pollen. Huntley and Birks (1983) suggest that ash pollen values of 1% indicate its local presence, and these of 5% – its domination or occurrence as one of main components of forest. The curves of *Fraxinus* and that of *Corylus* started simultaneously, but the former reaches the values over 1% only during the culmination of alder. Ash migration ca. 8900 years BP initiated the formation of riverine communities with this species. Lower values of *Alnus* in the younger phase of the *Pinus* subzone can indicate a drier climate, lower water level and a reduction of habitats suitable for alder. This episode preceded the rise in the values of *Betula*, which can compete successfully with mesotrophic species in the periods when the balance of forest ecosystem is disturbed. Then birch was replaced by pine, which also tolerates hydrological changes. The increasing proportion of pine and the appearance of lime characterised forests in the *Pinus* subzone of the *Corylus-Quercus-Alnus* zone. The continuous curve of *Tilia*, with values over 0.5%, started ca. 8600 years BP. Lime migration marked the last stage of the great migrations of main forest components in Lake Perespilno environs during the early Holocene. The described zone is correlated with the Boreal chronozone. The progressive warming in this time is evidenced by the appearance of *Viscum* (mean July temperature > 17°C) at around 8670 years BP (Fig. 4).

Pollen concentration in the *Pinus* subzone (Figs 7, 9) is very high, probably due to low sedimentation rate in the lake. The results of Cladocera analysis indicate a rise of water level in the shallow eutrophic lake at that time (Bałaga et al. 2002). The characteristic feature of the sediments of cladoceran zone IIa (depth 1700–1750 cm) is an increase in the Na, Ca,

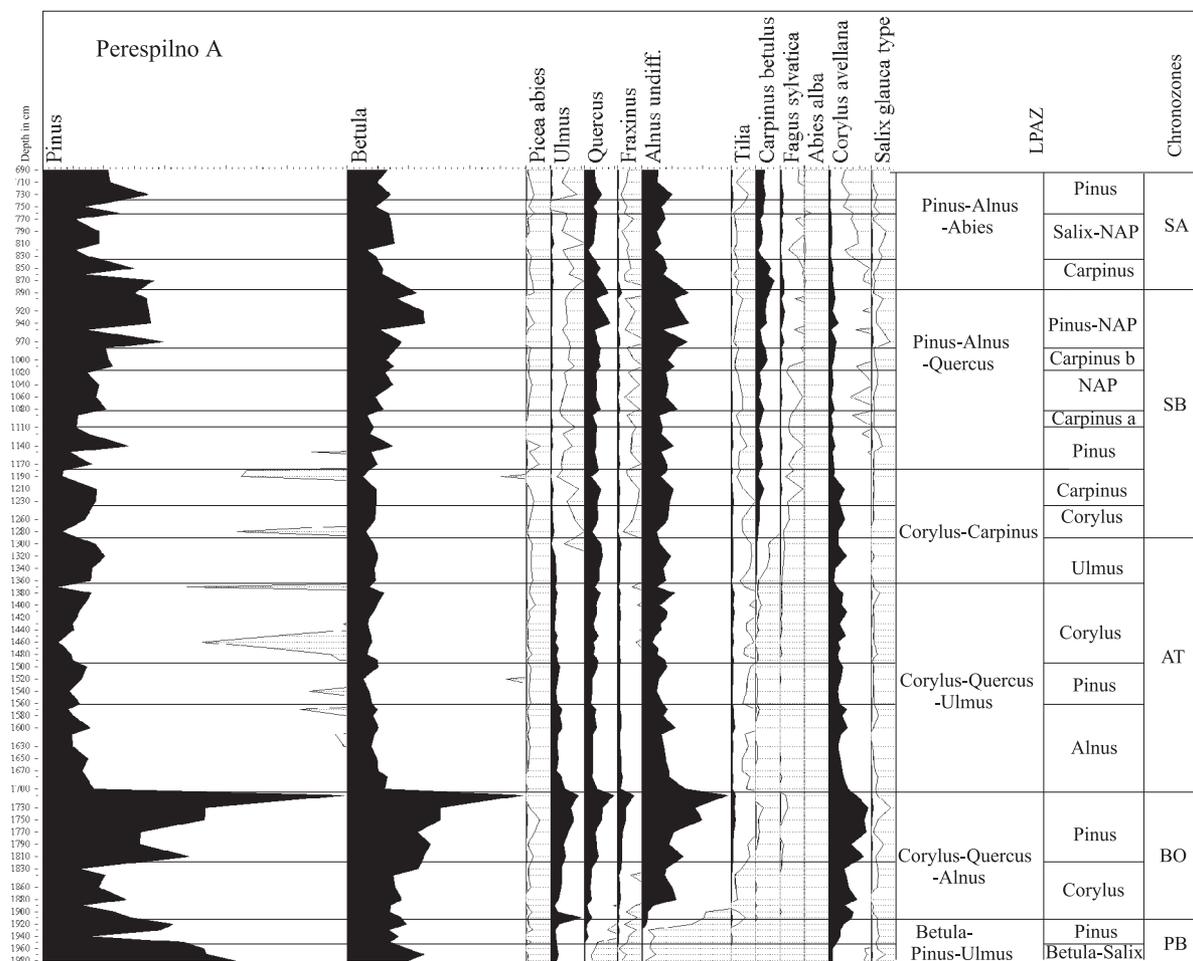


Fig. 9. Diagram of pollen concentration of selected taxa (profile A)

CaCO₃ content, and a slight decrease in the Fe, Mg and K content. The lowering of water level in the lake about 200 years later corresponded with the abrupt decrease of pollen concentration of all taxa found in the core at a depth of 1700 cm, a significant decrease in the Ca, Na content, and a higher of mineral material (Bałaga et al. 2002). These fluctuations of water level could have been conditioned by climate changes, though the influence of hydrogeological conditions (karst and/or thermokarst?) cannot be excluded. The sharp changes of pollen concentration and Cladocera composition can also indicate the occurrence of "hiatus" in the sediment sequence.

Corylus-Quercus-Ulmus LPAZ (Fig. 7)

The role of pine-birch forests was decreasing from ca. 7900 years BP. The pollen values of thermophilous deciduous species (oak, elm, alder, lime, ash, and hazel) rise or become stabilized. Climax multispecies deciduous forests were formed. The appearance of *Hedera helix* pollen (around 7970 years BP), the spatial

distribution of which is controlled by summer and winter temperatures, suggests climate moistening (Iversen 1944, Bottema 2001).

The area covered by pine forests was reduced in the *Alnus* and *Corylus* subzones. Pine forests spread only in the middle part of the zone (*Pinus* subzone), partially replacing elm, alder, and oak communities for about 320 years. This change was preceded by increased values of *Pteridium aquilinum* and *Artemisia*. The transformation of forests in the *Corylus* subzone consisted in the temporary (for about 200 years) rise in oak and elm proportions, and reduction of alder as evidenced by the decrease in pollen values of *Alnus* to 12.8%. A subsequent increase in *Alnus* percentages indicates a probable new spread of alder forests replacing elm-oak communities. Hazel dominated in shrub understorey at that time. In this subzone pollen values of *Corylus* are similar to those from the earliest phase of the formation of multispecies deciduous forests in the early Holocene. The percentages of *Corylus*, remaining high since the Boreal chronozone,

can be also related to the occurrence of shrubs of *Peucedano-Coryletum* type on warm soils rich with calcium carbonate. Both *Corylus* and *Tilia* are tolerant of low winter temperatures but the ripening of their seeds requires high mid-summer temperatures (Pigott 1981, Pigott & Huntley 1981). The dependence of *Tilia* on high summer temperatures is demonstrated by its present distribution patterns. *Tilia* occurs in different communities in fertile and wet habitats.

Maple-trees also occurred in forests at that time. In view of the fact that they belong to the trees of low pollen productivity, usually only single grains represent them in pollen spectra (Andersen 1970), their real proportion being probably higher. Pollen of *Picea abies* reaches low but constant values since the Late Glacial. The investigated site is situated in the area with the dispersed occurrence of the spruce (compare Bałaga 1990). In the final part of the subzone the curves of *Artemisia* and *Pteridium* rise, and the first pollen grain of *Plantago lanceolata* appears, probably indicating the presence of man. The described zone corresponds to the early and middle phases of the Atlantic chronozone.

***Corylus-Carpinus* LPAZ (*Ulmus* subzone; Fig. 7)**

In the older part of the zone the forest communities in Lake Perespilno environs underwent transformation. The rise in the pollen values of *Pinus* indicates that this species played an important role in the forests again. The decrease in *Ulmus* frequency (<2%) provides evidence of its reduction in forests, probably due to unfavourable climatic conditions (Iversen 1941, 1960), economic activities of man during the earliest Neolithic settlement (Troels-Smith 1953, 1955), or the so-called Dutch illness of elms (Groenman-van Wateringe 1983, Peglar 1993).

The decline of elm was accompanied by the rising proportion of hazel, which better developed in good light conditions resulting from the decreasing density of forest canopies. At the same time the curve of *Alnus* slightly falls, and that of *Quercus* slowly but constantly rises. The subzone corresponds to the younger phase of the Atlantic chronozone. The construction of a precipitation curve (Ralska-Jasiewiczowa & Starkel 1988, 1991, Starkel 2002) indicates the reduction of precipitation

in the last part of the Atlantic chronozone. The drying of the climate could have resulted in the replacement of alder communities by mixed coniferous forests with oak. The rise in the *Quercus* pollen values indicates that oak, and especially *Quercus robur*, could have encroached on peat soils.

CHANGES OF VEGETATION IN THE LATE HOLOCENE

***Corylus-Carpinus* LPAZ (*Corylus* and *Carpinus* subzones; Fig. 7)**

The stable ecosystem of multispecies deciduous forest in Lake Perespilno environs was disturbed ca. 5200 years BP. The decline of elm was accompanied by the appearance of continuous curves of *Carpinus* and *Fagus*. Pollen values of *Carpinus* rise systematically evidencing a stage of hornbeam expansion in multispecies deciduous forests of the Polesie. Hornbeam has rather low edaphic requirements but it prefers fertile, fresh habitats. Huntley & Birks (1983) assumed that the pollen values exceeding 1% provide evidence of the occurrence of single stands with hornbeam, the frequency over 5% – an important role of hornbeam in forest, and those over 10% – a local domination of hornbeam. Therefore, pollen values of *Carpinus* reaching the maximum of 9% indicate that hornbeam was an important component of forests near Lake Perespilno at that time. After a short decline, the proportion of *Corylus avellana* also increased reaching its last Holocene maximum. Simultaneously the proportion of ash decreased as evidenced by its pollen values below 2%. These changes were associated with rising humidity and cooling of the climate between 5000 and 4500 years BP (Starkel 1991). The rising curves of *Sphagnum* and Musci provide evidence of mire development near the lake, also indicating a wetter climate with cool summers (Seppä & Birks 2001). Anthropogenic impact was unimportant at that time, as values of anthropogenic indicators are low. The *Corylus* and *Carpinus* subzones correspond to the early Subboreal chronozone.

***Pinus-Alnus-Quercus* LPAZ (Fig. 7)**

From about 4300 years BP, *Corylus* pollen values are decreasing below 4%. Together with the decline of elm, ash and lime this indicates

a complete transformation of forests, which became similar to the modern ones. Beech could have formed an admixture in oak-hornbeam forests. It migrated from the west to the Polish Lowland and reached its eastern limit. Pollen values over 2% can evidence the occurrence of scattered local stands of beech (Huntley & Birks 1983, Huntley et al. 1989). In the Perespilno profile the frequency of *Fagus* range between 0.1 and 2.3% being the highest in the *Pinus-Alnus-Abies* zone. In these days beech is absent from the Polesie area (compare Bałaga 1990). The rising proportion of anthropogenic indicators (*Artemisia*, *Urtica*, *Plantago lanceolata*, and *Cerealia*) indicates that the vegetation cover of the discussed zone was formed under the increasing influence of man activity.

***Pinus-Alnus-Abies* LPAZ** (Figs 7, 8)

Pollen of *Abies alba* appears in pollen spectra of the *Pinus-Alnus-Abies* zone about 2500 years BP. It occurs sporadically, not forming continuous curve, and its values do not exceed 0.5%. Therefore, it can be supposed that fir was not a component of forests in Lake Perespilno environs (compare Bałaga 1990). The highest values of hornbeam are characteristic for the *Carpinus* subzone of this zone, and indicate an important role of this species in the forests near Lake Perespilno at the beginning of the Subatlantic chronozone. The changes in vegetation cover of the subzone were associated with forest regeneration and synchronous with the second episode of high pollen concentration (Figs 7, 9), not as high as in the Boreal chronozone, though.

The oscillation in the curve of the cladoceran species *Bosmina coregoni*, noticeable in the composition of zooplankton, is smaller than the one occurring in the *Ulmus-Quercus-Alnus* zone, and it indicates the lowering of water level in the lake (Bałaga et al. 2002). Higher frequency of other Cladocera – *Allona guttata*, *Monospilus dispar*, and *Lepidora kindtii*, as well as the decrease in the curve of *Chydorus sphaericus* (which usually lives in littoral zone) are characteristic for this zone.

***Pinus-NAP* LPAZ** (Fig. 8)

The zone distinguished in the profile Perespilno A-1 is characterized by distinctly higher proportion of herbs. Anthropogenic indicators provide evidence of the heightened influence of arable agriculture on vegetation

cover from ca. 1700 years BP. Pollen values of all trees decrease, indicating strong deforestation. Pine, alder and oak remained the main components of forests. A strong decline of hornbeam is reflected by its pollen frequency not exceeding 1.3%.

TRACES OF HUMAN ECONOMIC ACTIVITY

From the palynological data, i.e. the increased values of *Pteridium aquilinum* and *Urtica* in the *Ulmus-Quercus-Alnus* zone and in *Corylus-Quercus-Ulmus* zone (*Alnus* subzone), one can assume that people influenced vegetation cover in the examined area as early as in the Mesolithic. Archaeological artefacts found in the area between Lake Perespilno and Lake Koseniec also confirm the presence of the economic activities of the Mesolithic tribes associated with the Komornice and Janisławice cultures (Fig. 10). However, these societies did not considerably modify natural environment. The first qualitative changes of pollen spectra are found in the layer dated at about 6400 years BP. The first pollen grain of *Plantago lanceolata* appeared, which is considered to be an indicator of pastoral agriculture. However, the presence of Neolithic people in the examined area is questionable. At that time the Neolithic tribes populated mainly loess uplands of southern Poland (Gurba 1960). Small clearings occurred in forests as evidenced by the increased values of *Artemisia* and *Pteridium aquilinum*. This phenomenon was associated with the existence of Mesolithic people. It seems that a Mesolithic economy survived in the Lake District till the end of 4th millenium BC (Telepko 1987). The Janisławice culture disappeared probably in the period when the Neolithic economy encroached on sandy soils, which probably took place in the middle of the Neolithic Period. The next phase of anthropogenic influence occurred after the decline of elm (*Corylus-Carpinus* zone). Next pollen grains of *Plantago lanceolata* appear, providing evidence of grazing development. The values of *Artemisia* pollen increase, and the curve of *Pteridium* also slightly rises. The first pollen grain of *Cerealia* type, and a more frequent occurrence of *Plantago lanceolata* from about 4600 years BP are the first palynological proofs of agriculture. Higher percent-

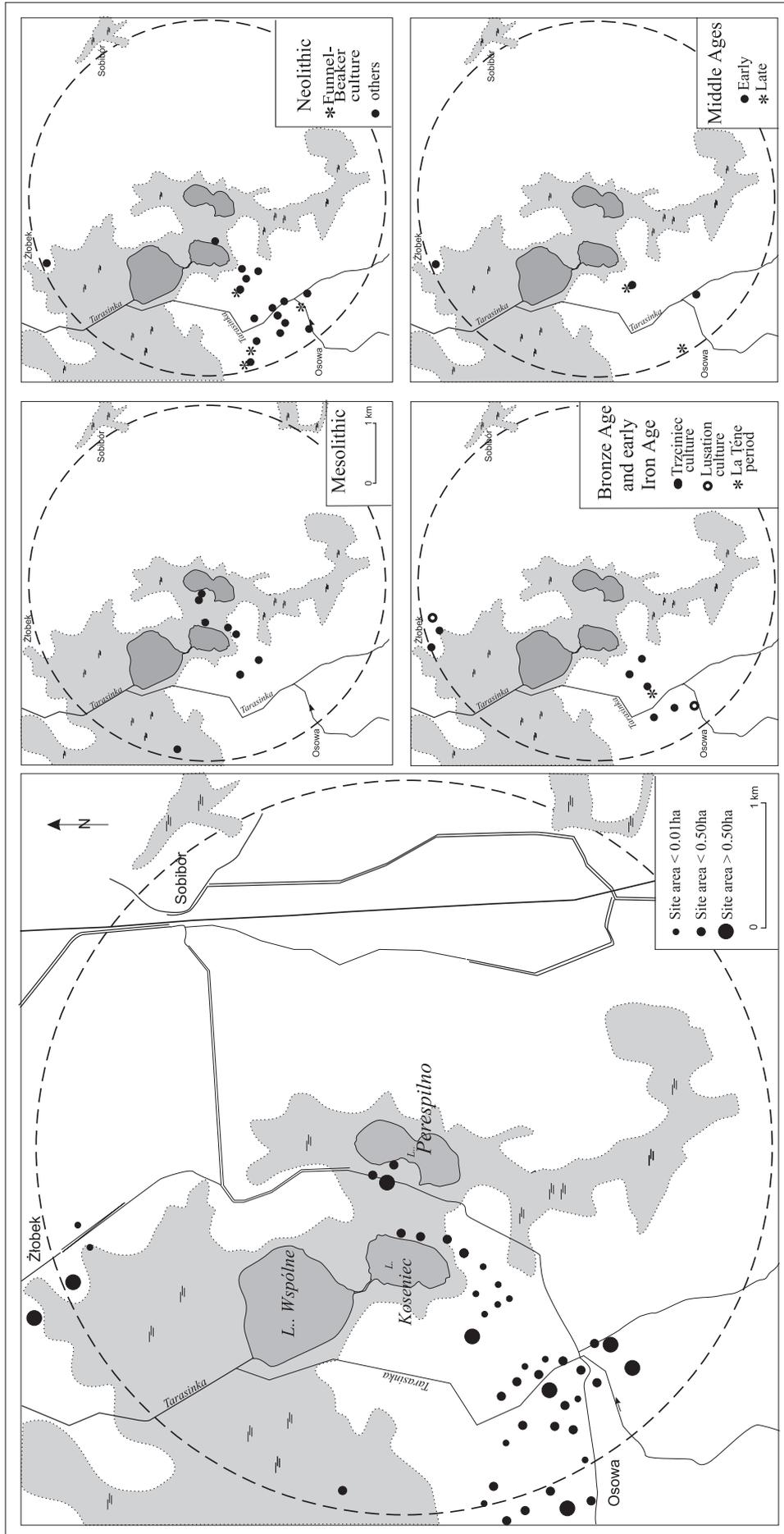


Fig. 10. The location of archeological sites in the vicinity of Lake Perespilno (after Balaga et al. 2002, supplemented)

ages of *Rumex acetosa/acetosella* type are found in pollen spectra. Those new forms of farming can be related to the activities of the Neolithic people. Settlement of the Neolithic cultures successively developed on the grounds of local Mesolithic cultures (Mazurek 1991). Artefacts of the Funnel-Beaker culture predominate in the Neolithic findings near Lake Perespilno, and in the whole area of the Łęczna-Włodawa Lake District.

After a short period, when forest with a higher proportion of hornbeam regenerated (*Carpinus* -a subzone) human activities increased again at about 3800 years BP as evidenced by the repeated rise in anthropogenic indicators. The indicators of pastoral farming still prevail. A small rise in the NAP curve does not indicate a considerable deforestation at that time though some changes occurred in forest structure, i.e. the proportion of pine increased. This phase should be attributed to the activities of people of Bronze Age (mainly Corded Ware and Trzciniec cultures) but anthropogenic impact on vegetation was still weak. Agriculture and breeding were continuously supplemented by finish and gathering fruit and plants, which were the natural methods of getting food in lakeside and forest environments (Taras 1995). Archaeological sources confirm a moderate settlement ratio in the Lake District at the time (Fig. 10).

The successive phase of reduction in farming resulted in a repeated expansion of hornbeam, which reaches higher values in pollen spectra (*Carpinus* -b subzone).

The next intensification of the economic activities caused greater changes in the landscape near Lake Perespilno. Higher percentages of NAP can indicate greater deforestation. A more distinct depression in the hornbeam curve can evidence a stronger felling of this tree species at that time. A small decrease and then an increase of the oak curve probably indicate that older oak trees avoided being cut, and their canopies, better exposed to the light, produced larger amount of pollen. Proportions of birch and willow increased as a result of deforestation. Pollen of cultivation indicators (e.g. *Triticum*) is more frequent. The extending fields under cultivation were successively replacing dry-ground forests, which were being still exploited. This phase should be linked with the activities of the Lusatian Culture population (Fig. 10), which probably

survived in this area till the beginning of third century BC.

The next period of hornbeam and oak regeneration started at about 2500 years BP and lasted for about 200 years. More expansive hornbeam reaches its maximum in the Holocene pollen spectra then.

The next period of intensive economic activity (the increase in the pollen values of *Artemisia*, *Pteridium aquilinum*, and *Cerealia*, the decrease in the frequency of AP) began at about 2400 years BP. The appearance of *Secale cereale* was characteristic for this period, which corresponded to the La Tène and Roman settlement phases (*Pinus* subzone – profil A, and probably NAP subzone – profil A-1).

The successive phase of hornbeam forest regeneration (period of migration of nations) was followed by the next settlement phase. A strong transformation of the environment is recorded in the pollen spectra from profile A-1, and not noticeable in those from profile A (probably due to the lack of top sediments). Cereal growing became more intensive; hemp (*Cannabis*) and buckwheat (*Fagopyrum*) were probably also cultivated. The occurrence of fields under cultivation is evidenced by more numerous pollen grains of weeds (*Artemisia*, *Chenopodiaceae*, *Rumex acetosella*, and *Centaurea cyanus*). This period is characterised by a constant rise in the pollen values of herbs, which reach 35.9% (cultivation indicators make about 10% of this sum) in the last, top sample. At the same time, the pollen frequency of almost all trees decline. The most intensive anthropogenic transformation of ecosystems started in the Early Middle Ages. At that time, settlement in the Lake District successively developed but only few sites are found near Lake Perespilno (Fig. 10). Many artefacts of the early Middle Ages settlement were found in the higher situated areas, southward of the examined site, i.e. in the environs of Osowa and Wola Uhruska.

CONCLUSIONS

The studied sequences of pollen spectra from two profiles characterize the changes of vegetation, which have occurred from about 12 800 years BP till the present time. 4 pollen zones with 5 subzones were distinguished in the Late Glacial part of sediments, and 7 pollen zones with 19 subzones – in the Holocene

part. It should be stressed that the Late Glacial vegetation history is recorded in the sediments laminated annually (Bałaga et al. 1998, Goslar et al. 1999). This pattern of vegetation changes, with two distinct coolings, is typical of the whole area of the Łęczna-Włodawa Lake District. Till now these coolings have been usually correlated with the Older and Younger Dryas (Bałaga 1990, Bałaga et al. 1995, 1998). However, the radiocarbon dating of the lower part of the lacustrine sediments from Lake Perespilno (Goslar et al. 2000) indicates that the earlier cold phase corresponds to the decline of pleniglacial. The occurrence of a distinct cooling between the Early Interstadial and Late Interstadial (Allerød) is questionable. However, the pollen spectra provide evidence of minor oscillations during this time span (Oscillation Period, see Fig. 5), some of them suggesting cooling or decreased humidity.

In the early Holocene the migration of trees occurred in the following order: elm, hazel, oak, ash, alder, and lime. From ca. 9000 years BP multispecies deciduous forests were forming. Lime entered these forests as the last component at ca. 8600 years BP. During the climatic optimum, correlated with the *Corylus-Quercus-Ulmus* zone and *Corylus-Carpinus* zone (*Corylus* subzone), the composition of deciduous forests was rather stable, but with two phases of pine forest regeneration (*Pinus* and *Corylus* subzones). This last phase of pine regeneration corresponded to the late part of the Atlantic chronozone, and was associated with the decline of elm, spread of oak, and the appearance of new tree species, i.e. hornbeam and beech. Further transformations of forest communities occurred at the beginning of the Subboreal chronozone. The remaining components of deciduous forests, i.e. ash and lime declined, and hornbeam became more and more important. Hazel was retreating from ca. 4300 years BP, and the composition of forests resembled that of the modern ones.

Weak anthropogenic impact on vegetation cover, indicated by the increase in the pollen values of *Pteridium aquilinum* and *Urtica*, was associated with the migration of the Mesolithic tribes in Boreal and Atlantic chronozones (phases a and b). The economic activities of the Neolithic people were more intensive but strong changes of vegetation cover under the influence of man have been recorded since about 1700 years BP.

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