

# Local Holocene vegetation changes and settlement history based on pollen analysis of Lake Kwiecko sediments, West-Pomeranian Lake District, NW Poland

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Received 13 March 2012; accepted for publication 31 May 2012

**ABSTRACT:** The sediments of Lake Kwiecko, located in the eastern part of the Bytowskie Lake District (part of the West-Pomeranian Lake District, Poland), were studied by pollen analysis. Holocene vegetation history was reconstructed from the beginning of the Preboreal to the Late Middle Ages. On the basis of the curves of selected taxa and the occurrence of plant indicators of the presence of man 6 settlement phases were distinguished and correlated with archaeological data. The investigations have shown that the first weak palynological indications of human presence around the lake were connected with the Atlantic chronozone, while the strongest impact of man on vegetation was recorded in the Middle Ages and modern times.

**KEYWORDS:** Holocene palynology, vegetation changes, settlement history, West-Pomeranian Lake District, Lake Kwiecko

## INTRODUCTION

In spite of investigations carried out by many palaeobotanists in north-western Poland, vegetation history of the West-Pomeranian Lake District and particularly of the Bytowskie Lake District is not satisfactorily known. In the synthesis of the international IGCP 158B program (Ralska-Jasiewiczowa 1987, Ralska-Jasiewiczowa & Latałowa 1996) only two sites, Lake Wielkie Gacno (Hjelmroos-Ericsson 1981) and Lake Suszek Mały (Miotk-Szpiganowicz 1989, 1992) situated in the South-Pomeranian Lake District, are considered fully representative also for the eastern part of the West-Pomeranian Lake District. The list of localities, which were used for drawing isopollen maps for Poland shows that in the 50 km radius of Lake Kwiecko there were no sites with chronologically justified pollen records (Ralska-Jasiewiczowa et al. 2004). In the last years palynological investigations in the West-Pomeranian Lake District were carried out by Malkiewicz & Tomaszewska (2009) and Święta & Latałowa (2003), and in the adjoining

terrains (Tuchola Forest, South-Pomeranian Lake District) for instance by Berglund et al. (1993), Milecka (2005), Milecka & Szeroczyńska (2005), and Lamentowicz et al. (2008).

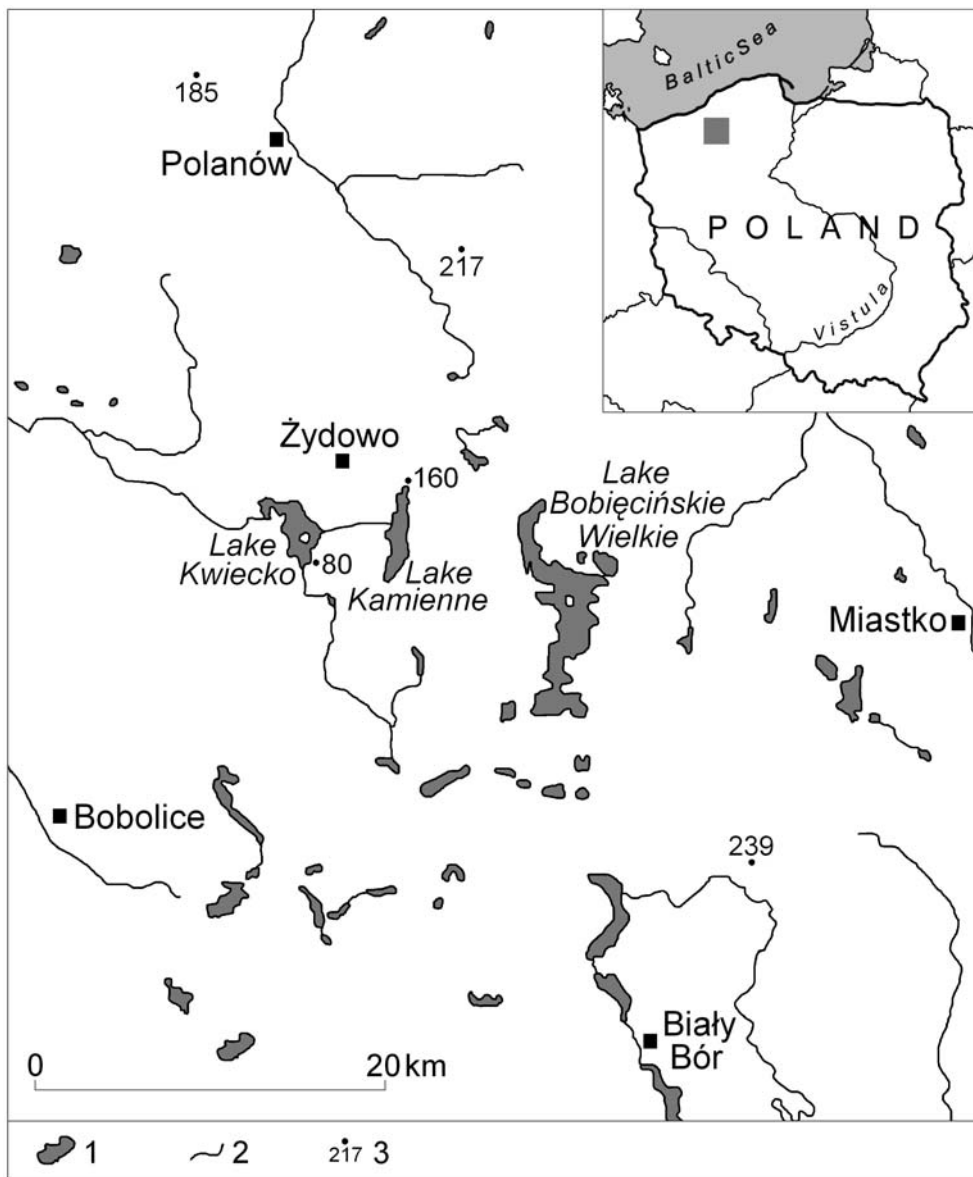
The studies of the genesis, age, and evolution of the Lake Kwiecko were initiated by Więckowski in 1969 (Więckowski 2009), and a pilot pollen analysis of four bottom samples from one of the cores was carried out by Wasylikowa (unpubl.). The present paper supplements the hitherto available knowledge of natural and anthropogenic vegetation changes since the decline of the last glaciation to the late Subatlantic chronozone in the West-Pomeranian Lake District.

## DESCRIPTION OF THE SITE

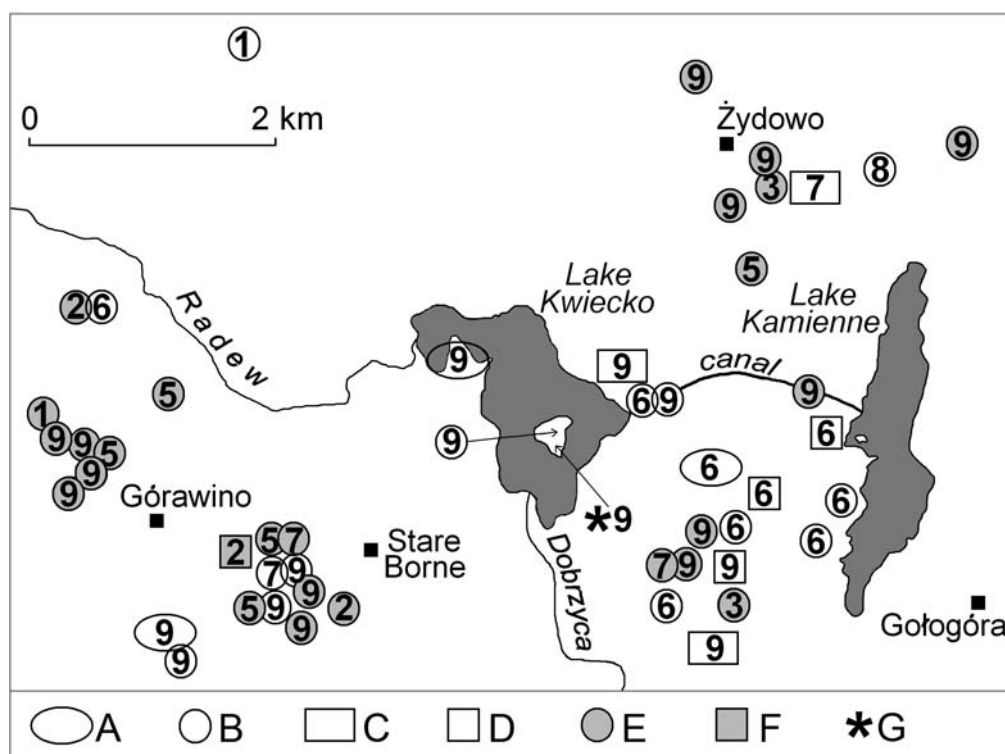
Lake Kwiecko (54°01'30"N, 16°42'00"E) is situated in north-western Poland (Fig. 1), in the Bytowskie Lake District, which stretches

for about 100 km in west-east direction and belongs to the West-Pomeranian Lake District (Kondracki 2002). This is a glacial flow-through lake situated at an elevation of 80 m a.s.l., in a natural valley surrounded by moraine hills. The largest lake tributary is river Dobczyca falling at its southern end, outflow constitutes river Radew rising in the north-west end of the lake (Fig. 2). Lake Kwiecko is a shallow, up to 3 m depth lake with the basin of irregularly triangular shape stretches about 900 m in west-east and 1400 m in north-south direction. In the southern part of the lake the island (5 ha) is located. Lake Kwiecko constitutes the lower reservoir for the pumped-storage power station functioning since 1970 in the nearby Żydowo. For this reason Lake Kwiecko is also

known as Lake Żydowskie or Dolne. While the plant is at work, the 80 metres natural difference between the elevations of Lakes Kamienno (upper reservoir) and Kwiecko makes the water flow by the system of canals from Lake Kamienno to Kwiecko and drive the electric turbine. Then, the water is pumped back to the upper reservoir by a system of pipes. During the work of the plant the great twenty-four hours' water level oscillations, coming up to 3 m, are recorded. When the lake is filled to a maximum its total water surface covers 127 ha (Korzeniewski & Śpiwakowski 1977). The lake bottom is covered by lake sediments overlain by sands or more often by a thick mud layer. The examination of four cores from Lake Kwiecko by Więckowski revealed the



**Fig. 1.** Map of Poland and location of Lake Kwiecko. 1 – lakes, 2 – rivers, 3 – elevation a.s.l.



**Fig. 2.** Location of archaeological sites in the nearest vicinity of Lake Kwiecko. **A** – stronghold, **B** – settlement, **C** – cemetery, **D** – settlement point, **E** – settlement trace, **F** – camp site, **G** – Bronze Age ornaments treasure, **1** – Mesolithic, **2** – Mesolithic/Neolithic, **3** – Neolithic, **4** – Funnel Beaker culture, **5** – Bronze Age, **6** – Lusatian culture, **7** – Pomeranian culture, **8** – Wielbarska culture, **9** – Middle Ages

occurrence of distinct laminae at the depth of 19–21 m, which accumulated in 8–13 years' cycles connected with changes of solar activity. An unusual feature of the sediments of this lake is the presence of exoskeletons of *Chara fragilis* stems with numerous oospores (Więckowski 2009). The coring took place in the deepest place (3 m) of the northern part of the lake.

#### GEOLOGY AND GEOMORPHOLOGY

In the light of the existing divisions of Poland into tectonic units the Bytowski Lake District is situated within the range of a marginal syncline and Pomeranian-Kujavic embankment (Pożaryski 1969).

The evidence of four Quaternary glaciations can be traced in the Bytowski Lake District. The oldest San I glaciation left behind the boulder clay covers preserved only in some depressions. During the San II glaciation the thickness of the ice-sheet was 1500–2000 m at least. The Oder glaciation had similar character (Mojski 1993). For the last time the glacier cover spread over the whole area of the Bytowski Lake District during the Vistula glaciation (Borówka 2002). The important

glacier stages were its southward transgressions, the effect of which are the now existing deposits and land forms, attributed to the main marginal phase of the Pomeranian stage and Kashubian-Warmia and Koszalin phases (Karczewski 1994).

The thickness of the Pleistocene deposits usually exceeds 100 m and most often they were formed by the glacial and fluvioglacial accumulation, for instance glacial tills, sands, gravels, loams, and clays. The relief of the landscape developed under the influence of the systems of subglacial channels, river valleys, kettle holes, hills of front moraines, and eolian forms. The highest elevation of 256 m a.s.l. is located on the top of a front moraine (Siemierzycza Góra near Bytów). On the territory of the Bytowski Lake District there occur numerous small water basins and lakes (e.g. the largest Bobięcińskie Wielkie Lake is 48 m deep and covers 524.6 ha).

#### SOILS

The dominating surface formations on the territory of the Bytowski Lake District are the deposits of the last glaciation, among which boulder clays are the most significant,

while sands, gravels, erratic blocks, and in the central part also fluvioglacial deposits are less important. Holocene lake-and-mire sediments (gyttja, mud, peat) are also present. Swampy soils usually follow gullies, melts, and river valleys and are represented by the sludge-bog, peat, and decay soils.

Holocene deposits include also various soil types, which were formed in the course of complicated pedogenesis processes, with the predominance of those developed on glacial deposits and peats. The distribution of soils reveals some sort of zonation: brown soils occur mainly on ground moraine, while podsoles and pseudo-podsoles on outwash plains (Bednarek & Prusinkiewicz 1999), which cover 75% of the Bytowskie Lake District. The area of the terminal moraines is covered by a mosaic of soils mentioned above. The arable land is dominated by brown soils developed on clays and podsoles formed on sands.

The soils of the Bytowskie Lake District, irrespective of the bedrock from which they were formed, are acidified to a high degree, poor in humus, and relatively poor in assimilable elements like phosphorus, potassium, and magnesium (Kordiasz & Kozłow 1998).

#### CLIMATE

As regards climatic conditions, the Bytowskie Lake District belongs to the East-Pomeranian region. It has more severe climate compared to the rest of the West Pomerania, with an average of 35.9 days with temperatures below 0°C per year. The average number of sunny, rainless days is 127.9 per year. Mean January temperature equals -3 to -2°C, mean July temperature equals 17-18°C and mean annual temperature is 6-7°C (Kon-dracki 2002). Mean annual precipitation is 600-700 mm, mean number of days with snow cover varies around 60 per year (Czarnecka 2001). The length of the growing season is about 190 days (Woś 1999, Koźmiński & Michalska 2001).

#### VEGETATION

For years, the whole West-Pomeranian Lake District, including the Bytowskie Lake District, was the centre of interest of botanists. Therefore its flora is now relatively well known. Among scientists who carried out investigations in this area (especially

Bytowskie Lake District) should be mentioned for instance Czubiński (1950, 1960), Żukowski (1962), Jasnowska & Jasnowski (1983), and Śpiewakowski & Korczyński (1993).

A large area of the West-Pomeranian Lake District is covered by beech forests, with the dominance of *Melico-Fagetum* association, while on drier and more acidic soils the acidophilous beech forest *Luzulo-Fagetum* predominates. Planted *Pinus sylvestris* often occurs in forest stands. Mixed beech-oak forests from the class *Quercetea robori-petraeae* grow on lessivé and rusty soils of steep moraine slopes. The frequent forest type is represented by mixed pine-oak woods (*Quercu-Pinetum*). The sub-oceanic middle-European pine forests *Leucobryo-Pinetum*, with small shrubs of *Vaccinium myrtillus*, *V. vitis-idaea*, and *Calluna vulgaris* in the herb layer, play a great role in the whole of the West Pomerania. Hornbeam forests (*Stellario holostea-Carpinetum*) cover small areas on fertile, humic habitats, on brown and lessivé soils. In the Bytowskie Lake District, as in the whole Western Lake District, fragments of carrs can be found along some rivers and streams, alder-ash carr *Circaeo-Alnetum* being the most frequent among them. Swamp scrub and wet alderwoods from the class *Alnetea* are common on boggy habitats and near springs.

In flowing waters *Ranunculetum fluitantis* is the most frequent association of hydrophytes, with *Batrachium fluitans*, *B. trichophyllum*, *Potamogeton fluitans*, *Butomus umbellatus*, *Nuphar luteum*, *Sparganium erectum*, as well as several species of mosses and algae. The aquatic vegetation in eutrophic lakes is dominated by associations *Potamogetonnetum lucensis*, *Nupharo-Nymphaeetum albae*, and *Hydrocharitetum morsus-ranae*, in which *Hydrocharis morsus-ranae*, floating on water surface, and *Stratiotes aloides*, rooted in the muddy bottom, play an important role. A characteristic association is *Isoëto-Lobelietum* with *Lobelia dortmanna*, *Isoëtes lacustris*, and *Litorella uniflora* proving the Bytowskie Lake District as a great floristic region. The bottom flora of oligotrophic lakes is dominated by associations composed of species from the genus *Chara*. Furthermore, the Bytowskie Lake District, similarly as the greater part of the West Pomerania, has many different types of mires.

Among the vegetation, which developed under the influence of human activity on

undrained and not fertilized terrains, the meadows from the alliance *Molinion*, mown once a year, are dominant. The drained and well fertilized areas are occupied by moist and wet meadows, mown twice or many times a year, among which *Cirsio-Polygonetum* is the most important association. The most frequent communities of highly productive, well manured fresh meadows in the Bytowskie Lake District belong to the association *Arrhenatheretum medioeuropaeum*.

According to the map of potential natural vegetation (Matuszkiewicz 1984), the area of the Bytowskie Lake District would be covered by the lowland forb-rich beech forests (*Melico-Fagetum*), lowland acidophilous beech forests (*Luzulo pilosae-Fagetum*), and continental oak-pine forests (*Pino-Quercetum*), depending on the local environmental condition. The azonal communities of the Middle-European alder carr (*Carici elongatae-Alnetum*) would be growing in smaller patches in the area.

## ARCHAEOLOGY

The archaeological knowledge about the closest vicinity of Lake Kwiecko is far from being satisfactory. Various parts of the study area are not evenly examined. The distribution of sites in the nearest vicinity of Lake Kwiecko (Fig. 2) was based on data gathered in 1986–1991 in the frame of the Archaeological Picture of Poland project (AZP) and on the synthesis of archaeological investigations carried out on the territory of the Polanów district, West-Pomeranian Lake District (Skrzypek 2010). Archaeological documentation of human presence in the area of Lake Kwiecko during the Palaeolithic and Mesolithic is rather poor. The Mesolithic is represented by the population belonging to the Duvensee community and the Chojnicko-Pieńkowska culture (Bag-niewski 1996). The main type of economy of Local groups of Mesolithic people was hunting-fishing economy supplemented by gathering (Kaczanowski & Kozłowski 1998, Bag-niewski 1996).

In the northern part of an island on Lake Kwiecko the traces of a Mesolithic camp site were discovered, which comprised microlithic flint inventory connected with the Chojnicko-Pieńkowska culture community. Various flint objects connected with these cultures were

often found in the Bytowskie Lake District. During the AZP investigations the Mesolithic settlement traces were recognized for instance in the vicinity of Gołogóra and Polanów (Skrzypek 2010).

Among the Neolithic cultures present in the Western Lake District two Funnel Beaker and Corded Ware cultures are well archaeologically represented in the studied area. The beginning of the Bronze Age on the territory of Poland is conventionally dated to 3750 BP. In the Early Bronze Age almost whole of the Western Lake District remained under the influence of the Unietycka culture. Also in the area close to Lake Kwiecko archaeological findings connected with this culture were found, but another much stronger represented Bronze Age culture was Lusatian culture. A very intensive development of this culture is testified by the frequent findings of bronze ornaments treasures. From the beginning of the Iron Age a new group – Pomeranian culture is known. The economy of the population of this culture was based mainly on animal husbandry, hunting and fishing, while plant cultivation played a subordinate role, which made possible frequent changes of dwelling places (Skrzypek 2010). After the burial form this culture is also called the Face-Urns or Cist Grave culture. The often findings of Cist Grave in the Lake Kwiecko vicinity proof the local presence of Pomeranian culture people. Under Roman influences the new unit called the Wielbarska culture developed and persisted till the early phase of the Migration Period (Grabarczyk 1997). The disturbance of the hitherto existing trade relations as well as by the migrations of Germanic tribes, contributed to the almost complete break of contacts of Polish territories with the Roman Empire along the former amber route. It seems that the whole Western Pomerania suffered least from the change of trade routes during the Migration Period (375–576 AD), because from this area the greatest number of coins is known (Ciołek 2001). In the light of archaeological data the Early Medieval settlement of Slavs in the vicinity of Lake Kwiecko started in the beginning of 9<sup>th</sup> century where two main settlement centers: Żydowo and Polanów were present. In 972 AD, after the victorious battle of Mieszko I at Cedynia, the West Pomerania became part of the Polish State.

## MATERIAL AND METHODS

### THE SAMPLING TECHNIQUE AND POLLEN ANALYSIS

A core about 20 m long and acquired with Więckowski-type piston corer was chosen for pollen analysis. Samples for palynological analysis (1 cm<sup>3</sup>) were taken in 10 cm steps from most parts of the core. In the regularly laminated core section samples of 1cm<sup>2</sup> were collected, each comprising 10 couplets of laminae corresponding to a 50-year period. Samples were prepared by standard procedure: calcareous gyttja was treated with 10% HCl and silica was removed with hydrofluoric acid. All samples were prepared according to Erdtman's acetolysis method. Absolute pollen counting was done according to the method described by Stockmar (1971). An average of ca 1000 pollen grains of trees and shrubs was counted in each sample. In the case of low frequency smaller numbers were counted. Percentage values were calculated from the sum of trees, shrubs and herbaceous plants, excluding spores and pollen of aquatic plants. Aquatic algae were also counted but not included in separating pollen assemblage zones. The software package POLPAL for Windows (Walanus & Nalepka 1999) was used for drawing diagrams.

### SEDIMENT DESCRIPTION

Most of the Lake Kwiecko sediment was composed of gyttja, which was regularly laminated in a small bottom section (Table 1). The lowest core segment contained fine silt and brown moss peat with numerous moss fragments of *Drepanocladus aduncus*, *Calliergon stramineum*, and *Scorpidium scorpioides*.

**Table 1.** The description of sediments from Lake Kwiecko, profile K-1 (after Wasylikowa unpubl., changed)

Depth in cm	Sediment
0–1929	calcareous gyttja with four laminae at 1846 cm
1929–2106	calcareous gyttja regularly laminated
2106–2208	fine silt, charophytes at 2190 cm
2208–2227	brown moss peat (mostly <i>Drepanocladus</i> and <i>Calliergon</i> ) slightly decomposed, with some sand

### RADIOCARBON DATING

Fifteen radiocarbon dates were obtained by AMS technique: 10 for pollen extracts, 2 for undetermined wood fragments of terrestrial plants, and 3 for moss remains (Table 2). All the dates are given in uncalibrated radiocarbon years BP. The most of <sup>14</sup>C dates do not agree with palynological dating because they are distinctly too old. This question, together with the description of the material dated and the results of radiocarbon dating presented in calibrated years were discussed in a separate article (Madeja & Latowski 2008).

## RESULTS

### PALYNOSTRATIGRAPHY OF CORE K-1

The diagram has been divided into local pollen assemblage zones L PAZ (Fig. 3) (Birks & Berglund 1979, Birks 1986, Janczyk-Kopikowa 1987), which are described in Table 3.

**Table 2.** Results of AMS radiocarbon dating of various types of material from Lake Kwiecko sediments

Laboratory code	Type of material dated from Lake Kwiecko / depth	Radiocarbon age (yr BP)	Cal age BP		Remark of the Laboratory
			Conf. intervals		
			68.3% (1 sigma)	95.4% (2 sigma)	
Poz-2298	pollen extract /175 cm	1760 ± 30	1619–1674	1567–1739	0.5 mgC
Poz-2299	pollen extract /365 cm	1940 ± 30	1865–1926	1822–1949	
Poz-2300	pollen extract /555 cm	2840 ± 35	2919–2996	2863–3064	
Poz-2301	pollen extract /805 cm	3810 ± 30	4151–4240	4137–4295	
Poz-2303	pollen extract /1255 cm	5630 ± 40	6393–6452	6314–6487	
Poz-2297	pollen extract /1465 cm	6010 ± 40	6791–6897	6745–6948	0.45 mgC
Poz-2304	pollen extract /1930 cm	7860 ± 120	8543–8787	8429–8997	0.1 mgC
Poz-2305	pollen extract /2096 cm	9500 ± 90	10656–10832	10561–11143	0.2 mgC
Poz-203	wood /2123 cm	9480 ± 50	10654–10787	10582–10833	
Poz-206	wood /2131 cm	10220 ± 50	11953–12050	11751–12130	
Poz-2307	pollen extract /2185 cm	11900 ± 200	13535–13979	13293–14203	0.1 mgC
Poz-2308	pollen extract /2215 cm	12050 ± 380	13458–14491	13210–15099	0.05 mgC
Poz-304	mosses fragments /2223–2225 cm	16270 ± 230	19168–19580	18997–19870	0.2 mgC
Poz-211	mosses fragments /2223–2225 cm	16420 ± 100	19466–19588	19411–19844	
Poz-264	mosses fragments /2223–2225 cm	16490 ± 170	19495–19816	19307–19998	

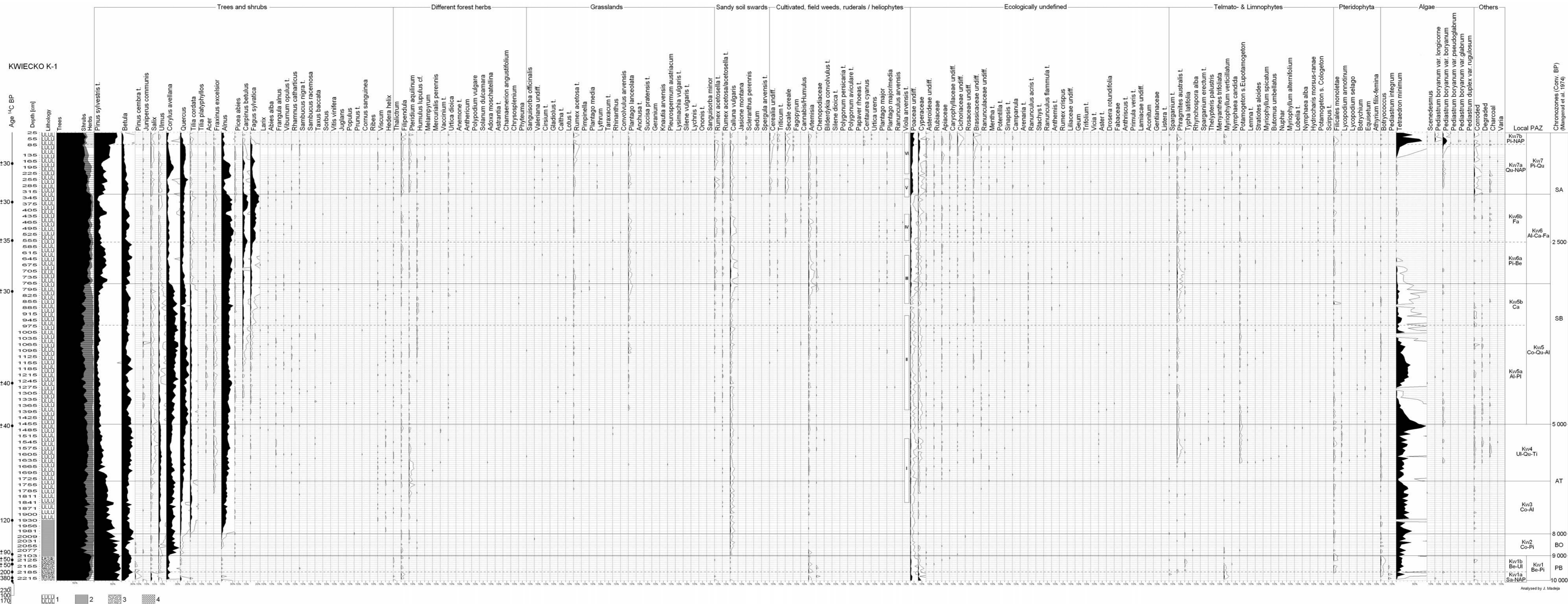


Fig. 3. Percentage pollen diagram from Lake Kwiecko (profile K-1). Abbreviation used in column Local PAZ (Local Pollen Assemblage Zone): **AI** – *Alnus*, **Be** – *Betula*, **Ca** – *Carpinus*, **Co** – *Corylus*, **Fa** – *Fagus*, **NAP** – Non Arboreal Pollen, **Pi** – *Pinus*, **PI** – *Plantago*, **Sa** – *Salix*, **Ti** – *Tilia*, **UI** – *Ulmus*, **Qu** – *Quercus*. Lithology column: 1 – calcareous gyttja, 2 – calcareous gyttja regularly laminated, 3 – fine silt, 4 – moss peat.

**Table 3.** Description of local pollen assemblage zones (L PAZ) distinguished in K-1 profile

L PAZ	Name	Depth (cm)	Description
Kw-1	<b>Betula–Pinus</b>	2225–2096	<i>Pinus sylvestris</i> ca 55% to over 75%, <i>Betula</i> ca 7.5% up to 30%, <i>Corylus</i> up to 10%. The zone is divided into 2 subzones.
Kw-1a	<i>Salix</i> –NAP		<i>Salix</i> up to 3.5%, <i>Pinus cembra</i> t., <i>Ulmus</i> , <i>Juniperus</i> sporadically present. Poaceae up to 5.5%, Cyperaceae up to 8%.
Kw-1b	<i>Betula</i> – <i>Ulmus</i>		<i>Betula</i> ca 30%. Start of continuous <i>Ulmus</i> curve. <i>Salix</i> sporadically present. Continuous <i>Artemisia</i> curve up to 1%. Rise of telmatophytes' diversity.
Kw-2	<b>Corylus–Pinus</b>	2096–1993	Rise of <i>Corylus</i> with sharp peaks. <i>Corylus</i> at its Holocene maximum (34.5%), <i>Pinus sylvestris</i> fluctuating and slowly decreasing. Start of continuous <i>Quercus</i> and <i>Alnus</i> curves. Depression of <i>Betula</i> (min. in the middle of the zone). Beginning of continuous <i>Calluna vulgaris</i> curve, decrease of <i>Artemisia</i> , Cyperaceae, and Poaceae.
Kw-3	<b>Corylus–Alnus</b>	1993–1736	Slightly decreased but still high and fluctuating <i>Corylus</i> . Rising <i>Alnus</i> (up to 24.7%), <i>Tilia</i> (up to 8.7%) and <i>Quercus</i> (up to 11.0%). Single grains of <i>Acer</i> and <i>Fagus sylvatica</i> . <i>Viscum</i> , <i>Hedera helix</i> , <i>Rumex acetosa</i> t. and <i>R. acetosa/acetosella</i> t. present. Poaceae max. 2.1%.
Kw-4	<b>Ulmus–Quercus–Tilia</b>	1735–1455	Dominance of <i>Betula</i> (up to 40.1%) and <i>Alnus</i> (up to 29.4). Decreasing <i>Pinus sylvestris</i> (min. 11.8) and <i>Corylus</i> (11.0%). <i>Quercus</i> up to 17.5%, <i>Tilia</i> up to 6.3%, and <i>Ulmus</i> up to 11.7%. Continuous curve of <i>Salix</i> (up to 3.2) begins, <i>Fraxinus</i> present. <i>Acer</i> , <i>Frangula alnus</i> , and <i>Taxus baccata</i> sporadic. Rise of the NAP. Single grains of Chenopodiaceae, <i>Bilderdykia convolvulus</i> t. and <i>Papaver rhoeas</i> t. present. More telmatophytes and pteridophytes appear.
Kw-5	<b>Corylus–Quercus–Alnus</b>	1455–765	Dominance of <i>Corylus</i> (up to 37.9%), <i>Alnus</i> (up to 35.5%), <i>Quercus</i> (up to 26.8%), and <i>Betula</i> (up to 33.3%). Gradual increase of <i>Carpinus betulus</i> and <i>Fagus sylvatica</i> . <i>Juniperus communis</i> , <i>Larix</i> , and <i>Abies alba</i> sporadic. First appearance of <i>Cerealia</i> undiff., <i>Triticum</i> t., <i>Cannabis/Humulus</i> , <i>Plantago major</i> t. and <i>Plantago major/media</i> t. The zone is divided into 2 subzones.
Kw-5a	<i>Alnus</i> – <i>Plantago</i>		Beginning of sporadic appearance of <i>Plantago lanceolata</i> .
Kw-5b	<i>Carpinus</i>		Continuous curves of <i>Carpinus betulus</i> (up to 5.8%) and <i>Fagus sylvatica</i> (up to 4.8%). Poaceae undiff. Cyperaceae, <i>Plantago lanceolata</i> , <i>Artemisia</i> , Chenopodiaceae, and <i>Calluna vulgaris</i> slowly increasing in the upper spectra.
Kw-6	<b>Alnus–Carpinus–Fagus</b>	765–325	High <i>Alnus</i> (up to 41.4%), increased Poaceae (up to 4.5%). Higher number of herbaceous plants. The zone is divided into 2 subzones.
Kw-6a	<i>Pinus</i> – <i>Betula</i>		<i>Pinus</i> and <i>Betula</i> high and fluctuating. Increased <i>Carpinus betulus</i> and <i>Fagus sylvatica</i> . Decline of <i>Corylus avellana</i> , <i>Quercus</i> , <i>Tilia</i> , <i>Fraxinus</i> , <i>Ulmus</i> . Slight increase of <i>Filipendula</i> , <i>Artemisia</i> , Chenopodiaceae, Poaceae undiff, Cyperaceae, <i>Cerealia</i> undiff., <i>Triticum</i> t., <i>Plantago major/media</i> .
Kw-6b	<i>Fagus</i>		Dominant <i>Alnus</i> (up to 37.6%) decreasing at the top. <i>Fagus</i> high and slowly rising (up to 27.6%). <i>Carpinus betulus</i> high at the bottom and top of subzone (up to 17.6%). <i>Pinus</i> and <i>Betula</i> decrease and fluctuate. First appearance of <i>Secale cereale</i> , <i>Cannabis/Humulus</i> present. More telmatophytes present.
Kw-7	<b>Pinus–Quercus</b>	325–0	<i>Pinus</i> increasing and high amounts at the top of the zone, increasing NAP. The zone is divided into 2 subzones.
Kw-7a	<i>Quercus</i> –NAP		<i>Pinus</i> pollen amounts increasing and fluctuating, <i>Fagus</i> and high <i>Quercus</i> decreasing in the middle of the subzone together with <i>Corylus</i> , <i>Alnus</i> and <i>Carpinus</i> peaks. Increased number of taxa and higher percentages of herbs. Increased Poaceae (up to 11.8%) and slightly Cyperaceae. Increased <i>Cerealia</i> undiff. (up to 1.1%), <i>Secale cereale</i> (up to 1.8%). Reappearance of <i>Triticum</i> t. First appearance of <i>Fagopyrum</i> at the top of the subzone. Relatively high percentage of corroded grains.
Kw-7b	<i>Pinus</i> –NAP		<i>Pinus</i> high (up to 63.3%). <i>Fagus</i> , <i>Carpinus</i> , <i>Quercus</i> decreased. Holocene maximum of NAP. Increased Poaceae (up to 27.6%), Caryophyllaceae undiff., Cichorioideae, and Brassicaceae. Slightly increased <i>Cerealia</i> undiff., <i>Secale cereale</i> , <i>Artemisia</i> and <i>Centaurea cyanus</i> . First appearance of <i>Urtica urens</i> . Telmatophytes strongly reduced.

## POSTGLACIAL VEGETATION HISTORY

PAZ Kw-1 *Betula*–*Pinus*

Pollen spectra from the bottom section of Lake Kwiecko sediments indicate the predominance of forest communities with *Pinus sylvestris* playing initially the most significant

role. The other important forest component was *Betula*, which successively increased in abundance. The regular occurrence of *Corylus* pollen confirms the development of this light demanding shrub on more fertile soils of forest mantles and in the shrub layer of pine forests. Considerable pollen representation of Poaceae,



*Filipendula*, *Thalictrum*, and Cyperaceae may be an effect of their spread on wet habitats, which created favourable conditions for the development of these plants. *Myriophyllum verticillatum* dominates in the aquatic environment suggesting that mean July temperature was not lower than 13°C (Wasylikowa 1964, Weber & Nooden 1974).

The distinct dominance of *Tetraedron* among the chlorophytes may be connected with the amelioration of climatic conditions (Ralska-Jasiewiczowa et al. 2003), though the occurrence of still cold, oligotrophic or dystrophic lake water is indicated by the presence of *Pediastrum boryanum* var. *longicorne* and *P. integrum*. The appearance of the unknown *Botryococcus* species and of *Pediastrum boryanum* var. *boryanum* have no indicative value due to their broad ecological tolerance with respect to habitat and climate (Jankowska & Komárek 2000, Wacnik 2009).

#### Subzone Kw-1a *Salix*–NAP

Species usually occurring abundantly in the Late Glacial sediments were present in this zone, particularly in its lower section. Here belonged *Pinus cembra*, not noted in the corresponding period in the neighbouring sites (Obidowicz et al. 2004), as well as *Artemisia* and Chenopodiaceae. *Juniperus communis* appeared only at the very bottom of the zone. *Salix* was probably growing on the low lying terrains characterized by higher soil moisture or even periodically inundated. From the beginning of the zone *Corylus* appeared in quantities indicating its presence in the local vegetation. The beginning presence of *Corylus* pollen slightly precedes the start of continuous presence of *Ulmus*. According to Huntley and Birks (1983) the early Holocene *Ulmus* migration proceeded at a high rate of about 1 km per year. They suggested that values of 1.5–2% of *Ulmus* pollen indicate the presence of elm in local vegetation. In the diagram from Lake Kwiecko the percentages of continuous *Ulmus* pollen curve range between 1% and 2%. Hazel and elm possibly appeared near Lake Kwiecko at the same time but the spread of elm, which is characterized by slow growth particularly in the juvenile stage, was probably limited by such a strong competitor as hazel, growing and expanding much faster (Hjelmroos-Ericsson 1981).

#### Subzone Kw-1b *Betula*–*Ulmus*

The recorded vegetation changes suggest the amelioration of climatic conditions, which could cause the decrease of *Salix* and promote *Ulmus* expansion. The representatives of shore and water vegetation appear, for instance for the first time *Typha latifolia* is present.

#### PAZ Kw-2 *Corylus*–*Pinus*

*Corylus* became an important element in pine-birch forests. Rapid increase of its frequency had considerably restricted light penetration to the forest bottom. The dynamic expansion of *Corylus*, which lasted about 1000 years according to the number of pairs of laminae counted in this core section, initiated the transformation of forest stands. This resulted in the reduction of areas occupied by *Betula*, because its light demanding seedlings had no favourable growth conditions. Contemporaneously the successive decrease of pine abundance started in the forests. Single pollen grains of *Pinus cembra* type were still present, probably coming long distance transported.

More fertile and wetter sites were slowly colonized by *Ulmus*, the spread of which was however delayed by the expanding *Corylus*. *Quercus* was a new tree that appeared in small quantities preceding the spread of *Alnus*. A different situation was observed in the region of Lake Wielkie Gacno, where the arrival of *Quercus* was delayed in relation to *Alnus* by about 200 years (Hjelmroos-Ericsson 1981). *Alnus* was certainly growing on the lake shores, in places previously occupied by willow thickets or moist meadows. On more fertile and drier habitats *Corylus*, *Ulmus*, and *Quercus* could have started to form small patches of mesophilous forests.

Dry sandy areas created favourable conditions for the spread of shade-intolerant *Calluna vulgaris* (Hester et al. 1991, Iason & Hester 1993).

The most conspicuous change among the aquatic vegetation was the reduction of communities with *Myriophyllum verticillatum*. Distinct decrease of *Botryococcus* occurred.

#### PAZ Kw-3 *Corylus*–*Alnus*

Distinct change of forest communities is recorded in this pollen zone. Pine successively gives way to oak and elm. Quick migration of *Alnus* takes place, over 15% pollen curve

documents local presence of this tree. The spread of *Alnus*, though proceeding fast, was not as rapid as in the Lake Gościąg region, where the 15% increase of its curve occurred during 100 years (Ralska-Jasiewiczowa et al. 1998a). Therefore successful expansion of *Alnus* was probably possible due to its low edaphic and light demands (Jaworski 1994) as well as high seed production. Alder occupied moist or periodically inundated areas.

From the beginning of the zone *Tilia cordata* was constantly present in the forests (while only two pollen grains of *T. platyphyllos* were found in this zone). As lime is usually underrepresented in pollen diagrams, already a few percentages of its pollen document the local presence of this tree in the surroundings of Lake Kwiecko (Huntley & Birks 1983, Kupryjanowicz et al. 2004). *Ulmus* spread over larger areas in fertile and wet habitats. Light demanding *Corylus* could grow at forest edges or in the shrub layer indicating the low density of forest canopy.

The participation of the heliophilous plants was extremely low. Single representatives of this group, such as *Filipendula*, *Thalictrum*, Poaceae, and Cyperaceae found favourable growing conditions on lake shores while *Calluna vulgaris* occupied drier places. Pollen of a few climatic indicators like *Viscum* and *Hedera helix* were recorded in this zone. In forest clearings *Pteridium* developed.

#### PAZ Kw-4 *Ulmus-Quercus-Tilia*

*Fraxinus* appears as the next element in the Atlantic chronozone forests and remains their important component between about 6500 and 4000 years BP (Tobolski & Nalepka 2004). Ash prefers wet soils, rich in humus and nutrients (Wardle 1961). According to Andersen (1970) it is a poor pollen producer with low ability to pollen dispersion. It is often underrepresented in pollen diagrams therefore 1% pollen curve indicates its local occurrence (Huntley & Birks 1983). Bennett (1986) suggests that in some situations *Corylus* can be replaced by *Fraxinus*. The occurrence of *Fraxinus* together with an increasing participation of *Quercus*, both being frost sensitive taxa (Jaworski 1994), and in association of *Hedera helix* and *Viscum* suggests that climate became much milder. The increased *Quercus* pollen curve characteristic for this zone may also reflect the enlargement of space available for oak due to the drying

up of wet places and gradual overgrowing of lakes or to soil degradation (Iversen 1960). The decrease of *Pinus* participation was probably caused by the competitive pressure of *Ulmus*, *Tilia*, and *Quercus*.

Most probably some of the local vegetation changes could have been caused by the activities of Mesolithic and Neolithic people penetrating this region. The existence of openings within forests is indicated by the presence of *Pteridium aquilinum*, which does not tolerate shade. Thinning of forests could be caused by fires additionally favouring the germination of *Pteridium* spores and thus promoting the development of communities with the participation of bracken (Page 1986). The occurrence of fires is confirmed by the presence of charcoal dust in the middle section of Kw-4 zone. The absence of the larger charcoal fragments suggest that fires were located at a distance of at least tens of metres from the lake and not in its immediate surroundings (Clark & Patterson 1997). Fires could have been caused by natural factors, with no human interference (e.g. Komárek 1983, Engelmark 1984, 1987, Patterson & Backman 1988), but according to the generally accepted opinion natural fires of mixed forest were rare during the time of climatic optimum (Robin et al 2012).

The very low values of herbaceous plants indicate that the region must have been densely wooded. Rare representatives of herbs were probably growing in the lake marginal zone. Well developed reedswamp vegetation included for instance Cyperaceae, *Phragmites australis* t., and *Typha latifolia*. Inshore shallow water belt was covered mainly by species of *Potamogeton* section *Eupotamogeton*.

In spite of the fact that *Tetraedron* percentages are slightly reduced, its curve shows distinct fluctuations suggesting periodical massive growth, which could hamper the development of other algae, for instance of the thermophilous taxa.

#### PAZ Kw-5 *Corylus-Quercus-Alnus*

The area around Lake Kwiecko was still forested. The regional vegetation changes, initiated at the Atlantic/Subboreal transition and connected with the decreased participation of elm in the species-rich deciduous forests are observed in the pollen record from the studied site.

*Ulmus* fall is accompanied by the increased percentages of *Corylus avellana*, which takes

advantage of better light conditions and attains second maximum of development. This maximum is less pronounced than the Boreal one but more prolonged. Contemporaneously with *Ulmus* fall the frequency of *Betula* and *Pinus* decrease and fast expansion of *Quercus* can be seen. The intensive development of *Corylus* and *Quercus* in this period was recorded in several pollen diagrams (e.g. Ralska-Jasiewiczowa et al. 1998b, Hjelmroos-Ericsson 1981, Latałowa 1982 a, b). Oak, with some admixture of pine, could grow in the well-lighted oak forests or could form a kind of mixed coniferous forests with *Betula*, *Tilia*, *Pinus*, and *Fraxinus*. *Ulmus* curve shows a few short-lasting phases of the rise and fall of pollen frequencies, which could have anthropogenic causes.

Reedswamps and aquatic vegetation shows no changes compared to the previous zone. Communities dominated by *Phragmites australis* and species of Cyperaceae grow in the marginal lake zone, water plants are represented mainly by *Potamogeton* section *Eupotamogeton*.

Still very high *Tetraedron* curve declines at the top of the zone. It seems that the anthropogenic agent, which was one of the important causes of vegetation changes in the surroundings of Lake Kwiecko in this period, did not influence much the chlorophyte succession in the lake.

#### Subzone Kw-5a *Alnus-Plantago*

*Acer* and *Fagus*, which were already present in the region, gained in significance. *Carpinus* occurring throughout the zone, in the upper section attains the values as high as 1% suggesting that scattered hornbeam stands were present in the vicinity of Lake Kwiecko (Huntley & Birks 1983). They probably developed on fertile, fresh or periodically moist, brown or lessivé soils (Faliński & Pawlaczyk 1993). Continuous curve of *Carpinus betulus* begins slightly below the beginning of the continuous *Fagus* curve. The success in the colonization of new areas by *Carpinus* in the later period is connected with its low light demands and great reproduction ability due to the production of suckers and large number of seeds (Rychnovská & Bednář 1998).

The formation of open forest patches of short duration is documented by the oscillations of *Corylus* and *Betula* pollen curves as well as by variations in frequency and taxonomic

composition of shrubs such as *Juniperus communis*, *Rhamnus catharticus*, *Frangula alnus*, and *Hedera helix* as well as higher percentages of *Pteridium aquilinum* and *Rumex acetosa*. These changes are connected most probably with the man activities. Human impact is confirmed by the increased pollen frequency of such bioindicators as *Plantago lanceolata*, *P. major*, *Cerealia*, *Triticum* t., and *Chenopodiaceae*, as well as by the occurrence of charcoal in the sediment.

#### Subzone Kw-5b *Carpinus*

In the top section of Kw-5b subzone fast vegetation changes are recorded, which manifest themselves first of all by the decreased significance of *Corylus*, *Betula*, *Quercus*, *Tilia*, *Ulmus*, *Fraxinus*, and *Acer*. The spread of *Carpinus betulus* and *Fagus* over larger areas is indicated by the rise of pollen amounts of these trees. Synchronously the values of several herbaceous plants increase, including for instance *Poaceae*, *Artemisia*, *Chenopodiaceae*, *Plantago lanceolata*, and *Rumex acetosella*.

#### PAZ Kw-6 *Alnus-Carpinus-Fagus*

The vegetation change, which occurred at the time corresponding to this zone, led to the local domination of *Alnus*. The significance of *Pinus* and *Betula* increased, *Carpinus* and *Fagus* had a few episodes of maximum development, short-lasting in the case of *Carpinus*. Herbaceous plants played slightly greater role mainly due to the higher *Poaceae* percentages.

In the water basin *Tetraedron* was distinctly reduced; it forms continuous curve only in the lower section of the zone and becomes relatively rare toward the top. Scattered occurrences of *Botryococcus* and *Pediastrum boryanum* var. *boryanum* were recorded.

#### Subzone Kw-6a *Pinus-Betula*

Changes in plant communities, which are reflected in this subzone must have had complex causes. Great role was undoubtedly played by the intensified impact of various forms of settlement and economic activity of people but the influence of climatic changes also cannot be excluded. It is interesting that the decrease of pollen amounts of *Corylus avellana*, *Fraxinus*, and some other taxa from Lake Gościąg at about 3500 BP coincides with the quick

*Carpinus* expansion, while in Lake Kwiecko the distinct rise of *Carpinus* frequency is dated as late as 2840 BP. Most probably the main cause limiting the spread of *Carpinus* was the activity of people who intensively exploiting the environment in Lake Kwiecko region.

Simultaneously with the decrease of the proportions of *Corylus avellana*, *Quercus*, *Tilia*, *Ulmus*, and *Fraxinus* the increase of *Betula* and *Pinus* took place. Evidently the elimination of the first group of trees by the economic activity of people gave chance to the expansion of birch and pine into new areas. *Pinus* probably spread on the less fertile sandy habitats, which were previously covered by mixed conifer forest. At the same time herbaceous vegetation attained greater significance, particularly Poaceae and *Artemisia*. The distinct increase of *Calluna vulgaris* frequency could be connected with the development of the secondary heaths on soils impoverished by overexploitation. Two pollen grains of *Anthericum* were recorded. The species of this genus grow in forest openings or in a narrow belt between forests and grasslands, such as for instance xerothermic grasslands or dry meadows (Matuszkiewicz 1984).

#### Subzone Kw-6b *Fagus*

The maximum development of *Carpinus* in the surroundings of Lake Kwiecko occurred about 2840 BP. Much earlier, because about 3500 BP, the similar phenomenon was recorded in the eastern part of the Baltic Coastal Zone (Latałowa 1982 b) and in Wielkopolska (Great Poland) after Tobolski (1990 a, b). Hjelmroos-Ericsson (1981) described four maxima of *Carpinus* pollen amounts in Lake Wielkie Gacno sediments, the oldest of which was dated to 3150 BP, while in Lake Gościąż the first *Carpinus* maximum occurred earlier, namely about 3330 BP after Ralska-Jasiewiczowa et al. (1998).

The subsequent decrease of the amount of hornbeam trees in the forests had certainly anthropogenic causes because at the same time pollen frequency of human indicators increased. The diminished frequency of *Carpinus* pollen is correlated with the increased percentages of *Betula* and the decline of *Ulmus* and *Corylus*. Simultaneous sharp depression of *Alnus* may reflect the negative water balance.

In the top section of this subzone the regeneration phase of *Carpinus* and *Fagus* can be seen. The NAP values decline indicating the

diminution of open areas, although pollen of *Juniperus communis* is still recorded. These vegetation changes were possible due to the lesser anthropogenic influence testified by decreasing percentages of human indicators.

At the bottom of the subzone pollen sum of herbaceous plants shows distinct increase. The whole period corresponding to the subzone Kw-6b was probably characterized by the development of xeric grasslands, as is indicated by the appearance of pollen grains of *Sanguisorba minor* and *Anthericum*. An increase was also noted among pollen indicators of human husbandry. *Secale cereale* appeared for the first time in the pollen diagram. Latałowa (1992) encountered the first single rye pollen grains in the diagram from Wolin Island (profile II) as early as the Neolithic. According to this author such an early finding of rye pollen should be connected with the growth of rye as weed. The appearance of a single pollen grain of *Convolvulus arvensis*, a typical weed of winter cultivations, correlates with the depression of *Carpinus* curve in the bottom section of this subzone.

#### PAZ Kw-7 *Pinus-Quercus*

The distinct phase of forest regeneration was followed by a series of changes, occurred on a large scale with a hitherto not noted intensity and their beginning is marked by the clear border in the diagram. The NAP (mainly Poaceae) frequency distinctly increases up to 20%.

In the top section of this zone, the frequency of chlorophytes, such as *Botryococcus* and *Pediastrum boryanum* var. *longicorne*, distinctly increased. The occurrence of single coenobia of *Pediastrum angulosum*, *P. boryanum* var. *pseudoglabrum*, *P. boryanum* var. *glabrum*, and *P. duplex* var. *rugulosum* could have been caused by the slight increase of water eutrophication degree.

#### Subzone Kw-7a *Quercus-NAP*

The development of more open woodland is indicated by the occurrence of pollen grains of shrubs including *Juniperus communis*, *Sambucus nigra*, and *Calluna vulgaris* as well as spores of *Pteridium aquilinum*, in correlation with charcoal dust.

Significant changes occurred in the forest composition. Clearing of hornbeam forests

took place again and pollen percentages of this tree fell from about 18 to 3%. The frequency changes noticed in the history of *Carpinus* can undoubtedly be explained by human activity (Ralska-Jasiewiczowa 1964). Contemporaneously, the occurrence of *Fagus* and *Alnus* became limited. Concerning *Quercus* pollen amounts, its percentages slowly but systematically increased probably due to the selective protection of this tree by various groups of people who settled in this terrain.

The observed changes were certainly the effect of considerable intensification of settlement processes, indicated by the frequent occurrence of palynological human indicators. Cereal cultivation carried out on a large scale included rye and wheat, which is documented by the regularly recorded pollen grains of *Cerealia*, *Secale cereale*, and *Triticum t.* Pollen grains of *Artemisia* were present all the time and few grains of *Chenopodiaceae* appeared, both taxa containing heliophytes that grow in open habitats.

The period of intensive exploitation of the environment was followed by a phase of decreased human activity that made possible distinct regeneration of forests, mainly by communities with *Carpinus* and *Fagus*. Parallel to this change the retreat of *Quercus* occurred, possibly because oak could not compete with the other trees in a situation when its protection by people ceased. Areas occupied by *Alnus* considerably increased suggesting the development of forest stands resembling alder carr. The communities of herbs were reduced and among them the frequency of farming indicators decreased, including *Cerealia* undiff., *Secale cereale*, and *Plantago lanceolata*.

The next stage of the vegetation transformation in the surroundings of Lake Kwiecko, was again strongly influenced by human action. Forest clearings reduced the woody cover. *Betula* and slightly later also *Fagus*, *Corylus avellana*, and *Quercus* were decreasing. The same concerns *Alnus*, which withdrew to the narrow zone on the lake shore. At the same time the importance of *Pinus* successively increased. The increase in pine pollen amounts can reflect the actual increase in the number of pine trees but also pollen transport from distant surroundings after deforestation. The existence of open landscape in the area is confirmed by the presence of *Artemisia* and *Chenopodiaceae* pollen.

#### Subzone Kw-7b *Pinus*-NAP

In the top section of the profile changes connected with the continued devastation of forests can be seen. Pine is the only tree showing increased pollen percentages. Forest stands with *Carpinus betulus*, *Fagus*, and *Ulmus* were practically eliminated from the landscape. Only *Betula*, *Corylus avellana*, *Quercus*, and *Alnus* played a considerable role in the formation of forests in the region of Lake Kwiecko. Open areas covered by herbaceous plant communities became distinctly enlarged, particularly abundant were *Poaceae*, which attained maximum percentage values in this subzone.

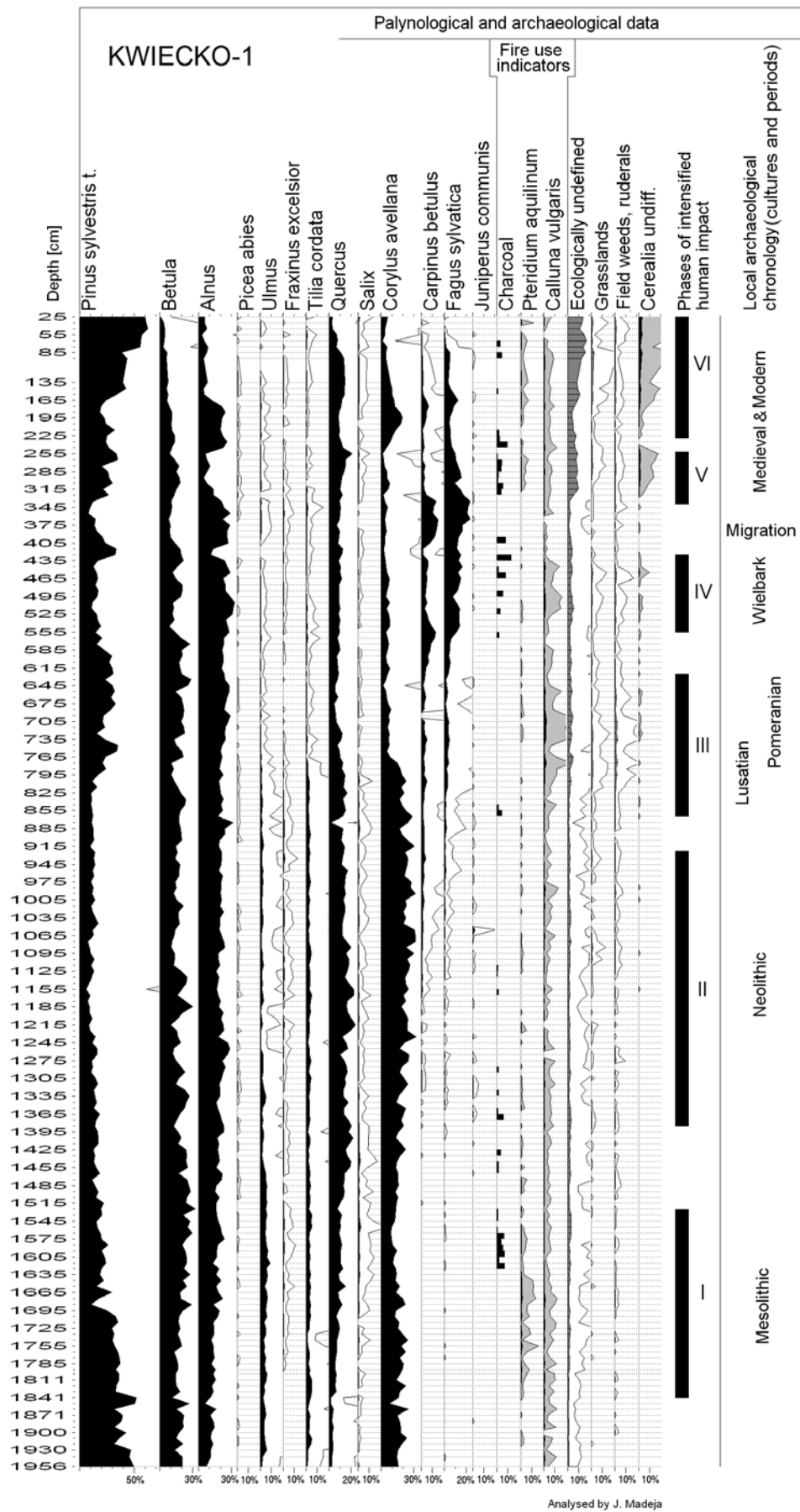
### SETTLEMENT PHASES IN THE SURROUNDINGS OF LAKE KWIECKO

On the basis of pollen analysis of the bottom sediments of Lake Kwiecko six settlement phases were distinguished and correlated with archaeological data (Fig. 4).

#### PHASE I – MESOLITHIC

The oldest evidence of the activity of humans in the vicinity of the lake can be seen in the middle of the Atlantic chronozone. The percentages of *Pteridium aquilinum* increase and continuous presence begins. As the shade intolerant species, bracken indicates the appearance of openings in the forest structure, while its preference to ash enriched habitats suggests the use of fire for clearing woodland in order to gain ground suitable to economic activities. Toward the end of this zone charcoal dust appears and the retreat of elm pollen amounts is observed. The percentages of pine also decrease. The fluctuations of *Ulmus*, *Tilia*, and *Corylus* pollen curves, which can be seen from the beginning of the Atlantic chronozone, could also have been caused by the selective periodical removal of these trees by people.

Pollen of *Sambucus nigra* was found together with the indistinct rise of the herbaceous plants pollen, which included taxa indicating human activity and the existence of nitrophilous communities (Behre 1981) such as: *Poaceae*, *Artemisia*, *Chenopodiaceae*, *Rumex acetosella*, *R. acetosa*, *Aster*, and *Urtica dioica*. The overall increase of the NAP values is small but considering the generally low



**Fig. 4.** Diagram showing the results of pollen analysis from Lake Kwiecko with phases of intensified human impact (selected taxa only).

NAP percentages in the whole profile even the slight oscillations in their values may be significant.

Palynological data permit to suppose that the surroundings of Lake Kwiecko were penetrated by human groups already in the Mesolithic, but their impact on local vegetation was minimal. They could have cleared small spaces within forests creating areas preferably visited by game and used by people for building camps (Ralska-Jasiewiczowa & van Geel 1992).

During archaeological investigations in the nearest surroundings of Lake Kwiecko two settlement traces were discovered represented by the Mesolithic tools of scraper type as well as one settlement trace and the remnants of one camp-site dated to the Mesolithic/Neolithic. Also in the northern part of the island located on the Lake Kwiecko some Mesolithic tool connected with Chojnicko-Pieńkowska culture were found. It seems that the vegetation changes described above could result from the activity of Mesolithic people of Maglemose complex, including the Chojnicko-Pieńkowska culture best represented in the West-Pomeranian Lake District (Bagniewski 1996). Similar changes were recorded several times on the territory of Poland (Hjelmroos-Ericsson 1981, Miotk-Szpiganowicz 1992, Latałowa 1992, Makohonienko 2000, Ralska-Jasiewiczowa & van Geel 1998). The population of the Chojnicko-Pieńkowska culture specialized, depending on the environmental conditions, in hunting, fishing, or gathering. According to the archaeological data obtained from the Mesolithic sites, the list of hunted animals was quite long (Galiński 2002). Bows were used for hunting, most often made of elm wood, with arrow shafts made of young and strait hazel suckers. The best documented gathering is connected with the exploitation of hazel nuts. Short-lasting camps connected with nut harvest in areas covered by hazel shrubs were discovered at the site Duvensee Moor in northern Germany. Nuts were later brought to the specialized workshops, where they were broken and roasted (Galiński 2002).

#### PHASE II – NEOLITHIC

The second settlement phase near Lake Kwiecko was fixed after the first elm fall, when *Plantago lanceolata* pollen grains appeared. The occurrence of this pollen type may

indicate that open plant communities spread as the result of grazing. *Rumex acetosa* pollen, another species connected with pastures (Latałowa 1992), is also present. For the first time *Plantago major* appeared, an indicator of trodden places and ruderal habitats (Behre 1981). Repeated falls and rises of *Ulmus* percentages may have anthropogenic reasons.

The appearance of light-demanding *Juniperus communis* and constant presence of *Calluna vulgaris* indicate the existence of open spaces within forest stands, which later were submitted to overgrowing. The repeated fluctuations of *Corylus* abundances were probably caused by intensified pollen production encouraged by better light conditions (Ralska-Jasiewiczowa & van Geel 1998). The intentional use of certain technical measures, provoking the development of hazel thickets as the permanent source of the raw material and nuts rich in proteins and fat, seems very likely (Kubiak-Martens 1999).

In this phase a single pollen grain of *Vitis vinifera* subsp. *sylvestris* was found. *Vitis vinifera* subsp. *sylvestris* was growing in natural habitats mostly during the Atlantic chronozone, but its pollen grains were also noted from territory of Poland in Subatlantic. From the same period single pollen grains of *Vitis vinifera* subsp. *sylvestris* were recorded for instance in the sediments from Lake Gościąż, where they were dated to 4680±20 yrs BP (Ralska-Jasiewiczowa et al. 1998b).

Vegetation changes in the surroundings of Lake Kwiecko, which are reflected in pollen diagram, occurred on a small scale. The most probable causes could have been the fairly weak settlement along with the character of economy based on gathering, hunting, and fishing and possibly pig rising. A small open places within forests were probably used for plant cultivation because for the first time in this phase *Triticum* t. pollen were found and, one grain of *Cerealia*.

The changes in the vegetation cover noticed during phase II most likely can be connected with the Neolithic population representing the Funnel Beaker and Corded Ware cultures. Often remnants of these cultures are known from the Bytowskie Lake District. On the maps prepared in the frame of the AZP project (Fig. 2) 10 settlement traces dated to the Neolithic are shown in the 6 km radius from Lake Kwiecko. Unfortunately only one of them was

identified as Funnel Beaker culture, while the culture type of the others was unclear.

#### PHASE III – LUSATIAN AND POMERANIAN CULTURES

The beginning of this settlement phase is marked by the distinct increase of the frequency of Poaceae, *Artemisia*, *Plantago lanceolata*, *Rumex acetosa*, and other ecologically undetermined herbs. Distinct qualitative and quantitative changes occurred among the trees. *Corylus* frequency rapidly decreased, synchronously with the falls of *Tilia* and *Fraxinus* and the gradual *Ulmus* decline. The decrease of *Quercus* amounts was probably caused by the use of oak timber as building material, for instance for the construction of strongholds. These changes correlate with the increased *Pinus* frequency. Vegetation changes in the environments of Lake Kwiecko, which took place during the discussed phase, could have been caused, to a high degree, by human populations.

Considerable intensification of settlement processes during the Bronze Age is documented by archaeological data. Within 6 km radius from Lake Kwiecko 13 settlement traces of the Lusatian culture were discovered. They included 9 settlements, 1 stronghold, and 2 settlement points as well as 1 bronze treasure found on the island on Lake Kwiecko. Archaeological investigations document also 8 settlement facts connected with the Pomeranian culture, which include 5 settlement traces, 1 settlement, and 2 cemeteries.

The economy of the Lusatian culture people was not based mainly on animal keeping but had a mixed character, including both animal husbandry and plant cultivation (Bukowski 1998). Pollen grains of *Triticum t.* and *Cerealia* document local cereal cultivation. One pollen grain of *Juglans* was also recorded. It cannot be excluded that this tree was planted by people but this is a relatively early finding considering the history of *Juglans*. In Poland, the oldest archaeobotanical record of *Juglans regia* fruits originates from Pruszcz Gdański, from the Roman influence period (Klichowska 1971, Latałowa 1994), but walnut pollen was recorded in Lake Gościąg (Ralska-Jasiewiczowa et al. 1998b) sediments dated to about 7270 BP.

After the time of the vigorous economic

activity of population in the vicinity of Lake Kwiecko recorded in this phase, an interruption of human impact on the natural environment can be seen. It is reflected in the increased significance of *Carpinus betulus* and the decline of *Artemisia* and *Calluna vulgaris* percentages, and the absence of *Triticum t.* pollen.

#### PHASE IV – ROMAN PERIOD

The pollen record from Lake Kwiecko shows the changes in settlement dynamics. The beginning of the settlement activity coincides with the distinct fall of *Carpinus* and *Betula* and the minor decrease of *Ulmus*. Synchronously the NAP values, mainly Poaceae increase. The presence of ruderal plants such as *Artemisia*, Chenopodiaceae, *Urtica dioica*, and *Plantago major* indicates the development of communities growing on trodden places and in habitats enriched in nitrogen. The area of fresh meadows increased, probably due to the increased significance of animal breeding and pasturage. The occurrence of *Plantago lanceolata*, *Rumex acetosa*, and *Filipendula* was recorded as well as pollen of *Anthemis* and *Potentilla*. The presence of *Secale cereale* and *Cerealia* type pollen suggests the existence of small cultivated fields probably not far from the lake.

Multidirectional contacts of people inhabiting the Pomerania in the Roman period were one of the causes of demographic increase, which resulted in large scale changes of the natural environment. From the older Roman period the plough marks originate (Chojnice and Wierusz district) that document the use of plough for soil cultivation. Stock raising had certainly great importance not only as the source of food but also of wool, used as a valued raw material for making clothes. The investigations of tissue fragments preserved in graves of the Wielbarska culture situated in the Koszalin province have shown that most of them were made of sheep wool (Maik 1981). The predominance of woolen fabrics may, however, be due to poor preservation of the other tissues, for example made of hemp.

Several archaeological sites discovered in 6 km radius from Lake Kwiecko can be connected with this settlement phase. They include 9 loose settlement traces and 4 cemeteries dated to the Roman period as well as 1 settlement and 1 cemetery belonging to the Wielbark culture.



When the time of extensive exploitation of the natural environment, connected with the IV settlement phase, came to an end, a new phase of regeneration of plant communities began during the Migration Period (375–ca 586 AD). The subsequent settlement regression caused distinct changes in forest stands. The increased frequencies of *Carpinus* and *Ulmus* were connected with the regeneration of forest communities, in which these trees were growing. After the initial rise, the area covered by *Pinus* and the light-demanding *Betula* diminished. The occurrence of herbaceous plants decreased, including palynological indicators of the economic activity of people, for instance *Artemisia* and *Cerealia*. The absence of charcoal and *Pteridium aquilinum* spores suggests that there were no fires in the near vicinity of Lake Kwiecko.

#### PHASE V – MEDIEVAL

The beginning of this period is distinguished by rapid changes in the forest composition and by the increase of palynological indicators of human activity (Behre 1981). Simultaneously the frequency of *Betula* increased, that of *Carpinus* and *Fagus* decreased, the participation of *Alnus* and to a lesser degree of *Tilia* diminished. Among the herbaceous plants the rapid rise was noted in the percentages of Poaceae (ca 10%) and in taxa of undefined ecological requirements.

In this phase, pollen grains of *Secale cereale* and *Cerealia* undiff. occurred frequently, sporadically those of *Triticum* t. and *Cannabis/Humulus* were found. Field weeds and ruderal plants appeared in higher percentages, particularly *Rumex acetosella* and *Urtica dioica*. Pollen grains of *Artemisia* and *Chenopodiaceae* were also present.

The increased anthropogenic activity during the Middle Ages is well documented archaeologically. Hereafter developing early medieval strongholds and open settlements, the traces of which are present near the lake basin, give evidence of the intensive settlement processes, which must have had enormous influence on the natural environment. In the radius of 6 km from the lake 28 settlement traces from this time were identified, 7 open settlements, 3 strongholds, and 2 cemeteries, one of which contained 22 burials dated to the 10<sup>th</sup>–11<sup>th</sup> century (Tota 2010). Among the cited settlement

traces, in the closest vicinity of Lake Kwiecko, a cemetery dated to the 11<sup>th</sup>–12<sup>th</sup> century was found on east shore. On west shore, in the village Stare Borne, a well preserved stronghold dated to the 8<sup>th</sup>–10<sup>th</sup> century was discovered, from which 39 pottery pieces and 4 animal bones were excavated (Olczak & Siuchniński 1969). On the island situated in the southern part of Lake Kwiecko a settlement existed from the 10<sup>th</sup> to 12<sup>th</sup> century, which was founded on the place of the previously existing settlement of the Lusatian culture (AZP, unpubl. and personal comm. information from Ignacy Skrzypek M.A., the curator of the Archaeological Museum in Koszalin).

The most frequent types of open settlements in the surroundings of Lake Kwiecko, as in the whole West-Pomeranian Lake District, were small settlements covering the surface of about 1 ha. Among the strongholds the most numerous were those of single-segment structure and in respect of size approaching open settlements (Olczak 1991).

#### PHASE VI – MODERN TIMES

The decrease of the representation of trees must have been connected with forest clearings undertaken in order to enlarge the areas of cultivated fields or pastures and with timber exploitation which is documented in archaeological and historical sources. Almost total elimination of *Carpinus* from forest stands was probably the effect of the use of hornbeam wood for fuel or as raw material for charcoal production. Other uses of its wood, for instance as timber, were limited due to the relatively small toughness compared to the other timber species (Surmiński 1993, data of the Wood Technology Institute, unpubl.). The diminished *Carpinus* significance in the forests could also be caused by many years' cattle grazing, the consequence of which was the formation of well-lighted oak forests (Faliński & Pawlaczyk 1993).

The increase of oak percentages was probably caused by the selective protection of this tree by man in order to provide acorns, which can be stored up to three years (Weckerly et al. 1989) and used as fodder for pigs, particularly in winter time. The acorns are the source of a high-energy food and nowadays, in certain seasons of the year, they may constitute even 50% of the diet of some wild animals. Also oak

leaves are rich in proteins (Pekins & Mautz 1988, Elowe & Dodge 1989). It is possible that acorns were consumed by people as well, just as it is the case recently among the aborigines of North America. According to Pekins and Mautz (1988) the acorn production can be increased significantly by selective felling of trees in the forests and by the protection of mature specimens.

The existence of open surfaces is indicated by the presence of *Juniperus communis* pollen and the increase of the curves of herbaceous plants, mainly Poaceae, but also for instance Cyperaceae, Cichorioideae, and Caryophyllaceae. Pollen data indicate the intensification of plant cultivation, particularly of cereals, because Cerealia and *Secale cereale* pollen are constantly present and attain high percentages. The occurrence of *Triticum t.* pollen suggests that wheat was also locally cultivated. The direct tillage indicators are accompanied by several plants, such as for instance *Rumex acetosella*, Brassicaceae, *Centaurea cyanus*, and *Scleranthus*. Hitherto not recorded *Fagopyrum* pollen appears as well, indicating that at that time buckwheat was probably part of agriculture. At the same time considerable participation of ruderal plants was recorded in Lake Kwiecko, including *Artemisia*, *Urtica dioica*, *U. urens*, Chenopodiaceae, and *Plantago major/media*. Taxa which often occur in disturbed communities are represented for instance by pollen grains of *Melampyrum* and *Calluna vulgaris*. Charcoal dust was sporadically recorded.

Considerable increase of *Pinus* pollen probably reflects pollen transportation from distant areas, which was possible due to the development of open landscape or/and the existence of pine plantations, as it was the case in the vicinity of Lakes Wielkie Gacno (Hjelmroos-Ericsson 1981) and Mały Suszek (Berglund et al. 1993).

## SUMMARY

Pollen analysis of Lake Kwiecko sediments allowed to reconstruct Holocene vegetation changes in the surroundings of the lake and to connect some of them with the presence and economic activity of local human groups.

Pollen spectra from the bottom section of lake deposits indicate that their sedimentation

began about 10 000 years ago. Palynological age estimation was not confirmed by the radio-carbon AMS dating of this part of the deposits but the AMS dates were considered too old due to the "old carbon effect". Vegetation changes around Lake Kwiecko initiated at the beginning of the Preboreal chronozone indicate the amelioration of environmental conditions, which resulted in the development of forest communities with deciduous trees during the Atlantic chronozone. Starting from this period the observed changes in the vegetation cover may partly be interpreted as the consequence of human activities. During the Subboreal chronozone forest composition has changed; *Ulmus* lost its significance, *Quercus* expanded, *Carpinus* and *Fagus* appeared for the first time. The appearance of pollen indicators of human economic activity document at least temporary settlements of people in the vicinity of the lake. Considerable intensification of settlement processes recorded in the Subatlantic, particularly in its top section, was one of the important causes responsible for quick changes in forest structure. The enlargement of the space used for plant cultivation brought about forest devastation on a hitherto not noted scale.

## ACKNOWLEDGMENTS

I would like to thank to Prof. M. Ralska-Jasiewiczowa and Prof. K. Wasylkowa for handing over the materials for this study. I also would like to thank to Prof. R. Ochrya for identification of moss macroremains deposited in the sediment. I would like to express my warmest thanks to Prof. Krystyna Harmata and Dr. Agnieszka Wacnik who always devoted their time to help and advise me. I am grateful to Prof. M. Latałowa for her valuable suggestions.

This work is a part of a PhD thesis and was financially supported by the Polish Ministry of Science and Higher Education (grant 3 P04F 018 23).

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