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POSTGLACIAL DEVELOPMENT OF VEGETATION IN THE VICINITY OF THE WIGRY LAKE

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Abstract: The Late Glacial and Holocene development of vegetation in the vicinity of the Wigry Lake is reconstructed using pollen analysis. The Late Glacial sediments include the Allerød and Younger Dryas chronozones. The Holocene section is complete. Pollen data combined with archaeological evidence and radiocarbon dating permit the recognition and characterisation of human influence on the local plant cover caused by settlers of Mesolithic and Neolithic cultures, by west Balts, by Grand Dukes of Lithuania and by Cameldolites order. On the basis of pollen analysis the development of aquatic and mire vegetation in the Wigry Lake is described.

Keywords: pollen analysis, palaeoecological reconstruction, vegetation history, human impact, Late Glacial, Holocene, Lake Wigry, north-eastern Poland.

1. INTRODUCTION

Attempts to reconstruct vegetation history in Suwałki region after retreat of the last glaciation were undertaken repeatedly (**Fig. 1**). The first report concerning these problems was published in the middle thirties of the previous century (Bremówna and Sobolewska, 1934). Later the synthetic palaeobotanical study based on results of pollen analysis from several lakes and mire was prepared by Ołtuszewski (1937). Unfortunately due to obsolete methods, nowadays both of these studies are unimportant for palaeobotanical reconstructions. The latest palynological data descend from the middle sixties and the beginning of seventies (Stasiak 1963; 1965 and 1971). The lack of radiocarbon dating in analysed deposits is a big drawback of these studies. It causes that in none of the both latest synthetic studies showing vegetation development in Poland during the Late Glacial and Holocene, the Suwałki region is not represented by any locality (Ralska-Jasiewiczowa, 1989a and Ralska-Jasiewiczowa *et al*., 2004a).

The latest borings at Słupiańska Bay of the Wigry Lake supply several new profiles of bottom deposits and make possible new undertaking of these problems. Interdisciplinary project elaborated by Professor Jacek Rutkowski contained numerous radiocarbon (Piotrowska and Hajdas, 2006; Piotrowska *et al*., 2007) and lead (Gąsiorowski and Hercman, unpublished) dating, pollen analysis (Kupryjanowicz, 2004a; 2006a; 2006b and Kupryjanowicz and Piotrowska, 2005), Cladocera analysis (Zawisza and Szeroczyńska, 2006 and 2007), diatom analysis and lithological and chemical analyses (Rutkowski *et al*., 2002a; 2002b; 2006a; 2006b; 2007; Rutkowski and Król, 2006 and Osadczuk *et al*., 2006) of examined profiles. It created an exceptional chance for modern detailed paleoecological reconstruction.

The main objective of the palynological work presented below was to recognise the stages of vegetation development in the Wigry region after the last glacial period.

2. STUDY SITE

The Wigry Lake is one of the biggest and deepest lakes in Poland (area 21.2 km^2, max. depth 73 m). The different basins separated by islands and peninsulas, lead to isolation of water masses and habitat differences. About 90% of the shoreline down to the depth of 1.5 m is bordered by emerged vegetation dominated by *Phragmites*. Submerged macrophytes occur down to the depth of 4.5 m and cover about 13% of the lake bottom. Due to the reduction of water transparency, some heliophilous

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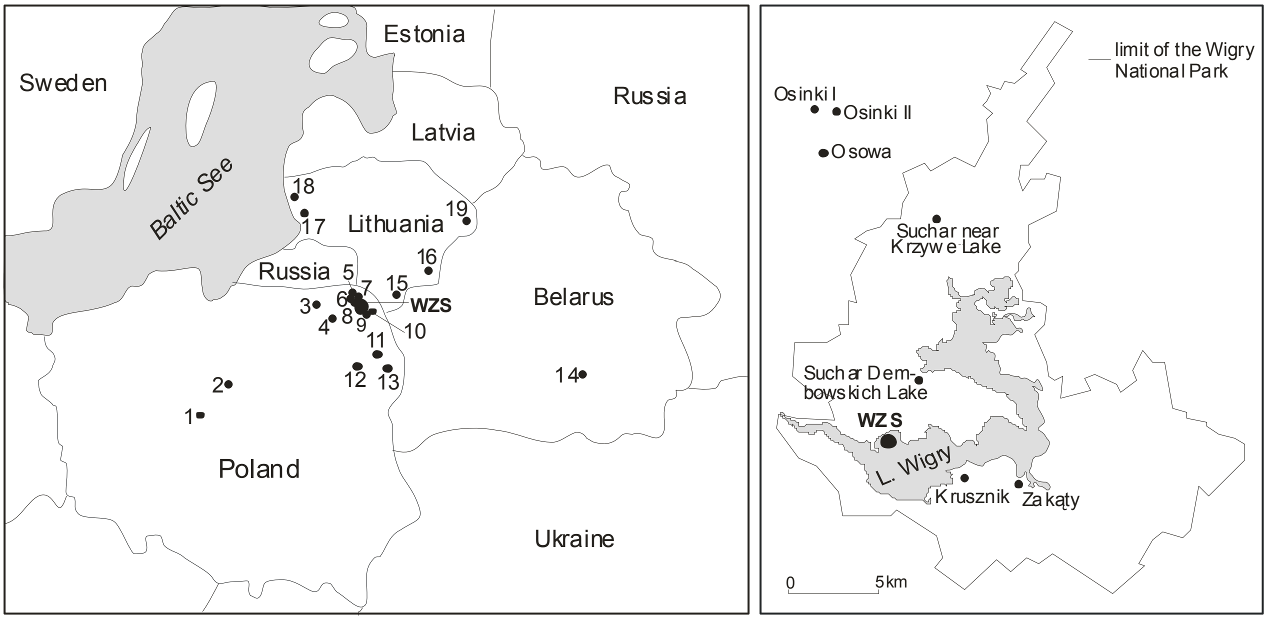

Fig. 1. *Location of the studied site (WZS) and other localities cited in the text: 1 – Gniezno (Makohonienko, 2000), 2 – Lake Gościąż (Ralska-Jasiewiczowa et al., 1998c), 3 – Lake Miłki (Wacnik, 2003), 4 – Lake Mikołajki (Ralska-Jasiewiczwa, 1966 and 1989b), 5 – Osinki I and Osinki II (Ołtuszewski, 1937), 6 – Osowa (Stasiak, 1971), 7 – suchar near Krzywe Lake (Ołtuszewski, 1937), 8 – Suchar Dembowskich Lake (Ołtuszewski, 1937), 9 – Krusznik (Stasiak, 1971), 10 – Zakąty (Ołtuszewski, 1937), 11 – Kładkowe Bagno (Kupryjanowicz, 2004b), 12 – Maliszewo (Balwierz and Żurek, 1989), 13 – Stare Biele (Kupryjanowicz, 2000), 14 – Ozernoe 1 (Kryval'cevič and Simakova, 2004), 15 – Lakes Dūba and Pelesa (Stančikaitė et al., 2002), 16 – Biržulis Lake (Antanaitis-Jacobs and Stančikaitė, 2004), 17 – Kebeliai-2 (Antanaitis-Jacobs and Stančikaitė, 2004), 18 – Kasuciai Lake (Kisielienė et al., 2005), 19 – Grūda Lake (Kabailienė et al., 1997)*

species, such as *Chara*, decrease in number whereas shade toleranting species increase (e.g. *Fontinalis*, *Ceratophyllum*). Plants are often covered with calcareous encrustations.

Detailed description of the Wigry Lake is comprised in paper of Rutkowski *et al.*, 2007.

3. PRESENT-DAY CONDITIONS OF THE ENVIRONMENT IN THE STUDY AREA

According to the regional division of Poland made for palaeobotanical studies, the Wigry Lake region belongs to the Suwałki-Augustów Lake District (P-y), which is the most north-eastern part of the larger unit – the Lake Districts (Ralska-Jasiewiczowa, 1989a). In the physical-geographical division it is assigned to two mezoregions – East Suwałki Lake District and Augustów Upland that are parts of the Lithuania Lake District (Kondracki, 1994).

The relief of the area was modelled by the Vistula Glaciation (e.g. Ber, 2000; Marks, 2002).

The Suwałki region with its continental climate is the coldest region of Poland (Woś, 1995). The mean annual temperature there is equal to 5.3ºC (Krzysztofiak and Olszewski, 1999). The growing season is exceptionally short. It begins in the middle of April and lasts until the middle of October – it is over one month shorter than in central Poland.

The Wigry Lake lies in the central part of the Wigry National Park. The forests of the park constitute the northern part of the Augustów Primeval Forest, which covers almost 1 150 km^2 and is one of the largest forest complexes in Poland. The severe climate of north-eastern Poland results in the occurrence of forest communities of a boreal character (Sokołowski, 1999). The most conspicuous differences in comparison with forests in other parts of Poland are the absence of beech (*Fagus silvatica*), fir (*Abies alba*) and broad-leaved linden (*Tilia platyphyllos*), and the abundance of spruce (*Picea abies*), which occurs in almost all forest communities.

Various topographic features, differentiation of soil fertility and moisture cause that nearly all forest communities typical of north-eastern Poland may be found in the park. 112 plant associations occur here (Sokołowski, 1988 and 1999). Forest communities dominate and cover above 62% of the park. The most extensive area is occupied by mixed forests, which are represented by 5 associations: *Calamagrostio-Piceetum*, *Calamagrostio-Pinetum*, *Pino-Quercetum*, *Querco-Piceetum* and *Betulo pubescentis-Piceetum*. In northern and central part of the park *Corylo-Piceetum* dominates. The raised shores of lakes are overgrown mainly by *Aceri-Tilietum*. Alder woods, mostly *Circaeo-Alnetum*, more seldom *Stellario-Alnetum* and *Piceo-Alnetum*, are present along water-course and in places of ground-water exudation. *Ribo nigri-Alnetum* dominates in sunken depressions, in which also *Sphagno squarrosi-Alnetum* and *Sphagno-Betuletum pubescentis* may occur. *Vaccinio uliginosi-Pinetum* occupies without-outflow depressions and shores of dystrophic lakes. *Sphagno girgensohnii-Piceetum* grows in small areas in the vicinity of these lakes. At sandy dry soils *Vaccinio vitis-idaeae-Pinetum* is present. Here and there shrub communities such as *Salicetum pentandro-cinereae* and *Salici-Sphagnetum* accompany forests. Deforested areas are occupied by cereal and root-plants cultures, and grasslands, mainly by slightly moist meadows (*Arrhenatheretum elatioris* and *Lolio-Cynosuretum*).

Large areas are overgrown by mire communities – of rised-bogs (*Sphagnetum magellanici*), of transitional mires (11 associations) and of lowland mires (tall-sedges and typical rushes represented by numerous associations). Isolated hills are covered by xerothermic communities, mainly by *Hieracio-Thymetum pulegioidis* and *Arctostaphylo-Callunetum*.

The oldest archaeological findings proving man habitation around the Wigry Lake date back to the Late Palaeolithic Age, that is more than 12 000 years ago. During the Mesolithic Wigry region was under the influence of the Kunda cultures (Ambrosiewicz *et al.*, 1997; Brzozowski and Siemaszko, 1993 and Brzozowski 1999). The Neolithic settlements were associated with para-Neolithic forest cultures. At the beginning of the Neolithic areas surrounding the Wigry Lake were also under the influence of the Globular Amphore culture and later of the Corded Ware culture. Little is known about Bronze Age (1800-550 BC). Very poor findings from this period may indicate weak population. The character of these findings shows civilisation backwardness. According to archaeologists in this time the so-called settlement emptiness probably took place. The significant turn in the north-eastern Poland history befell at the beginning of the Iron Age in the middle of 6th century BC, when Balt tribes with provenance from the River Dnepr basin, reached the region. In the Middle Ages (7th-13th centuries) the Wigry region was inhabited by the Jatvings – one of the Western Balt tribes. After the decline of the Jatvings the vicinity of the Wigry Lake was uninhabited for almost two centuries. The exploitation of primeval forest resources started in the times of the regime of the Grand Dukes of Lithuania that is in the 15th century. Also the activity of the Cameldolites order was essential for the settlement in the Wigry Lake surroundings. The order was granted at the Wigry Peninsula in 1667. As a result of the third partition of Poland the area surrounding the Wigry Lake was annexed by Prussia. Prussian authorities confiscated the order's properties. After 1815 this land was annexed by Russia and included into the Congress Kingdom of Poland. Gradual colonisation started in government owned estates, and then peasants started to be charged with the rent, and land integration was initiated. The colonisation of the area surrounding the Wigry Lake was completed by mid 19th century. Contemporary settlement has only rural character and is marginally connected with forest economy.

4. MATERIAL AND METHODS

Material for pollen analysis was taken from two cores, which were cored in the central part of the Słupiańska Bay (**Fig. 1**). In this part of the lake the depth of water attains 23 m. The WZS/03 coring reached the bottom of the lake sediments at the depth of 5.26 m. The WZS/03a coring was made in the vicinity of the previous one. It contains only the top layer of the deposits, to the depth of 0.44 m. Detailed information about the both corings are showed in papers of Rutkowski *et al.*, 2007.

The deposits were described using the Troels-Smith's system (Troels-Smith, 1955) (**Table 1**).

Table 1. *Description of the deposits from WZS/03 core according to Troels-Smith's system (Troels-Smith, 1955).*

Layer	Depth (m)	Description	Troels-Smith formula
1	5.26-5.00	Dark lacustrine sandy mud with a low amount of carbonates and organic matter	(As+Ag)3, Lc1, Ld+, Dg+, Dh+, Gg(min.)+, nig.2, elas.0, strf.0, sicc.3
2	5.00-4.20	Dark-grey calcareous gyttja	Lc3, Ld1, Dg+, Dh+, (As+Ag)+, Gg(min.)+, nig.2, elas.1, strf.0, sicc.3
3	4.20-0.86	White-beige lacustrine chalk, very fine-grained and plastic	Lc4, Ld+, Dg+, Dh+, (As+Ag)+, nig.0, elas.0, strf.0, sicc.3
4	0.86-0.10	White-beige lacustrine chalk with increasing content of water, jellylike in consistency	Lc4, Ld+, Dg+, Dh+, (As+Ag)+, nig.0, elas.0, strf.0, sicc.2
5	0.10-0.00	Green to dark-grey, liquid, calcareous gyttja with high water content	Lc3, Ld1, Dg+, Dh+, (As+Ag)+, nig.2, elas.0, strf.0, sicc.2

25 samples of sediments from the WZS/03 profile were dated by radiocarbon method (Piotrowska and Hajdas, 2006). The WZS/03a profile was dated by the lead method (Gąsiorowski and Herman, unpublished). The obtained data permit to define the calendar age of each analysed palynological sample.

95 samples for pollen analysis were taken from the WZS/03 profile at 5-cm intervals and 30 samples from the WZS/03a profile at 2-cm intervals. Pollen samples were 1 cm^3 in volume. They were prepared using the Erdtman's acetolysis method (Faegri and Iversen, 1975). The samples containing mineral material were pre-treated with hydrofluoric acid.

Green algae such as *Botryococcus braunii*, *Pediastrum* ssp. (Jankovská and Komárek, 2000) and *Tetraedron* – no-pollen microfossils, important for paleoecological reconstruction – were also determined and counted during the pollen analysis.

In order to establish the absolute sporomorphs concentration in the sediments, 2 *Lycopodium* indicator tablets (12×12,077 spores) were added to each sample (Stockmarr, 1971).

The obtained results were presented as a pollen diagram (**Fig. 2**), constructed in accordance with recommendations made by Berglund and Ralska-Jasiewiczowa (1986). The percentage values were calculated on the basis of the total sum including trees and shrubs (AP) and herbs (NAP), and excluding aquatic and mire plants pollen, spores and other microfossils. The diagrams were drawn using the computer program POLPAL (Walanus and Nalepka, 1999 and Nalepka and Walanus, 2003).

Part of the diagram, which shows pollen data from the WZS/03 profile, was drawn on the basis of the calendar scale elaborated by Piotrowska and Hajdas (2006).

The sample from the depth of 5.26 m in the WZS/03 profile, which was investigated by professor Kazimierz Tobolski before the start of systematic palynological investigations (Tobolski, 2000), was joined to the pollen diagram.

5. POLLEN STRATIGRAPHY

In the main part of pollen diagram containing pollen curves of trees and shrubs (AP), and terrestrial herbs (NAP), 10 local pollen assemblage zones were distinguished (**Fig. 2**). Their short characterisation is presented in **Table 2**. Pollen zones illustrate various stages of vegetation succession around the Wigry Lake. Due to the big size of the lake accumulation basin, the obtained pollen record registers mainly regional changes of vegetation (see Prentice, 1985; Jacobson and Bradshaw, 1981 and Sugita 1993; 1994). In relation to that, distinguished palynostratigraphical units could be treated as regional pollen assemblage zones (R PAZ).

Water and mire vegetation is very poorly represented in the sediments of the Wigry Lake. Nevertheless, the small changes in percentage values and frequency of their remains allow distinguishing 5 local pollen zones illustrating the main stages of vegetation development in the lake (**Fig. 2**).

A few rises of frequency and/or values of human indicators (ca. Behre, 1981) enable the distinction of 7 pollen phases of human activity (**Figs 2, 3** and **4**).

6. RECONSTRUCTION OF VEGETATION DEVELOPMENT

The pollen assemblage zones based on the available radiocarbon and lead dating (Piotrowska and Hajdas, 2006 and Gąsiorowski and Hercman, unpublished) are presented in the periods treated as chronozones in accordance with the proposal of Mangerud *et al*. (1974).

Obtained pollen data permit to reconstruct the vegetation changes in the Wigry Lake vicinity from 11,820 cal BC to 2003.

Regional changes of land vegetation

Late Glacial

In the profile from the Wigry Lake, the lowest local pollen zone W-1 *Pinus-Betula*-NAP (the depth of 5.25-4.70 m) represents the period from 11,829 to 10,465 years cal BC and generally corresponds to the Allerød. However its upper boundary does not correlate with the end of this interstadial, but with the early part of the Younger Dryas.

The pollen record of the zone registers a presence of boreal pine forest with a gradually increasing proportion of birch. The relatively large areas were overgrown by open communities with grasses (Poaceae) and heliophilous herbs such as *Artemisia*, *Botrychium* and Chenopodiaceae. The very low pollen concentration documents a weak density of the plant cover.

A similar pollen record of Allerød vegetation is characteristic for whole lowland Poland (e.g. for Gostyńskie Lake District in central Poland – Ralska-Jasiewiczowa *et al.*, 1998a; Mazury – Wacnik, 2003; Wielkopolska – Makohonienko, 2000; Biebrza Valley – Balwierz and Żurek 1989; Białystok Upland – Kupryjanowicz 2000 and 2004b), and also for the area of south-eastern Lithuania (Stančikaitė *et al*., 2002), which is situated in the neighbourhood of the Suwałki region.

The disappearance of Allerød boreal forest took place in the Wigry region between 10,465 and 10,189 cal BC In profiles of laminated sediments from the Gościąż Lake this moment is dated on ca. 12,660 cal BP = 10,710 cal BC (Ralska-Jasiewiczowa *et al*., 1998a). This date is at least 200 years older than in the Wigry profile. These divergences ensue probably from the too large distances between samples in this section of the WZS/03 profile. A rate of sediment accumulation was very low in this part of the profile, and 5-cm distance between samples represents about 300 years.

Regional pollen zone **W-2 NAP-*Juniperus-Salix-Betula nana*** (depth 4.65-4.61 m) is represented by only 2 pollen spectra. Their dating (10,189 and 9961 cal BC) shows that the vegetation changes are connected with the younger part of the Younger Dryas.

Pollen record shows a mosaic character of vegetation in the Wigry region with alternating pieces of dwarf shrubs tundra with willows (*Salix*) in moist places, and thickets of juniper (*Juniperus*) and steppe grass communities with *Artemisia* and goosefoot family (Chenopodiaceae) on the dry habitats. Pollen of pine (*Pinus sylvestris* type) and tree birches (*Betula alba* type), which dominate in spectra, may descend from the long transport. However the occurrence of small park groups of these trees among herb and shrub vegetation is also very likely.

The zone reflects the reaction of plant communities to the climatic change. It is expressed by the spread of grasslands with dominant *Artemisia* and Chenopodiaceae, and of *Juniperus* shrubs that coincide with the reduction of woods. These changes suggest not only the temperature decline, but also the moisture decrease (ca. Ralska-Jasiewiczowa *et al*., 1998a).

Pollen record of the Younger Dryas in profile from Wigry is characterised by a relatively low proportion of herbs (NAP) and juniper (*Juniperus*) in comparison to the other sites from north-eastern and northern Poland (e.g. Latałowa, 1989; Noryśkiewicz and Ralska-Jasiewiczowa, 1989; Ralska-Jasiewiczowa, 1989b; Kupryjanowicz, 2000 and 2004b; Wacnik, 2003 and Szwarczewski and Kupryjanowicz, 2006a and 2006b) and Lithuania (Kabalienė, 1998; Stančikaitė *et al*., 2002 and Kisielienė *et al*., 2005). It is not excluded that pollen record of this stadial is incomplete in the Wigry profile. The whole Late Glacial section in the WZS/03 profile from Wigry is known with a very poor resolution. Surely it must be bored again and subjected to supplementary research.

The dating of disappearance of steppe-tundra in profiles from Gościąż Lake on ca. 11,540 cal BP = 9590 cal BC (Ralska-Jasiewiczowa *et al*., 1998a) is similar to the dating of this moment in the profile from Wigry, where it is comprised between 9961 and 9613 cal BC. In general, this age corresponds to the boundary of the Late Glacial and Holocene in chronostratigraphy of the youngest part of the Quaternary. However, plateaux occuring at the radiocarbon age of ca. 10,000 ^{14}C BP, which is the worldwide accepted date of the Pleistocene/Holocene boundary (e.g. Mangerud *et al*., 1974), complicates absolute dating of this event. At Lake Gościąż, the Younger Dryas/Holocene transition is dated at 11,510±50, based

Table 2. *Characterisation of regional pollen assemblages zones (R PAZ) and subzones (R PASZ)*

R PAZ and R PASZ	Depth (m)	Age (cal years)	Description of pollen spectra
W-1 *Pinus-Betula*-NAP	5.25-4.70	11 820-10 465 BC	Domination of *Pinus sylvestris* type (43.4-79.3%) and *Betula alba* type (5.4-49.1%); low NAP proportion (below 10%). Pollen concentration rising from 0.2 to 1.6x10^5 grains/cm^3. Upper boundary marked by rise of NAP above 10% and slight fall of *Pinus sylvestris* type.
W-2 NAP-*Juniperus-Salix-Betula nana*	4.65-4.61	10 189-9961 BC	Peak of NAP (ca. 15%); relatively high values of *Juniperus* (3.4-4.1%), *Salix* (2.6-3.2%) and *Betula nana* type (0.7-1.9%). Decline of pollen concentration (0.5-0.7x10^5 grains/cm^3). Upper boundary at beginning NAP decrease and *Pinus sylvestris* type increase as well as at pollen concentration rise to ca. 2x10^5 grains/cm^3.
W-3 *Pinus-Betula-Ulmus*	4.55-4.35	9613-8512 BC	Very high proportion of *Pinus sylvestris* type (57.8-74.9%); still presence of *Populus* and *Picea abies* (below 1%); start of continuous curves of *Ulmus* and *Corylus avellana*; gradual fall of NAP. Pollen concentration rising from 0.2 to 1.6x10^5 grains/cm^3. Upper boundary showed by rise of *Ulmus* above 3% and *Corylus avellana* above 10%.
W-4 *Corylus-Ulmus*	4.30-3.97	8264-6854 BC	Maximum of *Corylus avellana* (22.6%); *Ulmus* proportion fluctuating from 2.8% to 5.6%; start of *Alnus*, *Quercus*, *Tilia cordata* type and *Fraxinus* continuous curve; gradual fall of *Pinus sylvestris* type; still presence of *Picea abies* (below 1%). Upper boundary at fall of *Corylus avellana* to 10.3% and rise of *Alnus* to 12.1%.
W-5 *Alnus-Tilia-Ulmus-Quercus*	3.92-3.07	6670-4200 BC	Maximum values of *Ulmus* (7.5%) and *Tilia cordata* type (3.7%); rising curve of *Quercus* (from 2.0% to 7.0%); high proportion of *Alnus* (6.5-17.3%); percentages of *Corylus avellana* lower then at previous zone (5.8-12.6%); still presence of *Picea abies* (below 1%). Pollen concentration gradually decreasing from ca. 2.5 to 0.8x10^5 grains/cm^3. Upper boundary at decrease of *Ulmus* and small increase of *Pinus sylvestris* type.
W-6 *Quercus-Picea-Ulmus*	3.02-2.02	4066-2093 BC	Culmination of *Quercus* (max. 13.7%); increasing values of *Picea abies* type (max. 3.9%). Upper boundary characterised by rise of *Picea abies* type and fall of *Corylus avellana* and *Quercus*. Three subzones are distinguished at W-6 zone:
W-6a *Pinus*	3.02-2.52	4066-2759 BC	Rising proportion of *Pinus sylvestris* type.
W-6b *Quercus*	2.47-2.20	2652-2234 BC	Absolute maximum of *Quercus* (13.7%).
W-6c *Corylus*	2.17-2.02	2209-2093 BC	Culmination of *Corylus avellana* (8.7-10.2%).
W-7 *Picea-Pinus-Carpinus*	1.97-1.37	2022-186 BC	Maximum values of *Picea abies* type (13.7%); relatively high proportion of *Quercus* (4.5-8.2%). Upper boundary at increase of *Carpinus betulus* above 3%.
W-8 *Carpinus-Betula-Quercus*	WZS/03: 1.32-0.40 WZS/03a: 0.44-0.38	33 BC - 1601 AD	Culmination of *Carpinus betulus* (1.1-4.1%); slight rise of *Betula alba* type; values of *Picea abies* from 1.2% to 7.2%, Upper boundary at increase of NAP proportion above 10%.
W-9 *Pinus-Picea*-NAP-*Juniperus*	WZS/03: 0.24 WZS/03a: 0.36-0.02	1621-1998 AD	Proportion of NAP relatively high (max. 16%), still presence of *Juniperus* (below 1%) and taxa being human indicators. Upper boundary at decrease of NAP and rise of *Pinus sylvestris* type.
W-10 *Pinus-Picea*	WZS/03a: 0.01-0.00	2001-2004 AD	Domination of *Pinus sylvestris* type (77.7-86.7%); relatively high values of *Picea abies* type (4.1-6.7%); very low proportions of all other pollen taxa.

on the varve thickness sequency, and 11,440±120 cal BP, based on the AMS radiocarbon dates (Goslar *et al*., 1998).

Holocene

The Holocene history of forests in the Wigry Lake region may be divided to 4 main development stages.

1st stage – boreal pine-birch forests (9613-8512 cal BC). Initial stage of the Holocene forests development is represented by regional pollen zone **W-3 *Pinus-Betula-Ulmus*** (depth 4.55-4.35 m). Generally it corresponds to the Preboreal chronozone. The upper boundary of the pollen zone is dated between 8512 and 8264 cal BC, so is only little older than upper boundary of the Preboreal chronozone, which is dated on 8150 cal BC (Mangerud *et al*., 1974; Walanus and Nalepka, 2005).

The climatic change affected the shrub and herb vegetation around the lake: it is indicated by a reduction of juniper shrubs and xeric grasslands with *Artemisia* and Chenopodiaceae. The changes had not involved yet the dominant tree taxa *Betula* and *Pinus sylvestris* in any essential way. The percentage values of both plants remain oscillating within the limits similar to those attained during the Younger Dryas, what is clear from their pollen concentration (**Fig. 2**). It took up to 1,5x10^{5}grains/cm³.

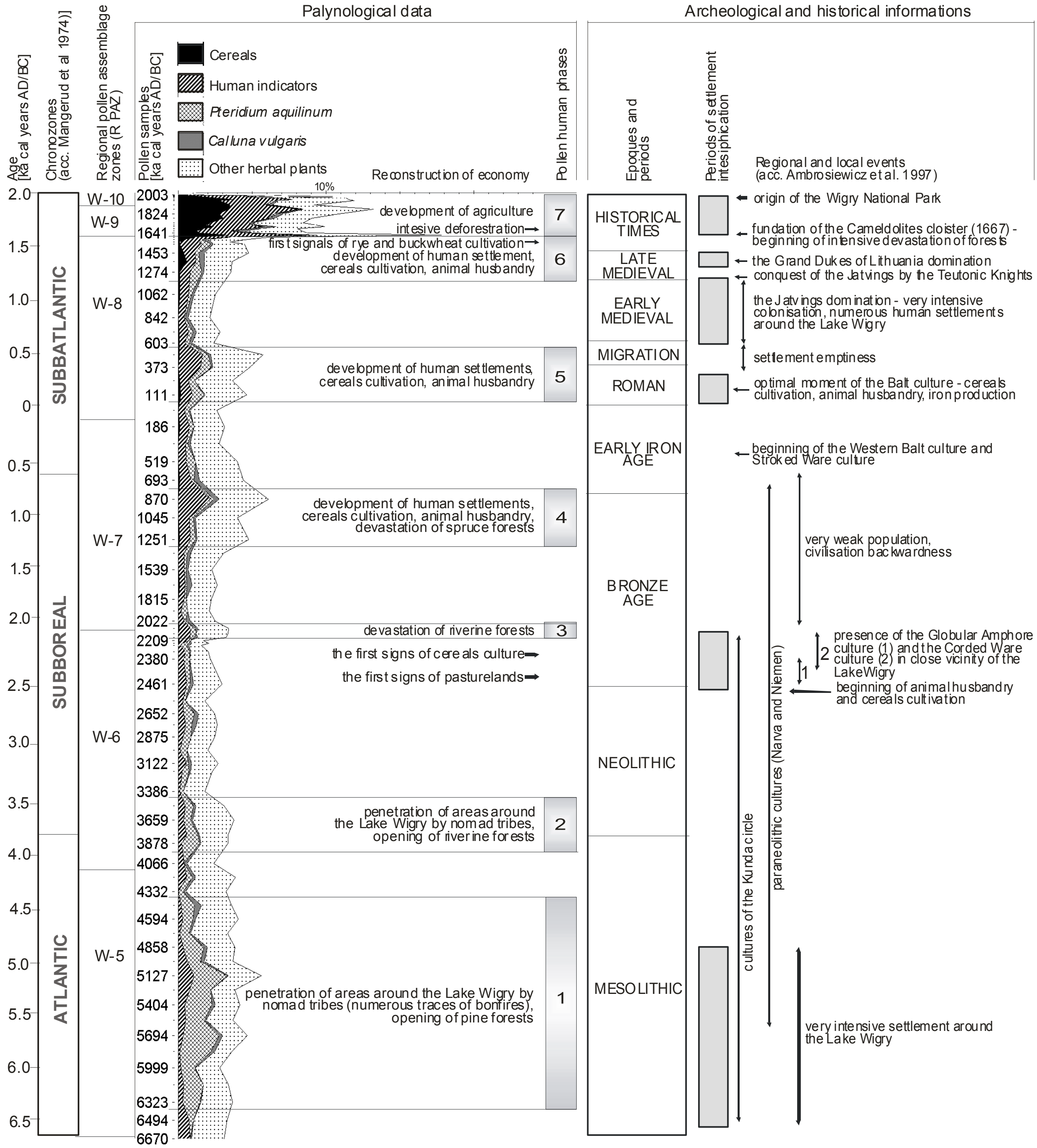

Fig. 3. *Comparison of pollen and archeological/historical data relating to the human settlement in the Lake Wigry vicinity. Total pollen diagram contains spectra from profile WZS/03 (from 6670 BC to 1453 AD) and from profile WZS/03a (from 1539 to 2003 A.D). Dating of pollen samples according to Piotrowska and Hajdas (2006) and Gąsiorowski and Hercman (unpublished).*

Already in this time aspen might have appeared in the tree stands (*Populus* pollen). At the decline of the stage, about 8719-8512 cal BC, the first trees and shrubs with greater climatical demands, such as elm (*Ulmus*) and hazel (*Corylus avellana*), might have approached the Wigry region. It is documented by the start of continuous pollen curves of these taxa. Huntley and Birks (1983) suggest that only pollen values over 2% may indicate their local presence. However values of *Ulmus* pollen higher than 1% may already indicate the scattered presence of elm in the region (Zachowicz *et al*., 2004). The investigations of the surface pollen depositions have proved that hazel can still occur locally even when its pollen values are lower than 2% (Miotk-Szpiganowicz *et al*., 2004).

In the central Poland *Ulmus* appeared slightly earlier than in the Suwałki region, ca. 10,760 cal BP =

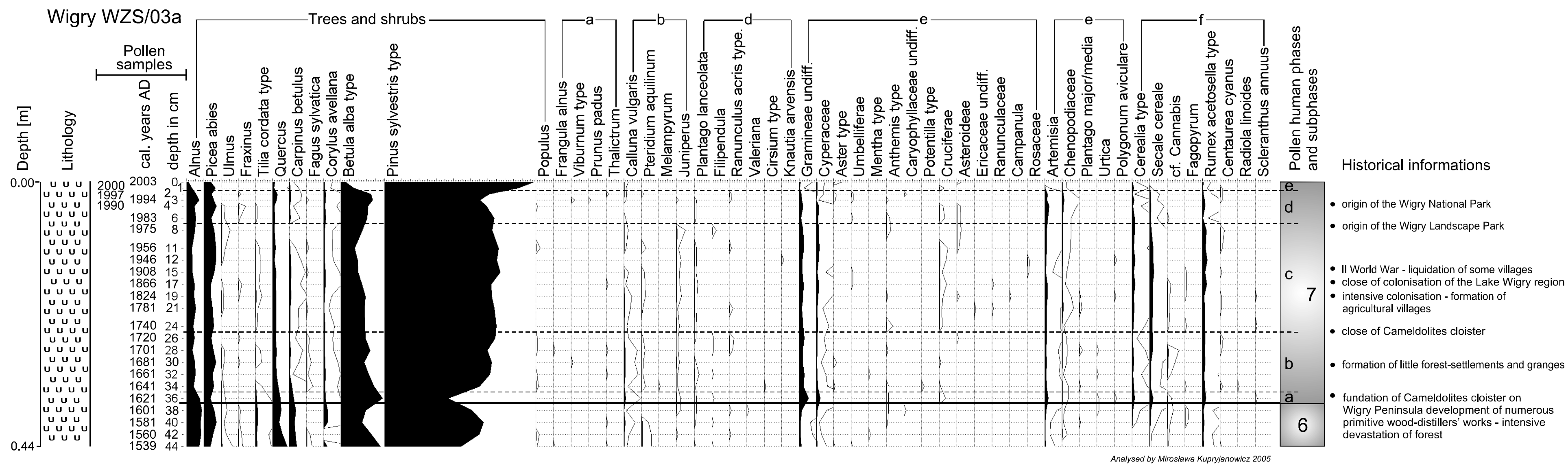

Fig. 4. *Percentage pollen diagram from profile Wigry WZS/03a showing the human impact on the landscape during the youngest settlement phase. Curves of herbs related to the economic activity of man have been grouped according to Behre (1981): a – mantle/outskirt shrubs, b – grazed woodland, d – fresh-wet grasslands (meadows), e – taxa ecologically undefined (family or genus type rank mostly), but favoured by human use, f – ruderals, g – cultivated plants and fields weeds. Dating of pollen samples according to Piotrowska and Hajdas (2006) and Gąsiorowski, and Hercman (unpublished). For other explanations see* ***Fig. 2****.*

ca. 8810 cal BC (Ralska-Jasiewiczowa *et al*., 1998b). That fact may support the *Ulmus* migration maps in north-eastern Poland at its earliest stages (Zachowicz *et al*., 2004).

The continuous curve of *Picea abies* contains the lowest values reaching up to 0.2%. However it may suggest that the spruce range had occurred already in this time in not too far distance from the Wigry Lake. The more so because the large pollen grains of this taxon usually are not transported on long distances. Pollen data from Lithuania (Stančikaitė *et al*., 2002) confirm that spruce might have been present at this time in this part of Europe. So early presence of spruce on these areas may be caused by its spreading from glacial refugia located in west Russia (ca. Huntley and Birks, 1983 and Terhürne-Berson, 2005). At this time began also the spruce expansion from refugia located in the Carpathians in south-eastern Poland (Obidowicz *et al*., 2004)

2nd stage – multispecies mixed forests (8264-4200 year cal BC). Broad-leaved trees and shrubs with higher thermal demands attained their optimal Holocene spreading in stands.

In the oldest part of the stage (8264-6854 cal BC), represented by regional pollen zone **W-4 *Corylus-Ulmus*** (depth 4.30-3.97 m), the expansion of hazel took place. Probably hazel had appeared in the Wigry region earlier, at the decline of the previous stage, ca. 8512 cal BC, when its pollen values exceed 2% (ca. Huntley and Birks, 1983). Between 8512 and 8264 cal BC hazel attained a great significance in forest communities, in which probably formed understorey. It is documented by the increase of *Corylus avellana* pollen proportion over 10% (ca. Huntley and Birks, 1983). The moment of the hazel's appearance and spread in Mazurian Lake District is dated similarly (Wacnik, 2003). In central Poland, in Gościąż region, hazel was present from ca. 10,400 cal BP = ca. 8450 cal BC (Ralska-Jasiewiczowa *et al*., 1998b). On the other hand its continuous curve that remains still over 1% from ca. 10,608 cal BP may suggest that it had appeared here earlier.

The hazel's importance maintained in forest communities of the Wigry region till ca. 6854 lat cal BC. On the same time the pine significance clearly declined. The moist habitats were being gradually occupied by alder (*Alnus*), which appeared in the Wigry region ca. 7796 cal BC (increasing of its pollen over 2%). *A. incana* probably reached the region as the first (ca. Szczepanek *et al.*, 2004). This species, which forms mainly riverine forests at young alluvial soils, in areas around the Wigry Lake did not find suitable habitats for its development. So its significance in a landscape was small. *Alnus incana* migrated from south mainly along the Vistula valley, where it found better conditions for its expansion. That is also the probable reason of the rapid rise of *Alnus* pollen percentages immediately after the appearance of this tree at the sites located along Vistula. For example, in the profiles from Gościąż values of *Alnus* rapidly rised up to 20% just ca. 9850 cal BP (=7900 cal BC), directly after the start of the continuous curve of this taxon (Ralska-Jasiewiczowa *et al*., 1998b). It proves its explosive expansion. In the Wigry region alder expansion is dated on ca. 6854-6670 cal BC, almost 1000 years after its appearance in this region and its expansion in the Vistula valley. Probably it was connected with spreading of the *Alnus glutinosa*, which formed the alder forest on wet and peaty shores of lakes. These communities might be similar to the present-day *Ribo-nigri-Alnetum* association (ca. Szczepanek *et al.*, 2004). Similarly "delay" of *Alnus* expansion, in comparison to the moment of its appearance, is observed on the area of Puszcza Knyszyńska Forest (e.g. Kupryjanowicz, 2000 and 2004b).

The other mesophilous trees started their invasions to forests around the Wigry Lake – oak (*Quercus*), lime (*Tilia cordata* type) and ash (*Fraxinus excelsior*) appeared. Elm (*Ulmus*) systematically increased its contribution. The continuous low-percentage pollen curve of *Picea abies* suggests that spruce occurred around the Wigry Lake or not far away from this region.

In the middle part of the stage, in the time from ca. 6670 to ca. 4200 years cal BC (**W-5 *Alnus-Tilia-Ulmus-Quercus* R PAZ**, depth 3.92-3.07 m), termophilous trees, such as lime, elm and ash, attained optimum of their Holocene development. In shady forests with their participation, the conditions for hazel's development worsened. It resulted in the less abundant blooming and even in its partial elimination from understorey. The oak's significance systematically increased. The rise of *Picea abies* values up to 0.5-1.5% may indicate a local presence of single spruce trees (ca. Björkmar, 1996). However numerous palynologists admit that only pollen values higher than 5% may indicate the local presence of this tree (Markgraf, 1980 and Huntley and Birks, 1983)

In the youngest phase of the stage, between 4066 and 2093 years cal BC (**W-6 *Quercus-Picea-Ulmus* R PAZ**, depth 3.02-2.02 m), oak was a dominant tree in the forest communities. It is documented by the increase of the *Quercus* pollen percentage values over 10%. The significance of lime, elm and ash decrease. On the contrary spruce was more and more frequent (the increase of *Picea abies* pollen). On wet habitats alder attained the maximum of its Holocene development.

3rd stage – mixed spruce-oak forests (2022 cal BC-1581 AD). The stage is represented by the regional pollen zones **W-7 *Picea-Quercus-Carpinus*** (depth 1.97-1.37 m) and **W-8 *Carpinus-Betula-Picea-Quercus*** (depth 1.32-0.40 m in the WZS/03 profile and 0.44-0.38 m in the WZS/03a profile). It corresponds to Late Subatlantic and Early Subboreal chronozones. Its beginning was correlated with one of the most important changes of forests composition in the whole Holocene in the Wigry region. Spruce occupied its maximum Holocene area in this part of Poland. The percentage values of its clear culmination dated to 2022-1539 cal BC (max. 12%) are 2-3-time higher than the *Picea abies* values noted in the same time in other sites in north-eastern Poland (e.g. Obidowicz *et al*., 2004). The spruce expansion was connected with the clear reduction of elm, lime and ash. The importance of hazel decreased. Among the thermophilous trees only oak still maintained its significance. Still its area was smaller than in the previous stage.

Already at the beginning of the stage spruce-oak forests had been formed. They became dominating plant communities in this part of Poland (Czerwiński, 1973). Spruce relatively fast dominated and transformed existing plant associations. According to Czerwiński (1973), the reconstruction of this type transformations is possible on the basis of the composition of contemporary habitats with spruce domination. For example, the pine forest of *Dicrano-Pinion* alliance was probably converted into *Lycopodio-Piceetum*, oak-pine forest of *Quertion pubescentis* alliance into *Calamagrosti arundinaceae-Piceetum*, poorer and more acidified associations of *Carpinion* alliance into *Querco-Piceetum*, and associations of *Alnion glutinosae* alliance into *Sphagno Girgensohni-Piceetum*.

Such drastic changes in forest composition may have had various causes. Spruce might have been protected by cooling and moistening of the climate. Other alleged cause of this change might have had anthropogenic character. In pollen record the transition into spruce-oak forests is preceded by the intensification of human settlements in the Wigry region (human phase 3 – see the next part of this paper), which might have led to the former forest devastation and formation of numerous gaps in tree stands. After the retreat of settlement pressure their existence additionally protected spreading of more competitive trees.

Spruce is present recently in all forest associations within the limits of its continuous range, whereas at island sites it appears only in some associations, e.g. in the *Leucobryo-Pinetum*, *Carici elongatae-Alnetum* and *Tilio-Carpinetum calamagrotetosum* (Czerwiński 1973), and in the *Lycopodio-Piceetum* (Faliński, 1965 after Czerwiński, 1973).

Since about 2022 cal BC hornbeam (*Carpinus betulus*) might have been locally present in the Wigry region. Its pollen values are relatively low (0.2-2.0%) in this section of the profile. However, in surface samples from the sediments of few lakes from Pomerania situated in forests with hornbeam, its pollen occurred only in a small quantity (Ralska-Jasiewiczowa *et al*., 2004b). The proportion of *Carpinus betulus* pollen in sediments from the Wigry Lake is repeatedly lower than in the other sites from north-eastern Poland (e.g. Kupryjanowicz, 2004b and Ralska-Jasiewiczowa *et al*., 2004b). Intensive spread of hornbeam in plant communities of the Wigry region was probably restricted by climatic conditions. Presently the north limit of *Carpinus* range is not far away from this place (Jalas and Suominen, 1976 and Bortyńska, 1993). One of the most important factor shaping recent range of hornbeam is fact, that due to cold climate, it did not shape tree-form (Czerwiński 1973). It did not enable effective reproduction and spread. Likewise also the phytosociological dependences might have been caused of poor representation of hornbeam as well as of beech. Both specieses reached the Suwałki region as the latests of trees. They contributed to plant associations with spruce and oak domination, which in stern climate of north-eastern Poland had better conditions for their development. They were more competitive than hornbeam and beech, which did not develop properly near their range limits.

In younger part of the stage (33 years cal BC – 1601 years AD), represented by regional pollen zone **W-8 *Carpinus-Betula-Picea-Quercus***, the hornbeam and birch significance slightly increased, whereas the spruce participation decreased. The significance of elm, lime and ash was still delimited. These changes may have been partly caused by anthropogenic factors (see description of 5 and 6 human phases).

4th stage – pine-spruce forests (1621-2003 AD). The stage is the youngest period of vegetation changes in the Wigry region. It is represented by two regional pollen zones: **W-9 *Pinus-Picea*-NAP-*Juniperus*** (depth 0.24 m in the WZS/03 profile and 0.36-0.02 m in the WZS/03a profile) and **W-10 *Pinus-Picea*** (depth 0.02-0.00 m in the WZS/03a profile). Pollen data show degradation of the majority of trees with high thermal demands, such as lime, elm and ash, and spreading of pine. Relatively high values of herbs pollen (NAP), cultivated plants and plants connected with human activity in pollen zone **W-9 *Pinus-Picea*-NAP-*Juniperus***, reflect the highest degradation of forest communities in whole Holocene and expansion of the fields, meadows and human settlements. However the relatively low proportion of plants of these groups, in comparison with majority of other Polish sites, suggests that anthropopressure has never been here so advanced as in the central and western Poland (e.g. Latałowa, 1992; Milecka, 1998 and Makohonienko, 2000).

The youngest phase of vegetation development was registered only in the WZS/03a profile (**W-10 *Pinus-Picea*** R PAZ, depth 0.02-0.00 m). It represents the period from 1998 to 2003. It is characterised by a decline of herbs proportion, mainly human indicators, and a rapid rise of pine significance; it indicates the reduction of fields and meadows area, and the extension of pine forests. Partly it may be connected with the process of nature preservation in this region. However, it may result from the immigration of local inhabitants to towns.

The impact of man on the vegetation of the Lake Wigry area

Human phase 1 (6494-4463 cal BC) and **human phase 2** (3878-3522 cal BC) were distinguished by two culminations of *Pteridium aquilinum* (to 3% and 1.5%, respectively). Their pollen record indicates traces of fires and rather slight development of herb communities.

These phases reflect the presence of Mesolithic hunter-gatherer group in the Wigry Lake vicinity. They were connected with cultures of Kunda circle, which according to archaeological data appeared in this region in the second half of 8th millennium BC and remained here probably till the middle of Neolithic (Ambrosiewicz *et al*., 1997).

Human phase 3 (2175-2093 cal BC) is characterised by the increase of frequencies of the classic human indicators such as *Artemisia*, Chenopodiaceae and *Rumex acetosella* type, and the first appearance of Cerealia type pollen. Pollen record is not expressive, in a similar way as in human phases 1 and 2, and the percentage values of human indicators are relatively low. It documents only small spread of open communities connected with man. The increase of *Corylus avellana* proportion may show thinning of forest stands and intensive development of shrubs layer, what resulted from the better light conditions in forest understorey. In this phase clear oscillations of *Pinus sylvestris* type values and a fall of *Ulmus* pollen curve are visible. Because of that probably the forests with pine and elm participation were mainly destroyed. However a range of this devastation was not large, what is suggested by low NAP proportion. In this phase the first palynological signs of cereals cultivation are noted (first pollen grain of Cerealia type). The earliest appearance of cerealia pollen in south-eastern Lithuania is dated back to 5800-6000 BP (Antanaitis and Stančikaitė, 2004).

The first signs of pasturage (pollen grain of *Plantago lanceolata*) were present before this human phase.

The settlement of human phase 3 corresponds chronolocically to the Early Bronze Age. However it might be connected with Neolithic agricultural cultures, probably mainly with the Globular Amphore culture and/or with the Corded Ware culture, which numerous traces were found in close vicinity of the Wigry Lake, e.g. in Burdyniszki, Gawrychruda, Piertanie and Sobolewo (Ambrosiewicz *et al*., 1997). They were dated at the second half of 3rd millennium BC.

Human phase 4 (1251-870 cal BC) corresponds with the Late Bronze Age and the beginning of the Early Iron Age. Its pollen record is characterised by the rise of percentage values of human indicators, such as *Artemisia*, *Rumex acetosella* type and Poaceae, by the regular presence of Cerealia type pollen and by the decrease of pollen proportion of *Picea abies*, *Ulmus* and *Tilia cordata* type. It suggests the development of settlements and of cereals cultivation, and destruction of mixed forests with spruce participation. On the most fertile habitats, forests might have been destroyed to obtain grounds for growing.

Unfortunately the relatively clear pollen record of changes in natural environment, which may be connected with human economy, contradicts the archaeological data. Basing on the exceptionally poor finds from period between 1800 and 550 BC archaeologists suggest that it was a period of a very weak population in the Wigry vicinity and backwardness of local cultures (Ambrosiewicz *et al*., 1997).

Human phase 5 (111-492 cal AD) corresponds to the Late Iron Age. It was connected with the period of the Lusatian culture domination, the Roman period and older part of the Migration period. The phase is marked in the pollen record equally clearly as previous human phase. Its beginning coincides with the considerable decrease of *Picea abies* values, which suggests the new degradation of forests with spruce domination.

The beginning of the phase chronostratigraphically agrees with the optimal moment of Balt culture development, which is dated by archaeologists on the 2-4th century. Archaeological data document cereal cultivation, animal husbandry, iron production and weaving.

Time between 5 and 6 human phase fell on the Early Medieval, which in north-eastern Poland was the period of Jatvings' domination. Based on pollen record (the decrease of human indicators frequency, light rise of *Picea abies* and *Carpinus betulus* values), it was characterised by the considerable lessening of settlements number, the reduction of cultivated area and the regeneration of forest communities. Unfortunately such a picture of changes contradicts the archaeological data which indicate very intensive colonisation and presence of numerous settlements around the Lake Wigry. Explanation of these divergences is a subject of additional palynological-archaeological investigations.

Human phase 6 (1274-1601 cal AD) is connected with the Late Medieval. Pollen record shows small intensity of anthropogenic changes. Decreasing values of *Ulmus*, *Quercus* and *Carpius betulus* point to the devastation of mixed forest. The deforested areas were overgrown by birch, what is shown by clear peak of *Betula alba* type. The increase of Cerealia type values illustrates the development of crop cultivations. The rise of the continuous curve of *Secale cereale* suggests the beginning of rye growing. The first appearance of *Fagopyrum* evidences the start of buckwheat cultivation.

According to archaeological data, at the time following the conquest of the Jatvingians' lands in the 13th century, the Wigry Lake was surrounded by primeval forests that was left almost unexploited by man and used as the Lithuanian dukes and Polish kings' hunting grounds.

Human phase 7 (1621-2003 cal AD) represents historical time. The proportion of human indicators clearly increases and is the highest in the whole Holocene. The phase was divided to five sub-phases (**Fig. 4**).

Sub-phase 7a is represented by one pollen spectrum only, which is dated at ca. 1621 AD. It is characterised by declines of *Pinus sylvestris* type and *Picea abies*, by the decrease of *Alnus*, *Ulmus*, *Tilia cordata* type, *Carpinus betulus* and *Corylus avellana*, by the peaks of *Betula alba* type and by many human indicators proportions, mainly Poaceae undiff., Cyperaceae, *Artemisia*, *Rumex acetosella* type, Cerealia type and *Secale cereale*. This pollen record shows considerable intensification of colonisation and deforestation of the Wigry vicinity.

The sub-phase was probably connected with foundation of Cameldolites cloister (1667) and the beginning of exploitation of commercial forests for timber. Charcoal and technical potassium carbonate (is a kind of ash obtained from wood of deciduous trees; it has been used for tanning hides and soap production) were produced and wood pitch and turpentine were distilled there. The exploitation of forests was undertaken in a predatory manner, e.g. by felling of pine, spruce and the most valuable deciduous trees (Ambrosiewicz *et al*., 1997). The explosive development of birch was the first stage of plant succession at deforested areas – it is shown by the rapid rise of *Betula alba* type values in pollen spectra.

Sub-phase 7b represents the period from ca. 1641 to 1720 AD. It is characterised by continuation of the numerous trees population decrease (*Ulmus*, *Tilia cordata* type, *Quercus*, *Carpinus betulus*) and by a decrease of *Corylus avellana* proportion. The values of human indicators are slightly lower then in the former sub-phase. Such pollen record indicates the slight reduction of anthropopressure. It might have been connected with the king's annection of the considerable part of Cameldolites' properties. They returned to the king, whose administrators preserved better forest-riches. According to historical data, it was the time of formation of little forest-settlements and granges, which built the specific "ring" protecting the forest against the Cameldolites. Low-percentage continuous pollen curves of Cerealia type and *Secale cereale* as well as presence of cf. *Cannabis* and

Fagopyrum pollen indicate the small range of cereals, hemp and buckwheat cultivation.

Sub-phase 7c is connected with period from 1740 to 1975. It is characterised by the highest values of Cerealia type and *Secale cereale* in the whole profile, which document the spreading of cereal cultivation the largest in the history of this region. This phenomenon is confirmed by the culmination of *Rumex acetosella* type and the highest in the whole profile frequency of *Centaurea cyanus* pollen. These both taxa probably occurred as weeds in cereal cultivation. Also pollen of cf. *Cannabis* and *Fagopyrum* is present, what indicates hemp and buckwheat cultivation. It was the period of the maximum agriculture development at the surroundings of Wigry Lake.

The historical references point to formation of numerous agricultural villages in that time (Brzozowski, 1999). Till the second half of the 19th century, the forests shrink had continued. The deforested areas were taken over by villages and farmlands. From the middle of 19th century, a planned forest management practice was introduced. The fallings of trees were been carried out on regular plots. The young forests regenerated spontaneously from surrounding trees or from tree seed left on the clearings. On the same time, the regeneration of forest was enhanced by the manual sowing of the tree seeds. In the 1920s, the practice of planting young saplings bred in forest plantations was started. All the above-mentioned methods of regenerating forests preferred coniferous species, what resulted in the development of pine and spruce forests. The proportion of deciduous species was progressively reduced. As a result of these practices, pine predominates now in almost 80% of the forest areas. Since the beginning of the 20th century, a slow increase in the forested lands has taken place. The areas of the Wasilczyki, Białe and Słupie villages, where in 1903 the populations were resettled from, were the first to undergo forestation. The next series of forestation projects were carried out after World War II in the areas occupied beforehand by the villages Zakąty, Jastrzęby and Czerwony Krzyż, which were completely destroyed by the Germans during the pacification operations. None of these events is reflected in the pollen record – probably the scale of ecological phenomena caused by them was unimportant or the resolution of pollen record too low.

Sub-phase 7d lasted from 1983 to 1999. It is characterised by clear peaks of *Betula alba* type and culminations of *Corylus avellana* and ruderals (*Artemisia* and Chenopodiaceae). The proportion of other trees is similar to the previous sub-phase, but the proportion of other human indicators is lower.

In the second half of the 20th century the cultivation of poor soils was abandoned. The forest spontaneously started to take over the drained meadows along rivers and lakes, as well as the boggy depressions amongst the fields. Pine trees were planted in the dry and sandy patches of the former farmlands.

Sub-phase 7d may reflect the first stage of plant succession on derelict fields. It shows the expansion of birch and the development of ruderal communities with *Artemisia* and Chenopodiaceae.

Sub-phase 7e is characterised by the very rapid rise of *Pinus sylvestris* type and the fall of all other trees (*Alnus, Picea abies*, *Ulmus*, *Quercus*, *Carpinus betulus*, *Betula alba* type), *Corylus avellana* and all human indicators. It probably documents the second succession stage overgrowing fields, which is manifested by the expansion of pine forest.

Development of aquatic and mire vegetation

Changes in the percentage curves of local aquatic and mire plants enabled to carry out the specific zonation related exclusively to these taxa (**Fig. 2**). The succession of the Wigry Lake vegetation has been reconstructed using this basis. Boundaries of aquatic/mire zones do not agree with the boundaries of regional pollen assemblage zones.

1st stage is represented by local pollen assemblage zone W_{am}-1 Cyperaceae (depth 5.25-4.90 m; 11,820-11,341 cal BC) and corresponds to the older part of the Allerød. Cyperaceae are dominant among local plants. Single coenobia of *Botryococcus braunii* and *Pediastrum*, and Filicales monolete spores are present.

2nd stage (W_{am}-2 *Pediastrum* L PAZ; depth 4.85-4.70 m; 11,167-10,465 cal BC) corresponds to the younger part of the Allerød and older part of the Younger Dryas. The appearance of *Pediastrum integrum* indicates clear and cold water of lake (Jankovská and Komárek, 2000).

3rd stage (W_{am}-3 *Botryococcus* L PAZ; depth 4.65-4.55 m; 10,189-9613 cal BC) corresponds to the younger part of the Younger Dryas and beginning of the Holocene. Culminations of *Botrycoccus braunii* might show so considerable worsening of the lake's condition (e.g. lowering of water temperature), that only the least exacting algae were able to occur (ca. Jankovská and Komárek, 2000). Mass appearance of Bryales spores in some pollen spectra might indicate the temporary lowering of water level in the lake and the development of moss communities in emerged littoral zone.

4th stage (W_{am}-4 Filicales-*Equisetum*-*Botryococcus* L PAZ; depth 4.50-0.24 m in the WZS/03 profile and 0.44-0.08 m in the WZS/03a profile; 9324 cal BC – 1976 cal AD) represents almost the whole Holocene. There are continuous pollen curves of *Equisetum*, Cyperaceae, *Botryococcus braunii* and Filicales monolete (macrosporangia of Filicales and spores of *Thelypteris palustris* are present). Single pollen grains of *Typha latifolia*, *Typha angustifolia*/*Sparganium*, *Phragmites* type and *Potamogeton* as well as spores of *Sphagnum* and coenobia of few species from the genus *Pediastrum* are noted. In some spectra, Bryales spores and *Tetraedron* coenobia occur in masses.

5th stage (W_{am}-5 *Pediastrum*-*Tetraedron* L PAZ; depth 0.06-0.00 m in the WZS/03a profile; 1984-2003 cal AD) represents the last 20 years of the lake history. Its main feature is the increasing proportion of green algae from *Pediastrum* and *Tetraedron* genera.

7. CONCLUSIONS

The most important regional features are:

1) the proportion of hornbeam in forests surrounding the Wigry Lake in younger Holocene was considerably lower than in the other regions of Poland, even those that are direct neighbours of Suwałki-Augustów Lake District;
2) in younger Holocene the significance of spruce was here clearly higher than in other parts of Polish lowland;
3) beech and fir were probably not present in local forests at all (in pollen spectra only single pollen grains of this taxa are present, they may have originated from long transport);
4) in distinction to the majority of other regions of Poland, the vegetation changes connected with the development of human settlement have probably never been intensified in the Wigry region, and nearly natural character of the vegetation remained up to the present-day.

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