9. LAKE GOŚCIĄŻ:
RECORD OF HUMAN IMPACT ON NATURAL ENVIRONMENT SINCE MESOLITHIC TILL TODAY

9.1. PREHISTORIC AND EARLY HISTORIC ANTHROPOGENIC CHANGES RECORDED IN THE LAKE GOŚCIĄŻ SEDIMENTS

9.1.1. ARCHAEOLOGIC EVIDENCE OF PREHISTORIC SETTLEMENT IN THE AREA NEAR LAKE GOŚCIĄŻ

Andrzej Pelisiak & Małgorzata Rybicka

Systematic archaeologic researches on the prehistoric settlement near Lake Gosciąż began in 1990. The territory of 10 km radius around Lake Gosciąż was a basic area of investigations. As the first step, all data about the oldest excavations, surface surveys, and accidental discoveries were collected (Głosik 1962). The results of the Archaeological Surface Survey of Poland (ASS) have also been included (Figs 9.1–9.5, Tab. 9.1).

Within the basic area a smaller zone of 5 km in radius around Lake Gosciąż was intensively investigated. No archaeological sites were known from this zone before our investigations. The area in question was examined several times by the systematic surface surveys. Numerous sites from the Late Palaeolithic to Modern time were discovered. In order to define precisely the chronology of the occupation of this area and to complete the information about the settlement system, several sites assumed to be representative of different periods were excavated. The main aim of all the archaeological investigations near Lake Gosciąż was to describe the relationships between the prehistoric settlements and the economy, as well as the changes of the natural environment recorded in the annually laminated sediments of Lake Gosciąż (Ralska-Jasiewiczowa & van Geel 1992).

Late Palaeolithic remains

During the excavations of the sites Gosciąż 11 and 12 (Fig. 9.2), remains of Late Palaeolithic encampments were found. Small assemblages of flint artefacts confirm the penetrations of the area around Lake Gosciąż in this period. The Late Palaeolithic flint assemblages consist of several double platform blades and leave points. No traces of any settlement places were found at these sites. The lack of diagnostic tools caused difficulties with precise chronological interpretation of the sites. The leave points suggest the Sviderian Culture.

The Mesolithic

18 Mesolithic sites concentrated in two groups were discovered in the area studied (Fig. 9.2). One group consisting of 5 sites is located in the zone along the edge of the Lakes Na Jazach valley. The other site concentration was found in the dunes extended along the Vistula valley. 47 sites found in the Lake Gosciąż surroundings are represented by very poor assemblages or even single flint artefacts. It is very probable that the majority of those sites belong to the Mesolithic period too.

Beside the old investigations at Wistka Szlachecka (Schild et al. 1975) several Mesolithic sites were excavated by the authors during the 1990–1994 field seasons. Five of them are located in the upland zone and in the valley of Na Jazach lake complex. The majority of those sites appeared to be heavily destroyed. The site Gosciąż 11 (Fig. 9.1) is the only one containing the primary pattern of flint artefacts suggesting the tool processing practised on the spot. Flint assemblages from the particular sites were rather poor. The biggest assemblage contained several hundred artefacts. In addition various Neolithic potsherds and/or Palaeolithic flint artefacts were found at many sites.

Numerous Mesolithic sites were also found in other parts of the Gostynińskie Lake District. The geographical

Table 9.1. Prehistoric sites in the Lake Gosciąż region.

<table>
<thead>
<tr>
<th>Cultures</th>
<th>Numbers of sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesolithic</td>
<td>18</td>
</tr>
<tr>
<td>Undefined (Stone Age)</td>
<td>47</td>
</tr>
<tr>
<td>Funnel Beaker Culture</td>
<td>27</td>
</tr>
<tr>
<td>Comb Pitted Culture</td>
<td>4</td>
</tr>
<tr>
<td>Epibeaer Horizon</td>
<td>1</td>
</tr>
<tr>
<td>Globular Amphora Culture</td>
<td>2</td>
</tr>
<tr>
<td>Corded Ware Culture</td>
<td>1</td>
</tr>
<tr>
<td>Early Bronze Age</td>
<td>25</td>
</tr>
<tr>
<td>Lusatian Culture</td>
<td>59</td>
</tr>
<tr>
<td>Przeworsk Culture</td>
<td>28</td>
</tr>
</tbody>
</table>
Fig. 9.1. Prehistoric sites in the Lake Gōciąż region (found by A. Pelisiak & M. Rybicka): 1 – Gōciąż, site 1 – Stone Age (undefined); 2 – Gōciąż, site 2 – Medieval Period; 3–5 – Gōciąż, sites 3–5 – Stone Age (undefined), Lusatian Culture (?), Przeworsk Culture (?), Modern Times; 6 – Gōciąż, site 6 – Modern Times; 7 – Gōciąż, site 7 – Funnel Beaker Culture, Comb-Pitted Culture; 8 – Gōciąż, site 8 – Mesolithic; 9 – Gōciąż, site 9 – Stone Age (Mesolithic); 10 – Gōciąż, site 10 – Stone Age (Mesolithic); 11 – Gōciąż, site 11 – Late Palaeolithic, Mesolithic, Bronze Age (Trzciniec Culture); 12 – Gōciąż, site 12 – Late Palaeolithic, Mesolithic, Funnel Beaker Culture, Comb-Pitted Culture, Epibeaker; 13 – Gōciąż, site 13 – Medieval, Modern Times; 14 – Gōciąż, site 14 – Stone Age (undefined); 15 – Gōciąż, site 15 – Stone Age (undefined); 16 – Gōciąż, site 16 – Stone Age (undefined); 17 – Gōciąż, site 17 – Stone Age (undefined); 18 – Gōciąż, site 18 – (Skoki Duże) – Mesolithic; 19 – Gōciąż, site 19 – Stone Age (undefined); 20 – Gōciąż, site 20 – Modern Times; 21 – Gōciąż, site 21 – Stone Age (undefined); 22 – Gōciąż, site 22 – Stone Age (undefined); 23 – Gōciąż, site 23 – Lusatian Culture; 24 – Gōciąż, site 24 – Bronze Age (Trzciniec Culture/Lusatian Culture); 25 – Gōciąż, site 25 – Stone Age (undefined); 26 – Gōciąż, site 26 (Skoki Duże) – Mesolithic; 27 – Dąb Polski, site 9 – Funnel Beaker Culture; 28 – Dąb Polski, site 1 – Lusatian Culture, Modern Times; 29 – Dąb Polski, site 2 – Funnel Beaker Culture, Modern Times; 30 – Dąb Polski, site 3 – Medieval Period; 31 – Dąb Polski, site 4 – Stone Age (undefined), Modern Times; 32 – Dąb Polski, site 5 – Funnel Beaker Culture, Modern Times; 33 – Dąb Polski, site 6 – Funnel Beaker Culture, Modern Times; 34 – Dąb Polski, site 7 – Early Bronze Age, Medieval Period; 35 – Dąb Polski, site 8 – Funnel Beaker Culture, Modern Times; 36 – Telażna Lesna, site 12 – Przeworsk Culture; 37 – Telażna Lesna, site 13 – Funnel Beaker Culture; 38 – Telażna Lesna, site 14 – Mesolithic.
situation of the sites located in the area near Lake Gościaż reflect the rules that characterize the settlements of the Mesolithic cultures in the whole Gostynińskie Lake District (Galinśki 1988) as well as in the Kaszuby Lake District (Bagniewski 1987).

Up till recent time almost all studies on the Mesolithic Period in Poland were directed to typological analysis of flint assemblages, chronological and cultural classification, and cultural connections or differentiations. Studies on the settlements, economy, and analyses of relations among settlement, economy, and environment are very rare. Changes of the natural environment caused by hunters-gatherers-fishermen populations were described from the British Isles (Innes & Simmons 1988). Some attention to these problems has also been paid in Poland during recent decades (Bogucki 1988, Latalowa 1992b). However, these papers do not present any analysis of the Mesolithic settlement systems based on archaeological data in connection with the interpretation of pollen diagrams. Poor archaeological background to the considerations on anthropogenic origin of environmental changes recorded in pollen diagrams makes difficult the satisfactory interpretation of these changes in prehistoric terms. In addition, none of the Mesolithic microregions was studied according to modern palaeogeographical methods (Bogucki 1988). In spite of these deficiencies some general trends in land use by Mesolithic people are clear. The hunter-gatherer-fisher groups mostly inhabited dunes or other sandy places near lakes or on river terraces. The last systematic archaeological surveys revealed highly clustered concentrations of Mesolithic sites in many parts of the Polish Lowlands (Bogucki 1988). All are located in places such as mentioned above. Many thousands of flint artefacts found in particular sites suggest that these dwelling places were inhabited during long periods of time or were periodically inhabited many times. Concentrations of sites may suggest relative stabilisation of settlements in the Late Mesolithic. All these concentrations are connected with sandy zones. The Mesolithic sites are almost lacking in the loess and fertile zones in Kujavia. Single flint artefacts found within these zones show only rare penetration but never occupation and exploitation by hunter-gatherer-fishermen populations.

Basing on mentioned discoveries near Lake Gościaż it is difficult to reconstruct the precise chronology of the Mesolithic settlements there. Two main techno-typological groups of artefacts can be described. The first one is connected with production of single-platform microblade cores and utilization of regular microblades and their fragments for the production of tools. Local flint and chocolate flint raw materials were used. The artefacts made of regular microblades refer to the classic Mesolithic Komornica and Chojnice-Pieńki cultures. The artefacts of the second techno-typological group were made mainly from local flint. Blades are not regular. It can be supposed that such blades were made of multi-directional cores. This group can be connected with assemblages of the Wistka Szlachecka Type (Schild et al. 1975). There are two possibilities for the interpretation of these flint assemblages. According to the first one these assemblages may represent several different chronological phases of settlement. The second one is that typological differentiation of artefacts reflects a specific technological type of the Mesolithic near Lake Gościaż. It is difficult to answer these questions, but the general observations of the sites suggest the first interpretation rather. According to this supposition there were two main phases of the Mesolithic occupation of the area near Lake Gościaż. The first one could be placed within an old and/or middle Atlantic period, the second one could be referred to the late Atlantic period.

The Mesolithic settlements near Lake Gościaż can be connected with the disturbances of the natural environment described on the basis of pollen diagram from G1/87 profile (samples 150–176; 8000–6650 cal BP = 7300–5800 14C BP; Ralska-Jasiewiczowa & van Geel 1992, and Chapter 9.2.4). These changes can be considered in terms of the settlements and hunter-gatherer-fisher economy of the Mesolithic people who lived near Lake Gościaż.

The Neolithic

Within a radius of 10 km around Lake Gościaż 35 Neolithic sites were found. Materials of the Funnel Beaker Culture (FBC) occur at 27 sites, the so-called Comb-
Fig. 9.3. Neolithic sites in the Lake Gościąż region. 1 – Funnel Beaker Culture, 2 – Comb-Pitted Pottery Culture, 3 – Globular Amphorae Culture, 4 – Corded Ware Culture, 5 – Stone Age (undefined).

Pitted Pottery Culture at 4 sites, the Corded Ware Culture at 1 site, and 2 sites were defined (by ASS researchers) as belonging to the Globular Amphorae Culture. No remains of the Early Neolithic Linear Pottery or Lengyel Cultures were discovered near Lake Gościąż. The last observation is very important for the interpretation of the oldest phases of disturbance of the natural environment. It should be emphasized that such poor habitats as those surrounding Lake Gościąż were very rarely and only temporarily settled by communities of Danubian Circle Cultures. Those cultural groups have occupied and used only very fertile loess or clay soils. The nearest known settlements of Danubian Circle Cultures are located near Brzesz Kujawski about 30 km to the west of Lake Gościąż (Grygiel 1984). These sites are situated on the morainic plateau, outside the sandy Plock Basin (Madeyska, Chapter 2.2). Because of the distance the economy of those communities could not influence directly the natural environment near Lake Gościąż. These data and the distribution of Mesolithic sites near Lake Gościąż support strongly the thesis about the Mesolithic rather than Neolithic people being responsible for the disturbances of the natural environment dated between 7050–6650 cal BP (6200–5800 14C BP; samples 168–176).

The Funnel Beaker Culture settlement

27 Funnel Beaker Culture (FBC) sites have been found in the area of a 10 km radius around Lake Gościąż. Two of them are located very near the Na Jazach lake complex (Fig.9.3). These sites (Gościąź 7 and 12, Fig. 9.1) are situated on the sands within the transition zone between the glacifluvial terrace surface and the lake depression. The results of the excavations may suggest that the sites were only small short-time encampments. No remains of FBC dwellings were recovered. Potsherds and flint artefacts are not numerous. The chronology of these sites can be placed within the Wióreka Phase of the FBC (Pelisiak & Rybicka 1998).

Seven sites of FBC were discovered near Dąb, about 1.5–2.5 km NE of Lake Gościąż (see Fig. 9.6). These encampments are situated on the terrace of the old Vistula River bed.

The other concentration of FBC sites was discovered near Lake Telżyna 4–5 km west of Lake Gościąż (see Fig. 9.6). One of them was excavated in 1993. This settlement, as other sites of this group, belongs to the Wióreka phase of the FBC.

No sites of the oldest Sarnowo Phase of FBC were found in the investigated area. It should, however, be stressed that some site of this FBC phase were also found in the Gostynińskie Lake District. One of them (Heleńów, site 1 – Papiernik & Rybicka, in print) is located in a ca. 30 km distance to the south-east of Lake Gościąż. It is not unlikely that people of FBC Sarnowo phase penetrated or even exploited the surroundings of Lake Gościąż. Potsherds that might be referred to the Luboń Phase were discovered at the site near Dąb. It should be taken into consideration, however, that the potsherds found during the surface survey often bear not enough typical features, and on the basis of such material it is difficult to define precisely the chronology of sites.

Some questions concerning the settlement patterns and system of economical exploitation of particular landscape zones by FBC communities arise from the results of the analysis of the distribution of the FBC sites. It seems that the poor sandy terrains very close to the Lake Gościąż were not permanently settled by the FBC populations. Remnants of encampments found here show that this zone was penetrated and probably temporarily exploited by the FBC people, but the permanent settlements were connected with the more fertile clay soils around Telżyna.

Similar relations between FBC settlements and natural environments were also found in the other parts of the Polish Lowlands. In the Kujavia, the large FBC settlements were located on the dunes or different sand soils, but the sites were surrounded by fertile soils. Such relations were recognized there at Pikutkowo (Niesiołowska 1967), Opatowice, and Radziejów Kujawski (Kośko & Szymt 1993 Rybicka 1995), where FBC settlements situated on sandy hills were surrounded by clays, which form the substratum of fertile Kujavian black soils. However, the short-time FBC sites are often situated within areas where sands dominate. Good example of this pattern are the sites from Bachorza valley (Kujavia): encampments at Dęby (Czebreszuk & Szymt 1992) and Papros (Kośko...
1987). Location of FBC settlements near an area of relatively fertile soils is confirmed in the Grabia Basin, Sieradzkie province (Pelisiak 1991) as well as in the other parts of Central Poland (Pelisiak 1988).

Such relationships between FBC settlement and natural environments must have been determined by the economic preferences, first of all by the conditions suitable to the slash-and-burn farming method, and to the formation of good pastures.

General chronology of FBC in the investigated area provided the chronology for disturbances of the natural environment represented by samples 181–200 (6400–5200 cal BP = 5560–4500 14C BP).

Settlement of so-called Comb-Pitted Pottery Culture

Remains of the so-called Comb-Pitted Pottery Culture (Kempisty 1972, 1973) were discovered at four sites (Fig. 9.3). Two of them (Gosciąż 7 and 12, Fig. 9.1) are located in the northern transition zone between the glaci-fluvial terrace and Na Jazach lakes valley. Both sites were excavated. At Gosciąż 7 a small encampment was recovered. The CPC assemblage consists of several dozen potsherds and flint artefacts. At Gosciąż 12 remains of a relatively long-time settlement occurred. This rich assemblage consists of almost 700 potsherds and more than 400 flint artefacts (Pelisiak & Rybicka 1998).

It should be added that CPC sites are often situated in places where the Mesolithic flint artefacts were also found. Similar relations between CPC and Mesolithic sites were stated in different parts of Polish Lowland (Kempisty & Sulgostowska 1976, Bagniewski 1983). In contrast in the Gostynińskie Lake District encampments of CPC are located at the same sites as FBC. It is however not always possible to define the chronologic relationships between those cultures. It is also difficult to reconstruct the economy of the communities of these cultures in the area studied. On the basis of the locations of CPC encampments near lakes it is supposed that fishing and gathering was a base of the economy for these communities (Wiślański 1979). It should be emphasized that the settlement at Gosciąż 12 is located less than 100 meters from the present shore of Lake Mielec, and its history should be clearly recorded in the sediments of that lake.

Chronology of the Gosciąż 12 site was defined on the basis of pottery ornamentation. This material refers to the Linin Type (Kempisty 1973), and the chronology of the settlement can be estimated at 4450–4250 14C BP. Considering the location of the site and its chronology, there is strong probability that the disturbances of the natural environment found by pollen samples 203–209 dated at 5050–4750 cal BP (4500–4150 14C BP) were mainly caused by CPC people from the settlement recorded at Gosciąż 12 site.

The Epibeaker Horizon

A small concentration of potsherds of so-called Epibeaker Horizon (Kośko 1981) was also found at the site Gosciąż 12 (Fig. 9.1 and Pelisiak & Rybicka 1998). This material can be interpreted as the remains of a small encampment. It indicated the youngest phase of Neolithic occupation of the area near Lake Gosciąż. The age of this encampment can be estimated within a period of 4250–4050 14C BP. Such chronology refers also to the phase of human impact distinguished in samples 203–209.

The Early Bronze Age

There were 21 Early Bronze Age (EBA) sites discovered in the area within a 10 km radius of Lake Gosciąż (Fig. 9.4), most of them located near the old Vistula River valley about 5–7 km north-east of Lake Gosciąż. Two sites are located close to the Na Jazach lake complex. The first small encampment is located near the northern shore of Lake Wierzchoń, on the southern slope of the glaci-fluvial terrace (site 24, Fig. 9.1). The second one is situated between lakes Gosciąż and Mielec (site 11, Fig. 9.1).

The encampment near Wierzchoń was excavated during the 1993 and 1994 field seasons. Several dozen potsherds were recovered within a small area. The chronology of the site can be estimated as the III period of the Bronze Age. However, the potsherds are not typical, and there were some difficulties with the cultural identification of this assemblage. Technology of the potsherds and the shape of recovered fragments suggests that the site may be referred to the Trzciniec Culture as well as to the oldest phase of Lusatian Culture.

Fig. 9.4. Early Bronze Age sites in the Lake Gosciąż region. 1 – Early Bronze Age (undefined).
The Early Bronze Age site found between lakes Gośćciaż and Mielec is represented by only one fragment of pottery.

Numerous EBA sites are known from the whole Gostyniński Lake District, but the organization of settlements has not yet been studied. The majority of sites are located in small river valleys. The sites are rarely placed near lakes. Due to the lack of excavated sites it is difficult to reconstruct the size of dwelling places and to say which sites have been long-time settlements and which have been short-time encampments.

The Early Bronze Age settlements correspond chronologically to the disturbances of the natural environment recognized by samples 222–232 (4100–3500 cal BP = 3800–3300 14C BP).

**The settlements of the Lusatian Culture**

The settlements of the Middle and Late Bronze Age and Early Iron Age are represented by 59 sites (Fig. 9.5). Moreover, the sites of the East Pomeranian and Bell Grave Cultures are also noted. It should be emphasized, however, that the materials of the Lusatian Culture and East Pomeranian and Bell Grave cultures found during the surface surveys are very similar to each other, and it is very difficult to separate potsherds of these cultures in such material. Because of the difficulties in the cultural interpretation, the material of all the three cultures found on the surface was classified as “Lusatian Culture” s.l.

Nearly all 22 sites found are concentrated in the area of about 7 km² near Lake Telążna. Most of the sites are represented by small and untypical assemblages of potsherds recorded during the surface search. Only two sites of Lusatian Culture were discovered close to Lake Gośćciaż. One of them was found between lakes Gośćciaż and Mielec and the other near Lake Wierzchon. Both are represented by single fragments of pottery. During excavations of these sites no other material of Lusatian Culture was found. These facts show that the area near Lake Gośćciaż was not permanently settled by communities of Lusatian culture but it was penetrated and may have been temporarily exploited. The more fertile soils nearby were permanently settled by the Lusatian people.

It is clear that Lusatian communities first settled and economically exploited the land where the environment offered the best conditions to live. Large unfertile and dry sandy areas were not permanently settled then yet. The situation around Lake Gośćciaż seems to reflect tendencies of Lusatian settlements typical for the Polish Lowlands.

There is an almost 1000 year period of disturbances of the natural environment representing this culture in pollen diagrams from Lake Gośćciaż. This period (samples 233–251; 3500–2550 cal BP = 3250–2500 14C BP) comprises all stages of development of the Lusatian Culture.

**The settlements of the Przeworsk Culture**

There are 28 sites of the Przeworsk Culture found within a 10 km radius of Lake Gośćciaż (Fig. 9.5). All the sites are located several kilometres from the lake, the nearest of them at Telążna at 5 km from Lake Gośćciaż. The results of excavations suggest that their chronology can be attributed to the Late La Tene Period. It is difficult, however, to recognize the chronology of sites on the basis of surface material only. The sites might have been occupied during the Late La Tene Period as well as the Roman Period.

The record of the economical changes in the pollen diagram attributed to this culture (samples 257–259; 1950–1750 cal BP = 2020–1850 14C BP) is not reflected by the archaeological evidence. Because there are no Przeworsk Culture sites very near Lake Gośćciaż the interpretation of this pollen record is difficult. It is possible that we missed finding some sites in this area, or that the recorded changes were connected with large-scale economic activity of people who inhabited settlements located several kilometres from Lake Gośćciaż (e.g. from the Lake Telążna region). The elucidation of Przeworsk Culture settlements and economy in this area should be the aim of further archaeological studies near Lake Gośćciaż.

**Comments on the success of archaeological researches in the Lake Gośćciaż region**

The first aim of the archaeological investigations in this region was to correlate the phases of disturbance of the natural environment found in the pollen record with...
the phases of prehistoric settlement evidenced in the lake surroundings. Next stage of studies was to reconstruct the settlement system of prehistoric cultures and to describe the economical base of these communities. From the results of the investigations carried out so far, the first part of this program was successfully completed. It appeared possible to reconstruct a general chronology of the prehistoric cultures near Lake Gościąz. The distribution of sites shows which landscape zones have been inhabited and exploited during different periods of time. Some data were obtained concerning the size of sites and how long the sites could have been inhabited. Many problems connected with settlements and exploitation of the natural environment of this area were, however, only touched. The problem of the Przeworsk Culture near Lake Gościąz remains still unresolved. The lack of sites close to the lake as compared to the heavy destruction of the environment recorded in the lake sediment should be the aim of investigations. There is also a shortage of information about internal organization and economy of prehistoric settlements near Lake Gościąz.

9.1.2. SETTLEMENTS AND THE ECONOMY IN THE LAKE GOŚCIAZ AREA SHOWN IN PRINTED DOCUMENTS (FROM AD 1300 TO 1700)

Małgorzata Rybicka & Andrzej Pelisiak

The settlement and the economy in the Medieval and Modern periods can be analysed on the basis of both archaeological material and printed documents. Relatively few documents refer to Medieval settlement in the Lake Gościąz region (the earliest come from 13th century (Nowak 1991)) and the early periods of the Middle Ages. The Medieval archaeological material is rather poor. Results of a surface survey from the area between Wistka and Duninów (Fig. 9.6) are insufficient to reconstruct settlement organization in the Medieval period up to the 14th century. More precise information about the population and economy of the people who lived near Lake Gościąz is contained in later documents: in the 15th century (AD 1385–1434). There was a second track, called Vistula river-side track, leading through Łęg and Duninów, used too (Góralski 1962). These data indicate that the dispersed archaeological material recovered from this area (mainly single potsherds, Fig. 9.6) can be interpreted as remains of the short-time stays of the people using the tracks.

However, the Medieval pottery remains found near Lake Gościąz may represent settlements that existed at this area from 13th century (Fig. 9.6). In a document from 1228 an information exists about a village named Dąb (Nowak 1991). The documents of Siemowit, Prince of Dobrzyń from the transition of 13/14th century support this information. Wistka, and probably Dąb and Dobiegniewo, were mentioned in this document as villages connected with the Dobrzyń castellany (Tab. 9.2, Nowak 1991). It is assumed that the two nameless villages located on the left bank of the Vistula mentioned in the Teutonic Knights documents refer to Dąb and Dobiegniewo (Bieniak 1986). This information may suggest that the area north of Lake Gościąz was permanently settled during those centuries.

The documents confirm the existence of several tracks leading through the investigated region. In the King’s Zygmunt I document from 1519 the “Vias Dobrinensem et Vladislaviensem” were mentioned (Guldon 1968). On the basis of data from the 18th century Nowak (1991) suggests that “…Dobrzyń Track led from Telążna to Dobiegniewo, where a boat-ferrying through the Vistula River functioned”. After Gąsiorowski (1972) this track was used from the times of King Władysław Jagiełło (AD 1385–1434). There was a second track, called Vistula river-side track, leading through Łęg and Duninów, used too (Góralski 1962). These data indicate that the dispersed archaeological material recovered from this area (mainly single potsherds, Fig. 9.6) can be interpreted as remains of the short-time stays of the people using the tracks.

Fig. 9.6. The Medieval sites in the Lake Gościąz region. The present location of towns and villages (●) mentioned in the text is also indicated. 1 – Medieval Period, 2 – Modern Times.
About 1314, the Kowal castellany was separated from the Brześć castellany (Guldon & Powierski 1974). It is impossible, however, to reconstruct the size of this castellany and to decide whether it comprised the territory that later became the northern part of the Kowal district. Still it should be supposed that the change of administration of villages located along the Vistula River that earlier belonged to Dobrzyn Land (probably Dąb and Dobiegniewo) took place in 1409, after the conquest of the Dobrzyn Land by the Teutonic Knights (Bieniak 1986). The village Duninów appears in the document of King Kazimierz the Great dated to 1361, evidencing that Duninów belonged to the Kowal Lands (Nowowiejski 1930).

Further economical activity on the area between Wistka and Duninów proceeded during the 15th century (Nowak 1991). The villages at Skoki and Wistka Szlachecka came into being then (Tab. 9.2). The first well documented information about Dobiegniewo should also be ascribed to this period but data on the earlier existence of Dobiegniewo are more speculative. The first lists of land properties from the Kowal Lands are contained in the “Register of Kowal Lands” from 1489 (Senkowski 1961), as well as in the “Register of the Sors” from 1494 (Posadzy & Kowalewicz 1957). But there are no data about Dąb, Dobiegniewo, and Duninów in these documents (Tab. 9.3). It is known, for instance, that a village named Skoki, built around 1462, had already been abandoned in 1494 (Nowowiejski 1930).

During the 13th-15th centuries villages had been located on the basis of Teutonic Law. The typical feature of those villages was the regular arrangement of fields. The agriculture organization system was based on rents. The land area utilized at Wistka Królew ska and Wistka Szlachecka villages had been 2 sors (1 sor = ca. 16.8 ha) (Tab. 9.3). It is impossible, however, to evaluate the size of particular farms in these villages at the time of their location. Documents show that from the 15th century on a process of division of farms took place. According to Nowak (1991), in both Wistka Szlachecka and Wistka Królew ska lived 6 farmers, and a total size of individual farm was no more than 2 sors.

In the second part of the 15th century the area between Wistka and Dobiegniewo had a considerable population density. Two new churches were built there at that time, one at Duninów built about 1470, and another one at Wistka Szlachecka about 1496 (Nowak 1991). The parish at Wistka Szlachecka originated from the end of 15th century. Three mills were in use at Dobiegniewo, Duninów, and Wistka Szlachecka then (Tab. 9.3); the mill at Dobiegniewo was built about 1455 (Tab. 9.4).

### Table 9.2. Villages around Lake Gościąż in documents up to the end of the 15th century (after Nowak 1991).

<table>
<thead>
<tr>
<th>Village</th>
<th>Date of first mention</th>
</tr>
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<td>Dąb</td>
<td>1228</td>
</tr>
<tr>
<td>Dobiegniewo</td>
<td>1454</td>
</tr>
<tr>
<td>Duninów</td>
<td>1361</td>
</tr>
<tr>
<td>Skoki</td>
<td>1462</td>
</tr>
<tr>
<td>Środoń</td>
<td>1488</td>
</tr>
<tr>
<td>Wistka Królew ska</td>
<td>1300</td>
</tr>
<tr>
<td>Wistka Szlachecka</td>
<td>1489</td>
</tr>
</tbody>
</table>

### Table 9.3. Villages around Lake Gościąż acc. to the Register from 1489 and the Survey from 1494 (after Nowak 1991).

<table>
<thead>
<tr>
<th>Village</th>
<th>Used sors</th>
<th>Number of mills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dąb</td>
<td>lack of data</td>
<td></td>
</tr>
<tr>
<td>Dobiegniewo</td>
<td>lack of data</td>
<td>1</td>
</tr>
<tr>
<td>Duninów</td>
<td>lack of data</td>
<td>1</td>
</tr>
<tr>
<td>Ruda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skoki</td>
<td>abandoned village</td>
<td></td>
</tr>
<tr>
<td>Środoń</td>
<td>lack of data</td>
<td></td>
</tr>
<tr>
<td>Wistka Królew ska</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Wistka Szlachecka</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

### Table 9.4. Mills around Lake Gościąż (after Nowak 1991).

<table>
<thead>
<tr>
<th>Village</th>
<th>Date of erection</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dąb</td>
<td>1616</td>
<td>Lustracja 1616, p. 637</td>
</tr>
<tr>
<td>Dobiegniewo</td>
<td>1455</td>
<td>Nowak 1991, p. 64</td>
</tr>
<tr>
<td>Duninów</td>
<td>1489</td>
<td>Nowak 1991, p. 64</td>
</tr>
<tr>
<td>Ruda</td>
<td>1556</td>
<td>Nowak 1991, p. 64</td>
</tr>
<tr>
<td>Telążna</td>
<td>1607</td>
<td>Nowak 1991, p. 64</td>
</tr>
<tr>
<td>Wistka Królew ska</td>
<td>1539</td>
<td></td>
</tr>
<tr>
<td>Wistka Szlachecka</td>
<td>1489</td>
<td>Lustracja 1489, p. 118</td>
</tr>
</tbody>
</table>

During the 16th-18th centuries the districts were the basic units of state administration. However, the rent execution was based upon the parish division. Most parts of the area in question belonged to the Wochlew Bishopsric, except for the neighbourhood of Duninów, which belonged to the Plock Bishopsric (Nowak 1991). The area between Wistka and Duninów had generally been royal land. A small part of the area between Dąb and Skoki belonged to the church, and the neighbourhood of Wistka Królew ska had been a gentle land. Several new villages were built in the 16th century, for example Ruda and Nowa Wieś (Nowak 1991).

On the basis of documents from the end of the 15th and the beginning of 16th century it is difficult to reconstruct the size of villages and the population of Dąb, Duninów, and Dobiegniewo. Comparison of information from the register of sors from 1489, the survey from 1494, and the registers of rents from 1557 and 1566 shows that the size of the occupied area had grown con-
siderably and that the social differentiation of the inhabitants progressed (Tabs 9.3 and 9.5).

Totally two sors were prepared for settlement in both Wistka Szlachecka and Wistka Królewska at the time of their location (Tab. 9.3), but it is difficult to say how much of the land was actually used. In Wistka Królewska in the 17th century the rent was paid according to the area of 6 peasant sors (Tab. 9.5). In Wistka Szlachecka only one peasant sor was in use but 6 craftsmen paid rent (Tab. 9.5). In Dąb 6 peasant sors were in use. The particular farms, however, were rather small. In 16th and 17th centuries farms in Dobiegniewo were no more than 0.25 sor in size each (Nowak 1991). Duninów was a relatively big village at this time; 17 peasant sors were used, and 2 craftsmen and 12 farmers paid rents there.

Beside farming, other forms of utilization of the natural environment took place. Beside the mills existing at Dobiegniewo, Duninów, and Wistka Szlachecka in 15th century, new mills were built in the 16th century at Ruda and Wistka Królewska. The brewery at Duninów started to function already in 16th century. According to 17th century documents the inhabitants of some mentioned villages were engaged in fishing (Nowak 1991). Fishponds were often connected with mills, where the millers took care of the fish. By the permission of King Zygmunt I from 1521, the inhabitants of Dobiegniewo and Dąb were involved in wild-forest bee keeping. There were also bee keepers at Wistka Królewska and Duninów. Cutting trees for timber is mentioned in documents from the 15th century (Nowak 1991). Logs were worked in water sawmills at Dobiegniewo and Duninów. In the 16th and 17th centuries the inhabitants of Duninów worked also as raftsmen floating wood. From the end of the 15th century a woollen cloth-shearing manufacture functioned at Dobiegniewo (Tomczak 1963).

Manufacturing of iron at Ruda is confirmed from the end of 16th century. Near ironworks 10 houses were built then (Guldon 1974). At the same time 2 blacksmiths, 4 coal merchants, 4 miners, and 2 smelting-furnace operators paid rents at Ruda.

The above data suggest high professional differentiation of people living in the area between Wistka and Duninów during the 15th and 16th centuries. However, it is impossible to reconstruct the number of inhabitants of the villages near Lake Gościaż during that period. Information about rents and incomes from sawmills (Nowak 1991) implies that this region was intensively exploited economically.

In the 16th century the fishermen from Dobiegniewo paid a rent of 7 florens. Moreover, the inhabitants of villages situated along the Vistula River paid 4–8 bushels of hops (1 bushel = 36 litres). The cultivation of hops was probably connected with the brewery at Duninów. In 1564, the sawmill at Duninów gave a profit of about 60 florens.

The process of settling people in the region discussed continued in the 17th century, when the village Telążna came into being (Nowak 1991). All the previously mentioned villages were active at that time.

In the 17th and 18th centuries the royal stores of salt from Wieliczka existed at Dobiegniewo (Nowak 1991). In 1674, 55 people from Dąb paid rent. The brewery at Duninów worked throughout all that time, and some inhabitants of this village were engaged in fishing. The ironworks at Ruda were still functioning. Information is lacking about the sawmill at Dobiegniewo. Millers from Dobiegniewo and Wistka Królewska paid a conventional rent, and they were obliged to fatten hogs and do the carpenter services (Nowak 1991). Animal breeding in peasant farms then included cattle, horses, pigs, sheep, geese, and hens. In the Kowal district rye was the most commonly cultivated cereal. The population of Dobiegniewo parish in the 17th century is unknown, but in the Duninów parish 470 people lived at that time (Nowak 1991).

The distribution of archaeological sites confirms the above informations, and shows the general settlement patterns (Figs 9.1 and 9.6). In spite of the poor natural environment, which was not friendly to farming, the areas between Wistka and Duninów have been permanently inhabited during the Medieval Period and Modern Time.

9.1.3. HUMAN IMPACT ON THE VEGETATION OF THE LAKE GOŚCIĄŻ SURROUNDINGS IN PREHISTORIC AND EARLY-HISTORIC TIMES

Magdalena Ralska-Jasiewiczowa & Bas van Geel

The Na Jazach Lakes region is a rather special and interesting area for tracing the participation of past human populations in the transformations of the natural environment. As an area of rather poor soils unsuitable for intensive farming, it has never been radically deforested. On the other hand, it is situated quite close to important habitation centres active during different crucial periods of cultural history, e.g. the chernozem region of Kujavia

Table 9.5. Villages around Lake Gościaż (rent registers from 1557 and 1566, after Nowak 1991).

<table>
<thead>
<tr>
<th>Village</th>
<th>Number of sors</th>
<th>farmers</th>
<th>tenants</th>
<th>craftsmen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dąb</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dobiegniewo</td>
<td>1.5</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Duninów</td>
<td>17</td>
<td>12</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Skoki</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Środoń</td>
<td>5.5</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Wistka Królewska</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Wistka Szlachecka</td>
<td>1</td>
<td></td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>
(Fig. 9.7), its borderlands lying hardly 30 km west from Lake Gościąz and inhabited intensively from early Neolithic since it became the earliest cradle of Polish Statehood in the 10th century. Still closer were important pre- and early historic strongholds at Płock, the capital of Poland in late 11th century AD (Szafranski 1983) and slightly younger one at Włocławek (Fig. 9.7). The study area is also located very near Vistula River, the largest and most important waterway in the history of Poland. Lying within the sphere of influences of those active areas, the Na Jazach lakes region was populated nearly continuously. However, because of the unfriendly environment, human impact could hardly develop intensively here, leaving possibilities for natural vegetation to keep its stands, although still subject to anthropogenic transformation.

The human impact on the vegetation as presented in this chapter is based on the interpretation of a pollen diagram for profile G1/87 from the centre of Lake Gościąz, discussed already for its records of Late-Glacial and Holocene vegetation history in Chapters 7.4 and 8.3. The pollen-analytic record from this profile is assumed to represent regional changes, i.e., in case of human activities, to reflect also some events taking place several kilometres away from the lake.

The basic data concerning the evidence of human activity in the Lake Gościąz region between ca. 7750–4550 cal BP (= ca. 6700–4100 14C BP) have been presented by Ralska-Jasiewiczowa and van Geel (1992), and data concerning the human-indicator value of some Cyanobacteria by Van Geel et al. (1994, 1996). These data will be also summarized here to make the settlement history complete.

To update the information published in 1992 the following questions must be mentioned:

1. The archaeological field-work carried out by Pelsiak and Rybicka during the years 1992–94 (Chapter 9.1.1) completed the fragmentary picture of human presence in the studied region that was formerly sketched on the basis of available sources for the Mesolithic and Neolithic periods.

2. The very detailed studies of the sediment chronology in the top part based on frozen cores (Goslar, Chapter 9.2.1), and the numerous AMS 14C datings on terrestrial macrofossils from the central and bay cores (Goslar et al., Chapter 6.2) greatly improved the former floating chronology of the whole sediment sequence. It allowed us to correct and define more precisely the time spans attributed to particular cultural groups in the region.

3. The pollen diagram published in 1992 was based in its bottom part on pollen spectra counted with a time resolution of 100 yr. The ensuing complement of counts to 50 yr resolution revealed the evidence of humans in the area at least 200–300 years earlier than previously supposed (8000–8100 cal BP) (Fig. 9.8).

In describing the anthropogenic environmental changes we decided to use the calendar (varve) time scale as the primary time scale in accordance with the entire study on Lake Gościąz sediments, adding for convenience its conversion into the 14C chronology (see Goslar, Appendix 1).

Mesolithic

Phase 1 (8100–7270 cal BP = ca. 7350–6400 14C BP)

The earliest changes in the pollen diagram interpreted as evidence of human activities (Phase 1, Fig. 9.8) occur within the older part of Ulmus-Fraxinus-Quercus PAZ, representing the Atlantic chronzone. The main vegetation types in the Na Jazach lakes region then were pine and mixed pine forests with substantial amount of Betula, Quercus, Corylus, and Populus tremula on the elevated sandy grounds prevailing in the region, their poorest forms overgrowing sand dunes. Mixed deciduous woods with dominant Ulmus and with Fraxinus excelsior, Quercus, both Tilia ssp. and Corylus avellana occurred on
slopes and lower terrain of more fertile brown soils, passing gradually into alderwoods with different deciduous trees, *Picea, Salix,* and *Frangula* and with ferns. The generally high forest density is evidenced by low pollen influx (Fig. 9.9) and pollen diversity (Fig. 9.10), both around their lowest values for the entire Holocene (Chapter 8.3, Figs 8.23 and 8.24). Mixed pine forests were somewhat more open, with some patches of light-demanding vegetation (*Artemisia, Rumex acetosella, Calluna vulgaris*).

The changes recorded in pollen spectra from ca. 8000 cal BP may indicate the following effects of human interference in the natural vegetation:

The increased abundance and diversity of wood understory taxa (small peaks of *Corylus* and *Populus cf. tremula,* appearances of *Frangula alnus, Rhamnus cathartica, Viburnum opulus, Sambucus nigra* -t.) and also of herb-layer taxa provide evidence for some disturbance and creation of openings in different types of wood communities. The herb taxa document disturbance mostly in two types of woods: dry mixed pine forests (pronounced rise of *Pteridium aquilinum* curve, increased frequencies of *Melampyrum, Calluna vulgaris, Rumex acetosella,* appearance of *Polypodium vulgare*), and humid alderwoods (*Humulus lupulus, Urtica dioica, Thalictrum (?), Cirsium, Filipendula, Valeriana, Calystegia sepium, Mercurialis perennis*).

Some taxa of humid habitats appear then in the pollen diagram, like *Sanguisorba officinalis, Trollius europaeus, Rumex acetosa, Lythrum,* etc., which are typical today of humid meadows. Some other plants showing increased pollen frequencies are clearly nitrophilous (*Urtica dioica, Artemisia, Chenopodiaceae, Sambucus nigra* -t., the latter evidenced for the first time) and indicate formation of nitrogen-enriched habitats arising around human camps.

The very characteristic maxima of *Pteridium* curve (Fig. 9.8) may indicate regular fires, most probably of anthropogenic origin (Bennett et al. 1990). *Pteridium* expands effectively not only by a good light supply but particularly so on soils enriched in ash, which highly im-

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**Fig. 9.9.** Lake Gościąt, profile G1/87. Section of pollen-influx diagram (selected major pollen type) with evidence of Mesolithic and Neolithic settlements. Pollen-influx values (black bars) are superimposed on the percentage pollen curves (dotted). For other explanations see Fig. 9.8.

Melampyrum pollen often increases in frequencies in connection with the indicators of human activities (Behre 1986). It may represent species of different ecological affinities and however, several species are characteristic of woodland disturbances, including burning of forest herb layer and also of mire surfaces.

It was e.g. regularly found in mire profiles from North Yorkshire, UK (Turner et al. 1993) in connection with the evidence of Mesolithic man presence. Its appearance there was interpreted as indicative of changes in forest herb layer following the lopping of branches and burning the ground vegetation.

During the following period of about 200 yr (ca. 7270–7065 cal BP) the indicators of human presence near the lake decrease in frequencies (Populus cf. tremula, Urtica, Pteridium) or partly disappear, possibly suggesting temporary departure of nomadic groups to other areas. However, after ca. 7070 cal BP the signs of their return to the region increasingly reappear.

**Phase 2 (7070–6610 cal BP = ca. 6200–5770 14C BP)**

The record of phase 2 (Fig. 9.8) starts with a brief peak of pollen influx, involving mostly Pinus, Betula, Quercus and Alnus (doubled influx) (Fig. 9.9). The consistently increased Betula and Quercus influx continues, suggesting some stabilization of human impacts in mixed pinewoods (Ralska-Jasiewiczowa & van Geel 1992). It is confirmed by the indications of wood disturbance similar to that in the previous phase as well as to some new ones. We can see again a maximum of Populus cf. tremula and an increased variety and representation of understory shrubs, including this time also Cornus sanguinea and Taxus baccata, and rises of Pteridium aquilinum and Urtica dioica. Different rather heliophilous herb taxa appear, some of them of xerothermic affinities, such as Plantago media, Sanguisorba minor, Pulsatilla, and Anthericum, documenting openings created in dry mixed pinewoods, together with ecologically undefined taxa like Geranium, Dianthus, Trifolium, Hypericum, Anthemis type, and others. The changes described are accompanied by the continuous record of charred tissues (Fig. 9.8) mostly of Gramineae epidermis and more rarely also of small wood fragments. The regularity of recorded fires speaks strongly for their anthropogenic origin. In the late part of phase 2 around 6600 cal BP the contribution of Aphanizomenon akinetes (Cyanobacteria) to the pollen spectra suddenly rises, interpreted by van Geel (Ralska-Jasiewiczowa & van Geel 1992) as evidence of increasing lake eutrophication.

**Comparison of pollen-analytic and archaeological data on Mesolithic man in the Lake Gościąż region**

As stated by Ralska-Jasiewiczowa & van Geel (1992) the two phases described, each lasting at least several hundred yr, correspond generally to the periods when “there was human activity in the regional pollen-source area”. However, the shape of pollen curves such as Populus cf. tremula and Urtica suggests the occurrence of several short cycles of human activity within each phase, probably connected with the mobility of nomadic tribes.

The evidence of Mesolithic man long has been sought in pollen diagrams (Hicks 1972, Jacob et al. 1976, Simmons & Innes 1987, Simmons et al. 1989, Simmons 1992, Latałowa 1992a, b, etc.), and some of records in-
terpreted as consequences of human activities connected with those cultures are particularly suggestive (Kloss 1987, 1990, Innes & Simmons 1988). The records include, first of all, the evidence of frequent forest fires, interpreted most often as caused by Mesolithic hunters (Jacobi et al. 1976). Forests with dominant pine are the easiest to set on fire, while the deciduous trees are rarely affected by natural fires (Rackham 1988), so the charcoal evidence from the Mesolithic including tree species other than pine is commonly assumed to be anthropogenic (Bennett et al. 1990). Latalowa (1992b) considers that regular fires on light sandy soils may produce favourable conditions for the development of a rich herb layer with dominant *Pteridium aquilinum*, limiting the re-generation of *Pinus* seedlings and favouring the advance of *Quercus*. This interpretation may explain very well the changes in the pollen record observed in phase 2 of Gośćcąd diagram.

In the G1/87 profile charred tissues start occurring much earlier than the noticeable pollen record of human presence (Fig. 9.8), and they may possibly be a signal of Mesolithic camps in a greater distance from the lake, for the archaeological data confirm the development of Mesolithic cultures in central Poland since the beginning of the Holocene.

The pollen/charcoal evidence, however, is rarely supported by the archaeological evidence found practically in situ. Out of 18 sites of flint artefacts found in the Lake Gośćcąd region (Pelisiak & Rybicka, Chapter 9.1.1) and recognized positively as Mesolithic, besides 47 poor flint assemblages, that at least partly may also represent Mesolithic, 5 sites were located on the sandy upland and on the ridge above the Lakes Na Jazach valley between the northern Lake Gośćcąd bay and Lake Mielec (Chapter 9.1.1, Fig. 9.1). One of them (site 11) contains the original undisturbed pattern of flint artefacts and suggests the tool processing executed in situ. This site is located very close to the lake, while the others follow the valley edge farther to the north-east.

According to Pelisiak and Rybicka (Chapter 9.1.1) two technological types of flints are represented here, one typical for the Komornica and Chojnice-Pieriki cultures, the other specific for the Gośćcąd microregion and connected possibly with the Wistka Szlachecka type of Janisławicka Culture (Schild et al. 1975, Więckowska 1975). The human-impact phases 1 and 2 as distinguished in the pollen diagram could then correspond to two different cultural phases of the Mesolithic, not to a single one, as previously supposed (Ralska-Jasiewiczowa & van Geel 1992).

The radiocarbon chronology for particular Mesolithic cultures in Poland (Kozłowski 1989) places the main development of the Komornica Culture between 9500 and 7200 14C BP (= ca. 10,500–8000 cal BP, see Appendix 1), its late stages persisting in western and northwestern Poland for the next two millennia. The Chojnice-Pieriki Culture in certain areas would be its successor from around 7000 14C BP (= 7800 cal BP), and Janisławicka Culture is presumed to spread only from ca. 6500 14C BP (= ca. 7400 cal BP). In this chronological context phase 1, dated between ca. 8000 and 7300 cal BP, could be well correlated with the presence of tribes of the Komornica/Chojnice-Pieriki cultural complex, and the younger phase 2 (ca. 7100–6600 cal BP) with the late-Mesolithic population of the Janisławicka Culture, producing flints of Wistka Szlachecka type.

It should be mentioned that from ca. 6500 14C BP (= 7400 cal BP) the first early-Neolithic cultural groups started to penetrate the Kujavia region adjoining the study area to the west (Fig. 9.7). They could coexist within or more probably near the regions where Mesolithic populations persisted even until 5000 14C BP = 5900 cal BP (Kozłowski 1989). The landscape (soil, vegetation) qualities were the decisive factors here. The rich centres of early-Neolithic settlements within 30–40 km to the west from Lake Gośćcąd on areas of highly fertile soils are dated at ca. 6180 14C BP (= ca. 7145 cal BP), with the oldest uncertain dates of 6490±450 14C BP (= 7380±500 cal BP) for the Linear Pottery Culture (Grygiel 1984) and 5700±140 14C BP = ca. 6484±140 cal BP for the Lengyel Culture (Grygiel 1984, Grygiel & Bogucki 1997). The dates coincide with the age of younger Mesolithic phase 2 at Lake Gościa, and some contacts between those different populations cannot be excluded. Single pollen grains of *Triticum* type are present in pollen spectra at that time too. However, both the type of habitat around Lake Gośćcąd and the type of environmental disturbance deduced from the pollen record speak against linking phase 2, or at least its youngest part, with the activities of early-Neolithic people. Nonetheless the single pollen grains of *Cerealia* -t., *Triticum* -t., and *Hordeum* -t., appearing sporadically from ca. 7300 cal BP on, might have been wind-transported from those early-Neolithic settlements.

The 200-yr section of the pollen diagram following Mesolithic phase 2 suggests a time of much reduced – if not totally ceased – human activities, *Artemisia, Urtica, Pteridium aquilinum* frequencies decline, single indicator herb taxa disappear. If late-Mesolithic populations were still present in the region at all, they certainly were rather scarce and not living close to the lake.

Neolithic

Phase 3 (6400–6260 cal BP = 5610–5450 14C BP)

The new signals of human presence in the study area start appearing from ca. 6400 cal BP (Fig. 9.8). Until 6250 cal BP they are rather indistinct and similar to the Mesolithic records. They include new increases in *Urtica dioica* -t., *Chenopodiaceae*, and Rubiaceae pollen, *Perti-
Neolithic settlement in the region, with animal breeding by grazing in the forest but with little developed pastureland husbandry and questionable early stages of agriculture. The economy of these populations must still have been based to a large degree on hunting and fishing. No evidence was found for their dwelling in the direct neighbourhood of the lake.

Phase 5 (5910–5550 cal BP = ca. 5150–4830 14C BP)

At ca. 5910 cal BP a classical *Ulmus* fall occurs in the pollen diagram (Fig. 9.8). It is accompanied by different indications of rather substantial ecological changes, not necessarily, however, of anthropogenic origin. The changes in the AP percentage diagram are not so drastic: they include a short lasting rise of *Betula*, followed by further increase of *Corylus* values, less distinct rises of *Quercus*, *Populus tremula* -t., and *Tilia platyphyllos*, small temporary declines of *Fraxinus* and *Picea*, and the first appearance of *Juniperus*. More expressive are changes in the AP influx (Fig. 9.9), which nearly doubles between 5934 and 5884 cal BP and remains high until ca. 5650 cal BP. Its first rapid rise is caused mostly by *Betula, Alnus, Quercus, Corylus,* and *Tilia*. In the later part of this stage *Corylus* influx is still high. A small but definite rise of NAP influx is first caused mostly by Gramineae, supported by *Artemisia*. The frequencies of other ruderals like *Urtica dioica, Plantago major,* and later Chenopodiaceae increase slightly too. Fresh/wet-meadow indicators are very scarce, except for slightly increased *Filibunda*. The latter may have come from the alderwoods, where the formation of openings is suggested by higher frequencies of *Frangula alnus, Rhamnus catharticus, Humulus lupulus, Solarum dulcamara,* and *Thalictrum.* The other wood types have been subjected to some disturbance as well, as evidenced by increased pollen occurrences of *Melampyrum* and *Mercurialis perennis* and substantial contribution of *Pteridium aquilinum* and *Calluna vulgaris*. Single pollen grains of *Anthericum, Gypsophila fastigiata, Armeria maritima,* and *Plantago media* document the formation of dry-land swards. The appearance of *Juniperus* is connected with that type of vegetation. The existence of small corn-fields cannot be excluded, as single cereal pollen mainly of *Triticum* -t. appear more regularly in this phase. However, all the evidence together speaks for grazing in the forest as the main economic activity for the population living near the lake.

The real fall of *Ulmus* pollen influx (Fig. 9.9) is indicated only at 5834 cal BP, delayed compared with *Ulmus* pollen percentage fall. This shows that all the processes connected with the *Ulmus* reduction were more extended in time than the percentage diagram can show: the first thinning of the elm population let the light into the forest and enabled the remaining elm trees to bloom abundantly for the next few tens of years. However, the repeating reduction of elm resulted in its final very serious elimina-
tion from the area. The *Ulmus* fall is strictly coincident with the changes in sediment laminae (Fig. 9.11). The changes start with the drastically increased thickness of the dark parts of the couplets, the beginning of this change indicated slightly earlier than the onset of the *Ulmus* percentage fall (unfortunately no year-by-year pollen analysis was performed) and continuing for ca. 90 yr. It is followed by a sediment section with the dark couplet parts not so thick, but with the total couplet thickness distinctly though not regularly increased.

The above facts described also by Goslar (Chapter 6.3 and 8.2), were explained by Ralska-Jasiewiczowa & van Geel (1992) as increased soil erosion caused by the opening of woods surrounding the lake due to the *Ulmus* elimination (see Hirons & Edwards 1986). The primary cause of the *Ulmus* fall, however, was not discussed more thoroughly then. To support its possible interpretation the following facts should be remembered: the appearance of Neolithic people in the Lake Gosicza area during phase 3 is no more than very probable, but the records of phase 4 leave no doubt about the presence of settled populations, with animal husbandry by forest grazing accompanied by wood coppicing and pollarding (Rackham 1980, 1988, Géransson 1982, Pott 1986, and others). The evidences of those practices appear in the pollen diagram at least 300 years before the *Ulmus* fall, and though the increased human activities are indicated around the *Ulmus* fall itself, the strongest evidence of land occupation appear in the diagram only ca. 400 yr later, at the onset of settlement phase 6 (Fig. 9.8). This makes the purely anthropogenic origin of *Ulmus* fall highly improbable. Pathogenic attack as an important factor contributing to the *Ulmus* fall must be accepted as the most popular explanation of this episode in Holocene European forest history (Groenman-van Waateringe 1983, Birks 1986, Girling 1988, Molloy & O’Connell 1991, and many others). The hypothesis proposes the rapid spread of so-called Dutch elm disease caused by a fungus *Ceratocystis ulmi* by beetles of two *Scolytus* species – *S. scolytus* and *S. multistriatus* (Rackham 1980, Peglar 1993). In some cases *Scolytus* fossils were found in association with the elm decline (Girling & Greig 1985, Girling 1988). The year-by-year analysis of the *Ulmus* fall recorded in annually laminated sediment at Diss Mere described by Peglar.
(1993) reveals a position of the Ulmus fall in the sequence of anthropogenic forest disturbance similar to that found at Lake Gościąz. Peglar accepts also an important role of elm disease in the loss of elm trees.

One cannot estimate to what extent the elm disease is responsible for the Ulmus fall recorded around 5900 cal BP in Lake Gościąz sediments, and how far human activities contributed to it. Most probably both factors were of substantial importance here. Similar are the opinions of different authors dealing with the problem of European Ulmus fall in detail, as presented very accurately by Peglar (1993), quoting Rackham’s (1980) and Girling’s (1988) considerations on the subject. In summary, it is assumed that the elm disease might have been present in the area already for some time before the main Ulmus fall, causing less serious attacks on elm trees (in case of the Lake Gościąz profile, the Ulmus curve depressions during phase 3 and possibly also between phase 2 and 3). However, as the Neolithic settlement developed, the damaging of elm trees by animal grazing and the different human activities in the forest weakened the elm trees, increased their susceptibility to infection and provided new habitats for Scolytus beetles contributing to the outbreak of a strong epidemic.

Phase 6 (5550–5230 cal BP = ca. 4830–4500 14C BP)

A new cycle of anthropogenic change beginning between 5600 and 5500 cal BP (Fig. 9.8) is signalled first by rising pollen frequencies of the ruderal taxa Artemisia, Chenopodiaceae, and Plantago major. The AP influx, rather low at the onset of the phase (Fig. 9.9), rises rapidly to reach a short maximum around 5370 cal BP, then decreases slowly. The percentage curves of Corylus and Quercus form then large depressions, and Ulmus and Fraxinus decrease to minimum values, later to rise again. On the other hand, percentages of Betula, Populus tremula -t., Salix, Picea, and Pinus show distinct increases. Sorbus aucuparia starts appearing continuously. At the time of the highest AP influx, the NAP influx rises too (Fig. 9.9), and the whole group of cultural indicators forms percentage maxima. In this central part of the phase the pollen spectra were counted with a finer time resolution (Fig. 9.12).

The deforestation for pasturelands becomes evident: formation of open grazed land on more humid soils is confirmed by regular occurrence of Rumex acetosa, presence of Sanguisorba officinalis, Centaurea jacea, Trifolium repens, Cirsiun, and quite a few of ecologically undefined herb taxa like Ranunculus acris -t., Rhi-nanthus, Potentilla -t., Anthemis -t., Campanula, Dia-nthus, and others, strictly accompanying a sharp Plantago lanceolata peak up to 1.5% of the pollen sum. On the other hand, the similar and synchronous maximum of Rumex acetosella and the coincident appearance of heliophilous rather xeric taxa like Jasione montana, Pulsatilla vulgaris -t., Helianthemum nummularium -t., Coronilla varia, and Knautiav arvensis document the deforestation of drier habitats. All those changes indicate the approach of Neolithic settlers closer to the lake and the occupation of adjacent grounds. The type of economy seems to be still based mostly on animal breeding – cereal pollen remains scarce, but by shortening the distance between the cultural activities and the lake shore the more local succession of changes could be recorded.

Together with the maxima of anthropogenic indicators one Vitis pollen grain was found, but the cultivation of grape-wine at that time is rather doubtful. This find contributes to the still not fully explained history of wild Vitis in the Holocene of Poland (see Chapter 8.3 and this Chapter p. 292).

Phase 6 seems to reflect the following land-occupation cycle (Figs 9.8 and 9.12):

1. arrival and settling (spread of the ruderals Artemisia, Chenopodiaceae, Plantago major)
2. extension of clearings, formation of pasturelands (high AP influx, percentage depression in deciduous trees, rises of pioneer trees, maxima of grasslands taxa and Urtica)
3. some recession of pastoral economy in situ, overgrowing of abandoned grounds (increases of Artemisia, Peridium, Taxus, Juniperus) and starting regeneration of trees by sprouting (Fraxinus, Ulmus, later Quercus, Corylus).

The decline of local human activities is recorded in the diagram as a slow and gradual process, and it is difficult to define when indeed the population settled near the lake retreated from the area. The end of the phase is marked at the beginning of a distinct depression of ruderals and the temporary disappearance of Plantago lanceolata and Rumex acetosella.

The progress of a subsequent Ulmus decline during the land-occupation phase seems to show direct connection with human activities. Its minimum, concurrent with those of other deciduous trees and Corylus, must have been the effect of forest clearings as evidenced by maxima of grassland herbs. Its slow rise at the phase decline coincides with the decrease of anthropogenic indicators. This pattern confirms the opinion discussed earlier, that beside the Dutch elm disease the activity of Neolithic settlers played a very important role in the history of Ulmus in post-Atlantic times.

The short-lasting retreat of human populations from near the lake between ca. 5230 and 5080 cal BP is mostly expressed by a distinct reduction of some of culture-indicator taxa (Artemisia, Urtica dioica -t.) or even a temporary disappearance of others (Plantago lanceolata, Rumex acetosa -t., R. acetosella -t., Chenopodiaceae) and rising indicators of overgrown openings in pinewoods (Calluna, Juniperus). Ulmus and Tilia values rise slightly, and Quercus reaches its absolute Holocene maximum.
Phase 7 (5080–4730 cal BP = 4510–4160 14C BP)

The last settlement phase attributed to Neolithic population (Fig. 9.8) shows a similar set of NAP evidence as in phase 6, especially concerning the representation of ruderal and meadow taxa. The cereal pollen grains of *Triticum* and *Hordeum* types are slightly more frequent, suggesting small fields present not far from the lake. Some open places, particularly on drier sandy soils, were abandoned and subjected to natural succession, as documented by decreasing pollen values of *Calluna vulgaris, Rumex acetosella,* and *Melampyrum* and rise of *Populus tremula.*

The pollen influx of both AP and NAP is rather low (Fig. 9.9): *Quercus* pollen influx, making a sudden maximum at the onset of the phase shows later a depression corresponding to the rise of *Corylus* influx and percentages and the steady declines of *Ulmus* and *Tilia platyphyllos.* This indicates progressive clearings of deciduous woods already disturbed rather heavily during the preceding Neolithic settlements.

As mentioned by Ralska-Jasiewiczowa & van Geel (1992), an interesting record is made by *Taxus* pollen, forming a distinct maximum in the middle of the phase. The explanation of this phenomenon in the above publication proposes *Taxus* expansion on abandoned pastures or fields. A small rise of *Taxus* frequency occurs also in the later part of the preceding settlement phase 6, where it coincides with a rise of *Picea.* A rise of *Picea* also follows *Taxus* maximum in phase 7. We can suppose that both trees were present in the understory of alderwoods surrounding the lake (*Taxus* appeared for the first time during the settlement phase 2), and that they expanded from there on the unused grounds, most probably the pasturelands (see also this Chapter p. 286).

Discussion of pollen and archaeological evidence of Neolithic settlements in the Lake Gos'cią region

When we compare the palynological data with the archaeological information for the study area the following conclusions can be drawn:

The anthropogenic changes in vegetation ascribed to activities of Neolithic settlers must have been mainly connected with the tribes of the Funnel Beaker Culture (Pelisiak & Rybicka, Chapter 9.1.1). Their presence in the neighbouring Kujavia region (Fig. 9.7) on areas of podsolic soils on sandy substratum is dated at least from 6200 to ca. 5430 cal BP (= 5350–4650 14C BP), and on chernozem soils ca. 200 yr earlier, late populations surviving there until ca. 4800 cal BP (Czerniak 1994). The sites of the oldest FBC Sarnowo phase, which was first described from Włocławek region (Gabałówna 1968, 1969) have also been found in the Gostyniński Lake District (Pelisiak & Rybicka, Chapter 9.1.1). Some doubts may then arise about the cultural attribution of phase 3, as its age seems slightly too old to correlate it even with the earliest FBC phase in the area, and the character of changes recorded in the diagram does not define it clearly as Neolithic. On the other hand its position in the diagram, as mentioned before, connects it continuously with phase 4, which is doubtless Neolithic. As proposed by Erny-Rodmann et al. (1997) for the Swiss Plateau, we may speculate about the possibilities of acculturation of autochthonous late-Mesolithic populations by early-Neolithic people of Danubian cultural cycle. In
our case they were settled on neighbouring fertile soils of Kujavia (Czerniak 1994), e.g. from Brześć Kujawski centre (Fig. 9.7) (Grygiel 1984), but no evidence of such processes is available.

The population of Funnel Beaker Culture seems to have been most widespread in the study area (27 sites). The remains of their periodic encampments were found close to the lake and in other nearby places, but no permanent dwelling place was discovered as near by Pelisiak and Rybicka (Chapter 9.1.1, Fig. 9.3). The camps were situated on sandy terraces or in the transition zone between the terrace and the lake depression. It is then supposed by the analogy with the other FBC sites that the permanent settlement place of those people must have been situated on more fertile soils, possibly some 4–5 km to the west. Such interpretation agrees quite well with the palynological record of phases 4 and 5. It seems, however, that in phase 6 the land occupation reached terrains neighbouring the lake, where rather extensive forest clearings took place and pasturelands arose; therefore it is probable that the permanent dwelling place was also moved closer towards the lake.

The situation of phase 7 seems to be slightly different: it is distinctly separated in the diagram from phase 6 by an episode of ca. 150 yr suggesting the retreat of the former land-users from the lake region. The pollen record of phase 7 documents the formation of new open spaces exposed to grazing, a part of cleared surfaces being soon eliminated by overgrowth. The type of pottery represented by two pollen phases. The following period, when human populations retreated from the lake surroundings, lasted up to 600 yr (ca. 4730 - 4130 cal BP). It is shown in the pollen diagram by a strong reduction of anthropogenic indicators (Plantago lanceolata maintains a continuous curve), rise of Melampyrum and Calluna, but not much change in the tree composition. The end of this period the next 14C BP fall is compensated by rises of Alnus and Fraxinus pollen values, which may suggest a new attack of Dutch elm disease, affecting mostly the elm trees contributing to alderwoods.

From ca. 4130 cal BP the human groups started reappearing and were active in the region studied more or less continuously for the next ca. 1500 yr, though with different intensity and changing land-use tendencies and with short-lasting retreats. Both archaeological and palynological evidence shows that we have to do with the activities of at least two main cultural cycles, each of them represented by two pollen phases.

**Early Bronze Age**

Phase 8 (4130–3760 cal BP = ca. 3780–3480 14C BP)

The phase beginning is indicated by returning higher frequencies of most common ruderal plants like *Artemisia, Urtica dioica*, and Chenopodiaceae, the appearance of *Polygonum aviculare* and *Plantago major*, and the rise of *Rumex acetosella*, Gramineae, and some other ecologically undefined taxa (Fig. 9.13). No cereals except for a single pollen grain of *Hordeum* type appear. A distinct increase of AP and small one of NAP pollen influx start from the middle of phase (Fig. 9.14). The changes in AP composition are more significant: the early part of the phase shows clearly a regeneration of deciduous woods, as documented by small maxima of *Fraxinus, Ulmus*, and *Tilia* following a maximum of *Alnus*, recorded still before the onset of the phase. This sequence could suggest some natural succession proceeding synchronously with the retreat of *Betula*, its pollen curve declining to very low values. On the other hand, massive peaks of *Pinus* at the
beginning and end of the phase coincide with the depressions of *Quercus*, *Tilia*, and *Ulmus* and with a minimum of *Betula*, all reflected also in pollen influx (Fig. 9.14). This pattern of changes is very difficult to explain without involving a human factor (clearings). The *Carpinus* curve rises consistently throughout the whole phase to ca. 7% at its decline. According to Huntley and Birks (1983) *Carpinus* pollen values above 5% indicate that hornbeam is a “prominent tree in the regional forests”.

Altogether the changes described above cannot be clearly explained in forms of the development of human settlements at least in the older part of the phase. In its younger part the rises of *Corylus* and *Populus* when *Ulmus* and *Tilia* decline and both AP and NAP influx rise may possibly be connected with human activities.

In conclusion we can suppose that some cultural interference in the lake surrounding, expressed mostly by the formation of nitrogen-enriched ruderal habitats and some grassland patches, proceeded from the beginning of phase, but the coincident changes in wood communities, if at all connected with human activity, could only progress in a significant distance from the lake. Around the middle of phase at ca. 3960 cal BP (ca. 3650 14C BP) more distinct indications of anthropogenic disturbance of deciduous woods, possibly not so far from the lake, are to be seen. This would facilitate the *Carpinus* invasion into those communities. It seems, however, that neither pasturage nor agricultural activities took place close to the lake at that time.

Phase 9 (3760 – ca. 3480? cal BP)

The most characteristic feature of the following ca. 300 yr is a rapid expansion of *Carpinus*, coincident with the spread of *Betula*, expressed in rises of both pollen percentage and influx values (Figs 9.13 and 9.14). The low-percentage *Fagus*, *Populus*, and *Taxus* pollen curves increase slightly; *Corylus* and all other deciduous trees still present in the area are clearly in retreat. *Pinus* decline, distinct in the percentage curve, is not so pronounced in pollen influx. The changes in the NAP composition, including especially rises of Gramineae, *Plantago lanceolata*, and *Rumex acetosa* -t. curves, and later appearance of single pollen of diverse wet and dry grassland taxa (*Rhinanthus*, *Lythrum*, *Pimpinella*, *Jasione*, *Plantago media*, *Centaurea scabiosa* -t.), suggest formation of open meadow-like surfaces used probably for cattle grazing. Ruderals were not widespread (slight rise of *Urtica*; *Artemisia* distinctly declines!!). No cereals appear at all. The interpretation of changes in wood communities during this phase in terms of human impact is still difficult, because of persisting strong imbalance between intensities of both records — the evident profound transformation of woods is out of proportion to the rather slight evidence of land-use. The expansion of *Carpinus* during this phase might be explained by its general migration, the anthropogenic forest disturbance being here only a stimulating factor. However, it is coincident with the spread of *Betula*, clearly a pioneer tree indicating in prehistoric times an extensive anthropogenic disturbance of natural woods. Symptomatic is also a progressive retreat of still remaining deciduous taxa, especially *Fraxinus* and *Corylus*. We are not able to give a reliable interpretation of the vegetational changes proceeding during the phases 8 and 9.

Archaeological data on Early to Middle Bronze Age cultures in the Lake Gościąż region versus pollen-analytical record

The archaeological data available do not help us too much to understand the real role of people in the transformation of landscape during the phases 8 and 9, corresponding chronologically to the early to middle periods of the Bronze Age. Pelisiak and Rybicka (Chapter 9.1.1) found 21 sites of this age, most of them located several kilometres east of Lake Gościąż, but only 2 of them situated very close to the lake. One such site was excavated, and its chronology was estimated approximately as period III of Bronze Age with the probable attachment to Trzciniec Culture. Another one, though very poor, represents a classical phase of Trzciniec Culture. The precise chronology and cultural classification of all other Early Bronze Age sites found within the study area and in other parts of Gostynińskie Lake District (archival data, see Pelisiak & Rybicka, Chapter 9.1.1) are unclear.

The Trzciniec Culture was formed in the catchment areas of the middle and upper Vistula by uniformation of older, rather differentiated Early Bronze Age cultures (Iwierska, Unietycka Culture) probably during the 16th cent. BC = from ca. 3850 cal BP (Godłowski & Kozłowski 1979). This time corresponds approximately with the decline of phase 8 in the pollen diagram. The economy of Trzciniec populations was mostly based on animal husbandry, exploiting for grazing all open spaces available and dwelling in small encampments situated on drier rather sandy soils; agriculture was of minor importance (Godłowski & Kozłowski 1979). This type of economy should not provoke such essential changes in the forest structures as those observed during the phases 8 and 9.

Late Bronze/Early Iron Age

Phase 10 (ca. 3480–3150 cal BP)

This phase develops gradually from phase 9, and its lower boundary is hardly seen in the percentage pollen diagram alone (Fig. 9.13). However, the transitional zone between phases 9 and 10 is marked by 2 short peaks of AP influx, formed mostly by *Carpinus*, *Quercus*, and *Alnus* pollen, and by a smaller rise of NAP influx (Fig. 9.14). All those taxa show at that time rather decreasing tendencies in percentage values. Such a pattern is a char-
characteristic indication of the beginning of wood felling, and, indeed, it is followed by the evidence of progressing extensive clearings expressed first by a strong decrease of *Carpinus*, and then of *Quercus* and *Corlylus* percentage and influx pollen curves, a decrease of *Pinus* pollen influx, and a general deep depression of AP influx, with the coincident rise of *Populus*, *Juniperus*, and *Salix*. NAP influx increases too, as the cumulative effect of a substantial rise of Gramineae and small rises of different low-frequency pollen taxa connected in many ways with human activities.

The woodland communities of different types were then affected by human activities. Open surfaces were created in pine woods on dry sandy habitats (*Pteridium, Melampyrum, Calluna vulgaris, Rumex acetosella, Jasione montana, Pulsatilla vulgaris*) and on more alkaline grounds (*Plantago media, Centaurea scabiosa, Helianthemum nummularium*). Humid and fresh grasslands were developing and extending due to grazing (*Plantago lanceolata, Rumex acetosa*, and *Rhinanthus, Potentilla, Ranunculus acris*, *Anthemis*, *Centaurea jacea*, *Cirsium* species, and many other meadow plants represented by family/genus type pollen taxa). The rises of *Frangula alnus, Humulus, Thalictrum, Filipendula*, and Cyperaceae pollen frequencies evidence disturbances in alderwoods. The increasing frequencies of ruderal plants (*Artemisia, Chenopodiaceae, Urtica dioica, Plantago major, Polygonum aviculae*) document the formation of nitrogen-enriched habitats. The most significant evidence of the small-scale agricultural activities not far from the lake is the appearance of cereal pollen (*Hordeum*, *Triticum*) together with the first sporadical field weeds like *Scleranthus annuus, Lithospermum arvense, and Linaria (L. vulgaris)*.

The NAP percentage curve, rising consistently from the beginning of the phase, reaches in its later part ca. 20%, based mostly on Gramineae, *Artemisia, Rumex acetosella*, and *Calluna* contributions. The quantitative input of herb anthropogenic vegetation, though not quite adequate for the scale of human activities suggested by changes in tree pollen curves, is certainly expressive enough to signal the first real change of forest/open land ratio. The taxon diversity rises abruptly, reaching values similar to those found in early historical times (Fig. 9.10).

A not very distinct episode of reduced human activities in the Lake Gościąż region, lasting slightly over 100 yr, separates phase 10 from the following phase 11 (Fig. 9.13). It is indicated mostly by somewhat decreased herb pollen influx and percentages, by rises of *Betula, Populus*, and then *Quercus* pollen values, and by depressions in anthropogenic indicators (*Rumex acetosella, Plantago lanceolata, Artemisia*, Chenopodiaceae). No evidence of agriculture beside the first single pollen grain of *Secale* was found in that diagram section. This episode probably documents some movements in the settlement pattern within the region and the temporary abandonment of grounds situated closer to the lake.

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**Fig. 9.14.** Lake Gościąż, profile G1/87. Section of pollen-influx diagram with evidence of Trzciniec, Lusatian, and Roman settlements, selected major pollen types. For other explanations see Figs 9.8 and 9.9.
Phase 11 (3020–2500 cal BP = 2910–2480 $^{14}$C BP)

This settlement phase (Fig. 9.13) is distinguished by the record of changes in forest communities comparable in scale to that of early historical times. The changes progressing continuously throughout the whole phase include declines of Fraxinus and Ulmus, and reduction of Taxus and Acer to single occurrences. Populus disappears in the middle of phase, and Carpinus, Quercus, and Corylus decreases progressively, especially in its later part. Betula and Pinus together with Alnus dominate absolutely, as confirmed by pollen influx (Fig. 9.14).

The record of changes in herb vegetation is rather striking: NAP influx, higher in the early and middle parts of phase, lowers towards the end, resulting from the progressively decreasing input of Artemisia, Rumex acetosella, and Plantago lanceolata pollen. Sporadic dry-grassland pollen taxa present at the beginning of the phase and later disappearing gradually include Lychnis viscaria -t., Helianthemum nummularium -t., then Centaurea scabiosa -t., Pulsatilla vulgaris -t., Scleranthus perennis and finally Jasione montana and Scleranthus annuus. Pteridium spores become scarce. This succession seems to reflect a progressive reduction of openings in dry pine and mixed pinewoods, which probably served earlier for animal grazing. Otherwise, the abundance of low-frequency pollen taxa originating probably from the fresh to wet grasslands is distinctive of the whole phase, in addition to substantial curves of Plantago lanceolata, Rumex acetosa -t., and Filipendula. This group includes Centaurea jacea -t., Alchemilla -t., Ranunculus acris -t., Rhinanthus, Cerasistium -t., Valeriana, and sporadic Linum catharticum, Geranium, Vicia cracca, Lotus, and Lychnis flo-cuculi. Most of them disappear around the end of the phase or shortly later. A similar occurrence is shown by the majority of “ecologically undefined” pollen taxa, rather frequent during the phase (Compositae SF Cichorioideae, Compositae SF Asteroideae, Aster -t., Anthemis -t., Potentilla -t., and others), suggesting their probable connection with the fresh-wet meadow communities.

This pattern may suggest some essential change in the ways of animal breeding; the shift from grazing mostly in different types of mixed pine forests dominant in the area to the intentional formation of the grasslands – “meadows” on selected surfaces more effective in fodder production – on more fertile, fresh to humid habitats. The grassland communities, formed gradually then, could be of a type of meadow communities classified nowadays within Molinio-Arrhenatheretea class.

The alderwoods might have been affected to some extent by these activities too; the distinct evidences of their disturbance, such as increases in frequencies of Frangula alnus, Rhamnus cathartica, Humulus, Solanum dulcamara, and Thalictrum (?), begin to decline still during the later part of phase 10.

The evidence of agriculture during this phase includes, beside a single Secale grain, pollen of Hordeum -t. and Triticum -t., regularly occurring throughout the whole phase, and some typical field weeds (Lithospernum arvense, Scleranthus annuus) appearing together with the increase of Rumex acetosella, which might grow in primitive cereal cultures as well as on other open sandy surfaces (Behre 1981). Striking is also the shape of Plantago lanceolata curve, forming peaks coincidently with Rumex acetosella. Plantago lanceolata may be an indicator species not only for fresh grasslands but also for fallows (Behre 1981), or may grow as a weed on arable grounds (Groenman-van Waetringe 1986, Regnell 1989).

The accompanying frequent fragments of charred tissues suggest that slash-and-burn techniques were still in use for the woodland clearance by the Lusatian population that settled then probably around the adjacent Telčza Lake (Figs 9.1 and 9.5, Chapter 9.1.1).

The ruderal vegetation, in spite of the Artemisia pollen curve being distinctly lower in the upper part of zone, has a good representation all the time (Plantago major, Polygonum aviculare, Xanthium, Carduus, and continuous Chenopodiaceae and Urtica cf. dioica pollen curves, as well as possibly some species of Rumex crispus -t.).

Some discrepancy in pollen record again exists between the evidence that wood-felling intensity clearly increased towards the end of the phase and the consequences of these activities. The latter seem altogether not very strong and, as shown by the main anthropogenetic indicator taxa, start decreasing before the end of the phase. No better explanation could be found for this imbalance than the assumption that we have to do with a record of regional location of settlement. In the older part of the phase the grounds used by man would then be situated closer to the lake, but later on the centre of activities would move towards more distant areas, where more fertile soils, still bearing remnants of deciduous woods, survived earlier waves of land occupation. This may be a good example of the relationships between the particular groups of pollen indicators we find in the centres of rather big lakes. The speculation presented above can find some grounds in archaeological evidence.

Anthropogenic phase 11 is followed in the pollen diagram by a ca. 500 yr record of forest regeneration documenting the retreat of people from the area (Fig. 9.13). The pollen record of this period documents a typical long-term succession of forest on post-farming grounds, starting with a maximum spread of Betula (up to 40% of total pollen), followed by a still more extensive development of dominant Pinus (up to 50%), and leading to some local regeneration of deciduous multispecies woods (small rises of Fraxinus, Ulmus, and Fagus pollen values) but with a distinct prevalence of Carpinus and Quercus. A very high AP influx by the end of the phase (its main components being first Betula, and Pinus and
later *Alnus, Carpinus,* and *Quercus*) may suggest not very dense forest structure. The NAP decline drastically both in percentages and diversity of taxa, all previously well represented human indicators falling to minimum values and the sporadical ones almost totally disappear.

All this means a strong reduction of grounds exploited by farmers and of all other open-land vegetation followed by intensive overgrowing processes. Noteworthy, however, are the regular occurrences of different cereal pollen types, including *Hordeum* s-l., *Triticum* s-l., *Secale,* and *Cannabis sativa* cf., in numbers similar to those during settlement phase 11. They suggest the existence of at least a small agricultural settlement through the whole time at a distance within the reach of the cereal pollen rain.

**Comparison of pollen evidence with the archaeological data on the development and decline of Lusatian Culture in the Lake Gościąż region**

The time span of phases 10–11 (3480–2500 cal BP = 3290–2480 ^14C BP) (Fig. 9.13) corresponds in the archaeological classification with the cultures of Middle to Late Bronze Age (III to V periods) and Early Iron Age. The most important culture of those times in central Poland, occurring here through the whole period in question, was the Lusatian Culture (Gardawski 1979, Dąbrowski & Gardawski 1979). The study area was also temporarily reached by populations of Bell Graves Culture and possibly also by East Pomeranian Culture (Bukowski 1979, Godłowski & Kozłowski 1979, Węgrzynowicz 1979). During the field search by Pelisiak and Rybicka (Chapter 9.1.1) 59 sites of Lusatian Culture, a few of them containing also some not very typical artefacts of Bell Grave and East Pomeranian Cultures, were found in the study area. Most of them were located around Lake Telążna (Fig. 9.7), forming a distinct centre ca. 7 km west of Lake Gościąż, and only 2 were located within the Na Jazach Lake complex (Chapter 9.1.1, Fig. 9.5). Pelisiak and Rybicka (Chapter 9.1.1) argue that the areas closest to the lake were probably temporarily exploited but not permanently settled during the times when Lusatian populations inhabited the region. Their permanent settlements must have been concentrated on more fertile grounds, e.g. centred around Lake Telążna.

According to the pollen record, the lands close to the lake were exploited during the time of Lusatian settlement at least twice. It is evidenced first from the phase 10 (ca. 3270–3150 cal BP), when some small corn fields and grazed open spaces must have existed close by. Later during the early to middle parts of phase 11 (ca. 3000–2730 cal BP), it is documented again by rises of ruderals and of indicators of diverse grassland types and of cereal cultivation. However, the devastation of deciduous woods within the region *sensu lato* reached its maximum only by the end of phase 11.

The following ca. 500 yr in the pollen diagram records the regeneration of forest, caused undoubtedly by the retreat of the settlement. This depopulation was a part of generally observed decline of Lusatian Culture in Poland around 2500–2400 cal BP (Godłowski & Kozłowski 1979, Niewiarowski 1995, and others). Its composite reasons include the invasion of Scythian tribes from the south, the expansion of Pomeranian and Baltic Cultures from the north (Fig. 9.7), and generally also the climate and water-level changes. During the last centuries BC the eastern part of Masovia was reached by tribes of Pomeranian and Bell Grave Cultures, both mixed with the impoverished remnant populations of the Lusatian Culture and degraded. On that basis the new Przeworska Culture started to arise, in some places already in the 2nd or 1st cent. BC, in other areas much later, as broadly discussed in the archaeological literature and not presented here in more detail.

**Roman Period**

Phase 12 (1990-ca. 1600 cal BP = 2050-ca. 1700 ^14C BP)

This rapid and brief settlement episode differs distinctly in its pollen record from the earlier phases (Fig. 9.13). It started about 40 yr before 1 AD (if not slightly earlier); its end has not been exactly defined because the sample interval was too large. The beginning is indicated by a rise of *Betula* and decreases of *Fraxinus* and *Ulmus,* followed immediately by a sharp reduction in *Carpinus* and *Alnus* pollen values.

The increases of the main human indicators occur in a succession, starting directly above the onset of the phase, with rises of Gramineae, *Plantago lanceolata,* and *Calluna vulgaris,* coincident with the appearance of *Hordeum* s-l. and beginning of the continuous *Secale* pollen curve; the increases of ruderals (*Artemisia, Urtica,* Chenopodiaceae, *Rubus acetosella*) and of *Secale,* and the occurrence of Cannabis sativa cf. starting ca. 50 yr later. This may mean first the exploitation of nearby grounds for grazing and later the movement of the settlement towards the lake. Between 1890 and 1715 cal BP the NAP influx reaches high values (Fig. 9.14), similar to those recorded in the 18th and 19th centuries. The taxa diversity, however, though distinctly higher than during the preceding and following forest regeneration phases, is substantially lower than during the periods of Lusatian and Neolithic settlements (Fig. 9.10).

The lists of taxa associated with both dry-sandy and fresh to humid grassland communities are much poorer than in the earlier settlement phases, though Gramineae and *Plantago lanceolata* form distinct maxima. Clearly increased is only the variety of pollen taxa undefined ecologically.

*Rubus acetosella* values rise substantially to levels higher than ever before (up to 1.8%). This increase, how-
ever, may have a new meaning here, as the most important and distinguishing feature of this phase is a conspicuous record of developing agriculture. Besides the regular appearance of *Triticum*–type pollen, *Secale* forms a continuous curve up to 1%. *Rumex acetosella* might have then entered crop cultures, becoming a common grain-field weed on sandy soils (Behre 1981, 1992). Phase 12 gives the first undoubted evidence of rye cultivation. Sporadically occurring *Secale* pollen was observed much earlier, in diagram sections between phases 10/11 and 11/12, both documenting reduced human activities in situ. More or less continuous evidence exists for cereals grown probably some distance from the lake. *Secale* might have accompanied those cultures as a field weed. Another important cultivated plant at that time was *Cannabis sativa*, its pollen values reaching nearly 2% (for a wider discussion on *Cannabis* and *Secale* see p. 292 and 293).

The rises of most typical ruderals (*Artemisia*, *Urtica dioica*–*t.*, and Chenopodiaceae) form a distinct phase. As a whole it is the record of a rather intensive though short land-use period, starting with a pre-phase when the settlers appeared within some distance from the lake. The maximum of farming activities lasted slightly more than 100–120 yr, and focused on agriculture rather than animal breeding. It was probably connected with the shift of settlement towards the lake.

Discussion of pollen and archaeological data on settlements from Roman period in the Lake Gościaż region

According to the archaeological chronology the settlement phase 12 corresponds with the Roman period (Roman Iron Age, 1 AD–375). At that time the Przeworska Culture was already strong and widespread, occupying southern, eastern, and central parts of Poland. However, in the late-Roman period the populations of Przeworska Culture retreated southwards, pushed from the north and north-east by the expanding tribes of the Wielbark Culture. The Vistula valley in its middle course was then a borderland between those two cultures. A cemetery with cinerary urns originating from that time was found at Korzeń (Fig. 9.7), east of Gostynin town (Gódłowski & Koslowski 1979).

However, the archaeological information from the study area itself is scanty and hardly supports the palaeoecological data. All except one of the 28 sites of Przeworska Culture found by Pelisiak and Rybicka (Chapter 9.1.1) are dispersed >5 km from Lake Gościaż, and most of them are situated on the right side of Vistula valley (Pelisiak & Rybicka, Chapter 9.1.1, Fig. 9.5). The authors suggest their possible connection with the Late La Tène period (the results of excavations at Telążna site 36). This could partly explain the regular presence of cereal pollen during the forest regeneration phase between phases 11 and 12. However, the sites may as well originate from different phases of the Roman period. The only fragment of ceramics found close to Lake Gościaż, representing most probably Przeworsk Culture pottery, can only confirm the penetration of the lake surroundings by people of those tribes, but it cannot help in any further interpretations of pollen data.

Unfortunately, the successional processes recorded in this and the next phases could not be followed in the diagram with the precision comparable to that in earlier sections because of deficient sediment sampling. The time intervals between samples are irregular and generally too large. In consequence also the age definition for the boundaries between recorded events is sometimes approximate.

Migration Period

Judging from the pollen record, during 600–700 years following phase 12 (approximately AD 300–900/1000), the region of Na Jazach Lakes seems to have been almost depopulated (Figs 9.13 and 9.15). This enabled the processes of forest succession to reproduce different types of woodlands in the area: the total AP influx is initially very high on account of successively occurring maxima of *Betula* and then of *Carpinus, Quercus*, and *Alnus*, but later it decreases drastically because of increasing woodland density (Fig. 9.16).

The expansion of pioneer corses on abandoned grounds documented by a huge peak of *Betula* (ca. 40%) was followed by the development of *Carpinus*-dominated woods, with some contribution of other deciduous trees. Alderwoods regenerated around the lakes. The pine-woods seem not to follow those forest regeneration processes to a higher extent. The percentage contribution of *Pinus* pollen is then lower, its pollen influx remains mostly similar to that during the preceding phase 12, and later it decreases significantly.

The NAP influx is very low, the pollen curves of nearby all human indicators are reduced to minimum values, or sporadic grains, some of which disappear periodically. The only exception is a substantial pollen curve of *Urtica dioica*, which, together with *Melampyrum* and *Calluna vulgaris* overgrew abandoned lands.

The depopulation period recorded between phases 12 and 13 (Fig. 9.15) coincides roughly (ca. AD 350–after 875) with the Migration period. The settlement recession seems to have been prolonged in the study area by at least 200 yr, or more within the early Early Medieval time (Fig. 9.15). The deficient samples resolution leaves only one pollen spectrum (sample 264, AD 875) to support such supposition, but the slow and poor economic development of the area during the next centuries (phase 13) makes it probable.

There are no archaeological findings from the Migration period in the study area. The central part of Poland was then probably very scarcely populated; the nearest
sites of late Przeworska Culture from the decline of 5th century are known from Łęczycyca and Kalisz region (Gódłowski 1989) (Fig. 9.7).

Medieval and Modern Periods

Phase 13 (ca. AD 875/1130 – ca. AD 1420)

The age of the lower phase boundary, contained between the levels dated at AD 875 and 1130 (Fig. 9.15) approximates the beginning of the Polish State.

The changes in pollen record express first the renewed felling of the deciduous woods (declines of Carpinus, Quercus, Fraxinus, and Tilia), followed from AD 1130 by the disturbance in alder and pinewoods (declines of Ulmus and Salix, rises of Alnus, Pinus, and Populus, and of Calluna and Pteridium), a part of cleared grounds being left unused (Betula rise).

The indicators of agriculture reappear but in low frequencies, the only continuous curves are formed by Secale cereale and Cannabis sativa cf., with Rumex acetosella possibly contributing as a weed to the cornfields. Triticum -t. and undefined cereal pollen are sporadic. A slight rise of ruderals (mostly Artemisia) is indicated, but more distinctly the rise in the frequencies and diversity of fresh-wet meadow taxa (Plantago lanceolata, Rumex acetosa -t., sporadic appearances of Ranunculus acris -t., Alchemilla -t., Filipendula) together with taxa undefined ecologically (Gramineae, Cyperaceae, sporadic Composi-
tae both SF.’s, Anthemis -t., Potentilla -t.). Because of poor time resolution the described changes in the lower part of the phase may only be treated as a signal of some economic activation of the region.

From AD 1225 pollen spectra have better time resolution (ca. 50 yr or less), and confirm some development of agriculture. However, the most evident changes of that time, such as a change in the ratio of deciduous forest trees to Betula or the increasing values of anthropogenic indicator taxa of high pollen productivity such as Secale or Rumex acetosella may document human activities in the region sensu lato, not necessarily in the lake surroundings.

Pollen data versus Early-Medieval sources

The general historical knowledge about the Early-Medieval development of eastern Masovia seems to corroborate the conclusions based on pollen-analytical evidence. The region was inhabited by Masovian ethnic groups from the time preceding the official foundation of the Polish State (AD 966) by ca. 180 yr (Szafran’ski 1983). Płock functioned already in the 9th century as the main centre of pagan rites for those tribes until it came to an end by the Christian conversion in AD 968. At the beginning of the 11th century Płock and Włocławek functioned as important strongholds ca. 45 km from each other, but Płock belonged to the estates of the Polish

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Fig. 9.16. Lake Gościąż, profile GI/87. Section of pollen-influx diagram with evidence of Medieval and Modern settlements, selected major pollen types. For other explanations see Figs 9.8 and 9.9.
king, and Włocławek was in possession of a noble family. The study area was probably situated within the borderland between those two estates. In the last decades of the 11th century Plock was the capital of Poland. During all those times the settlement must have existed in the region between those two active centres close by, with economic and trade routes crossing it.

During the 12th and 13th centuries the area in question was repeatedly invaded first by Pomeranian and next by Baltic and Prussian tribes (Fig. 9.7), and it was set in war and fires, but in spite of that the local settlement in the part of Gostynińskie Lake District discussed started to develop at least in the early 13th cent.: Dąb village is first mentioned in written sources from AD 1228 (Rybacka & Pelisiak, Chapter 9.1.2), and two other villages from the turn of 13/14 cent. These data correspond in time with evidence of economic development recorded in the upper part of phase 13.

Phase 14 (ca. AD 1420–1650)

From the beginning of the 15th cent. the pollen record reveals the drastic changes in the forest cover of the Lake Gościąż region (Fig. 9.15). It starts with the deep depression of the Betula pollen curve between ca. AD 1450 and 1550 (1600?), suggesting total clearings of birch- overgrown (postfarming?) grounds, followed after AD 1465 by more gradual declines of Carpinus, Fagus, Ulmus, Fraxinus, and Tilia, the latter three genera vanishing temporarily from pollen spectra or appearing only as single pollen grains by the end of the phase. The Quercus curve forms also a distinct depression, but its pollen maintains a substantial though minor role. The decreasing AP influx is composed mostly of Pinus with subdominant Alnus. Such a record documents total clearings of all still existing fragments of deciduous woods that persisted on more fertile grounds in this generally poor region. The NAP percentages rise, exceeding 20%. Most characteristic for this phase is the rise of indicators of agrarian activities, starting at the beginning of the phase and culminating from ca. AD 1625, after an episodic rise of Betula, Corylus, and Salix by the end of the 16th cent., connected possibly with some shift of land-use. The most pronounced are indicators of cereal cultivation: the dominant Secale cereale pollen, reaching ca. 3% around AD 1625, is accompanied by high values of Rumex acetosella and from AD 1525 by a continuous occurrence of Centaurea cyanus. Hordeum and Triticum -t. are also continuously represented. The cultivation of Fagopyrum is documented from AD 1625, and from AD 1675 Avena -t. starts appearing as a probable evidence of oat-growing. Besides cereals, Cannabis sativa was also grown at that time, its small peak around AD 1650–1625 suggesting possibility of hemp retting in the lake. The coincidently increased Humulus pollen frequencies might result from some difficulties in separation it from Cannabis, however the archival data support the probability of hops cultivation at that time as well.

The spread of ruderal vegetation is distinctly indicated through the whole phase. The diversity of fresh-wet meadow and ecologically undefined taxa increases (Trifolium pratense, Trifolium -t., Pimpinella, Cerastium -t., Lotus -t., Serratula -t., Geum -t.), and such main meadow taxa as Gramineae, Cyperaceae, and Plantago lanceolata show increased frequency from ca. AD 1650, but generally no particular extension of open grazed land is evidenced. It is highly probable that in view of a shortage of fertile grounds the grazing in the forest was still practiced, as is reported by Szczepański (1990).

Pollen record from historical times compared with the archival data

The economic activation of the study area recorded from the early 15th cent. coincides in time with the occupation of the Dobrzyń land by Teutonic Knights in AD 1409, when the Vistula left-bank terrains were included in the Kowal Castellany. The written sources document the development of population between Wistka and Dobigniewo, location of new villages on Teutonic law, and building of new churches and mills (Rybacka & Pelisiak, Chapter 9.1.2).

Of special interest is the first mention about Ruda village as an “industrial settlement” (Ruda means ore in Polish) in AD 1565 (Tomczak 1963, Guldon 1964, Goslar, Chapter 9.2.1), which proves that smelting works existed there at that time. The need for timber for that primitive industry caused undoubtedly an intensive tree-felling, as described from the changes in pollen diagram. The other demands for timber were provided by at least two known local water sawmills; the timber was also floated (Rybacka & Pelisiak, Chapter 9.1.2).

The brewery functioning at Duninów in 16th century (exact date of its foundation unknown) needed hops, resulting in the imposition of a tribute on peasants partly to be paid in hops to encourage its cultivation in the area. The tributes paid then also in hemp are reported from the neighbouring Gostynin Land (Szczepański 1990). Woollen cloth manufactures functioned at Dobigniewo (Tomczak 1963) and Duninów (Szafrański 1983) from the end of the 15th cent., for the prevalence of poor soils started sheep-breeding in the area. There existed also dye-works (Szafrański 1983); the production of the purple dye was a speciality of the whole Masovian region, started probably as early as in Medieval times, with an optimum in the 15th cent. and lasting at least until the 17th cent. (Bystroni 1976). The dye was exported to many countries, e.g. Italy, The Netherlands, Turkey, and others. It was produced from the maggots of a beetle Porphyrophora polonica feeding preferably on roots of Scleranthus perennis (Gloger 1958), but also on other Ca-
ryophyllaceae. In this respect the abundance of sandy soils in the area was an advantage. The occurrence of *Scleranthus perennis* is confirmed by pollen from AD 1625, and later.

Generally, the time of a rather good situation in the rural economy in the Gostynin and Kowal Lands lasted till the end of the 16th cent., and during the 17th cent. it started to deteriorate. The degradation of the country had complex reasons: not only tributes were too high, but also the relation between the agriculture and animal husbandry was wrong; poor soils were overexploited by corn cultivation, for because of too low animal stock they were not fertilized enough and could no more yield enough crop. Peasants began to leave for towns (Szczepeński 1990), and this situation affected in turn the towns too by reduction of trade and handicraft. The deepest crisis was reached after the Swedish invasion in 1665–60, when army troops brought pests and epidemics devastat-

Fig. 9.17. Lake Gościąź, profile G1/87. Synthetic pollen diagram showing the contribution of different types of anthropogenic vegetation in the successive human phases. The grouping, following roughly Behre (1981) and Berglund & Ralska-Jasiewiczowa (1986), has been slightly modified to fit the vegetation types distinguished in this chapter. However no taxa are included in two different groups as in the case of the tables. The following taxa groups are represented: 1 – cultivated land, 2 – ruderals, 3 – grazed woodland, 4 – fresh-wet grasslands (meadows), 5 – dry grasslands (pastures), 6 – mantle/outskirt shrubs, 7 – taxa ecologically undefined (family or genus type rank mostly), but favoured for human use.
ing the population. However, local villages survived, and in AD 1674 55 inhabitants in Dałb paid rents, and brewery and iron-works of the region were functioning (Rybicka & Pelisiak, Chapter 9.1.2). The time of reduced economic activities is indicated between AD 1675 and 1760 by a depression in NAP curve caused by declines of all cultivated, weed, and ruderal pollen taxa and by rises of Quercus, Salix, Populus, and Juniperus pollen values as well as of herbs overgrowing forest openings (like Melampyrum and Calluna).

Phase 15 (ca. 1800–1985 AD)

The distinct signs of economic restoration of the study area only appear in pollen diagram around the beginning of 19th cent., but the section of the pollen diagram between 1625 and 1816 has again a very poor time resolution (Fig. 9.15). The next pollen spectra up to 1887 register the rise of “economic boom” (in proportions adequate for the regional possibilities), until the time of the 2nd World War, and the following recession in consequence of depopulation and reforestation of Na Jazach Lakes surroundings. However, the youngest period of settlement history in this area from 1663 till today has been reconstructed with a very fine time resolution basing on data from the cores collected by the technique of freezing in situ (Goslar, Chapter 9.2.1). This story is presented and discussed in detail by Ralska-Jasiewiczowa and van Geel in Chapter 9.2.4.

**Development of different anthropogenic vegetation types through consecutive settlement phases, and comments on some selected taxa**

This chapter aims to trace the development of particular anthropogenic vegetation types recorded in the Lake Gościąż profile G1/87 through the subsequent phases of human activities from Mesolithic till modern times. Some discussion on more interesting or controversial pollen taxa is also included.

The pollen data are presented in tables listing taxa typical for the particular vegetation types. The authors are fully aware of the deficiencies of such tables. The grouping, especially when taxa of different taxonomic rank are concerned, could only be very approximate and simplified, as the majority of taxa, even those treated as main cultural indicators, can occur in fact in several different vegetation types (Behre 1981). In some such cases, when we have to do with a species of a broad ecological spectrum (e.g. *Rumex acetosella*), or a higher-rank taxon covering species of different ecological attachments, this taxon is placed parallel in different tables. But, even then, only the most common ecological settings of a taxon are pointed out.

The picture we get in this way is rough and generalised, but it makes the long-term changes of anthropogenic vegetation easily readable, though with inevitable lack of precision.

The subdivision into phases used in tables has partly been simplified as compared with the human phases distinguished in pollen diagram (Figs 9.8, 9.13, and 9.15). The Neolithic phases are grouped in 3 columns: phases 3/4 (human presence weakly indicated, in some distance from the lake), phases 5/6 (human impact distinct, close to the lake), and phase 7 (another Neolithic culture). Also both Early Bronze phases (8/9), Lusatian phases (10/11), and phases of historical to modern times (14/15) are treated jointly.

**Vegetation of disturbed/grazed forests (Table 9.6)**

Table 9.6 includes taxa overgrowing places within the forests of different types (from mixed deciduous woods on moderately fertile and humid soils to mixed pine and pine woods on rather poor and dry soils), disturbed by man in many ways – e.g. by tree pollarding/coppicing, felling, burning, and forest grazing.

The taxa diversity does not change very much in subsequent columns. It is richer during the later stages of the

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**Table 9.6. Vegetation of disturbed/grazed forests.**

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Mesol</th>
<th>Neol</th>
<th>EBr</th>
<th>Lus</th>
<th>Rom</th>
<th>EMed</th>
<th>His/Mod</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BO-early AT</td>
<td>1</td>
<td>2</td>
<td>3/4</td>
<td>5/6</td>
<td>7</td>
<td>8/9</td>
</tr>
<tr>
<td><em>Melampyrum</em></td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>+</td>
</tr>
<tr>
<td><em>Pteridium aquilinum</em></td>
<td>+</td>
<td>+</td>
<td>●</td>
<td>●</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Mercurialis perennis</em></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>+</td>
</tr>
<tr>
<td><em>Allium ursinum</em></td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td><em>Anemone</em></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Polypodium vulgare</em></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Taxus baccata</em></td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>●</td>
<td>X</td>
<td>+</td>
</tr>
</tbody>
</table>

+ – sporadic occurrence, X – regular occurrence, ● – abundant occurrence, ( ) – cultivated?

Mesol – Mesolithic, Neol – Neolithic, EBr – Early Bronze, Lus – Lusatian, Rom – Roman, EMed – Early Medieval, His/Mod – Historical to Modern
Neolithic (5,6,6) and Lusatian settlements (7) and lower in the Mesolithic (4,5) and Roman and historical times (4,4,4). However, the frequencies of particular taxa are distinctly differentiated.

Pine forests on poor soils were then mostly affected (Pteridium aquilinum, Melampyrum, Polypodium vulgare; see also Calluna vulgaris in Table 9.8). The highest amounts of Pteridium aquilinum spores in phases 1 and 2 together with Melampyrum shows clearly that Mesolithic populations used fire as a main tool in forest “management” (Jacobi et al. 1976, Latałowa 1992a). Pteridium never appeared again in such abundance. Deciduous woods might have also been penetrated (Mercurialis perennis, Allium ursinum). During the later stages from Neolithic II till the Roman period, the nearly continuous and sometimes quite abundant (Lusatian phases) occurrence of Melampyrum together with Peridium and Calluna may document animal grazing in the pine and mixed forests but burning of forest herb layer as well (Turner et al. 1993). The Neolithic populations disturbed also humid deciduous forests, as is suggested by regular presence of Mercurialis perennis during all Neolithic phases. The last appearances of Mercurialis and Allium ursinum are noted during the Lusatian phase.

An interesting connection with the anthropogenic forest disturbance is shown by Taxus. Its pollen, recorded first in the Mesolithic phase 2, occurs rather regularly but in small amounts during the earlier Neolithic phases, rises slightly at the decline of “land occupation” phase 6, and then forms a distinct maximum in the middle of phase 7. In the Early Bronze and Lusatian phases Taxus pollen still occurs regularly but never increases in frequencies. Later it appears only rarely.

A similar Taxus spread was observed in connection with Neolithic settlements in several pollen diagrams from the British Isles (Watts 1984, Bennett 1988, O’Connell et al. 1988, Peglar et al. 1988). A simple comparison of successional processes in areas belonging to different climatic regions, may cause many doubts. However, such processes are known from Poland still today: Taxus bacata, growing mostly in the understory of Fagetalia and Alnetalia forests, can escape from the wood to overgrow an abandoned pastureland. Pfabe (1950) reports such a case from the northern margin of Kraków-Częstochowa Upland in SW Poland, where Taxus thickets of ca. 200 specimens covered an old pasture in a wood clearing.

From Roman time on, the indicators of forest grazing are sporadic during the phases of active settlement; their values increase rather when human activities weaken, e.g. during the Migration period, the early Early Medieval time, or in 18th cent. (Figs 9.15 and 9.16). Only Calluna abundance increases in the Lusatian and historical times as the indicator of the spread and stabilization of poor acidic pastures and heaths.

### Table 9.7. Vegetation of forest mantle and outskirt communities (Rhamno-Prunetea, Trifolio-Geranietea).

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Arch. periods</th>
<th>BO-early AT</th>
<th>Mesol 1</th>
<th>2</th>
<th>3/4</th>
<th>5/6</th>
<th>7</th>
<th>8/9</th>
<th>10/11</th>
<th>12</th>
<th>13</th>
<th>14/15</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Human phases</td>
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<tr>
<td>Frangula alnus</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
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<td></td>
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</tr>
<tr>
<td>Rhannus catharticus</td>
<td></td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>+</td>
<td></td>
<td></td>
<td>+</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viburnum opulus</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
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<tr>
<td>Sambucus nigra - t.</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
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</tr>
<tr>
<td>Sorbus aucuparia</td>
<td></td>
<td>+</td>
<td>+</td>
<td>X</td>
<td></td>
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<td></td>
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<td>Cornus sanguinea</td>
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<tr>
<td>Rubus</td>
<td></td>
<td>+</td>
<td>+</td>
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<td>Genista - t.</td>
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<tr>
<td>Humulus</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>Melampyrum</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
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<td>Calystegia sepium</td>
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<tr>
<td>Anthericum</td>
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<tr>
<td>Hypericum</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Geranium</td>
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<td>+</td>
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<td></td>
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</tr>
<tr>
<td>Coronilla varia</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Campanula - t.</td>
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<td>+</td>
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<td></td>
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<tr>
<td>Pimpinella</td>
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<td>+</td>
<td>+</td>
<td>+</td>
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For explanations see Tab. 9.6
Vegetation of forest mantle and outskirt communities (Table 9.7)

Table 9.7 contains taxa belonging to the undisturbed forest communities as well as those that may participate in the advanced overgrowing stages of forest openings. All those taxa are typical today for the forest mantle and outskirt vegetation formed at the forest/open-land ecotone (*Rhamno-Prunetea* Rives Godet et Carb. 1961, *Trifolio-Geranieta* Müll 1962 (Brzeg 1989)). Table 9.7 may therefore illustrate the development of such type of vegetation in connection with prehistoric human activities.

This problem, taken up by Troels-Smith as early as 1955, was then extensively discussed by Groenman-van Waateringe (1976). Neolithic people were assumed to make use of natural growth of forest understory shrubs in places where trees were felled down or coppiced in order to form enclosures to protect arable grounds or pastures from wild animals. Natural hedges would be formed in that way, their specific herb vegetation originating mostly from the forest herb layer. They gave an additional profit by production of edible fruits. Such plant communities have been widespread in Poland till recent times (Matuszkiewicz 1981, Brzeg 1989). Some of their characteristic plants are repeatedly documented as pollen, seeds, or charcoal in connection with the Neolithic settlements (e.g. *Rhamnus catharticus, Cornus sanguinea, Frangula alnus, Viburnum opulus, Sambucus nigra, Sorbus aucuparia, Acer (campestre), Rubus ssp., Humulus lupulus, Hypericum, Geranium, Allium ursinum, Anemone nemorosa*, etc.) (Groenman-van Waateringe 1986, Wasylikowa et al. 1991). These taxa occur also in the Lake Gościczeń pollen diagram. They are listed mostly in Table 9.7 but also in Table 9.6, and most of them start appearing coincidently with the earliest evidence of prehistoric man. Strikingly, a substantial increase of their diversity starts in connection with the appearance of Mesolithic populations (5 taxa in BÖ/early AT, before Mesolithic penetrations, 9 during the phase Mes 1, and 10 during Mes 2 – see also Tab. 9.6). This may raise again the discussion of a possible “woodland management” by Mesolithic tribes in order to get a more abundant herb/understory browse for wild animals (Jacob et al. 1976). The repeated burning is supposed to be used to obtain this effect, but the deciduous wood is not so easy to burn, so the girdling of trees might have been another way to let the light penetrate down to the forest herb layer (Göransson 1986 and earlier papers, Latalowa 1992b). The question of method applied cannot be answered here, but the essence of the problem seems to be evidenced by our pollen data.

During the Neolithic settlement phases the diversity of forest-mantle taxa still increases (Neol. 3/4 – 12 taxa), especially when settlement was supposed to approach the lake (Neol. 5/6 – 14 taxa), and some taxa became also more frequent than (*Frangula alnus, Rhamnus catharticus, Sorbus aucuparia, Humulus, Melampyrum*). However, to fit the image of thorny hedges protecting fields and pastures of Neolithic settlers, such taxa as *Rumus, Crataegus, Rosa* (Rosaceae undiff.) would be required, but evidence is lacking.

This type of vegetation might have been still relatively widespread during the Early Bronze and Lusatian settlements (10 and 12 taxa), but less and less common later, in connection with changing management methods, and perhaps also in consequence of strong soil degradation.

Vegetation of grasslands on xeric/alkaline to sandy soils (Table 9.8)

Table 9.8 includes pollen taxa that might represent xeric grasslands and swards of habitats on more alkaline (recent *Festuco-Brometea* Br.-Bl. et T. Tx. (1943) class) to rather acidic, poor sandy soils (*Sanguisorba minor, Helianthemum ssp.*, or *Centaurea scabiosa, Plantago media* can occur in the fresh grassland communities as well, but just xeric grasslands were the type vegetation assumed to persist on special habitats in the early-Holocene expansion of forests, and *Plantago media* can be traced in the pollen diagram all the way from the Younger Dryas up. The group of taxa discussed cannot be well separated from those forming the herb layer in the forest mantle and outskirt shrubs (Tab. 9.7). The number of taxa rises first in phase 2, when Mesolithic people created more openings in the woods, then once again in connection with the middle Neolithic “land-occupation” close to the lake (phase Neol 5/6). During the Lusatian phase (10/11) *Plantago media* might have also entered the increasing meadow-like fresh grasslands. Following the processes of soil degradation the vegetation type discussed later lost any meaning.

The group of grassland taxa of poor acidic soils shows somewhat different pattern. Evidently the patches of heliophyte vegetation containing such taxa were naturally present in Boreal forests of looser structure (7 taxa), and they later were limited by the development of dense deciduous woods (AT – 2 taxa). The only taxa of this group documented through the phases 1 and 2 are *Rumex acetosella* and *Calluna vulgaris*. It is rather astonishing that the late Mesolithic populations, which are known to prefer camping in rather open and dry pine woods did not contribute more to the extension of this vegetation type. The number of heliophyte taxa of sandy soils reaches a...
maximum in the middle Neolithic phase 5/6 (8) and decreases only slightly in the following late Neolithic phase (6), whereas the heliophyte taxa of richer soils practically disappear then. It might be the effect of a different economy of the Comb-Pitted Pottery population that settled at the lake during phase 7 (less cattle grazing?).

In the younger phases, besides some rise during the Lusatian settlement (phases 10/11), the number of acidic grassland taxa is low, although the frequencies of the few remaining ones rather increase. This concerns again the same species: *Rumex acetosella*, which expanded as well in other types of poor soil communities (e.g. segetal weed communities), and *Calluna vulgaris* which together with *Juniperus communis* document the spread of heath patches. The appearance of taxa characteristic for the *Sedo-Scleranthea* class (*Scleranthus perennis, Sedum, Jasione montana*) in historical time (phase 15) could have some relationship with the development of dye-manufactures connected with woolen-cloth production. The commonly used purple dye was then obtained from beetles feeding on sandy soil Caryophyllaceae species (see p. 283, 284).

Table 9.8. Vegetation of grasslands on xeric/alkaline (*Festuco-Brometea*) to sandy soils (*Sedo-Scleranthea, Nardo-Callunetea*).

<table>
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<tr>
<th>Taxa</th>
<th>Arch. periods</th>
<th>BO-early AT</th>
<th>Mesol</th>
<th>Neol</th>
<th>EBr</th>
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</table>

For explanations see Tab. 9.6

Vegetation of fresh to wet grassland communities (Table 9.9)

Table 9.9 is meant to represent the fresh to humid grassland communities, which were the nuclei of subsequently formed meadows of *Molinio-Arrhenatheretea* Tx. 1937 class (Matuszkiewicz 1981). Many genus-type or species-type taxa placed here may represent meadow grassland species as well as species of other affinities, but their behaviour in the diagram (e.g. coincident rises of *Plantago lanceolata* and of *Anthemis -t., Potentilla -t.*, etc.) suggests their essential connection with the communities of meadow type.

The number of taxa in particular phases is rather variable. It apparently rises during the Mesolithic (10 and 10 in phases 1 and 2), and earlier Neolithic (9 in phase 3/4) as compared to the earlier times (5 in BO and 2 in early AT), suggesting the creation of gaps in the forest where light-demanding herb vegetation could develop. During the Neolithic phases 5/6 following the *Ulmus* fall and the land occupation at the lake, the number of taxa is doubled (18), and it is nearly as high as recorded later during the Lusatian phases (20). It is hard to define the differences
between middle Neolithic and Lusatian taxa assemblages. The Lusatian list contains some new taxa like *Linum catharticum*, *Vicia cracca* cf., *Symphytum* (?) or *Cerastium* -t., and some of them (e.g. *Alchemilla* type) appear then regularly in all younger human phases. However, the taxa pattern of the Lusatian phase is substantially different from the middle Neolithic because of increased frequencies of many broad, ecologically undefined taxa in the rank of family or genus type, known as largely contributing to meadow communities (Gramineae, Umbelliferae, Compositae SF. Cichorioideae and SF. Asteroidae, *Fili pendula*, and a few others (see the bottom of Tab. 9.9 and Fig. 9.13).

The widely discussed history of meadow formation (Knörzer 1975, Greig 1984, and others) is still not well recognized. If we strictly use the species combination of

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Arch. periods</th>
<th>BO-early AT</th>
<th>Mesol</th>
<th>Neol</th>
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<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Lythrum</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Polygonum bistorta</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valeriana</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

**Table 9.9. Vegetation of fresh to wet grassland communities (Molinio-Arrhenatheretea).**

<table>
<thead>
<tr>
<th>Taxa number</th>
<th>5</th>
<th>2</th>
<th>10</th>
<th>10</th>
<th>9</th>
<th>18</th>
<th>10</th>
<th>10</th>
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<th>8</th>
<th>7</th>
<th>23</th>
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**Undefined:**

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<th>Gramineae</th>
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<th>X</th>
<th>X</th>
<th>X</th>
<th>X</th>
<th>X</th>
<th>X</th>
<th>X</th>
</tr>
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<tr>
<td>Umbelliferae</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>+</td>
<td>+</td>
</tr>
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<td>Comp. SF. Asteroid.</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<td>+</td>
</tr>
<tr>
<td>Comp. SF. Cich.</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Filipendula</td>
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<td>X</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>+</td>
<td>X</td>
</tr>
</tbody>
</table>

**Taxa number**

| 3 | 3 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 3 | 5 | 5 | 5 |

For explanations see Tab. 9.6
the present hay-meadows as an indication of meadow formation, the macrofossil evidence of meadows in the Neolithic is practically absent from central Europe (Behre & Jacomet 1991). However, the presence of macrofossils of wet marsh/meadow species being reported from Neolithic sites, e.g. from Switzerland or The Netherlands (van Zeist 1991) and the pollen records often suggest extensive Neolithic clearings for animal grazing. The information on macrofossils of grassland species from the Bronze Age archaeological sites is sparse, the hay-meadow species are still absent, and the species spectra resemble often those of Neolithic sites (van Zeist 1991). Behre & Jacomet (1991) explain it by the long-lasting transformation processes succeeding from pastures to hay-meadows, stimulated later by mowing. The pre-Roman Iron Age is assumed as the time when hay-meadows began to arise (Knörzer 1975, Greig 1984).

All the above listed taxa in the rank of family, genus -t., genus, or species t. showing increased frequencies in Lusatian phase 11 may represent the fresh-wet grasslands of *Molinio-Arrhenatheretea* type. Their rises are signalled already in phase 10, and their presence continues till the end of phase 11 or only a little longer. In the authors’ opinion this might express the formation of grasslands in the type of fresh-wet meadows already during the time of Lusatian settlement, though mowing was not necessarily practised then.

The number of wet/fresh grassland taxa becomes distinctly impoverished in the records of the Roman period and Early Medieval time. This might result from the occupation of more fertile grounds by agriculture, the progressive degradation of soils, and a weak population density around the lake. In the later (historical to modern) times, when the lake surroundings were deforested and settled, the number of meadow taxa is at its maximum.

**Vegetation of ruderal/field-weed communities (Table 9.10)**

Table 9.10 contains taxa of former *Rudero-Secalinetea* class (Braun-Blanquet 1936), later divided into several

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Arch. periods</th>
<th>BO-early AT</th>
<th>Mesol</th>
<th>Neol</th>
<th>EBr</th>
<th>Lus</th>
<th>Rom</th>
<th>EMed</th>
<th>His/Mod</th>
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<tr>
<td></td>
<td>Human phases</td>
<td>1 2 3/4 5/6 7 8/9 10/11 12 13 14/15</td>
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<td></td>
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</tr>
<tr>
<td>Plantaginetea majoris</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Plantago major</td>
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<td>+</td>
<td>+</td>
<td>X</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Polygonum aviculare</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Rumex crispus -t.</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>+</td>
<td>+</td>
<td>X</td>
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<td>Artemisietea</td>
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<td>●</td>
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<td>●</td>
<td>X</td>
<td>●</td>
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<td>+</td>
<td>+</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Carduus</td>
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<td>+</td>
<td>+</td>
<td>+</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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</tr>
<tr>
<td>Stellaria media cf.</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Xanthium</td>
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<td>+</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Linaria</td>
<td>+</td>
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<td>+</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Urtica urens</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Secalietea</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rumex acetosella</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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</tr>
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<td>Scleranthus annuus</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Lithospermum arv.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>Polygonum persic.</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Centaurea cyanus</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Bilderdikia con. -t.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Anthoceros punctatus</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>8</td>
<td>7</td>
<td>6</td>
<td>7</td>
<td>14</td>
</tr>
</tbody>
</table>

For explanations see Tab. 9.6

The table is strikingly poor and stable except for the Lusatian phase and historical times. The foot-path vegetation (Plantagineta majoris) is documented by three taxa only, from the earliest Neolithic phases (3/4) (stable occurrence of Plantago major and Rumex crispus -t. with occasionally appearing Polygonum aviculare) till recent times.

The main taxa of Artemisietea class (Artemisia, Urtica dioica) were present in natural communities through the entire Holocene and earlier. They show distinctly increased though oscillating frequencies in all human phases from Mesolithic on, accompanied by a small enrichment of taxa number during the Lusatian settlement and historical times.

The annual ruderals/rootcrop weeds group is practically represented by chenopods only, with very few other taxa (Xanthium, Urtica urens, Stellaria media cf.), appearing in the Lusatian phases and in the youngest historical period.

The group of segetal weeds practically does not exist till the Lusatian phase, as earlier its only representative is Rumex acetosella, a species of a broad ecological spectrum. The appearance of some segetal weeds (Scleranthus annuus, Lithospermum arvense) just during the Lusatian phase is astonishing, as most probably the fields were then mostly located at some distance from the lake, and the evidence of cereal growing is rather poor. Those weeds do not reappear with the well documented development of Secale cultivation in the Roman period. The corn-field weeds are best represented in the historical up to recent times by abundant Centaurea cyanus, sporadic Bilderdijkstra convolvulus, Polygonum persicaria, and few other pollen taxa together with spores of the therophyte liverwort Anthoceros punctatus, which lives in moist field depressions.

The overall representation of weeds and ruderals during the time of Lusatian settlements approximates the numbers (14) noted again in historical times only (17), while it is much lower in all other phases (5–8).

Cultivated and planted plants (Table 9.11)

Table 9.11 contains pollen taxa ranging from field crop plants to fruit and decorative trees and shrubs. Four taxa susceptible to various interpretations have been included here, because of their position in the diagram and way of occurrence. These are Solanum nigrum -t., including S. tuberosum, which appears exactly at the time when potatoes were introduced in the study region (see also Chapter 9.2.4); Humulus lupulus cf., placed also in Table

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Arch. periods</th>
<th>BO-early AT</th>
<th>Mesol</th>
<th>Neol</th>
<th>EBr</th>
<th>Lus</th>
<th>Rom</th>
<th>EMed</th>
<th>His/Mod</th>
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<tr>
<td></td>
<td>Human phases</td>
<td></td>
<td>1/2</td>
<td>3/4</td>
<td>5/6</td>
<td>7</td>
<td>8/9</td>
<td>10/11</td>
<td>12</td>
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<tr>
<td>Cerealia -t.</td>
<td>(+)</td>
<td>(+)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>+</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Triticum -t.</td>
<td>(+) (+)</td>
<td>(+) (+)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>+</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Hordeum -t.</td>
<td>(+)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>X</td>
<td>+</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Secale cereale</td>
<td></td>
<td>+●X</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Avena -t.</td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Vitis vinifera</td>
<td></td>
<td>(+)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Cannabis sativa cf.</td>
<td></td>
<td></td>
<td>+</td>
<td>+●</td>
<td>+●</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Fagopyrum</td>
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<td></td>
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<td>Juglandes</td>
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<tr>
<td>Malus cf.?</td>
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<td>Medicago sativa</td>
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<td>Zea mays</td>
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<td>Solanum nigrum -t.</td>
<td></td>
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<tr>
<td>Syringa vulgaris</td>
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<td>Aesculus hipp.</td>
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<td>Glaucom flavum</td>
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<td></td>
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</tr>
<tr>
<td>(Humulus ?)</td>
<td>(+) (+)</td>
<td>(+) (+)</td>
<td>(+)</td>
<td>(+)</td>
<td>(+)</td>
<td>(+)</td>
<td>(+)</td>
<td>+</td>
<td>+●</td>
</tr>
<tr>
<td>(Cruciferae ?)</td>
<td></td>
<td>(+) (+)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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</tr>
<tr>
<td>Taxa number</td>
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<td>(5) (3)</td>
<td>3(4)</td>
<td>5(6)</td>
<td>4(5)</td>
<td>4(5)</td>
<td>5(6)</td>
<td>6</td>
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</tr>
</tbody>
</table>

For explanations see Tab. 9.6
9.7, but showing a distinct rise in the historical time: Cruciferae, their only substantial increase occurring in historical time too, and *Vitis vinifera*.

The record of Cerealia starts with sporadic big Gramineae pollen grains of the type of *Hordeum*, *Triticum*, and Cerealia undiff., found in both Mesolithic phases and also earlier. As mentioned by Ralska-Jasiewiczowa and van Geel (1992) those pollen grains, especially *Hordeum* -t., may originate from wild grass species (see Beug 1961, Andersen 1979). “Cereal-like” Gramineae pollen was sometimes observed in pre-agricultural zones of pollen diagrams; speculations on its origin include possibilities of polyploid forms or of wild Gramineae species not identified palynologically so far.

In Mesolithic phase 2 the transport of single cereal pollen from the nearest early-Neolithic settlements cannot be excluded (Chapter 9.1.1). This possibility should also be taken into account regarding Neolithic phases 3/4. In the following Neolithic phases 5/6 and 7 the representation of cereals is substantial enough to suggest agricultural practices proceeding in the study region.

From Early Bronze phases the cereal evidence is practically absent, and only the Lusatian and Roman phases give a rather reliable evidence of cereal cultivation. This includes *Triticum* -t. and *Hordeum* -t. during the Lusatian settlement, in agreement with the general palaeoethnobotanic knowledge about the grain cultivation during this period (Wasylikowa et al. 1991).

During the Roman phase 12 *Triticum* was grown and *Avena* -t. pollen appears for the first time, but *Secale cereale* undoubtedly became the dominant cultivated cereal.

Increased pollen frequencies of *Secale* were observed in pollen diagrams from different parts of Poland in sections corresponding to the Roman period (Noryśkiewicz & Ralska-Jasiewiczowa 1989, Bińka et al. 1991, Latalowa 1992b, Ralska-Jasiewiczowa & Latalowa 1996), and in some sites from S-Poland even earlier (Ralska-Jasiewiczowa 1980, Szczepanek 1982). The hypothesis assuming the change of rye status from weed to cultivated plant was discussed in detail by Behre (1992). On the basis of macrofossil finds he specifies the time of this change from the pre-Roman to the Roman periods, but the general expansion of *Secale* cultivation in central Europe assuming in Medieval time only. Some of his data, however, document the cultivation of rye as a main crop on poor soils in NW Germany since the Roman period. The macrofossil data from Poland compiled by Lityński-Zajac (1997) suggest that rye was grown in South Poland as early as the late pre-Roman period, it was present (?) in the grain-fields of middle-Polish areas occupied by the Przeworska Culture during the Roman period, and its role was substantial in the territories of the West Balt Culture (NW Poland) in the late Roman period. Wasylikowa et al. (1991) concludes from both macrofossil and pollen evidence that rye cultivation, also as monocultures, was practiced in the Roman period in all of Poland. The data from Lake Gościąz fit this pattern quite well. The Early-Medieval record (phase 13) gives evidence of rather poorly developed agriculture with the continuous occurrence of *Secale* alone, and only the later historical and modern phases (14 and 15) document the presence of all cereal types in cultivation, with *Secale* being still the dominant crop.

The origin of a single *Vitis* pollen grain found in middle Neolithic phase 6 is unclear. It seems rather well documented by now that wild *Vitis vinifera* ssp. *sylvestris* occurred in different parts of Poland during the warmest periods of the Holocene, growing in the humid forests, probably of alderwood type (Latalowa 1976, Ralska-Jasiewiczowa 1980, Madeyska 1989, Bińka et al. 1991). At Błędowo Lake (central Masovia, ca. 100 km to the east of Lake Gościąz, Bińka et al. 1991, see Chapter 8.3), two of *Vitis* pollen finds coincide with Neolithic phases, as in the Lake Gościąz profile. No evidence from the archaeologic sites of Poland exists, however, about the cultivation of wine until Early-Medieval times (Wasylikowa et al. 1991). Some more evidence is still needed to try to find any explanation to those pollen finds.

*Malus* cf. pollen in Early Bronze phase (Fig. 9.14) possibly could have been brought from a wild *Malus* stand. *Malus sylvestris* seeds are often found in archaeological sites from former Czechoslovakia and also from Poland since Neolithic times (Wasylikowa et al. 1991). One *Juglans* pollen grain around the onset of Przeworska Culture phase 12 at ca. AD 1 has no explanation, as the earliest data about the cultivation of *Juglans regia* in Poland comes from the Early-Medieval time (Wasylikowa et al. 1991).

Table 9.11 includes also the record of *Humulus lupulus* cf. and *Cannabis sativa* cf. pollen. *Humulus*, as a native component of humid woods, was present in the area from the beginning of the Holocene, well before the formation of alderwoods. However, a distinct rise in its pollen curve in historical times only (phase 15) was probably the effect of its cultivation, connected with the large-scale production of beer. The common macrofossil finds and written sources evidence the cultivation of hops in Germany from early-Medieval times (9/10 cent. AD, Behre 1984). According to Nowiński (1970), on the territories inhabited by Slavs beer-brewing was known much earlier, in pre-Christian times. It seems reasonable to assume that hops were then gathered from their wild stands, in our case abundant in alderwoods surrounding the lakes. At any rate our pollen data give no grounds for speculation about intentional growing of *Humulus* before the 15th century.

The identification of *Cannabis sativa* cf., which in fact means its separation from *Humulus lupulus* pollen, was based mostly on pore protrusion, with the pollen-grain size and wall thickness treated as complementary
diagnostic features (Godwin 1967, French & Moore 1986). Though always difficult (see Whittington & Gordon 1987, Whittington & Edwards 1989), it seems in this case to be reasonably reliable, giving at least approximate contribution of both taxa to the pollen spectra. In the Lake Gościc¸aˇz profile Cannabis type begins to appear sporadically from the later part of Lusatian phase 11 (ca. 2700 cal BP = 2500 14C BP, Hallstatt C/D), including the following depopulation time during the La Tène period. These are very early finds and may concern untypical Humulus pollen. The first substantial Cannabis maximum occurs during the Roman period, and after a break during the Migration time, it is noted continuously, though with low frequencies throughout the Medieval and Modern times, forming another maximum only between AD 1420 and 1650. In Bjäresjö, southern Sweden (Gaillard & Berglund 1988), the pattern is different, the Cannabaceae (?) make the first small rise during the Roman period and a massive maximum during the Early Medieval (Vendel/Viking time). The authors quote the data suggesting the introduction of hemp cultivation in Sweden in the first centuries AD. Dörfler (1990) in his synthetic work on Cannabis history in central Europe assumes the possibility of its local introduction in Germany (Hochdorf) as early as in the Pre-Roman period, and documents the spread of Cannabis cultivation from the areas south of the Alps far northwards during the Roman period.

In some pollen diagrams from Poland Cannabis appears coincidently with the first rise of Secale pollen at the time of the supposed Roman period (Ralska-Jasiewiczowa 1981, Szczepeanek 1987, 1989, Bíňka et al. 1991, Noryśkiewicz 1995), but not all profiles are well dated. On Wolin Island (NW Poland) it was found in small quantities during the pre-Roman period (Latalowa 1992b).

Macrofossil finds of Cannabis sativa were reported from South Poland, Cracow area, from La Tène and Early Roman periods (Wielowiejski 1981), but its common cultivation in Poland is documented only from the Medieval time (10th century AD), as in Czech Republic and Slovakia (Wasylkowa et al. 1991). According to Nowiński (1970), hemp (C. indica) were first known as hashish and later used for fibre and oil, but still prepared dry; the retting was discovered much later, and probably only since then Cannabis cf. pollen was found in the pollen spectra from lacustrine sediments more often and in higher frequencies. Nowiński assumes an essential role of pre-Slavonic populations in the transference of Cannabis cultivation from Asia westwards; the Scythian invasions would be an important stage of this process.

The data above show that the first substantial spread of Cannabis cultivation during the Roman period is well documented, not only from the south, but also from lowland Poland. We cannot exclude its first appearance in connection with the Scythian incursions into Poland that reached also the Kujavia and Toruń regions around 2600–2500 cal BP (Godłowski & Kozłowski 1979).

The Cruciferae pollen curve was also listed in Table 9.11. This, of course, must be controversial, because there is no possibility to separate the pollen of cultivated crucifer species from the wild ones. Cruciferae, occurring sporadically from the time of Mesolithic settlements, might have originated from any type of open herb vegetation. However, a massive rise of Cruciferae curve late in historical times resulted undoubtedly from the cultivation mostly of edible oil or medical crucifer plants (e.g. Raphanus, Brassica, and accompanying weeds like Sinapis, Capsella, Sisymbrium, and other genera). It is shown more precisely in the fine-resolution pollen diagram of the last 330 yr (Chapter 9.2.4).

Syringa vulgaris, Aesculus hippocastanum were first planted, and Glauclum flavum appeared in late-historical times.

The indicator value of remains of Cyanobacteria

In an early stage of our analysis of pollen and other microfossils of the Gościc¸aˇz-material it became evident that two types of – at that time still unknown – characteristic, grey-coloured, cigar-formed, 15–60 μm long microfossils often were abundant to extremely abundant, especially during the second half of the Holocene. Our efforts to identify these fossils with the help of colleagues were successful, and Ralska-Jasiewiczowa & van Geel (1992) could illustrate one of these ‘Types’ as the akinetes of Aphanizomenon (Cyanobacteria, formerly called Blue-green algae). In first instance it was already evident that the phases of high representation of these akinetes had to be interpreted as an indication for eutrophication of the lake water, but the mechanism was not yet completely understood by us. With the records of the late Holocene deposits it became even more urgent to fully understand the increases of Cyanobacteria, especially because curve matching showed that the curves of akinetes of Aphanizomenon and Anabaena paralleled the pollen curves of herbaceous upland taxa that are human impact indicators. The full interpretation of blooms of Cyanobacteria as reflected in our fossil record could be given by Van Geel et al. (1994, 1996), after having consulted Dr L.R. Mur, who is an expert in the study of blooming of Cyanobacteria in relation to pollution of fresh-water lakes.

The first rise of Aphanizomenon frequencies in pollen samples that could be connected with some human interference into the natural ecosystem of the lake appeared at the decline of the late-Mesolithic (phase 2, around 6600 cal BP = phase II in Ralska-Jasiewiczowa et al. 1992). Its much higher values (approaching 1000 %) were then reached during the time when the terrains very close to
the lake were occupied by the population of the Neolithic Funnel Beaker Culture (phase 6 = phase IIId in paper quoted above, ca. 5500–5200 cal BP). Once again the high rise of Aphanizomenon occurred during the Late Neolithic (ca. 1200 %, phase 7 = phase IV in paper quoted above, ca. 4800–5000 cal BP). The settlement of Comb-Pitted Pottery Culture was situated directly at the lake then, and inhabited this area during a fairly long time. Throughout the Bronze and Early Iron Ages, and the Roman Iron Age, the frequencies of Cyanobacteria remain low (Van Geel et al. 1994), suggesting lack of strong anthropogenic influences on the lake itself. Considerable blooms of Cyanobacteria started only during the Early-Medieval times, after AD 1000.

The interpretation of the fossil Medieval record does not differ from the present situation in polluted lakes: phosphorous enrichment from effluent and excreta in the catchment area of the lake can at times become so high that nitrogen-limited growth conditions occur. In such conditions Cyanobacteria, capable of active nitrogen fixation, became very efficient in the competition with the green algae and they showed strong increases, often with negative effects for other organisms as a consequence of the production of toxic substances by the Cyanobacteria. However, in the deposits representing the last ca. 330 years (Goslar et al. in print) there was a decline of Cyanobacteria and Chlorophyta (green algae) took over the dominance. This is interpreted as the effect of a change from nitrogen components as a limiting factor (as a consequence of phosphate eutrophication) to light as a limiting factor, under conditions of extreme eutrophication and increased turbidity as a consequence of dense algal populations. The process of nitrogen fixation is an energy (light) consuming process and in conditions where Chlorophyta are able to survive and to live in water with a dense population of algae, the Cyanobacteria lose their strong position in the competition as a consequence of lack of sufficient light.

9.1.4. CORRELATION BETWEEN HUMAN ACTIVITY AND TROPHIC STAGES IN LAKE GÓŚCIAZ DEVELOPMENT BASED ON CLADOCERAN ANALYSIS

Krystyna Szeroczyńska

Results of Cladocera analysis are very important and useful for reconstruction of the history of lakes and of lake trophy, usually connected with human activity. Cladocera remains have been present in Lake Gościaz from its initial period until the present day.

According to concentration and percentage diagrams of species composition (Figs 9.18, 9.19 and Fig. 8.30 in Chapter 8.4), and in particular the curves of Bosmina longirostris, Alona rectangula, and Alonella exigua, increased trophy existed in Lake Gościaz in periods: 9100–8500, about 8000, 5800–5200, 4200–3800, 1800–1400, and 600–100 cal BP.

A considerable increase of trophy was noted before the record of human impact begins, in the sediments accumulated during the time 9100–8500 and about 8000 cal BP. It was registered by a drastic expansion of the eutrophic species Bosmina longirostris. This increase of trophy was probably a result of changing climate.

The stages of increased trophy partly correlate with phases of human activity identified on the basis of palynological analysis, partly supported by results of archaeological research (Pelisiak & Rybicka 1993, Pelisiak & Rybicka, Chapter 9.1.1. and 9.1.2., Ralska-Jasiewiczowa & van Geel, Chapter 9.1.3). Therefore, it may be supposed that the increase of trophy in the lake was provoked by the activity of people settled near the lake. Such a relation was also confirmed in the studies by Alhonen.

Fig. 9.18. The planktonic/littoral ratio in the cladoceran stratigraphy and eutrophication in profile G1/87 (Holocene) in comparison with the pollen zonation and phases of human influence (after Ralska-Jasiewiczowa & van Geel, Chapter 9.1.3).

Generally, on the basis of changes in the species composition of Cladocera, we can assume that out of six stages of increased trophy distinguished for Lake Gościcy, the last four were probably connected with human influences. The 15 settlement phases distinguished in the pollen record (Ralska-Jasiewiczowa & van Geel, Chapter 9.1.3) are partly reflected in the history of the lake by faunal changes (Fig. 9.18).

Phases 1 and 2 corresponding with Mesolithic settlement, are not precisely reflected in the results of Cladocera analysis. No intensive increase of eutrophic species was observed, but some important changes took place in the lake during these periods. Due to an absolute absence of Bosminidae, in particular the eutrophic species *Bosmina longirostris*, these changes cannot be precisely interpreted, especially in terms of their relation to the activity of Mesolithic tribes. The observed change in the species composition of Cladocera, a complete disappearance of Bosminidae, and a development of littoral forms such as Chydoridae and a few species from the families Daphnidae and Sididae, may have been provoked by other factors, such as climatic or chemical changes. Also predation pressure by fish should be taken into consideration. However, in lakes earlier studied the situation of an absolute disappearance of all Bosminidae for such a long time (about 2,000 years) provoked by fish predation has never been noted. Changes in the lake level also seem to be an insufficient explanation. How great should fluctuations of the water level have been that Bosminidae were not able to exist any more? It is also possible that water chemistry may have radically changed. Changes of living conditions were recorded in the results of chemical analysis (Łącka et al., Chapter 8.2., Kuc et al. 1993), and palaeomagnetic analysis (Sandgren 1993).

An increase of certain species of Chydoridae during these periods is worth noting. According to diagrams of
absolute concentration and percentage composition (Figs 9.18, 9.19 and Fig. 8.30 in Chapter 8.4). Alona rectangula and Pleuroxus uncinatus rose in numbers. Some of the authors, who recognize these species as indicators of rising trophy in the lake, often connect their increase with man’s activity (Sandoy & Nilssen 1986, Whiteside 1970). Therefore the supposed increase of trophy estimated on the basis of the abundance of these two species, whose development may have been provoked by an intervention from outside the lake, was marked with a dashed line in the diagram (Fig. 9.18).

Phases 3–7 corresponding with the Neolithic settlement are also poorly reflected in the Cladocera record and are only indicated by a domination of Alona rectangula, Alonella exigua, and Pleuroxus uncinatus and reappearance of the eutrophic species Bosmina longirostris (eutrophication stage 3). So it may be supposed that activity of Neolithic settlers was similar in abundance and in range to that of the Mesolithic. Maybe this similarity, in particular of the older Neolithic phase (Pelsiak & Rybicka 1993), provoked analogous effects. In the lakes of Northern and Central Poland studied earlier, influence of the Neolithic settlement was represented by a distinct domination of eutrophic species (Biliak et al. 1991, Mikulski 1977, Szeroczyńska 1985, 1991). However, those lakes were not very deep, so their rapid and distinct reactions to changes in water chemistry were easier reflected in changes of trophy. This may explain the differences between records of the influence of Neolithic activity in Lake Gościąż and other lakes.

Phases 8–11 correspond with the settlement of the Bronze Age. They are recorded in the species composition of Cladocera by a slight increase in abundance of species indicating rising trophy (eutrophication stage 4). Species of Bosminidae, especially the eutrophic species Bosmina longirostris, reappeared in the lake (Fig. 9.18). The abundance of littoral species, such as Alona rectangula and Pleuroxus uncinatus, was at the same level as noted during earlier periods of human activity. Also the β-mesotrophic species Alonella exigua significantly increased in number, thereby indicating rising trophy in the lake (Fig. 9.19 and Figs 8.29, 8.30 in Chapter 8.4).

Phase 12 – corresponds with Roman settlement. It is distinctly recorded in the species composition of Cladocera by an expansion of eutrophic species population (eutrophication stage 5). The rising eutrophication is well demonstrated in a concentration diagram showing the abundance of Bosmina longirostris, Alona rectangula, and A. quadrangularis and species of Pleuroxus (Fig. 8.30 in Chapter 8.4). A sudden increase of these species indicates an excessive inflow into the lake of compounds provoking rising eutrophy, which might have been a result of neighbouring settlers’ activity what is, however, not confirmed by any archaeological finds.

Phases 13–15 correspond with the Medieval and modern times up till the present day (eutrophication stage 6). During these periods a lot of changes recorded in palynological analysis and Cladocera analysis took place in the lake. The number of littoral and planktonic Cladocera species changed. It should be assumed that suitable climatic and edaphic conditions for Cladocera development existed in the lake at this time. With the beginning of the activity of Early-Medieval settlers, a rise of trophy was marked by a domination of the trophic indicator species such as Alona rectangula, Chy dorus sphaericus, Leydigia acanthocercoides, and other littoral taxa. According to concentration curves of eutrophic species, especially Bosmina longirostris and Alona rectangula, about 800–600 cal BP the eutrophication process was temporarily restricted. These changes may have been connected with settlement fluctuations in this time.

Nowadays the lake is surrounded by forest and thus from the time of its early growth it probably has been less exposed to direct influences of human activity. It may have been a temporary restriction of the eutrophication process, in particular in the sediments deposited during the last decades. In the recent sediments, all species from the family Bosminidae were found. Bosmina coregoni was dominant among planktonic forms, and littoral forms were dominated by species from the alkaliphilous and “indifferent” groups (Krause-Dellin & Steinberg 1986). At present the lake is considered to be eutrophic (a lot of phosphorus and nitrogen, Kentzer & Żytkowski 1993). The lake is not exposed to high anthropopressure, such as sewage inflow or excessive tourism. Its evolution is mainly natural (Zbikowski 1993). Therefore, according to the results of analyses of water and sediments deposited during recent years, the number of species existing in the lake is relatively high (Tab. 8.5, Chapter 8.4). Littoral species are insignificant due to a weakly developed littoral zone, whereas planktonic zooplankton species are of great importance in the ecosystem energy chain. The large number of planktonic species may indicate weak predation pressure by fishes (Błędzki 1993). Błędzki recovered the greatest percentage of zooplankton in the epilimnion during the summer months. Megard et al. (1993), observed the culmination of zooplankton in the metalimnion and hypolimnion of Elk Lake (Minnesota) during the spring and autumn months and their decrease in summer. The authors interpret this as a result of predation by fishes. So the statement by Błędzki that in Lake Gościąż the predation pressure is weak is important for the interpretation of Cladocera evolution in this lake. It is particularly important for examination of increased trophy periods marked by a domination of Bosmina longirostris, which, in this instance, is an indicator of rising trophy, the predation pressure by fishes being not the limiting factor here.
The influence of settlers resident in the proximity of Lake Gościąż since the Mesolithic is much weaker than in other Polish lakes studied earlier (Bińka et al. 1988, 1991, Szeroczyńska 1985, 1991). In these lakes strong induced eutrophy existed during the periods of intensive anthropopressure, from Neolithic times to the present day. However, the lakes studied earlier, such as Błędowo, Skrzetuszewskie, Woryty, are small. Therefore an inflow of organic and mineral compounds into a lake, provoked by settlers’ farming, radically changed the water chemistry and was followed by an intensive expansion of cladoceran species that prefer eutrophic living conditions.

According to Cladocera analyses for deep lakes, such as Lake Gościąż (25 m) and Lake Lednickie (15 m) (Szeroczyńska 1998), the settlement was not too important for changes in the species composition. It caused only a slight increase of species preferring rising trophy, and it eliminated neither planktonic nor clear-water species. An extraordinary period in Lake Gościąż history was the period of the Mesolithic settlement, characterized by a long-lasting absence of Bosminidae. Such a situation was noted in lake sediments in Poland for the first time. An absolute absence of Bosminidae for the Preboreal period was observed by Flössner (1990) in Barsch-See (Germany), but this lake is an acid one with a dominance of acidophilous species *Alonella excisa*, so it cannot be compared to Lake Gościąż.

This phase is connected with the Atlantic period, with a warm and humid climate. In the Polish lakes studied earlier the presence of both the families Bosminidae and Chydoridae was noted during the Atlantic period. What caused such drastic changes in the plankton composition in Lake Gościąż? What caused an almost total extinction of the *Bosmina* species? Was it a result of the activity of the Mesolithic people? It seems rather unlikely, because their activity is only insignificantly reflected in the history of the lake. It should not be forgotten, that the lake has always been supplied by ground water. So it may suggest that a change in the ground-water supply caused an important change in the oxygenation of the lake and thereby in the species composition of Cladocera.

9.2. RECORD OF HUMAN IMPACT FROM AD 1660 TILL RECENT TIMES IN THE LAKE GOŚCIĄŻ SEDIMENTS

9.2.1. ARCHIVE DATA AND ECONOMIC-SOCIAL BACKGROUND TO THE ANTHROPOGENIC CHANGES IN THE LAKE GOŚCIĄŻ REGION FROM AD 1700 UNTIL TODAY

Tomasz Goslar

Lake Gościąż is situated in the Gostynińskie Lake District, being now protected by the Włocławek-Gostynin Landscape Park. Due to its situation far from towns (20 km east of Włocławek with >100,000 inhabitants, 15 km northeast from Kowal with <3500 inhabitants, and 6 km south of Dobrzyn at the opposite bank of Vistula River with <2500 inhabitants) and from industrial plants, and on sandy soils of low fertility, it has never been too strongly influenced by human activity. Also for that reason the historical sources do not give too many details about human occupation of the lake vicinity. Instead, only general remarks about the developing settlements are available.

The Lake District is placed in the southeastern part of Kujavia historical region. In 16th century, the majority of the area was the property of Polish kings. In nearby Kowal, the king Kazimierz the IIIrd, called “the Great” was born in 1310.

At present the whole catchment area of the small stream Ruda, connecting a system of four lakes (Fig. 9.20), is almost completely covered by pine forest. The southern edge of the forest lies ca. 6 km from Lake Gościąż. The area south of lake, at the present forest limit, is covered by relatively high unsettled sand dunes. Probably also for that reason, any data about settlement in that area has not been found. Directly north of lake, and farther west, the forest nearly reaches the dammed Włocławek lake on the Vistula River. To northeast the forest limit approaches the lake at ca. 2.5 km. The nearest public road runs parallel to the Vistula bank. Forest roads are closed for public traffic. Human settlements closest to the lake include a small farm situated ca. 1 km downstream from the Lake Mielec and a forester’s lodge ca. 1 km farther down, where Ruda stream is dammed (by 1–2m). The individual farms dispersed outside the northern forest edge form small villages: Dąb Mały, Dąb Wielki, Dąb Polski, Skoki Duże, and Dobiegniewo.

The earliest written remarks on village Dąb (old spelling “Domb”) come from 1228 (Pelsiak & Rybicka, Chapter 9.1.2) and 1489 (Senkowski 1961). The villages Dąb, Dobiegniewo, and the “industrial settlement” Ruda are mentioned in 1565 (Tomczak 1963, Guldon 1964) and are also documented in the 17th century (Guldon 1981). The name of village Ruda (ore) corresponds to that “...a mill and primitive smelting factory, 10 buildings altogether...” existed there already in AD 1565 (Tomczak 1963). In the mill, situated probably near the present dam on Ruda stream, a rye flour was produced (Tomczak 1963). The date when the smelting was stopped is not known, but the settlement (10 inhabitants) is mentioned in a Geographical Lexicon (Sulimiarski et al. 1882). On the other hand, the mill was working in 1634 (Guldon & Guldon 1973) and in 1760 (Zytkowicz 1957), and according to A. Rerych (oral inf.) it was burnt in January 1945.

The development of Dąb, mentioned as a single settlement still in 1786 (Wizytacja 1786), is documented by a growing number of villages of related names (Dąb Wiel-
The common core of the name (Dąb means oak) would suggest some split of a single settlement, but the villages could also have been settled separately in a forest rather abundant in oak. Such an interpretation would be supported by significant percentage of *Quercus* pollen in the Gosiąż sediment from before the 19th century (Ralska-Jasiewiczowa & van Geel, Chapter 9.2.4). Development of villages was probably connected with the so-called “HollandII” (or “oleśnierskie”) settlement. Intensification of HollandII settlement on the “low-fertile, forested areas, especially upon Vistula River” is dated to the 18th century (Zimecki 1990) or more exactly to 1775–89 (Guldon & Guldon 1984). The word “Oleśn” refers to “a free man, settled by a privilege, engaged in forest clearing and drying the bogs” (Burszta 1958). As shown in Fig. 9.21, the Dąb... villages were mentioned in the official state registers, in church documents, and a Geographical Lexicon. Fig. 9.21 would suggest that they were settled mostly by the end of the 18th or beginning of the 19th centuries. The
Dąb Niemiecki (means German) with 38 buildings, was reported as newly settled in 1789 (Tomczak 1977), though Zimecki (1990) gives a much earlier date (1746) for the establishment of the villages of Dąb Niemiecki, Dąb Mały, Jazy, and Dębniaki, settled together by 47 families.

The map published by Gilly (1802, Fig. 9.22), shows the Dąb (denoted as “Domb”) villages northeast of Lake Gosćiaż (= Jazy). Surprisingly, Gilly’s map does not show Dąb Niemiecki, and according to Tomczak (1977) it was probably identified with Dąb Mały (= Kl.), situated between Dąb Polski and Wielki (= Gr.). This seems to be supported by the Geographical Lexicon (Sulimierski et al. 1880), which for AD 1827 reports Dąb Mały, Dąb Polski, and Dąb Wielki but not Dąb Niemiecki.

Gilly’s map shows the mill at Ruda and also one in Telążna. Two villages called “Buden” west of Gosćiaż were settled in 1775–89 (Guldon & Guldon 1984). They do not exist now, but the date of their abandoning is not known.

After the loss of independence by the Polish State in 1795, the territory of Poland was partitioned by neighbouring states, and the eastern part of the Kujavia region fell first under Prussian and after 1807 under Russian administration. After the defeat of Polish insurrection in 1863, the next intensification of settlement took place in the region (Burszta 1958). The Russian administration, especially after the insurrection, tried to suppress Polish nationality at the western borders of state, by favouring the German colonisation (Burszta 1958) through the so-

Fig. 9.22. Map of Lake Gosćiaż region from the beginning of 19th century (Gilly 1802).
called “Prussian Colonial Commission” (Świech, oral inf.). At that time, the village Dąb Borowy (the closest village to the lake) was settled. The first written mention about this village comes from 1880 (Sulimierski et al. 1880). The register of settlements, published irregularly in annual reports of Wistka parish, includes Dąb Borowy for the first time in 1892. The development of Dąb Borowy could be attributed to the distinct increase (reported annually) of the number of parishioners between 1882 and 1883 (Roczniki, 1863–1991; Fig. 9.23). As shown on the map from 1927 (Fig. 9.24), Dąb Borowy consisted of individual farms spread around Gościaż and adjacent lakes and in the forest (bór – means conifer forest) upon the Ruda stream in its upper course. The lake surroundings were not forested at that time. The vicinity of Gościaż was probably most intensively inhabited before the Second World War, fifty-fifty by Polish and German farmers. During the war the German farmers were gradually moving to the more fertile areas in western Kujavia, while the Polish farmers were forced to abandon the settlement in 1944 (Zjawinski, oral inf.). After the war, Dąb Borowy was not settled again, the buildings were gradually destroyed, and now the former farms are only traced by agglomerates of ruderal vegetation.

Before the war, Lake Gościaż was surrounded by pastures, meadows, or arable land. After 1945, the land was gradually forested. According to Kosiński (oral inf.), the
whole area has been planted with trees until the middle of the sixties, and the lake shore itself by the middle of fifties (1954–56). During forestation, however, the nonforested area of abandoned farms was still used by inhabitants of neighbouring villages who planted cereals and vegetables there.

Only a few elemental disasters from the last two centuries are known to struck the area. In 1921, an especially strong fire destroyed ca. 400 buildings in Kowal and was moved by wind to the next village, ca. 2 km away (Zimecki 1990). The forest fires are not mentioned in written sources. According to Zjawinski (oral inf.) the strongest one happened in summer 1946 and reached the southern shore of Lake Gosciaż. The high flood of the Vistula River has been noted in 1867 (Chudzyński 1990b) and 1934. Cholera epidemics in eastern Kujawy were noted especially in the first half of the 19th century: 1831, 1837, 1847, 1848, 1852 (the strongest), and 1894 (Chudzyński 1990a, 1990b). One may expect that they influenced the population growth at that time.

Generally at the beginning of the 19th century the system of three-year crop rotation (winter crop, spring crop, idle land) was applied in the region (Szczepeński 1990). In the second half of century, it was being gradually replaced by the system of shift of crops. At that time, fertilizers (superphosphate) were introduced (Chudzyński 1990a). The production of potassium fertilizers in Łowicz started in 1895–1897. Chudzyński (1990b) mentions the strong failures of potato crops in 1847, 1849, and 1850. However, the details of agriculture development in the immediate surroundings of Lake Gosciaż are not reconstructed.

9.2.2. CHRONOLOGICAL BASE AND RECONSTRUCTION OF YEARLY CYCLES IN THE LAKE GOŚCIAŻ YOUNGEST SEDIMENTS

Tomasz Goslar

Correlation of the cores frozen in situ

The long piston cores of sediment from the central deep of Lake Gosciaż show no lamination in the fragment above 1.26 m. This is mostly a result of coring, as it is clearly demonstrated by the occurrence of regular laminations above 1.2 m in the cores of sediment frozen in situ (Walanus, Chapter 4.1.2 and Goslar, Chapter 8.1). In the years 1989 through 1993, 20 cores were raised in such a way. Usually tube samplers were used, except of the case of cores G31-33f and G42-43f, collected with the wedge-shape sampler (Walanus, Chapter 4.1.2). The individual cores were 0.22–1.60 m long.

The laminated sequences of all the cores were copied on adhesive tape according to the tape-peel method (Simola 1977, Goslar 1993). The copies are easy to handle and store for a long time, and they were used in precise visual correlation of laminae in individual cores, enabling the construction of continuous, replicated sequence (Fig. 9.25). In that sequence, the characteristic layers are marked in all the cores. The sedimentation rates differ among cores, and the depth scale for the common sequence is an average of all the cores.

Seasonal changes of sediment composition

The seasonal changes of sediment composition along the selected fragments of cores were recognized by microscopic inspection of the tape copies. Each inspected area was ca. 0.5 mm wide, and 200 contiguous areas were analysed per each 10 cm of profile. The main components recognized were chrysophycean cysts, diatoms, carbonate, and organic matter. In each area the chrysophycean cysts and frustules of Centricae (except for Aulacoseira sp.) and Pennatae (except for Fragilaria, Synedra, and Asterionella) diatoms were counted. The frustules of abundant genera of Aulacoseira, Fragilaria, Synedra, and Asterionella were counted separately. Abundances of calcite and organic matter were expressed as percentages of the microscopic image covered by the carbonate and by organic fragments, and the mean size of calcite grains was determined qualitatively. Additionally, the occurrence of vivianite, pyrite, Pinus pollen, and

Fig. 9.25. Diagram illustrating the replication of varve chronology in the uppermost sediment from Lake Gosciaż, based on the cores frozen in situ.
quartz was noted. In fragments of the cores G6f and G13f, charcoal fragments were also counted.

A second set of identical tapes was leached for 1 h in hydrofluoric acid, to make easier the identification of organic matter. Comparison of results obtained on both sets of copies show no distinct differences. It also appeared

![Fig. 9.26. Up: Diagram showing changes of sediment composition in annual cycles, an example from the fragment of core G5f, 140 to 162 cm below the lake bottom. A – Asterionella, F – Fragilaria, S – Synedra, M – Aulacoseira (Melosira). Down: Photograph of considered fragment of the core G5f (replica on an adhesive tape). The dominant components of characteristic laminae are indicated as follow: C.c. – chrysophycean cysts, F.c. – Fragilaria crotonensis; S.a. – Synedra acus; M.(?) – Aulacoseira (Melosira) islandica ?; C. – calcite, C.d. – centric diatoms, A.f. – Asterionella formosa, A.g. – Asterionella gracillima (diatom species identified by H. Simola).](image)

![Fig. 9.27. Photographs illustrating the lamination on dried surface of a frozen core (right) and on surface of melted core (left) in the sediment deposited between AD 1920 and AD 1928.](image)
that leaching in HF, which dissolved diatoms and produced white crystals of fluorite in place of the larger calcite grains, made the laminated structure simpler, and hence much easier for varve counting by eye.

The annual cyclicity is most clearly visible in the fragment 140–165 cm (Fig. 9.26). In each cycle (the boundaries are marked by vertical lines) the maximum concentrations of chrysophycean cysts, centric diatoms (mostly *Stephanodiscus hantzschii*, species determination after Simola, pers. comm.), size of calcite grains (up to ca. 20 μm), and concentrations of calcite and of organic matter occur in a succession. It must be mentioned that carbonates in the Lake Gosiaź sediment are also abundant in organic layers, but in form of fine grains (<1 μm).

On the melted surface of the core (Fig. 9.27) the layers of diatoms and cysts are grey, yellowish, or greenish, calcite laminae are light cream-coloured, and layers of organic detritus are light brown, dark brown, or almost black, depending on the content of carbonates. After drying, the diatom layers become snow-white (Figs 9.26 and 9.27).

The succession observed in varves of Lake Gosiaź sediment is typical of calcareous lamination (Tippett 1964, Kelts & Hsu 1978, O’Sullivan 1983, Saarnisto 1986). The cysts and diatoms were presumably deposited in spring, big crystals of calcite represent summer, and the dominance of organic matter corresponds to the off-season (autumn and winter). Occurrence of spring layers of diatoms and cysts was documented in laminated sediments of many lakes (Geyh et al. 1971, Simola 1977, Saarnisto et al. 1977, Simola & Uimonen-Simola 1983, Fig. 9.28).
Simola et al. 1990). Observations of seasonal changes of modern phytoplankton in Lake Gos’cia (Giziński et al., Chapter 3.5) document blooming of *Stephanodiscus* in spring.

The summer calcite layers were observed in laminated sediments by Merkt (1971) and Lotter (1989). It is commonly accepted that calcite growth in lacustrine environments is caused by supersaturation of CO$_3^{2-}$ ions due to the rise of temperature and/or consumption of dissolved CO$_2$ by growing phytoplankton (O’Sullivan 1983, Wetzel 1975, p. 170–171). According to Wachniew and Rózanski (Chapter 3.6) the saturation index in modern Lake Gos’cia is permanently high enough to permit precipitation. The mentioned authors observed calcite precipitation between April and October, and, since the accumulation rates of calcite and plankton changed in parallel, it is proposed that the growth of calcite grains in Lake Gos’cia is stimulated by seasonal appearance of plankton particles, playing a role of nucleation centers. Analysing the SEM pictures of Holocene sediment, Łącka et al. (Chapter 8.2) pointed to diagenetic reprecipitation of calcite on the surface of other minerals or organic particles. Such an effect might be partly responsible for the occurrence of fine carbonate grains in the off-season layers of young sediment. On the other hand, the almost monospecific composition of layers of big calcite grains (Fig.

![Fig. 9.29](image-url) Diagram showing changes of sediment composition in annual cycles, an example from the fragment of core G6f, 64 cm to 89 cm below the lake bottom. A – *Asterionella*, F – *Fragilaria*, S – *Synedra*, M – *Aulacoseira* (Melosira).

![Fig. 9.30](image-url) Diagram showing changes of sediment composition in annual cycles, an example from the fragment of core G13f, 46 cm to 76 cm below the lake bottom. A – *Asterionella*, F – *Fragilaria*, S – *Synedra*, M – *Aulacoseira* (Melosira).
9.28) does not suggest precipitation depending on other particles. Gizinski et al. (Chapter 3.5) have documented a significant role of resuspension in modern sedimentation in the central deep of Lake Goscia, suggesting that some laminae could be formed by redeposited sediment. However, the upper 50 cm (last 30 yr) of the Lake Goscia sediment is not laminated (see Goslar, Chapter 9.2.3), and modern observations may be inadequate analogues for the past. Unfortunately, neither Wachniew nor Giziniski et al. analysed the grain size of calcite deposited in traps.

Besides the basic annual pattern, some varves reveal extra laminae of diatoms. One can see, (Figs 9.26, 9.28, 9.29, and 9.30) that Asterionella (mainly A. formosa (Fig. 9.28) and A. formosa var. gracillima) occurs mostly in spring, Fragilaria (F. crotonensis, Fig. 9.28) and Synedra (mostly S. acus) appear usually in summer, whereas Aulacoseira (= Melostra, mostly A. islandica?, Fig. 9.28) reveals blooms in the autumn season. Similar seasonality in occurrences of Asterionella formosa and Synedra acus was observed in sediments of Lake Lovojärvi (Simola 1977, Simola et al. 1990). The species of Aulacoseira (A. italica and A. granulata) observed in Lovojärvi revealed maxima later than other diatoms. Also, Wetzel (1975, p. 285) has shown a delay between maxima of Asterionella sp. and Fragilaria sp. The seasonal pattern in occurrence of observed diatoms seems to confirm the annual character of lamination.

The grains of vivianite (Fe₃(PO₄)₂) were usually observed in the second part of the annual cycle (autumn, winter?), especially in core G5f (Fig. 9.26, see also Fig. 9.34), in agreement with the findings from Lovojärvi (Saarnisto et al. 1977, Simola 1977). On the other hand, no seasonality has been observed in the occurrence of other Pennatae diatoms, quartz, pyrite, and Pinus pollen grains.

The annual character of lamination has been independently confirmed by the analyses of ²¹⁰Pb (Wachniew...
The specific activity of excess lead-210 in Gościąż sediment below ca. 50 cm, shows a reasonable dependence on time if the time scale is provided by varve counting (Fig. 9.31). The non-monotonic $^{210}\text{Pb}$-depth relationship in the section above 50 cm, where the lamina- tion was not preserved, may be partly explained by resus- pension and mixing of sediment and partly by an in- creased molecular mobility of lead in the youngest part of profile (Wachniew 1993, Goslar, Chapter 9.2.3).

An interesting feature is the two- or three-year periods of higher concentration of *Stephanodiscus*, recurring each ca. 6 years, especially visible in the fragment 140–165 cm (Fig. 9.26) and less clear between 85 and 60 cm (Figs 9.29 and 9.30). Examples of such a cyclicity in other laminated sediments are not known to the author.

**Varve chronology of the youngest sediment**

Correlation of laminated sequences of individual cores frozen *in situ* enabled the construction of a continuous
varve chronology. Unfortunately, varve counting was not possible in the uppermost 47 cm of sediment, where only a few single laminae are visible. Therefore the age of chronology was determined using other markers. They are peaks of concentration of $^{137}$Cs and of charcoal. The analysis of $^{137}$Cs is widely used for dating the youngest sediments (Walling & He 1993). The basis for using $^{137}$Cs in this context is that radiocaesium is rapidly and strongly bound to fine particulates and that its distribution in the sediment profile directly reflects the chronology of sediment deposition. The significant total annual fallout of radiocaesium since the middle of the 1950s is related to the tests of nuclear weapon and shows maxima in 1959 and between 1962 and 1964, and a drop to very low values after 1965 (Cambray et al. 1982). Because bomb-radiocaesium was injected into stratosphere, its worldwide distribution is rather uniform. A second substantial fallout took place in 1986, after the Chernobyl accident (Higgitt et al. 1992), but it was spread over a limited area. The profile of $^{137}$Cs concentration in the...
Lake Gościąż sediments (J. L. Reyss, pers. comm., Fig. 9.32), shows a single broad bomb maximum around 50 cm, and also a high value in the uppermost sample, probably related to Chernobyl accident.

The wide bomb-caesium maximum in Lake Gościąż may only partly reflect integration of $^{137}$Cs signal in thick samples. Unclear separation of bomb $^{137}$Cs peaks and lack of substantial reduction towards the surface is common in lacustrine sediments (Walling & He 1993). Explanations involve molecular diffusion (Davis et al. 1984), resuspension and focusing of deposited sediment (Bruns-kill et al. 1984), or the influence of delayed inputs of radiocaesium from the drainage basin of the lake (Miller & Heit 1986). The small area of Gościąż drainage basin suggests that the majority of the radiocaesium in Lake Gościąż descended from direct atmospheric fallout, and that the delayed input from the surrounding soils is negligible. This seems additionally confirmed by the small content of allochthonous matter in the sediment. A contribution of soil inwash may also be estimated from the total inventory of $^{137}$Cs in the Gościąż sediment. Because of scarcity of data points and not precisely determined dry-sediment density (0.1–0.15 g/cm$^3$), it may be only roughly estimated to 150–400 mBq/cm$^2$. Comparison of that estimate to total atmospheric fallout of 285 mBq/cm$^2$ recorded in two British lakes (Walling & He 1993), where no influence of Chernobyl was noted, and to 800 mBq/cm$^2$ recorded in soils from Polish Carpathians (Froehlich et al. 1993), where ca. 50% of total fallout was that of Chernobyl, supports hypothesis that the input of radiocaesium from the drainage basin is small. The most probable explanation for the smooth $^{137}$Cs profile is thus the resuspension and focusing of deposited sediment. The effects of resuspension could be especially strong after the middle of the 1960s, when the lamination disappeared. Resuspension in the recent Lake Gościąż sediments was investigated by Giziński et al. (Chapter 3.5).

About 20 cm below the peak of $^{137}$Cs, a maximum of charcoal concentration was documented in two cores (Figs 9.29 and 9.30). This was attributed to the strongest known forest fire, in spring 1946, which reached the southern shore of Lake Gościąż (Goslar, Chapter 9.2.1). It must be stressed that the dating of the varve sequence by caesium peak and by charcoal maximum support each other. According to Clark (1988a, 1988b), local forest fires are well documented in lacustrine sediments by charcoal fragments bigger than 50 μm, while the small fragments (5–20 μm) may be transported over long distances. The charcoal maximum in the Lake Gościąż cores is shown by large (up to 150 μm) as well as small fragments (above 15 μm). The broad charcoal maximum extends over three years. It remains unknown, if single fire could raise charcoal concentration in the sediment through a few years; nevertheless Clark (1988b) mentions such a possibility.
Relying on the charcoal marker, the level of 71 cm was dated to 1946. Accordingly, the youngest clear varve (47 cm) was dated in 1966, and mean accumulation rate in the last 30 yr was estimated to ca. 1.6 cm/yr. The direct comparison of cores raised in May 1990 and March 1991 indicated an increment of ca. 2 cm, in rough agreement with estimated mean deposition rate, especially if the effects of sediment compaction are taken into account.

The chronology of sediment above and below 71 cm was constructed by counting varves in correlated frozen cores. In most of the cores, the varves were identified by eye, relying on the pattern of seasonal cyclicity recognized in fragments of cores G5f, G6f, and G13f. In fragment 175–92 cm, varve identification was supported by a qualitative microscopic analysis of dominant sediment components in a single core. The quality of lamination in frozen cores varies with depth (Fig. 9.33). Below ca. 190 cm, the laminae are bent, in some fragments the light layers are hardly visible, and in some sections on the core surface only individual agglomerates of carbonate occur, which do not form any continuous layers. In this fragment the use of the freezing technique did not improve preservation of varves in comparison with conventional coring, and the error of chronology is the same as discussed in Chapter 8.2. The regular laminae occurred between 190 and 47 cm, but between 75 and 47 cm they were hard to interpret when not analysed under the microscope.

The record of laminae thickness

Between 1.75 and 0.92 m the sediment composition was analysed qualitatively under microscope. The sections with several dominant components were distinguished. The components were chrysophycean cysts, centric diatoms, calcite grains, organic matter, and other diatoms and vivianite crystals. In some varves a significant amount of organic matter was observed through the whole varve. Besides the basic laminae of large coarse calcite, the large grains were also dispersed in many layers of centric diatoms. They were presumably rebedded from another parts of the lake during spring. The boundaries between sections with different dominants were illustrated in Fig. 9.34. Thickness of each section was measured with an accuracy of 0.1 mm. Moreover, the size of 20 typical grains was measured in each calcite layer. The thickness of separate sections of each varve is plotted in Fig. 9.35. For individual components, only the sections with distinct dominance of a single component were displayed. The analysed sequence spans between AD 1839 and 1904. The increase of deposition rate is accompanied by a decline of chrysophycean cysts, which, according to Smol (1985), probably reflects lake eutrophication. First increase occurred together with the blooms of *Synedra*, *Asterionella*, *Fragilaria*, and *Aulacoseira* (*Melosira*) diatoms. It has been suggested that an Araphidinae-to-Centriceae ratio of 2 indicates eutrophication (Stockner 1971). This suggestion was confirmed by extensive investigations of Lake Ahvenainen (Tolonen 1978), where the highest level of eutrophication corresponded to the maximum occurrence of Araphidinae diatoms. In Lake Gosćia the Araphidinae diatoms were developing in the early stage of eutrophication, and after 1928 until 1960 (Figs 9.29 and 9.30). Also between 1860 and 1870, the regularity of very distinct dominance of a single component in each layer, was broken. The regular dominance of cysts in the beginning of the annual cycle ended between AD 1876 and 1877. The distinct change of sediment composition in the seventies of the 19th century is documented better by the quantitative analyses (Figs 9.26, 9.29, and 9.30). The appearance of vivianite from 1873 on (Fig. 9.26) is followed by an increase of varve thickness and distinct decrease of chrysophycean cysts after 1877. All observed changes could then indicate eutrophication of Lake Gosćiа between 1873 and 1878. An increase of lake productivity corresponds also to the distinct change of radiocarbon concentration in the carbonate fraction between 160 and 150 cm to 150 and 140 cm (Goslar et al. 1992). In all probability, eutrophi-
cation was connected with the settlement of village Dąb Borowy (Goslar, Chapter 9.2.1) in the near vicinity of the lake.

Some decrease of trophy is indicated at the depth of 76 cm (Figs 9.29 and 9.30) by a rise of Chrysophyceae concentration and decline of varve thickness, followed by an almost total extinction of vivianite in AD 1946. It might reflect the reduction of agricultural activity after farms were abandoned near the lake.

Short-term variations of laminae thickness were compared with those of tree-rings. For each varve, the sequences of thickness of light layer (i.e. that containing cysts, centric diatoms, and coarse calcite), dark layers (i.e. that of organic matter, deposited after calcite layer), light+dark, and the ratio of light/(light+dark) layers were compared with the sequences of tree-ring widths from 14 local oak chronologies from different regions of Poland (Waźny 1990, and pers. comm.). The correlation is reasonably dependent on geographical location of oaks (Fig. 9.36), showing the highest similarity of Gościaż sequences with those of oaks from the regions situated along the NW-SE transect of Poland. The best case of correlation is illustrated in Fig. 9.37. The documented positive correlations between tree-ring width and light/(light+dark) ratio as well as negative correlation between tree-ring width and organic varve thickness were the basis for searching for the correlation between the varve sequence from the Subboreal chronozone and the German oak chronologies (Goslar, Chapter 6.3). The mechanism linking tree-ring thickness and varve thickness parameters has not been resolved. According to Waźny (1990), the oaks in sequences from northern, western and eastern Poland respond positively to summer precipitation. The dependence of oak growth on temperature is less clear, e.g. the oaks from northern Poland show significant positive response to the temperature of May, while those from eastern Poland seem to respond negatively to the temperature of June. The record of varve thickness was also compared with the instrumental records of monthly air temperature and the sum of precipitation, but no significant correlation was found.

9.2.3. ANTHROPOGENIC CHANGES IN THE CHEMICAL COMPOSITION OF THE LAKE GOŚCIAŻ SEDIMENTS

Tomasz Goslar

The seasonal variations of sediment composition, described in the previous section, were used to study the annual cycle and to construct the calendar chronology of sediments. Climatic and anthropogenic environmental variations are recorded in the sediment on a longer time basis. The composition of sediment may then reflect the human- and climate-driven changes of conditions in the lake catchment as well as in the lake itself. Here the time relationship between known anthropogenic events or climatic variations and the changes of chemical composition of sediment are presented.

In this study, the contents of organic matter, calcium carbonate, 14 elements, and accumulation rate were analysed.

For single varves between AD 1821 and 1955, the content of organic matter and carbonate was determined by the loss of sample mass during heating for 3h in 550°C (LOI = loss on ignition) and 900°C, respectively. The initial mass of dry sample was determined after heating in 130°C. In calculations it was assumed that all carbonate is that of calcium. The previous analyses, made on
10 yr samples from the whole profile, demonstrated the correspondence between LOI (Wicik 1993) and organic carbon (Łańcka et al., Chapter 7.3 and 8.2) which, before 1000 cal BP, constituted ca. 50% of LOI, although the correlation is not very high (Fig. 9.38a). The reasons for the weak correlation are difficult to explain. The successful modelling of apparent radiocarbon age of organic fraction of sediments (Goslar, Chapter 6.2), which used the organic carbon content derived from LOI, seems to suggest that the weak correlation between C and LOI results rather from imprecision of chemical than ignition analyses. On the other hand, the deviation of model predictions in the last 1000 yr (Goslar, Chapter 6.2) could be explained by lower C/LOI ratio (ca. 40%, see Fig. 9.38a), suggesting real change of the ratio of organic carbon to organic matter after 1000 cal BP. Surprisingly, the ratio of organic C (Łańcka et al., Chapter 8.2) to single-year LOI analyses presented here from 19th and 20th century, is similar to that observed in sediment prior to 1000 cal BP. The small year-to-year variation seems to prove that the precision of single-year LOI measurements was satisfactory (Fig. 9.39).

Much better correlation is that between Ca and ignition-calculated CaCO₃ content (Fig. 9.38b). The good stoichiometric correspondence between calcium and calcium carbonate proves the general reliability of results obtained by both methods. The spread of data around the linear relationship, however, is high. It might partly result from the fact that the sampling for both sets of analyses was done on different cores, and any sample of given varve could comprise not precisely defined admixture of material from adjacent varves. If this was the case, the correlation for three-year averages should be better than for single-year results. However, taking of three-year averages does not improve the correlation, so the most probable explanation of data spread is the imprecision of chemical analysis. Nevertheless, the general trends in carbonate (and calcium) content may be regarded as real.

The content of carbonate (Fig. 9.39a) reveals 10–20 yr fluctuations superimposed on a general decreasing trend between 60% and 40%. The fluctuations clearly coincide

**Fig. 9.38.** Comparison of results of chemical and thermal analyses of the Lake Gościaż sediments. a – organic carbon content (C) versus loss on ignition (LOI). Diamonds – 10-yr samples from the whole profile of sediments: light diamonds – before 1000 cal BP; heavy diamonds – after 1000 cal BP; circles – single varve samples from the uppermost sediment. Organic carbon analyses were made by Łańcka et al. (Chapter 8.2). b – correlation between CaCO₃ content determined by loss of mass in 900°C and Ca content in the uppermost sediments.

**Fig. 9.39.** Diagram of main sediment fractions and sedimentation rate of dominant components in the regularly laminated fragments of the youngest Lake Gościaż sediments. a – of organic matter (represented by LOI) and calcium carbonate content in the fragment of the Lake Gościaż sediments deposited between AD 1826 and AD 1955. The ratio of thickness of diatom laminae to whole varve is shown for comparison. b – accumulation rates of main sediment components in the fragment AD 1839/1926. c – ratio of LOI/CaCO₃ contents.
with those of diatom content. Distinct lowering between AD 1870 and 1880 was simultaneous with the presence of *Synedra* (see Chapter 9.2.2, Fig. 9.35), the high maximum of carbonate content about AD 1900, and a smaller one about AD 1920 coincide with the temporal extinctions of Centricae, while the lowering between AD 1905 and 1915 corresponds to the massive blooms of centric diatoms. It seems therefore that the residual matter is composed mostly of diatoms. Synchronous variations of sedimentation rates of three sediment components (Fig. 9.39b) suggest that they were controlled by a common factor, e.g. productivity of lacustrine biota. The relationship between calcite precipitation and organic productivity in the modern lake was evidenced by Wachniew and Różyński (Chapter 3.6). As demonstrated in Fig. 9.39c, the ratio of organic matter to carbonate between 1830 and 1950 increased by ca. 50%. The general trend of the LOI/CaCO₃ ratio could be an effect of decay of organic matter, which is faster than dissolution of carbonate. However, fairly constant content of organic matter with respect to total sediment over the whole period seems to exclude a diagenetic explanation. A decay hypothesis cannot also explain the coincidence between short-term variations of LOI/CaCO₃ and varve thickness. The ratio of C+P+N/Ca, of meaning similar to LOI/CaCO₃, was used by Tolonen (1978) as an indicator of trophy of Lake Ahvenainen, Finland. She assumed that the increased sedimentation of these elements due to increased productivity cannot be eliminated by the correspondingly increased mineralisation of the sediment. In Gościaż sediment, both sedimentation rate and LOI/CaCO₃ ratio reveal minima in AD 1850–1860, about AD 1890, in AD 1895–1905, and about AD 1920, and maxima in AD 1880–1885, about AD 1893, and in AD 1910–1920. Such a coincidence, and the arguments presented above indicate that the observed changes in sedimentation rate and sediment content were driven mostly by varying biological productivity of the lake (including significant amounts of diatoms), which was followed by somewhat damped changes of precipitation of authigenic minerals.

The largest and most detailed record is that of elemental composition. The samples from the section of sediment for AD 1620–1881 encompassed 2–3 varves, and for AD 1882–1966 usually single varves were sampled. Because of no lamination, the boundaries between annual increments in the youngest section (AD 1967–1990) were not known. Therefore, the youngest section was divided into 24 fragments, assuming the exponential rise

![Fig. 9.40. The records of content of 14 elements in the youngest 300 years of laminated sediments of Lake Gościaż. The contents of Ca, Fe, Mn, and Mg are given in per cent dry mass, the rest in ppm. The results of single analyses made by Łącka & Starnawska (crosses) are shown for comparison.](image-url)
of accumulation rate. Each sample was dried out at room temperature and powdered, and 150 mg of dry sediment was used for further processing. The samples were treated with 1 ml 36% HCl, diluted to 10% with distilled water, and stored in 100°C for 1/2 h. Next distilled water was added to obtain 15 ml of solution, and the composition of the solvent was analysed by atomic absorption spectrometry. The analysed elements were: Ca, Fe, Mn, Mg, Na, K, Pb, Zn, Cu, Ni, Cr, Cd, and Li. The chemical pre-treatment and spectrometric analyses were done in the “Ekopomiar” laboratory by L. Chróst. This rather simplified procedure was chosen to minimize the number of steps that potentially might introduce additional spread of analytical results. It is suitable to study the changes rather than absolute concentrations, since the systematic error may be as high as a factor of two (Chróst, pers. comm.). Nevertheless, the comparison (Fig. 9.40) with the analyses of a few samples by more quantitative method (Łącka et al., Chapter 7.3 and 8.2), demonstrates reliability of results obtained.

The most abundant element is calcium, occurring as calcium carbonate. According to Łącka et al. (Chapters 7.3, 8.2) the other abundant elements are (in order of decreasing concentration): carbon (5–10%), iron (~5%), and silica (<5%). The other elements (including phosphorus, nitrogen, and sulphur) constitute less than 1% of sediment. Most components analysed here may be regarded as minor and trace elements.

The record of chemical sediment composition may be divided into three zones.

Zone A – ca. AD 1620–1780. This zone is characterized by rather constant chemical composition of sediment. Especially high with respect to the next zone are the contents of calcium and strontium. Other elements of high concentration are iron, manganese, and magnesium. Constant low concentration is revealed by potassium, lead, zinc, copper, and lithium. The separation of zone A in other elements is less distinct. The end of zone A is marked by a sharp minimum of nearly all analysed elements.

Zone B – AD 1780–1950. In this zone, the composition of sediment varies significantly. The general long-term increase is shown by potassium, lead, zinc, copper, and lithium. The increases of potassium and zinc are rather linear through the whole zone, while for lead, copper, and lithium the strongest increases occurred between ca. AD 1865 and ca. AD 1885. The concentrations of calcium, magnesium, strontium, and nickel decrease. Much less distinct is the decline of iron and manganese concentrations. Besides the long-term trend, calcium and strontium show also short-term variations, revealing distinct minima at AD 1880 and at the end of zone B and a maximum at AD 1905.

Zone C – AD 1950–1990. At the boundary between zone B and C the concentration of almost all elements changes abruptly. Most distinct are the drops of iron, manganese, copper, and lithium, synchronous with increases of zinc and nickel. Less abrupt and somewhat delayed is the increase of calcium, strontium, potassium, lead, chromium, and cadmium. The trends of concentrations within this zone are rather weak.

The records in Fig. 9.40 show that certain groups of 14 elements have similar patterns of variations in concentration with time. Therefore their variability can be expressed with respect to principal components. Each principal component (PC) is a linear combination of 14 variables (concentrations) reflecting some specific pattern of similarity among element concentrations, and these combinations are orthogonal (i.e. not correlative) to one another. The coefficients of linear relationship between each PC and variables are called loadings. Then the composition of each sample is expressed by PC’s. The principal component analysis was made by A. Walanus, using the program POLPAL, developed for palynological purposes. Prior to the calculation of principal components, the standard deviations of all variables were normalized to the same value. It appeared that 66% of total variance in the 14 transformed concentrations, might be expressed by only three principal components.

The loadings, and the records of three first PC’s are shown in Fig. 9.41. The loadings demonstrate which element had the largest influence on creating the principal component. The sign of loading (positive or negative) represents the sign of the relationship between variable (element) and PC. The affinity of any variable to PC may be also expressed by the correlation coefficient between the record of the variable and that of principal component (Tab. 9.12).

The first principal component (42% of total variance) is rather constant before ca. AD 1770 (zone A), declines

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<td>0.22</td>
</tr>
<tr>
<td>Sr</td>
<td>0.83</td>
<td>0.38</td>
<td>0.15</td>
</tr>
<tr>
<td>Zn</td>
<td>-0.80</td>
<td>0.24</td>
<td>0.10</td>
</tr>
<tr>
<td>Cd</td>
<td>0.32</td>
<td>0.42</td>
<td>0.45</td>
</tr>
<tr>
<td>Li</td>
<td>-0.60</td>
<td>-0.12</td>
<td>0.18</td>
</tr>
</tbody>
</table>
linearly in zone B (AD 1770–1955), and shows no
general decline after AD 1955. The most important posi-
tive loadings to this PC are those of Ca, Mg, and Sr; the
negative are K, Pb, Zn, and Li. Consequently the vari-
ations of the first PC are similar to the variations in con-
centration of most important positive loadings and simi-
lar to the inversed variations of negative loadings. The set
of positive loadings is a consequence of high similarity of
strontium and magnesium to calcium. This seems reason-
able, since all these elements are usually bound in auth-
igenic carbonates, though in some lakes, e.g. in Elk Lake,
Minnesota, both magnesium and strontium appear to be
associated with the clastic fraction (Dean 1993). The con-
centrations of iron and manganese are also positively
correlated with the first PC. This might suggest that also
some iron and manganese occur in form of carbonates.
The proportion of loading suggests that iron and man-
ganese carbonates constitute <5% and <1% of total car-
bonates, respectively. Such low concentrations are diffi-
cult to detect by X-ray diffraction, especially when they
occur in the form of fine-grain fraction.

The highest negative loading to the first PC (and
correlation coefficient, see Tab. 9.12) is that of potas-
sium, which shows nearly linear increase from ca. AD
1770 on. Potassium and other alkali elements occur in
most lake sediments primarily in allogenic clastics eroded from catchment soils and rocks (Engstrom &
Wright 1984). Therefore it is frequently interpreted as an
indicator of erosion (Davis & Norton 1978, Tolonen
1993). On the other hand, Michler et al. (1980), who rec-
structured in detail the relationship between changes of
concentrations of Na, Cu, and Mg in the sediment of
Lake Ammersee, German Pre-Alps, and the change of
area undergoing erosion in the lake catchment since Me-
dieval time, could not find explanation for the permanent
increase of potassium concentration. The increase of both
K and Na concentration in recent years was attributed by
Michler et al. (1980) to soil fertilization.

The concentration of potassium in the Lake Gościąž
sediment is very well correlated with the ratio of organic
to carbonate fraction (Fig. 9.42). As argued in former sec-
tions, that ratio is an indicator of biological lake produc-
tivity. Therefore the potassium in sediments of Lake
Gościąž seems connected mostly with organic productiv-
ity of the lake. The onset of its increase about AD 1770
(Fig. 9.40) might be related to the “Hollandii” settlement,
resulted in a split of “Đąb” settlements in the area (gos-
lar, Chapter 9.2.1). The distinct maximum at ca. AD
1883–1884 seems to be related to the settlement of Đąb
Borowy and is delayed by 6–10 years with respect to the
eutrophication suggested by the ratio of chrysophycean
cysts to centric diatoms and other indicators (goslar,
Chapter 9.2.1). The long-term rise of potassium content could be caused by the increasing crop of potatoes (fixing large amounts of that element) from the beginning of the 19th century on, and the gradual replacement of the three-year crop rotation by the shift of crops in land use. It appears that these changes were connected with enhanced soil fertilization. Mineral potassium fertilizers were introduced in the region only at the end of the 19th century (Goslar, Chapter 9.2.1).

The first principal component of 14 element concentrations reflects thus the decrease of carbonate content of sediment, related probably to the increasing lake productivity. The onset and termination of the decrease coincide with the development and abandoning of villages in the lake vicinity.

The second principal component (Fig. 9.41) remains rather constant below AD 1850, shows two broad minima in periods AD 1850–1890 and AD 1930–1955 and a large abrupt increase started in AD 1952 and completed before AD 1960. The II PC seems negatively correlated with the quality of lamination (see Goslar, Chapter 9.2.2, Fig. 9.33). The highest values of II PC occur in the non-laminated section, and the lowest values in the section AD 1825–1950, where the lamination was distinctly more regular than below. As shown by the loadings and correlation coefficients (Tab. 9.12) this PC reflects the opposition of iron and manganese with respect to other elements. Both iron and manganese are important paleolimnological indicators, and their geochemistry requires a more detailed discussion.

The iron and manganese can be found in lake sediments bound in the allogenic clastics and as components of authigenic oxides, sulfides, carbonates, and organic complexes. Authigenic forms of Fe and Mn are potentially labile, and their abundance in lake sediments is considerably dependent on post-depositional preservation. Thus the profiles of Fe and Mn are controlled by historical changes in both rate of supply to the lake and in processes controlling degree of preservation. The supply of these elements is a function of environmental processes occurring in the catchment, while preservation depends on conditions within the lake. The crucial point is that both elements exhibit very low solubility under oxidizing conditions, but under reducing conditions they may be released from the catchment soils as well as from lake sediments. Within the oxic regions, both elements exist in oxidized forms (Mn(IV), Fe(III)) as insoluble oxyhydroxides. In anoxic environments those elements are in their reduced forms (Mn(II), Fe(II)) and exist as mobile metal ions Mn^{2+} and Fe^{2+} (see e.g. Balistrieri et al. 1994). There are two important differences in the behaviour of Mn and Fe. First, Mn is more soluble than Fe, and it is first to be mobilized under oxygen depletion (Engstrom & Wright 1984). Second, Fe tends to be more involved in the sulphur cycle than Mn, and under extremely low redox potential, where H_{2}S is produced.

![Fig. 9.43. Plot of the selected elemental content in the youngest fragment of sediments of Lake Gosica. For iron and manganese the contents of non-carbonate forms are shown (see text).](image-url)
through the decay of organic matter, it may precipitate in the form of very insoluble iron sulfides, FeS or FeS$_2$ (Wetzel 1975). Manganous sulfides, on the other hand, are much more soluble, and production of H$_2$S does not inhibit dissolution of Mn from sediments (Engstrom & Wright 1984).

The effects of changing supply on Fe and Mn concentrations were demonstrated in studies of the post-glacial history of many lakes. In two Labrador lakes, Engstrom and Wright (1984) found marked increase of Fe and Mn concentrations coincident with the transition from tundra to coniferous forest in the drainage area. This change was interpreted as increased mobilization of both elements from the soils produced through the humus accumulation under conifer vegetation. Similar explanation was given by Dean (1993) for the high early-Holocene accumulation of Fe in Elk Lake, Minnesota. Mackereth (1966) hypothesized, that the differential mobility of Fe and Mn could be used to reconstruct redox conditions in catchment soils. He reasoned that the increase of the Fe/Mn ratio accompanied by the increase of Fe itself indicate lowering of redox in the surrounding soils. Such a change in the Lake Gosćiąż sediment at the Pleistocene/Holocene boundary (Łącka et al., Chapter 7.3; Goslar, Chapter 8.1) could thus be connected with the development of coniferous forests in the drainage area.

Beside its effect on mobilization of Fe and Mn from soils, the redox-solubility relationship is also important for the transport of these elements to lakes. Accordingly, both elements are transported to the lakes by oxygen-depleted groundwater, and the declines of Fe and Mn in sediment profiles from several Swedish and Norwegian lakes (Digerfeldt 1975, 1977) were explained by the progressive decrease in the flux of subsurface water.

The second, equally important factor controlling Fe and Mn profiles is the preservation in lake sediments. Iron and manganese, precipitated from the oxidized water column and accumulated in the sediments may easily be redissolved. In most lakes, only a thin uppermost layer of sediment is oxidized. The consumption of oxygen by microbial activity below that layer causes both Fe and Mn to be considerably more mobile and to enter into solution. They then may diffuse upwards and precipitate in the oxidized surface sediments. Such a migration results in Fe and Mn peaks at the top of sediment, which do not reflect the historical changes in sediment deposition (Engstrom & Wright 1984). The oxidized surface preserves these elements, once buried, from dissolution and escape back to the lake water. If hypolimnionic waters, and hence the uppermost sediments, become deoxygenated, the manganese, followed by iron, diffuse from the sediment into bottom waters. Such a mechanism is responsible for the hypolimnionic maxima of Fe and Mn concentrations near the water/sediment interface. In meromictic lakes, e.g. Hall Lake, Washington, USA (Balistrieri et al.

Mackereth (1966) reasoned that in weakly anaerobic hypolimnion manganese, because of its greater mobility, could be selectively depleted in sediments, while under more severe anoxia both Fe and Mn will be lost. An additional separation of Mn from Fe may result from dissolution of Mn precipitates while they descend in anoxic waters (Davison 1981). Because of separation, the lowering of hypolimnetic redox should be reflected by peaks in the Fe/Mn ratio, coincident with minima in iron concentration.

Mayer et al. (1982) suggested that in some eutrophic lakes the release of Fe and Mn from sediments may be mediated by the formation of carbonates (siderite, rhodochrosite). Such a behaviour explains the correlation between Fe, Mn, and total carbonates, envisioned in IPC. Presumably a part of the observed variation of Fe and Mn is connected with the formation of carbonates. If we assume that the ratio of FeCO$_3$ and MnCO$_3$ to total carbonates was constant, we may calculate the concentration of both elements fixed in sediment in form of non-carbonate compounds. These concentrations (Fig. 9.43) do not reveal the long-term trend. Comparison of records in Figs 9.40 and 9.43 suggests that the carbonate compounds
constituted ca. 35–65% of total iron, and 20–50% of total manganese.

Having documented the changes of human presence in vicinity of Lake Gościa (Goslar, Chapter 9.2.1) and changes of lamination quality (Goslar, Chapter 9.2.2), one would expect drastic changes in the concentration of accumulated iron and manganese. The variations of concentrations of both elements are well correlated but, surprisingly, the ratio of total as well as of non-carbonate Fe to Mn deposited in the Lake Gościa sediments (Fig. 9.43) was more or less constant through the last 300 years. This would indicate that the redox potential in hypolimnion was usually low enough to inhibit the effects of changing separation between Mn and Fe. The only exception is the period AD 1800–1830 of the Fe/Mn maximum, coincident with minimum of Mn, and only minor lowering of Fe concentration. Palynological data suggests that most oaks were cut out at that time (Ralska-Jasiewiczowa & van Geel, Chapter 9.2.4), presumably used by the settlers of the developing “Dąb” villages (Goslar, Chapter 9.2.1). The maximum of Fe/Mn could thus be explained by temporal opening of forests, which caused the short-lasting soil oxidation and inhibited mobilization, especially of Mn, from the catchment soils.

The striking feature is an abrupt drop of Fe and Mn concentrations in AD 1953 (with no change of Fe/Mn ratio), 9 years after farms were abandoned near the lake (Goslar, Chapter 9.2.1). The drop of non-carbonate Fe is followed by the gradual decrease until AD 1967, coincident with the extinction of lamination after AD 1966. It is important that in the sediment deposited after AD 1966 not only calcite laminae are lacking but also diatoms and chrysophycean cysts do not form clear layers, which precludes the responsibility of post-depositional chemical processes, i.e. dissolution of calcite, for the observed lack of lamination. Another possible mechanism is mechanical disturbance, either by benthic fauna or wind-driven water movements. However, the abundance of benthic fauna in the present lake (Żbikowski 1993) is too low to produce appreciable disturbance of sediment (Giziński, pers. comm.). On the other hand, the occasional vertical circulation reaching lake bottom is documented by the profiles of temperature (see Fig. 3.6, Churski, Chapter 3.3). Such circulation could disrupt lamination not only by direct mixing in situ but also through the well documented (Giziński et al., Chapter 3.5) resuspension of sediments from shallower parts of the lake. Nevertheless, as documented by the presence of a few dispersed layers and by the well defined bomb-peak of 14C (Goslars et al. 1994), both mixing and resuspension could not affect the sediment deeper than a few centimeters.

Both the drop of Fe and Mn and extinction of lamina- tion could result from abandoning of farms and consequent lowering of lake trophy in AD 1940–1946, suggested by Goslar (Chapter 9.2.2). The enhanced organic productivity and more intense decay of organic matter in the upper sediment could increase the density of bottom waters, inhibiting the vertical circulation and decreasing the strength of spring and autumn overturns. Such a mechanism could explain the higher quality of lamination during periods of more intense human occupation in the last 3000 years (see Goslar, Chapter 8.2, Fig. 8.19), and also the appearance of regular lamination after development of “Dąb” villages at the beginning of the 19th century. If real, however, the circulation mechanism does not explain the observed drops of Fe and Mn concentrations by significant oxidation of sediment. The long-lasting oxidation should decrease the solubility, raise the concentrations of Fe and Mn, and also lower the Fe/Mn ratio. If, however, the redox potential increased at the very low level, it might inhibit formation of iron and manganese sulphides through the H2S-involving mechanism and result in faster release of Fe from sediment. Such a mechanism should affect mostly iron, because the manganese sulphides are much more soluble.

The sulphide hypothesis explains the delay between changes of lake productivity and those of non-carbonate Fe concentrations, since decay of organic matter deposited proceeds through several years. Unfortunately, it cannot explain the abrupt drop of Fe in AD 1951 and especially the accompanying drop of Mn in AD 1949. An additional possible mechanism is that, driven by short-lasting circulation, replacement of Fe-Mn-rich hypolimnetic waters by the Fe-Mn-poor masses from lake surface would stimulate further diffusion of both dissolved elements from sediment. The Fe and Mn atoms would thus undergo more intense cycling between epilimnnion and sediment before final burial, which of course increases probability of their loss from the lake with the outflowing water. Since manganese is more soluble than iron, increased circulation should be accompanied by an increase of Fe/Mn ratio. In fact, a small increase of the Fe/Mn ratio is observed.

Another paleoredox indicator is the ratio of copper to zinc concentrations. Vuorinen (1978) found that the decrease of redox potential of bottom waters from 100 mV to -200 mV was accompanied by an increase of Cu/Zn ratio from 0.1 to 0.4. In the Lake Gościa sediments both elements tend to increase (perhaps due to inereasing lake productivity) prior to AD 1949. Until AD 1948, the Cu/Zn ratio remained nearly constant, and in AD 1949 it dropped abruptly by a factor of two. Such a change seems to confirm slight oxidation of bottom waters, in accordance with the circulation hypothesis.

The drop of Fe concentration in AD 1951 is opposite to the increase in AD 1884 - 1887 following the lake eutrophication after settlement of Dąb Borowy. The delay of 7–13 years between the decline of trophy after abandoning the farms and the drop of Fe is similar to that between eutrophication after settlement of Dąb Borowy and
rise of Fe lasting (depending on trophy indicator) 8–12 years. If the variations of Fe and Mn concentrations were driven by lake productivity through the sulphide or circulation mechanisms, they should be correlative with the indicators of organic productivity. As shown in Fig. 9.44, the variations of non-carbonate Fe and Mn concentrations show some delay with respect to the changes of potassium content (see Fig. 9.42). The asymmetry of correlation as a function of delay is reasonable, as the changes of organic productivity affect the rate of sulphide production in several following years but do not act back in time. Such a delayed correlation strongly confirms that the measured variations of element concentrations were not an artefact of simple interference with other elements (e.g. Ca) in the analytical process, but they document real dynamic ecological process.

Unlike potassium, iron, and manganese, all reflecting mostly human influence, the concentration of sodium seems to comprise the climatic information. This as well as potassium may be taken as an index of chemical weathering in the drainage basin and/or the erosive transport of soil particles to the lake (Engstrom & Wright 1984, Dean 1993). The concentration of sodium was compared with the mean annual sum of precipitation in Warsaw (ca. 100 km east of Lake Gościąz). The instrumental meteorological data were collected by S. Paczos and H. Maruszczak (Paczos 1993, Maruszczak 1988). In the analysed period AD 1825–1960, the Na concentration is significantly positively correlated with the annual sum of precipitation (Fig. 9.45), suggesting that the slope wash rather than chemical weathering is the main factor controlling the variations of Na content in lake sediment. The more detailed comparison, showing the weakest Na-precipitation dependence during summer season, when the soils are most stable against erosion, seems to support this interpretation. The concentration of potassium, however, is not correlative to precipitation. This was unexpected, since potassium undergoes less intense weathering and thus a stronger effect of erosion than sodium. As discussed earlier, similar behaviour of both elements was found in Lake Amersee in Germany (Michler et al. 1980).

The concentration of lead in the Lake Gościąz sediments (Fig. 9.43) increased first after AD 1880, and once again between AD 1950 and AD 1960. The lead concentrations in lake sediments were frequently used to study the effects of anthropogenic pollution (e.g. Renberg & Segerström 1981, Renberg 1986). The record from the Lake Gościąz sediments, however, seems seriously affected by the mobility of lead above AD 1950, clearly evidenced by the non-monotonic profile of $^{210}$Pb concentrations (Goslar, Chapter 9.2.2, Fig. 9.31). As discussed by Wachniew (1993), lead may be easily mobilized in reductive environments when the lack of sulphur inhibits fixation of Pb in form of sulphides. Therefore the profile of Pb in Gościąz, though it documents the increase after Second World War, is probably strongly flattened. Mobilization of lead in the upper part of the sediment of Lake Gościąz is concordant with effects explaining the Fe and Mn profiles.

The changes of other elements amounts are difficult to interpret. Those of Ni, Cd, and Li (Fig. 9.38) could reflect the industrial pollution by these metals; nevertheless, observed increases after AD 1960 are very low, perhaps because of situation of Lake Gościąz far from industrial centers.

9.2.4. POLLEN RECORD OF ANTHROPOGENIC CHANGES OF VEGETATION IN THE LAKE GOŚCIĄZ REGION FROM AD 1660 UNTIL RECENT TIMES

Magdalena Ralska-Jasiewiczowa & Bas van Geel

In the sediment cores from Lake Gościąz, obtained by means of piston corer, the quality of annual laminations deteriorates in the upper part of the sediment sequence until nearly total disappearance of laminae in the top 1.26 m. Thanks to the application of freezing in situ technique (Walanus, Chapter 4.1.2) the youngest part of sediment, except for its topmost ca. 50 cm, revealed also the existence of annual lamination, which enabled the construction of a continuous chronology based on correlation of laminae in 20 short frozen cores back to the middle of the 17th century (Goslar, Chapter 9.2.2). The new longest
core from 1995, very well correlated with the piston-core sequences, allowed some age corrections to close the sequence between the dates AD 1660 and 1990. The samples for pollen analysis collected by T. Goslar come from cores G21f (AD 1990–1940), G32f (AD 1941–1906), G31-3f (1894–1816), and G33f (AD 1779–1662) (Goslar, Chapter 9.2.2, Fig. 9.25). The average time resolution of counted samples in the part covering yrs AD 1818–1990 is ca. 2.9 yr, and between AD 1660 and 1779 it appeared to be slightly over 5 yr, because of the correction of time scale. The pollen samples were prepared at Palaeobotanical Laboratory in Cracow (see Chapter 4.6.1). The calculations were based, as in core G1/87, on the combined pollen spectra from M. Ralska-Jasiewiczowa and B. van Geel. As the volume of the samples was not quite uniform, the calculation of pollen influx was too rough to be useful.

Construction of pollen diagram and significance of some microfossil taxa for palaeoecological interpretation

The subdivision of the pollen diagram (Fig. 9.46) is supported by numerical analyses (CONSLINK, Principal Component Analysis) based on selected most frequent pollen taxa (Fig. 9.47). The basic division shows in the first component (39% loading) two main parts of the diagram, with the boundary around the 1820s (GF1c/GF2): the older part is distinguished by higher proportions of Quercus, Alnus, and Betula and by lower contribution of human indicators except for Cannabis sativa; the younger part by maximum of Pinus, higher Juniperus, and maximum of anthropogenic pollen taxa. These proportions change gradually in the 2nd half of 20th century because of a decrease of human indicators and increase of Betula and Alnus, as shown distinctly by 2nd component (17% loading). The 2nd component points to one more boundary of lower rank around the 1750s, distinct also in CONSLINK analysis (Fig. 9.47) and constrained probably by the fall of Cannabis values.

The comparison of the GF pollen diagram with the corresponding part of diagram G1/87 (Fig. 9.48) shows the convergence in the basic division of both sequences into main periods (see Chapter 9.1.3, Fig. 9.15). The section from the middle of the 17th century up to the end of 18th or early 19th centuries, with rather high Quercus and slightly increased Corylus, appears in both diagrams as a time of decreased economic activities in the area, the only essential difference being the lower and earlier maximum of Cannabis (AD 1625) in G1/87, which however, might be the effect of poor sample resolution in G1/87 and lack of pollen spectra below 1662 in the GF sequence. The section from the 1820s to recent times shows in both cases the intensification of agriculture.

The patterns formed by pollen taxa of minor quantitative importance allowed for further subdivision of the GF
Fig. 9.48. A comparison of selected pollen curves from the GF pollen sequence (black silhouettes) and from the top part of G1/87 pollen diagram (hatched silhouettes) based on the common calendar time scale.
diagram, leading in some cases to the exact correlation of changes in the pollen record with economic and historical events known from archival sources. Sometimes the lack or delay of response of the pollen spectra to the known facts was observed. This altogether may be of methodical value for the interpreters of pollen diagrams, as it is seldom the case that a pollen record can be correlated with an event with such a time accuracy. As the subdivision into the local pollen zones has mostly been based on many subtle changes in pollen composition, their description has not been separated from interpretation in order to avoid too many repetitions.

The treatment of pollen samples with the acetolysis destroys more delicate palynomorphs. Due to this reason only selected non-pollen microfossils with more resistant wall could be found in pollen spectra. The records of some microfossil taxa (Aphanizomenon, Anabaena, Tetraedron, Trichocerca cylindrica, Tintinnopsis lacustris, Staurophya and especially Pediastrum; Fig. 9.49, see also Goslar et al. in print) seem to be indicative for the changes in water chemistry and lake trophy. Pediastrum coenobia, combined here into one group – genus Pediastrum – are mostly planktonic, but some species grow also in other wet habitats. Round (1973) mentions Pediastrum as epipelagic, growing on sediments and according to Cronberg (1982) in some lakes in southern Sweden high increases of Pediastrum were found in connection with the periods of increased lake pollution. This can also result from the coincident development of macrophyte zone creating suitable habitats for periphytic Pediastrum species. In records from Lake Gościąž Pediastrum is also indicative for the periods of increasing eutrophication.

Description of local pollen zones and interpretation of vegetational changes in connection with the history of settlement

Four local anthropogenic pollen zones and three subzones have been distinguished in the GF pollen sequence. The recovered process of vegetation changes may be described and explained as follows:

**GF-1 Quercus-Betula-Alnus** LPAZ (AD 1662–1820)

*Quercus, Betula,* and *Alnus* pollen values exceeding generally 10% each. *Corylus* and *Carpinus 1–2%, Pinus below 40%. *Cannabis* at maximum of ca. 10% in the lower part of the zone, then declining. *Secale* up to 2%, other farming and grazing indicators continuously present but with low pollen values.

These pollen proportions, as compared with the section of the G1/87 pollen diagram of earlier age (AD 1525–1625) (Ralska-Jasiewiczowa & van Geel, Chapter 9.1.3, Fig. 9.15) indicate the time of rather reduced though functioning settlement in the area. This is in agreement with the history of Masovian lands, where the most of the 17th century was a time of economic depression. The crisis was caused first by too oppressive villager services, which generated wrong farming practices (continuous dominant cultivation of cereals, lack of fertilization bringing impoverishment of soils, etc.) and resulted in mass exodus of farmers to the towns (Szczepański 1990). The following great invasion of Poland by Swedes (in AD 1655–1660), with burning of towns and villages and progressing depopulation, ruined the economy of the area.

The pollen zone discussed can be divided into 3 subzones:

*Cannabis-Secale* PASZ (GF-1a: AD 1662–1740)

Continuous (up to 1–2%) *Carpinus, Fagus,* and *Corylus* and initially continuous but later interrupted occurrences of *Fraxinus, Ulmus,* and *Tilia cordata,* evidence the still existing small fragments of mixed deciduous woods. *Quercus,* its pollen percentages exceeding 10%, contributed to these and other forest communities, growing probably most frequently in mixed pinewoods common on more elevated poorer habitats. The importance of this tree of high value in the area of dominating pinewoods (e.g. its acorns were certainly used for feeding pigs) was documented by the use of its name (*Dąb*) for naming settlements in the lake surroundings (Goslar, Chapter 9.2.1). Alderwoods were widespread around the lake, and *Betula* occurred in different often devastated wood types.

The local presence of farmlands is well recorded and shows the structure of cultures changing in time: *Cannabis* pollen curve, up to 10% in the lower part of the zone (hemp retting in the lake?), declines after ca. 1713, while from AD 1698 cereal-growing (mostly *Secale,* but possibly also *Hordeum*) seems to increase in area, as is also stressed by field weeds (*Centarea cyanus, Rumex acetosella,* *Polygonum aviculare,* *Scleranthus annuus,* *Bilderdykia convolvulus*). Around 1713–1720 *Fagopyrum* and probably some crucifer plants appear in cultivation. At the same time a *Humulus lupulus* curve, rather substantial from the diagram base, drops rapidly to single scattered occurrences in the whole overlying part of the profile. It is impossible to decide whether *Humulus* pollen originated from its native habitats in alderwoods or from cultures. However, the peasant tributes in hops are mentioned from that time, in connection with the existence of breweries at nearby Duninów and at slightly more distant Gostynin and Gabin. Each of them produced in AD 1630 300–450 barrels of beer per year (Szczepański 1990). The brewery at Duninów ran from at least the 16th century, and no information was found when it stopped working. All this makes the supposition about hop cultivation in the area very probable. AD 1720 would then be the end of its cultivation, the overlying scattered occurrences of its pollen coming from natural sites.

Around that time the peaks of *Cyanobacteria* (*Aphanizomenon, Anabaena,* etc.) are well visible in the pollen sequence, up to 10% in the lower part of the zone, possibly also *Botrydium variabile* (SGA) starting to increase (AD 1720–1740), while after AD 1740 the decline in the presence of *Cannabis* and *Secale* is visible.
zomenon and Anabaena, Fig. 9.49) suggest the eutrophication of lake water with phosphates (Van Geel et al. 1994, 1996).

The situation described above corresponds and slightly follows in time the temporary improvement of economic conditions reported from the part of Masovia discussed for the 1680s and 1690s (Szczepański 1990). In 1674 at Dąb village, situated close to Lake Gościąż, 55 families were reported to pay rents (Pelisiak & Rybicka, Chapter 9.1.2). However, the next subzone seems to reflect the resumption of economic crisis:

Corylus-Calluna-Artemisia PASZ (GF-1b: AD 1740–1767)

The diagram records the first reaction to the abandoning of some terrain utilized earlier by farmers, i.e. the spread of ruderals initiated by Chenopodiaceae, then Artemisia, Rumex crispus L., Urtica dioica, and sporadically Echium. Some rise of Juniperus and less distinctly increasing Betula, Populus, Salix, and Alnus, followed with a 20–30 yr delay by small rises of Carpinus, Corylus, and Ulmus pollen frequencies may evidence the successional overgrowing of abandoned lands and local regeneration of woods. The changes in the AP record are not, however, that conspicuous; more significant are depressions in the pollen curves of the cultivated plants: Secale cereale, Hordeum L., Cannabis sativa L., Cruciferae (?), and of the weeds Centaurea cyanus, and Rumex acetosella. Some less frequent cultivated or weed taxa like Fagopyrum, Polygonum aviculare, Scleranthus annuus periodically disappear. The overgrowth of open spaces on poor sandy soils is evidenced by rising Calluna and appearance of Jasione, Sedum, and Scleranthus perennis pollen; the indicators of fresh meadows do not reveal any distinct changes on those habitats.

The lake trophy was then low, as suggested by the low frequencies of Cyanobacteria in the pollen spectra (Fig. 9.49).

Artemisia-Secale PASZ (GF-1c: AD 1767–1820)

The first signs of new economic activity are registered in the pollen record from ca. AD 1770, but the criteria for defining this section of the zone as a separate subzone are poor and mostly negative. They include small falls of Carpinus and Corylus but also of Populus, Juniperus, and Calluna pollen frequencies, indicating probably local clearings of overgrown surfaces both on more fertile and on sandy, rather poor habitats. Small rises of Secale, Cannabis and different weed and ruderal pollen taxa evidence some renewal of farming activities. Unfortunately, the sequence of changes is disrupted at 1779 by a ca. 30 yr gap, but similar AP proportions with some indices of slowly developing agriculture occur also in the first decades of the 19th century. A distinct change in pollen record is indicated only from ca. AD 1820.

To understand the settlement processes in the area discussed some general historical knowledge should be recalled. The German colonization on the Gostynińskie lands, developing from the second half of the 18th century with the so-called “Hollandii” (Hauländer?) settlement as one of its widespread forms, was connected with the foundation of several new villages in the area (see Goslar, Chapter 9.2.1). The dates of their establishment are not quite certain (AD 1746 by Zimecki 1990, AD 1789 by Tomczak 1977), but the dates for the introduction of “oleder” settlers in particular estates are mostly grouped in the last 15 yr of the century (Szczepański 1990). On the map from 1802 published by Gilly (Goslar, Chapter 9.2.1, Fig. 9.22) the open lands approach Lake Gościąż from N-NE, surrounding already Lake Wierchon. During the passages of Napoleonic troops in 1806–
1812 the area was heavily exhausted because of frequent requisition of goods and animals, which, however, brought also some economic activation, especially the development of small towns and intensification of food production (Kociszewski 1976). After the formation of the “Congress Kingdom” in 1816, the upgrowth of small towns in the Gostyniński Lands initiated by the new administration was to be based on cloth production (Szczepański 1990). This resulted in an increased exploitation of wood and stimulated sheep breeding. All those events led to essential changes in the functioning of the local economy influencing the environment, as is clearly recorded in the diagram from ca. 1820.

GF-2 Pinus-Juniperus- Secale LPAZ (AD 1820–1910)

The zone is distinguished by the highest Pinus (up to 60%), generally lowered Betula and Alnus pollen curves, and substantial Juniperus values (up to 4%); Quercus is much reduced (to ca. 3–5%), Carpinus and Corylus decrease to 1% or less, and other deciduous tree taxa are sporadic. Cannabis slowly declines, but Secale and Rumex acetosella increase distinctly throughout the zone, Cruciferae reach up to 1%, and Fagopyrum appears regularly in the lower and upper parts of the zone.

All those changes are evidence of intensive settlement connected with the felling of woods. The clearing included secondary woods overgrowing old abandoned farmlands, the alderwoods in the lake surroundings (beside Betula and Alnus, depressions of Populus and Salix curves), the still existing fragments of mixed deciduous woods, and even drastic extermination of oak trees. The dominant pinewoods might have also been affected, as suggested by increased flowering of Pinus, and spread of Juniperus, and of dry heath-grassland vegetation (Calluna, Melampinggium, Jasione, Sedum, etc., and ferns – Filicales monoletae ca. 2%).

Agriculture was developing. The pollen-analytic data point to Secale as the dominant cultivated grain, the other cereals being in deep minority. How far would such record be affected by their different pollination type (wind transport for Secale and elyptogamic pollination for the other cerealina)? In the Gostynin Land, as documents from the beginning of the century say (Szczepański 1990), agriculture functioned in a three-field rotation system: winter cereals (Secale, seldom winter Triticum); spring cereals (Hordeum, Avena, seldom spring Triticum) or Fagopyrum, Pisum, Panicum, potatoes; and fallow land. However, it was in fact based primarily on rye. Two times less barley and oats, and four times less wheat and potatoes were grown. In the pollen record this pattern is resembled, but proportions are much exaggerated.

Solanum nigrum - t. pollen, representing most probably S. tuberosum, appears sporadically from AD 1818, and then more regularly in the top part of profile. The historical sources are not quite positive about the introduction of potatoes to Poland supposed for the end of 17th century. They certainly became widespread from the time of partition of Poland a century later, and particularly after the passages of Napoleon troops during AD 1802–1812 (Nowiński 1970, Herse 1980). The development of potato cultivation in Poland in the first decades of 19th century was interrupted by a fungus pest (Phytophthora infestans) spreading throughout Europe in ca. 1840–1851 (Nowiński 1970, Körber-Grohne 1988). It reached the study area in 1847–1850 (Chudzyński 1968).

The single appearances of Solanum nigrum - t. span times before (AD 1818, 1830) and after (AD 1870) the epidemic.

Another rare and rather astonishing evidence is Zea mays pollen. Maize was probably introduced to Poland by the end of the 18th century from Roumania or Hungary (Herse 1980). Being, however, a plant of high climatic demands it presumably could grow in the warmest regions only. According to Körber-Grohne (1988), in Germany it was cultivated until the first decades of the 19th century mostly in regions suitable for the vineyards. It spread a little outside those regions after the first potato pest in 1805–6, and after the famine following the great plague in 1840–51 the new more resistant maize varieties were introduced in central and north Germany. The single finds of Zea mays pollen in Lake Gościąż profiles are dated at AD 1834 (GF profile) and around AD 1839 (G1/87 profile). Was Zea mays cultivated in central Poland that early? There was no mention about it in available sources.

No information was also found about the role of crucifer plants in the farming structure of the discussed time, though the diagram shows clearly their importance. The fields were very weedy, the more so because the soils were mostly poor. Rumex acetosella was the dominant cereal weed, as shown by its pollen curve strictly following the Secale curve, though it might have also grown in different disturbed biotops of sandy soils (Behr 1981). Its maximum contribution to the field flora falls between AD 1840 and 1870, and afterwards the fields might have been slightly cleaner. Besides, Centaurea cyanus, Polygonum aviculare, and many sporadic weed taxa appear. Scleranthus annuus, Bilderdikya convolvulus, Polygonum persicaria - t., Spargula arvensis, Anagallis arvensis, Consolida - t., Nonea, and later (AD 1860–70) also Agrostemma and Viola arvensis. Of cultivated Leguminosae plants only a single occurrence of Vicia faba was noted at AD 1848.

The existence of grazed surfaces close to the lake is evidenced by high Gramineae, substantial Plantago lanceolata, Rumex acetosa - t. pollen curves, and many other meadow taxa of different habitats occurring regularly (Rhinanthus, Trifolium pratense, Trifolium undif., Lotus, etc.), or sporadically (Sucessa pratensis, Geum, Lythrum, Polygonum bistorta). A considerable proportion of eco-
logically undefined pollen taxa originated probably also from those vegetation types. However, the local farmers suffered heavily from a shortage of soils suitable for good pasturrounds; the efficiency of cows was very low, lots of goats and sheep were bred, and pigs were fed also on pastures but mostly in woods.

The development of agriculture and animal breeding coincides with the increase of lake eutrophication as suggested not only by the increase of eutrophic Cladocera, but also by the rise of *Plagiastrum* (Fig. 9.49).

In the younger part of zone, from between AD 1858 and 1864, some decline of *Pinus* was coincident with rises of *Juniperus* and *Populus* and with further reduction of *Carpinus*, suggesting devastation of pine and mixed woods. The AP changes are accompanied by growing frequencies of *Secale* and other cereals (*Hordeum* -t., *Avena* -t., *Cerealia undiff.*), of *Fagopyrum* and Cruciferae, field weeds and ruderals, as well as by increases of some fresh meadow indicators (e.g. *Plantago lanceolata*) and rising diversity of taxa.

All those changes tend to show the growing density of population and intensification of agriculture resulting from new waves of German colonisation in response to Polish insurrections; after the first one in 1831, particularly after the second one in 1863. We should expect that the development of “Dąb Borowy” village (Dąb = oak; Borowy = in pine forest), closest to Lake Gościącz, in the late 1880s (Goslar, Chapter 9.2.2) would find a direct reflection in pollen spectra, but not much change is to be seen in connection with this date: these are only small falls in *Quercus*, *Betula*, and *Populus*, single evidence of newly planted taxa (*Aesculus* and *Vitis*), and rise of *Plantago lanceolata*. Unfortunately, another gap, between AD 1894 and 1906, disturbs the observation of the following changes. However, it seems rather obvious that substantial changes in pollen spectra start from around 1912 only.

The disturbance of lake ecosystem by the settlements approaching the lake shores is then evident: the blooms of *Tetraedron minimum* start appearing from AD 1868. The other symptoms of this disturbance are described by Goslar (Chapter 9.2.3).

**GF-3 Secale-Plantago lanceolata LPAZ (AD 1912 –1953/58)**

The zone is distinguished by reduced *Pinus* and *Populus* and increased *Salix* pollen values. *Juniperus* is initially high, but after AD 1928 decreases slightly, coincidentally with a rise of *Betula* and *Alnus*. The indicators of agrarian economy are at maximum values, with dominant *Secale* exceeding 10% between ca. 1932 and 1941, high *Rumex acetosella*, and peaks of *Centaurea cyanus* and Cruciferae at AD 1917–1930. *Cannabis* and *Avena* -t. are continuous up to 1%, other cereals are less frequent, and *Fagopyrum*, *Solanum nigrum* -t., and *Zea mays* pollen occur regularly. The frequencies of most common ruderals (*Artemisia*, *Chenopodiaceae*, *Urtica*), lowered at the zone beginning, start rising around 1940. The pollen values of plants associated with fresh/wet meadows are quite high (*Gramineae*, *Plantago lanceolata*, *Rumex acetosa* -t.), as is the representation of those communities rich in taxa (*Lychnis flos-cuculi*, *Polygonum bistorta*, cf. *Vicia cracca*, *Succisa pratensis*, *Centaurea jacea* -t., *Trifolium pratense* -t., *Rhinanthus*, *Lotus*, *Cirsium* -t., *Euphrasia*, *Mentha* -t., etc.), including many taxa which are ecologically undefined.

According to the historical sources (Chudzyński 1990), the first decade of 20th century in the study area was the time of economic stagnation, deepened still by extreme climatic phenomena (years of drought alternating with years of too high precipitation). However, the poverty and primitive economy of farmers of this historical stage can hardly find any expression in the pollen record. Some progress began in the second decade, but it was soon interrupted by the outbreak of the First World War.

The economic breakdown connected with the destruction of many villages by military actions in 1914, requisition of domestic animals and goods and other disasters, culminated in the famine winter 1917/18, called a “turnip cabbage (rutabaga) winter” (rise of Cruciferae pollen in 1917–21?). The German invaders heavily devastated local woods, breaking all the rules of extirpation and falling up to 70% of total tree stands (Chudzyński 1990). The *Pinus* fall and minor changes in AP frequencies following ca. 1918 might record the consequences of those events.

The post-war years 1918–39 of regained state independence witnessed the efficient development of the area, particularly of small local towns, which, however, was connected again with too extensive clearing of forests, its progress clearly evidenced in the diagram. On the map from 1927 (Goslar, Chapter 9.2.1.), the cleared grounds surrounding Na Jazach lakes extend towards the east of Lake Wierzchoń, where houses are grouped, and towards the northwest along the Ruda stream to the broadly opened Vistula valley. From the south-southeast the forest approaches Lake Gościącz.

The lake eutrophication is strongly indicated during the time between two World Wars. Besides the development of *Araphidinae* diatoms (Goslar, Chapter 9.2.2 and Goslar et al., in print), *Aphanizomenon*, *Tetraedron minimum*, and *Coelastrum reticulatum* form then distinct maxima for the last time.

During the 2nd World War the gradual evacuation of German families from the closest Dąb Borowy settlement was concluded in 1944 by expulsion of the remaining Poles (Goslar, Chapter 9.2.1). A distinct increase of ruderals (*Artemisia*, *Chenopodiaceae*) reflects those events in the pollen record, and from 1944 *Secale* and *Avena* -t.
pollen curves begin to decline. The village was not settled again after 1945 as many other villages in the region were. However, for several years more some land was still in use by farmers from neighbouring settlements. As evidenced in pollen diagram they were still growing some cereals, mostly rye and possibly also Fagopyrum, hops, and usable Cruciferae species. Open surfaces were certainly used for animal grazing, as the increased Plantago lanceolata pollen values and other less frequent meadow taxa persist to the late 1950s, and only then decline or disappear. Increased contents of charcoal were found during sediment analysis by Goslar (in 1940/41, 1944 and from 1946 for several years, Chapter 9.2.2, Fig. 9.30) and during pollen analysis (1944, 1946/47, 1950 and later). The vegetation/landscape changes in consequence of depopulation proceeded in two steps: first the spontaneous overgrowth on abandoned land, and later the systematic forest plantation, but they are recorded in the pollen diagram as a slow gradual process. The only recognizable reaction to the fires from herb vegetation is the increase of ruderals. The rise of the Betula pollen curve starts in 1948 and of Salix in 1950, whereas the charcoal signals first serious war fires in 1940/41. This clearly corresponds with the time needed for Betula (B. pendula) to settle and then to pass from the juvenile phase to generative reproduction, estimated at 5–10 years on average and in extreme cases 2 years (Wareing 1959, Jonsson 1949, Stern 1961). The complexity of the Salix genus excludes any discussion on this matter.


The top zone of GF pollen diagram reflects the last decades of vegetational change around Lake Gościądz up to 1990, when the frozen core was collected. It covers the times of methodical reforestation on abandoned or degraded lands, concluded with the foundation of Gostynińsko-Wloclawski Landscape Park in 1979, with the Na Jazach lakes complex situated in its central-north part (Lenart 1994).

The years between 1952/3 and 1959 are recorded in the diagram as the time of substantial change: the decrease of Juniperus from 1953 (overgrown land cleared and then used for tree plantation?) is followed by a slight rise of Corylus, and from around 1959 by distinct rises of Betula and Alnus pollen. As the main planted tree in the area was pine (Załuski & Cyzman 1994), it should be supposed that those young cultures were soon spontaneously overgrown by birch, and closer to the lake by alder. The marginal zones of the lake were afforested by 1954–56 (Goslar, Chapter 9.2.1), but the diagram suggests that the last near-by fields persisted till 1957. Besides the decline of Secale and Rumex acetosella, some taxa of cultivated plants and field weeds, if sporadic before, disappear at this time from the pollen record (Fagopyrum, Solanum nigrum -t., Scleranthus annuus, Spargula, and many others), and the more frequent are reduced to single grains (Hordeum -t., Triticum -t., Zea mays, Centaurea cyanus, Polygonum aviculare).

After 1957 Secale cereale and Secale/Cerealia pollen stabilize at values making together over 4%. Avena -t. oscillates up to 1%, as does cf. Cannabis sativa. These pollen types are still today transported in a forested area from fields located at a minimum of ca. 3.5 km to the lake centre, while Rumex acetosella -t. pollen at continuous values of 3–5% may originate partly from fields but also from any open sandy habitats (Behre 1981). The above data contribute to our knowledge about the transport of field pollen to bigger lakes. The areas of unused meadows and sandy grasslands are reduced by overgrowing (decline in Plantago lanceolata, Rumex acetosa, Carex -t., Compositae SF. Cichorioideae, and recently also Gramineae). Their composition becomes distinctly impoverished as evidenced by gradual disappearance of sporadic meadow and sandy grasslands pollen taxa (Jasionne montana, Plantago media, Ononis -t., Silene vulgaris -t., Compositae SF. Cichorioideae, Trifolium -t., Rhamanthus, Geum, Valeriana dioica, Melampyrus). Some meadow taxa may now persist in other plant communities, e.g. in alderwoods. Ruderals expand (Urtica dioica, Artemisia, Chenopodiaceae, Plantago major, Xanthium, Sambucus nigra). As a result of fishing and tourist activities they find particularly suitable habitats at alderwoods edges and lake shores. However, as a whole, the taxa richness falls considerably.

The decline and extinction of settlement activities started to influence the lake ecosystem surprisingly early, already for 1938 when the decrease of Cyanobacteria and Chlorophyceae is to be seen (Fig. 9.49).

The further pollen-analytic studies based both on top-sediment frozen cores and on surface samples should be continued parallel with the observations on recent changes of flora and plants communities under legal protection.

Conclusions

The last 330 years in the woodland versus settlement history of the Lake Gościądz region, as recognized in the pollen record, can be divided into 3 main stages:

1. AD 1660–1820 – dispersed small and primitive settlements, slowly growing in number from late in the 18th century, agriculture not much developed. Deciduous woodlands still existing in small fragments, but the dominant forest community is mixed pine forest with rather abundant Quercus. Devastated habitats overgrown by birchwood. Alderwoods surround lakes.

2. AD 1820–1944/1956 – the progressive development of farming and animal breeding, culminating during the time of regained state independence between the two World Wars (1920–1939), resulted in the final exterrina-
nation of deciduous wood remnants. It heavily affected oak participation in pine forest and reduced secondary wood growth. *Juniperus* overgrowths were dominant in pine forest with frequent openings.

3. 1944/1956–1990 – after the depopulation of adjacent settlements and after a short intermediary phase of declining activities of farmers from more distant villages (1944–1956), a systematic plantation of pine on post-arable grounds and the spontaneous overgrowth on the rest of the abandoned land results in the covering of lake surroundings by secondary woods dominated by *Pinus* and *Betula*. Very small regeneration of *Corylus*, and *Carpinus* and spread of *Alnus* are recorded during the last decade (1980–1990). A significant transport of field pollen to the lake is constantly observed (dominant *Secale*), with closest fields at a distance of 3.5 km.

9.2.5. Discussion and Conclusions of the Human Impact During the Last 330 Years

**Magdalena Ralska-Jasiewiczowa, Tomasz Goslar, Bas van Geel & Krystyna Szeroczyńska**

The data presented in chapters 9.2.1 through 9.2.4 give a unique record of human impact on lacustrine environment and surrounding vegetation during the last 330 years. As reported previously (Goslar et al., in print), this record is very interesting for a few reasons. First, the lakes Na Jazach complex is located far from industrial centres, and its catchment is surrounded by forests, so the system was disturbed only through the agricultural activities in the few villages. Secondly, within the time span considered we could study the response of the system to the increasing anthropogenic stress as well as the return to more “natural” conditions after the withdraw of man from the lake vicinity. Third, the lamination of sediments enabled monitoring of events with the time accuracy to a single year.

In this chapter we attempted to confront the historical and palaeoecological data from individual chapters displayed on the common time scale (Tab. 9.13), and discuss them together. For reasons outlined in Introduction (Chapter 1) we decided not to refer our synthesis to the relevant regional or global data, but to focus it rather on the history of the Lake Gościąż region alone, in the local scale. This chapter will thus serve as a background for further research and more general discussion.

The different types of data are ordered in columns. The general historical background and the history of local settlement known from written documents is summarized in columns no. 1 and 2. Columns 3–6 show sedimentary records derived mostly from the analyses of cores collected by freezing in situ technique. Some supplementary data come from the uppermost part of profile G1/87. That profile was analysed with much lower time resolution, and relevant data in Table 9.13 are shown by dashed lines. Column no. 3 describes the changes in sediment formation. The data on lacustrine biota (column no. 4) coming from frozen cores are completed with Cladocera record, transferred from analyses of G1/87 profile (Szeroczyńska, Chapter 8.4). Similarly, in the column no. 5 concerning the content of organic matter and selected minerals, outside the period AD 1840–1965 studied in frozen cores, the CaCO$_3$ analyses from the core G1/87 (Wieckowskii et al., Chapter 5.1) were quoted. Variations of chemical composition along the profile are shown in column 6. In the reconstruction of land vegetation (column no. 7) based on palynological studies there is a gap covering the period AD 1779–1818 where the samples were lacking.

The four stages of settlement following historical sources can be recognized in the history of human impact recorded in the Lake Gościąż sediments during the last 330 years: moderate impact phase of small local hamlets (before ca. AD 1770), increasing impact phase connected with the “Hollandii” settlement (ca. AD 1770–1863), German colonization phase (AD 1863–1944) with intensification of agriculture from ca. AD 1910, and phase of reduced rural economy and restoration of natural environment (after AD 1945). This subdivision is partly but not substantially different from the zonation of pollen diagram.

**Phase of small local hamlets (before ca. AD 1770)**

During this period, besides the dominant pine and mixed pine forests with abundant oak, some more fertile parts of the area were still covered by deciduous woods, and birch copses were frequent on grounds used earlier by man. The local settlement had a form of individual farms spread in the woods, jointly called the Daż village. The agricultural activity was not very intensive (subzone GF-1a), what is especially well seen at the base of pollen record before ca. 1670 when it can probably be attributed to the general depopulation after Swedish invasion. The coinciding lack of *Bosmina longirostris* in sediments reflects rather low lake trophy. Some activation of farming after 1673 is marked by the distinct evidence of *Cannabis* cultivation (retting in the lake?) dominant till ca. 1710, by increasing crop of cereals (mostly *Secale*) after ca. 1695, and introduction of *Fagopyrum* after ca. 1715. The broad peak of *Aphanizomenon* and *Anabaena* (Cyanobacteria) at AD 1690–1730 indicates lake eutrophication at that time. A distinct fall of economy (GF-1b), connected with the increase of pests, and oppressive tributes resulting in the escape of farmers to towns, is reflected in the Lake Gościąż region after 1740. The area of cultivation was reduced significantly then, what left space for the spread of weeds and heaths (*Calluna*), and enabled small regeneration of deciduous woods (*Carpinus, Corylus*), this state prolonging through the next 50 years.
During the whole phase the chemical composition of sediments was rather constant, probably due to the influence of deciduous forests, stabilizing leaching of minerals from surrounding soils.

**Phase of ‘Hollandii’ settlement (ca. AD 1770–1863)**

Intensification of human impact at the end of 18th century is connected with the “Hollandii” colonization. The settlers formed new villages: Dąb Niemiecki (?), Dąb Polski and Dąb Wielki (mentioned at first between 1789 - 1803), consisting of individual farms grouped in the mixed pine woods, where oak was probably locally abundant (Dąb = oak) north of the Na Jazach lakes (see Kępczyński & Noryśkiewicz, Chapter 3.7).

Influence of “Hollandii” settlers on forests is initially poorly recorded (GF-1c), and detected only from the decline of 18th century. The destruction of still remained Carpinus and Corylus stands and, to some degree, also of Quercus, in favour of pines is evidenced then. Recession of deciduous trees coincided with the beginning of gradual increase of potassium content in lake sediments, and a new development of Cyanobacteria. The drastic drop of calcium, strontium and magnesium contents ca. 10 years later could also be triggered by the recession of trees, which depleted biogenic CO₂ in groundwater, led to weaker dissolution of carbonate rocks, and decreased input of carbonates, Ca and other relevant ions to the lake. The control of soil processes on carbonate content in sediments seems to be reflected in the high variability of Ca, Sr and Mg concentrations after 1780, in the period of beginning strong land-use changes.

The disturbance of forests around 1770 should have been accompanied by some development of agriculture, still through at least the next 20 years the frequencies of Secale and of other cereals in pollen spectra remain low. More extensive growing of Secale and crucifer usable plants are documented after 1818. The lack of pollen data between 1779–1817 disables unfortunately any detailed reconstruction of anthropogenic changes during that important transient period. One may, however, speculate that some clearing of alderwood, as documented by lowering of Alnus and rises of Graminae, Carex -t. and Filicales monoletae, initiated temporal oxidation of soils, as indicated by the maxima of Fe/Mn ratio in sediments. It was intensified in connection with the broad-scale clearings involving also Quercus and Betula.

Development of agriculture in the period of “Hollandii” settlement coincides with the improvement of lamination quality in sediments. This is probably due to gradual eutrophication of the lake, suggested by the increasing content of iron (bound in sediments in form of sulphides) and confirmed by increasing frequency of Bosmina longirostris and the rise of Pediastrum after 1840. The increase of potassium content after ca. 1825 seems to correspond with the cultivation of potatoes, introduced probably around 1820 (indicated by pollen of Solanum nigrum -t.).

Pollen of probable garden fruit trees (Malus -t., Prunus -t., Juglans) and decorative shrubs (Syringa) appearing after 1858, may reflect the occurrence of houses close to the lake. The increase of sedimentation rate at the same date seems accidental, as the houses surely were settled a few years before the flowering of fruit trees.

**German colonization phase (ca. AD 1863–1944)**

The defeat of January insurrection in 1864 triggered Russian authorities to support German colonization at the western borders of state, including also the study area. In this connection, the village of Dąb Borowy was settled, its existence mentioned first in 1880. Its farms located around the lakes, disturbed directly lake ecosystems and sediment chemistry.

The earliest signals of disturbance were the blooms of Tetraedron minimum and Araphidinae diatoms (accompanied by drop of carbonate content in sediments) after 1868. From 1873 on, vivianite started to appear regularly in sediment and, three years later, the regular spring blooms of Chrysophyceae were disturbed for the first time. These changes, indicating altogether the increase of lake trophy, were followed by the increase of sedimentation rate, the maxima of organic matter and potassium contents in sediments (1881–1885) and abrupt rise of iron concentration at 1882. That rise resulted probably from intensified decomposition of organic matter in sediments, what stimulated formation of insoluble iron sulphides. Such hypothesis seems to be supported by the gradual decline of iron content prolonging for ca. 15 years after the maximum of organic matter. The increase of lake trophy is indicated by the very high frequency of Bosmina longirostris from 1885, slightly lowered in 1903. Unfortunately, the time resolution of Cladocera analyses was too low to reconstruct their development in detail.

The data above indicate that human impact on lake biology and chemistry was strong already during the early phase of settlement of Dąb Borowy. However, the pollen data in general do not indicate initially any intensive development of agriculture at that time. Some increase of grassland indicators (e.g. Plantago lanceolata), suggests rather that the lake regime was more essentially influenced by animal husbandry. A significant development of agriculture commenced about ca. 1910 only. The pollen record evidences the increased cultivation of cereals (Secale, Avena-t., Hordeum-t. and Triticum-t.), potatoes (Solanum nigrum-t.), Fagopyrum and probably of usable species of Cruciferae. Forest clearing after 1910 affected also the pine woods. In the lake, the increasing human impact was reflected by blooms of Tetraedron minimum,
Table 9.13 List of more important information derived from individual studies on top part of Lake Gościąż sediment, and from historical written sources concerning the last 330 yr.

<table>
<thead>
<tr>
<th>Year AD</th>
<th>1 Historical background</th>
<th>2 Local settlement, villages</th>
<th>3 Visual features of sediment</th>
<th>4 Lacustrine biota</th>
<th>5 Org. &amp; mineral sed. fractions</th>
<th>6 Chemical sediment composition</th>
<th>7 Land vegetation</th>
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"January" insurrection

Dab Borowy

Regular lamination

Increase of sedimentation rate

End of regular spring blooms of Chrysophyceae

Gradual decrease of Chrysophyceae

Drop of Cu/Zn (oxidation of hyphymen)

Gradual increase of Poassium concentration

Low variable concentration of Ca, Sr and Mg

Plantago lanceolata

Expansion of introph. weeds: Chenopodiaceae, Artimisia, Avena, Hordeum, Poaceae, Paeonieae, Cruciferae

Decrease of agriculture

Expansion Betula - Alnus

Reforestation of the Gościąż shore and vicinity

Juglans (gardens)

Frutet trees, Syringa, Dactylis, Crataegus

Max. cultivation, Stipa

Max. collection, Stipa

Max. evaporation, Stipa

Tetrajuncta

Minima of CaCO₃

Apex of Papularia

Appearance of myxanite

Gradual decrease of organic matter calcite ratio

Rapid rise of Fe, followed by gradual decrease

Increase of Cu and Sr

Max. increase of Ca and Sr

Juncetum - Salix

Juncetum - Juncetum

"War - Isolation"

German colonization
Centriceae diatoms and, a few years later, by rising content of organic matter and iron in sediments. The progress of agriculture seems also connected with the maximum content of phosphorus in the sediment in 1925 (Łącka et al., Chapter 8.2), though the highest crops are suggested by the maximum frequencies of Secale pollen between 1934 - 1941 only. The expansion of nitrophilous weeds (Chenopodiaceae, Urtica, Artemisia) visible from ca. 1939, may be connected with the war events afflicting the local population.

Phase of restoration of natural environment (after AD 1944)

The beginning of phase is coincident with the abandonment of Dąb Borowy settlement by the end of Second World War. From this time on, the area was subject to gradual reforestation, completed until the middle of sixties, the lake shore itself being afforested by the middle of fifties (1954–1956). During this time, however, the open land of abandoned farms was still used by inhabitants of neighbouring villages, growing there cereals and vegetables. Now, the whole area is forested, and no agricultural activity proceeds in the close lake vicinity.

This history is clearly reflected in pollen data, showing first signs of farm degradation from ca. 1944, and significant decrease in frequencies of all cultivated plants and accompanying weeds from 1953, this process progressing till recent time. The drop of Secale pollen curve between 1957–1959 documents probably the stoppage of farming activities on close-by fields. This drop coincides with the fall of Juniperus and rise of Betula and Alnus pollen values indicating the spontaneous development of pioneer woods on grounds unused since late fourties, their progress documented till now. Interestingly, the present frequency of Secale in the Lake Gościaz sediments is nearly the same as before the settlement of the lake shore (Dąb Borowy village) in 19th century.

Expansion of tree and shrub vegetation was probably responsible for the increase of calcium and strontium content in sediments, clearly synchronous with the rise of Betula curve, the effect being reverse to that observed after 1770. The gradual extinction of farming activity near Lake Gościaz coincides with surprisingly abrupt changes in lake ecosystem. The earliest symptoms of change appeared in 1938 (decrease of sedimentation rate, decrease of Cyanobacteria and Chlorophyceae) and 1939 (restored blooms of Chrysophyceae). Abrupt extinction of vivianite from sediment in 1946 marks lowering of lake trophy. Further lowering of trophy is documented by rapid decline of phosphorus content in sediments after 1950, decline of Araphidinae diatoms after 1960 and expansion of planktonic Cladocera. As documented by the drop of Cu/Zn ratio, lake hypolimnion has been weakly oxidized since 1949. The replacement of Fe-Mn rich hypolimnetic water by the Fe-Mn-poor masses from lake surface, stimulating diffusion of both dissolved elements from sediment, was responsible for the abrupt drop of iron and manganese content in sediments above AD 1950. For iron, the abrupt drop was followed by gradual decline through ca. 15 years, reflecting probably weakening of sulphur release from the sediments after lowering of lake trophy, the scenario being similar to that observed after 1885.

Increasing strength of spring and autumn over-turns affected preservation of laminae in sediments, which became less distinct after ca. 1945 and almost completely disappeared after 1966. Lack of lamination in the modern sediments is a serious obstacle in monitoring the mechanisms of laminae formation in present time. It seems to be the “bad joke of nature” that the return to more natural conditions in the Lake Gościaz area disabled direct study of the most unique feature of the lake sediments, what occurred after almost 13 thousand years of continuous varve formation.

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