tion 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

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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 palaeoecologial 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 (Więckowski 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 Dąb 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 CO_2 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.

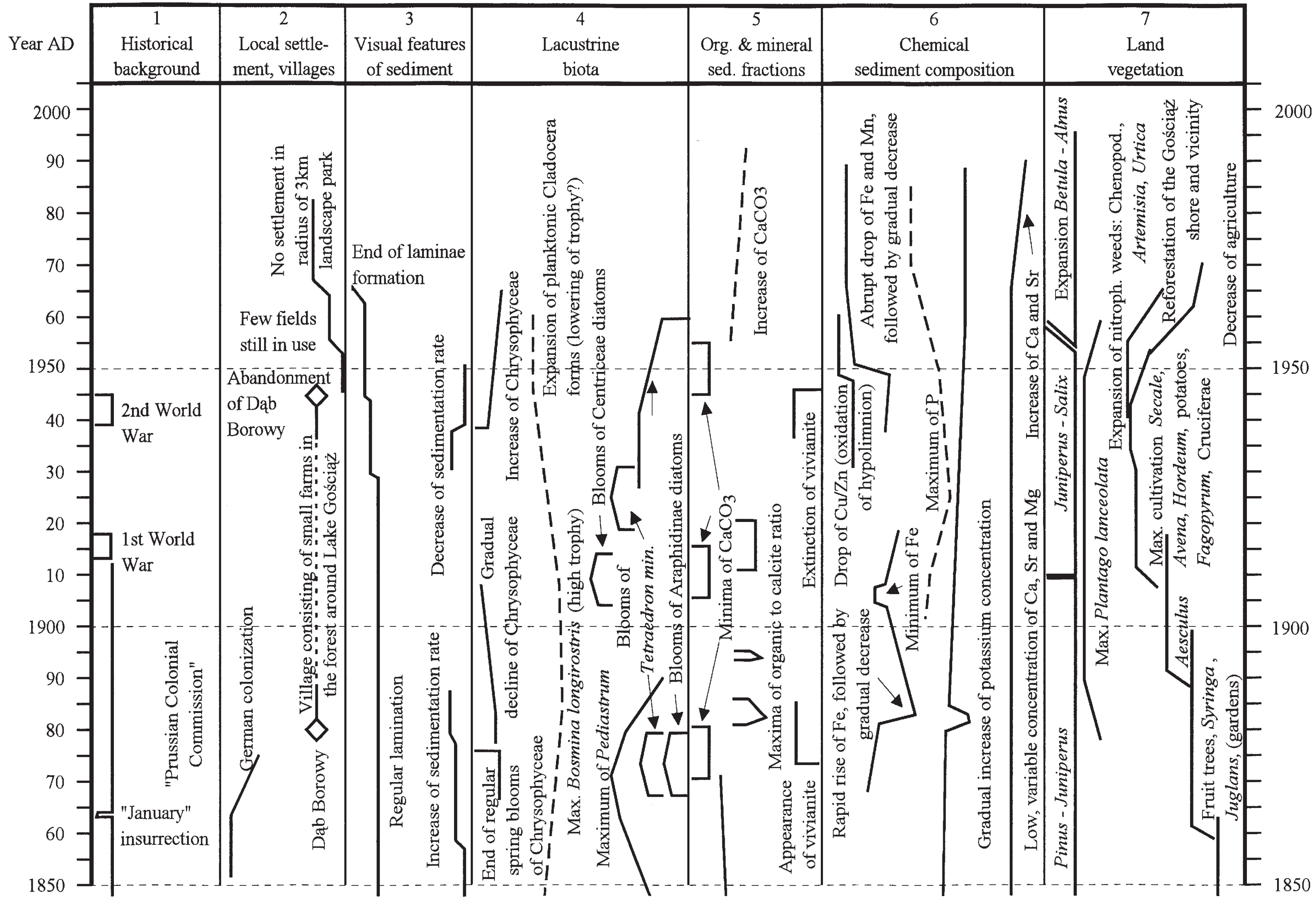
German colonization phase (ca. AD 1863–1944)

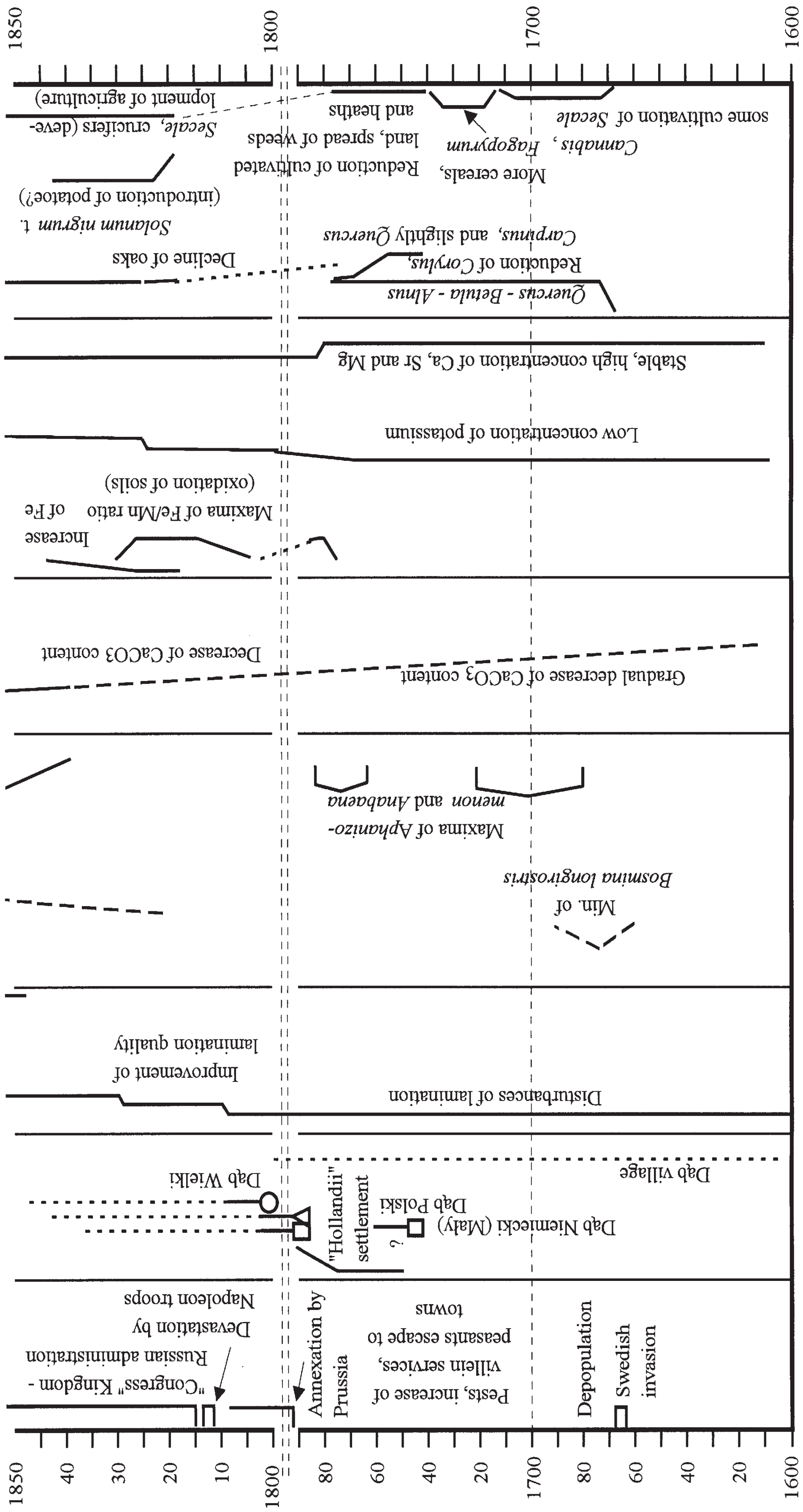
The defeat of January insurrection in 1864 triggered Russian authorities to support German colonization at the western borders of state, including also the study area. In this connection, the village of Dąb Borowy was settled, its existence mentioned first in 1880. Its farms located around the lakes,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




1850
1800
1700
1600
Secale, crucifers (development of agriculture)
Reduction of cultivated land, spread of weeds and heaths
More cereals, Cannabis, Fagopyrum
some cultivation of Secale
Solanum nigrum t. (introduction of potato?)
Decline of oaks
Reduction of Corylus, Carpinus, and slightly Quercus
Quercus - Betula - Alnus
Stable, high concentration of Ca, Sr and Mg
Low concentration of potassium
Increase of Fe
Maxima of Fe/Mn ratio (oxidation of soils)
Decrease of CaCO3 content
Gradual decrease of CaCO3 content
Maxima of Aphanizomenon and Anabaena
Min. of Bosmina longirostris
Improvement of lamination quality
Disturbances of lamination
Dąb Wielki
Dąb Polski
Dąb Niemiecki (Mały)
Dąb village
"Hollandii" settlement
?
"Congress" Kingdom - Russian administration
Devastation by Napoleon troops
Annexation by Prussia
Pests, increase of villein services, peasants escape to towns
Depopulation
Swedish invasion
1850 40 30 20 10 1800 80 60 40 20 1700 80 60 40 20 1600

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 Gościąż 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 Gościąż concides 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 overturns 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 Gościąż 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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