# I. SUMMARY

## Postglacial vegetation changes of the Wigry National Park on the background of cold climatic oscillations

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Intermittent cold glacials and warm interglacials occurred regularly during the Quaternary period. Each glacial-interglacial cycle was characterised by changes of climate and vegetation (Iversen, 1958). In general, the pattern of environmental changes during each cycle was very similar. Glaciation (the cryocratic stage of the cycle with the lowest temperatures) was followed by the oldest part of the interglacial, when temperatures gradually increased and subsequently soils and pioneering birch and pine forests were formed (the protocratic stage). The middle part of the cycle was the warmest climatic optimum of the cycle (the mezocratic stage). The sequence of occurrence of dominant thermophilic trees during the climatic optimum was characteristic of each cycle. Further, gradual climate cooling took place, accompanied by decreasing soil fertility and impoverishment of vegetation (telocratic stage), progressing until the beginning of the next glacial (cryocratic stage of the next glacial-interglacial cycle).

During the Holocene, which lasted ca. 11550 years, as in all previous interglacials, the pattern of environmental changes was consistent with the above-described one. However, the palaeoecological reconstructions employing increasingly higher-resolution chronostratigraphy carried out in recent decades revealed that the typical interglacial climate changes during the Holocene coincided with quite regular sudden and short (ca. 150-50 years) cooling periods. They form a series of climatic events repeated at every ca. 1470±500 years. These events (Bond cycles) have been investigated in detail in ice cores from Greenland and marine sediments from the North Atlantic. They also affected other parts of the world, which is reflected in the record of vegetational changes in some parts of Europe and fluctuations in water levels in the Central European lakes - a detailed literature review on this issue is provided in articles 2 and 3. These records show that palaeoecologists have still not reached a consensus on the global nature of cold mid-Holocene climatic events and the intensity of their effect on the environment in different regions of the world. Therefore, further palaeoecological studies aimed at clarifying these phenomena are necessary.

Particularly valuable information regarding the impact of sudden climatic events on vegetation are obtained from studies in regions where plants are most sensitive to all

environmental changes, including climate. One of these is north-eastern Poland, located in the transition zone between oceanic and continental climates. Many plant species have their limit of distribution here, which also means the limit of their ecological tolerance. Considering this fact, even minor and short-term climate changes may improve or deteriorate the condition of specimens representing these species and change pollen production, while prolonged cold periods may lead to significant changes in the composition of vegetation due to changes in the size of populations of some species, and may even shift the limits of their distribution range.

The main objective of the palaeoecological research carried out in Wigry National Park, located in north-eastern Poland, was to determine potential records of short mid-Holocene climate oscillations in this region and the impact of these oscillations on the postglacial development of vegetation. Three detailed aims of the study were formulated under the primary aim, and they also corresponded with stages of research: (1) to reconstruct the main stages of vegetational changes in the analysed region; (2) to identify possible disturbances in the interglacial vegetational succession and their climatic reasons through their chronostratigraphic correlation with short-term climate oscillations; (3) to explain whether changes were transient and had no significant impact on the vegetational succession during Holocene, which primarily depended on the main trend in the interglacial climatic pattern, or whether these changes had a significant impact on the succession pattern of Holocene vegetation, initiating or modifying its subsequent stages.

Deposits from three lakes were analysed: Suchar Wielki, Suchar II and Ślepe. The research mainly relied on pollen analysis, which allowed for the reconstruction of changes in terrestrial vegetation around the investigated lakes and in the them. The age of the analysed deposits was determined using radiocarbon dating and palynostratigraphic correlation of obtained pollen profiles with well-dated profiles from Wigry and Szurpiły lakes. Findings from additional palaeoecological analyses, such as cladoceran and diatom analysis conducted by specialists in this discipline, were also used for the interpretation of the obtained pollen data.

Data from the preliminary pollen analysis of sediments from all the investigated lakes are presented in **article no. 1**. They were used for the reconstruction of major stages of vegetational succession in the region of Wigry National Park in the late glacial of the last glaciation (Suchar Wielki) and during the Holocene (all the investigated lakes). The obtained pollen record was used to identify 10 regional pollen zones (R PAZ) characterising these stages. The study revealed that vegetational succession at that time was strongly shaped by the trend in glacial and interglacial climate changes, but some short-term changes in vegetation,

potentially caused by cold climate oscillations, were also documented. One of such changes was a sudden short-term expansion of birch in the younger part of the Preboreal period, possibly in response to climate cooling called Preboreal oscillation (PBO; 8$^{th}$ Bond event). The second was a temporary spread of spruce which was marked in the Subboreal period and could be associated with one of the cold climate oscillations of that period.

The reconstruction of the main stages of Holocene vegetational succession in the vicinity of the investigated lakes and identification of Holocene phases characterised by the probable effects of sudden climate cooling on the vegetation of Wigry National Park was followed by a more detailed investigation of changes in vegetation in two of these periods. **Article no. 2** presents a detailed reconstruction of changes in vegetation around and in Suchar Wielki lake during the Preboreal period (ca. 1160-9800 cal. years BP). Pollen analysis for that time documented as many as four short-term (ca. 50-150 years) cold climatic events. The first three were dated at ca. 11300-11150, 11100-11000 and 10900-10850 cal. years BP, and were separated by relatively short (ca. 50-100 years) warmer periods, which documents the significant climate instability of the older part of the Preboreal period. The last registered cooling took place in the younger part of the Preboreal period ca. 10300-10200 cal. years BP, and was preceded by a ca. 300-year-long gradual climate cooling. A series of three cold events recorded in the older part of the Preboreal was correlated with a Bond cycle, when the lowest temperature was dated at 11100 cal. years BP, and cooling registered in the younger part of this period with the Bond cycle was dated at 10300 cal. years BP.

The three early-Preboreal cold events corresponding with event 11.1 ka were reflected in the pollen record as lower pollen concentrations for both three species forming forests at that time, pine and birch, indicating a significantly limited florescence, and pollen production by these trees. During the oldest of these cold events the response of birch to cooling was less pronounced that of pine, which, in diagrams with pollen percentage, was manifested by the decreased share of *Pinus* pollen and peak value for *Betula* pollen. On the other hand, during both younger cold events, the response of pine and birch, reflected in limited pollen production due to climate deterioration, was very similar, which may suggest that the temperature drop was less marked at that time than during the oldest cooling. The composition of birch and pine forests probably did not change in any of the early-Preboreal cold events, which only caused changes in the intensity of pollen production by trees forming forests.

Late-Preboreal cooling correlated with event 10.3 ka in the area of Wigry National Park was associated with reduced climate humidity. During this cold event a short-term spread of

birch range in the studied area probably took place. This is supported by the fact that pollen concentration for this taxon increased, as well as its percentage share.

The comparison of obtained palynological and palaeoecological records for different parts of Europe has led to the conclusion that changes in flora and fauna described for the Preboreal periods probably occurred in response to a sequence of cold events that had different effects on the natural environment, and thus the response was different across the European continent.

**Article no. 3** presents a detailed reconstruction of changes in vegetation cover around and in Suchar Wielki and Suchar II lakes during the Atlantic period (ca. 9200-5750 cal. years BP). The reconstructed changes in vegetation pointed to five cold events during that time, dated at ca. 9050-8950, 8700-7800, 7600-7250, 7100-6600 and 6050-5900 cal. years BP. The most important was the second cold event, chronostratigraphically corresponding with oscillation 8.2 ka ($5^{th}$ Bond cycle).

It was demonstrated in this paper that cooling correlated with event 8.2 ka, and in the investigated area it could have lasted even ca. 900 years. During that period a temporary remodelling of forests probably took place, associated with changes in the share of individual forest-forming tree species. It was documented that hazel was the most sensitive to climatic oscillations considering all trees and shrubs forming forest community in the investigated area. In the pollen record this was reflected in a significant drop in hazel pollen concentrations, which, among other things, corresponded with a reduced percentage share of hazel, and could also result from the limited area of hazel during cold event 8.2 ka.

Other Atlantic coolings probably lasted for only several to several dozen seasons, with longer and colder winters, and affected only the intensity of pollen production by plants, particularly thermophilic ones. This suggests that all these climate changes had a much weaker effect on the local environment than the cooling at 8.2 ka. Nevertheless, the results of palynological studies confirmed the occurrence of a series of cold events that were also reported for other regions of Europe.

In conclusion, the high-resolution reconstruction of the postglacial vegetation development in the Wigry National Park area and the parallel changes in the aquatic environment of the studied lakes have provided new and important information on the effects of short-term, cold, mid-Holocene climate oscillations on the pattern of vegetational succession during the Holocene. The response of vegetation in Wigry National Park to climate cooling, i.e. Bond cycles, was documented. Thus, new data on the global nature of these climate oscillations has been provided. It has been shown that only coolings dated at ca.

10.3 ka and 8.2 ka could have caused a temporary remodelling of vegetation in the investigated area, while other cold events caused only periodic reduction in pollen production by trees and shrubs. This clearly shows that the cold events had no significant effect on the pattern of vegetational succession. Nevertheless, the reported cold events are important for the chronostratigraphic correlation of various records of environmental changes that took place in Europe. In addition, the obtained results helped identify climate changes of variable impact on the natural environment, indicating the complexity of correlations between climate and vegetation, and emphasizing the role of differences in the response of individual tree species, e.g. birch and hazel, during particular stages of the Holocene.