Natural changes in bog vegetation reconstructed by sub-fossil tree remnant analysis

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Changes in bog vegetation during more than two millennia are the subject of the paper. More than 300 specimens of *Pinus sylvestris* L. tree remnants collected from oligotrophic peat deposits were dendrochronologically analysed. By synchronising annual growth sequences of the sub-fossil pines and based on radiocarbon dating of some trees, the distribution of tree life spans along the temporal scale has been established and the dynamics of the bog woodstand reconstructed. Separate afforestation phases differing in stand development and extinction dynamics, and phases of open-land type vegetation, corresponding to cold and humid climatic periods, have been detected.

Key words: dendrochronology, Lithuania, palaeoecology, *Pinus sylvestris*, raised bog, vegetation history

INTRODUCTION

For the efficient use of natural resources and successful environmental decisions, not only data on the present status of the ecosystems, but also knowledge of the dynamic processes are necessary. In order to forecast the forthcoming environmental changes, evaluation of natural successions alongside the anthropogenic impact is essential.

Natural changes in the environment are usually slow, long-lasting and difficult to observe directly. Palaeobotanical analysis of plant remnants and other historical studies are used to obtain information on vegetation and environment history [1]. A more accurately dated information on the history of wooden plant growth dynamics and causal environmental processes can be revealed by dendrochronological investigations of annual ring sequences of trees that grew in the past [2–4]. In this study, dendrochronological analysis of tree remnants preserved in raised bog peat deposits was used to reconstruct the bog pine forest dynamics during a period of more than two millennia.

MATERIALS AND METHODS

The study site – Užpelkių Tyrelis raised bog – is located in the north-west part of Lithuania, Plungė district, 47 km east of the Baltic sea and 1 km north of Lake Plateliai (56°05' N, 21°50' E). The bog turned to its oligotrophic phase in the dry period at the end of Subboreal (2500–2600 years ago) [5]. Layers of oligotrophic peat were investigated for tree macro-remnants, and preserved timber specimens were mapped and collected by scientists and workers of the dendroclimachronological laboratory under the supervision of Dr. T. Bitvinskas. Timbers found in the peat consisted of *Pinus sylvestris* L. stumps and prostrated trunks. More than 300 specimens from the depth ranging 0.0 to 2.8 m were collected.

Wood samples were prepared and tree rings (layers of annual growth) analysed using a standard dendrochronological technique [6]. The surface of stem part cross-sections was sanded and tree ring width measured in 2 to 4 radii per specimen on a stereomicroscope with an accuracy of 0.05 mm. The tree-ring width sequences for each radius were plotted, synchronised and averaged to get a single series representing the sample.

The constructed sample ring series were synchronised among themselves in order to cross-date the tree life spans and growth series against each other with an accuracy to one year. To this end, all the growth series were compared in pairs, looking for the overlap position with highest values of statistical interrelation and the best visual cross-mach. In each overlap position the following statistical parameters were calculated: the coefficient of parallel variation [6], correlation coefficient, and Student's t value [7–9]. Having synchronised a group of series, the tree

ring data set for each year were averaged to get a tree-ring chronology representing a cross-dated timber group.

Separated tree-ring intervals of 28 timber specimens from various depths were dated by ^{14}C method at the Estonian Institute of Zoology.

RESULTS AND DISCUSSION

Synchronisation of the growth series of the sub-fossil trees has revealed the clustering of tree life spans in particular intervals of a time scale. Five clusters of timbers with cross-dated tree ring sequences were formed. Based on ^{14}C data of dated timbers, the clusters were positioned on a time scale. Separate afforestation phases in the bog vegetation history became evident after dating the sub-fossil tree life spans (see Fig. 1).

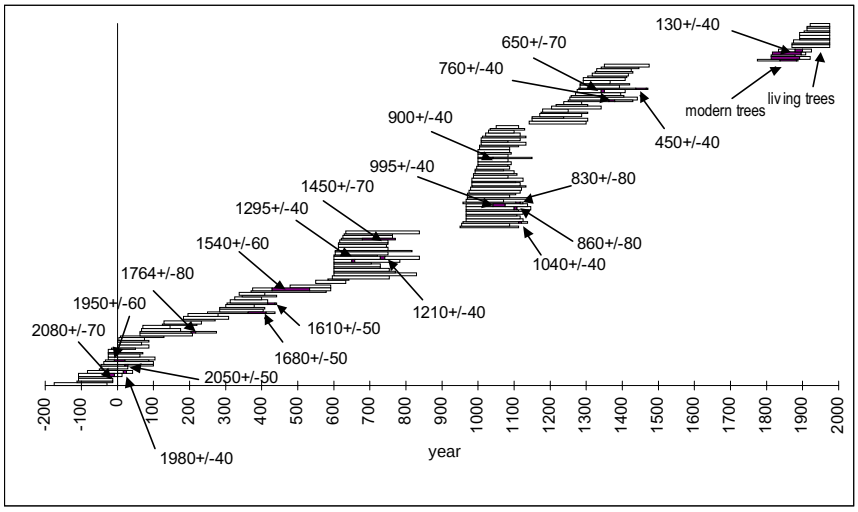

Fig. 1. Distribution of pine tree life spans (expressed by horizontal bars) along a time scale. Arrows indicate C-14 dates of the measured tree-ring intervals (yr BP)

Conditions in the beginning of the bog oligotrophic phase (approx. 2500–2600 years ago [5]) were not suitable for pinewood establishment. First solitary pine trees germinated in the 2nd–1st century BC. These trees settled on the undulating surface of the bog. For example, stem base depth of contemporary trees No 551 and 1365 (the difference between their germination dates was 5 years) differed by 0.45 m, though the trees grew 11 meters apart.

A more intensive formation of pine woodstand can be noticed at the very end of the 2nd century BC and about the turn of the first millennium AD. At the end of the 1st century AD and at the turn for the 3rd century AD, some gradual changes in forest generations can be traced.

This oldest afforestation phase lasted for almost eight centuries(from the 2nd century BC to about the 6th century AD). The pine stand was very thin at the end of the phase in the 5th–6th centuries.

The mass regeneration of pinewood (see the cumulative curve of tree germination in Fig. 2) took place around the turn of the 7th century AD. That afforestation phase lasted till the second half of the 9th century. Optimal conditions indicated by a higher than the average annual increment rate (sometimes reaching 195% of the average) persisted for more than a century and a half and changed for worse at the end of the 8th – beginning of the 9th century. The destruction of tree stand was gradual. No mass perishing of trees is noticed, except a higher mortality rate around the middle of the 8th century (see the cumulative curve of tree extinction in Fig. 2).

Pine trees started to spread quite rapidly onto the area again in the middle of the 10th century, after a phase of open-land type vegetation which lasted for about a century. The tree ring width chronology for this phase shows three intervals of better growth when radial increment was above the two-millennial average almost continuously for 30–40 years. The stand lived until the middle of

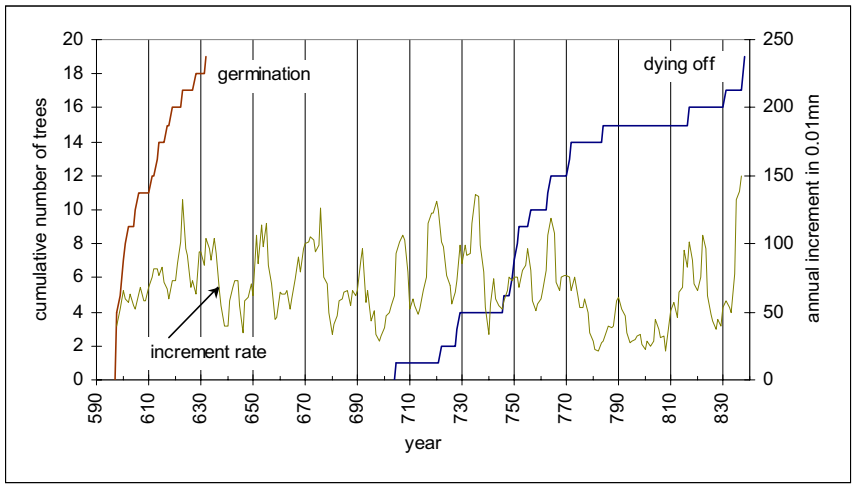

Fig. 2. Cumulative curves of annual tree germination and dying off in the 7th–9th century bog woodland phase. The light line represents the mean annual radial increment (growth chronology)

the 12th century. The pine stand dynamics indicates that a period with unfavorable climatic conditions in the 9th century separated two optimal for pine growth periods around the 7th century and around the 11th century.

In the second millennium pinewood began to spread in the middle of the 12th century again. The regeneration of trees was gradual and lasted two centuries. Lower than the average radial increment rate prevailed until the end of the phase in the 15th century. No pine trunks were found in posterior peat layers formed in the course of about three centuries. The absence of wooden macro-remnants indicates that open-land type plant communities dominated in the investigated area from the end of the 15th till the second half of the 18th century. This was the longest gap between afforestation phases.

A new afforestation phase started only in the second half of the 18th century and lasted till the beginning of peat exploitation in the 20th century. The annual radial increment rate of pine trees exceeded the two-millennium average in the middle of the 19th century and was higher than the average almost continuously during the 20th century.

A comparison of the reconstructed fluctuations in bog vegetation with palaeo-climatic evaluations in references [2, 4, 10–12] suggests that recurrent spread and destruction of bog pine stands followed the general European climatic fluctuations. This pertains in particular to the well known in palaeo-climatology climatic periods of "the medieval warm epoch" (circa AD 1000), during which a dense pine stand on the bog is documented, and "the little ice age" (in the 16th–18th centuries), when the open-land type vegetation dominated. Other phases of open-land type vegetation also correspond to the periods defined by increased humidity (the beginning of the Subatlantic period [1]) or decreased temperature (9th century AD [2, 4]).

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NATŪRALŪS PELKĖS AUGALIJOS POKYČIAI, REKONSTRUOTI ANALIZUOJANT SUBFOSILINES MEDŽIŲ LIEKANAS

S a n t r a u k a

Straipsnyje aprašomas pelkės augalijos pokyčių, vykusių per daugiau kaip du tūkstančius metų, tyrimas. Pateikiami per 300 *Pinus sylvestris* L. medžių liekanų, rastų aukštapelkės durpių kloduose nuo paviršiaus iki 2,8 m gylio, dendrochronologinės analizės rezultatai. Sinchronizavus praeityje augusių pušų metinio prieaugio sekas ir remiantis atskirų medžių radioanglies datomis, rekonstruota pušies medynų išplitimo ir žuvimo dinamika. Nustatytos atskiros medyno išplitimo fazės, besiskiriančios medžių atželimo intensyvumu, taip pat plyninės (bemiškės) augalijos vyravimo laikotarpiai, atitinkantys šalto ir drėgno klimato periodus.