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Dendroecological investigations on mountain bog pine (*Pinus rotundata* Link) in a peat bog in southwestern Germany

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Abstract

Increment cores of 200 mountain bog pines (*Pinus rotundata* Link) were collected in five sample plots along a hydrological gradient in a peat bog in Upper Swabia, Southwest Germany. The aim of the study is a dendroecological characterization of mountain bog pine growing on sites showing different qualities to provide a better understanding of environmental signals enclosed in fossil wood of bog pines excavated in archaeological sites. Beside ring width, wood anatomical features like traumatic tissue, intraannual density fluctuations, compression wood and the occurrence of tangential resin ducts were registered. Traumatic tissue more frequently occurs at the moistest site which carries an open stand of bog pine, while other wood anatomical features do not reveal any pronounced differences among the sites. Cumulated growth rates calculated from ring-width measurements are smallest at the moistest site and largest at the driest site, but do not differ markedly at the three intermediate sites. A combination of signal-to-noise ratio (SNR), mean sensitivity (MS) and mean correlation (MCor) also reveals a clear separation of the trees growing at the driest and moistest sites, respectively. Future studies will search for a climatological interpretation of wood anatomical anomalies and pointer years derived from ring-width chronologies.

Introduction

In the course of intensive archaeological explorations in peat bogs in southwestern Germany (Federseeried close to Bad Buchau, Upper Swabia), huge numbers of subfossil logs of mountain bog pine (*Pinus rotundata* Link) dating from middle and late bronze age times were excavated (Huber and Holdheide 1942; Billamboz 1992, 1996, 2002). Between 1570 and 1510 B.C., the tree-ring chronologies of mountain bog pine and other tree species from moist sites show synchronously occurring periodic growth reductions. These growth reductions mark a phase between two settlement periods of the so called „Siedlung Forschner“ and were interpreted as a climatic period of a rising peat bog water level (Billamboz 2002). Since today, however, only few dendroecological studies have been carried out on mountain bog pine (Freléchoux *et al.* 2000) which might partly be caused by the fact that the species and its natural habitats are under nature conservation.

Growth habitats of mountain bog pine (*Pinus rotundata* Link) in southwestern Germany are confined to marginal areas of acidic, oligotrophic ombrogeneous peat bogs. The species is a weak light competitor (Schmid *et al.* 1995) and is superseded by spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) or birch (*Betula pubescens*) under less extremely wet or oligotrophic conditions. Within peat bogs, *Pinus rotundata* occurs in several plant sociological units which differ in respect of their hydrological conditions (Wagner and Wagner 1996).

The present study investigates changes in growth reactions of mountain bog pine in dependency of a hydrological gradient from the drier margins to the very moist centre of a peat bog. On the other hand it shall be tested, if indications for different ecological site qualities can be derived from anatomical or dendroecological characteristics in the wood of *Pinus rotundata*. The results aim to provide a data basis for a better ecological and palaeoclimatological interpretation of the abundant subfossil material.

Study site and material

The study site „Pfrunger Ried" is located northwest of the town of Wilhelmsdorf (Upper Swabia) at 47°54'15''N/ 9°20'00''E in 610m a.s.l. Five sampling plots (A to E) were established along a hydrological gradient which can be reproduced with the help of the species composition of the understory. Within the plots, all trees were levelled precisely and two tree-ring samples per tree were collected by the use of an increment corer. The size of the sampling plots and the respective number of collected trees are given in Table 1.

Table 1: Characterization of the sampling plots

sampling plot	**A**	**B**	**C**	**D**	**E**
size in m^2	490	250	220	270	186
number of trees sampled: *Pinus rotundata* *Pinus sylvestris*	 24 12	 52	 40	 39	 45
No. of undatable samples	0	6	3	6	3

Plot A is located close to the edge of a former peat cutting area and represents the relatively driest site of the transect. Beside *Pinus rotundata*, *Pinus sylvestris* occurs and points to the dominance of competing species if conditions would get even drier. The understory is dominated by dwarf shrubs like *Vaccinium myrtillus* and *Vaccinium uliginosum*. In plots B to E, mountain bog pine is the only tree species. By means of plant sociology, plot B can be classified as Vaccinio uliginosi-Pinetum rotundatae rich in dwarf shrubs, plots C and D belong to a variant of the Pino mugo-Sphagnetum rich in *Eriophorum vaginatum* and plot E to the variant of the Pino mugo-Sphagnetum with *Sphagnum spp*. dominating (after Wagner and Wagner 1996). Whereas *Pinus rotundata* predominantly forms upright stems in plots A to C, growth forms in plots D and E become more stunted associated with a decreasing stocking rate.

Methods

All increment cores were cut with razor blades and contrasted with chalk. Ring width was measured with a precision of 0.01 mm using the measurement system LINTAB II. During measurement, the occurrence of wood anatomical peculiarities like traumatic tissue, density fluctuations, tangential resin ducts, and compression wood, was registered. The cumulated increment for the tree population of each plot was calculated by averaging all raw measurement curves when dated to a common pith date of 1. In case of the pith was not hit by the borer, the number of missing rings to the pith was estimated by the average ring width and the curvature of the innermost rings of the core. For an ecological characterization of the local chronologies of plots A to F, the signal-to-noise ratio (Wigley et al. 1984) and the mean correlation among the individual curves of each plot were calculated as a measure of the homogeneity of the growth signal. The mean sensitivity of the local chronologies is used here as an indicator of the average variability of the chronologies, not as a measure of their quality or their dendroclimatological potential. Variance was calculated as an alternative parameter, but basically produced the same results. Before these calculations were carried out, the biological age trend was removed from the ring width curves using the software ARSTAN. Wherever applicable, a linear age trend was removed from the raw measurements, otherwise a cubic smoothing spline with a length of 67% of the individual ring-width series length was chosen.

Results

Figure 1 summarizes the occurrence of anatomical anomalies in the wood of *Pinus rotundata* along the five sampling plots. Time series of the detected anomalies and their possible climatological triggering factors will be discussed more extensively elsewhere. The trees in plot A, showing slender and upright growth forms and growing under increased competition pressure, show the least percentage of compression wood and traumatic growth rings, which are predominantly interpreted as a consequence of severe frost events.

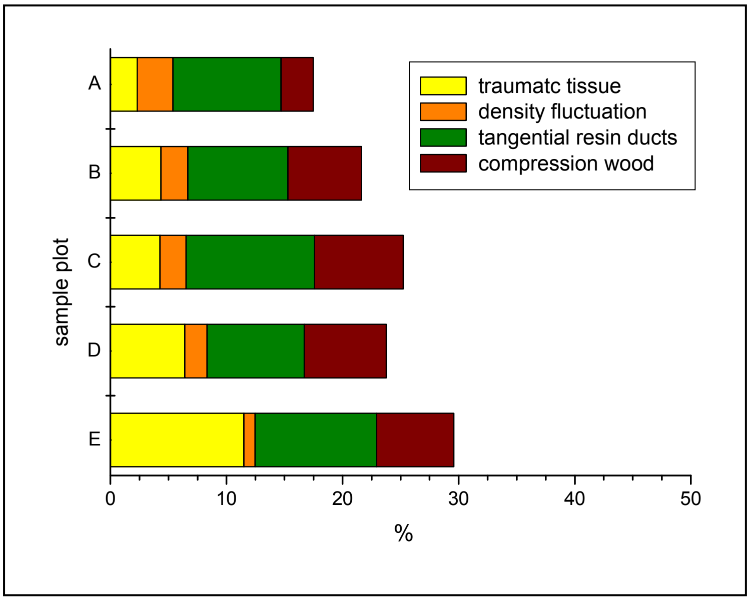

Figure 1: Percentage of wood anatomical anomalies in tree-ring samples on plots A to E

In contrast, a slightly increased occurrence of density fluctuations was found on plot A, whereas the lowest number of density fluctuations was registered at the moistest site E. At drought-sensitive sites, a close correlation was found between density fluctuations in different pine species and early summer drought (Villalba and Veblen 1996; Bräuning 1999; Wimmer et al. 2000). In spruce, however, Schweingruber (1980) found a close relationship between the formation of intraannual density fluctuations and low temperatures during the summer months, which seems to be a more plausible explanation for the site under consideration. The highest percentage of traumatic tissue in tree rings was found at site E, which might point to an increased endangerment to frost damage in the open tree stand without the equalising microclimate of a closed canopy. The occurrence of tangential resin ducts and compression wood does not exhibit significant differences among the sampling plots.

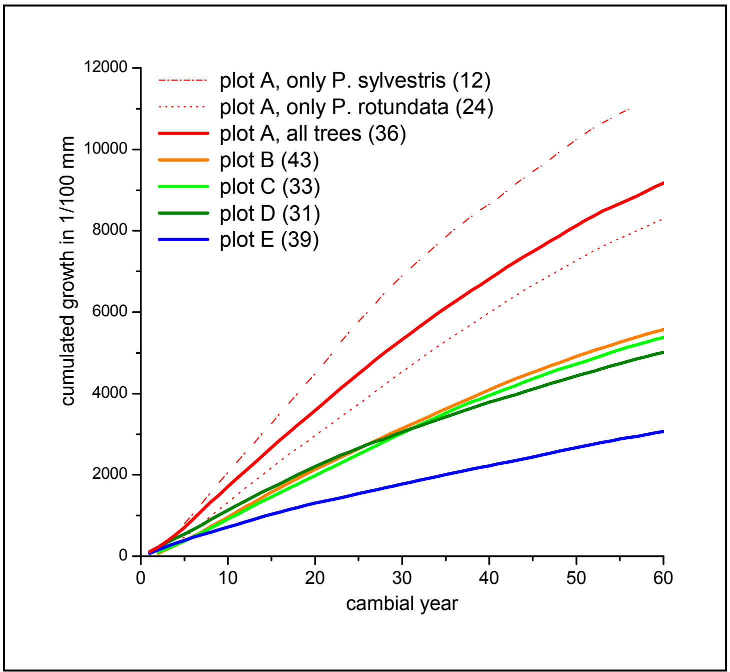

Figure 2: Cumulated growth on sample plots A to E. Numbers in parenthesis give the number of investigated trees per plot.

In figure 2, the cumulated growth curves for all plots are shown. For plot A, the growth curves for mountain bog pine and Scots pine are also presented separately. At all sites, a biological age trend is only weakly developed. At the drier sites, however, there is a slightly more pronounced decrease in growth rates with increasing tree age. The driest (A) and moistest plot (E) experience above and below average growth rates. Plots B, C and D, however, do not show any difference in growth rates. At plot A, growth rates of *Pinus sylvestris* are markedly higher than that of *Pinus rotundata*, which points to a beginning displacement of mountain bog pine by more vigorous competitors. Increasing growth rates of mountain bog pine related to falling ground water levels paralleled by an increase in interspecific competition was also found in peat bogs in the southern Black Forest (Schmid *et al.* 1995).

Several statistical parameters were tested for their usefulness for an ecological differentiation between the sampling plots. A combination of signal-to-noise ratio (SNR); mean sensitivity (MS) and mean correlation (MCor) turned out to be appropriate to reveal differences in growth behaviour. Although the values of SNR and MS are influenced by the sample depth (Briffa and Jones 1990), replication during the common interval of calculation seems sufficiently high at all sites to allow a comparison of the results.

The two extreme sites A and E clearly contrast with the other sampling plots (Fig. 3). Whereas the relatively dry site A is characterized by a low SNR and a slightly higher MS, the moistest site E depicts high SNR and MCor and a low MS, respectively. The three less extreme sites B to D can not be distinguished clearly by means of statistical parameters.

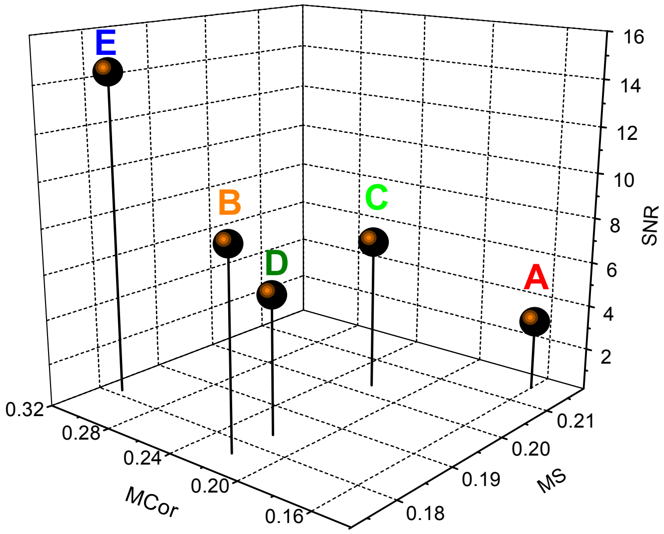

Figure 3: Combination of different statistical tree-ring parameters for an ecological characterization of the local chronologies A to E. In plot A, only Pinus rotundata is considered. SNR = signal-to-noise ratio; MS = mean sensitivity; MCor = mean correlation of all trees within a sampling plot.

Discussion

For a dendroecological characterization of *Pinus rotundata* on sampling plots along a hydrological gradient the frequency of tree rings showing traumatic tissue, the cumulated growth rate and a combination of the parameters SNR, MS and MCor turned out to be useful. However, only the extremely wet and dry sites differ significantly, less extreme sites can not be differentiated by the use of the parameters mentioned. Further studies shall be carried out to depict the relationship between pointer years in the ring width chronologies (Schweingruber *et al.* 1990; Cropper 1979), the occurrence of certain wood anatomical anomalies, like traumatic tissue and intraannual density fluctuations and the triggering climatic factors. After doing so, a more far-reaching dendroecological classification of sites B to D and a climatological verification of the findings for the extreme sites A and E can hopefully be carried out.

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