Source: Haneca K, Verheyden A, Beekmann H, Gärtner H, Helle G, Schleser G (eds.) (2007) TRACE - Tree Rings in Archaeology, Climatology and Ecology, Vol. 5: Proceedings of the DENDROSYMPOSIUM 2006, April 20th – 22nd 2006, Tervuren, Belgium. Schriften des Forschungszentrums Jülich, Reihe Umwelt Vol. 74, p. 54 - 59.

Tree growth - climate response in relation to habitat type in spruce stands of the Borecka Primeval Forest

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Introduction

The annual growth of a tree depends on several factors with climate usually being among the most important. However, under similar climatic conditions, other features that affect the formation of tree-rings and cause variation in the ring-width can be observed. Habitat type determined by, for example, site fertility (e.g. biomass production) or moisture content (water available for the plants) can be such a factor. Habitat conditions may sharpen or soften the climate influence on tree growth due to its variability. Sites with high moisture content in the soil may contain enough water to reduce unfavourable effects of low precipitation or high temperature (and hence increased transpiration). Under the same climatic conditions, trees on drier sites may suffer significant decrease in growth or even stop growing. Understanding these relationships may be useful, in particular for the production of good quality wood.

The objective of this study was to investigate how spruce trees growing in different habitat conditions respond to the climate and to examine whether their reaction to extreme conditions is similar or varies depending on the habitat.

Material and methods

Measurements were carried out in mixed forest stands with Norway spruce (*Picea abies* (L.) Karst.) being the dominant species. The forest stands were located in the Borecka Primeval Forest (Borki forest district, Diabla Góra forestry) in north-eastern Poland. Trees from three different habitat types characterized by different moisture content (fresh, humid and mixed marsh deciduous forest) were collected. The distance between sampling plots was relatively small (ca 1-1.5 km) and therefore it can be assumed that the sites are subjected to the same mezo-climatic conditions.

In total 43 trees were sampled by taking Increment cores at breast height level using a Pressler borer. The cores were then prepared, scanned and measured to the nearest 0.01mm using the PRZYROST program.

Synchronization of the samples was checked with COFECHA (Holmes 1999, Grissino-Mayer 2001) and modified ZGODA (Bruchwald 2000) programs. Series that did not show significant synchronization and convergence with others were excluded. After selection of the samples, a total of 34 samples remained for further analysis. The DPL package programs (Holmes 1999) were used for the statistical analysis, while the CRONOL program was used to build standard and residual chronologies representing individual habitat types as well as the whole area. The RESPO program was used to examine the relationships between the climate conditions and annual tree-growth. Mean monthly temperature and precipitation from October of the previous year to September of the current year (12 months) were used in the response function model. Finally, the author's program PYA which uses the idea of 'normalisation in a moving window' (Schweingruber et al. 1990) was used in the pointer year analysis. Event year values were calculated within 7–year windows. The threshold for negative or positive event years was set for 0.65. An individual year was considered a pointer year when at least 60 % of the trees showed the same kind of increment reaction (negative or positive event year).

Climate characteristics (monthly mean temperature and precipitation for the period 1951-2000) for the investigated area were obtained for a meteorological station in Suwałki (approximately 60 km eastwards) from the Institute of Meteorology and Water Management (IMGW) and from two Internet open sources (see references for URLs).

Results and discussion

Chronologies

Four chronologies covering the period 1875-2005 were constructed for the fresh, humid and marsh habitats, as well as for the whole area (a, b, c, d on Figure 1 respectively). The average ring width ranged from 2.36 mm (fresh habitat) to 1.43 mm (marsh) and decreased with increasing moisture content of the site. Standard deviation of raw measurement series varied from 0.70 mm (marsh) to 2.07 mm (humid type). Mean sensitivity values showed the same pattern as the average ring width and fall from 0.273 to 0.235.

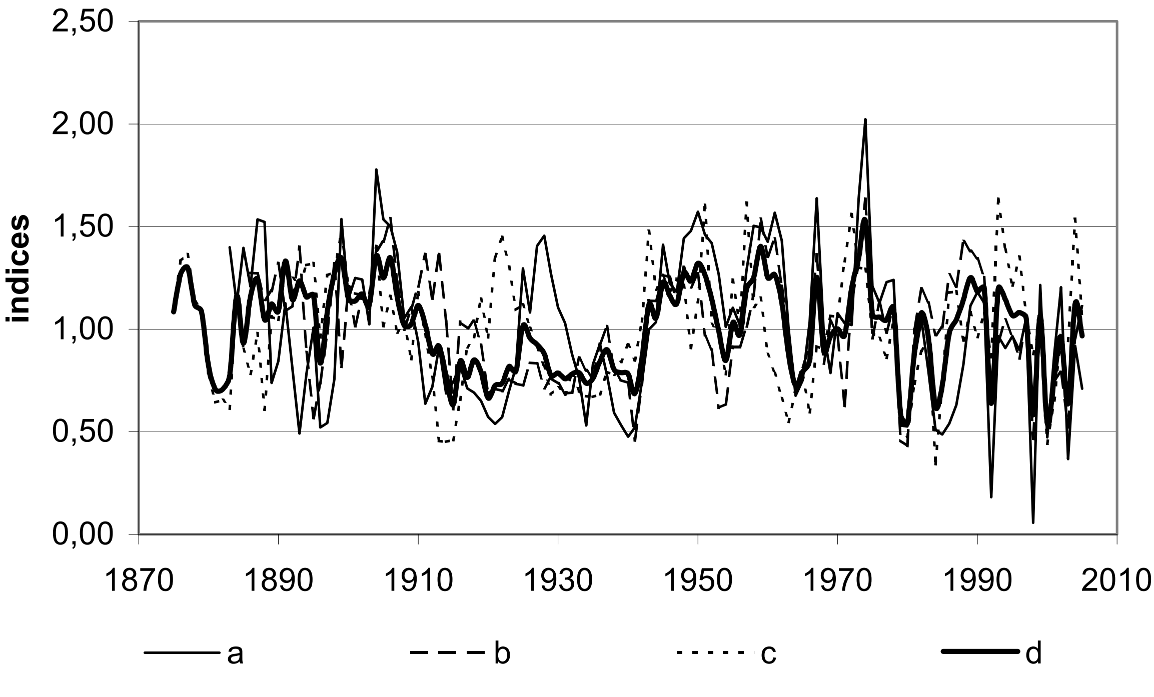

Figure 1: Standard chronologies of Norway spruce of Borecka Primeval Forest for fresh (a), humid (b) and marsh habitats (c) as well as the whole area (d)

Response to climate conditions

Analysis of the response of spruce trees to climate conditions showed that in Borecka Primeval Forest, climate determined less than half of the annual ring-width increment. Determination coefficients (R^2) reached only 40%. Koprowski (2003) obtained slightly higher results for this area. However, values of R^2 varied considerably when individual habitat types were investigated. Fresh and humid types showed a higher response to the climate variability with coefficient values of 57 and 45%, respectively. The formation of the annual rings in marsh habitats seemed not to be driven by climate in great extend as R^2 equals only 16%.

Results show that, as far as the whole area is concerned, warm conditions in September and pluvial in July are statistically the most important factors affecting tree-ring formation (Figure 2). Previous studies (Zielski, Koprowski 2001, Koprowski 2003) pointed out to March temperature and May-July or May-August precipitation as the main factors influencing growth of the tree rings. However, in those studies only fresh deciduous forest stands were analysed, which may cause this discrepancy.

Tree growth – climate responses were different for the different habitat types. The influence of temperature on tree growth was only significant for the the fresh habitat. No statistically significant relationships between temperature and growth were found for the humid and marsh sites. However, the fresh and humid sites share July as the most favourable month for growth due to relatively high precipitation. Again, no significant relationship between climate and tree growth was found for the marsh site.

Pointer years

Pointer years were identified for the period of 1900 to 2002 separately for each habitat type and for the whole area. In total 27 different pointer years were identified. Eleven of them were positive and 16 were negative (Tab. 1).

Table 1: Pointer years of spruce from Borecka Primeval Forest, 1900-2002

Pointer year	**Whole site**	**Habitat type**		
		fresh	**humid**	**marsh**
positive	1982 1974 1967	1982 1974 1967 1937 1925 1913	1988 1982 1974 1967 1959 1943 1937 1906	1993 1943 1904
negative	1992 1984 1980 1979 1964 1941	1998 1992 1980 1979 1965 1964 1941 1940 1921 1920	1998 1992 1980 1979 1971 1964 1954 1941	2000 1992 1984 1979 1966 1913

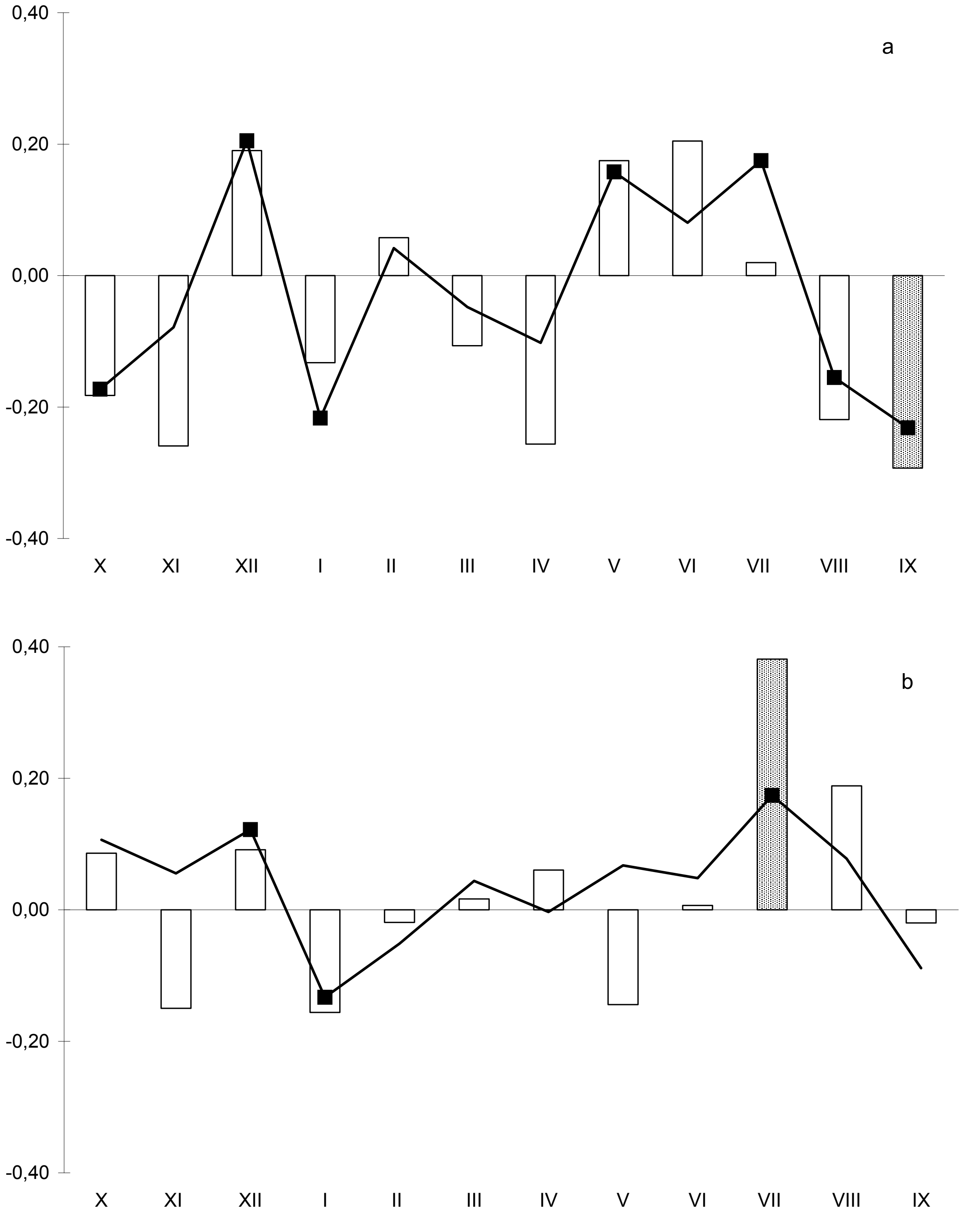

Figure 2: Relationship between increment pattern (residual chronology) and mean monthly temperature (a) and mean monthly sum of precipitation (b) in spruce stands of Borecka Primeval Forest. Bars represent coefficients of correlation and lines coefficients of regression. Hatched bars and squares show values significant at 0.05 level.

In general, fresh and humid habitat types reacted to extreme weather conditions in a very similar way. In both cases, 16 pointer years were detected; of which 9 are shared by both sites (3 positive and 6 negative). Particularly wide rings appeared in the years 1967, 1974 and 1982, while narrow rings appeared in 1941, 1964, 1979, 1980, 1992, and 1998. The marsh habitat showed not only lower sensitivity (less pointer years), but also a quite different pattern of the response to extreme weather conditions, in particular as far as positive pointer years are concerned. This indicates that this habitat type is much less climate-dependant than the other types. However, all sites, individually and as a whole, have two negative pointer years in common: 1979 and 1992. Very narrow rings in these two years were also identifies in neighbouring Olsztyńskie Lakeland (Koprowski, Zielski 2002) and Lithuanian (Vitas 2001, 2004) forest stands as well as in the whole boreal range of Norway spruce in Poland (Koprowski 2003). Similarly, the years 1967 and 1974 were distinguished as positive in Olsztyńskie Lakeland (Koprowski, Zielski 2002) and north-eastern Poland (Koprowski 2003). However, none of the pointer years (positive or negative) from more distant sites in southern Norway (Muter, Bednarz 2003) were present in Borecka Primeval Forest. This confirms that spruce trees from the Baltic region responds to extreme climate conditions homogeneously within small regions.

Conclusions

Annual growth of Norway spruce in Borecka Primeval Forest is dependent on both climate and habitat type. However, the latter factor affects the climate- tree growth responses to a great extent and causes significant differences in tree growth between the habitats. Results of the pointer year analysis show that despite those differences, climate- tree growth relationships of Norway spruce from the examined region resemble the general pattern obtained for the whole boreal range of Norway spruce in north-eastern Poland. The differences that were found in this study should be the starting-point for the further examination of relationships between tree growth, climate and various habitat types.

Acknowledgements

The author is grateful to Tomasz Michałowski for the support with the field work , Prof. Halina Lorenc and Katarzyna Jatczak from the Institute of Meteorology and Water Management (IMGW) for providing the climate data as well as the staff of Puszcza Borecka Station of Integrated Environmental Monitoring for help and co-operation.

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