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The potential of the dwarf shrub *Betula nana* L. as a climate indicator above the tree line in the southern Norwegian Scandes

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Introduction

At higher latitudes and in the alpine zone of mountain areas, dwarf shrubs represent a potential complement to dendroecological investigations of trees (Bär et al. 2008, Hallinger 2008, Schweingruber & Poschlod 2005). Particularly with regard to the reactions of alpine ecosystems to climate change, dwarf shrubs represent promising environmental indicators (Bär et al. 2007). Schweingruber & Poschlod (2005) already showed that various dwarf shrub species are suitable for dendroecological analyses. Especially, the dwarf birch (*Betula nana* L.) is an interesting species because it is part of a group of closely related species with a circumpolar distribution (Heß et al. 1967). Hence, we tried to enlarge the knowledge about the dendroecological potential of dwarf shrubs with special focus on *Betula nana*, especially concerning dendroclimatology. Growing near to the ground, dwarf shrubs are influenced by varying local climate conditions depending on the micro-topography (Gjærevoll 1956, Moen 1999, Löffler 2005). Therefore we analysed the effect of these micro-topographical differences on ring width, especially regarding the snow distribution.

Material and methods

The research area is located at Filefjell in the central southern Norwegian Scandes (61° 9,901’ N; 8° 6,235’ E). Mean annual precipitation at the study site is 770 mm and mean annual temperature is -0.4 °C. Mountain birch (*Betula pubescens ssp. czerepanovii*) forest ranges up to 1060 m a.s.l. forming the upper tree line. Above it lays the lower alpine zone dominated by a dwarf shrub heath in which dwarf birch (*Betula nana* L.) is a main constituent.

In the fine-scale alpine topography of a north-facing slope in the lower alpine zone (1125 m a.s.l.), an area including a snow depth gradient between two small ridges crossing a depression was chosen as the study site. The vegetation was mapped along two orthogonal transects. The distinct zonation of the vegetation indicated a strong influence of a characteristic alpine snow-cover gradient on plant distribution. In the following, the study site will be referred to snow-bed.

We collected 25 samples of *Betula nana* along the snow depth gradient to analyse the influence of snow distribution on ring width. The samples were taken as whole individuals cut at the soil surface.

To establish a reference ring width chronology, we collected increment cores from birch trees (*Betula pubescens ssp. czerepanovii*) from the same slope (990-1060 m a.s.l.). Four radii per tree were taken at breast height from 20 trees. We measured ring width with LINTAB-station and used TSAP-Win (version 0.53, Rinn 2003) for synchronisation of the ring width curves. In order to measure ring width of *Betula nana*, thin sections of the stems were prepared with a sledge microtome. The utilization of the whole stem section is necessary for being able to search for wedging rings and to synchronise the ring width curves of the radii (Bär et al. 2006). The thin sections were stained with solutions of safranin red and astra blue (Etzold 1983) and photographed sequentially with a microscope camera. The individual segments were then merged semi-automatically to get a complete picture of each thin section. Finally, ring widths were measured from digital photos with the software LignoVision (version 1.37, Rinn 2006).

Different dwarf shrub studies already demonstrated the problem of missing or wedging rings (e.g. Bär et al. 2007, Zalatan & Gajewski 2006, Petersdorf 1996). Therefore, we prepared two or three micro sections near the stem basis per sample and compared the ring width curves with the reference tree-ring chronology. In order to obtain complete ring width series of *Betula nana* and to synchronise them, it was not necessary to apply the complete serial-sectioning-method according to Kolishchuk (1990), but two or three thin sections near the root collar turned out to be sufficient. Although *Betula nana* exhibited many wedging rings, most of the ring width curves could be synchronised and 24 of 25 dwarf birch samples could be used to construct a chronology that was established in three steps: I) Ring width measurement along several (two to five) radii and establishment of mean curves for each thin section. II) Averaging thin section mean curves into specimen mean curves. III) Chronology establishment from several specimens' mean curves.

To analyse the influence of the micro-topography on ring widths of *Betula nana*, we built two dwarf birch local chronologies from the ridges and from the inner part of the depression, respectively. Since both chronologies were very similar, we constructed a master chronology from all dwarf shrubs irrespective of topographic location. To remove age-related growth trends, the specimen mean curves of *Betula nana* and *Betula pubescens ssp. czerepanovii* were both detrended using a cubic smoothing spline filter which removed 50% of the variance of frequencies with two thirds of the series length in ARSTAN (version 41d, Cook 1985). The standardised chronologies were then used for climate-growth analysis.

Climate data from different locations were used. Precipitation data from the hydrological measurement station Maristova were provided by the Norwegian Meteorological Institute. This station is located 806 m a.s.l. at a distance of 8 km to the study area. There is no climate station close to the study area measuring temperature continuously. Therefore temperature data for the study site were extrapolated from measured temperature data (1967-1974) of the nearby climate station Varden (Norwegian Meteorological Institute) and NCEP/NCAR reanalysis data (NOAA National Center for Environmental Prediction). To analyse climate-growth-relationships and to detect the main factors influencing the ring widths of *Betula nana,* linear correlations between the ring width indices and monthly mean temperature and precipitation were calculated using the software DENDROCLIM2002 (Biondi & Waikul 2004). Correlations were computed for the period from May of the previous year to September of the current year.

In this study we also calculated the pointer years according to Cropper (1979) for *Betula nana* and compared them to the mean July temperature.

Results

The two dwarf birch chronologies from the ridges and the depression of the snow-bed show high similarity (Fig. 1). The gleichlaeufigkeit between both chronologies is 73% ($p<0.001$), indicating that the dwarf birches from all micro-topographical locations are influenced by the same climatic factors. Individuals from the ridges were in general considerably older than the individuals growing in the depression.

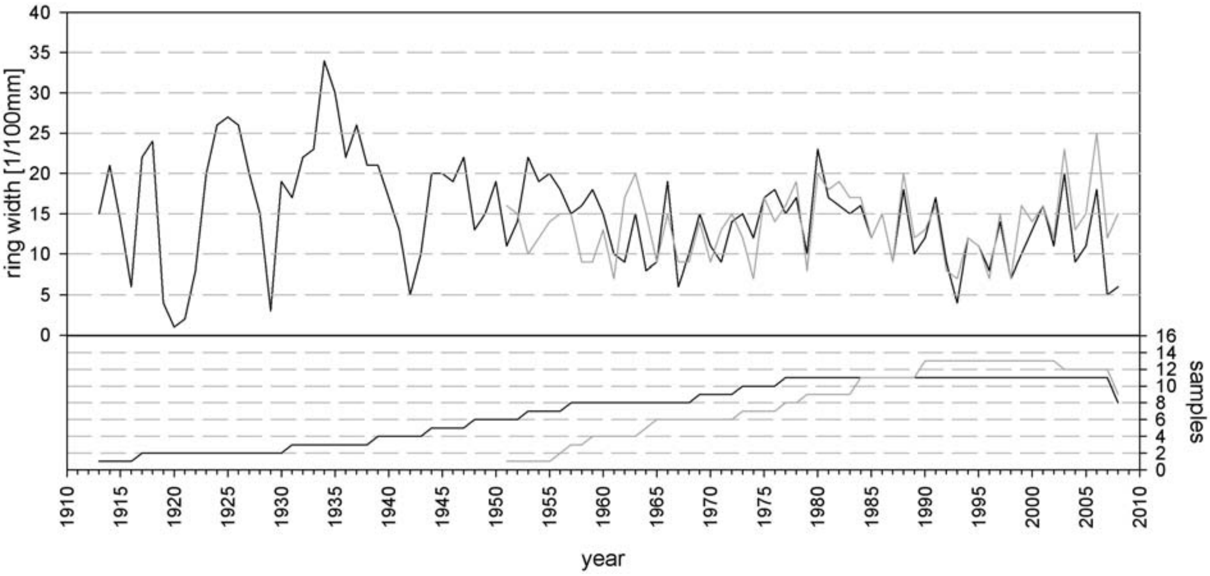

Figure 1: Betula nana raw value chronologies from the ridges (black lines) and the inner part of the snow-bed (grey lines).

We compared the final index chronology of *Betula nana* to the reference chronology of *Betula pubescens ssp. czerepanovii* (Fig. 2). Although both species belong to different life forms, the gleichlaeufigkeit between their chronologies is 68% (p<0.001). The high similarity indicates that growth-ring variations of *Betula nana* and *Betula pubescens ssp. czerepanovii* contain a common climate signal.

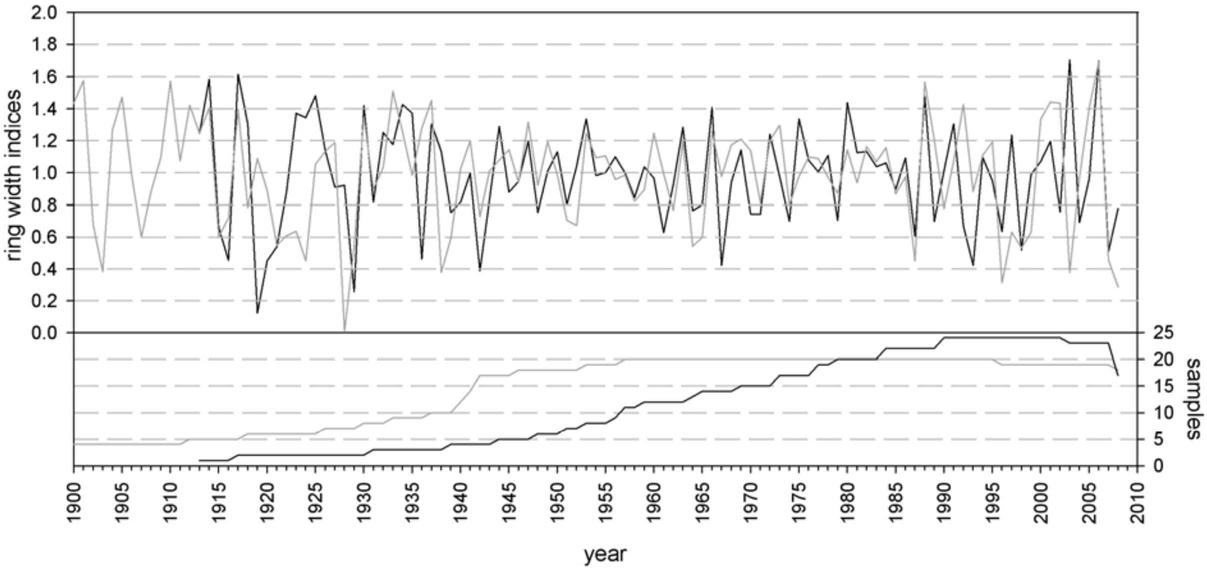

Figure 2: Chronologies of Betula nana (black lines) and Betula pubescens ssp. czerepanovii (grey lines).

The correlation between the *Betula nana* ring width indices and monthly mean temperatures shows high positive values during the vegetation period (July, August) of the current year (Fig. 3). This indicates that dwarf birch growth is mainly influenced by summer temperature (particularly July). Precipitation has only low impact on ring width variations, as indicated by insignificant correlation coefficients between ring widths and precipitation during the vegetation period.

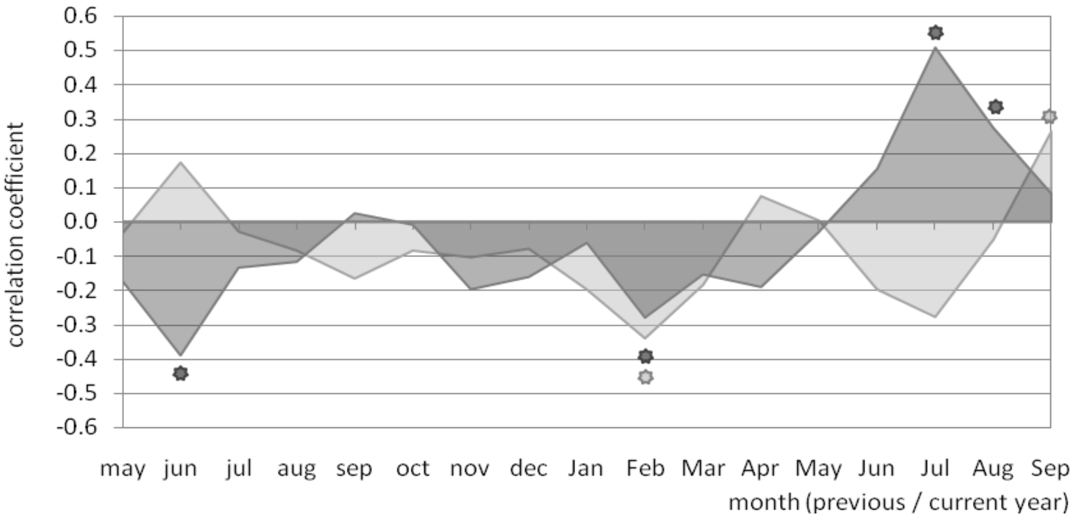

Figure 3: Correlation between ring width indices of Betula nana with monthly mean temperatures and precipitation data (1951-2008). Light grey indicates correlation with precipitation, dark grey with temperature. Stars indicate significant values (p < 0.05).

The strong influence of July temperature on ring widths is also seen in years with exceptional growth of *Betula nana*. Figure 4 compares pointer years of the *Betula nana* chronology according to Cropper (1979) and deviations of July temperatures from the long term mean. There are years where the data series do not conform to each other, e.g. in 1955, when July temperature was above average, but did not have a positive effect on ring widths, and in 1964, when the cold climate was not reflected by a negative pointer year. Yet, in the periods from 1970 to 1980 as well as from 1988 to 2006, the agreement of pointer years and mean temperature of July is high.

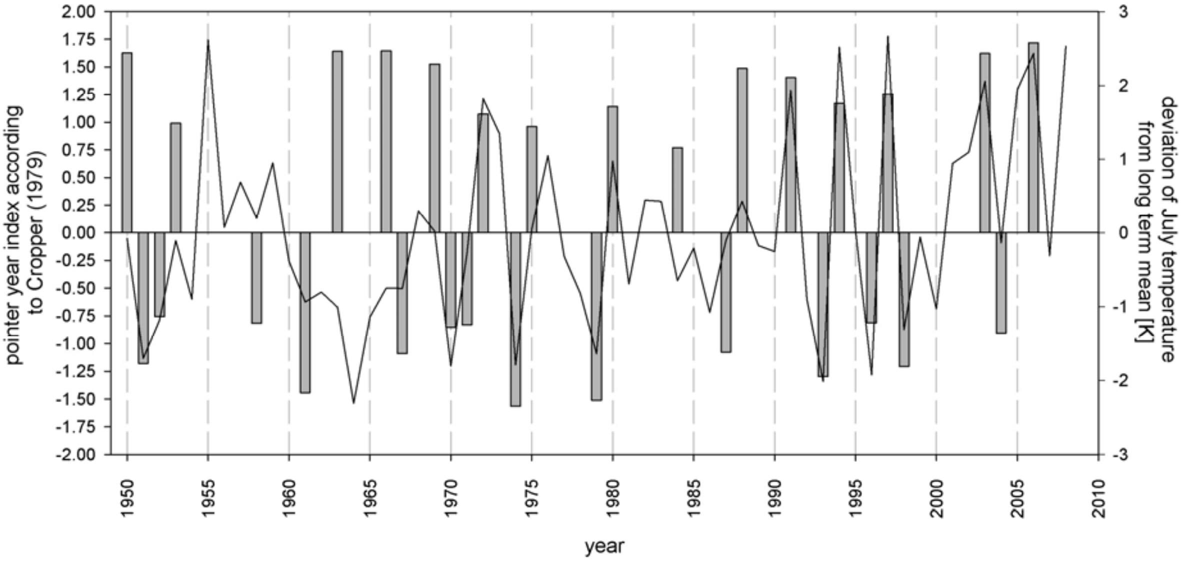

Figure 4: Pointer years of Betula nana according to Cropper (1979) (bars) and deviation of July temperatures from the long term mean (line).

Discussion and conclusions

The present study demonstrates the suitability of *Betula nana* for dendroecological analysis. Although wedging rings occur repeatedly in the stem discs, ring widths could be measured. Individual ring width series were successfully synchronised and chronologies were established.

The high similarity between the *Betula nana* chronology and the reference chronology of the tree species *Betula pubescens ssp. czerepanovii* suggests that ring width variations of *Betula nana* contain a climatic signal.

Ring widths of *Betula nana* are strongly influenced by summer temperature, mainly by temperature of July and August. The ring widths of the tree birches were also positively correlated with summer temperature (r_{May} = 0.27; r_{June} = 0.25; r_{July} = 0.34, all significant on the 95% level, study period 1951-2007), indicating that both species are mainly influenced by summer temperature. Because of the strong influence of mean July temperature, *Betula nana* can be used as an indicator for summer temperature in alpine habitats beyond the upper tree line. Similar results were described in other dwarf shrub studies. Bär et al. (2007) demonstrated the high influence of summer temperature on ring width of *Empetrum hermaphroditum*. July temperature is most important, followed by the temperatures of August and June. Hallinger (2008) reported positive correlations between ring width curves of *Juniperus nana* and the temperatures of June and July.

The comparison between the *Betula nana* chronologies from the ridges and the inner part of the snow-bed revealed that micro-topography does not significantly alter the climate response of *Betula nana*. Yet, in the age of the dwarf birches from the different locations a difference is detectable. Bär et al. (2008) analysed the impact of topography on ring widths of *Empetrum hermaphroditum* by comparing different microsites. Annual growth-ring increments were slightly modified by different microclimatic conditions, but nevertheless the common growth pattern was reflected at all microsites.

Considering the distribution of *Betula nana*, the suitability of this dwarf shrub species offers new perspectives for dendroecological studies into arctic and alpine zones to enlarge our knowledge about climatic variations in these regions.

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References

Bär, A., Bräuning, A., Löffler, J. (2006): Dendroecology of dwarf shrubs in the high mountains of Norway – A methodological approach. *Dendrochronologia* 24: 17-27.

Bär, A., Bräuning, A., Löffler, J. (2007): Ring-width chronologies of the alpine dwarf shrub *Empetrum hermaphroditum* from the Norwegian mountains. *IAWA Journal* 28 (3): 325-338.

Bär, A., Pape, R., Bräuning, A., Löffler, J. (2008): Growth-ring variations of dwarf shrubs reflect regional climate signals in alpine environments rather than topoclimatic differences. *Journal of Biogeography* 35: 625-636.

Biondi, F., Waikul, K. (2004): DENDROCLIM2002: A C++ program for statistical calibration of climate signals in tree-ring chronologies. *Computer & Geosciences* 30: 303-311.

Cook, E. R. (1985): A time series analysis approach to tree ring standardization. PhD dissertation. University of Arizona, Tucson.

Cropper, J. P. (1979): Tree-ring skeleton plotting by computer. *Tree-Ring Bulletin* 39: 47-54.

Etzold, H. (1983): Eine kontrastreiche, simultane Mehrfachfärbung für pflanzenanatomische Präparate. Fuchsin – Safranin – Astrablau. *Mikrokosmos* 72: 213-219.

Gjærevoll, O. (1956): The plant communities of the Scandinavian alpine snow-beds. F. Bruns Bokhandel, Trondheim. 405pp.

Hallinger, M. (2008): Shrub ecology and climate change in the Scandic mountains of north Sweden with special focus on *Juniperus nana*. Diploma thesis, University of Greifswald (unpublished).

Heß, H. E., Landolt, E., Hirzel, R. (1967): Flora der Schweiz und angrenzender Gebiete. Band I: Pteridophyta bis Caryophyllaceae. Birkhäuser Verlag, Basel, Stuttgart. 858pp.

Kolishchuk, V. G. (1990): Dendroclimatological study of prostrate woody plants. In: Cook, E. R. & Kairiukstis, L. A. (ed.): Methods of Dendrochronology. Applications in the Environmental Sciences. Kluwer Academic Publishers, Dordrecht, Boston, London. 51-55.

Löffler, J. (2005): Snow cover dynamics, soil moisture variability and vegetation ecology in high mountain catchments of central Norway. *Hydrological Processes* 19: 2385-2405.

NOAA National Center for Environmental Prediction: http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.surface.html (10.07.2009)

Norwegian Meteorological Institute (eklima): http://sharki.oslo.dnmi.no/portal/page?_pageid=33,6979,33_14938&_dad=portal&_schema=PORTAL (10.07.2009)

Moen, A. (1999): National Atlas of Norway: Vegetation. Norwegian Mapping Authority, Hønefoss. 200pp.

Petersdorf, M. (1996): Dendroökologische Untersuchungen an Zwergsträuchern. Diploma thesis, University of Zurich (unpublished).

Rinn, F. (2003): TSAP-Win (Time Series Analysis and Presentation for Dendrochronology and Related Applications). Version 0.53. User Reference. 110pp.

Rinn, F. (2006): LignoVision. Scanning of wood and tree-ring recognition. Version 1.37. User Reference. 24pp.

Schweingruber, F. H. & Poschlod, P. (2005): Growth rings in Herbs and Shrubs: life span, age determination and stem anatomy. In: Swiss Federal Research Institute WSL (ed.): Forest Snow and Landscape Research 79 (3). Swiss Federal Research Institute WSL, Birmensdorf. 195-415.

Zalatan, R. & Gajewski, K. (2006): Dendroecological potential of *Salix alaxensis* from the Kuujjua river area, western Canadian Arctic. *Tree-Ring Research* 62 (2): 75-82.