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Different radial growth responses of co-occurring coniferous forest trees in the Alps to drought

Walter Oberhuber and Julia Mennel
University of Innsbruck, Institute of Botany, Innsbruck, Austria (walter.oberhuber@uibk.ac.at)

Species-specific drought resistance will effect the development of forest ecosystems under a warmer and drier climate by changing species composition and inducing shifts in forest distribution. Therefore, we applied dendroclimatological techniques to determine drought sensitivity of three native coniferous tree species (Norway spruce, Picea abies; European larch, Larix decidua; Scots pine, Pinus sylvestris), which differ in phenological and successional traits and grow intermixed at dry-mesic sites within an inner-Alpine dry valley (750 m a.s.l., Tyrol, Austria). Ring-width chronologies (resolution 1 μm) of each species were developed by extracting two core samples from $\geq$ 80 mature trees (mean tree age 135 yr). To identify the climatic factors most closely associated with variations in radial tree growth, we calculated response and correlation functions for the common interval from 1911–2007 using yearly tree-ring indices and monthly and seasonal climate variables (precipitation, air temperature) and evaluated growth response to extreme hot and/or dry conditions during the growing season. Additionally, the impact of climate warming on long-term variability of climate-growth relationships was analysed by means of moving response functions.
Major finding of our study were: (i) current April through June precipitation was the environmental factor most strongly associated with growth of all three species (r = 0.484, 0.458, and 0.546 for Pinus sylvestris, Larix decidua and Picea abies, respectively; all $P < 0.001$), whereby Picea abies showed higher correlation coefficients with precipitation from May through June (r = 0.585, $P < 0.001$). (ii) Annual increment of Picea abies was most strongly limited by May through June temperature (r = -0.500, $P < 0.001$). (iii) Continuously increasing moving response function coefficients of monthly precipitation variables since the mid-20th century revealed increasing drought sensitivity of all species. During recent decades a significant inverse relationship between radial growth and early summer temperature was only detected for Picea abies. (iv) Analysis of distinct below-average growth in several years (1952, 1976, 1984, 1992 and 2005) indicated species-specific response to climate extremes, whereby Pinus sylvestris was the least drought sensitive species of the comparison.
Results demonstrate that within the study area different growth responses of coniferous species to climate exist, which might be explained by temporal shifts in cambial activity and wood formation. Furthermore, our study shows that high temperature and limited water availability has the strongest impact on the growth performance of Picea abies, which will likely lead to increased tree mortality. Instable climate-growth relationships during recent decades, which occur coincidently with the recent warming trend, indicate increasing drought stress of all species, whereby within mixed coniferous stands Pinus sylvestris may benefit from adapting better to drier conditions in the future. High mortality rates of Pinus sylvestris, which have been observed in recent years at more xeric sites, support our findings that drought initiates changes of forest structure and species composition within this dry inner-Alpine valley.