

## Ungulate impact on forest regeneration and dynamics and its implications for forest management and conservation – long-term data from Białowieża primeval forest, Poland

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A natural food chain found throughout European forests includes three trophic levels: forest plants, ungulates, and large carnivores. However, the natural structuring of that system has been affected by humans for so long and in so many ways that nowadays the prevailing notion of the ungulates' role in forests is that of damage agents to tree regeneration. One of the very few places that could help us understand the original role of ungulates in forest regeneration and dynamics is Białowieża primeval forest (Poland), which preserves the last remnants of European temperate forests with five species of ungulates (red deer *Cervus elaphus*, roe deer *Capreolus capreolus*, moose *Alces alces*, European bison *Bison bonasus* and wild boar *Sus scrofa*) and two species of large predators (wolf *Canis lupus* and Eurasian lynx *Lynx lynx*). Historical and contemporary human impact on Białowieża primeval forest have been diverse but much smaller compared to other European woodlands.

The impact of ungulates (mainly red deer, the species dominating in the community) on regeneration and dynamics of natural forests of Białowieża primeval forest was investigated at three time scales: 10-year experimental study, 70 years of observational study, and 150-200-year data on forest, ungulate, and carnivore inventories. The experimental study demonstrated that ungulates strongly affected the density and species diversity of tree regeneration in height class >50 cm. Data on 70 years of natural dynamics in tree recruitment showed that total recruitment of all tree species was negatively correlated with ungulate density. Yet, the variation in response among tree species was related to the preferences of herbivores: the most preferred forage species, hornbeam *Carpinus betulus*, showed high recruitment in periods of abundant deer, due to its browsing-tolerance. In the longest perspective (150-200 years), ungulate impact on forest dynamics was analyzed together with other factors such as climate change, human-caused changes in wolf and lynx densities (major agents of ungulate mortality) and forest fire history. At that longest time-scale, the primary force driving the observed changes in dynamics and species composition of Białowieża primeval forest was the abrupt decline in forest fires in the early 19<sup>th</sup> century. It triggered the change from *Pinus*-dominated forests (18<sup>th</sup> century), to *Picea*-dominated stands (1850-1950), to deciduous (*Carpinus*, *Tilia*) forests (after 1950). Ungulates appeared a secondary – but still important – agent modifying the densities and species composition of tree regeneration and recruitment. All data evidenced a highly dynamic and variable time structure of natural forests, in contrast to the rather static view which prevails in both the silviculture and the conservation approach.