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North Fennoscandian mountain forests: History, composition, disturbance dynamics and the unpredictable future

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ABSTRACT

North Fennoscandian mountain forests are distributed along the Scandes Mountains between Sweden and Norway, and the low-mountain regions of northern Norway, Sweden and Finland, and the adjacent northwestern Russia. Regionally, these forests are differentiated into spruce, pine or birch dominance due to climatic differences. Variation in tree species dominance within these regions is generally caused by a combination of historical and prevailing disturbance regimes, including both chronic and episodic disturbances, their magnitude and frequency, as well as differences in edaphic conditions and topography. Because of their remoteness, slow growth and restrictions of use, these mountain forests are generally less affected by human utilization than more productive and easily utilizable forests at lower elevations and/or latitudes. As a consequence, these northern forests of Europe are often referred to as "Europe's last wilderness", even if human influence of varying intensity has been ubiquitous through historical time. Because of their naturalness, the North Fennoscandian mountain forests are of paramount importance for biodiversity conservation, monitoring of ecosystem change and for their sociocultural values. As such, they also provide unique reference areas for basic and applied research, and for developing methods of forest conservation, restoration and ecosystem-based management for the entire Fennoscandia. However, the current rapid change in climate is predicted to profoundly affect the ecology and dynamics of these forests in the future.

Contents

1. Introduction

North Fennoscandian mountain forests are distributed along the remains of ancient mountain ranges, most notably the Scandes mountain range along the border between Sweden and Norway, and the low-mountain regions of northern and northeastern Finland, and the adjacent northwestern Russia (Fig. 1). These regions harbor both northern boreal forests and subarctic/subalpine birch forests, which are collectively henceforward referred to as *northern mountain forests*. Because of remoteness, low productivity and restrictions of use, the overall human impact on these forests has

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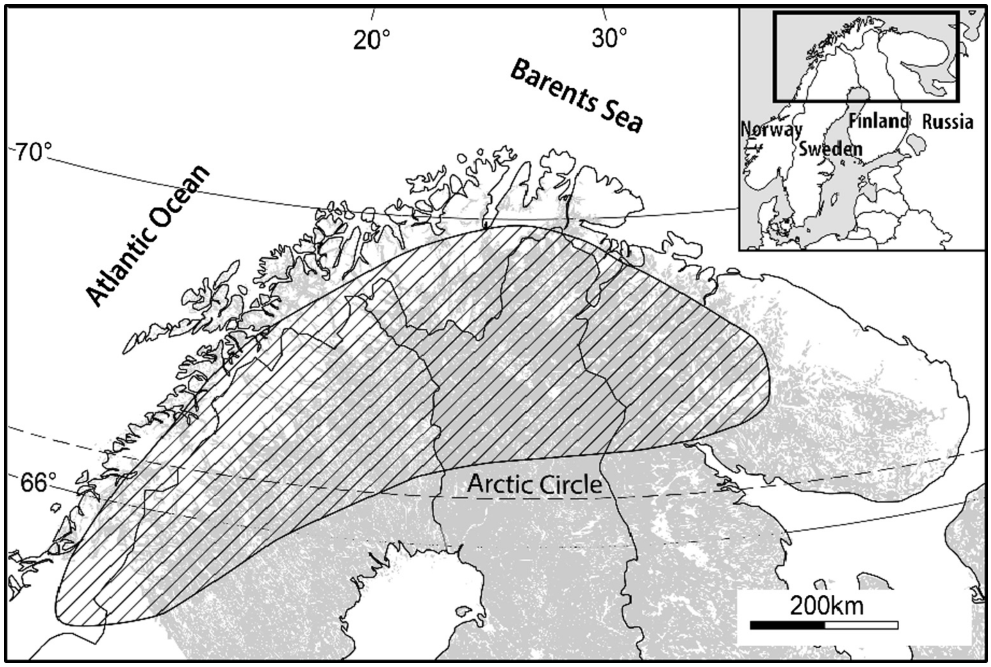

Fig. 1. The geographic region (dashed area) indication the mountain forests that are in focus in this paper. Grey shows the distribution of forest.

generally remained significantly lower compared with more southern boreal forests at lower latitudes and/or elevations (Veijola, 1998). However, over the entire region, some low-intensity human use of the forest has occurred for millennia, such as the influence of the Sápmi people and their reindeer herding culture (Josefsson et al., 2009). Reindeer herding continues to be a culturally important land use, which has recently also generated conflicts with other land uses like forestry (Helle and Jaakkola, 2008; Berg et al., 2008).

The exact degree of human impact, i.e. the extent to which the current forests deviate from a natural state, varies strongly across forest types and landscapes, from negligible to local deforestation (Östlund et al., 2015). Nevertheless, these mountain forests still harbor some of the largest areas of relatively natural boreal forest in Northwestern Europe (Aksenov et al., 2014). By natural forest we mean a forest which structure, species composition and processes have not been significantly altered by human activities (Brumelis et al., 2011). Much of our current understanding of natural forest disturbance and successional dynamics and their impact on biodiversity in Fennoscandian conditions is derived from these forests (Kuuluvainen and Aakala, 2011). The ongoing climate change, with a predicted mean annual increase of mean annual temperature by 4 °C and precipitation by 20% by the end of the 21st century (IPCC, 2013), is likely to profoundly affect the ecology, dynamics and productivity of these forests in the future (Kellomäki et al., 2008; IPCC, 2013; Gauthier et al., 2015).

The ecological character and biological diversity of northern mountain forests reflect to a large extent their Holocene climate and vegetation history. Because of their northern position, continental ice retreated from these areas as late as around 15–10,000 years before present (Parducci et al., 2012). Tree species colonized the region from different directions, following the course of retreat of the ice sheet. The developing early Holocene tree communities were accordingly characterized by the forests surviving the glaciation period and surrounding the retreating ice to the west, south and east (Kullman, 2008; Paus et al., 2011; Parducci et al., 2012). Current dominant boreal tree species, pine (*Pinus sylvestris* L.), spruce (*Picea abies* (L.)Karst.) and birch (*Betula pubescens* Ehrh.), all arrived in early Holocene 14–11 kyr B.P in the first de-glaciated areas of western Fennoscandia (Kullman, 2008). During the mid-Holocene climatic optimum, thermophilous deciduous tree species like elm and oak occurred in the region.

The historic timing of formation of boreal tree species dominance at stand or regional scales differs between species, with birch and pine predating spruce (Kullman, 2008). The spread and development of regional dominance of spruce has occurred in the last ca. 3000 years, in parallel with long-term climate changes favoring spruce but disfavoring thermophilous tree species (Kullman, 2001; Giesecke and Bennett, 2004; Bradshaw and Lindbladh, 2005). Concurrently with increasing spruce dominance, high elevation and high latitude forests retreated downhill and southwards (Payette and Lavoie, 1994; Kullman, 1995). This process was reversed after the termination of the Little Ice Age (Grove, 1988) in late 19th century. The rate of this recent regain of forest area differs somewhat between geographical regions and between tree species, but has generally accounted for ca. 0.6 vertical meters per year in the northeastern part of the mountain forest region (Aakala et al., 2014; Mathisen et al., 2014) and 0.9 vertical meters per year in the southern part (Kullman and Öberg, 2009). Latitudinal advance has occurred with ca. 150 m per year for birch forest and ca. 70 m per year for pine forests (Hofgaard et al., 2013).

The impact of climate change on forests close to their bioclimatic range limits entail a complex web of both gradual and episodic abiotic and biotic processes (Hofgaard, 1997; Scheffer et al., 2012). The warming climate changes ecosystem structure and composition through changing competitive relationships among the constituent tree species (Kellomäki et al., 2008). Climatic conditions are changing too fast for long-lived plant species such as trees to respond through natural migration, and this is predicted to increase the probability and severity of disturbance events. In addition other change rate-related developments, such as extreme weather events and insect outbreaks are likely to become more common (IPCC, 2013; Gauthier et al., 2015). These perturbations could counteract or reinforce climate-driven changes of the northern mountain forest ecosystems (Hofgaard, 1997; Koven, 2013;