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Structure of a Central-European mountain spruce old-growth forest with respect to historical development

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Abstract

This study examines the structural characteristics of the tree layer, dead wood, canopy openings, and regeneration patterns of a spruce old-growth forest in the Bohemian Forest, Czech Republic. An old-growth stand with minor human influence and a stand that was presumably logged about 200 years ago were analyzed and compared, as some forest managers considered the presumable human impact as a reason for salvage logging. Even though the stands differed in tree density, height and DBH structure, it was not possible to conclude whether it was due to management history or the environmental differences. The volume of dead wood also differed between the stands. There was about 142 and 83 m^3 ha^{-1} of dead wood in the old-growth stand and presumably logged stand, respectively. The amount of dead wood found in the old-growth stand was comparable with values reported from spruce old-growth stands across Central Europe. In both stands, many canopy trees were arranged in linear patterns, which was a result of spruce regeneration on nurse logs. This suggests that the origin and development of the stands were characterized by natural processes and during the past 200 years typical old-growth structural characteristics have already evolved.

Keywords: *Picea abies*; Natural forest; Forest dynamics; Dead wood; Spatial structure; Nurse logs; Bark beetle

1. Introduction

Old-growth spruce forests once covered large areas of the mountain regions in Central Europe. At present, there are only a few remaining remnants of these forests, many of which are located in the Bohemian Forest, a mountain region between the Czech Republic, Germany and Austria. Several old-growth stands in this region are preserved in Bayerischer Wald National Park (Germany) and Šumava National Park (Czech Republic). A large-scale bark beetle outbreak started in the 1980s in Bayerischer Wald National Park (Heurich, 2001), and followed in the 1990s in Šumava National Park (Jonášová and Prach, 2004). The mortality of the canopy that followed the bark beetle outbreak has raised many questions, highlighting the lack of information concerning disturbance regimes and natural dynamics in these forests. This is partly because of the scarcity of old-growth forests where disturbance can be studied, and also because site conditions have traditionally been thought to play a more important role in controlling forest structure and composition than disturbance in Central Europe (Splechtna et al., 2005). Because of the long tradition of forest management, disturbances in these forests have been viewed as a threat to forest production, rather than natural processes. As a result, many scientists and forest managers still consider large-scale disturbances in mountain spruce forests of Central Europe as an ''unnatural'' outcome of anthropogenic influences on the forest. Consequently, even in national parks disturbances such as windthrow or bark beetle outbreak are salvaged instead of studied.

During the last few years, this traditional view has slowly started to change. The dynamics of mountain spruce forests in Central Europe are now viewed as being regulated by a combination of large-scale disturbances (insect outbreak or windthrow), and individual tree fall gaps (Holeksa and Cybulski, 2001; Fischer et al., 2002; Kulakowski and Bebi, 2004; Holeksa et al., 2006). However, there are still few studies concerning temporal and spatial variation of different types of disturbances. Recent studies from Central Europe show that semi-natural Norway spruce forests regenerate and

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develop well after a large-scale disturbance, such as bark beetle outbreak or windthrow (Heurich, 2001; Fischer et al., 2002; Jonášová and Prach, 2004; Kupferschmid et al., 2006; Jonášová and Matějková, 2007). The establishment and survival of trees in stands that were not salvaged following bark beetle outbreak or windthrow was in most cases better than in salvaged stands (Heurich, 2001; Fischer et al., 2002; Jonášová and Prach, 2004; Kupferschmid et al., 2006; Jonášová and Matějková, 2007). Despite these results, there are still many questions regarding the management of spruce forests in the protected areas in Central Europe (Grodzki et al., 2006).

The naturalness of forest stands is often used as an indicator for decisions about salvaging after bark beetle outbreaks. However, there are few studies concerning structural characteristics of old-growth spruce forests in the region (Motta et al., 1999; Holeksa and Cybulski, 2001; Holeksa et al., 2006), so that the naturalness of these forests is poorly defined. The naturalness of old-growth spruce forests could be defined using the presence of typical old-growth characteristics, including down logs, standing dead trees (snags), large living trees, and horizontal and vertical structure (Holeksa, 2001; Franklin et al., 2002; Franklin and Van Pelt, 2004; Zenner, 2004).

Furthermore, when analyzing the structure of an old-growth stand, it is important to consider variation in disturbance processes and their effects on forest structure and dynamics. Based on recent studies, the dynamics of spruce forests in Fennoscandia is now viewed more as a relatively small-scale, gap-phase driven process (Kuuluvainen et al., 1998; Kuuluvainen, 2002a,b). In contrast, recent evidence from spruce forests in Central Europe shows that forest over an area of several square kilometers can have a homogenous structure, suggesting that dynamics could be affected by infrequent, large-scale disturbances (Holeksa et al., 2006). Therefore, disturbance processes that occur in one part of the natural geographical area of spruce cannot be directly applied in other regions. In Central Europe, old-growth spruce forests with complex horizontal and vertical structure are often assumed to be much less vulnerable to bark beetle outbreaks compared to managed stands or stands in the mid-successional stages with relatively homogenous structure (Průša, 1985; Korpel', 1995). However, because of the scarcity of old-growth spruce forests in the Central-European forest landscape, this paradigm has never been confirmed.

The purpose of this study was therefore to describe the structure of the most well preserved stand of old-growth spruce mountain forest in the Czech Republic, which has never been studied in the past, and also to compare the structure of the old-growth stand to a stand that was presumably logged about 200 years ago. The specific objectives were to describe basic stand characteristics and to discuss possible disturbance processes that influenced the development of the two stands. Our hypothesis was that stands influenced by historical management activities will show differences in their structural characteristics. The results of this study could be used as a basis for decision-making processes regarding management of protected spruce forests in the region.

2. Methods

2.1. Study site

This study was conducted in the Šumava NP located in the Bohemian Forest (Šumava Mts.), in a 600 ha old-growth forest known as Trojmezná. Study plots were located in the forest along the ridge between Třístoličník and Trojmezná (48°47′N, 13°49′E). The altitude ranges from 1220 to 1340 m. The total annual precipitation at this altitude is about 1400 mm, and the mean annual temperature is approximately 4 °C (Kopáček et al., 2002). The forest is dominated by Norway spruce (*Picea abies*) and less abundant Rowan (*Sorbus aucuparia*). Plant communities in the study area were classified as *Calamagrostio villosae-Piceetum* and *Athyrio alpestris-Piceetum* (Neuhäuslová and Eltsova, 2003), which belong to the Central-European spruce forest group (Chytrý et al., 2002). The dominant species in the herb layer correspond with the diagnostic species of spruce forests in the Bohemian Massif (Chytrý et al., 2002; Svoboda, 2003a; Svoboda et al., 2006). The area is mainly covered with Lithic Leptosols, Hyperskeletic Leptosols (Humic and Dystric) and Dystric Cambisols (Kopáček et al., 2002; Svoboda, 2003b). These soils are derived from biotitic coarse-grained granite.

The current state of the forest in the area has been influenced by bark beetle outbreak. Accelerated death of trees mainly due to bark beetle was reported since 1995. Results of the regular annual survey carried out by park authorities and visual assessment of aerial photos confirmed the beginning of the break up of the main canopy layer (Svoboda, 2005).

2.2. History of forest management

The area of the Trojmezná old-growth forest has been officially protected since 1933, and is considered to be one of the best preserved and largest examples of old-growth spruce forest in the Czech Republic (Průša, 1985, 1990). On the forestry maps from 1874, a substantial part of the area was classified as stands older than 140 years (recent age about 300 years) (Jelínek, 1997). However, there are some highly decomposed cut stumps and cut logs scattered throughout the forest. The second part of the study area was classified as about 60–80 years old (recent age about 200 years) on the forestry map from 1874. While some park managers suggest this area was harvested around 1790–1810, others believe the stand originated after a natural disturbance, possibly windthrow. There are no historical records describing wood extraction in the area, so the origin of this forest remains unknown.

2.2.1. Research plots

During the summer of 2002, three altitudinal transects approximately 700 m in length were established, covering both the old-growth portion of the stand and the adjacent area that was presumably managed. On each transect, six 0.2 ha circular plots were established (in total 18 plots). The distance between the transects was 500 m and the distance between the plot