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Age Structure and Historical Development of Forests in "Bistrishko branishte" Biosphere Reserve in Vitosha Mountain (Bulgaria)

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Abstract. In 2001 the territory of the Bistrishko Branishte reserve of the Vitosha Mountain (Bulgaria) was affected by wind throw. Almost 100% of the *Picea abies* trees on an area of 60 ha were overthrown. After 2003 in the periphery of the wind throw an outbreak of *Ips typographus* has started, which developed at high speed and by 2008 affected 200 ha of the forests in the reserve. These natural disturbances raised questions about the past of the ecosystem and possible relation of these events to the previous history of the forest. To study the age structure and historical development we extracted 165 samples with increment borer from different parts of the forest of the water-catchment of Bistrishka River. Samples were taken from trees representing various diameter classes and perhaps different cohorts. The samples were prepared following standard dendrochronological methodology consisting of gluing to wooden holders, sanding with sandpaper No. 250 and 600, scanning at 1200 dpi and measuring the tree-ring widths with the CooRecorder software. The resulting series were cross-dated using visual characteristics of the tree rings and statistical similarity with the CDendro software.

Our data showed that regardless of the location the age of trees is similar. The majority of dominant trees germinated after the 1870-s. Trees that are visually distinguishable with their larger sizes, had similar ages to neighboring dominants. There is no evidence for large-scale disturbances except for a known wind throw in 1956 in the tree line zone under Skoparnika peak. Over the past 100 years the forest has been affected primarily by small-scale disturbances. The similar age of dominant trees and forest structure are probably a consequence of fast forest recovery after reduced human activity by the end of the 19^{th} century.

Key words: wind throw; bark-beetle outbreak; natural disturbances; tree-ring analysis; Bistrishko branishte; Bulgaria

Introduction

Norway spruce (*Picea abies* Karst.) is one of the most widespread tree species in Eurasia. It is the main tree species in the subalpine zone of most European high mountains and occupies large territories. Norway spruce forests have very high importance as habitats, water catchment areas, protective forests against avalanches, rock falls, landslides, soil erosion and source of valuable timber (SCHUTZ, 1999; AMMAN *et al.*, 2002; RAFAILOV, 2003).

Subalpine forests are among the most frequently affected components by different types of natural disturbances in mountain ecosystems. Until the early 1980-s it was considered that natural disturbance have negative effect on plant biomass (GRIME, 1979). Yet, the summary of available studies made by PICKET & WHITE (1985) demonstrated that natural disturbances such as wind throws, fires and insect outbreaks are an integral part of the ecology of forests. They create conditions for the removal of the

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dominant canopy layer of trees, faster decomposition of dead wood and other cover soil, mineralization of complex organic substances in the soil. This usually creates conditions for establishment of fast-growing pioneer tree species and further on secondary succession and returning of shade-tolerant species such as Norway spruce in the subalpine forests of Europe. In the last decades there were significant efforts for studying in more details the natural disturbance regime of analogous forests such as the mixed-species forests in Central and South Europe (SZWAGRZYK & SZEWCZYK, 2001; BRANG, 2005; FIRM *et al.*, 2009; PODLASKI, 2010), low-elevation spruce-dominated forests in Central and North Europe (ULANOVA, 2000; GROMTSEV, 2002; KUULUVAINEN, 2002; SHOROHOVA *et al.*, 2008) or other coniferous forests in North America (OLIVER & LARSON, 1996; FRANKLIN *et al.*, 2002; ZENNER, 2005). Yet, studies of the disturbance regime of European subalpine forests were scarce mostly due to the perception that the human use had modified these forests and there were no relevant ecosystems. Sharp increase of the number of wind throws and bark-beetles in Central and Eastern Europe in the last 20 decades increased the interest for the disturbance regime of these forests and recently there are a number of studies done mostly in forest reserves in the Carpathians and the Balkan Mountains (SZWAGRZYK *et al.*, 1995; SVOBODA & POUSKA, 2008; ZEILONKA *et al.*, 2010; TSVETANOV *et al.*, 2011; PANAYOTOV *et al.*, 2010; PANAYOTOV *et al.*, 2011).

In May 2001 the territory of the Bistrishko branishte Biosphere Reserve in Vitosha Mountain (Western Bulgaria) was affected by very strong winds (SIMEONOV & GEORGIEV, 2003) which caused the uprooting of the mature trees on a territory of 60 ha. At the end of the summer of 2002, most of the uprooted trees were infested by *Ips typographus L. (ROSSNEV et al., 2005). By 2009 the affected territory by the bark-beetle outbreak was more than 200 ha (PANAYOTOV & GEORGIEV, in press).*

Despite the data for this event and limited data for a wind throw and forest structure in the tree line zone (PANAYOTOV, 2006) there is quite limited information for the past of the Norway spruce forests in Bistrishko branishte. Most of the other information is available from older local people and limited evidence from ZAHARIEVA (1940). She notes that by that period much of the mature trees were aged about 40-50 years and that in many places in the reserve there were visible traces of wood-charcoal production. This is a clue, that the forests of Bistrishko branishte reserve were probably actively managed by local people up to about 100-140 years ago. However, more data on forest structure and age is necessary. This would help to reveal the past history of the forests, the role of human use and probably disturbances. As these forest attributes are directly related to forest stability and resilience, such data would clarify whether there is a possible connection between the wind throw, bark-beetle outbreak and the history of the forest. Therefore, our aim is to study systematically the age structure of different regions in Bistrishko branishte forests.

Materials and Methods

Study site. The study site is the Bistrishka River ínim catchment in the Bistrishko branishte Biosphere Reserve (42°33′N; 23°18′E), located in the "Vitosha" Natural Park in Western Bulgaria (Fig. 1). The total íni of the reserve is 1177.2 ha, of which 600 ha above 1500 m a.s.l. are occupied by natural Norway spruce ecosystems. The local tree line is situated lower ín expected at 1850-1950 m a.s.l. due to frequent strong winds (PANAYOTOV, 2006). The climate is typical for high mountain location with average ínim ínimum ura of 3.3°C, ranging from -5.6°C in January to 12.4°C in July (data for Aleko hut climate station, 1800 m a.s.l.). Annual precipitation amounts to 1228 mm with ínimum in the April –June and ínimum in the August – September periods.

Data collection. Based on preliminary mapping done by satellite images (PANAYOTOV & GEORGIEV, *in press*) we selected areas with various altitudes, exposure and relief features in the Bistrishka

River water catchment. We excluded from our data collection practically inaccessible locations. We collected samples for dendroecological analysis with increment borer. In each area we located trees with different diameters to try to collect data from possibly different cohorts. In areas with natural disturbances that occurred recently we sampled dead and live trees to establish the year of occurrence of the event. In areas with older windthrow, samples were taken from single surviving trees or trees on the border of adjacent surviving forest areas. Following such scheme it is possible to determine the age of the individual sections, the occurrence of natural disturbances or other events that caused drastic changes in radial growth of trees (TSVETANOV *et al.*, 2010; PANAYOTOV *et al.*, 2011).

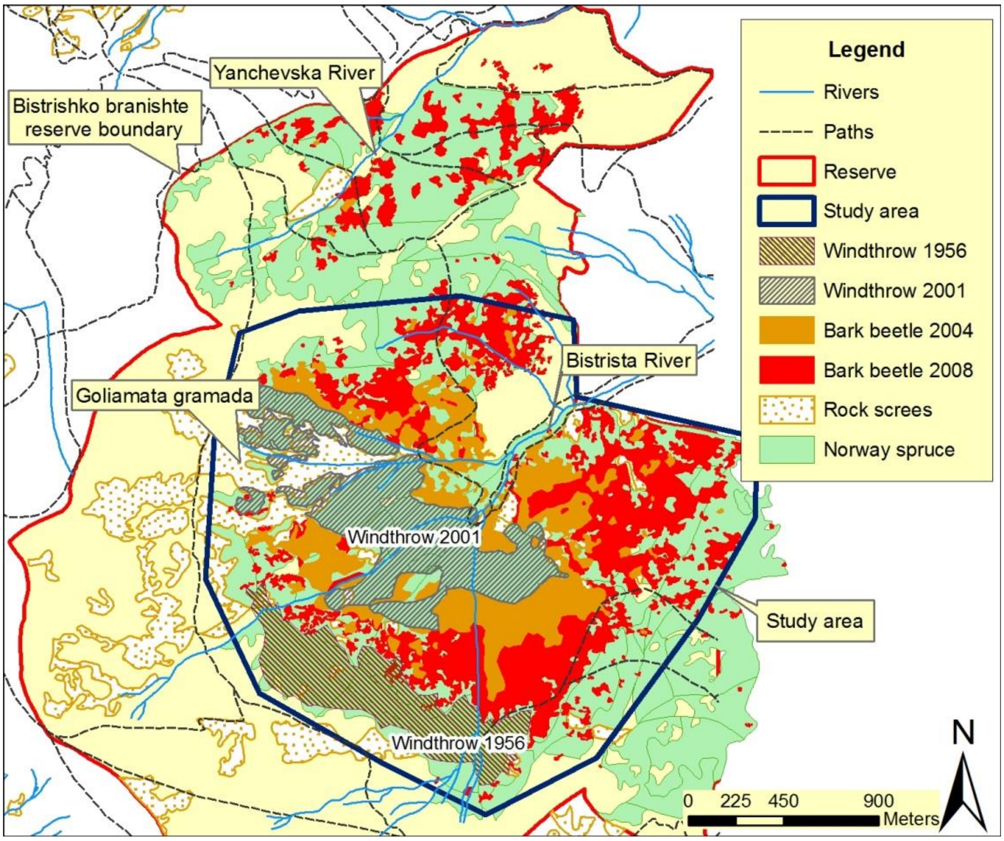


Fig. 1. Study site and location of known large-scale natural disturbances in "Bistrishko branishte" Biosphere Reserve

Samples were mounted on wooden holders, sanded with progressively increasing numbers of sandpaper (250 to 600). Then, they were scanned and cross-dated by visual analysis (STOKES & SMILEY, 1968) and the tree ring width was measured with CooRecorder 7.3 software (CYBIS ELEKTRONIK & DATA AB). The obtained tree-ring width series were cross-dated to establish the exact year of formation of each tree ring. This procedure was performed by visual and statistical comparison of similarities in the variation of the growth curves of individual trees for specific periods of time and tree rings with abnormalities in anatomical texture such as light rings and frost rings (STOKES & SMILEY, 1968; SCHWEINGRUBER, 1996). For the statistical comparisons we used CDendro 7.3 software (CYBIS ELEKTRONIK & DATA AB). Frost rings and light rings were compared with existing local chronology (PANAYOTOV, 2006).

Results and Discussion

Based on the initial mapping we selected eight areas to collect samples (Fig. 2). From three sections - "The Ridge", "Treeline - the Ridge" and "Windthrow 1956" we used initial dataset (PANAYOTOV, 2006) to which we added additional cores.

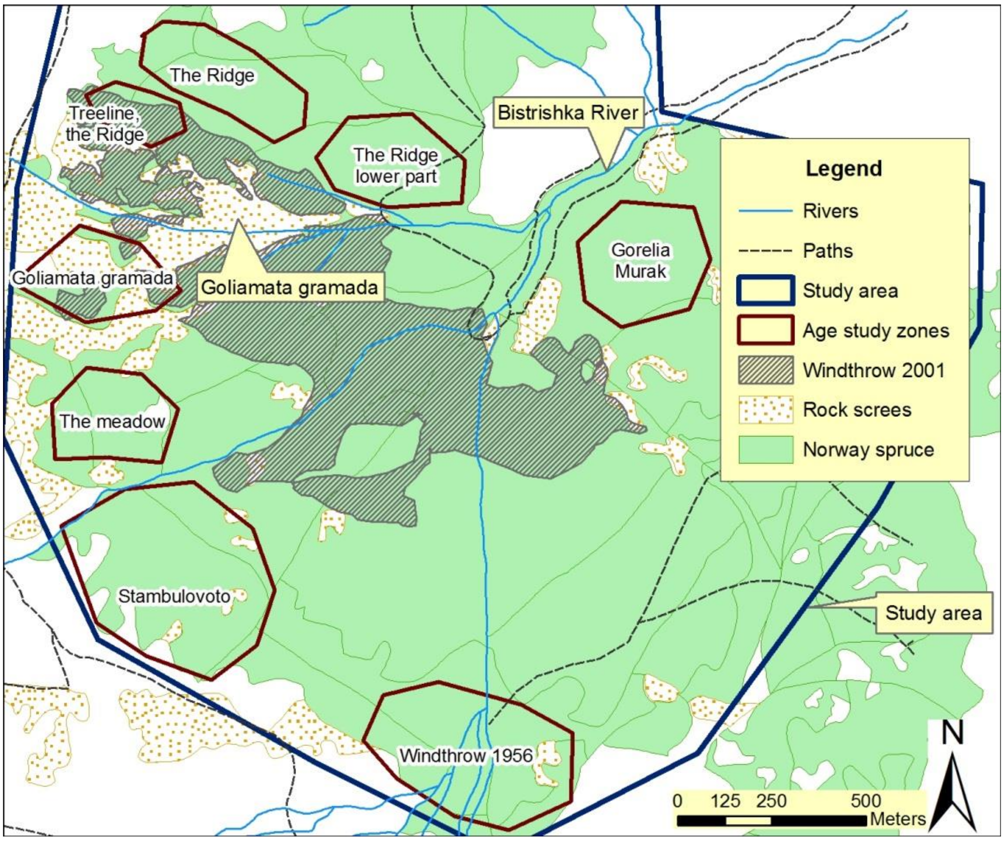
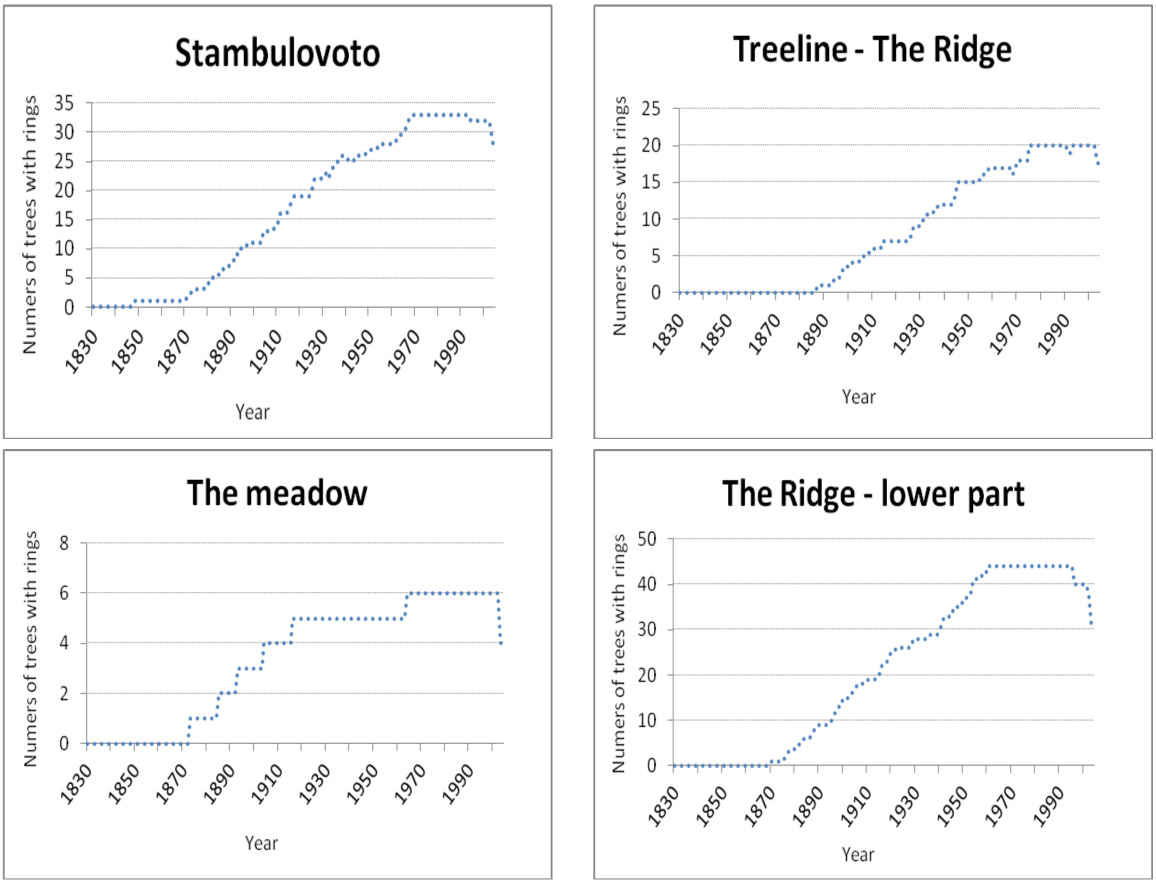


Fig. 2. Age study zones in "Bistrishko branishte" Biosphere Reserve

Data on occurrence of first tree rings (Fig. 3) shows that in all areas the trees were established after the 1870-s. The oldest trees were found in the highest areas of "Stambulovoto" region. Even trees that were visually much thicker than other were actually within the same cohort. Usually such bigger trees had big branches indicating large crowns typical for open growth without side or top shading. This was also demonstrated by tree-ring width patterns. All trees had rather wide tree rings from the very beginning of their growth, which is typical for open growth (SCHWEINGRUBER, 1996; PANAYOTOV, 2011). Our data does not show sharp increase in the number of trees at certain periods, which usually occurs after natural disturbances due to active regeneration in degraded areas (OLIVER & LARSON, 1996; FIRM *et al.*, 2009; TSVETANOV, 2010).

Instead, in the water catchment of Bistrishka River there is a gradually increasing number of trees. Such age structure could be an evidence of two situations – either gradual occupation by trees of areas that were quite spacey populated by few trees or gradual recovery after large-scale stand-replacing disturbance. However, we could not find even a single older tree with sharp release of growth that could be an indication for stand-replacing disturbance. Further, it would be expected that there should be at least limited historical evidence and memories for such large-scale event in the middle of the 19-th century.

Therefore, it seems more likely that the region was used very intensively for grazing and on-site production of charcoal. According to ZAHARIEVA (1940) in 40th of 20th century in the reserve there were numerous traces of charcoal production. Such practice was a traditional way to utilize wood in high-mountain areas where people could not transport large trunks to the valley floors. STEFANOV (1939) stated that the higher parts of Vitosha were actively used for grazing until the 1930-s. Therefore, it is likely that the current territory of the Bistrishko branishte Reserve, which includes extensive grasslands above the tree line zone was used for grazing also at lower altitudes. Perhaps these practices were reduced after the 1880-s when forest legalization limited the use of forests for grazing and the possibilities for salvage logging. This has created conditions for regeneration of spruce and fast occupation of empty spaces between existing small groups of trees and single trees. After initial closure of forests, mostly small-scale natural disturbances (gap formation) have caused loss of a few older trees and their replacement by new ones. This would explain the rather solid number of trees after the 1940s in all areas (Fig. 3).



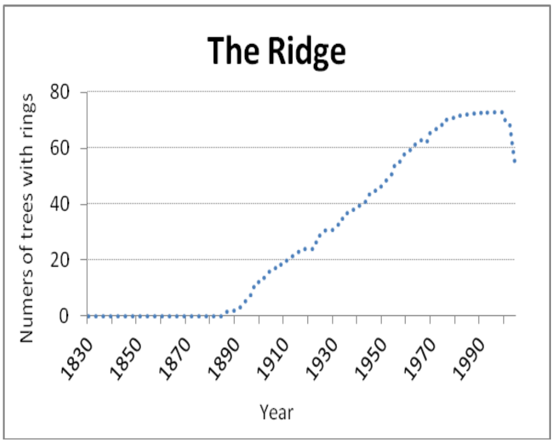


Fig. 3. Number of trees with annual tree rings in the surveyed areas of the "Bistrishko branishte" Biosphere Reserve

The observed reduction of the number of tree rings (and thus of live trees) after 2001 is a reflection both of the wind throw in 2001 and the subsequent *Ips typographus* outbreak. Besides the known disturbances after 2000, the only previous larger-scale natural disturbance was the wind throw in the tree line zone of Stambulovoto region in 1956. Although it affected a territory of approximately 60 ha, the trees were completely overthrown on a smaller area close to the main stream of Bistrishka River. Therefore, its character was quite different from the 2001 wind throw and within the borders of the older disturbances there are groups with older trees (e.g. 120-140 years., Fig. 3, "Stambulovoto") besides patches with younger trees (e.g. 40 years old., data not shown).

Homogeneous forests in which the majority of trees are with similar sizes and age are vulnerable to large-scale disturbances. This is especially true in the case of insect outbreaks, as they are usually specialized for certain species and size class of the trees (TSANKOV, 2005; PANAYOTOV *et al*. 2011). For example, *Ips typographus* prefers Norway spruce trees older than 60 years and seldom attacks younger trees (WERMELINGER, 2004). Indeed, in Bistrishko branishte forest the outbreak affected mostly forest patches with homogeneous structure and age above 100 years (PANAYOTOV & GEORGIEV, *in press*). It is therefore quite probable that the past history of the reserve, which predisposed a forest structure of large territories occupied by trees with similar age and lack of younger patches or patches with higher participation of different species, has facilitated the *Ips typographus* outbreak. Although wind throws are dependent on many factors and mostly on local wind speed, forests with heterogeneous structure are less susceptible to catastrophic damages and more resilient at least because of the presence of many younger groups that are capable of surviving the strong wind and then recover the forest quickly. This is demonstrated by the disturbance model of Parangalitsa Reserve in Bulgaria. There, the much older Norway spruce forest (age of trees > 200 years) has experienced numerous smaller wind throws (e.g. below 10 ha) during the last 150 years which have created a complex mosaic of forest patches with different age and species composition (PANAYOTOV *et al*., 2011). In addition, it has avoided larger insect outbreaks and is much more resilient.

Conclusions

The research conducted within the water catchment of Bistritsa River in Bistrishko branishte Biosphere Reserve indicates that the forest was with relatively similar age before the large-scale wind throw in 2001 and the following bark-beetle outbreak. Most of the bigger trees were 120-140 years old. The only larger natural disturbance was the wind throw in the tree line zone in 1956. The most probable reason for such similar age of the trees is the active use of the current forest territory for grazing and charcoal production on site until the last quarter of the 19th century. The homogeneous forest structure on vast areas occupied by trees of the same species (Norway spruce) with uniform size and age is among the most likely reasons for the scale of the *Ips typographus* outbreak after 2003. Although it was triggered by the 2001 wind throw, the absence of natural barriers as groups of trees of younger age, and other species, assisted the spread of the bark-beetles.

We expect that the disturbances from the last decade, including the recent fire in "Gorelia murak" region, will create conditions for forest heterogeneity at landscape-level and probably assist the occurrence of pioneer species such as *Betula pendula* and *Populus tremula*, besides the increase of the territories occupied by *Fagus sylvatica* for at least the next 50 years.

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