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Challenges for the Conservation of the Norway Spruce Forests in Vitosha Nature Park after Large-scale Natural Disturbances

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Abstract. In 1934 was established the first national park on the Balkan Peninsula, today Vitosha Nature Park. One of its management objectives is conservation of the subalpine Norway spruce (*Picea abies*) forests in the park. In the last 60 years, significant areas of these forests have been affected by a series of medium and large-scale natural disturbances such as windthrows, bark beetle outbreaks and fires. To study the influence of these natural disturbances on the development of Norway spruce forests in the park we made a literature review and GIS identification of the disturbed forests on the basis of actual forest maps and aerial photographs from 1966, 2005 and 2011. Our results show that in the last 60 years medium and large-scale natural disturbances affected a total of 28% of all spruce forests in the protected area. Most frequent have been the windthrows, while largest impacts have caused the bark beetle outbreaks. About 8% of all natural spruce forests have been replaced with plantations as result of the implementation of forest protection measures, which indicates worsening of the conservation status of the Norway spruce habitat in the park. In order to prevent further worsening of its conservation status, we recommend differential zoning of the park territory so that core zones are surrounded by buffer zones, as well as implementation of appropriate protection measures outside the non-intervention areas. Such measures include prompt treatment of bark-beetle infested trees, leaving sufficient amounts of deadwood in the cutting areas, tolerating natural regeneration and forming multi-species and uneven aged forest structures.

Key words: Norway spruce, *Picea abies*, natural disturbances, climate change, protected areas, Vitosha Nature Park.

Introduction

Subalpine Norway spruce (*Picea abies* Karst.) forests in Vitosha Mountain cover a total area of about 1450 ha. In order to preserve their high conservation value, in 1934 was established the first national park on the Balkan Peninsula, today Vitosha Nature Park. Part of these forests are strictly protected in the reserves "Bistrishko branishte" and "Torfeno branishte". Presently, the natural Norway spruce forests in the park form part of habitat 9410 "Acidophilous *Picea* forests of the montane to alpine levels (*Vaccinio-Piceetea*)", which falls under the protection of the Habitats Directive 92/43/EEC. The conservation of this habitat requires measures which maintain or restore its favorable conservation status. This means that the natural range of the habitat is stable or increases, its specific structure and functions continue to exist and its typical species are preserved.

During the last 60 years, significant areas of the Norway spruce forests in Vitosha Nature Park have been affected by a

series of medium and large-scale natural disturbances such as windthrows, bark beetle outbreaks and fires (DOUNTCHEV, 2007; PANAYOTOV & GEORGIEV, 2012). After 2001, unprecedented forest damages in the park resulting from large windthrows followed by severe bark beetle outbreaks triggered expert discussions about the implications concerning the management and conservation of spruce forests influenced by natural disturbances. The discussions have been polarized by the opposing of economic and nature conservation interests with regard to the management of the spruce forests in the park. At the same time, similar discussions have been ongoing in Europe and Northern America, where the scale of recent natural disturbances in protected and managed coniferous forests exceeds by hundreds of times (table 1) the scale of the natural disturbances in Vitosha Nature Park (by FORSTER *et al.*, 2000; FREY *et al.*, 1995; HALTER, 2011; SCHELHAAS *et al.*, 2003). Back in the 1990s, the storms "Vivian" and "Wiebke" caused windthrows and subsequent bark beetle outbreaks affecting hundreds of thousands of hectares of Norway spruce forests in Western and Central Europe (FISHER *et al.*, 1998). In 1999, the hurricane "Lothar" felled another 400 000 hectares of forests in Western and Central Europe (FISHER *et al.*, 2002), followed again by bark beetle outbreaks in vast areas of spruce forests. On November 19, 2004, a storm devastated over 10 000 hectares of coniferous forests in the Slovak Tatra mountains, whereby mainly affected were spruce plantations originating from the beginning of the 20th century (WWF, 2004) and the *Picea abies* trees in mixed Picea-Larix forests which originated after stand-replacing windthrows about a century ago (ZIELONKA *et al.*, 2009). On January 8, 2005, the storm "Gudrun" felled over 200 000 ha of Scots pine and Norway spruce forests in southern Sweden (SKOGSSTYRELSEN, 2005). On January 14, 2007, a hurricane damaged another 40,000 hectares of forests in Sweden. Even more alarming is the rate at which have been developing the bark beetle outbreaks in North America, where in recent decades were killed more than 28 million hectares of coniferous forests (HALTER, 2011; BERG *et al.*, 2006; WESTFALL, 2006).

Table 1. Area of coniferous forests affected by bark beetle outbreaks in Europe and North America in the last two decades

Vitosha Nature Park, Bulgaria	Bayerische Wald National Park, Germany	Western Europe	North America
300 ha	4 000 ha	1 000 000 ha	28 000 000 ha

In the past, the natural disturbances were perceived as "natural disasters". Latest scientific knowledge about the ecology of the forest ecosystems, however, proves that the natural disturbances play an integral role in forest dynamics by enhancing forest structural and biological diversity (FRELICH, 2002; PICKETT & WHITE, 1985). This is particularly valid for subalpine and boreal spruce forests, which are highly susceptible to natural disturbances such as windthrows or bark beetle outbreaks (HEURICH, 2001; SCHMIDT-VOGT, 1991). In the same time, natural disturbances create favourable conditions for the regeneration of spruce forests and contribute to the development of heterogeneous structures. Especially under the harsh climatic conditions of the high mountains and in the boreal zone, the regeneration of *Picea abies* occurs primarily on decaying wood that provides optimal microclimatic conditions for the growth of spruce saplings (EICHRODT, 1970; SCHÖNENBERGER *et al.*, 1992).

Recent studies on the dynamics of spruce forests in "Bistrishko Branishte" reserve indicate that the effective management and conservation of these spruce ecosystems in Vitosha Nature Park require extended knowledge about the

ecology of these ecosystems and better understanding of the role that natural disturbances and human activities play in their development (DOUNTCHEV, 2007; PANAYOTOV & GEORGIEV, 2012; TSVETANOV & PANAYOTOV, 2013).

In this regard, the aim of this study was to survey the changes in the development and distribution of Norway spruce forests in Vitosha Nature Park as result from natural disturbances during the last 60-70 years and to identify and address the main challenges for the management of those forests in the light of the conservation objectives of the protected area.

Materials and Methods

The natural Norway spruce (*Picea abies* Karst.) forests in Vitosha Nature Park (42°35'N; 23° 17'E) are situated in the water catchment areas of the rivers Bistrishka, Yanchovska, Vladayska and partially along the currents of the rivers Struma, Boyanska and Dragalevska at an altitude between 1400 and 2000 m (Fig. 1). The climate is typical for high mountain location with average annual temperature of 3.3 °C, ranging from -5.6 °C in January to 12.4 in July (data for Aleko hut climate station, 1800 m). Annual precipitation amounts to 1228 mm with maximum in the April-June and minimum in the August-September periods.

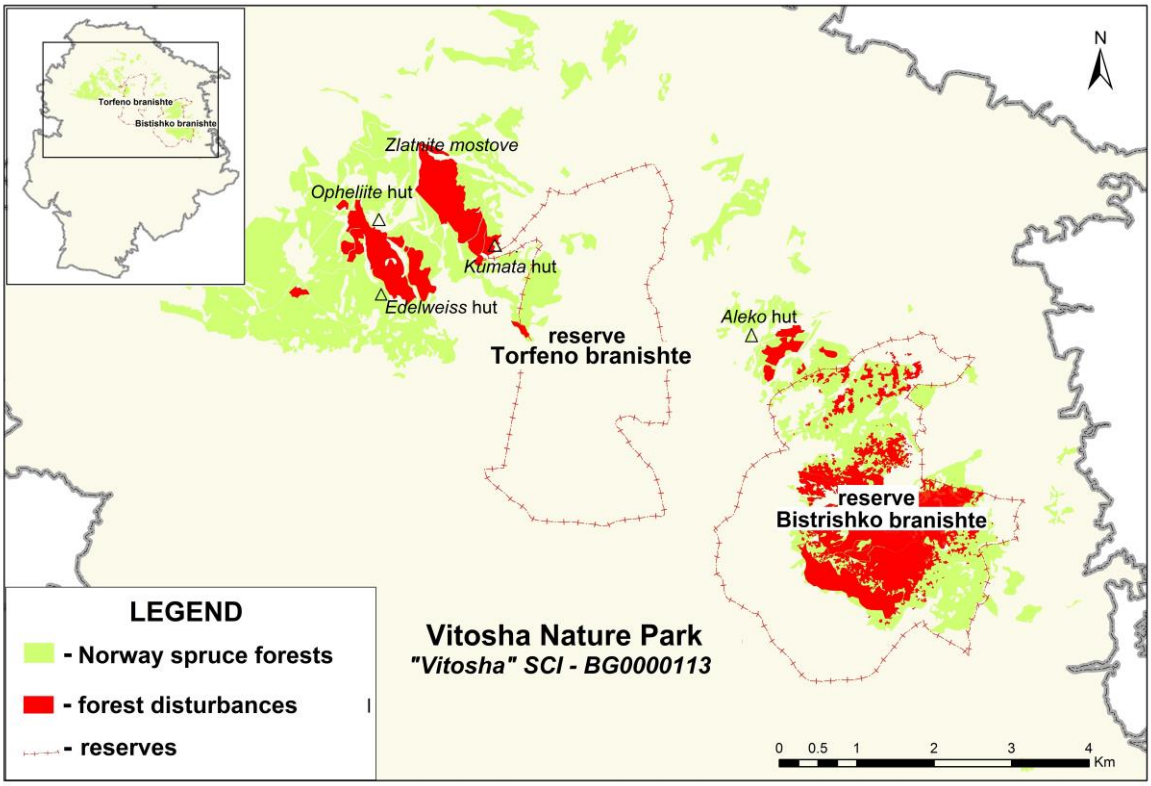

Fig. 1. Map of Norway spruce forests in Vitosha Nature Park.

Historical information about the natural disturbances in the Norway spruce forests in Vitosha Nature Park was collected on the basis of a review of available literature. Data for the distribution and development of spruce forests was acquired from the forest management plans of Vitosha Nature Park. Detailed identification and mapping of all polygons with disturbed Norway spruce forests was performed on the basis of actual forest maps and orthorectified digital aerial photographs from 1966, 2005 and 2011. The statistical data and the aerial photographs were processed and analyzed in Geographic Information Systems (GIS) using specialized software ArcGIS 10 (ESRI Inc.).

Results

According to the available scientific data, the Norway spruce forests in Vitosha Nature Park are most often affected by windthrows (Table 2.). On November 14-15

1941 a storm caused many small-scale windthrow gaps in spruce forests in the area between the "Zlatnite mostove" site and "Edelweiss" hut, whereby more than 2000 m^3 of spruce wood was sanitary logged (ZHEKOV, 1943). On June 14, 1956, a storm felled 110 hectares of spruce forests in the region of "Kumata" hut and in the tree line zone of Bistrishko branishte reserve (TASHEV, 1978). In both areas local people performed salvage logging and transported the logs by oxes. The windthrow area in the region of "Kumata" hut was planted over the years with Norway spruce and Macedonian pine (*Pinus peuce* Gries.). In this way, nearly 64 ha of the natural spruce habitats affected by the natural disturbance were converted into coniferous plantations. In "Bistrishko branishte" reserve, the windthrow area was estimated at 38 ha. It was left to natural regeneration. In 1986, a windthrow on an area of 3,5 ha occurred in spruce forests nearby "Aleko" hut (PANAYOTOV, 2006). There, the wind felled wood was removed, but because of its small size the windthrow area was also left to natural regeneration.

Table 2. List of the large-scale natural disturbances in the spruce forests in Vitosha Nature Park, 1940-2012

Year of distur-bance	Type of natural disturbance	Management measures	Site	Dis-turbed area
1956	Windthrow	cleared and planted	"Vetrovala" site - "Kumata" hut	64 ha
1956	Windthrow	cleared	"Bistrishko branishte" reserve	38 ha
1986	Windthrow	cleared	near "Aleko" hut	3,5 ha
2001	Windthrow	cleared and planted	near "Opheliite" hut	12 ha
2001	Windthrow	uncleared	"Torfeno branishte" reserve	2 ha
2001	Windthrow	uncleared	"Bistrishko branishte" reserve	60 ha
2002-2007	Bark beetle outbreak	non-intervention	"Bistrishko branishte" reserve	181 ha
2002-2007	Bark beetle outbreak	clear cut and planted	near "Opheliite" hut	48 ha
2002-2007	Bark beetle outbreak	clear cut and planted	near "Aleko" hut	15 ha
2012	Forest fire	non-intervention	"Bistrishko branishte" reserve	70 ha

On May 22, 2001, a storm passed through the "Opheliite" site and the territories of "Torfeno branishte" and "Bistrishko branishte" reserves (Dountchev, 2006; PANAYOTOV & GEORGIEV, 2012). According to our GIS analysis affected were respectively 12 ha, 2 ha and 60 ha of Norway spruce dominated forests. In the "Opheliite" site, the windthrow area was cleared in two years time, while the disturbed areas in both reserves remained without human intervention. In both cases, however, the larger windthrows were followed by outbreaks of *Ips typographus* L., which affected a total of 244 ha of the natural Norway spruce forests in Vitosha Nature Park. Outside the reserves, sanitary measures were implemented on an area of 63 ha, whereby all trees attacked by bark beetles and all trees in their perimeter within a radius of a tree stand height were cut and removed. The logging debris were burned and the cleared areas were planted with Norway spruce, Silver fir (*Abies alba* Mill.) and partly with European beech (*Fagus sylvatica* L.). In "Bistrishko branishte" reserve, the disturbed areas were left to regenerate naturally and a recent study showed that initial regeneration was dominated by Norway spruce (DOUNTCHEV, 2007; Dountchev- pers. comm).

On July 1, 2012, a forest fire in the eastern part of the "Bistrishko branishte" reserve burned an area of about 70 ha, which was previously affected by the windthrow in 2001 and the bark beetle outbreak in 2002-2007.

According to the results of our GIS-analysis (Table 3), in the period from 1940 to 2012 large-scale natural disturbances affected a total of 424 ha (i.e. 28%) of all spruce forests in Vitosha Nature Park. Nearly 139 ha (i.e. 8% of all spruce forests) of the latter were replaced by coniferous plantations, while 285 ha were left to regenerate naturally. Unaffected by natural disturbances are 1103 ha of the natural spruce forests, predominantly in the western part of the park.

Table 3. Distribution of spruce forest areas per type of natural disturbance and management approach

Intact natural spruce forests		Windthrow areas (incl. fires)		Areas affected by bark beetle outbreaks (incl. fires)		Total
1103 ha (72 %)		180 ha (12 %)		244 ha (16 %)		1527 ha (100 %)
Reserves	Managed forests	Natural regeneration	Artificial plantations	Natural regeneration	Artificial plantations	Total
252 ha	851 ha	104 ha	76 ha	181 ha	63 ha	1527 ha

Discussion

Our results show that large-scale natural disturbances have a dominant influence on the development of the natural spruce forests in Vitosha Nature Park in temporal and spatial aspect. During the last 60 years were affected nearly 1/5 of all natural spruce forests in the park. Windthrows occur at about 20 years in average.

From dendro-ecological point of view, the high frequency of windthrows in Norway spruce forests is connected with the limited individual stability of spruce trees (HEURICH, 2001; SCHMIDT-VOGT, 1991). Especially when growing on wet soils, the exceptionally shallow root system of spruce trees tends to be a critical factor for the individual stability of this species. STEFANOV (1939) assumed that this ecological feature of the Norway spruce appears to be an advantage and one of the reasons for the dominance of this species in the high parts of Vitosha Mountain, where soils are shallow and stony. However, these unfavourable edaphic conditions are a critical factor for the growth of spruce trees, not only with respect to its stability, but also with respect to its resistance to pathogens, especially during periods of drought (GANCHEV, 1987; FORSTER *et al*., 2000).

As particularly susceptible to natural disturbances are considered forest stands with low structural heterogeneity (HEURICH, 2001; SCHMIDT-VOGT, 1991), including protected forests which have lost their natural structure and resistibility as result of intensive management activities before their designation as protected areas (WEISSBACHER, 2004; ZATLOUKAL, 1998). This proves to be valid also for the spruce forests in "Bistrishko branishte" reserve. Recent studies (PANAYOTOV & GEORGIEV, 2012; TSVETANOV & PANAYOTOV, 2013) found that natural disturbances in the reserve had affected predominantly homogeneous even-aged stands not older than 140-150 years, with various signs of anthropogenic impacts before the establishment of the protected area.

Our survey results show also that since 2001 the greatest impact on the development of spruce forests in Vitosha Nature Park have the recent outbreaks of *Ips typographus* L. Under favourable conditions such as the presence of large amount of fresh deadwood (e.g. after a windthrow) or mild climate, this species is able to attack and kill sizable areas of spruce stands (FORSTER *et al*., 2004). TSANKOV (2005) assumes that immediate removal of wind felled trees was the decisive

measure for preventing severe bark beetle outbreaks after the windthrows of the mid-1950s. After 2001, however the rate of expansion of the bark beetle outbreak was similar in non-intervention forests as in managed forests (Table 1). GEORGIEV (2006) explained the uncontrollable expansion of the bark beetle populations after 2001 with the extremely dry weather in the period 2001-2005. Alternatively, after 2005, severe weather conditions such as cold and rainy weather during the growing season hampered the development of the bark beetles, increased the number of their natural enemies and finally lead to gradual subsiding of the bark beetle outbreak.

At the same time, numerous authors (FISCHER *et al*., 2002; FORSTER et al., 2000; FREY *et al*., 1995; HALTER, 2011) report that natural disturbances such as windthrows and bark beetle outbreaks affect even larger areas of coniferous forests in Western and Central Europe and Northern America. In essence, climate change is blamed for an increase in the frequency and intensity of devastating storms and extremely unfavourable for coniferous forests climate conditions (FISCHER, 1998; BERG *et al*., 2006; DALE *et al*., 2001; HALTER, 2011; WESTFALL, 2006). On the one hand, periods of extreme drought reduce significantly the resistance of Norway spruce trees against bark beetle attacks (ENGESSER *et a*l., 2008). On the other hand, the higher average temperatures improve the survival rate of bark beetles during the winter and favour the development of more than one and even two generations of bark beetles in the growing season (WERMELINGER & SEIFER, 1999; BERG *et al*., 2006; HALTER, 2011). Limiting the disastrous consequences of bark beetles outbreaks was elusive even when prompt sanitary measures were implemented (FORSTER *et al*., 2004).

The results in Table 2 and Table 3 reveal that except the natural disturbances and the climate change, the distribution and development of natural spruce forests in Vitosha Nature Park is strongly influenced by the type of management of these forests.

On the one hand, sanitary measures were implemented in all managed forests affected by large-scale natural disturbances. As argued by DOUNTCHEV (2006), these sanitary measures were not fully consistent with the ecology of Norway spruce ecosystems. Salvage logging was performed with extreme delay in relation to the fast rates of bark beetle expansion. In the same time, salvage logging reduced the stability of the stands on the edge of the clear cuts, leading to further forest damages. The natural undergrowth was irreversibly damaged, whereas the removal of deadwood compromised the natural regeneration in the long term. Clear cut areas were regenerated artificially with non-native spruce saplings, which were not adapted to the local environmental conditions. As a result, nearly 140 ha of natural spruce habitats were replaced with plantations. These facts indicate worsening of the conservation status of the spruce habitat because its area is decreased and its structures and functions are adversely affected.

On the other hand, despite the die-off of a larger part of the old spruce trees in "Bistrishko branishte" reserve, the non-intervention management applied there allowed preservation of the biodiversity and restoration of the natural character of the spruce habitats (DOUNTCHEV, 2007). This measure, however, lead to uncontrolled expansion of the bark beetle outbreak outside the reserve, affecting also the recreational zone of the park near "Aleko" hut.

When addressing the abovementioned challenges for the conservation of the natural spruce forests in Vitosha Nature Park, good experience could be gained from the German National parks "Bayerische wald" and "Harz" and the forest reserve "Dürenstein" in Austria. The most valuable spruce ecosystems in these protected areas are set aside in core zones where human interventions are limited. In the core zones, spruce ecosystems are left entirely under the influence of natural processes in order to maintain or restore their natural character (FISCHER et al., 2002; JEHL, 2001; KULAKOWSKI & BEBI, 2004). The core zones are surrounded by buffer zones with a

width of 300 to 1 000 m (NATIONALPARK BAYERISCHE WALD, 2005). The buffers are designed in a way which guarantees that the managed forests outside the protected area are not affected by the natural processes (e.g. bark beetle outbreaks) taking place in the core zones. The prevention measures applied in the buffer zone include intensive supervision and prompt treatment of infested trees by peeling and leaving the debarked tree in the forest. Outside the core zones, spruce forests are managed in a way which increases their resistibility by tolerating natural regeneration and forming multi-species and un-even aged forest structures (WERMELINGER, 2004).

Negative experience with regard to the conservation of natural spruce forests is reported in the Czech National park "Šumava" and the Belarusian National Park "Belovezhskaya Pushcha" (PAVLICHKO, 2005; KOZULKO, 2002; SOLAR & GALLAND, 2002). There, similarly to the experience in the "Ophellite" site shared by DOUNTCHEV (2006), the bark beetle outbreaks were counteracted by large-scale sanitary felling, which resulted in serious environmental problems such as excessive clear cuts, erosion and replacement of natural forests with artificial plantations.

Conclusions

The research data demonstrates that during the last 60 years large-scale natural disturbances such as windthrows and bark beetle outbreaks played a dominant role in the dynamics of natural spruce forests in Vitosha Nature Park. The occurrence and intensity of natural disturbances was often influenced by the climate conditions, the level of forest heterogeneity and the management types. Implementation of forest protection measures such as salvage logging followed by artificial regeneration lead to worsening of the conservation status of the natural spruce habitats in the protected area. Just the opposite, non-intervention management in the reserve territories guaranteed the preservation of the biodiversity and the natural character of the spruce ecosystems.

On the basis of an analysis of local and international experience in the management of Norway spruce forests in protected areas affected by natural disturbances, we recommend that effective conservation of the natural spruce habitats in Vitosha Nature Park should be achieved by differential zoning of the park so that core zones are surrounded by buffer zones. We suggest implementation of appropriate forest protection measures outside the non-intervention areas, which include prompt treatment of infested trees, leaving sufficient amounts of deadwood in the cutting areas, tolerating natural regeneration and forming multi-species and un-even aged forest structures.

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