WINDTHROWNS AND SPRUCE BARK BEETLES IN PROTECTED AREAS IN POLISH MOUNTAINS: SURVEY AND EXPERIENCES.

Wojciech Grodzki[1], Jerzy R. Starzyk[2], Mieczysław Kosibowicz[1], Tomasz Mączka[3], Jakub Michalcewicz[2],

[1]Forest Research Institute, ul. Fredry 39, 30-605 Kraków, Poland
(*e-mail: W.Grodzki@ibles.waw.pl, M.Kosibowicz@ibles.waw.pl*)
[2]Faculty of Forestry, Agricultural University, Al. 29 Listopada 46, 31-425 Kraków, Poland
(*e-mail: rljstarz@cyf-kr.edu.pl, jmichalcewicz@ar.krakow.pl*)
[3]Tatra National Park, ul. Chałubińskiego 42a, 34-500Zakopane, Poland
(*e-mail: tmaczka@tpn.pl*)

Abstract
In late 2002 wind damage occurred in Tatra and Gorce National Parks. The investigations on the bark beetle populations infesting lying and standing trees started in 2003. In the 1st year after damage only lying trees were infested, and in the 2nd season the attack on the standing trees started, resulting in local bark beetle outbreaks in damaged stands. This temporal pattern occurred in both observed objects, in areas under strict and active protection, and seems to be a rule in European conditions.

Keywords: Norway spruce, bark beetles, wind damage, protected areas

1. Introduction

Bark beetles can successfully use fallen and broken trees as their breeding base even in the second or third year after the damage occurred (Göthlin et al. 2000), when the number of infested trees increases and the threat to stands grows in 2 to 3 years after windthrowns occur (Forster 1998, Lindelöw & Schroeder 1998). Scandinavian and Swiss studies indicated that in unmanaged stands (i.e. those not covered by protection measures) the number of trees infested by *Ips typographus* (L.) was much (about twice) higher than in the similarly wind-damaged spruce stands covered by protection regime (Forster 1998, Lindelöw & Schroeder 2001). According to Capecki (1981), in the conditions of Polish mountains, it is necessary to remove first, all the fallen and broken lying trees and, then, standing trees infested by bark beetles. The question of human intervention in areas under nature protection is subject to controversies from many times. Whereas on the sites under strict protection the absence of such intervention is self-evident, in the areas under active protection the need to take protection measures in the stands damaged by abiotic factors and, as a result of this, threatened by bark beetles, is often questioned. A good scientific background is then needed to find right solution for this sensitive problem.
In October and November 2002 the wind damage affected large areas in the mountains in southern Poland, including the areas under protection regime in some national parks, among them – in Tatra and Gorce National Parks. In the eastern part of the Tatra National Park the wind broke or fallen trees with volume of about 38700 m^3, over a total area of about 3000 ha. Stands over an area of about 350 ha have been destroyed completely. Most fallen and broken trees occurred in the area under the active protection (lower forest-zone spruce stands with an admixture of fir); however, the spruce stands in the area under strict protection were also damaged, with the extent of the damage estimated at about 1.600 m^3. The extent of the damage in the late autumn of 2002 was greatest since the windthrown events in 1968 (Bzowski & Dziewolski 1974). In Gorce National Park the wind fallen or broken the trees of

the volume of about 700 m^3 over an area of about 5 ha in the upper forest-zone spruce stands, at an elevation of more than 1100 m asl,. The damage was clustered and localised in the area under strict nature protection (Grodzki & Starzyk 2004).The damage repeated in late 2004 in much larger areas dispersed in several parts of the Park; the size was then estimated on about 10 thousand m^3 (Grodzki et al. 2006).
The aim of presented study was the definition of the state and dynamics of *I. typographus* populations in the parts of stands which survived the wind disaster.

2. Materials and methods

The survey started in the vegetation season 2003 (just after the damage), was developed in two ways:

- the inventory of damage and tree mortality made by administration of the Parks,
- detailed research on selected plots, made by scientific staff.

The inventory of damage and tree mortality was based on the common practices applied by national parks' administration. It consists mainly of the field inventory of fallen/broken and infested trees in the strict reserves, and the registration of felled infested trees in the active protection zone. The collected data were the subject of spatial analyses.
The detailed research was done using earlier developed methods, in the following phases:

- establishment and measurement of observation plots in damaged stands, where the windblown trees were left in the forest,
- estimation of the infestation of windblown trees,
- current evidence of tree mortality (infested standing trees) on established plots, entomological analyses of felled standing infested trees, by the dissection of bark samples taken from characteristic tree sections (I – basal, II – middle between tree base and crown base, III – under the crown, IV – middle of the crown).

Data analysis consisted of:

- definition of the distribution of the volume of sanitary cuttings in the research area using digital map,
- simple spatial data analyses enabling the assessment of the bark beetle infestation level using the calculation of areas in individual bark beetle occurrence classes.

The bark beetle occurrence was defined by the calculation of the volume of infested trees (m^3) per 1 ha, using the following classes (Capecki 1981): 0 – no infestation, 0.01 – 0.40 – normal, 0.41 – 1.20 – premonitory, 1.21 – 2.40 – high, 2.40 – 20.0 – very high, > 20.0 – catastrophic. The area of stands in individual classes was calculated using the database concerning stand characteristics, including the area of individual forest sub-compartments.

3. Results

Size and location of damage

In the area of interest of the Tatra N.P., which covered 2391 ha, the damage was recorded on the surface of 1572 ha (65.8% of total), but the damage up to 20 m^3/ha prevailed (42.8% of total), and the damage over 50 m^3/ha occurred on 152 ha (6.3% of total). If the damage is expressed as the percentage of the volume stock, the stands damaged up to 10% prevailed (52.6% of total), and the most damaged (more than 50%) stands represented 1.4% of the total area of interest (fig. 1). The damage was dispersed inside the stands, but some continuous areas with broken/fallen trees occurred too.

Facing the clustered distribution of the damage in the Gorce N.P., such spatial characteristics were not developed. The damage from 2002 represented 11 clusters of broken/fallen trees, distributed over 5 forest compartments with the total surface of about 131 ha. Damage in 2004 affected the same area (fig. 2), as well as some other parts of the Park.

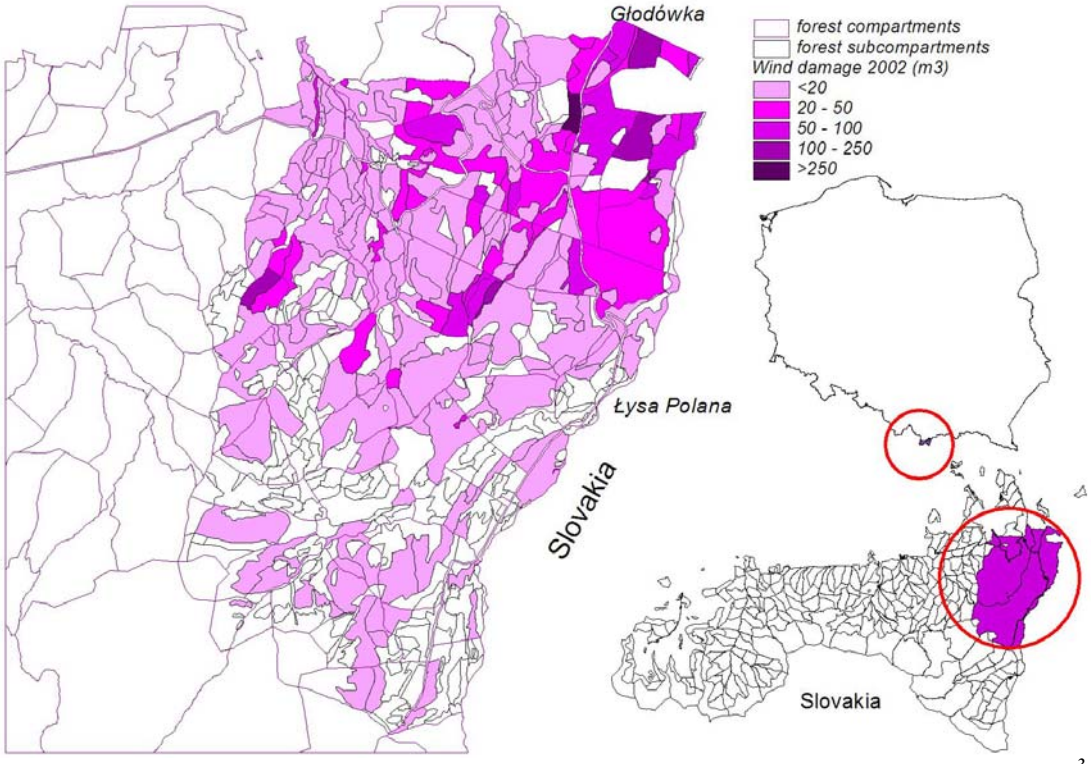

Figure 1. Distribution of the stands damaged by the wind (estimated size of damage in m^3 of broken/fallen trees in individual forest stands) in the eastern part of the Tatra N.P. in 2002

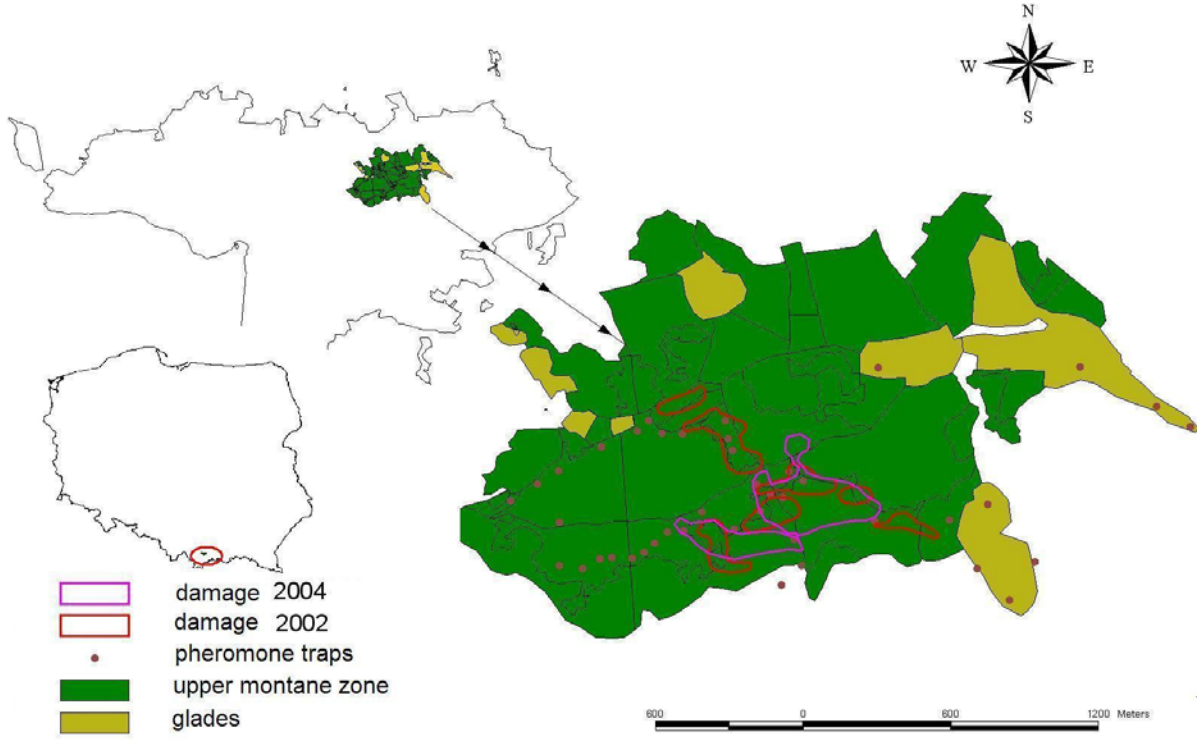

Figure 2. Location of the stands damaged by wind in the Gorce National Park in autumn 2002 and 2004 (map provided by Mr. Paweł Armatys, Research Station of the Gorce N.P.)

Occurrence of bark beetles in the Tatra NP

In the first vegetation season (2003) the insects infested the broken and fallen trees left in the forest, the number/volume of infested standing trees was negligible and the frequency of *I. typographus* – relatively low. No infested trees were then recorded in the observation plots. In the second year (2004) the number of standing trees infested by *I. typographus* increased significantly, especially on the plots with clustered wind damage (IBL_1 – IBL_4), located on insolated slopes (fig. 3a), while on the shady plots with broken trees dispersed under stand canopy the tree mortality was much lower. In 2005 the tree mortality on observation plots was low, however generally it increased in majority of wind-damaged stands (Grodzki et al. 2006b).

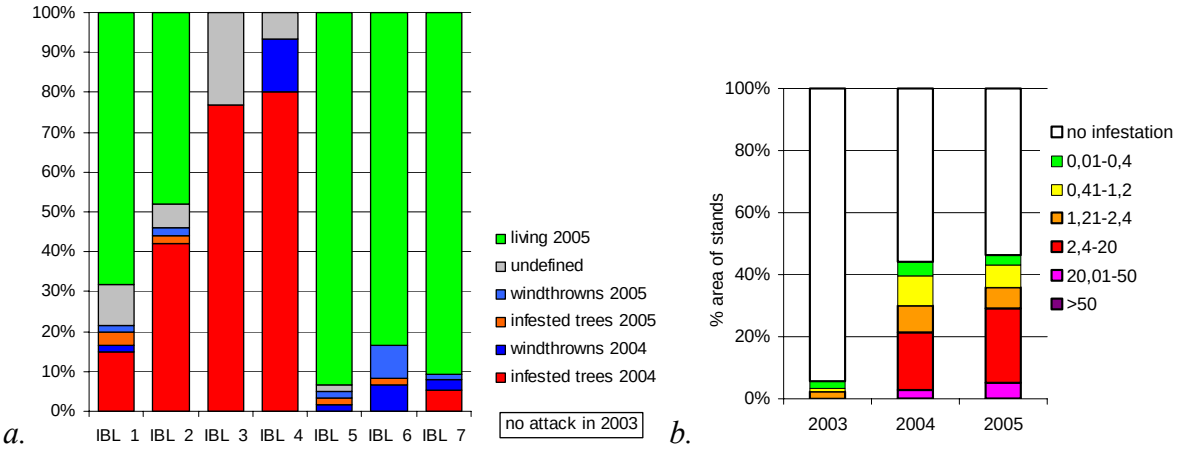

Figure 3. Tree mortality on the observation plots (a) and percentage of stands in individual infestation classes (b) in wind-damaged stands of the Tatra N.P. in 2003-2005

The intensity of bark beetles attack on standing trees in 2003 was very low – the area of the stands with recognized infestations was only 138 ha (5.7% of total), and the highest bark beetle occurrence level was the "high" one (2.4%). In 2004 the area of stands with recognized infestations increased to 1077 ha, and the stands with "high" and higher bark beetle occurrence level represented 732 ha (30.0%), while in 2005 these values were 1129 ha (46.3%) and 876 ha (35.9%), respectively, which indicates high increase of the bark beetle population level started in the 2nd vegetation season after the wind damage (fig. 3b).
The frequency of *I. typographus* on lying trees in 2003 was estimated on 87% in average, and in 2004 its level, estimated on attacked standing trees, increased to 93.5%.

Occurrence of the bark beetles in the Gorce N.P.

In the Gorce N.P. a number of 617 fallen (92%) or broken (18%) trees were labelled and about 20% of lying trees were sampled. In the spring 2003 *I. typographus* was found on 95%, and in the summer – on 98% of sampled trees, (the other species – on 31-32% of spruces), while in 2004 these values were 100% and 10-40%, respectively. In 2003, 2004 and 2005 the infestation density varied, reaching 1.0, 1.7 and 0.96 mating chamber/dm^2 respectively, with predomination of females (66-69%). In 2003 mainly lying trees were colonised, and no increase in the infestation of standing trees surrounding the wind-damaged areas was observed. The intensive bark beetle attack on open stand edges started in 2004, and high percentage of females indicates a dynamic growth of *I. typographus* populations (Grodzki et al. 2006a).
The results of the inventory made by the Park's administration also show the increase of the bark beetle population level in the second (2004) year after the first damage (fig. 4). The

insects, infesting first the lying trees, had the favorable conditions for its population building-up, which is expressed by the volume of infested material in 2003, including broken and fallen spruces. In 2004 only the standing trees next to damaged areas were infested, and the concentration of bark beetle in fresh windblown trees repeated in 2005 (Grodzki et al. 2006a).

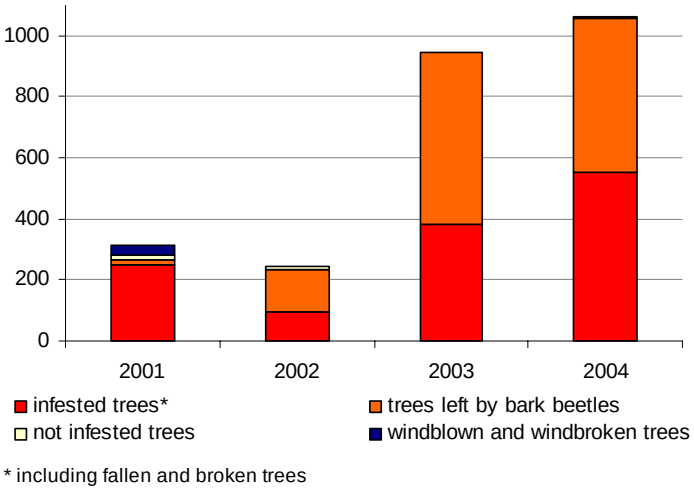

Figure 4. Gorce N.P. – development of the bark beetle outbreak expressed by the volume (m^3) of trees infested by bark beetles in 2001-2004

Forecast

Based on the long-term data and calculated polynomial trend the further dramatic increase in the tree mortality resulting from bark beetle infestation was predicted for both damaged National Parks (fig. 5). The observations done in the vegetation season 2006 confirm this forecast, even if the exact data is not yet available. The wind damage (once in Tatra N.P. and twice in Gorce N.P.) was the factor creating favorable conditions for bark beetle population building-up, which – facing extremely long and hot vegetation season in 2006 – entered in eruptive phase of the outbreak. This outbreak will continue to develop at least in the next year, depending on the weather conditions.

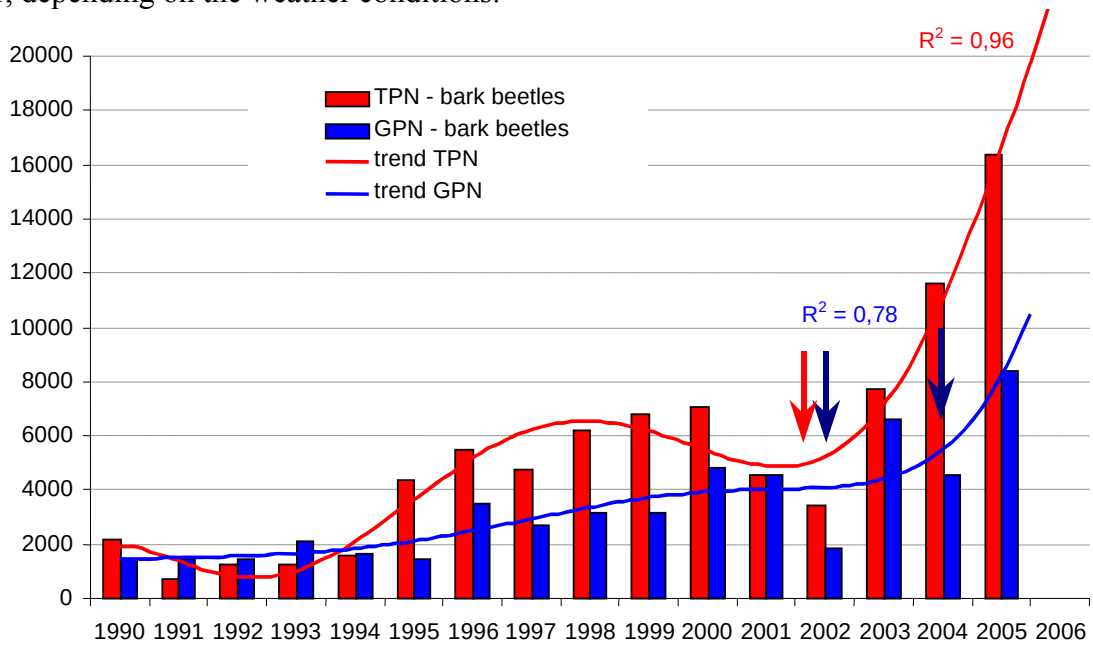

Figure 5. Development of the bark beetle populations in the Tatra and Gorce National Parks in 1990-2002 and after wind damage (marked by arrows) in 2002 and 2004

Activities undertaken

The described processes took place in the areas under both strict (Gorce N.P.) and active (Tatra N.P.) nature protection. Following the law regulations concerning nature protection system in Poland, no human activity (excluding monitoring) is allowed in the strict nature reserves, however in the active protection areas the classic forest protection measures (including pheromone traps but excluding any insecticide application) are allowed (Grodzki et al. 2003).
According to these regulations the only activity allowed in the strict protection area of the Gorce N.P. was the observation (monitoring) and research, which has been started just after the damage, being continued till present (Grodzki et al. 2006a). In active protection area of the Tatra N.P., beside the detailed research done from 2003 till present (Grodzki et al. 2006b), the forestry practices aimed to the active forest protection, were applied just after the damage. These activities consisted mainly of:

- timely removal of broken/fallen trees, including its use as trap logs for bark beetles,
- bark beetle populations' reduction by removal of infested standing trees and pheromone traps application,
- mitigation of the tree mortality by timely application of protection measures,
- stepwise conversion of pure Norway spruce stands towards the significant increase I the share of Silver fir and beech, at first in the areas affected by the most extended wind damage.

4. Discussion and conclusions

Wind damage have the significant effect on bark beetle populations. The fresh windblown and windbroken trees can easily be used as a breeding material for *I. typographus* and accompanying bark beetle species (mainly *I.amitinus* Eichh. and *Pityogenes chalcographus* L.). This is characteristic for the first year after damage, when the bark beetle populations are concentrated on lying trees and no or very slight standing trees' mortality is observed. The mass attack on open stand edges begins in the second year after damage, when already high *I. typographus* population related tree mortality can additionally increase, especially in favorable weather conditions. The same temporal pattern was recorded in two observed forest objects, as well as in the other areas damaged by the wind in Poland and Europe (Göthlin et al. 2000; Forster 1998; Lindelöw & Schroeder 1998, 2001). The increase in *I. typographus* population density is then related to temporary improvement of its breeding conditions by the abundance of fresh logs, combined with mechanical damage and physiological stress in surrounding parts of stands that survived the disaster. The dynamic bark beetle outbreak, started in 2004, is still developing despite control measures undertaken. It concerns both strict reserves, where no intervention was made, and active protection areas, where all classic measures against bark beetles were applied. According to the law regulations, the classic forest protection measures should be applied in these stands, in order to reduce bark beetle population density and related tree mortality. These regulations not only allow the human intervention in actively protected areas, but oblige Park's forestry services to take care about sanitary status of stands, remaining under their responsibility.
Facing the reduced resistance of actively introduced pure Norway spruce stands, urgent conversion towards the species composition adequate to site conditions, is needed in active protection areas, with maximum use of well recognized microsites. The effect of such activity will be the increase in biodiversity, which will positively affect future stand resistance to wind damage and insect outbreaks (Grodzki et al. 1999).

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