Population dynamics of spruce bark beetle in a nature reserve in relation to stand edges conditions

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Abstract
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Over the period 2006–2009 spruce bark beetle (*Ips typographus* [L.]) population was monitored after two windstorm events in a nature reserve in Slovak Ore Mountains. The monitoring was carried out with pheromone traps in three different forest edges: 1) edge of wind-felled trees area, 2) disturbed stand edge and 3) undisturbed stand edge. The one-way anova confirmed statistically significant differences among stand edges in each year and a post-hoc test was applied. In first two years after the primary disturbance the most attractive for spruce bark beetle was the edge of wind-felled trees area. After two years from the primary disturbance the most attractive became the disturbed stand edge. The undisturbed stand edge showed a similar attractivity for spruce bark beetles almost over the whole monitoring period.

Key words
nature reserve, pheromone trap, population dynamics, spruce bark beetle

Introduction

Spruce bark beetle (*Ips typographus* [L.]) is an integral part of spruce ecosystems. As a pioneer it colonizes dying trees and thus starts wood decomposition (Wermelinger, 2004) and it can be also considered as a natural tool for spruce forests restoration (Jonášová and Prach, 2004). In an outbreak conditions, however, the spruce bark beetle can cause considerable damage to production forests. In November 2004, Slovakia was hit by heavy windstorm and this event was followed by bark beetle outbreaks in several mountain units. One of the tool for bark beetle management are pheromone traps, which represents a tool for monitoring the beetle's populations as well as for reducing its abundance.

The windstorm in November 2004 hit also the Nature Reserve NR Fabova hoľa where the volume of wind fallen trees was about 7,600 m^3. Another storm in August 2007, left another 7,600 m^3 of felled trees. The area attacked in August 2007 was about 1.5 km far from the area attacked in November 2004. In both cases, the age of the forest stands was about 150 years. These events were followed by a gradation of bark beetles population in subsequent years. All the wind felled trees were retained in the nature reserve. In area, which was hit by the 2004 storm, barriers of pheromone traps were deployed and in the surroundings of the nature reserve sanitation felling was carried out.

The volume of wind felled trees in 2004 in the forest stands from which our data have been assembled was about 2,100 m^3 and the area of wind-throw was about 4.3 ha. Another 1,500 m^3 covering 2.9 ha were in the adjacent stand.

As the reserve was attacked by wind in November 2004, we considered the year 2005 as the first year of the development of bark beetle population. In this and in the following year (2006), the insects attacked primarily the fallen trees. In summer 2006, they started attack on the surrounding standing trees, but the main attack to standing trees began in 2007 with a volume of about 390 m^3 in the studied stands, and 750 m^3 in the adjacent stand. The windstorm event in 2007 left another 400 m^3 of wood in study stands.

In 2008, another 1,400 m^3 of standing trees were attacked in the study stands, and 850 m^3 in the adjacent stand, in 2009 these amounts increased by 1,200 m^3 and 300 m^3, respectively.

In summary, the amount of attacked wood in our study area was 3,000 m^3 and in the adjacent stand 1,900 m^3.

The aims of this study was to define the dynamics of development of spruce bark beetle's (*Ips typographus*) population and its inter-annual dynamics based on the catches in pheromone-baited traps in years 2006–2009 according to the trap position: on the edge of the wind felled area, in a new-formed stand edge (disturbed stand edge) and in an intact stand edge (used at the same time as the control plot).

Material and methods

Study area

The NR Fabova hoľa is situated in the ridge part of the mountain massive Fabova hoľa in the Veporské vrchy Mts belonging to the Slovenské rudohorie Mts (summit of Fabova hoľa: N 48°46.346", E 19°53.149") at 1,100 to 1,439 m a.s.l. The reserve has an area of 260 ha, more than 250 ha are covered with forests.

The bedrock material is crystalline complex of rocks, the climate is cold, mountainous, with average temperature in July 10–12 °C (Anonymus, 2009). The forest communities, belonging to the 6th and 7th forest vegetation tier, are: Fagetum abietino-piceosum, Acereto-Piceetum and Sorbeto Piceetum. The NR Fabova hoľa is a part of the National Park Muránska planina, mountain plateau.

Methods used in monitoring

Monitoring of the bark beetles was carried out in the NR Fabova hoľa in forest stands attacked by the wind storm in 2004. The wind attacked area was situated on a W-oriented slope at 1,250–1,350 m a.s.l., with an area of about 4.3 ha, and with 2,100 m^3 of windthrown wood.

For monitoring of spruce bark beetle Ecotrap pheromone traps were used over the whole study period (2006–2009), in 2006 Theysohn pheromone traps were also used. The traps were arranged in a barrier (Jakuš, 1998a) on circumference of the oval-shaped wind felled area.

The Ecotrap traps were provided with selective sieves – to prevent trapping larger insect species. Pheromone lures of two types: IT Ecolure Extra (Fytofarm Ltd.) in years 2006–2008 and Pheroprax A (BASF) in year 2009 were used. These two pheromone lures can be considered as comparable (Zahradník and Geráková, 2010). The arrangement of pheromone traps, application of pheromone lures as well as bark beetles sampling followed the Slovak standard STN 48 2711 (Anonymus, 1997) according which the distance to the nearest healthy spruce tree was at least 10 m and the active surface of the traps was placed from 1.5 to 2 m above the ground.

Data processing

The data for further processing were selected from the traps situated in the barrier in such a way that they can be clearly classify into one of the following category:

1. Edge of wind-felled trees area – it was the lower part of the barrier of pheromone traps placed around the wind-felled area. The traps were arranged on the boundary between the disturbed area and a young, artificially established spruce stand, not yet with closed canopy, aged of about 15 years. The traps were situated on a west-facing slope.
2. Disturbed stand edge, that means a new-formed stand edge above the wind felled trees area, i.e. the upper part of the trap barrier. In this place, the wind felled area came together with the adjacent closed canopy forest stands. These traps were also situated on a west-facing slope.
3. Undisturbed stand edge, i.e. stand edge undisturbed by wind. These traps were placed lowest, at a 400 m distance from the wind-felled area. The traps were situated on a slope facing S or SW. These traps served also as a control plot.

The catches of bark beetles were evaluated statistically, using the Statistica software. Annual catches of spruce bark beetle were evaluated. The catches were compared with one-way analysis of variance. Then a post hoc test (Fischer LSD test) was applied to compare the annual mean values per a trap according to the trap position. The traps were arranged in numbers as we can see in Table 1. The numbers of traps of different categories were different in most of the years, because of the terrain accessibility, damage by game and snow and in some years lures for six-spined spruce bark beetle (*Pityogenes chalcographus*) were also used.

Table 1. Numbers of pheromone traps used in our study

Stand edge type	2006	2007	2008	2009
Edge of wind-felled area	6	10	8	8
Disturbed stand edge	11	9	10	12
Undisturbed stand edge	11	11	9	12

Results

The data on annual catch of spruce bark beetles were processed by one-way analysis of variance. The results have been summarised in Table 2. The differences between catches in pheromone traps were found statistically significant in each year. The dependence of catches according to trap position was tested with Fischer LSD test separately for each year (Fig. 1). The LSD test was calculated for each year separately. In 2006, the disturbed stand edge differed from the undisturbed edge as well as from the edge of wind-felled trees. In 2007, the catches in the disturbed stand edge and in the edge of wind-felled trees area were already the same. In the following years (2008 and 2009), there were conspicuous differences between the three different forest edges.

Table 2. Results of one-way analysis of variance in annual catches of spruce bark beetles in pheromone traps in years 2006–2009

Year	F	p
2006	6.5091	0.005301
2007	10.6198	0.000396
2008	42.7076	0.000000
2009	8.5276	0.001222

Statistically significant at $p < 0.05$.

Over the whole monitoring period, an increasing trend in number of caught spruce bark beetle was observed in the disturbed stand edge.

The same trend was observed at the edge of wind-felled trees until 2008, in 2009 it was followed by the first drop in numbers of spruce bark beetles caught.

The disturbed stand edge trapped more individuals than the undisturbed one in the third year after the primary disturbance.

In 2009, the highest mean catches were obtained in the undisturbed stand edge. In our opinion, this was caused by tree felling and skidding near the pheromone trap barrier, which was placed alongside the undisturbed forest edge. This fact has been confirmed also when we modelled the population curve of spruce bark beetle population in year 2009 based on mean catches of bark beetles after each control of pheromone traps (Fig. 2).

Figure 2 clearly illustrates that during the first swarming period the mean catches of bark beetles in the undisturbed stand edge were only halves of the catches in the disturbed stand edge. In the summer swarming, however, the mean catches in the undisturbed stand edge were much higher compared to the disturbed stand edge, namely in the period when the mentioned tree felling and skidding was carried out nearby (so the beetles were not "attracted" by the stand edge primarily but by the freshly logged trees near the stand edge).

Discussion

The main purpose of the pheromone trap barrier installed in the NR Fabova hoľa was to eliminate the possible impacts of bark beetle outbreak on forest stands in the neighbourhood of the reserve. Based on the results obtained during the monitoring we can discuss two phenomena: we can assess the development of spruce bark beetle population and compare the attractiveness of different stand edges.

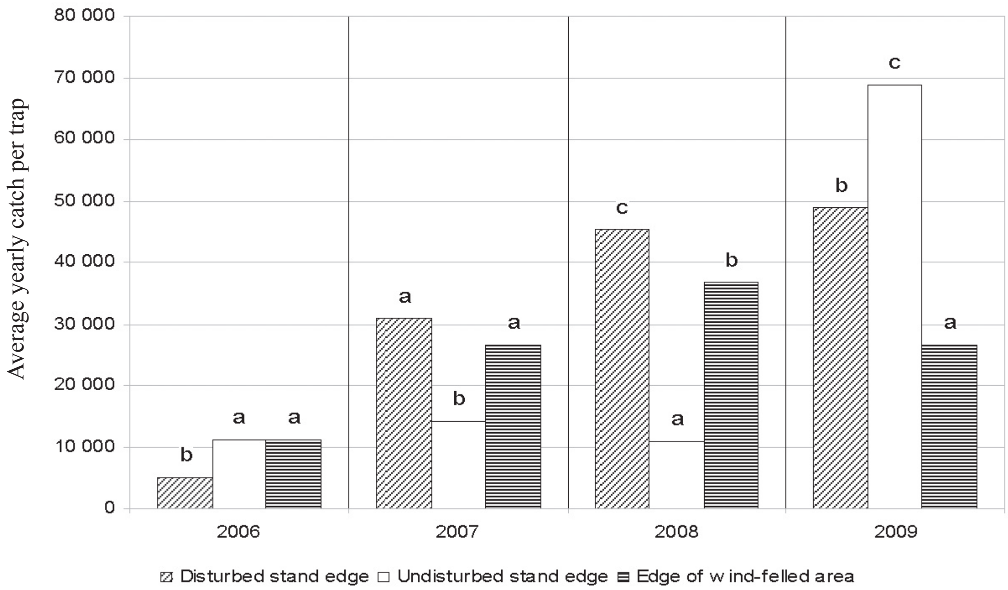

Fig. 1. Mean annual catches of spruce bark beetle per trap in years 2006–2009 and the result of Fischer LSD test.

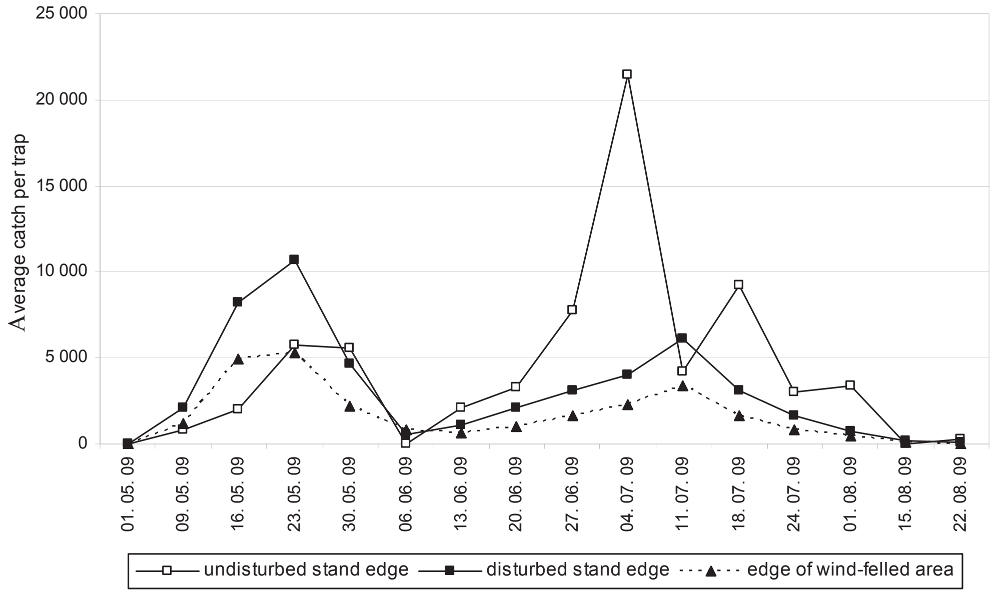

Fig. 2. Development of spruce bark beetle population in the NR Fabova hoľa in 2009 according to trap position.

Population dynamics of spruce bark beetle

A monitoring of bark beetles similar to our, was performed by Zach et al. (2009) in the National Nature Reserve Tichá dolina valley in the High Tatras National Park. The wind disturbance in the High Tatras Mts took place in the same year as the disturbance on the Fabova hoľa (2004). Fabova hoľa, however, was disturbed by wind again in 2007. The research in Tichá dolina was running with non-baited traps placed directly in stands with three different structures (heavy influenced, influenced and non-influenced); our results, on the other hand, were obtained in forest edges differing in structure, with baited pheromone traps arranged in barriers. The catches in Tichá dolina showed culmination in the third year after the disturbance (2007) followed by decreases in bark beetle catches in all the three stand types. On the other hand, the catches in Fabova hoľa culminated in 2008 – but only at the edge of wind-felled trees area. In the disturbed stand edge, a small increase in bark beetle catches was recorded even in 2009, five years after the primary disturbance. The question arises, however, to what extent can be compared spruce bark beetle catches in case of use of baited and non-baited pheromone traps. For example Niemeyer (1985) caught in non-baited traps from 3.7% to 27.9% of the amount of bark beetles caught in baited traps. The baited traps were placed only 1 m far from the non-baited ones. Another think to mention is that pheromone traps themselves can act as attractants for bark beetles. Stressed trees release primary attractants while the traps may be sources of secondary (Pheroprax) or even together primary and secondary attractants (IT-Ecolure) (Jakuš, 1998a). In such a way, there can be a synergic effect attracting more individuals of bark beetles into the barrier than either the stand wall or pheromone traps alone.

Catches of spruce bark beetle in Fabova hoľa did not differ from the catches in Tichá dolina only in time of their culmination. In Tichá dolina the most massive invasion was recorded just in 2006 but the catches in Fabova hoľa culminated one year later (2007). In Tichá dolina the catches of spruce bark beetles in partly influenced forest were conspicuously higher compared to the strongly influenced one. The differences between the edge of wind-felled trees area and the disturbed stand edge in Fabova hoľa were not such conspicuous. These differences, however, as mentioned above, could result from different monitoring methods of bark beetle (traps installed at stand edges and use of pheromone lures in case of Fabova hoľa).

Attractiveness of stand edge

As it has been just mentioned above, the first year of the spruce bark beetle population development in Fabova hoľa can be dated in 2005 in which monitoring with pheromone traps was not performed yet. But in the first two years, bark beetle individuals were invading the lying trees (documented with the data about the attacked wood volume), in the summer 2006, they started invading neighbouring forest stands. This was caused by the fact that an area covered with fallen trees and lacking standing ones provides favourable conditions for some bark beetle species in the first and the second year after the disturbance, while partially influenced (disturbed) area provides, thanks certain specific conditions, favourable substrate for longer time (Zach et al., 2009).

Considerable change took place in 2007 that means in the third year after the disturbance, with the highest number of spruce bark beetles trapped in the disturbed stand edge (Fig. 1). This could be caused by the fact that broken wind-thrown trees are attacked by bark beetles in the first year after the disturbance, while wind-thrown trees still keeping contact with soil are attacked in the second year (Jakuš, 1998b). Jakuš, on an endemic population of spruce bark beetle in the Poľana Mts observed, that damaged trees having good contact with the soil are colonised in the second year only in their upper parts, while their lower parts are invaded in the third year only. It means that in the first two years, bark beetles have sufficient feeding substrate on fallen trees, and that they attacked the disturbed wall only after they have colonised all this substrate. Another important factor influencing the colonisation of trees by spruce bark beetles is insolation, which effect is increasing in time elapsed from wind disturbance (Jakuš, 1998a, 1998b). Tree stems around area with wind-felled trees are stressed by enhanced solar irradiation, and the trees become more prone to attack from bark beetles. After die-back of all the trees in the closest neighbourhood of the area with wind-felled trees, further trees in the disturbed stand wall become suffer form insolation. This is the mechanism which underlies the highest attractiveness of disturbed stand edges for bark beetles over time.

Schroeder and Lindelöv (2002) report examples from Sweden in forest stands from which wind-thrown wood has not been removed. In these stands, most trees were dying in the 2nd and the 3rd year after the disturbance; on the other hand, practically no dieback was observed in the 1st year. The major part of dying trees was at stand edges, in years 1997 and 1998 representing 20 times more trees per one hectare in comparison with the stand interior. The observation of Zach et al. (2009), and Schroeder and Lindelöw (2002) are consistent with our observations to which one or two years after the disturbance, the most attractive forest edges for bark beetles became the disturbed stand edge.

The number of bark beetles catches to pheromone traps situated on the border of wind-felled trees area in Fabova hoľa culminated in the fourth year after the primary disturbance; while the numbers of bark beetles caught in severely influenced stands in Tichá dolina showed maxima already in the third year. This difference may have resulted from the fact that Fabova hoľa suffered an additional wind storm in 2007, resulting in additional cca 400 m^3 of trees suitable for bark beetle development. In the third year after the disturbance culminated also the bark beetle outbreak in the Alps (Wermelinger et al., 2002). A study carried out in the Nature Reserve Osaby in Sweden conducted after one wind-throw event in year 2005 (Komonen et al., 2010) showed that 10% of fallen trees were colonised in the first years after the disturbance and 64% of such trees were colonised in the second year after the disturbance. Wermelinger (2004) reports that the gradation of spruce bark beetle in low elevations or in wind-throws with broken trees, the peak of abundance of spruce bark beetle reaches in the second summer after the disturbance, in mountain conditions or areas with uprooted trees, in the third year after the disturbance. Wermelinger (2004) also notes, that bark beetle outbreak in ordinary conditions lasts between 3–6 years. The data concerning the bark beetle outbreak in the High Tatras Mts in years 1993–1998 from data of the attacked wood amount document a population drop in 1996–1997, that means about four years after the outbreak (Grodzki et al., 2006). Similar data present Schroeder and Lindelöv (2002) from Gruvskogen and Hochharz, where high tree mortality occurred even in the third year, and from Banwald Napf where it was still present in the fifth year after the disturbance. Schroeder (2001) lists in his analysis about 16 different localities with non-removed wind-thrown trees, and in five of them the tree die-back lasted longer than 3 years. High catches of bark beetles in pheromone traps in Fabova hoľa indicate the same course of the outbreak. Fabova hoľa is situated in cold mountainous climate where according to Bouget and Duelli (2004) tree die-back associated with spruce bark beetle is slower, but the outbreak itself takes more time. Moreover, another wind storm in 2007 has resulted in additional substrate suitable for bark beetle development.

In 2006, at the beginning of the monitoring, the catches in the undisturbed stand edge were similar to the catches in the edge of wind-felled trees. This was probably caused by the fact that the undisturbed stand wall could trap beetles migrating into the wind-thrown area. The catches in undisturbed stand edge were very similar over the whole period, so we suggest that the attractiveness of this stand edge for spruce bark beetle remained unchanged over the whole monitoring period. The 7-fold catch increase in the undisturbed stand edge in 2009 compared to 2008, may be due to wood felling and skidding in stands adjacent to the reserve and in the proximity of pheromone traps. Fresh logs and fresh felling residues are a source of primary attractants. Together with secondary attractants (pheromone lures in traps), they can attract higher amount of bark beetles, as reported e.g. by Austara et al. (1986).

Influence of trap barriers on bark beetle population

There are some records from the past when the use of pheromone trap barrier succeeded in drop in population of spruce bark beetles in outbreak conditions (Jakuš, 1998a; Schlyter et al., 2001). On the other hand, there have also been reported cases when application of pheromone traps had no influence on bark beetle population (Weslien, 1992). Dimitri et. al. (1992) suggest that a massive catch of bark beetles can limit their increase in their population to some extent, but the primary factors governing the population dynamics are still weather conditions and food accessibility. The catch numbers for bark beetles trapped in pheromone traps can serve as an indicator for assessment of the developmental trend for the bark beetle population in the following year (Faccoli and Stergulc, 2006). In case of Fabova hoľa it is evident that in spite of use of the pheromone traps, the catches of spruce bark beetles increased year after year but on the other hand, it is possible that the gradation rate of spruce bark beetles may have been slightly reduced thanks to these traps.

An experiment carried out by Duelli et al. (1997) showed, that one third of the local bark beetle population can be trapped in pheromone traps, and the other two thirds migrating to more remote localities. Weslien and Lindelow (1989) imply that about 80% of individuals caught belong to migrating ones; a similar figure (70%) was also given by Nemec et al. (1993). Wichmann and Ravn (2001) found out, that new spruce bark beetle infestations were formed mostly at 500 m distance from old attacked trees; that means that individuals leaving attacked trees on Fabova hoľa could migrate across the reserve and in its close neighbourhood. This may have been also the case of the border of area with wind-felled trees, showing high catch numbers even quite long after the primary disturbance. Another factor, probably affecting raising numbers of spruce bark beetle catches later, was a second wind storm; so the lower-situated traps – at the edge of the wind-throw area trapped the migrating individuals. This could result also in the fact, that the catches in 2006 in the undisturbed stand edge and in the edge of wind-felled trees area were very similar – because the lower situated undisturbed edge could trap also spruce bark beetle individuals flying to the one-year-old plot covered with wind-thrown trees.

Conclusions

1. The attractiveness of stand edges for spruce bark beetle is changing according to time elapsed from the primary disturbance.
2. In the first two years after the disturbance the most attractive are wind-felled trees offering the most suitable substrate for spruce bark beetle development.
3. When bark beetles deplete their substrate of wind-thrown trees, the most attractive is becoming the disturbed stand edge close to the windblown trees.
4. The catches of spruce bark beetles in pheromone traps can be considerably influenced by migration.

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References

Anonymus. 1997. *STN 48 2711 Ochrana lesa proti hlavným druhom podkôrneho hmyzu na ihličnatých drevinách* [Slovak Technical Standard 48 2711: Forest protection against main bark borers on needle-leaved trees].

Anonymus. 2009. *Rezervačná kniha Prírodnej rezervácie Fabova hoľa* [Documentation of Nature reserve Fabova hoľa]. Depon. in NP Muránska planina, Revúca.

Austarå, Ø., Bakke, A., Midtgaard, F. 1986. Response in Ips typographus to logging waste odours and synthetic pheromones. *J. Appl. Ent.*, 101: 194–198.

Bouget, Ch., Duelli, P. 2004. The effects of windthrow on forest insect communities. A literature review. *Biol. Conserv.*, 118: 281–299.

Dimitri, L., Gebauer, U., Lösekrug, R., Vaupel, O. 1992. Influence of mass trapping on the population dynamic and damage-effect of bark beetles. *J. appl. Ent.*, 114: 103–109.

Duelli, P., Záhradník, P., Knížek, M., Kalinová, B. 1997. Migration in spruce bark beetles (Ips typographus L.) and the efficiency of pheromone traps. *J. appl. Ent.*, 121: 297–303.

Faccoli, M., Stergulc, F. 2006. Can pheromone trapping predict Ips typographus outbreaks? An example from the Southern Alps. In Csóka, Gy., Hirka, A., Koltay, A. (eds*). Biotic damage in forests. Proceedings of the IUFRO (WP 7.03.10) Symposium, Mátrafured, Hungary, September 12–16, 2004*. Mátrafüred: Hungarian Forest Research Institute, p. 32–40.

Grodzki W., Jakuš R., Lajzová E., Sitková, Z., Maczka, T., Škvarenina, J. 2006. Effects of intensive versus no management strategies during an outbreak of the bark beetle Ips typographus (L.) (Col.: Curculionidae, Scolytinae) in the Tatra Mts. in Poland and Slovakia. *Ann. Forest Sci.,* 63: 55–61.

Jakuš, R. 1998a. A method for the protection of spruce stands against Ips typographus by the use of barriers of pheromone traps in north-eastern Slovakia. *Anz. Schädl.-Kde Pfl.- Umweltschutz* , 71: 152–158.

Jakuš, R. 1998b. Patch level variation on bark beetle attack (Col., Scolytidae) on snapped and uprooted trees in Norway spruce primeval natural forest in endemic condition: effects of host and insolation. *J. appl. Ent.,* 122: 409–421.

Jonášová, M., Prach, K. 2004. Central-European mountain spruce (Picea abies (L.) Karst.) forests: regeneration of tree species after a bark beetle outbreak. *Ecol. Engng*, 23: 15–27.

KOMONEN, A., SCHROEDER, L.M., WESLIEN, J. 2010. Ips typographus population development after a severe storm in a nature reserve in southern Sweden. *J. appl. Ent.*, 135: 132–141.
NEMEC, V., ZUMR, V., STARÝ, P. 1993. Studies on the nutritional state and the response to aggregation pheromones in the bark beetle, Ips typographus (L.) (Col., Scolytidae). *J. appl. Ent.*, 116: 358–363.
NIEMEYER, H. 1985. Field response of Ips typographus L. (Col., Scolytidae) to different trap structures and white versus black flight barriers. *Z. angew. Ent.*, 99: 44–51.
SCHLYTER, H., ZHANG, Q.-H., LIU, G.-T., JI, L.-Z. 2001. A successful case of pheromone mass trapping of the bark beetle Ips duplicatus in a forest Island, analysed by 20-year time-series data. *Integr. Pest Mgmt Rev.,* 6: 185–196.
SCHROEDER, L.M. 2001. Tree mortality by the bark beetle Ips typographus (L.) in storm-disturbed stands. *Integr. Pest Mgmt Rev*., 6: 169–175.
SCHROEDER, L.M., LINDELÖW, Å. 2002. Attacks on living spruce trees by the bark beetle Ips typographus (Col. Scolytidae) following a storm-felling: a comparison between stands with and without removal of windfelled trees. *Agric. Forest Ent.*, 4: 47–56.
WERMELINGER, B., DUELLI, P., OBRIST, M.K. 2002. Dynamics of saproxylic beetles (Coleoptera) in windthrow areas in alpine spruce forests. *For. Snow Landsc. Res*., 77: 133–148.
WERMELINGER, B. 2004. Ecology and management of the spruce bark beetle Ips typographus – a review of recent research. *Forest Ecol. Mgmt*, 202: 67–82.
WESLIEN, J., LINDELÖW, Å. 1989. Trapping a local population of spruce bark beetles Ips typographus (L.): Population size and origin of trapped beetles**.** *Ecography*, 12: 511–514.
WESLIEN, J. 1992. Effects of mass trapping on Ips typographus (L.) populations. *J. appl. Ent*., 114: 228–232.
WICHMANN, L., RAVN, H.P. 2001. The spread of Ips typographus (L.) (Coleoptera, Scolytidae) attacks following heavy windthrow in Denmark, analysed using GIS. *Forest Ecol. Mgmt*, 148: 31–39.
ZACH, P., KRŠIAK, B., KULFAN, J., CICÁK, A., KRIŠTÍN, A., VÁĽKA, J., VARGOVÁ, A. 2009. Dynamika podkôrnikovitých (Coleoptera: Scolytidae) v horskom smrekovom lese Tatier ovplyvnenom vetrovou kalamitou: lykožrút smrekový Ips typographus (L.) a lykožrút lesklý Pityogenes chalcographus (L.) [Bark beetle dynamics (Coleoptera: Scolytidae) in mountain spruce forest in Tatra mountains affected by wind disturbance: Ips typographus (L.) and Pityogenes chalcographus (L.)]. In TUŽINSKÝ, L., GREGOR, J. (eds). *Vplyv vetrovej kalamity na vývoj lesných na vývoj lesných porastoch vo vysokých Tatrách: analýza abiotických a biotických procesov a vývoja lesných porastov po vetrovej kalmite v Tatrách. Zborník recenzovaných vedeckých prác*. Zvolen: Technická univerzita, p. 165–173.
ZAHRADNÍK, P., GERÁKOVÁ, M. 2010. Jak dlouho účinkují feromonové odparníky? [How long are the pheromone lures effective?]. *Lesn. Práce*, 89: 74–75.

Populačná dynamika lykožrúta smrekového v prírodnej rezervácii v závislosti od stavu porastových okrajov

Súhrn

Populačná dynamika lykožrúta smrekového (*Ips typographus*) bola sledovaná v období rokov 2006 až 2009 v Prírodnej rezervácii Fabova hoľa v troch rôznych porastových okrajoch: v narušenej porastovej stene, nenarušenej porastovej stene a na okraji vývratiska. Monitoring bol robený pomocou feromónových lapačov na území prírodnej rezervácie. Údaje o odchytených lykožrútoch sme podrobili jednofaktorovej analýze variancie. Následne sme porovnali priemerné celoročné hodnoty odchytov lykožrútov na jeden lapač podľa pozície lapača post hoc testom (Fischerov LSD test). Rozdiely medzi odchytmi do feromónových lapačov boli v každom roku štatisticky významné.

Atraktivita porastových stien sa pre lykožrúta smrekového menila v závislosti od času od prvotnej disturbancie. Prvé dva roky po disturbancii bol najviac atraktívny okraj ležiacej hmoty, ktorá ponúkala najvhodnejší substrát pre vývoj lykožrúta smrekového. Aj naďalej však v nej stúpal počet odchytených lykožrútov, keďže prírodná rezervácia bola zasiahnutá vetrovým polomom ešte raz, čím pribudol vhodný substrát pre vývoj lykožrútov. Po ukončení vývoja lykožrútov na ležiacej hmote sa najatraktívnejšími stali vetrom narušené porastové okraje v blízkosti ležiacej hmoty. Nenarušená porastová stena si zachovala približne rovnakú atraktivitu pre lykožrúta smrekového takmer počas celého obdobia monitoringu.

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