

Effect of canopy closure of a young Norway spruce plantation on ground beetles

Z. Elek¹, T. Magura² & B. Tóthmérész³

¹Ecological Institute
Szent Istvan University
H-1077 Budapest, Rottenbiller 50
Hungary

²Directorate of the Hortobagy National Park
H-4010 Debrecen, Sumen 2
Hungary

³Ecological Institute
Debrecen University
H-4010 Debrecen
POB. 71
Hungary

Abstract

The effect of canopy closure on carabids was studied by sampling a young Norway spruce plantation for several years, and comparing it to a 15y old stand. We sampled ground beetles in the Bükk Mountains in Northern Hungary by pitfall traps. The first stand, a young Norway spruce (*Picea abies*) plantation was sampled 5, 6 and 8 years after planting. A second stand, a 15 years old forest of the same kind was sampled only in 1998. In the earliest year studied (year 5) of the plantation, there were relatively large open gaps. Shrubs of the native beech forest, grasses and common weeds were present. In years 6 and 8, the canopy started to close, spruce became dominant over shrubs and the herbs almost disappeared. *Bryum* mosses covered the soil surface in the 15-years old plantation. Habitat generalist species had rather constant abundance throughout the three-years of sampling. However, the proportion of the open habitat species decreased in the 8-years old phase, and the proportion of the forest species increased.

Key words: Open gaps, forest species, heterogeneous environment, Norway spruce

Introduction

In Hungary, planting non-native tree species was the preferred way of reforestation in the 1960s. Today, these stands constitute 45% of all Hungarian forests (Mátyás, 1996). The most often planted trees are non-native and include the black locust (*Robinia pseudo-acacia*), Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*), black pine (*Pinus nigra*), and different species of poplar (*Populus spp.*). Clear-felled deciduous forests in the hilly regions of Hungary were also replaced with non-native conifer trees, mainly Norway spruce. This species is favoured by foresters because of its high productivity and rapid growth. The reforestation after clear-cutting starts with grubbing (removal of tree trunks and roots) and deep loosening the soil. This practice drastically damages the native fauna and flora, and alters the microclimatic conditions, leading to spatial homogenization of these habitats.

One of the common forest-living arthropod groups affected are ground beetles (Coleoptera: Carabidae). Ground-dwelling carabid beetle larvae develop in the soil (Lövei & Sunderland, 1996) and are consequently sensitive to soil disturbance (Desender *et al.*, 1999; Magura *et al.*, 1997, 2001, 2002; Koivula *et al.*, 2002).

Assemblages of carabids change remarkably after reforestation. In planted, near-monoculture forests, only the habitat-generalist and forest-generalist carabid species are abundant (Szyszko, 1987; Baguette & Gérard, 1993; Niemelä *et al.*, 1993; Elek *et al.*, 2000).

The above studies have concentrated on long time scale and broad patterns, and less on the fine spatio-temporal scale. The mentioned studies concentrated on relatively long time scale, and did not pay attention to short time period (but see Koivula, 2002). We hypothesize that carabid beetles are able to perceive the fine-scale changes in the biotic and abiotic conditions of the area. These small changes may affect carabid species composition and abundance.

To study the carabids of young Norway spruce plantations, we carried out a follow-up study at stand age of 5, 6 and 8 years after clear-cutting and plantation of spruce. As a reference point, a 15-years old plantation was selected to compare the young plantation against an older one. That stand was homogenous (to the human eye), with closed canopy and few herbs or shrubs. Such forests usually have a thick layer of needle-leaf litter due to the acidic soil and slow litter decomposition (Magura *et al.*, 2002, 2003). These conditions can limit the resources, mainly the prey abundance for carabids.

We examined the following parameters of carabid assemblages. (1) The proportions of different carabid-species affinity groups in the different-aged plantations. We expected that the older stand should harbour fewer open habitat specialists and more forest species. (2) The assemblage composition may differ with respect to the overwintering strategy of the species. A high number of species overwintering as larvae would suggest suitable (stable) soil conditions for the larval development. Thus, we expected the share of the larval-

overwintering species to be higher in the older stand. (3) We also expected changes in the overall flight ability of the assemblage. The proportion of the winged species should intuitively be higher in the younger stand, as these species are often typical for early successional phases of regenerating stands (e.g. Koivula *et al.*, 2002).

Material and methods

The study was carried out in the Northern Hungarian Mountain Range, at the entrance of the Hor-valley in the Bükk National Park (48° 05' N, 20° 37' E). We selected a Norway spruce (*Picea abies*) plantation and followed the development of its carabid assemblage for three years.

(1) In 1998, the plantation was 5 years old, with an open canopy. Due to the mechanical soil preparation before planting of spruce, grasses, herbs, and other species typical for open habitats still dominated the dense herb layer, while the shrub layer was moderate.

(2) The same plantation was re-sampled in 1999. The canopy had already started to close. The herb and shrub layers did not show marked change.

(3) In 2001, this plantation was 8 years old, the herbs and shrubs had become sparse. The canopy was almost closed, and the herbs and shrubs layers were scarce. The needle litter cover was not remarkable.

(4) For comparison, a 15-years old stand with a similar origin was selected and sampled in 1998. In this stand, the herbs and shrubs were sparse, and a layer of mosses covered the soil. The ground had a thick needle litter cover.

Both plantations were established after the clear-cutting of a beech (*Fagus sylvatica*) forest. Soil preparation, grubbing and deep loosening was applied. Trees were planted in rows. The between-row distance was 2 m, and the average distance between trees was 3 m. Both stands were on a NW slope; 3 km apart from each other. Both stands were ca. 5 ha, and can thus be considered large enough to host self-supporting populations of carabids and not only immigrants from the surrounding habitats (Mader, 1984).

We used plastic pitfall traps (diameter 100 mm, volume 500 ml), partly filled with 75% ethylene glycol and a drop of detergent. The traps were covered with pieces of bark to protect them from litter and rain. In both study stands, 10 pitfall traps, in groups of 5, were placed randomly. Individual traps were 10 m apart from each other, and at least 40 m from the nearest forest edge to avoid edge effect (Murcia, 1995). Trap distance is an important factor in carabid studies. Digweed *et al.* (1995) found that the catch of traps placed less than 10 m from each another were not independent. To test for spatial independence in our trapping, we examined the similarities of the individual traps at different (10 - 90 m) distances from each other. The average similarity showed no trend with increasing distance (data not shown) and we concluded that our traps could be considered independent of each other.

Traps were checked monthly between March and November in 1998, 1999, and 2001. Carabids were transferred to 70% alcohol, and identified to species in the laboratory, using keys in Húrka (1996). Voucher specimens were deposited in the Department of Ecology, University of Debrecen, Hungary. For the numerical analysis, we pooled samples from the same stand and different months in each year. The seasonal total of a species over the whole growing season gives a good estimate of its abundance (Baars, 1979).

To study the effects of canopy closure on carabids, species were categorized according to their habitat affinity, based on Húrka (1996). We used three categories: forest, open-habitat and generalist species. Species were also categorized according to their overwintering strategy: adult or larval overwintering according to Húrka (1996) and Thiele (1977), and flight capacity (flightless, dimorphic or flying species, based on Thiele (1977)). Differences in the number of species in classes of habitat affinity, overwintering and flight ability were tested by Kruskal-Wallis non-parametric ANOVA and Tukey-type multiple comparisons. The analyses were carried out using the SPSS-PC program.

Results

A total of 1548 carabids was trapped, belonging to 38 species (Table 1). Results of the non-parametric ANOVA proved that there was a significant variation among the habitats in the number of carabid species per trap ($H= 21.500$, $d.f.= 3, 64$, $p<0.0001$; Fig. 1) and the number of individuals per trap ($H= 21.709$, $d.f.= 3, 64$, $p<0.0001$; Fig. 1). The Tukey-test showed that the number of species as well as the number of individuals (both $p<0.001$) were significantly higher at year 8 than in other plantation age.

The number of generalist species, forest species, and open habitat species proved to be significantly different among habitats (non-parametric ANOVA, generalists, $H= 6.498$, $d.f.= 3, 64$, $p<0.0001$ Fig. 2; forest sp. $H= 33.805$, $d.f.= 3, 64$, $p<0.0001$; Fig. 2; open-habitat sp. $H= 25.009$, $d.f.= 3, 64$, $p<0.0001$; Fig. 2). The number of generalist species was highest in the 6-years-old plantation (Tukey-test, $p<0.01$), the number of forest species were significantly higher in the 8-years-old plantation ($p<0.0001$), and the number of open habitat species were highest in the 5 and 6-years-old plantations ($p<0.002$).

There was a significant variation in the number of adult - overwintering species (non-parametric ANOVA, $H= 16.842$, $d.f.= 3, 64$, $p<0.0001$; Fig. 1). The number of adult overwintering species was highest in the 8-years-old plantation (Tukey-test, $p< 0.015$).

Table 1. Selected life history characteristic of the ground beetles captured in different-age. Norway spruce plantations in Northern Hungary. The species are arranged according to their habitat affinity and overwintering stage.

Species	Habitat affinity	Over-wintering stage	Flight capacity	Number of beetles trapped in forest clear-cut			
				5y ago	6y ago	8y ago	15y ago
<i>Abax carinatus</i>	forest	adult		1	0	0	0
<i>Pterostichus anthracinus</i>	forest	adult	macropterous	5	5	8	0
<i>Abax parallellus</i>	forest	adult		11	9	45	8
<i>Aptinus bombardarda</i>	forest	adult		1	13	7	0
<i>Carabus convexus</i>	forest	adult		6	2	55	3
<i>Notiphilus biguttatus</i>	forest	adult		0	2	0	0
<i>Pterostichus oblongopunctatus</i>	forest	adult		2	2	14	3
<i>Carabus nemoralis</i>	forest	adult		0	3	30	5
<i>Agonum assimile</i>	forest	adult	macropterous	0	1	0	0
<i>Carabus violaceus</i>	forest	larva		14	12	132	5
<i>Carabus coriaceus</i>	forest	larva		10	9	2	1
<i>Carabus glabratus</i>	forest	larva		12	2	103	5
<i>Carabus hortensis</i>	forest	larva		3	4	58	81
<i>Cychrus attenuatus</i>	forest	larva		0	0	0	1
<i>Cychrus caraboides</i>	forest	larva		0	1	26	0
<i>Calosoma inquisitor</i>	forest	larva	macropterous	0	0	1	0
<i>Pterostichus ovoideus</i>	generalist	adult		3	5	0	0
<i>Carabus cancellatus</i>	generalist	adult		0	0	6	0
<i>Stomis pumicatus</i>	generalist	adult		1	1	0	0
<i>Abax ater</i>	generalist	adult		34	26	187	174
<i>Molops piceus</i>	generalist	adult		34	38	17	3
<i>Harpalus marginellus</i>	generalist	larva	macropterous	1	0	0	0
<i>Platyderus rufus</i>	generalist	larva	macropterous	5	1	0	0
<i>Pterostichus niger</i>	generalist	larva	macropterous	37	41	20	23
<i>Harpalus latus</i>	generalist	larva	macropterous	4	15	0	0
<i>Pterostichus melanarius</i>	generalist	larva		13	15	22	46
<i>Metoponus punctatulus</i>	generalist	larva	macropterous	2	1	0	0
<i>Amara aenea</i>	open	adult	macropterous	1	0	0	0
<i>Amara communis</i>	open	adult	macropterous	4	7	0	0
<i>Amara curta</i>	open	adult	macropterous	0	1	0	0
<i>Amar littorea</i>	open	adult	macropterous	1	1	0	0
<i>Amara similata</i>	open	adult	macropterous	0	2	0	0
<i>Panagaeus bipustulatus</i>	open	adult	macropterous	0	2	0	0
<i>Harpalus rubripes</i>	open	larva	macropterous	0	0	1	0
<i>Harpalus rufipes</i>	open	larva	macropterous	20	4	0	1
<i>Semiophonus sigmaticornis</i>	open	larva	macropterous	1	1	0	0
<i>Synuchus nivalis</i>	open	larva	macropterous	1	1	0	0
<i>Harpalus samargdinus</i>	open	larva	macropterous	0	1	0	0
Total number of individuals				270	228	734	359

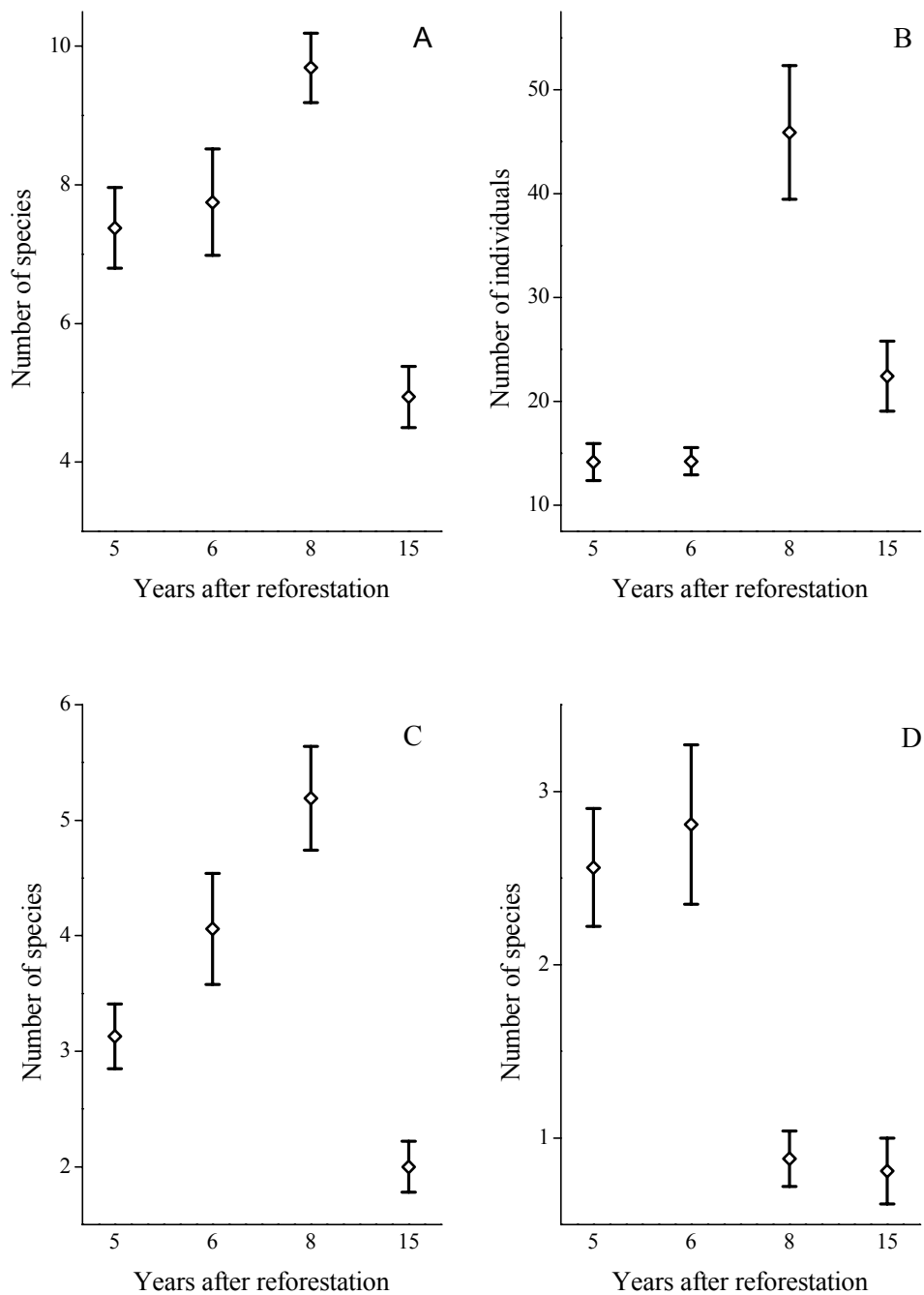


Figure 1. Comparisons of species richness per trap (A), activity density per trap (B), and selected bionomic characteristics (number of adult-overwintering species per trap – C; number of macropterous species per trap – D) among carabid assemblages in different-aged spruce plantations in Northern Hungary. Bars indicate \pm one standard error.

Examination of the flight capacity showed a significant difference among habitats (non-parametric ANOVA, $H = 23.827$, $df = 3, 64$, $p < 0.0001$; Fig. 1). The number of winged species was lowest in the 8 and 15-years-old plantations (Tukey-test, $p < 0.017$).

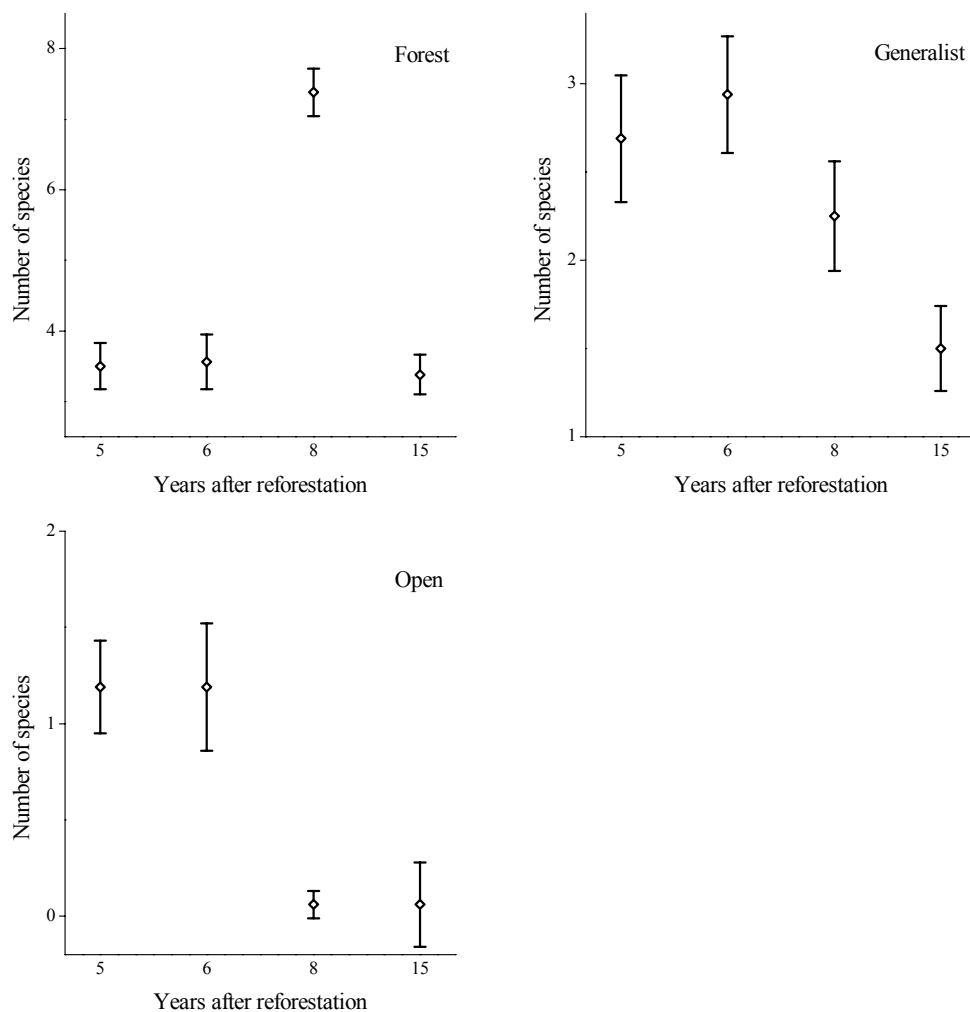


Figure 2. Average number of individuals/trap of forest specialist (“forest”), open-habitat specialists (“open”) and generalist (“generalist”) species in spruce plantations of different age in Northern Hungary. Bars indicate \pm one standard error.

Discussion

The age of the plantation seemed to affect the ground beetle assemblages via habitat structure. Not surprisingly, the 5-y old and 15-y old forests had different assemblages. The degree and nature of such a difference may be influenced by small scale geographic differences, succession, or habitat structure, or a combination of these. Young spruce plantations are patchy, containing open areas with shrubs and a dense herb layer. Open habitat species were abundant in the young plantation. As the developing canopy closes, species that prefer mature forests may appear. This seemed to happen 6-8 years after the establishment of the plantation. This recolonisation is possible because the soil pH is less acidic than under mature spruce

trees. The herb and shrub layer is, although becoming more sparse, still present, and provides more food and shelter than the bare ground in mature forest. The thinning of the herbs is the reason that the open habitat species are missing from this stand: they need larger gaps and a more dense herb layer. The deciduous forest species seek out these patches because these conditions are similar to the ones in a (native) deciduous forest, the natural habitat of these species. Due to the lack of proper replication in our study, this cannot be proven, but merits attention.

Theoretically, the fastest colonization is by flying. The high numbers of winged beetles in the 5 and 6 years old plantations, compared to the 15-years old one, can be explained by the colonization of a recently logged stand by winged species that occur in clear-cut boreal (Niemelä *et al.*, 1993; Koivula, 2002) and temperate conifer plantations (Baguette & Gérard, 1993; Butterfield, 1997). Beetles that colonize such patches of new habitat need to be good colonizers.

Previous studies have shown that in older plantations generalist species dominate (Baguette & Gérard, 1993; Butterfield, 1997; Elek *et al.*, 2000; Magura *et al.*, 2002). We found some evidence that before the complete closing of the canopy, deciduous forest species are dominant, as they were abundant in the 8 years-old plantation. Forest species thus seem to colonize older spruce plantations while herbs and shrubs are still present. The complete closure of the canopy reduces the number of herbs and shrubs, and it may consequently decrease the abundance and species richness of deciduous forest carabids. We found no evidence for larval overwinterers to be less abundant in the young stand compared to the older (15-years old) one, which would possibly have indicated that these carabids suffer from soil alteration but might recover later. However, previous studies (Thiele, 1977; Butterfield, 1997; Magura *et al.*, 2002, 2003) have emphasized that the number of ground beetles that overwinter as adult can be higher in habitats with more variable conditions, compared to stable habitats.

Acknowledgements

The authors would like to express their thanks to the Directorate of the Bukk National Park to give an opportunity to carry out this research work and to Dr. Gabor Lövei for comments which improved the manuscript.

References

- Baars MA. 1979. Catches in pitfall traps in relation to mean densities of carabid beetles. *Oecologia* 41, 25–46.

- Baguette M & Gérard S. 1993. Effects of spruce plantations on carabid beetles in southern Belgium. *Pedobiologia* 37, 129–140.
- Butterfield J. 1997. Carabid community succession during the forestry cycle in conifer plantations. *Ecography* 20, 614–625.
- Desender K, Eryvynck A & Tack G. 1999. Beetle diversity and historical ecology of woodlands in Flanders. *Belgian Journal of Zoology* 129, 139–156.
- Digweed SC, Currie CR, Cárcamo HA & Spence JR. 1995. Digging out the digging-in effect of pitfall traps: influences of depletion and disturbance on catches of ground beetles (*Coleoptera: Carabidae*). *Pedobiologia* 39, 561–576.
- Elek Z, Magura T & Tóthmérész B. 2000. Impacts of non-native spruce plantation on carabids. *Web Ecology* 2, 32-37.
- Hůrka K. 1996. Carabidae of the Czech and Slovak Republics. Kabourek, Zlín. 566 pp.
- Koivula M. 2002. Alternative harvesting methods and boreal carabid beetles (*Coleoptera, Carabidae*). *Forest Ecology and Management* 167, 103-121.
- Koivula M, Kukkonen J & Niemelä J. 2002. Boreal carabid-beetle (*Coleoptera, Carabidae*) assemblages along the clear-cut originated succession gradient. *Biodiversity and Conservation* 11, 1269–1288.
- Lövei G & Sunderland KD. 1996. Ecology and behavior of ground beetles (*Coleoptera: Carabidae*). *Annual Review of Entomology* 41, 231–256.
- Mader HJ. 1984. Animal habitat isolation by roads and agricultural fields. *Biological Conservation* 29: 81–96.
- Magura T, Ködöböcz V & Bokor Zs. 2001. Effects of forestry practices on carabids (*Coleoptera: Carabidae*) - Implication for nature management. *Acta Phytopathologica et Entomologica Hungarica* 36, 179–188.
- Magura T, Tóthmérész B & Bordán Zs. 1997. Comparison of the carabid communities of a zonal oak-hornbeam forest and pine plantations. *Acta Zoologica Academiae Scientiarum Hungariae* 43, 173–182.
- Magura T, Tóthmérész B & Elek Z. 2002. Impacts of non-native spruce reforestation on ground beetles. *European Journal of Soil Biology* 38: 291–295.
- Magura T, Tóthmérész B & Elek Z. 2003. Diversity and composition of carabids during a forestry cycle. *Biodiversity and Conservation* 12, 73-85.
- Mátyás Cs. 1996. Forestry ecology. *Mezőgazda Kiadó, Budapest*, 312 pp. (in Hungarian)
- Murcia C. 1995. Edge effects in fragmented forests: implications for conservation. *Trends in Ecology and Evolution* 10, 58-62.
- Niemelä J, Langor D & Spence JR. 1993. Effects of clear-cut harvesting on boreal ground-beetle assemblages (*Coleoptera: Carabidae*) in western Canada. *Conservation Biology* 7, 551–561.
- Szyszkó J. 1987. How can the fauna of *Carabidae* be protected in managed pine forest? *Acta Phytopathologica et Entomologica Hungarica* 22, 293–303.
- Thiele HU. 1977. *Carabid Beetles in Their Environments*. Springer, Berlin, 369 pp.