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Ground beetles (Carabidae) and edge effect in oak-hornbeam forest and grassland transects

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Abstract − We evaluated ground beetle diversity in relation to forest edge between an oak-hornbeam forest and adjacent herbaceous grassland. To test our hypothesis that the diversity of ground beetles was higher in the forest edge than the interior, pitfall trap samples were taken along two forest-grassland transects in northern Hungary. The diversity of ground beetles was significantly higher at the forest edge and in the grassland than in the forest interior. Ground beetle assemblages in the forest interior, forest edge and grassland could be separated from each other by ordination. Indicator species analysis detected five groups of species: habitat generalists, grassland-associated species, forest generalists, forest specialists, and edge-associated species. Rank correlation indicated leaf litter, herb, canopy cover, and prey abundance as the most important factors influencing carabid diversity. The high diversity of the forest edge resulted from the presence of edge-associated species and of species characteristic of adjacent habitats. Forest edges seem to play an important role in maintaining diversity. Serving as source habitats, edges also contribute to the recolonisation by ground beetles after habitat destruction or other disturbance in the adjacent habitats. © 2001 Éditions scientifiques et médicales Elsevier SAS

diversity / forest edge / ground beetles / indicator species / nature conservation

1. INTRODUCTION

Classical edge effect hypothesis states that diversity is higher in ecotones than in adjacent habitats [11]. Forest edges represent a type of ecotone, interpreted on the meso-spatial scale and the community level [4]. Habitat edges are a focus of conservation research [5], important to wildlife management and there is an increasing need for their appropriate management. This study aimed to evaluate ground beetle (*Coleoptera: Carabidae*) diversity in relation to forest edge between an oak-hornbeam forest and the adjacent herbaceous grassland. Ground beetles are suitable for such studies because they are diverse, abundant, their ecology and taxonomy is relatively well known, and they are highly sensitive to changes in habitat characteristics [6]. Our hypothesis was that the diversity of ground beetles would be higher in the forest edge than in the forest interior, as it was predicted by the 'classical' edge effect hypothesis. However, the precise mechanism generating such a higher diversity is not known.

2. MATERIAL AND METHODS

Our sampling area was located in the North Hungarian Mountain Range, NE Hungary (48°30'N, 20°31'E), that is in this region mostly covered by oak-hornbeam forest (*Querco-Carpinetum*). Three habitats, forming a transect, were studied: (1) forest interior: oak-hornbeam forest, with dense litter layer, moderate herbaceous and shrub layers. The dominant tree species were turkey oak (*Quercus petreae*) and hornbeam (*Carpinus betulus*). (2) the forest edge, characterised by a moderate cover of litter layer and a dense herbaceous vegetation originating from the nearby grassland. The shrub layer was also dense, consisting mainly of shrubs and saplings of the canopy trees (*Carpinus betulus*, *Corylus avellana*, *Prunus spinosa*, and *Quercus petreae*). (3) grassland (*Polygalo majori-Brachypodietum pinnati*): dense herbaceous

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vegetation dominated by *Brachypodium pinnatum*, *Polygala major*, *Carex montana*, *Betonica officinalis* and *Adonis vernalis*.

Two parallel lines of pitfall traps, 50 m apart, were established along the transect, with 8 unbaited pitfall traps in each of the 3 habitats; the distance between individual traps was 2 m. We emptied traps monthly from March to November 1997, i.e. during the whole snow-free period in this area. We measured five background environmental variables: the percentage cover of leaf litter, herbs, shrubs and the canopy layer was estimated within a radius of 2 m around each trap. The abundance of the potential food resources for ground beetles was obtained by counting other arthropods in the traps (the combined total of non-carabid Coleoptera, Chilopoda, Collembola, Diplopoda, Gastropoda, Isopoda, and Orthoptera).

To test for an edge effect, the Shannon diversity index per trap from the three habitats along the two transects were compared with each other. To determine differences in ground beetle diversity, Kruskal-Wallis non-parametric ANOVA and Tukey-type multiple comparisons were used. Spearman rank correlation was used to test the effect of the five environmental measurements on ground beetle diversity [12]. Principal coordinates analysis (PCA) using the Bray-Curtis dissimilarity was used to asses similarities in beetle assemblages among the traps, and the IndVal method [2] to find indicator species characteristic of the forest interior, forest edge and grassland.

3. RESULTS

The non-parametric ANOVA indicated significant variation in the beetle diversity among the habitats for both transects ($F = 6.34$, $d.f. = 2, 23$, $p = 0.007$; and $F = 24.55$, $d.f. = 2, 23$, $p < 0.0001$, respectively; *table I*). Diversity was significantly higher (Tukey-test, $p < 0.05$) in the forest edge and the grassland than in the forest interior for both transects, but not between the forest edge and the grassland (*table I*).

Rank correlation indicated that leaf litter, herb, canopy cover and prey abundance were the most important factors determining the diversity of ground beetles along the transects (*table II*).

Principal Component Analysis showed that samples from the forest interior, forest edge and the grassland were different from each other (*figure 1*). Forest habitats (forest interior and forest edge) and grassland separated along the first axis, while forest interior and forest edge separated along the second axis.

Table I. Shannon diversity (± one S.E.) of ground beetles per trap in the habitats studied. Different letters indicate significant differences ($p < 0.05$).

	Forest interior	Forest edge	Grassland
Transect 1	1.5557±0.1574^a	1.7806±0.1378^b	1.7228±0.0884^b
Transect 2	1.1972±0.1798^a	1.5696±0.1796^b	1.7745±0.1478^b

Table II. Spearman rank correlation coefficients for the relationships between the Shannon diversity of ground beetles and the five environmental variables. Statistical significance: ^{ns} – not significant, ** – $p < 0.01$ and *** – $p < 0.001$.

Background variable	Correlation coefficient
Leaf litter cover	-0.4642**
Herb cover	0.5840***
Shrub cover	-0.0329^{ns}
Canopy cover	-0.5558***
Prey abundance	0.5305***

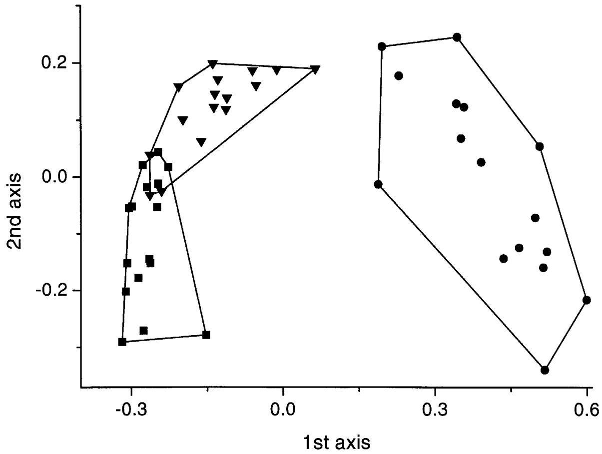

Figure 1. Ordination (PCA) of the pitfall catches by the Bray-Curtis dissimilarity. Legends: ■ – Forest interior, ▼– Forest edge, and ● – Grassland.

Five characteristic groups of species were detected by IndVal (*table III*): (1) habitat generalists, numerous in all habitat types; (2) grassland-associated species, either recorded exclusively or most abundant in the grassland; (3) forest generalists, occurring exclusively or being the most abundant in the forest habitats (forest interior and forest edge); (4) forest specialists, captured in largest numbers in the forest interior; and (5) edge-associated species, found exclusively or being the most abundant in the forest edge.

4. DISCUSSION

This study revealed a significant edge effect on ground beetles. The diversity of ground beetles was significantly higher in the forest edge and grassland than in the forest interior. There was no significant difference in the diversity of ground beetles of the grassland and the forest edge. This also emphasized the edge effect on ground beetles, because forested habitats were usually significantly less diverse than the open areas [1, 7].

Plant cover (leaf litter, herb or canopy cover) and prey abundance significantly influenced the diversity

Table III. Species indicator power for the habitats.

Species	IndVal (%)	Grassland	Forest Edge	Forest interior
Grassland				
Pterostichus melanarius (Illiger, 1798)	80.64**	66/13	1/1	0/0
Carabus violaceus Linnaeus, 1758	79.64**	79/15	25/11	3/3
Synichus vivalis (Illiger, 1798)	61.17**	23/10	1/1	0/0
Harpalus rufipes (De Geer, 1774)	54.55**	32/9	1/1	1/1
Pterostichus ovoideus (Sturm, 1824)	37.50**	11/6	0/0	0/0
Carabus montivagus Palliardi, 1825	22.22**	4/4	1/1	0/0
Calathus fuscipes (Goeze, 1777)	12.50^{ns}	2/2	0/0	0/0
Poecilus cupreus (Linnaeus, 1758)	6.25^{ns}	1/1	0/0	0/0
All habitats				
Abax parallelepipedus Piller et Mittelpacher, 1783	97.92^{ns}	63/15	229/16	313/16
Molops piceus (Panzer,1793)	81.25^{ns}	33/12	51/13	40/14
Carabus arcensis Herbst, 1784	39.58^{ns}	30/8	13/8	3/3
Carabus convexus Fabricius, 1775	33.33^{ns}	8/6	11/7	3/3
Carabus nemoralis O. F. Müller, 1764	31.25^{ns}	3/3	9/7	7/5
Abax parallelus (Duftschmid, 1812)	16.67^{ns}	3/3	1/1	6/4
Carabus intricatus Linnaeus, 1761	16.67^{ns}	2/2	4/4	2/2
Amara convexior (Stephens, 1828)	4.17^{ns}	1/1	1/1	0/0
Forest edge				
Carabus hortensis Linnaeus, 1758	74.09**	3/3	49/15	10/6
Carabus coriaceus Linnaeus, 1758	32.14**	2/2	12/6	0/0
Panagaeus bipustulatus (Fabricius, 1775)	14.06^{ns}	1/1	3/3	0/0
Amara ovata (Fabricius, 1792)	12.50^{ns}	0/0	2/2	0/0
Pterostichus niger (Schaller, 1783)	6.25^{ns}	0/0	1/1	0/0
Forest edge and Forest interior				
Pterostichus oblongopunctatus (Fabricius, 1787)	100.00**	0/0	69/16	197/16
Pterostichus burmeisteri Heer, 1841	90.80**	2/2	29/15	94/15
Forest interior				
Abax ovalis (Duftschmid, 1812)	63.16**	0/0	9/6	48/12
Aptinus bombarda (Illiger, 1800)	35.00**	1/1	1/1	8/7
Abax carinatus (Duftschmid, 1812)	20.00^{ns}	1/1	0/0	4/4

The IndVal column shows the species indicator value for the clustering level. ns – not significant; ** – $p < 0.01$. In the remaining columns, the first number indicates the number of specimens; the second is the number of traps in which the species was present.

of ground beetles along the transects (*table II*). The negative correlation between leaf litter cover and ground beetle diversity was unexpected because it is argued that deep leaf litter layer enhances ground beetle diversity through producing favorable microsites [10]. However, Guillemain et al. [3] showed that an increase in litter thickness was accompanied by a decrease in both total beetle abundance and species richness. The proportion of forest species has also increased, due to the disappearance of some ubiquitous species. At sites where litter got thicker, ubiquitous species tended to become less abundant and ultimately disappeared leaving only typical forest species in the assemblage. In the forest interior with thick litter, most habitat generalists, edge-associated species and grassland-associated species disappeared producing a decreased diversity of the assemblage.

The significant positive correlation between the diversity of ground beetles and herb cover was probably a habitat structure effect. Vegetation structure and its derived changes in microclimate are likely to be one of the most important factors determining the distribution of ground beetles [8]. Several studies emphasized that greater vegetation heterogeneity accompanied higher of ground beetle diversity [1, 9]. In the forest edge, herbs from the adjacent grassland and shrubs from the forest significantly contributed to habitat heterogeneity and generated a variety of microsites. The significant negative correlation between canopy cover and carabid diversity could be because ground beetles characteristic of grassland can colonize the forest edge if canopy closure is low and thus microclimate is more favorable for them. Abundant prey can result in an aggregation of ground beetles. This may explain the positive correlation between the diversity of ground beetles and prey abundance.

Ordination and indicator species analysis demonstrated that there were characteristic assemblages of the studied habitats (*table III* and *figure 1*). However, the different habitats were not isolated from each other and there was dispersal between them (*table III*). The high diversity of ground beetles in the forest edge may result from dispersal from the adjacent habitats. In the present study both dispersal and the presence of specific, edge-associated species (*table III*) contributed to the increased diversity of ground beetles in the forest edge. These could both be causes of the 'edge effect'. Forest edges therefore may act as source habitats for small-scale dispersal, contributing to the recovery of ground beetle assemblages in their adjacent habitats after those suffered disturbance/destruction such as burning, ploughing, grazing, or tree felling. Forest edges seem to have a remarkable potential to enhance succession and the regeneration of adjacent disturbed habitats.

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