Species richness of carabids along a forested urban-rural gradient in eastern Hungary

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Abstract

As part of the international Globenet project, effects of urbanisation on carabid species richness were studied along an urban-suburban-rural gradient representing decreasing intensities of human disturbance in an oak forest in eastern Hungary. Carabid beetles were collected using pitfall traps from four urban, four suburban and four rural sites during the growing season in lowland oak forest patches in 2002. Increased urbanisation had no significant effect on the overall carabid species richness. These results did not support the hypothesis that overall diversity should decrease in disturbed habitats (urban area). They also contradicted the intermediate disturbance hypothesis, as species richness was not the highest in the moderately disturbed suburban sites. However, the habitat specialist decrease hypothesis was supported, as species richness of the forest-specialist species increased from the more disturbed urban area to the less disturbed rural one. Multivariate methods also confirmed that species composition changed remarkably along the urban-rural gradient.

Key words: Increased disturbance hypothesis, intermediate disturbance hypothesis, urbanisation, human disturbance

Introduction

Anthropogenic modification of landscapes linked with a city (i.e. urbanisation) has important direct and indirect influences on the biosphere. Urban ecosystems are characterised by high-density human habitation and only remnants of natural habitats (McIntyre *et al*., 2001). To ensure that urban areas are managed both for the well-being of city-dwellers and urban nature, knowledge of ecosystem responses to the influence of urbanisation is needed (McDonnell & Pickett, 1990). Central among these considerations is the maintenance of biodiversity, which is an important indicator of the functional state of ecosystems (Naeem *et al*., 1994). Despite their global ubiquity, relatively little is known about how arthropods respond to urbanisation (Bolger *et al*., 2000; McIntyre *et al*., 2001), even though urbanisation is regarded as one of the leading causes of decline in arthropod diversity (Pyle *et al*., 1981). A way to estimate the anthropogenic effects (urbanisation) on nature is to study ecosystem structure and function along urban-rural gradients (McDonnell & Pickett, 1990).

In 1998, an international research framework to assess and compare the influence of urbanisation on biodiversity was initiated (Niemelä *et al*., 2000). This project applies the urban-rural gradient approach using a common methodology and a common invertebrate taxon (carabid beetles). Carabids were selected since they were sufficiently varied both taxonomically and ecologically, abundant and sensitive to human disturbances (Lövei & Sunderland, 1996).

Several hypotheses try to explain the effects of disturbance (like urbanisation) on biotic communities. The intermediate disturbance hypothesis (1) predicts an increase in diversity at intermediate levels of disturbance (Connell, 1978). This implicitly involves the increasing disturbance hypothesis (2), that states that species richness should decrease with higher levels of disturbance (Gray, 1989). Disturbance affects primarily the habitat specialists. We hypothesised that in our particular situation, the species richness of forest specialists should decrease from the rural area to the urban area (habitat specialist decrease hypothesis - 3).

In this paper, we tested the following predictions for carabids along a forested urban-rural gradient: (1) diversity should be highest in the suburban area according to the intermediate disturbance hypothesis, (2) diversity should decrease from high in the rural area to low in the urban area (increasing disturbance hypothesis), and (3) the species richness of the forest-specialist species should decrease from the less disturbed rural area to the more disturbed urban area (habitat specialist decrease hypothesis).

Material and methods

Study area and methods

Carabid beetles were studied along an urban-suburban-rural gradient in Debrecen (Eastern-Hungary), the second largest city of the country (Fig. 1). The urban, suburban and rural sampling areas were located in a continuous primeval forest (Nagyerdő Forest Reserve) bordering the city. All areas were situated in continuous patches of old forest (>100 yr) dominated by English oak (*Quercus robur*) and covering an area of at least 6 ha. The typical, native forest association of the sampling sites was *Convallario-Quercetum*. The criteria for distinguishing urban, suburban and rural area was the ratio of the built-up area to the natural habitats. In the urban area the built-up area exceeded 60%, in the suburban area it was approximately 30%, while in the rural area the built-up area was 0%. The area of the built-up environment and the natural habitats was measured by the ArcView GIS program using an aerial photograph. Distance between the sampling areas (urban, suburban, rural) was at least 1 km. In the urban area, several paths with asphalt surfaces had been created and the shrub layer was strongly thinned resulting in a park character, while in the suburban area the fallen trees were removed. The urban-rural gradient covered a distance of approximately 6 km.

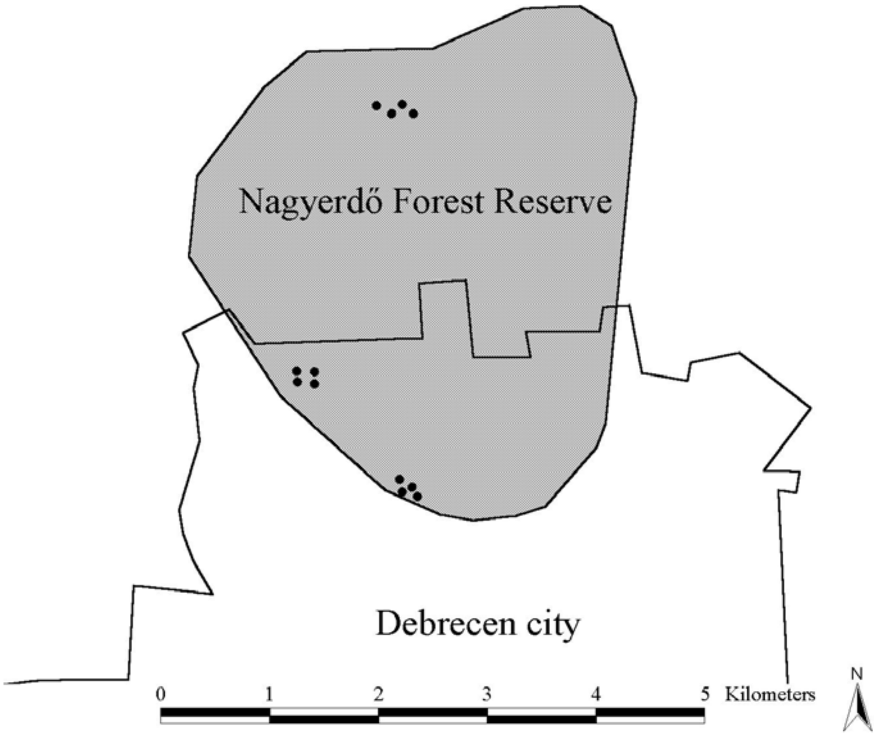

Figure 1. Map of the study area. Filled circles indicate sampling sites.

Four sites, at least 50 m from each other, were selected within each sampling area. Carabid beetles were collected at each of the 4 sites of the 3 sampling areas using pitfall traps. Ten traps were placed randomly at least 10 m apart at each site. This resulted in a total of 120 traps scattered along the urban-rural gradient (3 area × 4 sites × 10 traps). Each pitfall trap was at least 50 m from the nearest forest edge, in order to avoid edge effects (Molnár *et al*., 2001). The pitfall traps were unbaited, consisting of plastic cups (diameter 65 mm) containing about 200 ml of 75% ethylene glycol as a killing-preserving solution. The traps were covered with bark pieces to protect them from litter and rain. Trapped beetles were collected fortnightly from the end of March to the end of November, 2002. For the numerical analyses we pooled samples from the whole season.

Data analyses

To test differences in overall carabid species richness among the three sampling areas (urban, suburban and rural), and among the 12 sites, nested analyses of variance (ANOVA) were performed using data from the individual traps (sites nested within the sampling areas). Forest specialist species were identified from the literature (Hůrka, 1996). Differences in the species richness of forest specialist carabids were also tested by nested ANOVA. The distribution of data used in the ANOVA model was normal (tested by the Kolmogorov-Smirnov test, Sokal & Rohlf, 1995). When ANOVA revealed a significant difference between the means, an LSD (least significant difference) test was performed for multiple comparison among means.

The composition of the carabid assemblages along the studied urban-rural gradient was compared at site level by cluster analysis, using the Hellinger index of dissimilarity and the Ward fusion algorithm (Gordon, 1981).

Results

The total carabid catch consisted of 2281 individuals representing 46 species. Four hundred and sixty-seven individuals belonging to 38 species were collected in the urban area, 27 species and 569 individuals in the suburban area, and 28 species and 1245 individuals in the rural area. Overall, *Pterostichus oblongopunctatus* (F.) was the most abundant species, making up 45.15% of the total catch, followed by *Carabus violaceus* L. (8.11%).

The overall species richness did not change significantly along the gradient (Table 1), while the species richness of forest specialist carabids increased significantly from the urban to the rural area (Fig. 2).

There was a marked separation among the sites along the urban-rural gradient. The four urban sites separated into a distinct cluster based on the species composition, while the suburban and rural sites formed the other cluster (Fig. 3).

Table 1. Nested ANOVA showing differences in overall species richness and species richness of forest specialists along the urban-suburban-rural gradient and between the twelve sites. ns = not significant.

	Source of variation	d.f.	MS	F	p
Overall species richness	Gradient	2	23.73	3.59	ns
	Sites	9	6.62	1.30	ns
	Error	108	5.08		
Species richness of forest specialists	Gradient	2	23.73	67.79	<0.001
	Sites	9	0.35	0.82	ns
	Error	108	0.43		

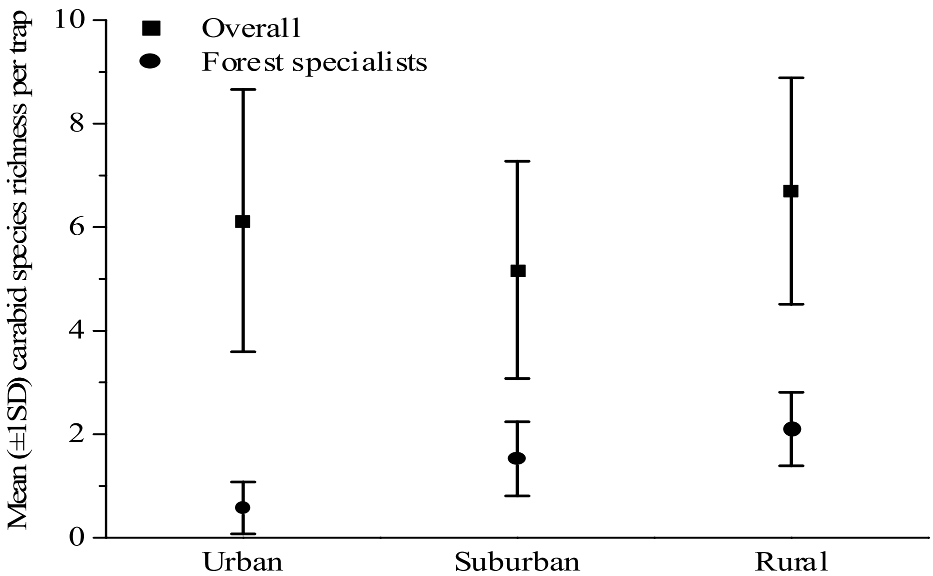

Figure 2. Overall carabid species richness and the species richness of forest specialist carabids along the urban-suburban-rural gradient. The nested ANOVA indicates no significant differences in the overall species richness along the urban-rural gradient. The nested ANOVA indicates significant differences in the species richness of forest specialist carabids along the urban-rural gradient, furthermore subsequent post-hoc comparisons test (LSD test) revealed that the urban area was significantly different from the suburban and rural area and that the suburban area was significantly different from the rural area.

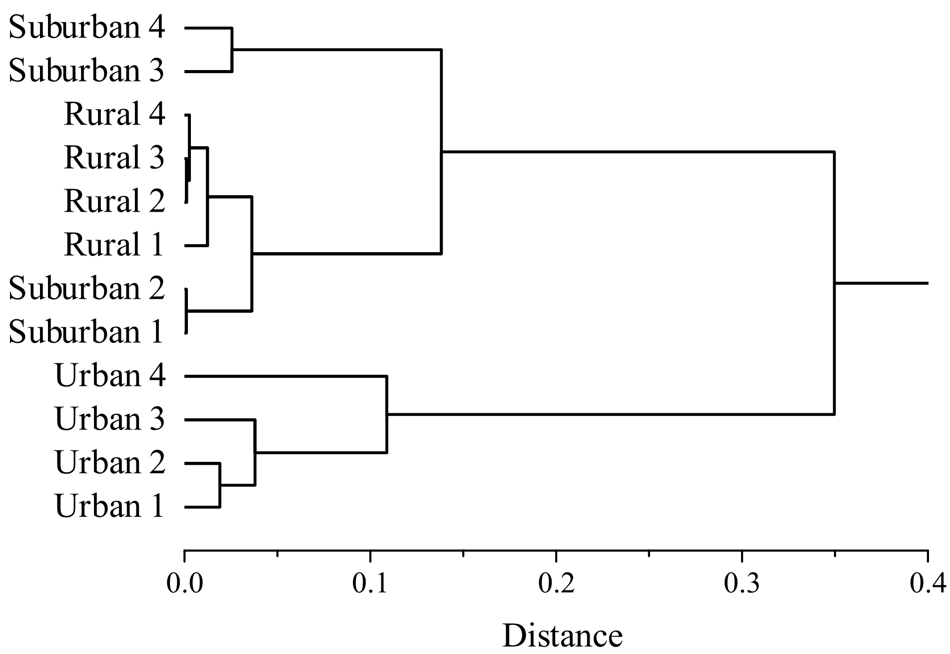

Figure 3. Cluster analysis dendrogram (using the Hellinger index of dissimilarity and the Ward fusion algorithm) showing differences in carabid assemblage structure along the studied urban-rural gradient.

Discussion

Responses of carabids to urbanisation

The findings of earlier studies performed as part of the Globenet project (Alaruikka *et al.,* 2002; Niemelä *et al*., 2002; Ishitani *et al*., 2003; Venn *et al*., 2003; Magura *et al*., in press) and those of the present study, contradict the Intermediate Disturbance Hypothesis (1; IDH; Connell, 1978). The overall species richness was not the highest in the moderately disturbed suburban areas as IDH predicts. IDH is a general framework considering different kinds of disturbance without precise, verifiable details regarding the ecological mechanisms of the changes in species richness. The increase of species richness may be ecologically important when only the species pool of the local, characteristic habitat type (i.e. native fauna) is involved. However, invasion by species from other habitat types or by generalist, opportunistic species would also increases species richness. The increase resulting from the presence of these species could offset the disappearance of habitat specialists.

Gray (1989) hypothesised that in disturbed habitats, overall diversity should decrease. Our results did not confirm this hypothesis (2). The overall species richness of carabids was almost as high in the urban area as in the rural one. Overall carabid species richness increased significantly with decreasing urbanisation in Canada (Niemelä *et al*., 2002), in Finland (Niemelä *et al.,* 2002; Venn *et al*., 2003) and in Japan (Ishitani *et al*., 2003). The pattern of overall species richness of carabids in Bulgaria was the same as that in our study (Niemelä *et al.,* 2002). Changes of overall species richness along the forested disturbance gradient (urban-rural gradient) can be complex, because individual species, depending on their habitat preferences, may respond differently to disturbance. Species richness of forest specialist species may decrease, while that of generalist and/or open-habitat species may increase as disturbance increases. Basic ecological relationships (such as the effects of urbanisation on carabids in this context) can be masked if one does not take into account the ecological characteristics of the species studied. This complexity may be the reason, why in Helsinki Niemelä *et al.* (2002) and Venn *et al.* (2003) found that overall carabid species richness increased significantly with decreasing urbanisation, while in another year Alaruikka *et al.* (2002) did not find any significant changes.

The habitat specialist decrease hypothesis (3) was confirmed: the number of forest specialist species significantly increased from the urban to the rural area. These results indicate that human impacts caused a pronounced change in the carabid assemblages. Forest species require microsites with a particular kind of environmental heterogeneity, such as favourable microclimate, the presence of dead and decaying trees, significant cover of leaf litter, shrubs and herbs, together forming the undisturbed, forest habitat (Desender *et al*., 1999). Changes caused by urbanisation eliminate such favourable microsites, thus altering the original habitats (Magura *et al*., in press). These disturbances affect the species most closely adapted to the original environment, the forest specialists. The degree of disturbance is higher in the urban area (paved paths, thinned shrub layer), than in the suburban (fallen trees removed), and lowest in the rural area. The changes in species richness of forest carabids closely followed this trend.

Preservation of biodiversity in the urban landscape

Our results showed that urbanisation had an effect on carabid assemblages. Species richness of forest specialist, as well as community composition, changed along the urban-suburban-rural gradient. Urban green areas, including the studied forested areas, improve the quality of urban life and thus should be conserved. But how can the biodiversity preservation function of urban parks be enhanced? We suggest that extensive alteration of habitat structure (e.g. by strong thinning and the removal of decaying wood material) and creating too many asphalt-covered paths should be avoided. Change in habitat structure causes changes to the microclimatic, abiotic and biotic conditions of the area. All these changes affect forest specialist carabids directly. Creating too many paths with asphalt surfaces also influences carabid beetles indirectly by fragmentation. Forest patches divided by asphalt-covered paths can be considered isolated from each other, as carabids usually do not cross such roads (Mader *et al*., 1990). The division of the original forests into smaller, isolated patches results in loss of forest specialist species through reduction in habitat area, an increase in remnant isolation and a decrease in habitat connectivity (Didham *et al*., 1996). Several studies emphasised that the number of carabid species decreased with the decreasing area of the forest patch (Davies & Margules, 1998; Magura *et al*., 2001). The population size of forest specialist carabid species in isolated patches could decrease because the patches are too small to maintain viable populations and because there is too little dispersal between patches. Small populations of forest specialist carabids in isolated patches are at greater risk of local extinction through stochastic population fluctuations than are the larger populations (Den Boer, 1985). Judicious habitat management can both serve the demand of city-dwellers for recreation and the maintenance of biodiversity.

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