Changes of ground beetle and isopod assemblages along an urbanisation gradient in Hungary

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Magura, T., Hornung, E. & Tóthmérész, B.: Changes of ground beetle and isopod assemblages along an urbanisation gradient in Hungary.
Contributions to Soil Zoology in Central Europe III. Tajovský, K., Schlaghamerský, J. & Pižl, V. (eds.): 97-101. ISB BC AS CR, v.v.i., České Budějovice, 2009. ISBN 978-80-86525-13-6

We investigated the effects of urbanisation on ground beetles (Coleoptera: Carabidae) and terrestrial isopods (Isopoda: Oniscidea) along an urban-suburban-rural gradient representing decreasing human alteration, as part of the international GLOBENET project. Ground beetles and isopods were collected by pitfall traps during their activity period in lowland oak forest patches in and around the city of Debrecen, Eastern Hungary. Overall species richness of the ground beetles was significantly higher in the rural and urban areas compared to the suburban area. We found no significant differences in the overall species richness of isopods along the gradient. These results did not support either the increased disturbance hypothesis (overall diversity decreases at higher levels of alteration/disturbance), or the intermediate disturbance hypothesis (diversity increases at intermediate levels of alteration/disturbance). The species richness of forest specialist ground beetles significantly increased along the urban-rural gradient. Species richness of forest specialist isopods was significantly higher in suburban and rural areas compared to the urban area. These results support the prediction of the habitat specialist hypothesis according to which diversity of forest specialist species increases along a gradient from area of high modification (urban) to area of low alteration (rural). To conclude, we found a significant effect of urbanisation on the composition of studied invertebrate assemblages. Moreover, our findings showed that overall diversity is not the most appropriate indicator of disturbance. Therefore, species with different habitat affinity should be analysed separately to evaluate the real effect of urbanisation.

Keywords: GLOBENET, Habitat specialist hypothesis, Increased disturbance hypothesis, Intermediate disturbance hypothesis, Species richness.

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Introduction

Urbanisation cause significant changes to environments and creates patchworks of modified land types exhibiting similar patterns throughout the world. Urbanisation is accelerating: 3.3 billion people around the world (49 % of the human population) live in cities (United Nations, 2008). Urbanisation involves profound modification of environmental conditions (McDonnell et al., 1997). Changes of environmental conditions result in a densely populated, built-up and often highly altered urban area (city centre) that is surrounded by areas of decreasing development and habitation with moderate (suburban area) or light alteration (rural area) levels. The highly affected city centre frequently maintains patches of natural habitats but these are usually more affected, managed, and fragmented than their suburban and rural counterparts. Such urban-rural gradients representing diminishing intensities of human influence are characteristic of many cities around the world. Despite the prevalence and acceleration of urbanisation and the fact that urbanisation is considered one of the primary causes for the loss of biodiversity (McKinney, 2002), little is known about whether or not changes caused by urbanisation affect biodiversity in similar ways across the globe (Niemelä et al., 2002).

Recently, an international research project called GLOBENET (Global Network for Monitoring Landscape Change) was set up to assess and compare the impact of urbanisation on biodiversity (Niemelä et al., 2002). This project applies the urban-suburban-rural gradient approach using a common, standardised methodology (pitfall trapping) to evaluate the responses of common invertebrates to urbanisation. Up to now, the majority of papers produced by the GLOBENET project have investigated ground beetles (Niemelä et al., 2002; Ishitani et al., 2003; Magura et al., 2004; Sadler et al., 2006; Elek and Lövei, 2007). Studies analysing

Presented at the 9th Central European Workshop on Soil Zoology, České Budějovice, April 17-20, 2007

other target invertebrates are limited (for spiders: Alaruikka et al., 2002; Horváth et al., 2008; for isopods: Hornung et al., 2007; Vilisics et al., 2007; Magura et al., 2008). However, without additional studies investigating other reliable indicator taxa along the alteration gradient, we can not answer whether urbanisation influences epigeic invertebrates in a similar manner across the world.

Urbanisation is usually considered to be a form of environmental disturbance (Rebele, 1994). There are several hypotheses to explain the effects of modification/disturbance on biotic communities. The first, and most widely known, is the intermediate disturbance hypothesis (Connell, 1978) which predicts the highest level of diversity at intermediate levels of modification/disturbance. As an alternative, the increasing disturbance hypothesis suggests that species richness decreases with the increasing level of modification/disturbance (Gray, 1989). As increasing disturbance affects primarily the specialist species, the habitat specialist hypothesis predicts that diversity of habitat specialist species should decrease as the level of modification/disturbance increases (Magura et al., 2004).

The aim of the present study was to investigate the effects of urbanisation on ground beetle and terrestrial isopod assemblages along an urban-rural gradient, and, in particular, to test the following predictions: (1) diversity should be highest in the moderately altered suburban area (intermediate disturbance hypothesis); (2) diversity should decrease from a high value in the lightly modified rural area to a low one in the heavily altered urban area (increasing disturbance hypothesis); (3) species richness of the habitat specialist species should increase from the more altered urban area to the less modified rural one (habitat specialist hypothesis).

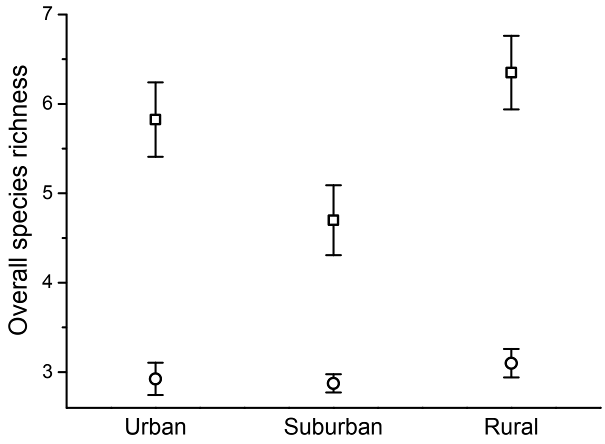

Fig. 1. Average values (± SE) of the overall species richness of ground beetles and isopods along the urban-suburban-rural gradient calculated for the pitfall traps. Notations: square – ground beetles, circle - isopods.

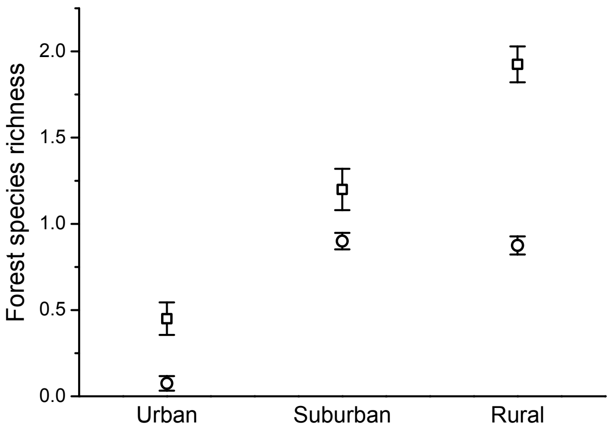

Fig. 2. Average values (± SE) of the species richness of habitat specialist ground beetles and isopods along the urban-suburban-rural gradient calculated for the pitfall traps. Notations: square – ground beetles, circle - isopods.

Material and methods

According to the GLOBENET project protocol three forested sampling areas were selected along an urban-suburban-rural gradient within the boundaries of Debrecen city (Eastern Hungary; 204,297 inhabitants in 2005), and in the surrounding forest reserve (Nagyerdő Forest Reserve). In all sampling areas old forest stands (Convallario-Quercetum forest association; >100 yrs) dominated by English oak (*Quercus robur*) were studied. All stands covered an area of at least 6 ha. Sample areas (urban, suburban and rural) were identified based on the ratio of built-up area to natural habitats measured by the ArcView GIS program using an aerial photograph in a square of 1 km^2 size around the sampling area. Buildings, roads and asphalt covered paths were regarded as built-up area. In the urban area the built-up part exceeded 60 %, in the suburban area it was approximately 30 %, while in the rural one there was no built-up area. The forest patches in the urban area belong to an urban park with several asphalt covered paths and the shrub layer was heavily thinned. In the suburban area fallen trees were removed, while in the rural area forest management was minimal. Distances between the sampling areas (urban, suburban, rural) were at least 1 km. Four sites were selected within each sampling area. Ground beetles (Coleoptera: Carabidae) and terrestrial isopods (Isopoda: Oniscidea) were collected at each of the 4 sites of the 3 sampling areas using unbaited pitfall traps, consisting of plastic cups (diameter 65 mm, volume 250 ml) containing 75% ethylene glycol as a killing-preserving solution. Ten traps were randomly placing at least 10 m apart from each other at each site. This resulted in a total of 120 traps scattered along the urban-rural gradient (3 area × 4 sites × 10 traps). Pitfall traps were checked fortnightly from the end of March to the end of November, 2001. During the analysis, samples of the individual traps were pooled for the whole trapping period.

To test differences in the overall species richness of ground beetles and isopods and in the species richness of habitat specialist ground beetle and isopod species 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). Based on the literature, forest specialist species were regarded as habitat specialist species (Hůrka, 1996; Gruner, 1966). The data were normalized using a log(*x*+1) transformation (Sokal and Rohlf, 1995). When ANOVA revealed a significant difference between the means, a Tukey test was performed for multiple comparisons among means. The composition of the ground beetle and isopod assemblages along the urban-rural gradient was compared at site level by multidimensional scaling (MDS) using the Matusita index of similarity (Legendre and Legendre, 1998).

Results

Overall, 2140 individuals belonging to 50 ground beetle species were collected. In the urban area 477 individuals, belonging to 43 species were captured, 457 specimens of 26 species in the suburban area, and 25 species and 1,206 individuals in the rural area. *Pterostichus oblongopunctatus* (Fabricius, 1787) was the most abundant species, which made up 49 % of the total catch. The total isopod catch consisted of 9,115 individuals representing 6 species. 3,548 individuals belonging to 6 species were captured in the urban, 5 species and 2,720 individuals in the suburban, and 4 species and 2,847 individuals in the rural area. The most numerous species was *Armadillidium vulgare* (Latreille, 1804), which made up 72 % of the total catch.

Overall species richness of the ground beetles was significantly higher in the rural and urban areas compared to the suburban one, while there were no significant differences in the overall species richness of isopods along the gradient by nested ANOVA (Fig. 1). These results did not support either the increased disturbance hypothesis, or the intermediate disturbance hypothesis. Species richness of the forest specialist ground beetles significantly increased along the urban-rural gradient, while the species richness of the forest specialist isopods were significantly higher in the suburban and rural areas compared to the urban one (Fig. 2). These support the habitat specialist hypothesis.

There was a marked separation among the sites along the urban-rural gradient for both the ground beetles and isopods. The urban, suburban and rural sites separated into three distinct groups (Fig. 3).

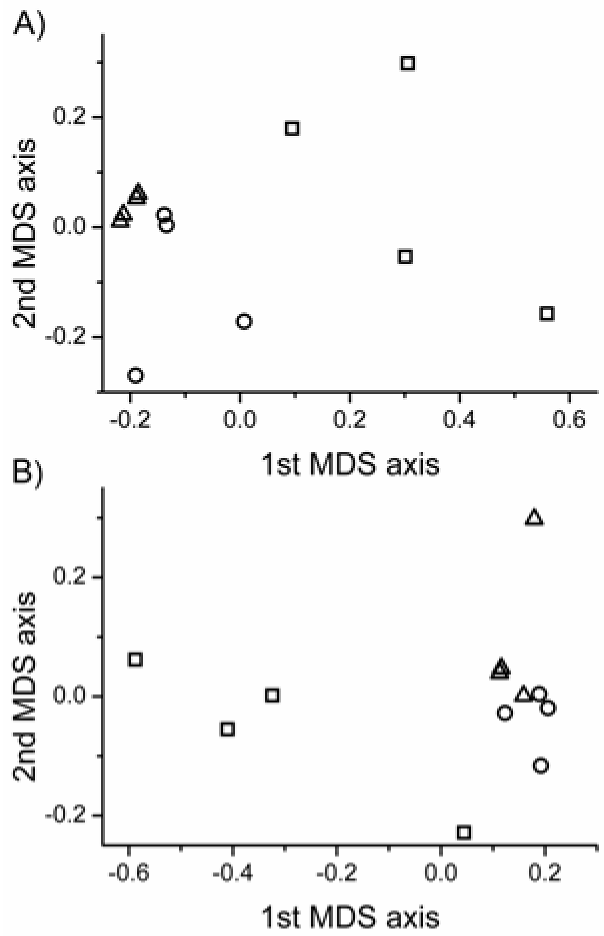

Fig. 3. Ordination of the ground beetle (A) and isopod (B) assemblages along the urban-rural gradient by multidimensional scaling (MDS) using the Matusita index of similarity calculated for the sites. Notations: square - urban, circle - suburban, triangle - rural.

Discussion

Our findings did not support the intermediate disturbance hypothesis, as the overall species richness of both the ground beetles and the isopods was not highest in the moderately modified suburban area. The explanation of this phenomenon might be that the impact of alteration/disturbance on biodiversity can be complex and the diversity-disturbance curves, deviating from a hump-shaped curve, may be bimodal, with a diversity peak at low alteration/disturbance and a second diversity peak at higher intensities (Johst and Huth, 2005). Other obvious reasons for failure of the intermediate disturbance hypothesis may be due to difficulties encountered when quantifying the type, frequency and size of disturbance events along urban-suburban-rural gradients. Therefore it is hard to arrange precisely the study areas along a disturbance continuum. Moreover, the intermediate disturbance hypothesis seems to be more appropriate when applied to the responses of non-equilibrium systems to natural disturbance processes (like fires, floods, storms etc.).

Our results did not support the increasing disturbance hypothesis as the overall species richness of ground beetles and isopods was almost as high in the heavily altered urban area as in the lightly modified rural one. One possible reason for this may be that invertebrates with a particular habitat affinity respond differently to alteration/disturbance: particular groups of species may suffer (e.g. habitat specialists), while others may benefit (e.g. generalists and/or invaders) from the disturbance and habitat alteration caused by urbanisation. For this reason, it is likely that overall diversity is not the most appropriate indicator for disturbance. Therefore, species with different habitat affinity should be analysed separately to evaluate the real effect of urbanisation.

In accordance with the habitat specialist hypothesis, species richness of the forest specialist ground beetles and isopods increased linearly (in case of ground beetles) or asymptotically (as regards isopods) along the urban-rural gradient. Habitat specialist species (forest specialist species here) require microsites with a particular set of environmental factors, such as favourable microclimate, presence of dead and decaying trees, and significant cover of leaf litter, shrubs and herbs, together forming an undisturbed forest habitat (Desender et al., 1999; Hornung et al., 2007). Habitat alteration caused by urbanisation appears to eliminate favourable microsites for specialist species and contributes to the decline of specialist species' richness in the assemblage. Along the studied gradient, alteration was highest in the urban area (paved paths, thinned shrub layer), moderate in the suburban area (fallen trees removed), and lowest in the rural area.

The multivariate analysis in this study showed that urban sites differed from the suburban and rural sites. This result also emphasised that urbanisation caused a pronounced change of ground beetle and terrestrial isopod assemblages. The appearance of species adapted to modified urban habitats (synanthropic species) and species from the surrounding matrix may cause the different species composition of urban sites.

In conclusion, this study showed that habitat modification caused by urbanisation significantly altered the ground beetle and terrestrial isopod assemblages able to survive in the area. Urban parks and other urban green areas within cities have a vital recreational importance and increase the quality of urban life. Therefore, there is a growing need for appropriate management strategies which consider simultaneously recreational, economic and conservation criteria. A wide-scale monitoring system also may support this process (Lengyel et al., 2008). We propose that extensive modification of habitats should be avoided, as these alterations lead to unfavourable changes in the microclimatic, abiotic and biotic conditions of the area.

Acknowledgements

Research was supported by the grants of the Hungarian Scientific Research Fund (OTKA research grant nos. F61651 and T043508) and by the Bolyai Research Fellow grant of the Hungarian Academy of Sciences (to T. M.). We wish to express our thanks to Tivadar Molnár, Ferenc Vilisics, Viktor Ködöböcz and Zoltán Elek for their help in field and laboratory works. We thank Deborah Procter (JNCC, Peterborough, UK) for comments on the manuscript.

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