Abundance patterns of terrestrial isopods along an urbanization gradient

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Abstract: The abundance of terrestrial isopods (Isopoda: Oniscidea) was evaluated along an urban-suburban-rural gradient. We tested two hypotheses regarding the response of species: (i) habitat specialist hypothesis, according to which the abundance of the forest specialists would increase, while the abundance of the urban environment specialist isopods would decrease along the urban-rural gradient, and (ii) opportunistic species hypothesis (abundance of the generalist species would increase by increasing level of urbanization). The abundance of the forest specialist isopod *Trachelipus ratzeburgii* increased significantly along the studied gradient. An opposite tendency was observed for the abundance of the urban environment specialist isopod *Porcellio scaber*, as it was significantly higher in the urban area than in the suburban and rural sites. One generalist species (*Trachelipus rathkii)* gained dominance in the urban area, while other two generalists (*Armadillidium vulgare* and *Porcellium collicola*) showed no significant changes in abundance along the gradient.

Nomenclature for isopods: Schmalfuss (2003).

Introduction

Urbanization as a main form of anthropogenic activities is an increasingly important force shaping the landscape by creating patchworks of modified land types. Urbanization associated with changes in the temperature (Hawkins et al. 2004), pollution (Conti et al. 2004) and the area and the quality of natural habitat (Bolger et al. 2000, McIntyre et al. 2001, Gibb and Hochuli 2002) results in a densely populated, built-up, developed and often highly disturbed urban area (city centre) which is surrounded by areas of decreasing development and habitation with moderate (suburban area) or light disturbance (rural area) level (Dickinson 1996). Such urban-rural gradients representing decreasing intensity of human influence exhibit similar patterns throughout the world. Despite the prevalence and acceleration of urbanization and that urbanization is considered as one of the primary causes for biodiversity loss, little is known on whether or not changes caused by urbanization affect biodiversity in similar way across the globe (Niemelä et al. 2000).

In 1998, an international research project, the "Globenet" project (Global Network for Monitoring Landscape Change), to search for generalizations in urbanization impacts on biodiversity was initiated (Niemelä and Kotze 2000, Niemelä et al. 2000). As the effects of urbanization on biodiversity can be explored most effectively through investigations along urban-to-rural gradients (McDonnell et al. 1997), the Globenet project also employs this gradient approach. During field survey, the Globenet project uses a common, standardized methodology (pitfall trapping) for ground dwelling arthropods (like carabid beetles, spiders and terrestrial isopods). In the frame of the Globenet project, several papers investigating carabid assemblages were published (Alaruikka et al. 2002, Niemelä et al. 2002, Ishitani et al. 2003, Venn et al. 2003, Magura et al. 2004, 2005, 2006, 2008, Gaublomme et al. 2005, Tóthmérész and Magura 2005, Sadler et al. 2006, Elek and Lövei 2007). Studies analyzing other target arthropod assemblages along the urbanization gradient are very limited (for spiders: Alaruikka et al. 2002). Terrestrial isopods (Isopoda: Oniscidea) are considered reliable biological indicator organisms of environmental stress both at the assemblage and species level (Dallinger et al. 1992, Jones and Hopkin 1998, Paoletti and Hassall 1999). Therefore, terrestrial isopods are potential targets for studying the effect of urbanization. Traditionally, urbanization is considered as a form of disturbance (Rebele 1994). Several hypotheses were put forward to explain the effects of disturbance on biotic communities. Species with different ecological characteristics may respond differently to urbanization (Magura et al. 2004): forest specialist species may suffer, while species associated with the altered urban habitat may benefit from the disturbance and habitat alteration caused by urbanization. Therefore, analyzing the overall species abundance along the gradient may be misleading and may disguise basic ecological rules (Magura et al. 2004). In an earlier paper (Hornung et al. 2007), we tested the Intermediate Disturbance Hypothesis and the Increasing Disturbance Hypothesis on isopods. Trends in the total number of individuals, number of species, and three diversity indices (Shannon, Simpson, and Berger-Parker) were evaluated. We did not find significant differences in these parameters between the studied sites (urban, suburban, and rural). These findings gave rise to the idea that groups of species with different ecological characteristics (forest specialists, urban environment specialists, generalists) should be tested as their reactions to urbanization could be different and could cancel each other out when evaluated together. Since increasing disturbance by urbanization affects primarily the habitat specialist species, we hypothesized that abundance of the forest specialist isopods should increase, while abundance of the urban environment specialist isopods (or synanthropic species) should decrease from the urban area to the rural one (habitat specialist hypothesis, Magura et al. 2004). Moreover, we hypothesized that the abundance of the generalist species should be higher in the urban area, as predicted by the opportunistic species hypothesis (Gray 1989).

Material and methods

Study area and sampling design

Following the Globenet sampling protocol, terrestrial isopods were studied along an urban-suburban-rural gradient in Debrecen (Eastern-Hungary), the second largest city of the country (Magura et al. 2004). The urban, suburban and rural sampling areas were situated in once continuous patches of old forest (Convallario-Quercetum forest association; >100 yrs) dominated by English oak (*Quercus robur*). These forest patches covered an area of at least 6 ha. The distinction of sampling areas (urban, suburban and rural) was 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 $1km^2$ 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 strongly thinned shrub layer. In the suburban area fallen trees were removed, while in the rural area forest management was only occasional at a low-intensity level. Distances between the sampling areas (urban, suburban, rural) were at least 1-1 km, as prescribed by the general methodology of the Globenet project (Niemelä et al. 2000). Four sites, at least 50 m from each other (in order to achieve independency, see Digweed et al. 1995), were selected within each sampling area. Terrestrial isopods 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 from the end of March to the end of November, 2001. Traps were emptied fortnightly. 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 traps were covered with bark pieces to protect them from litter and rain (Spence and Niemelä 1994). For analysis, catches from each trap were pooled for the whole year. Of course, other sampling methods (e.g. hand sorting, Tullgren funnel extraction, litter sieving) could enhance the possibility to catch rare and/or small sized, soil dwelling species.

Data analyses

To test differences in the overall isopod abundance, and in the abundance of the trapped isopod species among the three sampling areas (urban, suburban and rural) and among the 12 sites, nested analyses of variance (ANOVA) were performed. Data of individual traps were used (sites nested within the sampling areas). Normal distribution of the data was achieved by log(x+1) transformation (Sokal and Rohlf 1995). Ecological characteristics (forest specialists, urban environment specialists, generalists) of the terrestrial isopod species caught were based on the literature (Schmalfuss 2003). The urban environment specialist species are frequently non-native, but mainly invasive and/or established introduced ones (Vilisics et al. 2007b). When ANOVA revealed a significant difference between the means, the Tukey test was performed for multiple comparisons among means.

Results

The total isopod catch consisted of 9115 individuals representing 6 species. 3548 individuals belonging to 6 species were captured in the urban, 5 species and 2720 individuals in the suburban, and 4 species and 2847 individuals in the rural area. The most abundant species was *Armadillidium vulgare*, which made up 72% of the total catch. Out of the trapped 6 species, there were three generalist species (*Armadillidium vulgare*, *Porcellium collicola* and *Trachelipus rathkii*), one forest specialist (*Trachelipus ratzeburgii*) and two urban environment specialists, as established introduced species (*Cylisticus convexus* and *Porcellio scaber*) (Table 1).

Analyzing the trap-level data by nested ANOVA we found that there were no statistically significant differences in the overall abundance of isopods across the urban-rural gradient ($F= 0.4859$; d.f.=2, 9; $p>0.05$). The abundance of the forest specialist isopod *Trachelipus ratzeburgii* increased significantly from the urban area toward the rural one ($F=14.3469$; d.f.=2, 9; $p<0.01$; Fig. 1a).

An opposite tendency was observed regarding the abundance of *Porcellio scaber* (urban environment specialist isopod), which was significantly higher in the urban area than in the suburban and rural ones ($F=6.1014$; d.f.=2, 9; $p<0.05$; Fig. 1b). *Cylisticus convexus*, the other urban environment specialist species was excluded from the analysis because of its low catches (only 3 individuals were caught).

The abundance of *Trachelipus rathkii*, a generalist species, was significantly higher in the urban area compared to the suburban and rural ones ($F=9.4200$; d.f.=2, 9; $p<0.01$; Fig. 1c). The other two generalist species (*Armadillidium vulgare* and *Porcellium collicola*) showed no significant changes in abundance along the gradient ($F=0.3632$; d.f.=2, 9; $p>0.05$; and $F=0.5999$; d.f.=2, 9; $p>0.05$; respectively).

Discussion

Overall isopod abundance

Several previous papers have emphasized that terrestrial isopods respond predictably to disturbance and that disturbance causing habitat alteration impacted assemblage composition, leading to significant changes in the abundance and species richness (Kalisz and Powell 2004, Pitzalis et al. 2005, Tsukamoto and Sabang 2005). In contrast, we did not find any significant difference in the abundance of isopods across the city wide gradient.

The lack of significant difference in the overall abundance may be caused by the dissimilar response of isopods with different habitat affinity to disturbance. Forest specialists may suffer, while generalists and urban environment specialist may benefit from the disturbance and habitat alteration caused by urbanization (Magura et al. 2004).

Abundance of forest specialist, urban environment specialist and generalist isopods

Contrary to the overall terrestrial isopod assemblages, the forest specialist and the urban environment specialist species responded significantly to the changes in habitat conditions caused by the urbanization. Our findings illustrated that forest specialist species suffer, while urban environment specialist species benefit from the disturbance and habitat alteration. Our results indicate that urbanization has a very strong effect on the forest specialist isopod species *Trachelipus ratzeburgii*. This forest species is more stenotopic, demanding microsites with favorable microclimate, the presence of dead and decaying trees, and significant cover of coarse woody debris, leaf litter, shrubs and herbs, together forming an undisturbed habitat (Korsós et al. 2002). Habitat alteration caused by urbanization appears to eliminate favorable microsites for forest species and therefore contributes to their decline of abundance at the disturbed areas. Along the studied urbanization gradient, disturbance was the highest in the urban area (paved paths, thinned shrub layer), it was moderate in the suburban area (fallen trees removed), and was lowest in the rural one. This decreasing disturbance was also expressed by the increasing abundance of the forest specialist isopod species. Judas and Hauser (1998) studying the distribution patterns of isopods in beech forests emphasized that *Trachelipus ratzeburgii* was the most abundant in the habitat patches with dead wood material. Jabin et al. (2004) also showed that coarse woody debris was a significant positive predictor for the abundance of the terrestrial isopod species in a forested habitat. In the same forest patches sampled in this study, Hornung et al. (2007) evaluated the relationships between the abundance of isopod species and environmental factors. Their results proved that the abundance of *Trachelipus ratzeburgii* increased with the amount of the decaying wood material. Moreover, there was negative correlation between the abundance of *Trachelipus ratzeburgii* and the ground and air temperature indicating that this species prefers closely natural habitats, which are usually characterized by lower ground and air temperature (Hornung et al. 2007).

Our findings show that the urban park is the most favorable habitat for the urban environment specialist *Porcellio scaber*. Its abundance was significantly higher there compared to the suburban and rural area. The exclusive appearance of *Porcellio scaber* in the urban park is in accordance with its habitat preference. Contrary to some other European countries with Atlantic climate influence, in Hungary this species can be found only in human settlements, in and around houses because of the heat island effect and moist shelters (Schmalfuss 2003).

The preference of *Porcellio scaber* for higher temperatures was shown by Hornung et al. (2007), as its abundance increased as the ground and the air temperature on the surface increased. Moreover, this urban environment specialist species may tolerate heavy metals originated from air pollution by accumulating them in vesicles in the hepatopancreas (Paoletti and Hassall 1999). Thus, they can also survive in the polluted habitats, although their body size can decline significantly (Jones and Hopkin 1998).

Our result partly supported the prediction of the opportunistic species hypothesis, as one of the generalist species, *Trachelipus rathkii* gained dominance in the disturbed urban area. Hornung *et al.* (2007) showed that the generalist *Trachelipus rathkii* preferred the urban site, which usually can be characterized by higher average temperature (heat islands effect). The other two generalist species (*Armadillidium vulgare* and *Porcellium collicola*), however, showed no significant changes in abundance along the gradient. These facts indicate that there is no clear, unique pattern along the urban-rural gradient for generalist species, because their abundance pattern is controlled by their autecological characteristics in complex interaction with the environmental variables, and urbanization/disturbance level. Nevertheless, previous studies on ground beetles (Niemelä et al. 2002 for the Canadian and Finnish Globenet sites, Ishitani et al. 2003, Magura et al. 2004, Sadler et al. 2006, Elek and Lövei 2007) and on ants (Vepsäläinen et al. 2008) confirmed the opportunistic species hypothesis.

Urban forests and biodiversity

We trapped six terrestrial isopod species in the studied urban park. This species richness is in accordance with the overall isopod diversity of natural forests in Hungary where the average isopod species richness in natural or semi-natural deciduous forests is around 5-6 (Loksa 1966). However, the present study also stressed that habitat modification caused by urbanization altered remarkably the terrestrial isopod assemblages, as the abundance of the forest specialist isopods decreased, while that of the urban environment specialist isopods and partly generalist isopods increased with the increasing disturbance level. Thus, urbanization could be one of the leading reasons of alteration in indigenous arthropod assemblages as well (Davis 1978). On the other hand, urban parks and other urban green areas created by the rising urbanization 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 (Gilbert 1989). We propose that extensive modification of habitats should be avoided, as these alterations are accompanied by unfavorable changes in the microclimatic, abiotic and biotic conditions of the area. Positive effects of soft management (the cut grass, plant material, trimmed branches and litter were returned to the urban forest patches) on isopod diversity and abundance was proved in an urban park of Sorø, Denmark (Vilisics et al. 2007a).

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Table 1. The catches of the terrestrial isopod species and their ecological category along an urban-rural gradient.

Species	Ecological category	Urban	Suburban	Rural	Total
Armadillidium vulgare (Latreille, 1804)	generalist	2088	2280	2218	6586
Cylisticus convexus (De Geer, 1778)	urban environment specialist	1	2	0	3
Porcellium collicola (Verhoeff, 1907)	generalist	272	245	226	743
Porcellio scaber Latreille, 1804	urban environment specialist	28	0	0	28
Trachelipus rathkii (Brandt, 1833)	generalist	1143	10	64	1217
Trachelipus ratzeburgii (Brandt, 1833)	forest specialist	16	183	339	538

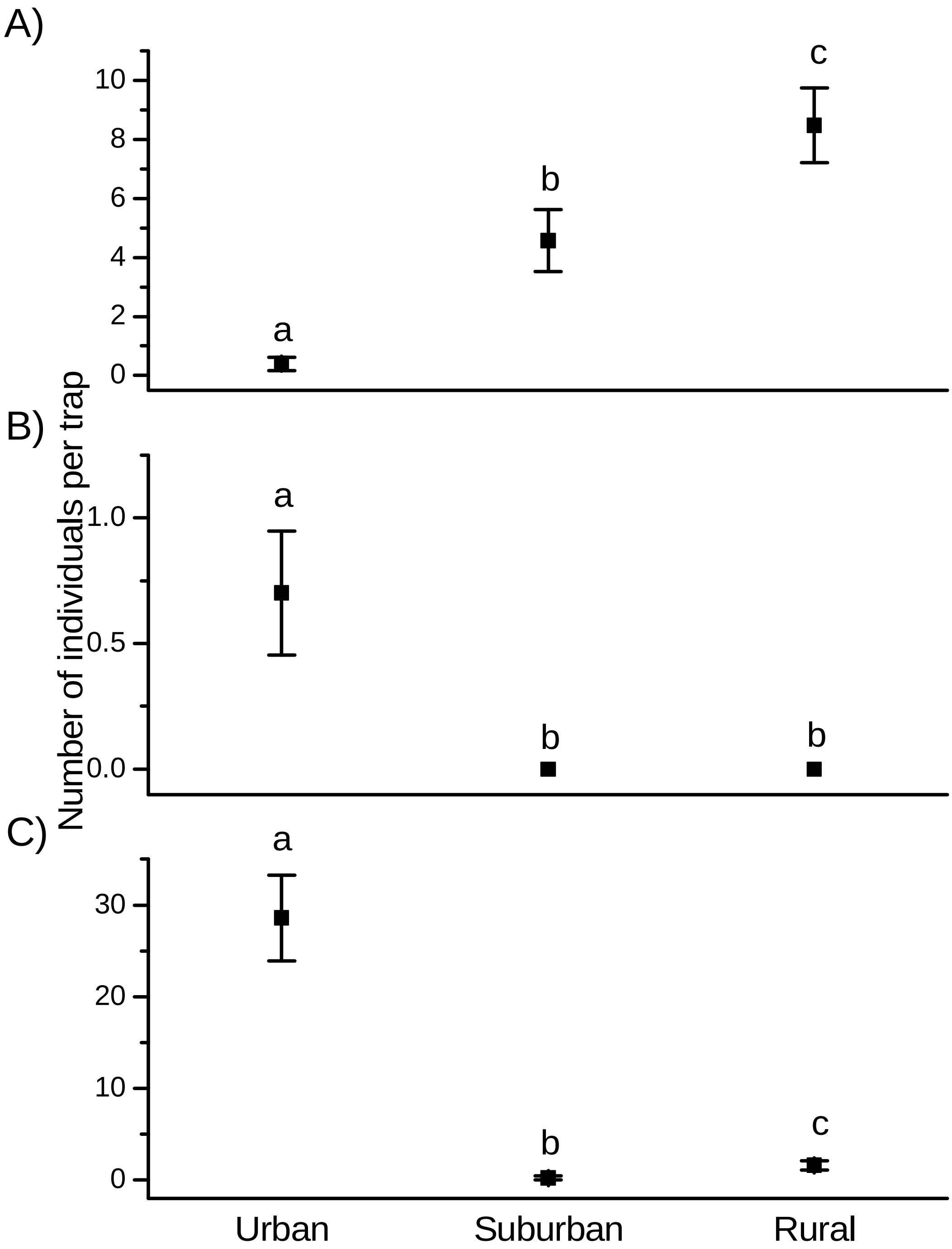

Figure 1. Average abundance values (±SE) of *Trachelipus ratzeburgii*, a forest specialist species (A), *Porcellio scaber*, an urban environment specialist species (B) and *Trachelipus rathkii*, a generalist species (C) calculated for the pitfall traps along an urban-suburban-rural gradient. Letters a, b and c indicate significant ($p < 0.05$) differences based on the Tukey multiple comparison test.