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Short Communications

THE REAL PATTERN IN THE SPECIES-AREA RELATIONSHIP – CASE STUDY USING GROUND BEETLES

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ABSTRACT

A central issue in conservation biology and nature management is whether or not characteristic species of a given habitat type could be preserved by fragmented habitat patches or not. The classical theory of island biogeography predicts that the number of species supported by an island increases with the area of the island. However, there is a significant difference between real and habitat islands. In real islands, the surrounding habitat (ocean, sea, lake, river etc.) is usually inhospitable to organisms occurring on islands. In the case of habitat islands, the bordering habitat (the matrix) is usually less hostile. Consequently, species richness of real islands is not influenced notably by the surrounding habitat. This difference is increasingly emphasized when studying the predictions of island biogeography theory on habitat islands. Clear distinction should be drawn between specialist species that truly perceive the habitat patches as islands and are unable to survive in the surrounding matrix, and those species that occur in both the habitat patch and the matrix (generalist species).

In this case study, we demonstrated that depending on the ratio of specialist and generalist species in an assemblage, the species-area relationship may be positive or negative. Ground beetles (*Coleoptera: Carabidae*) of sandy grassland patches were studied in Eastern Hungary (Central Europe). The total number of ground beetle species correlated negatively with grassland area. Based on this result, one can draw the (seriously false) conclusion that it is sufficient to conserve small patches because they support most species. This negative relationship was due to the increasing ratio of generalist species with decreasing patch size. Analyzing the habitat specialist species (open-habitat species associated with sandy soils), the significant negative relationship turned over, and became significantly positive; i.e. the ratio of habitat specialist species increased with patch size, as predicted by the theory of island biogeography.

INTRODUCTION

As a consequence of the increasing agricultural intensification, the area of natural and semi-natural grasslands declined worldwide (Reidsma et al., 2006). This decline created a network of isolated and fragmented grassland habitats. Habitat fragmentation has two main components. First, the total area of the habitat sustaining populations decreases. Secondly, these habitats tend to be more isolated (Saunders et al., 1991). Less mobile arthropod species, like ground beetles (*Coleoptera: Carabidae*), are especially sensitive to habitat loss and isolation (Samways, 2005; Lövei et al., 2006). A central issue in conservation biology and nature management is whether characteristic species of a given habitat type could be preserved by fragmented habitat patches or not. The classical theory of island biogeography predicts that the number of species supported by an island increases with the area of the island (MacArthur and Wilson, 1967). Recently, however, several papers refined the oversimplified original assumptions of the island biogeography theory concerning habitat island, which emphasizes the effects of surrounding habitats on the species richness (Kupfer et al., 2006; Lövei et al., 2006, Magura and Ködöböcz, 2007).

In the present case study evaluating ground beetles in sandy grasslands, we demonstrated that depending on the ratio of specialist and generalist species in an assemblage, the species-area relationship may be positive or negative.

METHODS

Study Area

Eight patches of formerly contagious sandy grasslands located in the Nyírség region (the Great Hungarian Plain, Eastern Hungary) were studied. In the 19th century, this region was covered by natural habitats (marshes, fen meadows, mires, sandy grasslands and sandy oak woods). During the 20th century, as a consequence of the intensification of farming and forestry, these habitats were abolished or became highly fragmented. Today, the fragmented sandy grassland patches are surrounded by arable lands and non-native tree plantations. Recently, the studied grassland patches (prevalent vegetation association was ***Potentillo arenariae-Festucetum pseudovinae***) have been lightly grazed with cows and sheep (cattle density was less than 0.25 heads/ha). The matrix habitats surrounded by these patches were similar: non-native deciduous tree plantations (black locust and ennobled poplar species) and croplands (maize and corn). The area of the studied patches varied between 2.3–353.5 ha and the distance between the patches was at least 2 km.

Sampling Design

The eight sandy grassland ground beetles were collected during three years (2001-2003) using unbaited pitfall traps, consisting of plastic cups (diameter 100 mm, volume 500 ml) with 70% ethylene glycol as a killing and preserving solution. There were 10 traps, scattered randomly within the individual patches (at least 100 m from the grassland edges). Traps were checked fortnightly from the end of March to the end of October in every year. Ground beetles were identified to species using the keys of Hůrka (1996). To ensure a more complete species inventory in the studied grassland patches, beetles caught from the three trapping years were pooled.

Data Evaluation

Based on the literature data (Hůrka, 1996), considering local conditions, collected ground beetle species were divided into two ecological groups according to their habitat preference: habitat specialist species (open-habitat species associated with sandy soils) and generalist species (species occurring likewise in both the closed and open canopy habitats and are not associated with sandy soils). The relationship between the patch area and the number of ground beetle species was examined by linear regression analysis (Kutner et al. 1996). We analyzed separately the total number of ground beetle species collected in the fragment, as well as the ratio of habitat specialists and generalists to the total number of species. Analyzing the ratio (or relative frequency) instead of the actual numbers removes the inherent differences in species richness among the studied patches. The distribution of data used in the linear regression analyses was normal (tested by the Kolmogorov-Smirnov test, Sokal and Rohlf, 1995).

RESULTS

From the eight studied sandy grassland patches 8,620 ground beetles belonging to 67 species were sampled during the three-year collecting period. The majority of the trapped beetles (7,469 individuals belonging to 31 species) were habitat specialist species, as they were open-habitat species associated with sandy soils.

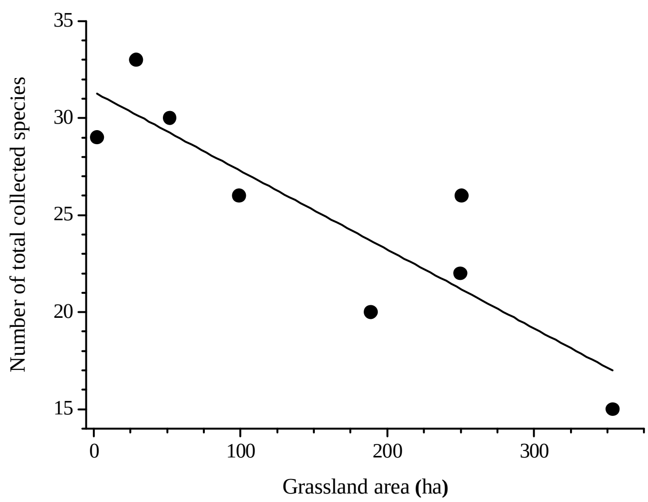

Figure 1. Relationship between the sandy grassland patch area and the total number of ground beetle species collected.

A significant negative relationship was found between the total number of ground beetle species and the area of the sandy grassland patch by linear regression analysis (F= 19.3805; d.f.= 1, 6; p= 0.0046; R= –0.8738; Figure 1).

The area of grassland patch and the relative frequency of generalist species (expressed by the ratio of the generalist species to the total number of species) also showed a significant negative relationship (F= 8.7794; d.f.= 1,6; p= 0.0252; R= –0.7707); a decreasing area resulted in an increasing generalist species ratio (Figure 2a).

A significant positive relationship was found between the relative frequency of habitat specialist species (open-habitat species associated with sandy soils) and the grassland area (F= 8.7794; d.f.= 1,6; p= 0.0252; R= 0.7707), indicating the importance of habitat specialist species with increasing patch size (Figure 2b).

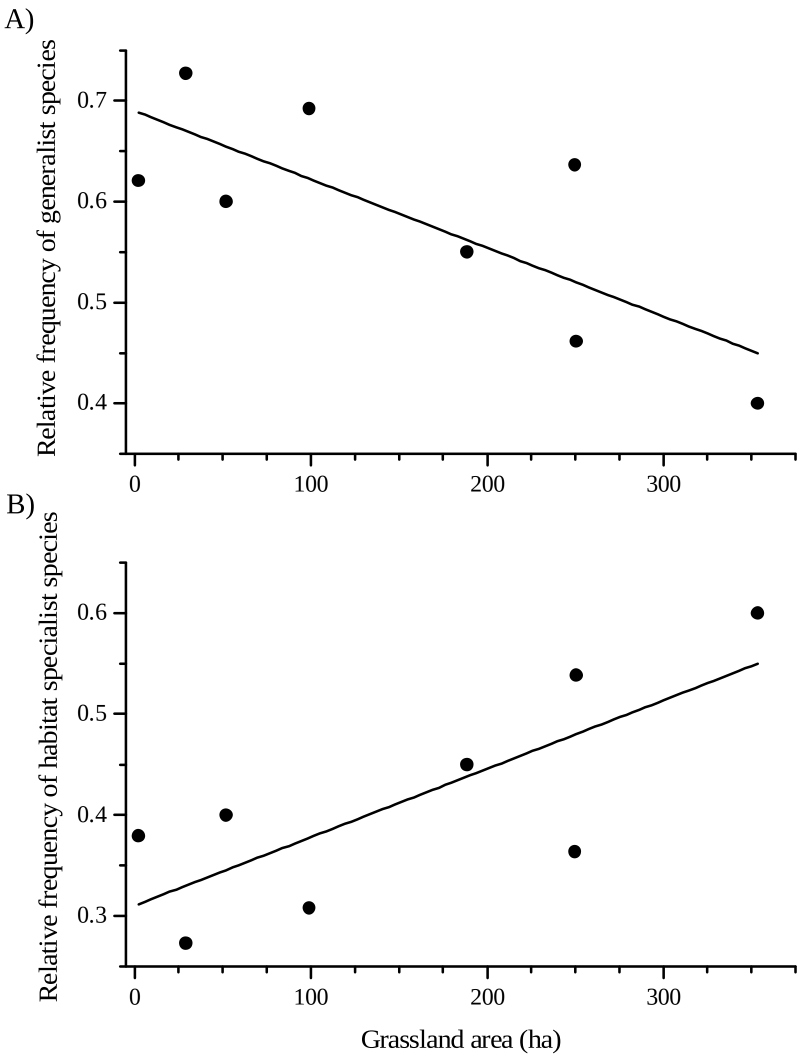

Figure 2. Relationship between the sandy grassland patch area and the relative frequency of generalist species (A) and the relative frequency of habitat specialist species (B).

CONCLUSION

Results of the published studies regarding the relationship between the area of habitat island and the number of observed animal species were rather inconsistent. Several authors, in accordance with the prediction of the classical theory of island biogeography, reported a significant positive correlation (Faeth and Kane, 1978; Mader, 1980; Nilsson et al., 1988; McCoy and Mushinsky, 1994; Bolger et al., 1997; Abensperg-Traun and Smith, 1999; Peintinger et al., 2003; Hovestadt et al., 2005; Watson et al., 2005). Others, contrary to the prediction, described a significant negative relationship (Bauer, 1989; Estades and Temple, 1999; Magura et al., 2001; Lövei et al., 2006). Furthermore, some studies found that overall animal species richness was unrelated to the habitat area (Ås, 1993; Hopkins and Webb, 1984; Davies and Margules, 1998; Brose, 2003; Gandhi et al., 2004; Juliao et al., 2004).

The above inconsistency could arise from the fact that the original theory of island biogeography considered real islands. There is a significant difference between real and habitat islands. In real islands, the surrounding habitat (ocean, sea, lake, river etc.) is usually inhospitable to organisms occurring on islands. In the case of habitat islands, the bordering habitat (the matrix) is usually less hostile. Consequently, species richness of real islands is not notably influenced by the surrounding habitat, while habitat islands could be inhabited by colonists from the matrix: "species can colonize the islands from the sea" (Cook et al., 2002). The above difference is increasingly emphasized when studying the predictions of island biogeography theory on habitat islands. Clear distinction should be drawn between those species that occur in both the habitat patch and the matrix (e.g. generalist species) and the specialist species that truly perceive the habitat patches as islands (Bauer, 1989; Magura et al., 2001, 2008; Cook et al., 2002; Lövei et al., 2006). The specialist species are unable to survive in the surrounding matrix.

In this case study, we demonstrated that depending on the ratio of habitat specialist and generalist species in an assemblage, the species-area relationship may be positive or negative. Based on the significant negative correlation between the total number of ground beetle species and the grassland area one can easily draw the (seriously false) conclusion that it is sufficient to conserve the small patches because they support most species. In fact, however, this was due to the increasing ratio of generalist species with decreasing patch size. Previous studies on ground beetles also emphasized that generalist species from the neighboring matrix and from the edge may cause increased overall species richness in habitat patches with limited size and/or high degree of isolation (Bauer, 1989; Halme and Niemelä, 1993; Desender et al., 1999; Magura et al., 2001; Lövei et al., 2006; Magura and Ködöböcz, 2007). Removing the non-habitat specialist species from the assemblages and analyzing the importance of only habitat specialist species (open-habitat species associated with sandy soils), the significant negative relationship turned over and became significant is positive as predicted by the theory of island biogeography. This duality in the species-area relationship concerning ground beetles is not a special case, as several studies reported similar results in different habitats. Bauer (1989) also found that the relationship between the size of limestone outcrop and the overall ground beetle species richness was significantly negative, while the number of limestone specialist species and the area of outcrop showed a significant positive relation. Species richness of farm woodland ground beetles also correlated positively with the area of woodland, while the total number of species did not (Usher et al., 1993). Similar patterns exist for conifer forest patches, where only the forest specialist species showed a positive species-area relationship (Halme and Niemelä, 1993). De Vries (1994) also reported that the relationship between the area of heath fragments and the species richness of heath specialist ground beetles was significantly positive, while the area-total species correlation was statistically not significant. The species-area relationship in deciduous forest patches was also significantly negative when all species were considered, while it was significantly positive for the forest specialist species (Magura et al., 2001; Lövei et al., 2006).

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