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The importance of fragmentation and habitat quality of urban grasslands for butterfly diversity

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ABSTRACT

Parks, remnants of natural habitats and other green areas are important for preserving biodiversity in urban areas. Here, we investigate the relative importance of habitat type and connectivity for butterfly species richness in the city of Malmö, Sweden. Further, we compare species richness and composition in the urban habitats with that in the surrounding agricultural landscape using previously published data. Both butterfly species richness and density increased with decreasing connectivity, measured as the proportion of urban green areas within 1 km, and were higher in ruderal sites than in traditional and semi-natural parks. Species richness was only slightly lower in the urban habitats than in semi-natural grassland remnants in the agricultural landscape surrounding the city and there was only a small difference in β (between site) diversity between urban and semi-natural landscapes. This study highlights the importance of "townscape" composition for species richness in urban habitats, but also demonstrates clearly that urban habitats, especially those characterized by an early-successional stage, can be of relatively high conservation value in regions dominated by intensive human land use.

1. Introduction

Urbanization is, along with agricultural intensification, one of the most important threats to biodiversity worldwide (Ricketts and Imhoff, 2003) and one of the most obvious examples of how human activities affect ecosystems (Rees, 1997). Nevertheless, several studies have demonstrated that urban areas can indeed harbour diverse habitats and a high biodiversity (Gilbert, 1989; Niemelä, 1999; Muratet et al., 2007; Kadlec et al., 2008).

During the last decades, the interest in urban ecology and biodiversity has increased markedly (Sukopp, 2002; Grimm et al., 2008; Hedblom and Söderström, 2008). As a consequence, there is an increasing effort to manage parks and other urban green areas in order to promote biodiversity. A number of studies have investigated how urban biological diversity is related to local park management and gardening practice (Cornelis and Hermy, 2004; Gaston et al., 2005; Andersson et al., 2007) but attempts to evaluate the success of different methods to increase urban biodiversity are still rare (Cornelis and Hermy, 2004).

Urbanization results in destruction and fragmentation of natural and semi-natural habitats, where small and isolated habitat remnants are surrounded by a matrix of uninhabitable areas (Niemelä, 1999; McKinney, 2002). Metapopulation theory predicts that the probability of population persistence in such fragments (patches) is positively related to fragment area and negatively to its isolation (Hanski, 1999). Translated to a multiple-species scenario, large and well-connected patches are predicted to contain more species than small and isolated patches (c.f. MacArthur and Wilson, 1967). Another situation when local species richness is related to the geographical setting is when habitat fragments are too small or of too low quality to support viable populations, and hence depend on immigration from nearby source populations (Pulliam, 1988; Leibold et al., 2004). In the case of urban environments, population sources may be situated either within or outside the urban area. Because urban green areas are typically surrounded by a completely hostile man-made matrix, even though gardens in suburban areas may provide additional resources for some organisms, urban areas provide an excellent opportunity to study the effects of habitat fragmentation.

For butterflies, important aspects of habitat quality include the occurrence and abundance of larval host plants, availability of nectar as a source of energy for adult butterflies and vegetation structure (Thomas et al., 2001; Pywell et al., 2004; Pöyry et al., 2005; Öckinger et al., 2006a; Öckinger and Smith, 2006) and it can be assumed that management practices that positively influence

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these factors could increase butterfly diversity in urban areas (c.f. Smallidge and Leopold, 1997).

Previous studies have demonstrated effects of isolation on both the incidence patterns of individual butterfly species (Bergman and Landin, 2001; Gutiérrez et al., 2001; Thomas et al., 2001) and on butterfly species richness (Wettstein and Schmid, 1999; Öckinger and Smith, 2006, 2007) in agricultural landscapes. In urban landscapes, studies have failed to find effects of isolation for butterflies (Wood and Pullin, 2002; Collinge et al., 2003), even though this has been demonstrated for other groups (e.g. birds; Melles et al., 2003) and the decreasing species butterfly richness along a rural-urban gradient observed by Blair and Launer, 1997 and Blair (1999) may indicate an effect of isolation from population sources outside the urban area.

Here, we investigate the relative effects of local habitat quality and landscape composition on butterfly species richness by selecting sites representing three types of habitat assumed to differ in quality and differing in their degree of isolation. We also compare the species richness and composition in the urban habitats with the species richness and composition in semi-natural grassland patches in the surrounding agricultural landscape (data from Öckinger and Smith, 2006) to test the hypothesis that urban habitats have lower species richness and smaller between-site differences (β-diversity) compared to grasslands in the agricultural landscape.

2. Methods

2.1. Study area

The city of Malmö is situated in southern Sweden (Fig. 1), has a population of about 280,000 and covers an area of 154 km^2 (www.malmo.se). The city is situated in one of the most densely populated regions in Sweden and is mainly surrounded by intensively farmed agricultural land, which probably contains few potential population sources for grassland butterflies (c.f. Öckinger and Smith, 2007). For this study, we selected 20 sites to represent three common types of urban green area, assumed to be of different quality as butterfly habitat. The sites were selected to include a large variation in isolation from other green areas, in the distance from potential population sources outside the city and in area. The area of the surveyed sites varied from 0.15 to 4.0 ha (mean = 1.33, median = 1.02 ha).

Four of the sites were "traditional parks", i.e. parks with well-mowed lawns, flower plantations and had a high proportional cover of planted trees. Eight were "semi-natural parks", i.e. parks where at least a part of the area had been either left for free development or contained tall grassland vegetation which was mowed only once or twice per year. The vegetation in such sites usually resembled the one in dry-mesic semi-natural grasslands even though the nutrient status typically was higher than that in semi-natural grasslands. The remaining eight sites were ruderal areas, i.e. formerly disturbed, often industrial or built-up areas, where the vegetation had re-established naturally and was characterised by an early-successional stage.

2.2. Butterfly survey

All sites where surveyed for butterflies (Rhopalocera) and burnet moths (Zygaenidae) using standardized transect counts (Pollard and Yates, 1993). Burnet moths are diurnal and are similar to butterflies in most ecological aspects (Naumann et al., 1999). Unless otherwise stated, "butterflies" refer to both groups. The transect length was proportional to the grassland area, with 150 m transect/ha area (for convenience rounded off to the nearest 100 m, c.f. Öckinger and Smith, 2006). All butterflies observed within 5 m ahead and on both sides of the observer were identified to species level in the field. Each site was visited five times. The first four visits were made between June 22nd and August 8th, 2006, but because some species only are found early in the season we made an additional visit to each site between May 21st and June 7th, 2007. Butterflies were only recorded on warm (minimum temperature 17 °C) and sunny day with no rain.

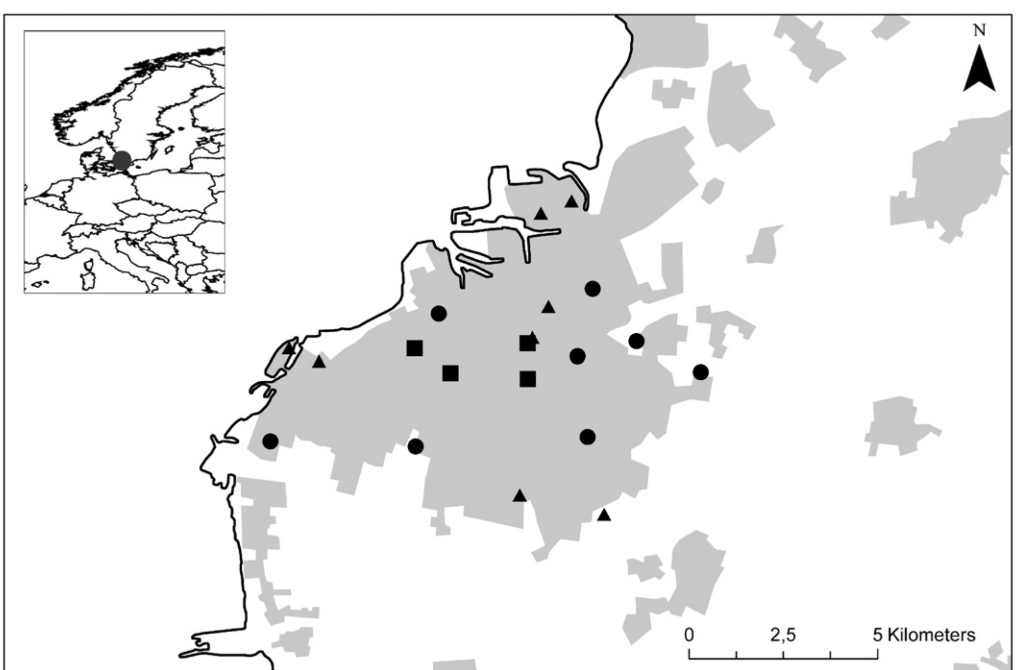

Fig. 1. (a) Distribution of the studied sites within the city of Malmö and the situation of Malmö in Sweden and Europe (small map). Squares = traditional parks, circles = semi-natural parks, and triangles = ruderal sites. Grey areas indicate the urban area.

Table 1
Mean (±SE) vegetation height, host plant diversity, flower abundance, bush cover and abundance of flowering bushes in the three habitat types. The superscript letters denote statistically significant differences.

Habitat type	Vegetation height	Host plant diversity	Flower abundance	Bush cover	Flowering bushes
Traditional park	12.8 (4.5)^{A}	1.3 (1.3)^{A}	8.7 (3.1)	0.12 (0.095)	0.00 (0.00)
Semi-natural park	13.1 (1.8)^{B}	7.0 (0.8)^{B}	6.4 (1.3)	0.03 (0.023)	0.024 (0.015)
Ruderal	22.9 (1.2)^{B}	9.5 (0.8)^{C}	5.1 (1.4)	0.07 (0.034)	0.014 (0.006)

2.3. Local habitat characteristics

Each site was classified as traditional park, semi-natural park or ruderal site (hereafter referred to as *habitat types*). In addition, we measured vegetation height, flower abundance, host plant diversity, cover of shrubs and bushes and the abundance of flowering bushes. *Vegetation height* was measured at the beginning of each transect segment) using a "grassland ruler", a graded, 17 cm wide, rectangular board which is placed vertically against the ground (Ekstam and Forshed, 1996). *Flower abundance* was measured by placing a 50 cm × 50 cm plot, divided into 25 squares of 10 cm × 10 cm at the beginning of each transect segment. In each sample plot we measured total frequency of flowers (number of 10 cm × 10 cm in which any flower occurred). Both vegetation height and flower abundance were measured during the second visit to each site (6–10 July 2006), and the site mean values were used in the analyses. Larval *host plant diversity* is the number of species of potential larval host plants for butterfly (according to Stoltze, 1996) and burnet moth (according to Naumann et al., 1999) species occurring in Malmö and its surroundings. We actively searched for potential larval host plants over the entire area at all sites. *Bush cover* at each site was calculated from aerial photographs using GIS (ArcGIS 9.1). The *abundance of flowering bushes* was measured by mapping the extent of such bushes onto aerial photos during the 2007 visit (21 May–7 June) and calculating the area using GIS. At each visit to each site, we also recorded whether the vegetation was mowed or not.

As we expected, both vegetation height (ANOVA: $F_{2,17} = 5.63$, $P = 0.013$) and host plant diversity ($F_{2,17} = 17.4$, $P < 0.001$) differed strongly between habitat types. Both vegetation height and host plant diversity was lowest in traditional parks (Table 1). Vegetation height was similar in semi-natural parks and ruderal sites, while the host plant diversity was significantly higher in ruderal sites than in both park types (Table 1). Because of these differences, we did not include vegetation height or host plant diversity as predictors when analysing how butterfly diversity and abundance differed between habitats. Neither flower abundance ($F_{2,17} = 0.90$, $P = 0.45$), bush cover ($F_{2,17} = 0.73$, $P = 0.50$) or the abundance of flowering bushes ($F_{2,17} = 0.91$, $P = 0.42$) differed significantly between habitat types and hence these variables were kept in the analyses.

2.4. Landscape variables

As measures of connectivity, we used the percentage of different types of urban green areas within 1 km from the study sites. We mapped the extent of gardens, ruderal areas, different types of parks, cemeteries and other green areas in the city of Malmö from aerial photographs using GIS (ArcGIS 9.1). Because different types of urban green areas can be assumed to be of different quality as butterfly habitats, we classified them into five categories; gardens, ruderal areas (here defined as disturbed sites with vegetation in an early-successional stage), urban parks (with planted trees, including cemeteries), grassland areas (mainly semi-natural grasslands situated outside the city, but also roadside vegetation and small grassland fragments in suburban areas) and other green areas (mainly suburban parks). The scale of 1 km was selected because we wanted to avoid including the countryside outside the city and to minimize the spatial overlap between landscapes. Also, at larger spatial scales, the contrast between landscapes would have become increasingly smaller. The reason for using the proportional area of each category rather than some distance-based connectivity index (see Kindlmann and Burel, 2008 for a review) was that some types of urban green areas, e.g. gardens and grassland fragments in suburban areas, are difficult to classify as discrete units. Also, the type of connectivity measure used is not likely to have any large influence on the results, because different types of connectivity metrics tend to be highly correlated (e.g. Winfree et al., 2005).

Because the total percentage of green areas was highly correlated with the total percentage of "other green areas" (Pearson correlation: $r = 0.85$, $N = 20$, $P < 0.001$) and gardens ($r = 0.81$, $N = 20$, $P < 0.001$), we excluded the latter two variables from the analyses. However, the total percentage of green areas was not significantly correlated with any of the other landscape variables (grassland: $r = 0.15$, $N = 20$, $P = 0.54$; ruderal: $r = 0.35$, $N = 20$, $P = 0.13$; parks: $r = 0.11$, $N = 20$, $P = 0.65$) so these were kept for further analyses.

To test whether immigration from the region surrounding the city influenced butterfly species richness and density in the city, we also measured the distance from the border of the built-up area to each site from the aerial photographs.

2.5. Statistical analyses

We analyzed the number of species and total density (expressed as the number of individuals irrespective of species per unit area) of butterflies per site in relation to local land landscape variables. We analyzed the species richness and density of butterflies per site by General Linear Models (SAS proc GLM). Local and landscape variables to be included in the final models were selected by means of backward elimination until only those with $P \leq 0.05$ remained.

2.6. Comparison between urban and agricultural landscapes

To study how valuable urban grassland sites are for butterflies in comparison with typical semi-natural grasslands in the region, we compared the results of the present study with those from a study of butterfly species richness in semi-natural grassland sites situated in the intensively farmed agricultural landscape that surrounds the city of Malmö (Öckinger and Smith, 2006). In the comparison, we included only the 16 sites (out of a total of 48 sites) in the most intensively farmed landscapes from that study, because this is the type of landscape that represents the surroundings of Malmö (see Öckinger and Smith, 2006 for details). Because most sites in the agricultural landscape study were significantly larger (mean = 4.25, SE = 0.79 ha) than the urban sites (1.33 ± 0.26 ha), we also compared the species richness and composition in the urban sites with the eight sites in the agricultural landscapes classified as "small" by Öckinger and Smith (2006) (1.24 ± 0.19 ha).

To test whether the β-diversity, e.g. the diversity between sites, was smaller in the urban area compared to the agricultural landscape, we performed additive diversity partitioning (Lande, 1996) to partition total species richness (γ) in each landscape type into its components α (diversity within sites) and β (diversity between sites). β is the mean number of species *not* found in a particular site out of the total number of observed species. Hence, $\beta = \gamma - \alpha$,

Table 2
Results of GLMs relating butterfly species richness and butterfly density to factors of local habitat quality and the surrounding landscape.

Variable	Species richness			Density		
	Slope	F	P	Slope	F	P
Local variables						
Habitat type		8.36	0.003		3.76	0.048
Area	1.677	1.52	0.24	−376.0	9.96	0.007
Flowers	−0.060	0.29	0.60	7.82	0.67	0.43
Bushes	−1.847	0.17	0.69	−293.7	0.53	0.48
Flowering bushes	0.001	0.27	0.61	0.023	0.03	0.87
Landscape variables						
Grassland	0.051	2.71	0.12	1.07	0.13	0.73
Ruderal	0.317	10.45	1.25	2.06	0.77	0.39
Parks	−0.186	0.51	0.49	3.30	1.60	0.23
Total green area	0.309	9.17	0.008	2.38	6.97	0.019
Distance from city border	−0.026	0.16	0.69	−49.1	2.93	0.11

where γ is the total number of observed species and α is the mean number of species per site. This comparison was only made with the eight small sites in the agricultural landscape.

3. Results

3.1. Species richness

In total, we found 4216 individuals of 17 species, with a mean of 8.0 (SE = 0.58) species per site. The number of species per site differed significantly between habitat types (Table 2 and Fig. 2), with significantly higher species richness in ruderal sites than in both traditional parks (P = 0.005) and semi-natural parks (P = 0.004). The mean number of species was lowest in traditional parks (Fig. 2) but due to the low number of traditional parks sampled (N = 4) the difference between the two park types was not statistically significant (P = 0.82). In addition, the species richness per site was positively related to connectivity, measured as the percentage of total green areas within 1 km (Fig. 3) but there was no effect of site area or of any other local or landscape variables (Table 2).

3.2. Butterfly density

The butterfly density showed the same pattern as the species richness, with an increasing density per site with increasing percentage of green area in the surrounding landscape (Table 2) and with significant differences between habitat types (Table 2), again with significantly higher density in ruderal sites than in both traditional parks (P = 0.031) and semi-natural parks (P = 0.040) but no statistically significant difference between the two park types (P = 0.64). There was also a significant negative relationship between butterfly density and site area, but not of any of the other recorded local or landscape variables (Table 2).

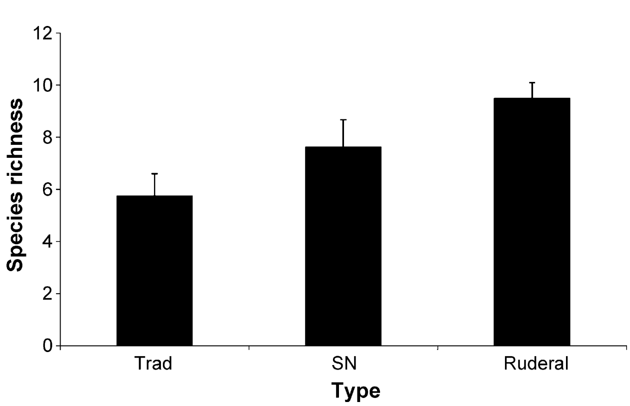

Fig. 2. Species richness (±SE) of butterflies in traditional parks (N = 4), "semi-natural" parks (N = 8) and ruderal sites (N = 8).

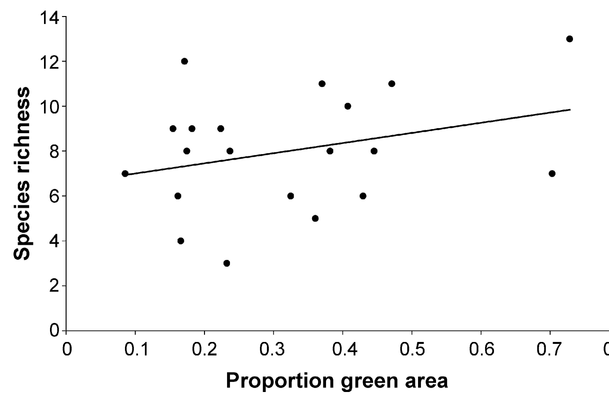

Fig. 3. The relationship between the proportion of green area in the surrounding landscape and local butterfly species richness.

3.3. Species richness in urban and agricultural areas

Two species were unique to the urban area, whereas 14 species were unique to the agricultural landscape (seven species if only the small sites are considered; Table 3). On average, there were more species in the grassland sites in the agricultural landscape (mean = 11.9, SE = 1.3) than in the urban sites (mean = 8.0, SE = 0.6; t-test: $t_{20.9}$ = 2.75, P = 0.012), but the mean number of species in the small sites in the agricultural landscape (mean = 8.3, SE = 1.3) did not differ significantly from that in the urban sites (t-test: t_{26} = 0.20, P = 0.84). Moreover, the number of species in the most species-rich urban habitat type, the ruderal sites (mean = 9.5, SE = 0.60) was not significantly lower than the mean number of species found in the agricultural landscape even when the large sites were included (t-test: $t_{20.9}$ = 1.83, P = 0.082).

The β-diversity, e.g. the proportion of the total diversity attributed to differences between sites, was slightly larger in the eight small sites in the agricultural (62.5%) compared to the twenty sites in the urban landscape (52.9%, Fig. 4).

4. Discussion

Knowledge about the relative influence of local and regional (landscape) factors on local biodiversity is crucial for conservation management. Here, we found significant effects of both habitat type and isolation on butterfly species richness and density in an urban area.

Table 3
Presence of butterfly and burnet moth species in site in the city of Malmö (this study) and in semi-natural grassland sites in the surrounding agricultural landscape (from Öckinger and Smith, 2006). The small sites in Öckinger and Smith (2006) are of comparable size (0.5–2.0 ha) as the sites in Malmö (0.15–4.0 ha) whereas the column "all" includes sites up to 10.0 ha in size.

Species	This study (N = 20)		Öckinger and Smith (2006)	
			Small (N = 8)	All (N = 16)
	Sites	%	%	%
Pieris rapae	20	100	25	56.3
Maniola jurtina	18	90	50	75
Polyommatus icarus	17	85	12.5	56.3
Aglais urticae	15	75	37.5	68.8
Zygaena filipendulae	13	65	–	–
Coenonympha pamphilus	13	65	50	62.5
Inachis io	12	60	50	68.8
Vanessa cardui	12	60	50	68.8
Lycaena phlaeas	11	55	25	37.5
Pieris napi	10	50	100	100
Aphantopus hyperantus	8	40	100	100
Vanessa atalanta	3	15	37.5	62.5
Thymelicus lineola	2	10	50	56.3
Pieris brassicae	2	10	50	68.8
Gonepteryx rhamni	2	10	12.5	25
Ochlodes sylvanus	1	5	25	50
Aricia agestis	1	5	–	–
Araschnia levana	–	–	37.5	56.3
Argynnis paphia	–	–	25	37.5
Anthocharis cardamines	–	–	25	31.3
Zygeana lonicerae	–	–	25	12.5
Argynnis aglaja	–	–	12.5	6.3
Zygeana viciae	–	–	12.5	6.3
Lasiommata megera	–	–	12.5	6.3
Boloria selene	–	–	–	25
Brenthis ino	–	–	–	12.5
Lyceana virgaureae	–	–	–	12.5
Polyommatus semiargus	–	–	–	12.5
Lycaena hippothoe	–	–	–	6.3
Plebejus idas	–	–	–	6.3
Hesperia comma	–	–	–	6.3

The observation that traditional parks had the lowest number of butterfly species was not surprising, because traditional parks usually lack most of the features that constitute suitable butterfly habitat. Typically, they have short grass turf that is cut regularly, low numbers of native plant species and a low structural diversity. Ruderal sites had higher species richness and densities of butterflies than semi-natural parks. This contrasts with the results of Blair and Launer, 1997 and Blair (1999) who found highest butterfly species richness at intermediately disturbed sites in urban environments, but is in agreement with Muratet et al. (2007) who found high species richness of plants in ruderal sites in Paris. Similarly, Gutiérrez (2005) found that ruderal areas, rather than nature reserves, constituted the most valuable habitat patches for the threatened butterfly *Erynnis tages* in a region in Wales. The most likely reason for the higher species richness in the ruderal sites in our study is the fact that these had both higher diversity of potential larval host plants compared to both traditional and semi-natural parks and also had taller vegetation than at least the traditional parks. Both these factors have been found to promote butterfly species richness in previous studies (Kruess and Tscharntke, 2002; Franzén and Ranius, 2004; Öckinger et al., 2006a). The higher species richness in the ruderal sites also highlights the importance of early-succesional habitats of anthropogenic origin, such as quarries (Benes et al., 2003) and power line corridors (Smallidge and Leopold, 1997; Forrester et al., 2005) as butterfly habitats. One reason for the high value of such habitats may be that they have a warm micro-climate, an important aspect of habitat quality for many insect species in temperate regions (Thomas, 1993; Smallidge and Leopold, 1997).

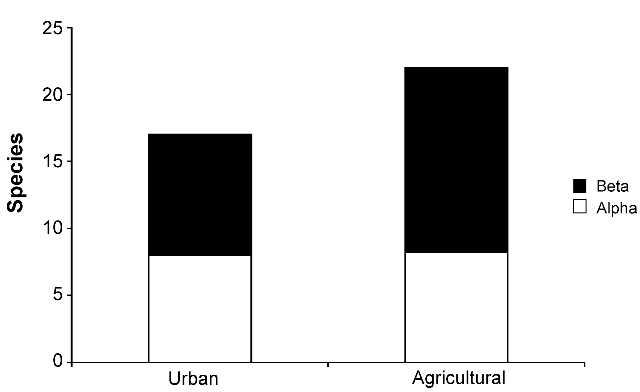

Fig. 4. Additive partitioning of species richness in grassland sites of comparable size in urban (N = 20) and agricultural (N = 8) landscapes.

A number of previous studies (e.g. Wettstein and Schmid, 1999; Öckinger and Smith, 2006) have found positive effect of connectivity on butterfly species richness in agricultural landscapes, but several other studies (Collinge et al., 2003; Krauss et al., 2003; Franzén and Ranius, 2004; Bergman et al., 2008; see Hanski and Pöyry, 2007 for a review) have failed to do so. One reason why we found such an effect in this study may be that the urban environment constitutes an entirely hostile matrix, as assumed by metapopulation (Hanski, 1999) and island biogeography (MacArthur and Wilson, 1967) theories, whereas in many other studies this may not be the case (Hanski and Pöyry, 2007). Differences in the quality of the urban matrix may possibly also explain the differences between our results and the one by Collinge et al. (2003), who studied butterfly species richness in remnant grasslands in an urbanized area in Colorado, USA. We found effects only of the total proportional cover of green areas in the surrounding landscape, but not of any of the particular types of parks, gardens etc. However, this does not imply that the quality of the urban green areas is not important. Instead, it is more likely to be an effect of the low precision in our landscape measures and that the cover of high-quality habitats is correlated with the total cover of green areas.

Surprisingly, we found no effect of patch area on local species richness. One reason for this may be that all patches were relatively small and that local quality was more important than area. The fact that we found effects of isolation on butterfly density could indicate that immigration and emigration rates have significant effects on local population dynamics in this system. Also the negative relationship between butterfly density and patch area indicate that emigration–immigration dynamics are important (Hambäck and Englund, 2005; Hambäck et al., 2007).

The composition of the landscape surrounding the urban area may affect urban biodiversity. It has been suggested (Kauffman et al., 2004; Snep et al., 2006) that urban areas may constitute sink habitats that depend on immigration from sources in the surrounding landscapes. This could result in a pattern of decreasing species richness along the rural-urban gradient as observed by Blair and Launer, 1997 and Blair (1999). Short distances from the large continuous grassland surrounding the urban area in the study by Collinge et al. (2003) might also explain the lack of isolation effects in that study. We found no effect of the urban area on butterfly species richness or density. The most likely reason for this is that the area surrounding the city of Malmö is dominated by intensive agriculture with a very small proportion of semi-natural grasslands and other butterfly habitats. Hence, there are no large potential population sources in the vicinity.

When comparing the butterfly faunas in the urban sites with that in semi-natural grasslands in the surrounding landscape (Table 3) it is striking that even though the mean species richness was relatively similar in the urban and agricultural landscapes, the total number observed (γ-diversity) in all of the 20 urban sites is much lower than that in all the 16 sites in the agricultural landscape and also smaller than the total number of species observed in the eight small sites in the agricultural landscape (Table 3 and Fig. 4). This is also reflected by the larger β-diversity (in both absolute and relative terms) in the agricultural landscape (Fig. 4). The smaller β-diversity in the urban area together with the lack of area effect on species richness indicate that regional processes are important in shaping local communities (but here it should be noted that the sites in the agricultural landscape were distributed over the entire region, some of them separated with more than 100 km). The relatively high local species richness could be due to a larger variation in habitat types situated within short distances to each other, resulting in a mass-effect (Shmida and Wilson, 1985; Leibold et al., 2004) which contributes to high species richness in well-connected sites. Also, the fact that we found a significant effect of isolation on butterfly density and the negative relationship between butterfly density and patch area indicate that emigration–immigration dynamics are important for local populations (Hambäck and Englund, 2005; Hambäck et al., 2007).

Koh and Sodhi (2004) found that butterflies in the city of Singapore were a non-random sample of the species found in the surrounding region. Forest specialists were absent from the city, which instead was dominated by cosmopolitan generalists. In our study, the total number of species was too low for a similar analysis, but among the species absent from the urban sites, there are both habitat specialists, such as *Argynnis aglaja*, *Hesperia comma* and *Zygaena viciae* as generalists as *Araschnia levana* and *Brenthis ino*. On the other hand, the specialized burnet moth *Zygaena filipendulae* was one of the most common species in the urban habitats but was not observed in any of the agricultural sites (even though it is relatively widespread in the immediate vicinity of Malmö (Öckinger, 2008)). Instead, the most obvious difference in species composition is that some species associated with moist grassland types, e.g. *Anthocharis cardamines*, *Boloria selene* and *B. ino*, are missing from the urban sites. The reason for the relatively similar diversity patterns in the urban and agricultural areas is probably that the small grassland fragments in the surrounding landscape already contain a rather impoverished fauna and a low proportion of uncommon species compared to similar grasslands in landscapes with less intensive agriculture (Öckinger and Smith, 2006).

5. Conclusions

Our study demonstrates two important issues in urban biodiversity. First, we show that both habitat type and the composition of the surrounding landscape (or townscape) affect local butterfly species richness, as has been demonstrated in other landscape and habitat types (Wettstein and Schmid, 1999; Öckinger and Smith, 2006). This has implications for urban planning. If the aim is to maximize biodiversity in urban habitats, it is more efficient to concentrate those areas managed for biodiversity spatially. Second, we demonstrate that, at least in regions dominated by intensive land use, cities can contain a relatively high biodiversity and conservation value. The fact that the nationally red-listed (Gärdenfors, 2005) *Z. filipendulae* was so abundant and widespread in the city is a good example of this. This is especially true for the ruderal sites in the city, which contained similar number of butterfly species as did semi-natural grassland sites in the agricultural region surrounding the city. The ruderal sites contain are also important because they represent a habitat in an early-successional stage, and species associated with this kind of habitat are decreasing in many regions (Öckinger et al., 2006b; Kadlec et al., 2008). In terms of management and urban planning, our study shows that ruderal sites have a high value for urban biodiversity and it may be more beneficial to leave ruderal sites unmanaged than to try to manage urban and suburban parks for biodiversity.

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