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Microhabitat preferences of *Maculinea teleius* (Lepidoptera: Lycaenidae) in a mosaic landscape

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Abstract. The Scarce Large Blue (*Maculinea teleius*) is an endangered butterfly throughout Europe due to its special life-cycle and habitat loss. Our aims were to describe the microhabitats available to this butterfly, to test what factors influence the presence and density of *M. teleius* adults and to investigate the relationship between host ant species and *M. teleius*. The vicinities of eight fens were sampled, where there are four types of microhabitats available for this butterfly: Narrowleaf Cattail (*Typha angustifolia*), Purple Loosestrife (*Lythrum salicaria*), Marsh Woundwort (*Stachys palustris*) and Purple Moorgrass (*Molinia coerulea*) dominated vegetation. In five transects (50 × 5 m) around each fen (running from the edge of the fen into the meadows) the number of imagos was counted twice a day during the flight period. Along the transects, the following parameters were measured or assessed: number of flowerheads of foodplant (*Sanguisorba officinalis*), microhabitat type, grazing intensity, soil humidity, vegetation height and host ant presence. The four microhabitat types differed significantly in soil humidity, vegetation height, foodplant density and distance from a fen. Generally the Typha microhabitat, situated closest to fens, had the highest soil humidity and vegetation height, followed by the Lythrum, Stachys and finally the Molinia microhabitat along a gradient decreasing soil humidity and vegetation height. The foodplant was most abundant in the Lythrum and Stachys microhabitats. Using linear mixed models and forward stepwise manual selection we found that microhabitat type was the most important factor determining the presence of *M. teleius*. The local grazing intensity had no direct effect but flowerheads of the foodplant had a positive effect on the abundance of butterflies. The number of butterflies was significantly higher in quadrats where the host ant (*Myrmica scabrinodis*) was present compared to those where they were absent. Our results suggest that grazing should be continued in order to maintain the current distribution of microhabitats and survival of the butterflies.

INTRODUCTION

Wet meadows are among the most important habitats of threatened butterflies in Europe (Kühn et al., 2005). More than half of the Hungarian Prime Butterfly Areas (PBA) are wet meadows (Van Swaay & Warren, 2003). It is now widely demonstrated that agricultural intensification (e.g. intense grazing, land drainage or improvement of grasslands) reduces the diversity and abundance of butterflies associated with extensively managed wet meadows (e.g. Van Swaay & Warren, 1999; Konvička et al., 2003; Zimmermann et al., 2005). Furthermore, as a result of changes in human land-use, the extensively managed semi-natural meadows have become increasingly fragmented (Kéry et al., 2001). In semi-natural habitats, vegetation structure, habitat features, such as microhabitat factors or management (grazing, mowing) and even ecological processes (e.g. the relationship between butterflies and ants) are important elements in determining the distribution of butterflies (Ravenscroft, 1994; Witek et al., 2006).

Maculinea butterflies are among the most intensively studied butterfly conservation model systems due to their special life cycle, endangered condition and because it is widely recognised that they are sensitive indicators of environmental change (New et al., 1995; Settele et al., 2005). Our study species, the Scarce Large Blue (*Maculinea teleius*, Bergsträsser, 1779), is an endangered butterfly throughout Europe (Van Swaay & Warren, 2003). Threats such as abandonment of traditional agriculture and habitat loss endanger the species in Hungary, although there are still several large populations (Bálint, 1991; Van Swaay & Warren, 2003). *M. teleius* breeds in wet meadows and oviposits in the flowerheads of its foodplant, Great Burnet (*Sanguisorba officinalis*). Therefore the butterfly's distribution strongly depends on the distribution of the host plant (Thomas, 1984). The species is obligately myrmecophilous (Thomas et al., 1989), the host ant species in the study area is *Myrmica scabrinodis* (Ylander, 1846) (Tartally & Csősz, 2004; Csősz et al., unpubl.). Young caterpillars – after developing to the final larval stage in the flowerheads of Great Burnet – are adopted by their host ants (Thomas, 1984). In the ant nests the caterpillars live as social parasites, i.e. prey on the ant brood until they complete their development the following year.

Figurny & Woyciechowski (1998) observed that *M. teleius*, in contrast to the sympatric species *M. nausithous* (Bergsträsser, 1779), oviposits on the younger and shorter flowerheads that are closer to the ground and have fewer flowers. However, the abundance of flowerheads at an appropriate stage of developement can be greatly affected by management (Johst et al., 2006). The habitat requirements of the early stages (eggs or larvae) are usually nar-

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rower and more specialised than that of the imago, so these stages determine the distribution of the butterfly (Ellis, 2003). Therefore, it is only when the niches of foodplant and host ant overlap that *Maculinea* populations persist, i.e. sufficient eggs must be laid within the foraging range of its host *Myrmica* colonies (Thomas et al., 1998).

We selected extensively grazed pastures around eight closely adjoining fens on the Hungarian Great Plain. The surrounding of each fen is characterised by a mosaic of swamp meadows, calcareous purple moorgrass meadows and salt steppes, which host different subpopulations of *M. teleius* (Kőrösi et al., unpubl.). Our aims were to describe the microhabitats available for the butterfly around the fens, to determine the factors that influence the presence and density of *M. teleius* and finally to investigate the relationship between host ant species and *M. teleius*.

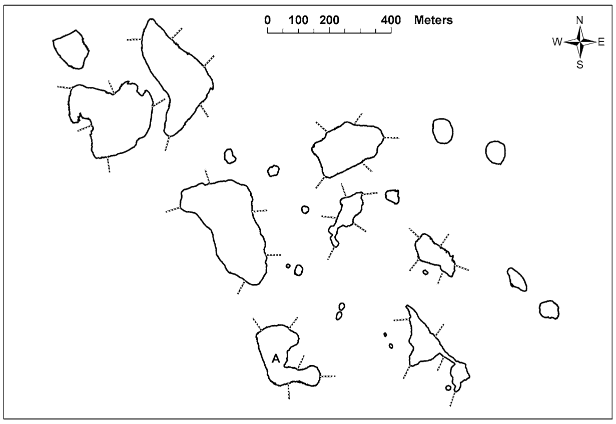

Fig. 1. Map of the study area. The fens are outlined by black lines, while the dashed lines indicate the transects. In the middle of the bottom part of the map is the most heavily populated fen (fen "A").

MATERIAL AND METHODS

The study area is situated at Kunpeszér, on the Hungarian Great Plain (Central Hungary, Kiskunság National Park). In the study area the mean annual temperature is about 10.3°C and mean annual precipitation about 520 mm. This large area (some hundreds of hectares) is a mosaic of fens and meadows. The patchiness of the area is due to the variation in local topography affecting soil humidity. Fens, situated in the most humid and deepest depressions, are characterised by willow bushes and reed and are not suitable habitats for this butterfly. Eight fens of a comparable size were selected (mean = 2.8 ha, range = 0.8–5.4 ha). Around them four types of microhabitat were available for this butterfly: vegetation dominated by Narrowleaf Cattail (*Typha angustifolia*, hence Typha microhabitat), by Purple Loosestrife (*Lythrum salicaria*, Lythrum microhabitat), by Marsh Woundwort (*Stachys palustris*, Stachys microhabitat) and by Purple Moorgrass (*Molinia coerulea*, Molinia microhabitat). The study area had been grazed by cattle for at least 5 years from early spring until late autumn. The cattle density was about 0.3 cows per hectare, and the grasslands were never fertilised or treated with pesticides.

Five 50 m long and 5 m wide transects were laid out at each marshland fen, from the edge of the fen perpendicularly outwards to the meadows and as far as possible from each other (Fig. 1). Transects were divided into ten 5 × 5 m quadrats (400 quadrats in total). The number of *M. teleius* individuals was recorded in each quadrat by walking along each transect in 2 minutes, usually twice a day (when weather conditions allowed) during the flight period from 31st of July to 25th of August in 2005, i.e. altogether 28 times. Observations on butterflies were carried out on relatively sunny, calm days, the first from 9:00 a.m. in the morning and second in the afternoon up to 4:00 p.m. Parallel to this study the basic population parameters of *M. teleius* were surveyed at the most populated fen (fen "A", see Fig. 1) using the MRR method. The daily number of individuals was about 500–700 and the population at fen "A" was around 2000 individuals, which means that the whole study area could support several thousands butterflies (Örvössy et al., unpubl.).

During the flight period we measured or assessed some local factors in the quadrats, which might be in association with the presence and density of the study species. We counted the number of foodplant flowerheads, measured soil humidity and vegetation height, and classified microhabitat type and grazing intensity in every quadrat. Soil humidity was based on a measure of the electrical conductivity at the end of the flight period. Vegetation height was measured at five random points in each quadrat and means of these measurements were used in the analyses. Grazing intensity was classified as absent, light or strong, based on the incidence of chewing and trampling. Furthermore, pitfall traps containing glycol were used to detect the presence of host ant species. One trap was placed in every second quadrat for two weeks shortly after the flight period. Thirty-two of the traps were lost due to trampling by cattle.

Since the species was not present in 209 quadrats, a logistic regression analysis was used to determine the relationship between presence of butterflies and explanatory variables. A nested design was used with transects nested within fens and quadrats within transects. A forward manual stepwise selection was made, and the null model had the presence-absence of the butterfly as the dependent variable, the number of foodplant flowerheads as the first covariate and fen and transect as random factors. Then, one by one all variables (soil humidity, grazing category, microhabitat type and vegetation height) were added until the best model was obtained (one with the smallest AIC value). Further, we took into account that the quadrats within a transect probably are not correlated equally with each other. Therefore, a correlation between the quadrats was built into the models, which were nested in transects. In this way it was possible to avoid edge effects causing bias in the models.

In the case of fen "A", where the most butterflies were observed, a linear regression analysis was carried out. The $\log_{10}$ transformation of the number of butterflies observed per quadrat was the dependent variable. In addition, the null model contained the number of foodplant flowerhead as the first covariate, the transect as a random factor and the above described correlation. Then the same forward manual stepwise selection procedure was applied as in the case of the logistic regression.

The comparisons between microhabitat types and distance from the fen, soil humidity, foodplant flowerhead density and vegetation height were tested using the Kruskal-Wallis test. The relationship between the number of *Maculinea teleius* and *Myrmica scabrinodis* was analysed using a Mann-Whitney test. All statistical analyses were performed using R software packages (R Development Core Team, 2004).

RESULTS

The position of the microhabitat types depends on the distance from the fen, usually in the order Typha microhabitat (edge of the fen), Lythrum microhabitat, Stachys

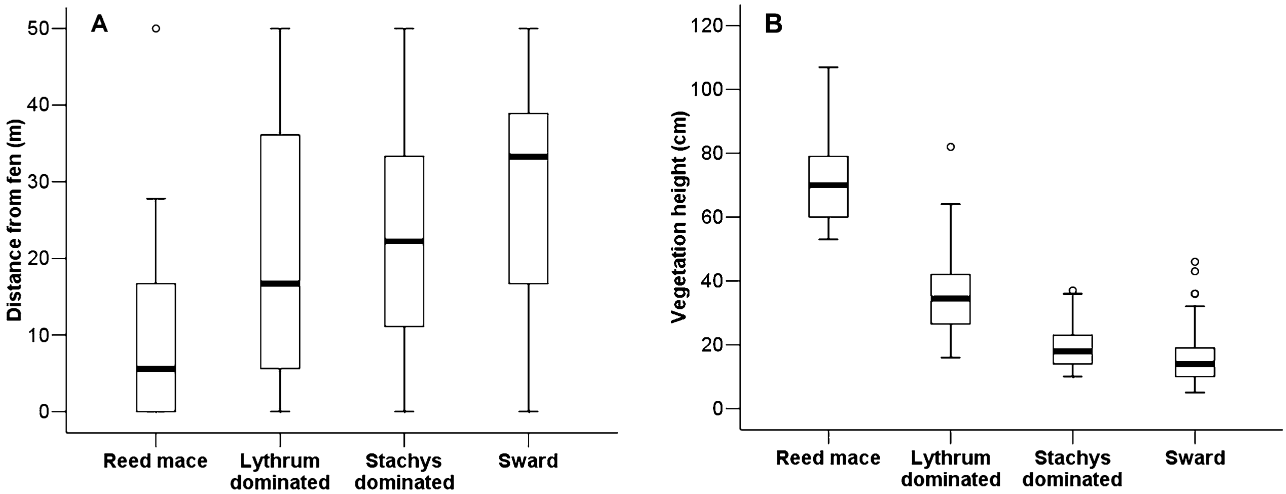

Fig. 2. Medians, quartiles and ranges of the four microhabitat types in terms of distance from a fen (A) and vegetation height (B). The circles indicate outliers.

microhabitat and Molinia microhabitat, furthest from the fen (Fig. 2a). This distribution is not a rigid one, as some of the microhabitats may not be present or not in this order. There are significant differences in the distances of four microhabitats from the edge of the fens (Kruskal-Wallis test; $\chi^2 = 55.2$, d.f. = 3, $p < 0.001$). This is due to differences in topography and soil humidity. There are significant differences in soil humidity (Kruskal-Wallis test; $\chi^2 = 176.6$, d.f. = 3, $p < 0.001$) and vegetation height among microhabitats ($\chi^2 = 235.4$, d.f. = 3, $p < 0.001$). The highest vegetation was at the edges of fens and declined along the transects as microhabitat types changed (Fig. 2b). The foodplant flowerhead density was significantly higher in the Lythrum and Stachys than in Typha and Molinia microhabitats ($\chi^2 = 62.1$, d.f. = 3, $p < 0.001$).

The best nested logistic regression model showed a significant effect for microhabitat type, but no effect of foodplant or grazing (Table 1). *M. teleius* seemed to prefer Stachys and Molinia microhabitats, where the butterfly was recorded in more of the quadrats, than in the Lythrum and Typha microhabitats, which were much less preferred (Fig. 3).

Altogether, there were obtained 553 individual sightings of butterflies, 290 were at the most populated fen (fen "A"). In the best linear regression model butterfly abundance was affected significantly by the number of foodplant flowerheads but not by grazing (Table 1). The abundance of *M. teleius* increased with the number of flowerheads (Table 1, Fig. 4).

Over the whole area the number of *M. teleius* was significantly higher in quadrats where host ants (*Myrmica scabrinodis*) were present compared to quadrats lacking the host ant (Mann-Whitney test, U = 2612.5, p = 0.003).

DISCUSSION

In this study microhabitat type was the most important factor determining the presence of *M. teleius* imagos in a large mosaic landscape (Stachys microhabitats were the most preferred), whereas at the most populated fen, only the density of foodplant flowerheads influenced the abundance of butterflies. However, the foodplant density was different in the microhabitats, the highest density occurred in Stachys and Lythrum microhabitats. This also means that the drier and shorter Molinia microhabitats, which were generally furthest from the fens and the wetter and higher Typha microhabitats close to the fens probably simply act as a matrix for the butterflies. Thomas & Elmes (2001) found that the foodplants preferred by *M. teleius* were most abundant in short (0–30 cm) vegetation in France and Poland. This is similar to our results, as in the Stachys microhabitat the range in vegetation height was 10–36 cm for the whole area, while at the fen "A" it was 16–34 cm and in the Lythrum microhabitat 22–44 cm. So this butterfly species seems to have similar vegetation height requirements in this region as in

TABLE 1. Effects of foodplant flowerhead density, grazing, microhabitat type, soil humidity and vegetation height on the presence (logistic regression) and abundance (linear regression) of *M. teleius* based on the transect counting method. The best models, after forward manual stepwise model selection do not contain all the explanatory variables. The results for the logistic regression were derived from all 40 transects at the eight fens, while the linear regression used only the data for the fen where the butterflies were most frequently recorded. Variance components of the logistic and linear regression models: random effect = 0.780, residuals = 0.934; random effect = 0.262, residuals = 0.271.

	Logistic regression				Linear regression			
	numDF	denDF	F	p	numDF	denDF	F	p
Foodplant flowerhead	1	354	0.008	0.928	1	42	10.956	0.002
Grazing	2	354	1.229	0.294	1	42	1.018	0.370
Microhabitat type	3	354	2.846	0.038				

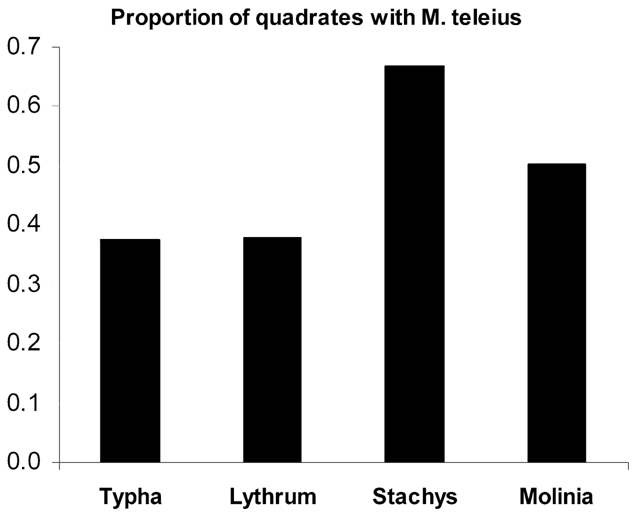

Fig. 3. Proportion of quadrats on each of the four microhabitats in the whole study area where *M. teleius* was present.

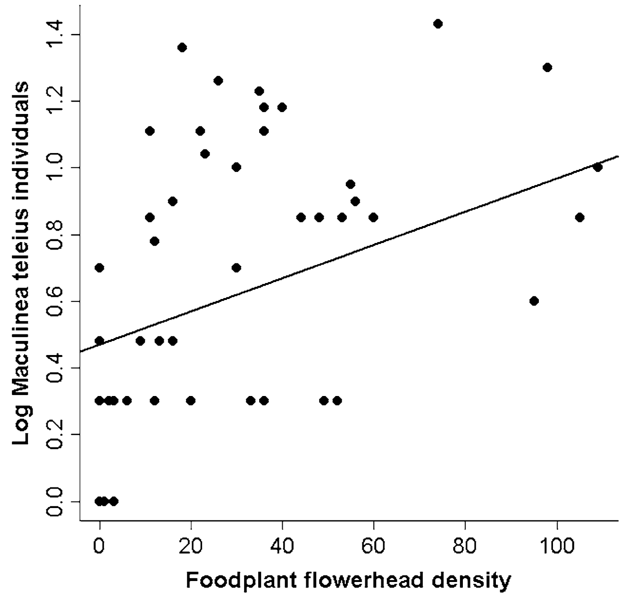

Fig. 4. Relationship between number of foodplant flowerheads per quadrate and the logarithm of *M. teleius* abundance at the most heavily populated fen. The solid line represents the fixed effect of the linear mixed model.

other parts of Europe. Furthermore, with increase in foodplant density the abundance of butterflies increased at the most populated fen. In contrast to our result, which comes from one fen, Nowicki et al. (2005a) found that at a metapopulation level foodplant density limits the abundance of *M. alcon* [(Denis & Schiffermüller), 1775], but not that of *M. teleius* and *M. nausithous*, while Loritz & Settele (2005) showed that foodplant availability affects *M. nausithous* occupancy. Furthermore, Anton et al. (2005) showed that the density of *M. nausithous* is positively correlated with the density of its host ant *M. rubra* (L., 1758), but not with that of its foodplant *S. officinalis*. Our result can be explained by butterflies occurring mainly at those sites where their foodplants are abundant. However, microenvironmental factors (e.g. soil humidity) determine foodplant abundance and type of microhabitat, so microenvironmental factors and microhabitat types probably have direct and indirect effects on the butterfly.

For the conservation of endangered species, it is important to maintain the quality of this remaining habitats (Maes et al., 2004; WallisDeVries, 2004, Johst et al., 2006). The present study did not indicate that local grazing intensity had a direct effect on butterfly occurrence or abundance. We did not compare sites with different grazing intensity or regimes as in other studies (e.g. Griebeler & Seitz, 2002; WallisDeVries, 2004), because the whole area was subject to the same management, but measured grazing by means of indicators of chewing and trampling by cattle. However, the low grazing pressure recorded is probably adequate management for this study site. Therefore, like others (Thomas, 1990; Griebeler & Seitz, 2002), we also think that grazing results in a particular vegetation height and cover of grassland favourable for the butterfly and especially its host ants.

Van Dyck et al. (2000) concluded that host-ant nests (either directly or indirectly) could influence oviposition in *M. alcon*. Thomas & Elmes (2001) did not accept that *M. alcon* can detect ant nests before oviposition. The fact that there was not an ant trap in each quadrat prevented the inclusion of host ant presence in the models and so it was only possible to test separately the relationship between host ant presence and *M. teleius* abundance. Though butterfly abundance was significantly higher in quadrats in which the host ant was present, this study is too limited to decide if this butterfly is directly or indirectly affected by the presence of host ants. But we draw attention to the fact that lower host ant density can increase the risk of local extinction (Thomas, 1994). However, most studies do not find a significant relationship between host ant presence and abundance of *Maculinea* imagos or eggs (e.g. Bonelli et al., 2005; Musche et al., 2005; Nowicki et al., 2005b; Prondvai et al., 2005; but see Anton et al., 2005; Glinka & Settele, 2005).

The implication for conservation is that grazing should be continued in order to maintain the current distribution of microhabitats. However, it must be emphasised that the grazing intensity in this study was about 0.3 cattle/ha, which is lower than the scheme prescribed in the current Hungarian Agri-Environment Program (0.5–1.2 cattle/ha depending on pasture productivity, Ángyán et al., 2003).

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