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Spatial ecology and habitat selection of Little Owl *Athene noctua* during the breeding season in Central European farmland

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Summary

Information on habitat requirements and spatial ecology is vital in conservation strategies and management of particular species. Little Owl *Athene noctua* is a highly threatened owl species whose populations have significantly decreased or are locally extinct in many European countries. In this study we report on spatial ecology and habitat selection of Little Owls during their breeding season in an agricultural landscape and discuss key management actions for its conservation. The mean home range size of radio-tracked Little Owls, determined by the kernel method, was 0.94 ha (SD = 0.95, 0.24–2.72 ha) and 4.30 ha (SD = 3.75, 0.88–11.70 ha) for 50% and 95% home range, respectively. The smallest home ranges were recorded in April–June (incubation and nesting period) with a significant increase in July–August (fledging season). The most important foraging habitat during the entire breeding season was grassland (especially pastures) reaching 90% for all locations. Vegetation height and cover were the main factors determining habitat selection: Little Owls significantly preferred sparse and short sward vegetation patches that enabled hunting of ground-dwelling prey. Conservation efforts for Little Owls should focus on the active management of prey-rich grassland habitats in the vicinity of breeding sites.

Introduction

The Little Owl *Athene noctua* is a farmland bird species that has experienced one of the steepest population declines across its entire European range during the last 60 years, when its distribution became highly fragmented and several populations became locally extinct (Cramp 1985, Tucker and Heath 1994, van Nieuwenhuyse *et al.* 2008). In the Czech Republic, the Little Owl is an endangered species that suffered a population decrease of 59% between 1985 and 2003 (Št'astný *et al.* 2006) and this negative trend still continues (Šálek and Schröpfer 2009). Due to the severe population loss of Little Owls, their protection should be treated as a high conservation priority.

The reasons for the marked decline are discussed in the literature and connected with several factors that include habitat destruction due to agricultural intensification (Cramp 1985, Schönn *et al.* 1991, Šálek and Berec 2001), harsh winters (Cramp 1985, Schönn *et al.* 1991, Bauer and Berthold 1996), predation by stone martens *Martes foina* (Luder and Stange 2001, van Nieuwenhuyse *et al.* 2008), disappearance of suitable nesting places (Exo 1983), road mortality (Exo and Hennes 1980, Hernandez 1988, Génot 1995), deaths in water reservoirs, air shafts and chimneys (Génot 1995, Bauer and Berthold 1996), contamination by biocides (van den Bring *et al.* 2003, Zaccaroni *et al.* 2003) and direct human interference (Schönn *et al.* 1991). Analysis of mortality of adult Little Owls shows two distinct peaks: a winter peak associated with severe winters that had long-standing snow cover and a summer peak connected with exhaustion of birds after the breeding season (Exo 1988, Šálek 2004). During the breeding season, birds expend

a high amount of energy in nourishing themselves and their offspring (energetic stress) and consequently reach the lowest body mass levels in comparison with other periods of their life cycle (Exo 1988, Gassmann and Bäumer 1993). Similarly, body mass of females before the incubation period is closely correlated with total breeding success (Gassmann and Bäumer 1993).

Home range size of long-lived sedentary birds should encompass enough feeding sites and adequate resources during the whole year to assure their survival (Newton 1979). Animals that occupy territories with a high availability of preferred foraging habitats have smaller home ranges which should affect reproductive and survival rates (Newton 1979). Some researchers indicate that grassland habitats such as pastures and mown hay fields are particularly important for Little Owls because they offer a continuous food supply, especially insects, earthworms and rodents, almost all year round (Finck 1990, Schmid 2003, Thorup *et al.* 2010). Orf (2001) recorded that the Little Owl`s home range reached 20.3 ha in grassland habitats and 74.8 ha in arable land. Furthermore, meadows and pastures were over-represented in home ranges of radio-tracked Little Owls in north-east France (Génot and Wilhelm 1993).

In the Czech Republic, the Little Owl occurs in localities that have a significantly larger proportion of grasslands, and are situated at lower altitudes, in an agricultural landscape (Šálek and Schröpfer 2008). The results indicate that the availability of short-sward grassland patches in Little Owl territories could be a limiting factor to their persistence in Central European farmlands, but information about detailed habitat utilisation during the breeding season is still missing. The goals of this study were to gain knowledge of spatial ecology and habitat selection of radio-tracked Little Owls during the breeding season and to determine the major management actions that would assure its successful conservation.

Methods

Study area

This study was carried out in five villages occupied by the Little Owl in western Bohemia, south-west of the city of Plzeň, Czech Republic, within a 50 km^2 area of agricultural landscape (49.40°N, 13.9°E; 350–486 m asl). These sites were chosen based on previous research on the distribution of Little Owls, with a minimal distance between adjacent sites of 2.3 km (average = 3.9 km). In this study area, Little Owls nest in artificial cavities, especially brick pigeon-lofts in old buildings, and its population density reaches 2.9 pairs/10 km^2 (Šálek 2004). The study area typically consists of intensely managed fields (45%), forests (32%) and grassland patches (10%). The grasslands are dominated by species of *Festuca*, *Phleum Trisetum*, *Alopecurus* and *Lolium*, among many others.

Radio-tracking survey and determination of vegetation characteristics

Data on foraging habitat preferences were gathered by radio-telemetry, carried out during the breeding season in 2002. Adult Little Owls were caught in a mist-net using a dummy combined with a territorial call played from a tape-recorder near the nests before the monitoring period (at the beginning of March). Birds were equipped with "back-pack" transmitters (Biotrack TW 4, 3.5 g; battery lifespan of up to 8.5 months). A three-piece Yaggi aerial and an ICOM R-10 wideband receiver were used to locate the individuals. Accurate geographical locations of radio-tracked Little Owls were assessed by triangulation from at least two locations every 15 minutes and were drawn on to 1:5,000 maps. Telemetry fieldwork was carried out during favourable meteorological conditions at intervals from one hour after dusk to one hour after midnight, which coincides with the period of highest foraging activity in Little Owls (Exo 1989, Fajardo *et al.* 1998).

In April, five adult male Little Owls were radio-tagged near their breeding sites. Additional tagging was also conducted in May when we equipped one female and two full-grown individuals with radio transmitters, however both young were predated by stone marten *Martes foina* during the first week and these data were not included in further analysis. To assess habitat preferences,

we randomly selected the same number of control locations within Little Owl home ranges. Spatial ecology of Little Owls was recorded during three phases of the breeding period (see also Finck 1990, Grzywaczewski 2009) including: incubation (15 April–17 May), nesting (18 May–28 June) and fledging period (29 June–22 August), which coincide with breeding timing of owls in our study area (J. Hruška unpubl. data).

For each habitat type surrounding Little Owl territory, we assessed the two main vegetation characteristics for each 14-day period: (1) Average vegetation height (AVH) – average height of vegetation measured by tape measure (in centimetres) and (2) Vegetation cover (VC) - estimated as percentage of ground that was covered with vegetation.

Analysis of radio telemetry data and habitat selection

Complete home ranges were defined as 100% minimum convex polygons (MCP). For more precise home range assessment and variation during the breeding season, the kernel density estimator was used (Worton 1989) and 95% and 50% kernels were calculated. All home range analysis was performed with the ABODE Kernel Home Range extension for ArcGIS 9.3 (Laver 2005). Criteria for estimating home-range size were as follows: kernel - fixed bivariate; bandwidth selection: least-square cross-validation method; grid resolution – resolution 100 (see Laver 2005 for more details). Flying distances of Little Owls from nesting/roosting sites to foraging areas were determined by measuring distances in Geoportal COSMC (http://www.geoportal.cz).

For the purposes of habitat selection of the Little Owl, we divided our study area into nine main groups on the basis of ortho-photo-maps using ArcGIS software: fields, forests, tall vegetation, buildings, roads, meadows, pastures, lawns and gardens. Compositional analysis (Aebischer *et al.* 1993) was used to test Little Owl habitat selection at two scale levels: (1) habitat composition within home range was compared to habitat availability in the total study area, and (2) the proportion of habitat used based on number of radio locations compared to habitat availability within the home range. Because compositional analysis is sensitive to the number of habitats (Aebischer *et al.* 1993), we joined all grassland habitats (meadows, pastures/lawns, gardens) into one group and analysed these as one habitat type.

Statistical analyses

Generalised linear mixed effect models (GLMM; lme4 package for the R statistical package) were used to evaluate the effect of progress of the breeding season (particular months, see above) on the size of the home range of the Little Owls. A logarithmic transformation of the entry dataset was used. The GLMM statistic was also applied to data of habitat characteristics preferences of Little Owls. The suitability of each model was assessed on the basis of the minimal AIC criteria, where the best model has the smallest AIC. The individual animal was treated as a factor with random effect to avoid pseudo-replications. All tests were performed in R statistical package (R Development Core Team 2009). The R statistical package was used to compute compositional analysis of habitat selection (see above). We used a randomisation test with 500 repetitions. Habitat that was not found within the particular home range (zero values in entry data matrix) was replaced by 0.01 (see Aebischer *et al.* 1993).

Results

Home range size

In total, we recorded 667 locations from five males and one female radio-tracked Little Owls which were used to determine the home range size and detail habitat use during the breeding season. During the five months of research we lost radio contact with three male Little Owls in the third (M1, M3) and fourth (M4) month of the radio-tracking. The mean home range size differed according to the method used (Table 1). The MCP home ranges were larger than those determined by the kernel

Table 1. Total home range size (ha) of individual radio-tracked Little Owls during breeding season in western Bohemia, Czech Republic (MCP, Kernel UD method, CI – 95% confidence intervals).

Bird	100% MCP (ha)	95 Kernel UD (ha)	50 Kernel UD (ha)
M1	0.55	0.48	0.12
F1	16.55	7.99	2.01
M2	6.25	1.91	0.39
M3	6.86	3.34	0.73
M4	11.87	4.87	1.03
M5	11.89	2.15	0.31
Mean ± SD	9.50 ± 6.03	3.46 ± 2.66	0.77 ± 0.69
CI	3.50-13.75	1.66-6.54	0.43-1.69

method ($n = 6$). Both the 95% and 50% home ranges varied significantly with the progress of the breeding season (Table 2). The smallest home ranges were recorded during April–June (incubation and nesting period), which expanded during July–August (fledging season; for time division of the breeding season see Methods; Figure 1).

The same pattern was obvious when flying distances from nest/roosting sites were compared during the breeding season (Figure 2). In April, the mean distance from roosts was 64.8 m ($n = 84$); this increased uniformly during the season up to 211.5 m in August ($n = 101$). Mean flying distance to the foraging area during the whole breeding season was 106.6 m ($n = 667$).

Selection of home range

Habitat composition of home ranges was assessed for 95% kernels. Little Owls slightly preferred certain habitats over others when they established their home ranges within the study area (compositional analysis 1: Wilk's $\lambda = 0.004$, $P = 0.06$). The two most preferred habitat types were those associated with human settlement, such as buildings and roads. Forest habitat was avoided.

Selection of habitats within the home range

Utilisation of habitats within the home-ranges differed only marginally significantly from habitat availability (compositional analysis 2: Wilk's $\lambda = 0.001$, $P = 0.068$, Figure 3A). Within the home ranges, grassland habitats and roads were two the most preferred habitat types and buildings the most avoided (Figure 3B).

Variation of habitat use during the breeding season

Utilisation and availability of different habitat types in home ranges changed markedly during the breeding season (Figure 4). In April, Little Owls predominantly hunted in gardens, whereas from

Table 2. Variability of home range (HR) size during the course of the whole breeding period (Generalised linear mixed effect models with Gaussian distribution, log-transformed HR size).

Explained variability	Model	df	χ^2	P
HR 95 size	1. Null (individual variability only)	3		
	2. Effect of month	4	12.1	< 0.0001
HR 50 size	1.Null (individual variability only)	3		
	2. Effect of month	4	10.6	< 0.001

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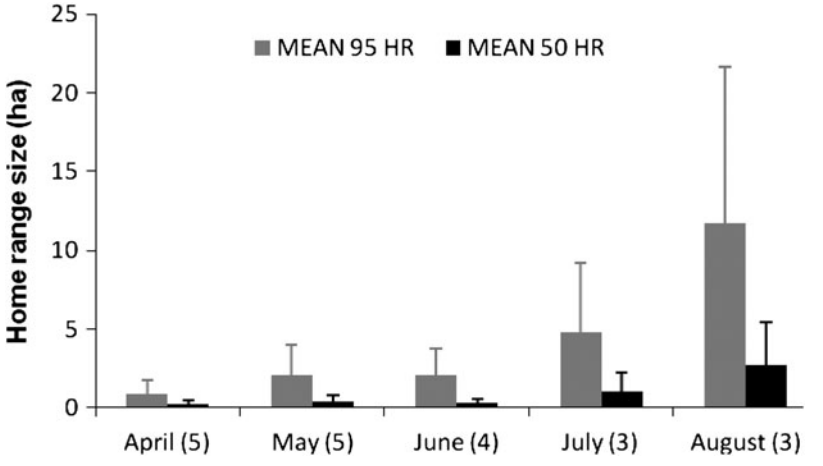

Figure 1. 95% and 50% kernel home ranges (ha) of radio-tracked Little Owls during the breeding season in western Bohemia, Czech Republic (means ± SD presented; numbers in parentheses indicate the number of owls monitored each month).

May to July they preferred short-sward pastures or lawns. Total utilisation of grassland habitats (pastures/lawns, meadows and gardens) was highest during the nesting and fledging periods (June) and reached up to 90% of all locations, while later in the fledging period (August) these areas were represented less and decreased to 51%.

Factors determining habitat use

Two factors, mean vegetation height (AVH) and vegetation cover (VC) were tested for their influence on the selection of foraging habitats of Little Owls. Both vegetation characteristics showed

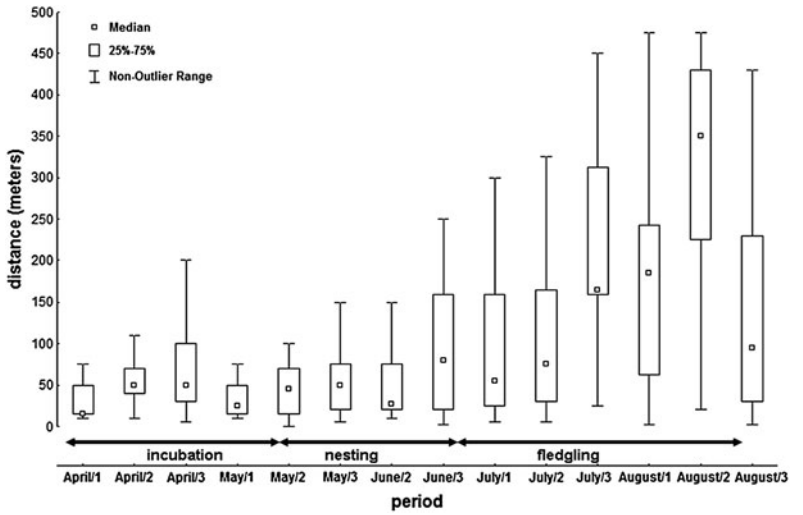

Figure 2. Changes in flight distance to foraging grounds (habitats) from roosting/nest sites of radio-tagged Little Owls during the breeding season (n = 667).

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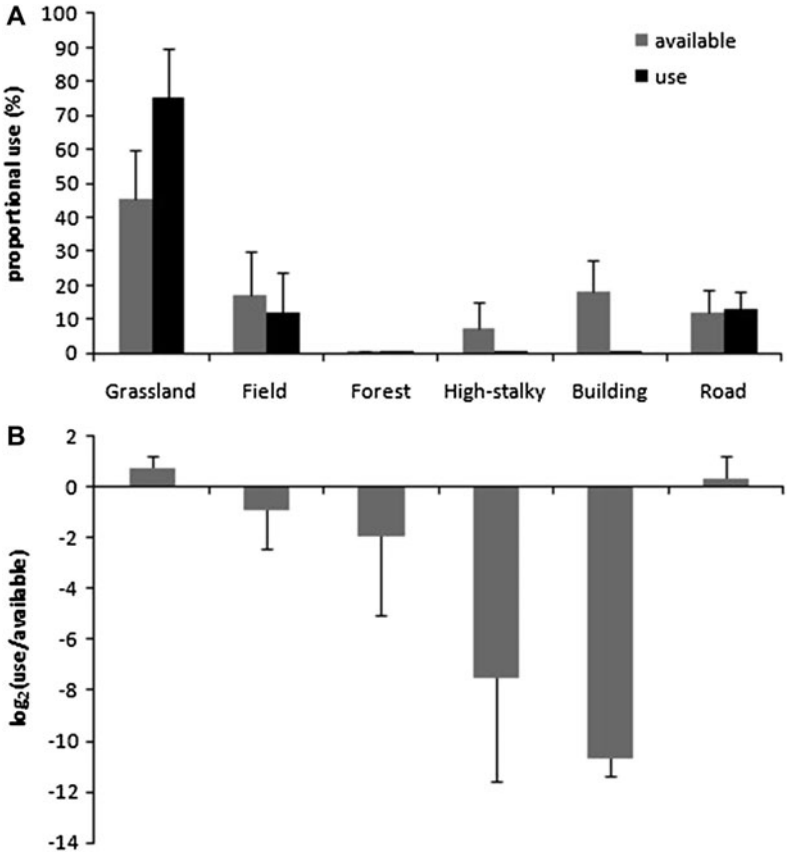

Figure 3. Habitat characteristics of home ranges of radio-tracked Little Owls and their hunting preferences: (A) habitat use (black bars) compared to availability of habitats (grey bars) within Little Owl home-ranges and (B) habitat selection on the basis of the same data (indexed as $\log_2$[use/availability]). Means ± SD are presented.

a significant relationship with Little Owl hunting preferences (Table 3). Average vegetation height of Little Owl foraging sites during the breeding season was 4.7 cm (SD = 5.9, n = 667) and total vegetation cover was 51.0% (SD = 34.6, n = 667), in contrast with 31.6 cm and 82.8% respectively in control locations. This pattern held consistently during the whole breeding season (Table 3). Little Owls predominantly hunted from elevated perches (87%), such as trees, poles and buildings that were on average 4.5 m above ground. In August they shifted their foraging activity to cereal fields after stubble ploughing and hunted on the ground (13%).

Discussion

Spatial ecology and habitat requirements are crucial aspects of the biology of a species, and as such they may contribute greatly to conservation strategies and management (see e.g. Newton 1979). The Little Owl is mainly a sedentary, ground-hunting predator with high site fidelity to year-round territories (Exo 1992, van Nieuwenhuyse *et al.* 2008). Our study focused on habitat use of Little Owls during the critical period, the breeding season, when birds reach their lowest body mass level during the year (Exo 1988, Gassmann and Bäumer 1993). Home range size during the

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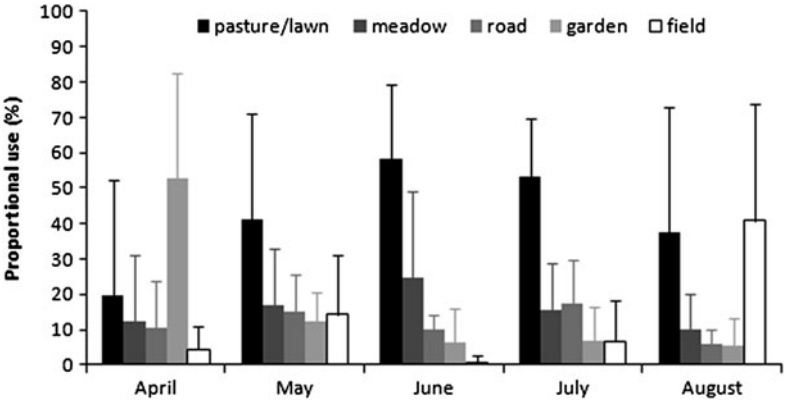

Figure 4. Seasonal differences in habitat use of radio-tagged Little Owls during the breeding season in western Bohemia, Czech Republic. Means ± SD are presented.

breeding season is influenced by many factors such as habitat structure and distribution of available food resources (McNab 1963, Jenkins 1981, Mace and Harvey 1983), which have to provide sufficient energy supplies for owls and their offspring. The mean home range size of 9.0 ha (MCP method) shown in our results is considerably smaller than those reported for Little Owls in other studies across Europe (range 14.5–41 ha; Exo 1991, Génot and Wilhelm 1993, Finck 1990, Sunde *et al.* 2009). Our study, however, focused on the breeding season where home ranges reach the smallest size during the whole year (Exo 1987, Génot and Wilhelm 1993). During the breeding season, Grzywaczewski (2009) reported mean home range size of 19.9 ha in an agricultural landscape and further noted that areas with more grassland habitats contained significantly smaller home ranges (see also Orf 2001). High proportion/availability of grassland habitats in Little Owl home range should explain the smaller sizes in our study area. Similarly Exo (1991) and Génot and Wilhelm (1993) documented that different types of grasslands were proportionally over-represented in Little Owl home ranges.

Our results show a gradual increase in home range size and flying distance to foraging sites during the breeding season. During the incubation period (April–May) the majority of foraging grounds have lower average vegetation height, which is the primary determining factor in habitat choice by Little Owls (see below and also in Šálek *et al.* 2010). The availability of short-sward vegetation patches in the vicinity of breeding sites rapidly decreased during the vegetative season and birds were thus forced to fly longer distances. Flying distances during the nesting period are, however, constrained due to the presence of offspring at the nest site. During the nesting and early fledging periods Little Owls significantly preferred mown hayfields, lawns and grazed pastures. Pastures are suitable for hunting as they contain short-sward vegetation throughout the breeding season (see also Finck 1990, Exo 1991). The rapid increase in home range size during the fledging season

Table 3. Factors affecting habitat use (on the basis of individual radio-fixes) of Little Owls during breeding season in western Bohemia (results of generalized linear mixed model, AVH = average vegetation height and VC = vegetation cover).

Variability explained: model	df	$\chi 2$	P
1. Habitat use: null, individual variability only	2		
2. Habitat use: effect of AVH	3	614.1	< 0.0001
3. Habitat use: effect of AVH + VC	4	26.4	< 0.0001
4. Habitat use: effect of AVH + VC + MONTH	8	31.2	< 0.0001

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(July–August) could be caused by harvesting of crop fields and subsequent stubble ploughing which offer ideal feeding conditions: high abundance of ground-dwelling beetles, the primary prey in our study area (Šálek *et al.* 2010), and bare ground (free access to hunting). The offspring, after leaving the nest site, remained in close vicinity of the foraging parents (Šálek pers. obs.) minimising their flight back to the nest. Finally, during the fledging season, male Little Owls reached their lowest level of aggressiveness and defended the smallest territory at any time during the year (Finck 1990).

Compositional analysis showed indicative preferences of Little Owls for buildings, roads and grasslands within their home ranges and an avoidance of forest and tall vegetation. The presence of buildings in Little Owl home ranges is connected with the availability of breeding sites. The majority of current Little Owl nest sites were found in man-made structures, especially agricultural objects and residential buildings (Šálek and Schröpfer 2008) and thus its recent distribution is concentrated around human settlements. Within home ranges, grassland patches are the most preferred habitat type, and together with roads and fields, they were visited significantly more than remaining habitat types. The importance of grassland was found in many previous studies in the Central European agricultural landscape (Loske 1986, Dalbeck *et al.* 1999, Šálek and Berec 2001). Similarly, our previous research has shown that localities occupied by Little Owls had a higher proportion of grassland than unoccupied localities (Šálek and Schröpfer 2008). The higher proportion of roads in the home range could be an important attribute of its territories in residential areas. Roads may be important alternative foraging grounds in periods when vegetation is higher in other habitat types (our results); however their utilisation may be associated with the risk of vehicle collisions (Exo and Hennes 1980, Hernandez 1988, Génot 1995).

Average vegetation height and cover were the major factors determining the habitat choice of Little Owls during the whole breeding season. In contrast to control locations, Little Owls significantly preferred sparse and short sward vegetation patches within their home ranges which provided access to ground-dwelling prey. In addition, Grzywaczewski (2009) found that Little Owls spent 80–95% of their time in short-sward vegetation patches. Although the importance of these structures for Little Owl foraging success is also cited in other studies (Exo 1991, Eick 2003, Schönn *et al.* 1991, Fajardo *et al.* 1998) as well as for many other farmland birds (Atkinson *et al.* 2004, Devereux *et al.* 2004), tall and dense vegetation patches may host a larger diversity and number of invertebrates and vertebrates (Dalbeck *et al.* 1999) and thus create "prey refuges" for the surrounding short-sward patches.

Management and conservation implications

Based on recorded data on the spatial ecology of the Little Owl during the breeding season it is obvious that active management has to be directed at the close vicinity of breeding sites. Short-sward grassland habitats, especially pastures with low and sparse vegetation cover, are the preferred habitat types of the Little Owl in their central European farmland territories (see also Exo 1988, Finck 1990, Šálek and Schröpfer 2008). If suitable patches with scattered and low sward vegetation are not present, owls are forced to forage in suboptimal or more distant sites, which can result in lower fitness of the adult birds and consequently higher mortality (Exo 1988, Thorup *et al.* 2010). High-quality home ranges of Little Owls consist of a high proportion of small grassland patches with regular grazing and mowing. Although the density of preferable prey (especially ground-dwelling insect) during the breeding season should be higher in patches with permanently tall vegetation, short-sward grassland habitats increase prey accessibility (Romanowski and Żmihorski 2008, Šálek *et al.* 2010), and its management should be highlighted for conservation of endangered Little Owls. Food limitation during breeding season is thought to be main factor explaining population decline of the Little Owl in Denmark (Thorup *et al.* 2010). Moreover, emphasis should be placed on the architecture and habitat structures of landscape elements within the Little Owl territory. The Little Owl prefers localities with higher number of small grassland plots over those with few large grasslands (Dalbeck *et al.* 1999). Furthermore, linear structures, poles and trees are

important as elevated hunting perches (Loske 1986, Dalbeck *et al.* 1999, Šálek 2004, this study). A fine-scale mosaic of different grassland patches and diverse spatio-temporal dynamics of mowing and grazing could thus provide suitable landscape characteristics and management actions for current populations. On the contrary, recent, most widespread agri-environmental management practices applied to grasslands are characterised by two cuts per year which lead to the homogenisation of grassland areas. Finally, due to the Little Owl's sedentary lifestyle (short distance dispersion of offspring, and high fidelity of adult individuals) future conservation planning and actions should be focused on occupied areas and their surroundings in order to support existing populations.

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