School of Doctoral Studies in Biological Sciences
University of South Bohemia in České Budějovice
Faculty of Science

The Ecology of the Little Owl in European Farmland

Ph.D. Thesis

Mgr. Monika Chrenková

Supervisor: Ing. Martin Šálek, Ph.D.
Institute of Vertebrate Biology, Czech Academy of Sciences, Brno
Faculty of Environmental Sciences, Czech University of Life Sciences Prague

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Annotation

The little owl population in the most of Europe is rapidly declining mainly due to dramatic changes and transformation of the agricultural landscape, which resulted in the loss of suitable foraging habitats. Due to rapid population decline and range contraction, urgent conservation measures have to be implemented to save the population from extinction in certain areas. The thesis aims were to identify long-term population trend in selected regions, to uncover the habitat selection of breeding birds and to evaluate the effectiveness of individual management measures for the little owl conservation in the European farmland. The research on population status in Czech Republic and Slovakia revealed long-term population decline and marked distributional range contraction of the little owl, documenting its rapid local extinctions over the last two decades. On the contrary, results from Hortobagy National Park, representing the first large-area systematic survey in Hungary, indicate high population density and its widespread distribution. In particular, the study uncovers one of the highest population densities of this species from an agricultural landscape in Central Europe. Further detailed investigation of habitat selection at three different scales shows the link between certain habitat characteristics and species occurrence and supports the hypothesis of agriculture intensification being the main driver of the population decline of little owl in the Central Europe. Finally, the thesis provides evidence on the effect of different conservation management measures on little owl population in Denmark, where the species is close to extinction. Research findings indicate that food limitation during the breeding season may be the main reason for the declining numbers of little owls in Denmark. To prevent little owl extinction, evidence based conservation measures, such as provision of suitable foraging habitats with high availability and good accessibility of prey close to nests, are inevitable.

Declaration

I hereby declare that I am the author of this dissertation and that I have used only those sources and literature detailed in the list of references.

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List of papers and author's contribution

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I. Šálek, M., **Chrenková, M.**, & Kipson, M. (2013). High population density of little owl (*Athene noctua*) in Hortobagy National Park, Hungary, Central Europe. *Polish Journal of Ecology*, 61: 165–169. (IF = 0.554).
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II. Šálek, M., **Chrenková, M.**, Dobrý, M., Kipson, M., Grill, S., & Václav, R. (2016). Scale-dependent habitat associations of a rapidly declining farmland predator, the Little Owl *Athene noctua*, in contrasting agricultural landscapes. *Agriculture, Ecosystems and Environment*, 224, 56–66. (IF = 4.099).
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III. Jacobsen, L.B., **Chrenková, M.**, Sunde, P., Šálek, M., & Thorup, K. (2016). Effects of food provisioning and habitat management on spatial behaviour of Little Owls during the breeding season. *Ornis Fennica*, 93: 121–129. (IF = 1.238).
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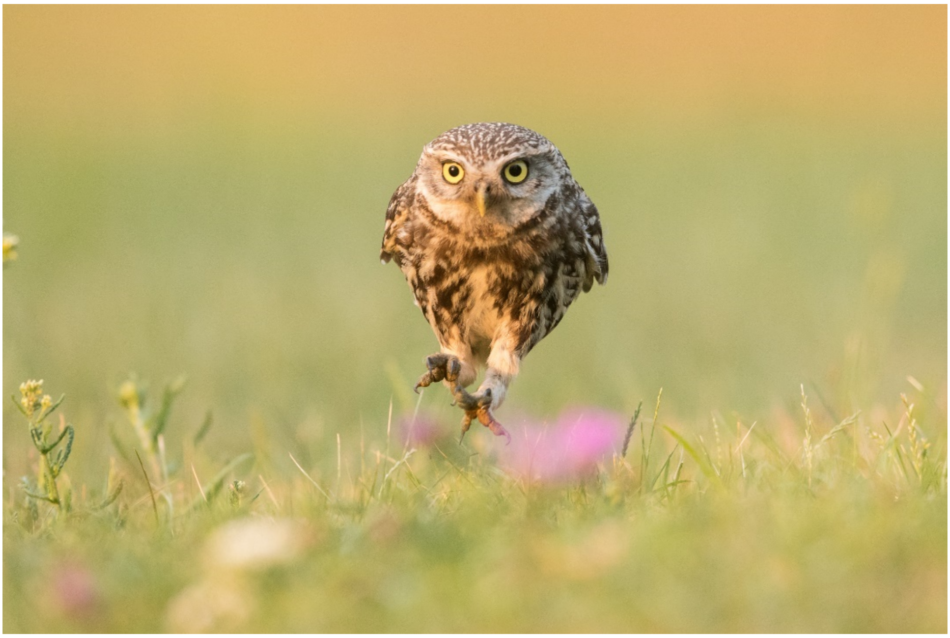
Contents

The Ecology of the Little Owl in European Farmland

CHAPTER 1

Introduction



Monika Chrenková, Ph.D. Thesis

1. Agricultural intensification and farmland biodiversity conservation

Agriculture represents the dominant land use throughout much of Europe, and a significant part of European biodiversity is associated with agricultural landscape (Robinson & Sutherland 2002). Pressure to increase food production to meet the demands of a growing human population leads to agricultural intensification (defined as increased production of agricultural commodities per unit area) and has detrimental effects on biodiversity and the delivery of key ecosystem services (Tilman et al. 2001, Sirami et al. 2019). Sustainable development requires the reconciliation of demands for biodiversity conservation and increased agricultural production (Martin et al. 2019). Assessing the impact of agricultural intensification on biodiversity and ecosystem services is therefore fundamental to this process (Butler & Gillings 2004). Despite many adjustments to agricultural policy across the European Union, agricultural intensification in some regions and concurrent abandonment in other regions remain the major threats to stability and function of agro-ecosystems impairing the state of soil, water and air and reducing biological diversity in agricultural landscapes (Stoate et al. 2009).

In the first half of 20th century, farmland throughout Europe was formed by mosaic of small patches with high diversity of crop types, field edges, and non-crop habitats (Baguette & Van Dyck 2007). Such heterogeneity positively influenced the abundance and diversity of species inhabiting agricultural landscape. In contrast, since the second half of the 20th century, modern, intensive agriculture has decreased this patchwork at a range of spatial and temporal scales. The fine-grained, diverse habitat mosaic, typical of much traditional agriculture, has become increasingly uniform under common agricultural management (Vickery & Arlettaz 2012). The configuration of the landscape has changed as field size increased, accompanying mechanization, the separation of animal and arable farming, landscape collectivization and consolidation programs (Tryjanowski et al. 2011). This often caused a reduction in field margins, including grass strips, hedgerows, and ditches, which are important refuges for biodiversity (Baude et al. 2016, Clough et al. 2020). Agricultural intensification from the 1930s-1940s onward, and in particular the access to modern machinery, have led to continual increase in mean field size (Robinson & Sutherland 2002). Landscape-wide patterns of field size are linked to patterns of land ownership and to land management (Clough et al. 2020). In countries of the former socialist bloc where collectivization was imposed, arable fields were consolidated, leading to very large field sizes (Hartvigsen 2014). Aggregation of the small plots into large field units leads to dramatic and comparatively rapid changes in scale and intensity of agricultural practices (Clough et al. 2020).

The historical changes in mechanisation, anthropogenic inputs and structural transformations were fundamental drivers of farmland biodiversity declines (Chamberlain et al. 2000, Tschumi et al. 2020), though the underlying ecological and demographic mechanisms differed between species (Donald et al. 2001). The populations of many species have been shown to suffer from intensification of agricultural management, reduction of landscape heterogeneity, habitat loss and fragmentation (Tryjanowski et al. 2011). Various studies document the mean size of agricultural fields in a landscape and the presence of noncrop elements as important drivers of diversity and abundance of farmland biodiversity taxa including plants, arthropods, and vertebrates (Šálek et al. 2018, Martin et al. 2019, Clough et al. 2020). The evidence for negative effect of decreased farmland heterogeneity and/or intensive farming practices has been provided on number of animal groups, namely butterflies, syrphids, bees, carabid beetles, spiders, frogs and birds in farmland (Fahrig et al. 2015, Collins & Fahrig 2017, Sirami et al. 2019, Martin et al. 2020). The declines have been recorded in species richness and population sizes of different taxa inhabiting farmland (Tryjanowski et al. 2011).

Biodiversity conservation in agricultural landscapes has therefore become a conservation priority on a regional as well as continental scale (Šálek et al. 2018). Conservation evidence suggests that reducing crop field sizes would be at least as effective for conservation of biodiversity within agricultural landscapes as guidelines designed to promote a wildlife-friendly farming practice, such as adoption of no-till or low-input (e.g. fertilizer, pesticide) farming practices or increase in representation of non-crop habitats (Martin et al. 2020). By altering agricultural intensity, local management can modify the suitability of identical land-cover types for biodiversity through consequently compromising the availability of resources (Tschumi et al. 2020). Extensively managed meadows, for example, especially when occurring in close vicinity of tall vegetation patches, support population of many wild species by offering nesting sites, high food abundance and accessibility (Schaub et al. 2010, Šálek et al. 2018). It is the availability of resources and not land cover type that drives species occurrence (Habel et al. 2015). Therefore, even where the farmland heterogeneity is similar, the crucial resources offered by these landscapes might differ significantly. While the discussions on effectiveness and suitability of agricultural practices continue at various levels, the impact of human activities and agricultural intensification in particular on population changes remains decisive for the survival of species within farmland, representing the main cause of habitat loss, isolation and fragmentation for many species and populations (Tilman et al. 2001, Pellegrino et al. 2015, Sirami et al. 2019).

Farmland birds are commonly used as indicators of land-use intensity and overall farmland biodiversity, due to their complex resource requirements and association with other taxonomic groups (Gregory et al. 2005, Tschumi et al. 2020). As shown by the European Farmland Bird Indicator (FBI), populations of farmland bird species in Europe have undergone a widespread and rapid decline by as much as 57 % since 1980 (Gregory et al. 2019), much of this biodiversity loss being attributed to agricultural intensification (Benton et al. 2003, Reif & Vermouzek 2019, Šumrada et al. 2021). The little owl (*Athene noctua*), a generalist farmland predator on the top of the foodchain, might be considered typical indicator of the biodiversity in agricultural landscapes. This opportunistic avian predator has severely declined in a major part of Europe during the past decades (Šálek & Schröpfer 2008; Żmihorski et al. 2009). If we consider the assumption that the population of a top predator reflects the overall biodiversity, the negative population trend of little owl across Europe stresses the alarming need to develop and apply research-based conservation measures to halt the loss of farmland biodiversity.

2. The Little Owl – species characteristics

The little owl (*Athene noctua*) is a nocturnal avian predator with trans-Palearctic distribution, occurring mainly in human-dominated landscapes (Van Nieuwenhuyse et al. 2008). It is a small (180-230 g, females slightly larger than males), resident owl species, occupying a wide variety of lowland habitats, generally avoiding mountainous, hilly and densely wooded areas (Mikkola 1983). The species inhabits a wide variety of semi-open areas, from steppes and stony semi-desserts to farmlands and open woodlands, villages, and urban areas. Within the farmland of Central Europe, little owl home ranges are selectively located in areas of high structural diversity, associated with anthropogenic habitats including agricultural landscapes (farmlands, orchards, pastures, meadows) and urban and suburban habitats (villages and urban buildings) and other extensively cultivated areas with scattered trees (Study 3, Appoloni et al. 2018, Fattebert et al. 2018).

The little owl is territorial and monogamous with rare to no extra-pair paternity (Van Nieuwenhuyse et al. 2008, Müller et al. 2001). The brood size can range from one to seven eggs (with an average clutch size from 2.65 to 5.24 in Europe) laid in natural and artificial cavities. As a cavity nesting species it may reside in tree and rock cavities, crevices in cliffs and man-made structures, and in the nests, holes, and burrows of other animals (Van Nieuwenhuyse et al. 2008). In Central Europe, strong preference for nesting in agricultural and residential buildings was found (Study 1). The incubation period starts variably between the first egg, subsequent eggs or even not before the clutch is complete (Van Nieuwenhuyse et al. 2008). Nestlings fledge at an age of 28 to 40 days, but parents continue to feed the owlets for about 30 days after fledging (Van Nieuwenhuyse et al. 2008). In the research of Tschumi et al. (2019) the nestling sex ratio was female-biased, mainly due to a significant female bias in the first-hatched chicks. Female nestlings showed on average a higher body weight and higher survival than males. Body weight of nestlings decreased with hatching sequence. The radio-telemetry study of Hauenstein et al. (2019) revealed sex-biased dispersal distance of little owl fledglings, with females showing longer individual flights and higher directional persistence.

The little owl is known to feed on a wide variety of prey, including small mammals, birds, reptiles, amphibians, insects, molluscs, crustaceans, and other invertebrate species (Van Nieuwenhuyse et al. 2008). The diet mainly consists of small rodents and large invertebrates (earthworms and insects). The little owl hunts mostly during nocturnal and crepuscular hours (Johnson et al. 2009), but the species may also hunt in daytime, especially during the breeding season (Negro et al. 1990). The method of hunting it uses is related to the type of vegetation and prey (Schönn et al. 1991) and may consist of running or hopping on the ground (Exo 1991, Schönn et al. 1991) or, more frequently, perch-hunting (Fajardo et al. 1998, Tomé et al. 2011). They can also catch prey on the ground while flying low. However, little is known on how the little owls adapt their hunting strategy to the foraging conditions of the habitat and how this affects their hunting success (Van Nieuwenhuyse et al. 2008, Tomé et al. 2011).

To understand the demographic characteristics of the little owl population, ringing data have been analysed in number of European countries (Letty et al. 2001, Schaub et al. 2006, Le Gouar et al. 2010, Thorup et al. 2013). Mostly geographical and temporal variations in age-specific survival rates and linked annual survival estimates to population growth rate in corresponding years, as well as to environmental covariates were investigated. Le Gouar and co-workers (2010) conclude that juvenile survival rate decreased with time whereas adult survival rates fluctuated regularly among years, low survival occurring about every four years. Previous studies had only detected linear variation across years of juvenile or adult survival rates for this species (Letty at al. 2001, Schaub et al. 2006). Years when the population declined in the Netherlands were associated with low juvenile survival (Le Gouar et al. 2010). Surprisingly, the small mammal dynamics did not explain the cyclic pattern in adult survival rate as observed for other owl species, such as Tengmalm's owl (*Aegolius funereus*, Hakkarainen et al. 2002) or barn owl (*Tyto alba,* Klok & de Roos 2007). Instead, dry and harsh winters with long-standing snow cover led to low adult survival rates, what might be caused by low availability of prey at these conditions. Low temperatures could influence the energy expenditure of little owls especially during winter, however the difference in adult survival rate in severe/mild winters in Netherlands was not significant alike the relationship between adult survival rate and snow cover (Van Nieuwenhuyse et al. 2008). Dry years might potentially decrease the availability of earthworms and insects on which the species also feeds. Low juvenile survival rates, that limit recruitment of first-year breeders, and the regular occurrence of years with poor adult survival, were the most important determinants of the population decline of the little owl in Netherlands (Le Gouar et al. 2010) and also contributed significantly to the negative trend of the population in Denmark (Thorup et al. 2013).

The study of Le Gouar et al. (2010) failed to find strong relations with a number of potential explanatory variables, what leads the authors into conclusion that different factors affect the variation of age-specific survival rates and that variation in survival is due to complex interactions. The analyses of ringing recoveries show two mortality peaks of adult little owls, one in summer (June – September) and the other in winter (November – February) (Exo 1988, Šálek et al. 2019a). The results of Exo (1988) clearly demonstrate an energetic bottleneck in July. The author associated this fact with the stress of rearing the young and the beginning of the moult, both incurring higher energy expenditure. The winter mortality peak, however, is caused by exceptionally high mortality rates in extraordinarily severe winters (Exo 1988). Šálek et al. (2019a) detected the highest relative mortality rates in first-year individuals during July and September, whereas adult little owls suffered the highest mortality during March, November and December.

The little owl is characteristic by the poor dispersal rate of both the juveniles and adults. According to Fuchs (1987) about 50% of the juveniles settled less than 6 km from their birthplace. Dispersal after the first breeding season is negligible. Exo and Hennes (1980) found that about 55% of the juveniles had settled within 10 km of their birthplace. Based on their survey, about 74% of all adults are recovered within 10 km from the ringing place and only 9% at over 100 km.

3. Habitat selection

Habitat selection is determined by different sets of ecological factors at different spatio-temporal scales (Study 3, Mayor et al. 2009, Fattebert et al. 2018, Šálek et al. 2019b). For little owls, food availability is a major characteristic of habitat quality, linking habitats with demographic parameters such as reproductive performance (Grüebler et al. 2018). At the scale of patches of suitable habitat, variation in the availability of resources and their spatial distribution creates heterogeneity to which little owl individuals respond by adjusting the location and size of their home-ranges (Apolloni et al. 2018). Fine-grained habitat structures such as vegetation height and density together with presence of non-cropped elements (e.g. field edges, hedges and grasslands) may affect the access to resources and the individuals' habitat use within the home-ranges (Schaub et al. 2010, Šálek et al. 2010).

The results of habitat selection studies are often difficult to interpret, as the land use data are usually available in an insufficient scale for a little owl territory – little owl spends 50% of its time in 125 m from the nest (Sunde et al. 2009). Data generalisation might lead to misinterpretation of results and overlooking of significant predictors of habitat occupation. For example, Van Nieuwenhuyse et al. (2002) applied for the little owl census the standardised inventory method on 25 ha grid cells and for the year 2000 they conclude, that low-stem orchards, habitat usually positively reflecting the little owl occurrence, showed a negative impact on cell occupation, what might possibly be also due to large scale and overlooking small but important areas of the preferred habitat.

Field edges have been recorded as having positive impact on the occupation of territories by the little owl (Van Nieuwenhuyse & Bekaert 2001). The edge effect is often linked to the mosaic-like landscape. A positive correlation of little owl occurrence was also observed with other linear elements, i.e. meadow edges (Van Nieuwenhuyse & Bekaert 2001), hedges and walls (Dalbeck et al. 1999) and fence-poles (Loske 1986). In Germany and France the distribution of the species is more related to the scale of the landscape than to the landcover types (Ferrus et al. 2002), while the species avoids villages with few large grassland areas and prefers those with a lot of small grassland plots (average plot less than 0.6 ha) (Dalbeck et al. 1999).

According to Dalbeck et al. (1999) there is a positive correlation between the population density of little owls and the area of grasslands with fruit trees and pastures. The average area of grassland in the little owl territories in Groningen even increased slightly, but not significantly so, from 7.3 ha per 25 ha to 10.9 ha (i.e. extrapolated 29.2 and 43.6 ha per km^2 respectively) in the past four decades. Dalbeck et al. (1999) also found a strong preference of little owls for small grassland parcels, especially smaller than 0.6 ha. On the contrary, Żmihorski at al. (2009) conclude, that the little owl shows a high degree of habitat plasticity. The decrease of the area of grasslands and numbers of pollard willows was not likely to explain the population decline of the species. The amount of forest and the proportion of built up areas appeared to be the best predictor of the occurrence of the little owl in central Poland (Żmihorski at al. 2009). At larger scales, the occupancy of apparently suitable areas was related to the structure and spatial composition of land use and, especially, to the proportion of forest plantation also in the region of Biscay, northern Spain (Zabala et al. 2006).

The findings of recent studies suggest that habitat selection and resource exploitation by little owls are related to farming practices and affected by current cultivation (Šálek et al. 2010, Apolloni et al. 2018). Orchards and grasslands are often highly preferred hunting grounds over other habitats (Apolloni et al. 2018). In habitats dominated by homogeneous cropland, home-ranges of little owls are much larger than in highly diverse habitats. Large home-ranges are associated with increased flight activity, distance travelled per night, increased duration of foraging trips covering larger distances, and reduced nest visiting rates (Staggenborg et al. 2017). Within home-ranges, little owls prefer to use structures with high prey abundance over-proportionally (Apolloni et al. 2018). Short sward areas are used intensively relative to availability especially during the breeding season (Grzywaczewski 2009, Šálek & Lövy 2012, Sunde et al. 2014). At the scale of foraging sites, little owls prefer patches with low vegetation over those with high prey abundance, establishing that prey accessibility is the main driver of little owl spatial movements (Apolloni et al. 2018). The study from Denmark shows, that habitat selection by generalist foragers such as the little owl, may be highly dependent on temporal variables such as weather, probably because such foragers switch between weather dependent feeding opportunities offered by different land cover types (Sunde et al. 2014). Habitat selection data are crucial for elaboration of evidence-based conservation measures. Besides planning of suitable land management practices to support little owl populations, the knowledge on habitat utilization of juveniles may provide the bases for determination of potentially suitable dispersal corridors to facilitate a recolonization of little owl habitat patches where the population significantly decreased or went extinct (Hauenstein et al. 2019).

The multi-level habitat model of Fattebert et al. (2018) combining citizen-science species observation data with radio-tracking data has provided valuable information for identification of both large-scale habitat suitability patterns to develop conservation strategies, and fine-scale clusters of high-quality habitats where conservation measures can be applied within the border region of Switzerland and Germany. Tschumi et al. (2020) further emphasise the need for fine-scale resource assessments complementing landscape-scale suitability models in order to consider the availability of crucial resources and their socio-economic moderators for conservation measures to be effective (see also Żmihorski et al. 2020). Such complex habitat maps significantly increase relevance of the study results for policy makers, wildlife managers and conservation practitioners alike, therefore it is essential to apply such multi-level approach also in other parts of the species distribution range.

4. Population dynamics

Little owls are widely distributed across large parts of Europe, Asia and North Africa and are categorized as 'least concern' by the International Union for Conservation of Nature (IUCN) (Ieronymidou et al. 2015). Little owl numbers have been declining in most of Europe. The species, once widespread and numerous in the rural landscapes of Europe, has suffered severe population declines and local extinctions in the most European countries (Cramp 1985, Vogrin 2001, Génot et al. 1997, Birdlife 2004, Van Nieuwenhuyse et al. 2008, Šálek & Schröpfer 2008, Grzywaczewski 2009, Sunde et al. 2009, Le Gouar et al. 2010, Study 1). The population in Central and Northern Europe, where the species is closely connected to human-modified agricultural landscapes, has been well studied especially during the last four decades (Van Nieuwenhuyse et al. 2008, Šálek & Schröpfer 2008, Thorup et al. 2010, Schaub et al. 2006). The severe population declines and local extinctions in most countries occurred concurrently with agricultural intensification (Génot & Van Nieuwenhuyse 2002, Šálek & Schröpfer 2008, Sunde et al. 2009). In some regions, the little owl territories are very isolated and restricted to suitable areas e.g. France (Génot 1995, 1997), Switzerland and Germany (Schaub et al. 2006), Denmark (Thorup et al. 2010), Poland (Żmihorski et al. 2006) or the Czech Republic (Šálek & Schröpfer 2008).

For example, in the Czech Republic, population of the little owl experienced a 41% decrease in their distribution area during 1985-2003 (Šťastný et al. 2006) and this negative trend continues (Šálek & Schröpfer 2008, Study 1). Currently the species is classified as endangered on the Red list of the Czech Republic and its total population size does not exceed 130 breeding pairs (Study 1). Significant population decrease was also recorded in Poland (population size 1000-2000 pairs, Żmihorski et al. 2006, Van Nieuwenhuyse et al. 2008) and in some parts of Slovakia (population size 800-1000 pairs, Danko et al. 2002, Van Nieuwenhuyse et al. 2008). In Poland, significant decline in the little owl population, leading to its disappearance, was observed especially in agricultural areas in central Poland (Żmihorski et al. 2006). In Hungary, the population size is estimated at 2000-2500 pairs and is probably stable after the decline (Van Nieuwenhuyse et al. 2008), however present data on distribution and population size are scarce (Study 2, Hámori et al. 2017). In certain regions of Hungary, namely in Hortobagy and Békés county, the little owl population remains stable, or the number of breeding pairs slightly increased in the last decades, probably in connection to the rise in the number of abandoned houses because of the unfavourable socio-economic situation in the region (Study 2, Bozó & Csathó 2017). A strong decline in little owl population has been noticed also in Slovenia, mainly in farmland of the sub-Pannonian region, where the species was considered common in the first half of the 20th century (Vogrin 2001). In Denmark, the species has declined from being the locally most abundant owl species in the 1970s to less than 100 pairs in the 2000s and 15 pairs in 2018 (Sunde 2018).

The study of Andersen et al. (2017), using population viability analyses, genomics and habitat suitability, forecasts the decline of the abundance of little owl in Europe with populations further to the north more likely to decline and potentially go extinct than populations further to the south. The data suggest that the declining population trend will continue and affect populations throughout the entire distributional range.

5. Causes of population decline

5.1. Landscape changes

Large-scale changes in agricultural landscapes, resulting in habitat loss and fragmentation of the traditional agricultural and pastoral landscapes, which may lead to food limitation during breeding season, are thought to be the main factors explaining population decline of the species (Šálek et al. 2010, Thorup et al. 2010). From the 1970s to the 1980s the most severe population decline of the little owl was found in the human-dominated landscapes and within most intensively used agricultural landscapes. The habitat changes are mostly related to the scaling-up of the size of fields and mechanisation in agriculture. The ever-continuing agricultural intensification leads to larger patches with smaller representation of bordering edge zones which are ecologically more important for little owls than large homogeneous areas with common management (Génot & Van Nieuwenhuyse 2002). Similarly, many high-stem traditional orchards, also functioning as important nesting places, have been removed, disappeared or replaced by low-stem and intensively used orchards. The decrease in the little owl population in various regions appears to be caused by a deteriorating habitat quality as a consequence of the intensification of agricultural landscape (Van't Hoff 2001). Ditches, farmland dirty roads, hedgerows, tree/shrub corridors, permanent fences and rows of pollard trees are linear landscape elements that are often used by farmland birds to hunt along since they function as excellent high-quality foraging habitats (Loske 1986, Vickery & Arlettaz 2012). From the mid-1990s onwards an increasing isolation and fragmentation of populations plays an important role in population decline. Occupied territories closer to conspecifics are the last to be abandoned despite the sometimes lower habitat quality (Van't Hoff 2001). Similar trend was observed also in Denmark, where Jacobsen (2006) mentions the tendency of the breeding pairs to cluster within certain core areas that lay as "islands" in the surrounding landscape where no or only few pairs occurred. Some studies have concluded that the availability and distribution of nest-sites, besides the prey availability, are also among the main factors limiting the population density of little owl across a large part of the species distribution range (Loske 1986, Exo 1992, Bultot et al. 2001). Also, weather conditions have been shown to influence breeding success (Génot & Van Nieuwenhuyse 2002).

There is a positive correlation between production of young and the area of grassy habitats, indicating that the population declines may be related to the large-scale landscape changes associated with changes in agricultural practices and management (Thorup et al. 2010). The amount of grassland habitats, on which the owls seem to depend for successful reproduction, has substantially decreased over the past century and is likely to be further reduced in the near future (Ellemann et al. 2001, Báldi & Batáry 2011). Previous study documents a link between breeding performance and habitat quality and indicates that this link is most likely caused by food limitation when suitable habitats are not available (Thorup et al. 2010). Génot and Wilhelm (1993) discovered, by use of radio-telemetry, that little owls were hunting over 80% of their time in areas, within their home ranges, that varied on average from only 3.5 ha in the summer to 6.0 ha in the winter. The study of Staggenborg et al. (2017) shows that in areas dominated by homogeneous cropland, the little owl home-ranges are six times larger in size than in highly diverse landscapes. Large home-ranges are associated with increased flight activity, increased duration of foraging trips, covering larger distances, and reduced nest visiting rates (Staggenborg et al. 2017). To analyse the effects of habitat on breeding performance, Thorup et al. (2010) measured the distance to individual land-use classes for all known little owl nesting sites and calculated the areas of each land-use class within a 1-km radius from the nests. The short distance to habitats categorized as little owl habitats (i.e. grazed area, grassland, and meadow) had a positive effect on clutch size as well as on the number of young fledged (0.47 ± 0.20 fledglings⁄km). However, the area of such habitats within 1 km buffer around nests did not correlate with any reproductive parameter. Instead, more young fledged from nests in sites with a high coverage of seasonally changing land cover within 1 km (0.63 ± 0.23 fledglings⁄km^2) (Thorup et al. 2010).

Besides the enlargement of agricultural fields, and with that the loss of edge habitats, there is the negative effect of the intensification of grassland management. Intensive grassland management, such as increasing nitrogen availability or reseeding with competitive species (e.g. *Lolium* sp.), result in taller and denser swards and may reduce the availability of the little owls' principle prey species (Šálek et al. 2010). Although the abundance of small mammals and insect prey is assumed to be relatively high, this prey may be unavailable to owls and other birds in tall and dense grassland (Whittingham & Devereux 2008).

Human-dominated landscapes considerably contribute to population declines also via non-natural/anthropogenic mortality of both juveniles and adult birds. Based on the study of Šálek et al. (2019a) the entrapment in vertical hollow objects, drowning in liquid reservoirs, and collision with vehicles accounted for highest proportion of known mortality of the little owl in the Czech Republic. Similarly, Thorup et al. (2013) indicates that accidental deaths associated with anthropogenic habitats might to some extent be considered as an important factor contributing to the present negative population trend of the Danish little owl population. On the contrary, the research of Naef-Daenzer et al. (2017) estimated the frequencies of main causes of mortality to 45% for predation, 20% for casualties due to collisions with vehicles and accidents at buildings and other human-built structures, and 34% for all other causes. The study suggests that the anthropogenic mortality may be considerably overestimated and the magnitude of natural mortality may be underestimated in mortality records and concludes that demography of little owls likely depends on predator–prey relationships rather than on human-induced deaths. However, the above-mentioned studies indicate that reducing the risk of anthropogenic mortality may significantly contribute to halting the decline of little owls, especially in regions with small and isolated populations.

5.2. Isolation and population fragmentation

Increased population fragmentation (with increasing distances between pairs), because of a declining habitat quality and low population densities, is probably the best explanation for the decline in the little owl population since the (mid-) 1990s (Van Nieuwenhuyse et al. 2008). For the early 1980s, Loske (1986) estimated an average nearest neighbour distance of 1434 m in Germany. In areas with high population densities, such as central Westfalen, this distance was as low as 435 m. In East-Flanders Van Nieuwenhuyse et al. (2002) have even found an average nearest neighbour distance of 210 m for calling little owl males. The nearest neighbour distances of 2.9 km and 3.3 km at the occupied and abandoned territories by far exceeds the audible distance of little owl calls of 650 m mentioned by Finck (1989). We might consider this as a critical distance between the occupied territories to maintain a stable population. Nowadays the increased isolation may become more important than the availability of high-quality habitats. This conclusion is very similar to the results of a study on little owls in East-Flanders, Belgium (Van Nieuwenhuyse & Bekaert 2001). They found that the vicinity of conspecifics had better predictive power on little owl presence than landscape elements, namely types of landcover and linear landscape elements. The vicinity of the last population clusters in Groningen is more attractive to little owls than the quality of the actual habitats. Some favourable regions in Groningen, featuring seemingly excellent little owl habitat but situated far from the existing population clusters, remain more or less unoccupied (Van't Hoff 2001). The same was apparent in the early 1990s when large areas of arable land were transformed into set-aside with long-term grassland which was very attractive to many breeding, migrating and wintering raptors and owls, except the little owl (Voslamber et al. 1993).

The human-related activities, such as habitat destruction and fragmentation, that have caused previously continuous populations to become fragmented and reduced in size can negatively affect the genetic diversity of populations (Frankham et al. 2002). Population decline coupled with increased population fragmentation increases the risk of local extinctions (Wiens 1994). The population decline might therefore be followed by the loss of genetic diversity (Groombridge et al. 2000). Loss of variation within populations is undesirable since the population may be less able to respond to and survive changes in the environment, which may itself increase the probability of local extinction (Frankham et al. 2002). However, findings of the large-scale genetic study of Pellegrino et al. (2015) showed a strong genetic structure and no evidence of genetic depletion in European little owl populations, although in several of the sampled countries the species has been in decline during the last decades (e.g. Denmark in Thorup et al. 2010, Czech Republic in Šálek & Schröpfer 2008).

5.3. Food limitation

Research findings suggest that food limitation during the breeding season may be the main reason for the declining numbers of little owls. (Thorup et al. 2010, Perrig et al. 2017, Grüebler et al. 2018). Little owl parents are very active and probably energetically stressed during the post-hatching period (Exo 1988, Holsegård-Rasmussen et al. 2009). The decrease in production of young with increasing distance to preferred habitat is probably a direct result of adults only being able to bring a smaller amount of food to the nest if they have to fly further to forage (Thorup et al. 2010).

Not only the area of “extensively” managed grasslands has significantly decreased in Europe (particularly between the 1970s and 1980s), but also the prey availability, e.g. voles, insects, and earthworms (Duffey et al. 1974). In correlation with agricultural intensification, including habitat loss and change, and the increased use of pesticides and fertilizers, there has been a dramatic decline in the abundance and biomass of larger insects (Benton et al. 2002), which is important part of the diet of the little owl. The rapidly declining Danish little owl population apparently feeds relatively more on earthworms than do other European populations (Ottesen & Svenné 2008).

An increasing input of dung and fertilisers, leading to higher proportions of nitrogen, have a negative effect on the average size of insects in the grasslands. The size of insects becomes smaller at higher nitrogen levels, significantly decreasing the insect production at potential hunting areas (Van’t Hoff 2001). The number of earthworms on the other hand is influenced by the level of dung (i.e. more dung, more earthworms), the reduction of water levels and the type of soil (Van’t Hoff 2001). The density of earthworms is significantly lower on clay than on sand and peat soil (Van Eekeren 2007). However, the negative impact of higher nutrient input on insects in intensified meadows apparently outweighs the possible positive impact of the earthworms, especially in regions with clay soils.

Furthermore, the widespread use of heavy pesticides in the last four decades is generally known as having a negative impact on raptors and owls. Prey availability seems to be more strongly affected by the agricultural intensification (i.e. loss of insect biomass), while factors that improve prey accessibility, i.e. short extensive vegetation and linear landscape elements in bordering zones like ditches, paths, permanent fences and rows of pollard trees (Génot & Van Nieuwenhuyse 2002), are reduced by the increase in size of plots.

5.4. Breeding places as the limiting factor

Little owl is a species closely tight to human landscapes, breeding mainly in hollow trees and buildings, and therefore the reconstruction of old buildings as well as the abandonment of traditional management of willows might cause the scarcity of nesting possibilities for this species in certain regions. In Central Europe, during the last decades, the little owl rarely breeds in natural tree cavities, but rather most nesting sites are situated in human settlements, especially within agricultural objects (Šálek & Schröpfer 2008).

Limitation of breeding density among little owls by lack of available nesting palces was confirmed by Exo (1992). The number and distribution of nest sites were identified as 'ultimate' limiting factors determining population density across the breeding range of little owl in Central Europe. For Wallonia (Belgium), the nest sites were also observed as the factor limiting breeding density (Bultot et al. 2001).

However, in many regions, where the population has been studied for long time and the supportive measures were initiated, it is believed that suitable nesting places are not a limiting factor for little owls. For example, in the region of Groningen (the Netherlands), farms are by far the most frequently used breeding sites, providing little owls with plenty of suitable roosting and nesting places. In northern Germany (Schleswig-Holstein, Lower Saxony), the little owl is mainly breeding in buildings on the edges of villages and in scattered farms (Loske 1986). Both populations are declining despite the fact the number of farms has not decreased in the past decades. Moreover, there is no difference in farm-density between the still occupied and the abandoned territories. Furthermore since 1977 a surplus of nest-boxes was placed in the wide surroundings of the two last population clusters in Groningen, however, none of these nest-boxes have been occupied by little owls in following 20 years (Van‘t Hoff 2001). Similar situation occurs in Denmark. Jacobsen (2006) describes the development of the breeding population during 1981–2000 and concludes, although there was a general loss of suitable nesting places over the years (e.g. due to modernization of farm buildings, cutting down of old trees with cavities), it is doubtful whether this had played any important role in the population decline. During the last years more than 150 nest boxes have been put up in the study area in northern Jutland, but very few of them were ever occupied.

6. Conservation management to support little owl populations

There are three main conservation measures to support little owl populations: 1) habitat improvement, 2) increase in safe natural or artificial nesting possibilities, 3) supplementary feeding. The areas to implement the conservation measures are being identified by the means of prioritisation based on population parameters and habitat suitability models (Tschumi et al. 2020).

6.1. Habitat improvement

Food availability is a major characteristic of habitat quality, linking habitats with demographic parameters such as reproductive performance (Grüebler et al. 2018). The importance of grasslands and pastures for little owls in the breeding season has been demonstrated by many previous studies (Loske 1986, Schönn et al. 1991, Dalbeck et al. 1999, Šálek & Berec 2001, Šálek et al. 2010, Thorup et al. 2010), and has also been shown for many other farmland birds (Vickery et al. 2001, Atkinson et al. 2004, Devereux et al. 2006). The availability of short-sward grassland patches, with suitable management, in little owl territories appears to be a limiting factor for the persistence of the species in arable-dominated central and northern European farmlands.

During the breeding period, adult owls are likely to pay high costs to nourish themselves and their offspring. Although this period is characterized by increasing insect abundance, tall and dense vegetation decreases its availability to the owls (Šálek et al. 2010). Because the main reason for reproductive failure appears to be related to food limitation after egg laying (which is the period in which offspring are most affected), the energetic situation of breeding birds is becoming the main target for conservation initiatives in some countries. The availability of short sward habitats is crucial for adults when providing food to the young (Thorup et al. 2010). Little owls prefer grassland patches (especially grassy pastures, short sward lawns and mown hayfields), which enable sufficient hunting on surface-active soil insects (Schönn et al. 1991, Ille 1992, Šálek et al. 2010). Hunting beetles in tall and dense swards is likely to be more difficult and energetically more costly and may result in lower breeding success (Gassman & Bäumer 1993) or higher adult mortality (Exo 1988).

Habitat improvements, through providing short-sward vegetation areas in the close vicinity of little owl breeding localities, could enhance productivity by increasing prey availability and accessibility in short distance from the nest. Land management initiatives aimed at improving the quality of little owl foraging habitats during the breeding period should give priority to areas as close as possible to the nesting sites, preferably within 100-200 m (Sunde et al. 2009). Grasslands, and we presume especially the “extensively” managed grasslands and their borders, are the main hunting areas for little owls. In contrast to arable land, grasslands also are suitable hunting areas during the breeding season and fiercely defended by little owls (Finck 1990, Finck 1993).

The effective habitat management requires a very complex approach. Short sward areas, ideal hunting grounds for many farmland bird species, are generally associated with lower abundance and diversity of invertebrates compared to taller more complex vegetation, creating a trade-off between prey abundance and accessibility (Vickery et al. 2001).

However, changing the overall land-use in a little owl territory is a very ambitious and often non-realistic measure. Therefore, manipulated accessibility of prey within field margins by creating a mosaic of short and long vegetation may serve as an acceptable solution. It enhances margin use by foraging birds, especially late in the breeding season when uncut vegetation is tallest. Given the importance of field margins as foraging habitat for a wide range of bird species during the summer (e.g. Rands 1986, Brickle et al. 2000, Wilson 2001, Perkins et al. 2002), conservation measures to improve their value could have considerable benefits for farmland bird conservation. Enhancing sward heterogeneity has shown positive results for 'in-field' foragers such as skylarks (Morris et al. 2004) and also for little owls (Study 4). Shorter swards may enhance prey accessibility and mobility for foraging birds (Butler & Gillings 2004, Devereux et al. 2004, Stillman & Simmons 2006). At the same time, the perceived predation risk of hunting little owls is lower in short sward habitats (Whittingham & Evans 2004).

6.2. Increase in safe natural or artificial nesting possibilities

The management measures in some countries consist of overdue trimming of high-stem orchards and pollard willows, planting new trees, especially on favourable, historical locations to increase the availability of natural nesting cavities, the adjustment of entrance to natural cavities and the introduction of new nest boxes in the area (Van't Hoff 2001, Valera et al. 2019, AOPK ČR 2020). The provision of artificial nest boxes brings equivocal results. The measure seems to be effective only in certain regions, with some nest boxes being occupied within a few days or weeks after installation even late in the season (Bultot et al. 2001), while not having any positive influence on little owl abundance in others (Jacobsen 2006). In France, Belgium, Germany and Luxembourg, several local species recovery programmes have shown that installing nest boxes in good habitat areas is a successful conservation measure leading to population recovery (Bultot et al. 2001, Van Nieuwenhuyse et al. 2008, Habel et al. 2015). However, the installation of next boxes requires a careful design to ensure safety against predators, such as stone martens or domestic cats. Valera et al. (2019) suggest that nest-site diversity and nesting in natural cavities should be preserved to reduce nest box dependence and illustrates the value of nest boxes when used alongside restoration of natural breeding sites.

6.3. Supplementary feeding programme

Food supplementation experiments have been widely used to get detailed insight into how food availability contributes to the survival and reproductive performance of wild animals (Byholm & Kekkonen 2008). Influence of supplemental feeding provision has been described on various species, such as Spanish imperial eagle (*Aquila adalberti*) (González et al. 2006), northern goshawks (*Accipiter gentilis*) (Dewey & Kennedy, 2001), hen harrier (*Circus cyaneus*) (Amar & Redpath 2002), eurasian kestrel (*Falco tinnunculus*) (Wiehn & Korpimäki 1997), burrowing owl (*Athene cunicularia*) (Wellicome 1997, 2000, Wellicome et al. 1997), Tengmalm's owl (*Aegolius funereus*) (Korpimäki 1987), and ural owl (*Strix uralensis*) (Brommer et al. 2004). Artificially increasing productivity through supplementary feeding programmes on a region-wide basis can only be viewed as a ‘stop-gap’ option (Temple 1986). This conservation measure may be justified in the short-term, given the severity of the problem for species in danger of extinction. Such a technique is intensive and does not present a viable long-term solution.

For species such as the little owl, which are precipitously declining in numbers, it is desirable to stabilize populations by slowing or halting their decline until ultimate causes can be identified and, if possible, corrected (Temple 1986). The study of Perrig et al. (2017) found that food supplementation substantially increased juvenile survival over the first three months what highlights trophic relationships as a fundamental driver of juvenile survival patterns and thus reproductive output. Furthermore, in an earlier study, Perrig et al. (2014) showed supplemented nestlings had longer wings, were on average heavier, and were more likely to develop subcutaneous fat deposits than control nestlings. They recorded experimentally induced changes in nestling development which probably affect individual performance beyond fledging. Grüebler et al. (2018) found an increase in nestling survival rates in response to food supplementation in low-quality habitats, but not in high-quality habitats. Food supplementation in their study caused parents to switch to smaller food items and to increase visiting rates, resulting in similar biomass brought to nestlings in supplemented and unsupplemented broods. Fattebert et al. (2019) from experiment with nestling food supplementation conclude that, where food is scarce, supplemented individuals emigrate later than unsupplemented individuals. In the short term, provision of additional food to breeding pairs was identified to be an efficient strategy for boosting the number of potential recruiters to the population by improving survival of initiated broods (Thorup et al. 2010). To confirm the results at the small scale and to determine the impact of food provision at the population level, the consequences of such management actions need to be monitored within longer time-periods. In case of the little owl, the short-term provision of supplementary feeding might immediately increase little owl reproductive output and help to determine whether the decline is linked ultimately to decreased productivity (Thorup et al. 2010). If, however, one can demonstrate that supplemental feeding has an important influence on the reproduction success and hence slows the population decline in the target area, this management technique can be recommended as a starting measure for the conservation of little owls in rapidly declining populations.

The current little owl conservation strategy is mainly focused to support the remaining local sub-populations, improve the prey availability and accessibility by special habitat management (i.e. cutting, mowing, grazing, plowing), increase safe nest site availability, remove traps (i.e. anthropogenic traps) causing risks to adults and newly fledged juveniles (Van Nieuwenhuyse et al. 2008, Šálek et al. 2019a). The most advanced little owl conservation strategies in Europe aim to secure the remaining local population clusters through increase of habitat heterogeneity by introduction of permanent fences, linear landscape elements, improvement of prey availability using field margins with special management, improvement of prey accessibility by mowing in strips of set-aside lands and adding perches, providing nesting places by management of pollard willows and installation of predator-safe nest boxes (Van’t Hoff 2001, Van Nieuwenhuyse et al. 2008, Habel et al. 2015). The carefully planned local policies and agri-environmental schemes can serve as an effective incentive to motivate farmers to apply the land management supporting the conservation of little owl and other farmland biodiversity in many European countries (Kleijn & Southerland 2003, Kleijn et al. 2004).

7. Aims and scope of the thesis

The little owl population in majority of Western and Central European countries is rapidly declining, while populations in most of Southern Europe are remaining stabile (see above). There are regions missing the basic survey, where the assessment of the population status and trend is impossible, causing important gaps in the overall picture of the little owl population in Europe. Some of the declining populations are very well studied and the reasons for the population decline as well as suggestions for conservation measures have been identified. However, the little owl seems to be threatened by various factors in different regions, most of them being covered by the umbrella of changes in agriculture, resulting in habitat loss and fragmentation, in some areas supported by mortality in artificial traps or insufficient supply of nesting places. The knowledge on the interconnection between a species and its environment and on the response of species to environmental changes in its (breeding and foraging) habitats must form the inevitable bases for the design of evidence-based conservation measures. The extent and effects of negative factors need to be studied in detail, to set priorities for conservation.

The main aim of the PhD thesis was to identify long-term population trend, habitat selection and management measures for the effective little owl conservation in the European farmland. The research on population status in Czech Republic, Slovakia and Hungary is followed by detailed study on habitat selection, in order to contribute with knowledge to identification of the main drivers of the population decline of little owl in target regions of Europe. The link was identified between habitat characteristics and species occurrence and the effect of different conservation management measures was tested on little owl population in Denmark, where the species is close to extinction. The aim of the study was to define the proper recommendations for the little owl conservation management.

The first study (Chapter 2: Chrenková et al. 2017) describes the long-term population decline and severe range restriction of the little owl in Czech Republic and Slovakia. Using two nationwide volunteer-based monitoring programmes during the years 2009-2016, we investigated distribution, population density and breeding associations of the little owl in the two target countries. We compared the data with the situation two decades ago and described the population trend and changes in little owl distribution. To gain better understanding of little owl preferences concerning breeding, we analysed the expected breeding places of all known pairs in the target regions.

In **the second study** (Chapter 3: Šálek et al. 2013) we investigated population status of little owl in Hortobagy National Park in northeastern Hungary. The main aim of this study was to determine the distribution and population density of little owl in region characterized by a high proportion of grassland habitats, considered to be the ideal habitats for the species. During March and April of 2011–2012, the little owl occurrence was surveyed using tape-recorded stimulation in 245 sampling points in an area of 489 km^2. In connection to population density, we analysed the main categories of land-use in the study area as well as on the expected breeding places of the surveyed individuals.

In **the third study** (Chapter 4: Šálek et al. 2016), we aim to highlight the common conservation priorities of the rapidly declining little owl in Central Europe. The study reflects the need to plan the habitat management at appropriate spatial scales. We identified important habitat selection forces that the species faces at the regional level. We analysed habitat associations of the little owl based on presence/absence data from contrasting agricultural landscapes of Czech Republic, Slovakia and Hungary. The habitat associations within and between regions at three different spatial scales: nest site, home range and landscape, were examined.

The fourth study (Chapter 5: Jacobsen et al. 2016) presents our research on the effectiveness of selected conservation measures implemented to support the breeding pairs. Assuming that food limitation during the breeding season is the main proximate cause of the population decline, efforts to improve breeding success of little owls in Denmark include providing breeding pairs with supplementary food and attempts to improve foraging habitats by creating short grass areas near the nests. In addition to increasing the reproductive output, feeding and habitat management may cause parents to work less hard improving their future reproductive value. Supplementary feeding can be used as a conservation measure to enhance reproductive output and to directly reduce the mortality in adult and juvenile owls. The proper management of foraging habitats can provide natural and long-term, therefore also more sustainable, support to endangered populations. However, in many cases providing birds with supplemental food is more convenient than changing the farming practices to alternatives enhancing biodiversity.

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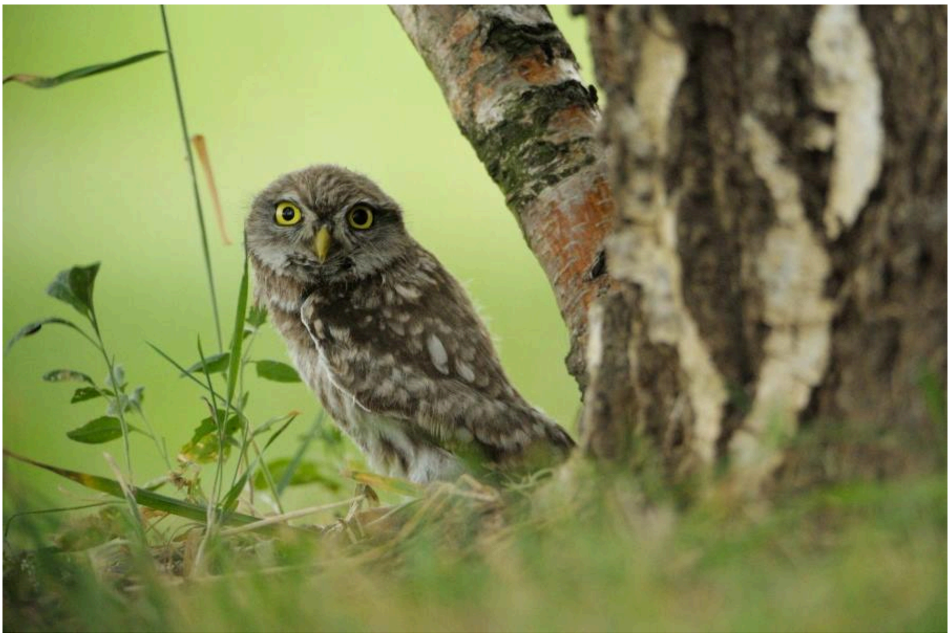
CHAPTER 2

Further evidence of large-scale population decline and range contraction of the little owl *Athene noctua* in Central Europe

Authors: Monika Chrenková, Martin Dobrý, Martin Šálek

Folia Zoologica 66 (2): 106–116 (2017)



Chrenková, M., Dobrý, M., & Šálek, M. (2017). Further evidence of large-scale population decline and range contraction of the little owl *Athene noctua* in Central Europe. *Folia Zoologi*ca, 66, 106–116.

Abstract

Long-term population decline of the little owl has been recorded in Western Europe and available evidence also suggests severe range restriction in many Central European regions. Using two nationwide volunteer-based monitoring programmes during the years 2009–2016, we investigated distribution, population density and breeding associations of the little owl in the Czech Republic and Slovakia. Across the two countries combined, the average population density of the little owl was 0.19 calling males/10 km^2. However, the population density was markedly higher in Slovakia (0.36 calling males/10 km^2) than in the Czech Republic (0.09 calling males/10 km^2). The overall breeding population of the little owl was estimated at 130 breeding pairs in the Czech Republic and 550 in Slovakia. Compared to the situation two decades ago, those estimates represented an 87–94 % decline in the breeding population in the Czech Republic and a 31–45 % reduction in Slovakia. Our data also revealed marked distributional range contraction of the little owl, indicating rapid local extinctions over the last two decades. The analysis of expected breeding places of the little owl confirmed a strong preference for man-made objects over the original breeding sites in tree cavities. In the light of our present results, we propose urgent preparation and implementation of a species action plan with conservation measures to halt the little owl's steep decline in Central Europe.

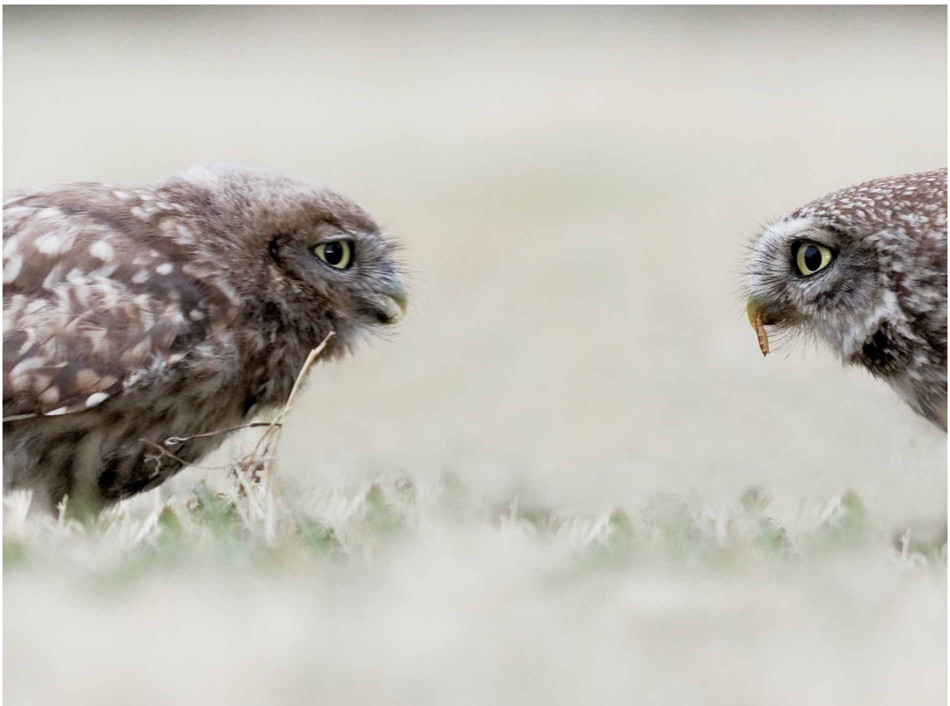
The Ecology of the Little Owl in European Farmland

CHAPTER 3

High population density of little owl (*Athene noctua*) in Hortobagy National Park, Hungary, Central Europe

Authors: Martin Šálek, Monika Chrenková, Marina Kipson

Polish Journal of Ecology 61: 165–169 (2013)



Monika Chrenková, Ph.D. Thesis

Šálek, M., **Chrenková, M.**, & Kipson, M. (2013). High population density of little owl (*Athene noctua*) in Hortobagy National Park, Hungary, Central Europe. *Polish Journal of Ecology*, 61: 165–169.

Abstract

Little Owl is a rapidly declining farmland species across Central Europe, however its population status is poorly known in Hungary. The main aim of this study was to determine the distribution and population density of Little Owl in Hortobagy National Park (north- eastern Hungary), which is characterized by a high proportion of grassland habitats. During March and April of 2011–2012, the Little Owl occurrence was surveyed using tape-recorded stimulation in 245 sampling points in an area of 489 km^2. In total, we recorded 245 calling males with relative positive occurrence of 75.5% in an individual sampling point. The average nearest neighbor distance of two calling males was 553.6 meters (min. = 70 m, max. = 3100 m). The average population density of Little Owls was 5.01 calling males/10 km^2, however this could reach up to 85.97 calling males/10 km^2 in 3.06 km^2 locally. Residential buildings and farms were the main expected breeding places in our study area. High density of the Little Owl in the study area is probably influenced by traditional pastoral management, extensive agriculture, and high proportion of grasslands. The particular role could be attributed to presence of short-sward pastures around human settlements, considered to be crucial for the species survival in Central Europe. Further monitoring of the Little Owl is necessary to assess its current population status across various parts of its distribution range.

The Ecology of the Little Owl in European Farmland

CHAPTER 4

Scale-dependent habitat associations of a rapidly declining farmland predator, the Little Owl *Athene noctua*, in contrasting agricultural landscapes

Authors: Martin Šálek, Monika Chrenková, Martin Dobrý, Marina Kipson, Stanislav Grill, Radovan Václav

Agriculture, Ecosystems and Environment 224: 56–66 (2016)

Šálek, M., **Chrenková, M.**, Dobrý, M., Kipson, M., Grill, S., & Václav, R. (2016). Scale-dependent habitat associations of a rapidly declining farmland predator, the Little Owl *Athene noctua*, in contrasting agricultural landscapes. *Agriculture, Ecosystems and Environment*, 224, 56–66.

Abstract

During the last half of century, agricultural intensification within European farmlands caused the deprivation of farmland biodiversity, including farmland birds. Since then, different conservation measures have been introduced to reverse declining trends of these birds. Yet, variable success of these measures suggests that habitat management requires planning at appropriate spatial scales. In this study, we examine habitat associations of the Little Owl, a rapidly declining farmland bird, within the context of Central European farmland. We collected presence/absence data from three different countries (the Czech Republic, Slovakia, and Hungary) and examined habitat associations within and between regions at three different spatial scales: nest site, home range and landscape. We show that certain habitat associations are shared across all study regions, namely those involving grasslands and farm buildings that are used for foraging and nesting, respectively. Inter-regional analysis reveals that grasslands, gardens/orchards and farm buildings are most important habitats at small spatial scales, whereas at large spatial scales, the owl is positively associated with open habitats in terms of arable fields. We suggest that conservation planning should take into account both regional and inter-regional aspects of a species' habitat associations to distinguish between common habitat requirements and local species-environment relationships.

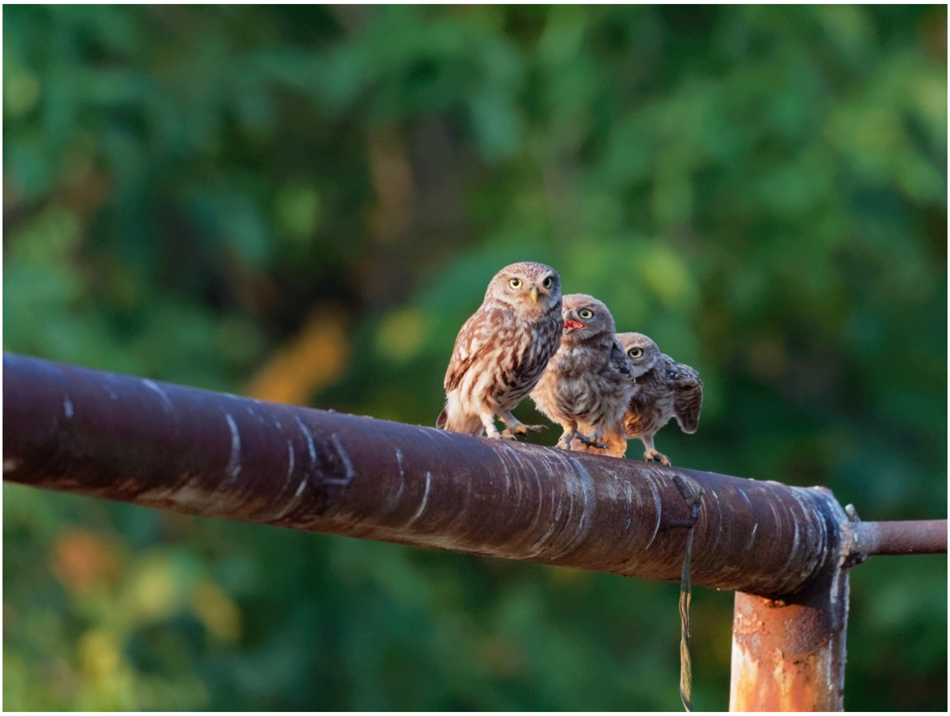
The Ecology of the Little Owl in European Farmland

CHAPTER 5

Effects of food provisioning and habitat management on spatial behaviour of Little Owls during the breeding season

Authors: Lars B. Jacobsen, Monika Chrenková, Peter Sunde, Martin Šálek, Kasper Thorup

Ornis Fennica 93: 121–129 (2016)



Jacobsen, L.B., **Chrenková, M.**, Sunde, P., Šálek, M., & Thorup, K. (2016). Effects of food provisioning and habitat management on spatial behaviour of Little Owls during the breeding season. *Ornis Fennica*, 93: 121–129.

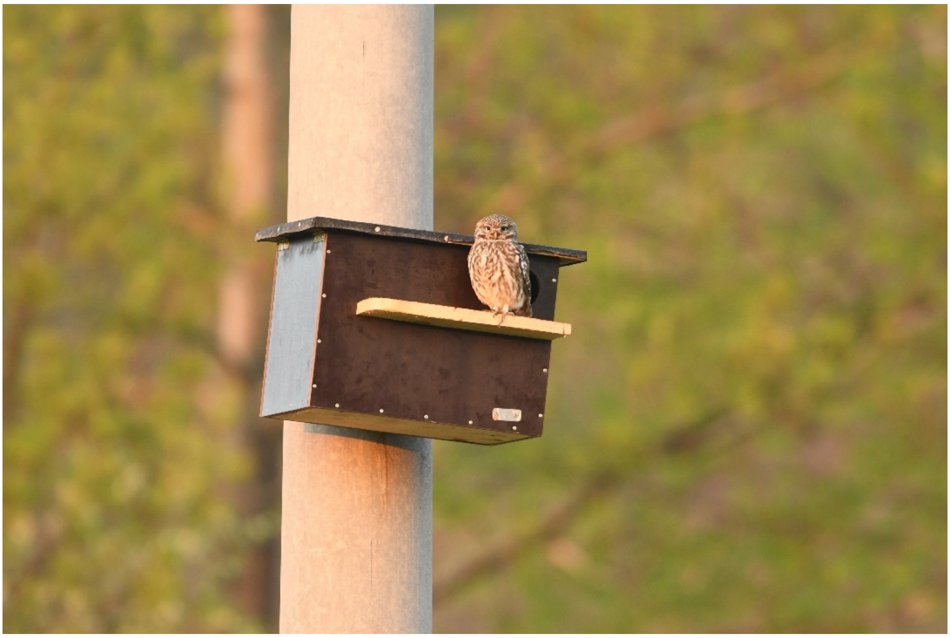
Abstract

The population of Little Owls in Denmark is close to extinction. The main cause is food limitation during the breeding season. Efforts to improve breeding success include providing breeding pairs with supplementary food and attempts to improve foraging habitats by creating short grass areas near the nests. In addition to increasing the reproductive output, feeding and habitat management may cause parents to work less hard improving their future reproductive value. We studied working efforts of five radio-tagged Little Owl pairs in years of absence and presence of food provisioning, and/or access to short sward vegetation areas near to the nest. We quantified movement as the minimum flight distance hour–1 (MFD), using the mean distance from the nest (DN) as a supplementary index. Under unmanipulated conditions, males had higher MFD and DN than females. If provided with food and/or areas with short sward vegetation, males but not females reduced their MFD and DN significantly. If MFD was adjusted for DN (the two measures correlated positively), both sexes reduced their DN-adjusted MFD as response to food provisioning but not to habitat provisioning. Food provisioning therefore had similar proximate effects on the foraging effort of males and females, whereas provisioning of short sward habitats had an indirect effect on male but not female MFD, because of decreased commuting distances between nest and foraging

sites. The results indicate that food provisioning not only leads to increased reproductive output in an endangered raptor, but also to decreased working effort, which in turn may improve adult survival.

CHAPTER 6

Summary of results



Monika Chrenková, Ph.D. Thesis

This thesis focuses on the little owl in European farmland, specifically on its distribution, population trend, ecology and possibilities for conservation. We systematically investigated the little owl populations in Czech Republic, Slovakia, Hungary and Denmark. We studied the habitat selection of breeding pairs on three different spatial scales: nest site, home range and landscape. With the assumption that the main cause of population decline is food limitation during the breeding season, we examined the effect of selected conservation measures on working effort of breeding individuals. Studies included in this thesis contribute to valuable knowledge on the rapidly declining species, reveal the drivers of the negative population trends in target regions and provide bases for evidence-based conservation measures.

In **our first study**, we compared little owl recent population data to the situation two decades ago. Our estimates represent a 87-94 % decline in the breeding population in the Czech Republic and a 31-45 % reduction in Slovakia. Our data also revealed substantial distributional range contraction of the little owl, indicating local extinctions over the last two decades. The analysis of the little owl's affinity to artificial and natural habitats confirmed a strong preference for man-made objects over the original breeding sites in tree cavities. The majority of the little owl territories were placed within farmsteads with livestock breeding or traditional farmsteads with old buildings that offer higher nest-site availability. In the light of our results, we proposed urgent preparation and implementation of a species action plan with conservation measures to halt the little owl's steep decline in Central Europe. In meantime, such species action plan has been elaborated for the little owl population in the

Czech Republic (AOPK ČR 2020) and the conservation measures are being implemented. In accordance with the proposal, we continued our research in the ecology of the little owl with the aim to gain further evidence for the design of the conservation measures.

The results of **the second study** revealed one of the highest population densities of little owl in Europe. We assume the high density of the species in the study area in Hortobagy region in Hungary is probably influenced by combination of extensive agriculture in the form of traditional pastoral management and sufficient supply of potential breeding places such as residential buildings and old farm infrastructure.

The results of **the third study** show that certain habitat associations are shared across all study regions in Czech Republic, Slovakia and Hungary, namely those involving grasslands and farm buildings that are used for foraging and nesting, respectively. Inter-regional analysis reveals that grasslands, gardens/orchards and farm buildings are the most important habitats at small spatial scales, whereas at large spatial scales, the owl is positively associated with open habitats in terms of arable fields. We suggest that conservation planning should consider both regional and inter-regional aspects of a species' habitat associations.

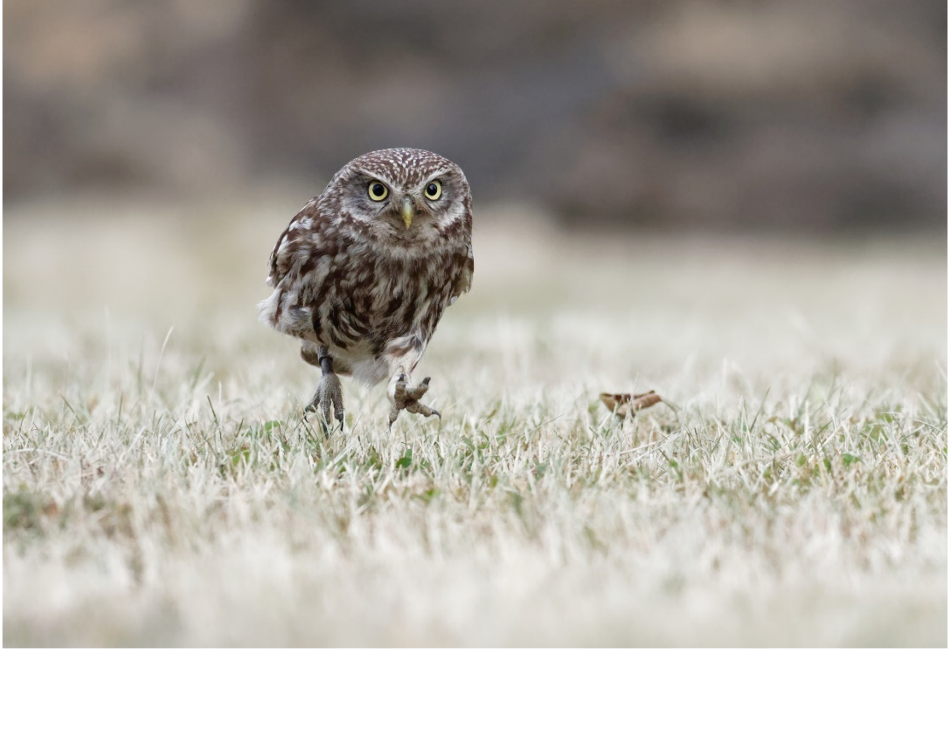
Based on these results, to gain more specific understanding of the relationship between the species and its close environment, we further studied the selective use of resources of breeding little owls in occupied habitats in an intensively managed agricultural landscape in Denmark, where the little owl population is close to extinction.

In **the fourth study** we tested the effect of conservation measures in Denmark. The measures aimed to improve breeding success through providing breeding pairs with supplementary food and attempts to improve foraging habitats by creating short grass areas near the nests. We studied if feeding and habitat management cause parents to work less hard improving their future reproductive value. The working efforts of ten radio-tagged little owls was analysed in years of absence and presence of food provisioning, and/or access to short sward vegetation areas near to the nest. We quantified movement as the minimum flight distance per hour. Within analyses we used the mean distance from the nest as a supplementary index. If provided with areas with short sward vegetation, males but not females reduced their working effort significantly. Our results suggest that the activity distance of females is constrained by brood guarding motives, which prevents flexibility regarding foraging distance. The results indicate that food provisioning not only leads to increased reproductive output in an endangered raptor, but also to decreased working effort, which in turn may improve adult survival. Provisioning of short sward areas adjacent to the nest reduced working effort indirectly through reduced commuting distances between foraging sites and the nest. Based on direct observations supported by telemetry results, short sward areas were used intensively relative to availability during the summer. Managed habitats were used most intensively in first hours/days after the management was implemented. Our results underline the importance of prioritizing habitats close to the nest sites when planning improvement of foraging habitats for little owls and other species which bring multiple, small, prey items to the nest.

The Ecology of the Little Owl in European Farmland

CHAPTER 7

Conclusions



Monika Chrenková, Ph.D. Thesis

The thesis contributes to knowledge on little owl ecology and population trend in the European context. Research revealed the negative population trend and evidence of regional decline and shrink of distribution area in the Czech Republic and Slovakia. These results support the alarming evidence about the unfavourable status of the species in most of Europe. On the contrary, study from the Hortobagy National Park, representing the first large-scale systematic survey in Hungary, indicates high population density and widespread distribution of the little owl. The study uncovers one of the highest population densities of this species in an agricultural landscape in the Central Europe. In fact, the favourable population status of little owls in the Hortobagy National Park, characterised by an extensive cover of steppe-like grassland habitats, can also be due to the prevailing commonness of traditional pastoral management of these habitats. Further research is necessary, including long-term demographic monitoring, to reveal distribution and status of little owls in other parts of its range and to estimate its population trend.

Complex analysis of habitat requirements reveals strong connection of the species to its preferred hunting habitats and expected breeding places in Central Europe. The investigation of habitat selection at three different scales shows the link between habitat characteristics and species occurrence. Certain habitat associations, namely grasslands and farm buildings that are used for foraging and nesting, are shared across all study regions. Inter-regional analysis reveals that grasslands, gardens/orchards and farm buildings are most important habitats at small spatial scales, whereas at large spatial scales, the owl is positively associated with open habitats in terms of arable fields. These findings support the hypothesis of agriculture intensification being the main driver of the population decline of little owl in selected regions of Europe. Our results also suggest large habitat plasticity of the species within studied regions. However, while the ambiguity of habitat associations of little owl in surveyed regions limits the generalizability of the results, the study provides new insight into the process of formulating conservation recommendations. Thus, researchers and conservation professionals should exercise a great caution when their conservation inference is solely based on knowledge on the species generated from research in a distant study area.

The thesis also provides an evidence on the effect of different conservation measures on little owl population in Denmark, where the species is close to extinction. Research findings indicate that food limitation, contributing to increased working effort of adult birds during breeding period, may be the main reason for the declining numbers of little owls. Our results show that tested conservation measures have positive effect on breeding performance. The study brings practical evidence and partial advice for effective protection of the species. The sufficient amount of available and accessible prey plays a major role in decreasing working effort of breeding birds, resulting in higher breeding success of the little owl. Rich and abundant prey provided by sufficient area of suitable foraging habitats is the main precondition for sustainable populations of the declining or even endangered owl species. To prevent little owl extinction, the evidence based conservation measures, such as provision of suitable hunting habitats with high availability and good accessibility of prey close to nests, are inevitable.

In conclusion, our data demonstrate ongoing steep population decline and range contraction of the little owl in selected parts of Europe. We propose that conservation authorities should respond immediately to this alarming situation with the introduction of short-term (e.g. supplemental feeding) and long-term (e.g. provision of suitable habitats) measures to support remaining populations of the little owl. Effective conservation measures for supporting high-quality foraging habitats (e.g. spatio-temporal grassland management) should be primarily implemented in recently occupied localities to facilitate dispersal and gene flow between individual subpopulations. This research clearly underlines the importance of prioritizing habitats close to the nest sites when planning improvement of foraging habitats for little owls, but it also raises the question of what type of habitat provides the best balance between the prey availability and accessibility at the same time. Thus, conservation activities should be focused on increasing the habitat heterogeneity in order to ensure enough foraging opportunities and resources during the whole year. The study also highlights the crucial importance of grassland habitats, including the mosaics of gardens and orchards with herb understory, and the habitat comprising farmland constructions (i.e. farmsteads). The mosaic of these habitats appears to provide crucial foraging and nesting opportunities for little owl. Moreover, conservation measures should be conducted mainly in farmland areas showing an extensive cover of open habitats. In order to support the declining little owl populations, it is crucial to halt any further loss and degradation of various grassland habitats. We further propose that the special conservation interest should be focused on the management and the restoration of grasslands, pastures and hayfields that have been substantially degraded by eutrophication and reseeded with nitrogen mixtures. Management activities mimicking historical small-scale farming methods (e.g. strip-mowing or spatio-temporal diversification of mowing), should be used to enhance the biodiversity of grasslands and orchards.

All the data and knowledge presented in this thesis contribute significantly to the overall understanding of the relationships between the endangered species and its environment with implications to the design of evidence-based conservation measures.

The Ecology of the Little Owl in European Farmland

APPENDIX

Curriculum vitae

Monika Chrenková, Ph.D. Thesis

MONIKA CHRENKOVÁ
Born: 25.9.1978 in Bratislava (born Kováčová)
E-mail: chrenkova@gmail.com

Education

2011 – present	PhD student in Zoology, Department of Zoology, Faculty of Science, University of South Bohemia
2004 – 2006	Bachelor´s Degree in Education of Biological Sciences, Faculty of Natural Sciences, Comenius University, Bratislava, Slovakia
1997 – 2002	Master's Degree (MSc.) in Biodiversity Conservation, Faculty of Natural Sciences, Comenius University, Bratislava, Slovakia
2001 – 2002	Course Certificate in Environmental Management and Policy, University of Wageningen, The Netherlands

Work experience

2007 – present	Biodiversity Expert Daphne – Institute of Applied Ecology, Bratislava, Slovakia
2006 – 2007	Executive Secretary – International Coordinator Carpathian Ecoregion Initiative, Bratislava, Slovakia
2002 – 2005	Regional Coordinator for the Danube Environmental Forum, DEF Secretariat, Bratislava, Slovakia

Internships and research stays

2011, 2015	Internship at the Centre of Macroecology, Evolution and Climate, University of Copenhagen, Denmark
2003	GEF IW:LEARN Exchange Programme (6 weeks) at the Mediterranean Information Office for Environment, Culture and Sustainable Development, Athens, Greece
2000	Course Certificate in Peatland Biodiversity (5 weeks), Darwin Initiative, Dundee, Scotland

Publications in peer-reviewed journals:

Chrenková, M., Dobrý, M., & Šálek, M. (2017). Further evidence of large-scale population decline and range contraction of the little owl Athene noctua in Central Europe. *Folia Zoologica*, 66, 106–116.

Šálek, M., Chrenková, M., Dobrý, M., Kipson, M., Grill, S., & Václav, R. (2016). Scale-dependent habitat associations of a rapidly declining farmland predator, the Little Owl Athene noctua, in contrasting agricultural landscapes. *Agriculture, Ecosystems and Environment*, 224: 56–66.

Jacobsen, L.B., Chrenková, M., Sunde, P., Šálek, M., & Thorup, K. (2016). Effects of food provisioning and habitat management on spatial behaviour of Little Owls during the breeding season. *Ornis Fennica*, 93: 121–129.

Šálek, M., Chrenková, M., & Kipson, M. (2013). High population density of little owl (Athene noctua) in Hortobagy National Park, Hungary, Central Europe. *Polish Journal of Ecology*, 61: 165–169.

Other publications:

Chrenková, M., Morávková, R., Lobbová, D., & Poledníková, K. (2020). World of European Ground Squirrel. Daphne, Bratislava. 43 pp.

Chrenková, M., & Královičová, A. (2015). World of salt marshes for young explorers. Daphne, Bratislava. 55 pp.

Chrenková, M., & Královičová, A. (2015). World of sand dunes for young explorers. Daphne, Bratislava. 50 pp.

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Viceníková, A., Chrenková, M., & Chrenková, V. (2007). Diversity of Life. DAPHNE, Bratislava, 178 pp.

Fedor, P., Kováčová, M., & Viceníková, A. (2005). Adaptations of organisms on ecological conditions in forests. In Viceníková, A. ed.: World of Forests. DAPHNE, Bratislava.

Kováčová, M. (2003). Threats and conservation of peatlands. In Viceníková, A. ed.: World of Peatlands – manual for teachers. DAPHNE, Bratislava.

chrenkova@gmail.com

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University of South Bohemia in České Budějovice
Faculty of Science
Branišovská 1760
CZ-37005 České Budějovice, Czech Republic

Phone: +420 387 776 201
www.prf.jcu.cz, e-mail: sekret-fpr@prf.jcu.cz