Hunting habitat selection of breeding great grey shrikes *Lanius excubitor* Linnaeus, 1758 in Luxembourg

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Abstract. In the course of agricultural land use changes there has been an ongoing loss of biodiversity in central Europe. For the great grey shrike *Lanius excubitor*, a farmland passerine bird species, a recent strong population decline has been observed in Luxembourg. We applied focal animal sampling to study the selection of hunting grounds of great grey shrikes in their breeding territories during April and May 2018. Great grey shrikes used intensively managed grassland and winter crops much less than could have been expected with regards to availability, and preferred hunting in extensively managed grassland, spring crops as well as structures such as dirt roads, woodpiles, margins and hedges. Great grey shrikes preferred areas with low or sparse vegetation and low perching opportunities (approx. 1,5 m height) as their hunting habitat. We provide concrete measures relevant for great grey shrike conservation in Luxembourg. Assuming that great grey shrike populations are limited by hunting habitat and consequently food supply during the breeding season, implementation of those measures could increase their reproductive fitness and support the local population of this threatened bird species.

Keywords. Land use, vegetation height, perch selection, semi-open habitat, critically endangered and decreasing species, predators, conservation and restoration measures.

1. Introduction

Land use changes have caused an ongoing loss of farmland biodiversity in central Europe (Benton et al. 2003). The large-scale intensification of agricultural practices has caused a decline in birds which thrived from previously extensively managed agricultural land (Butler et. al 2010, Reif et al. 2008). The great grey shrike *Lanius excubitor* Linnaeus 1758, a passerine bird species of national conservation concern, is often described as an indicator species for extensively managed semi-open habitats (Bechet & Moes 1999, Lefranc & Worfolk 1997, Panow 1996, Bechet 1995). While great grey shrikes are originally occupying territories in semi open landscapes where tree growth is naturally hampered, the species finds similar habitat conditions in cultural landscapes on extensively managed farmland with many vertical structures (Bechet 1995, Schön 1994).

In Central Europe, the great grey shrike is a year-round resident bird species. All 23 species of the shrike genus *Lanius* have one thing in common: they are carnivores, thus depending on the availability and abundance of their prey (Svensson et al. 1999, Panow 1996). Great grey shrikes typically hunt from perches, which they use in order to locate and pounce down onto prey (Lefranc & Worfolk 1997). Previous studies revealed that great grey shrikes mainly hunt for small mammals, particularly voles (*Microtus* spp.) and shrews (*Soricidae* spp.). Lizards, passerines and invertebrates, especially beetles, bees and grasshoppers can also form both spatially and/or temporally important prey sources (Grimm 2009, Hromada et al. 2002, Bocca

1999, Lefranc & Worfolk 1997, Cade 1995, Libois 1977). As a merely thrush-sized species, great grey shrikes are also subject to predation (Lefranc & Worfolk 1997). While corvids such as magpies *Pica pica* and carrion crows *Corvus corone* target the nests, diverse accipiters (*Accipiter* spp.) and falcons (*Falco* spp.) prey on the adults themselves (Lefranc & Worfolk 1997, Rothhaupt 1997, Panow 1996). Both hunting relatively large prey and being preyed upon, have important life history implications such as behavioural adaptations influencing the great grey shrikes´ habitat use, one example being the preference for using perches for both hunting and surveying the surroundings. Adult male great grey shrikes show a high tendency to return to the same breeding site year after year, this behaviour is less pronounced in females, thus increasing the risk of local extinction especially in fragmented landscapes (Massa et al. 1995).

Despite current decreases in population size, great grey shrikes are not considered to be threatened on a global level (IUCN Red List: Least concern) due to the species´ extensive range all over the western Palearctic, coupled with a population size that still has to be considered extremely large overall (BirdLife 2018). The decline, which is most pronounced in the species´ western breeding range, has caused local extinctions (Lefranc 2017, BirdLife International 2004, Jacob 1999, Lefranc 1999, Van Nieuwenhuyse 1999, Bassin 1995, Rothhaupt 1995) and has resulted in the great grey shrike´s being red listed and figuring as species of conservation concern in many European countries, including Luxembourg. Once a common breeding and wintering bird with accounts of up to 95 occupied breeding territories in 2006 (Biver et al. 2007, Bechet & Moes 1999), the species was recently listed as critically endangered (CR) in the national red list of the birds in Luxembourg (Lorgé et al. 2015) and figures as a high priority species in the national nature conservation plan (Mémorial 2017a). Two major factors believed to explain the population declines in western and central Europe are habitat loss and deterioration through agricultural intensification (Biver et al. 2009, Schön 2000, Lefranc & Worfolk 1997, Rothhaupt 1997, Panow 1996).

In order to better understand the mechanisms shaping and limiting a population in space and time, it is important to analyse the species´ niche and the interactions of individuals with their environment.

Since food availability directly affects breeding success in great grey shrikes (Martin 1987), we studied the birds´ hunting behaviour during the breeding season. By analysing spatial selection within the breeding territories, disproportionate uses of certain habitats may be detected and linked to advantages for survival and fitness (Krebs 2002, Jones 2001). The aim of our study was to analyse whether great grey shrikes exhibit preferences when it comes to selecting hunting grounds in their breeding territories. We studied whether 1) land use, 2) vegetation height or 3) perch height affect hunting habitat selection and derive recommendations for habitat management from our results.

2. Methods

2.1. Study areas

The study was conducted in two regions, each containing one of the two remaining clusters of great grey shrikes breeding in Luxembourg in 2018. One cluster was located in an area in the eastern lowlands of the Gutland near Junglinster, measuring approximately 30 km² and situated roughly at 300 m a.s.l., while the other cluster could be found at 450 m a.s.l. in a 40 km² area on the plateau of the Ardennes close to Troisvierges, in the northern region of the Oesling (Fig. 1). Whereas sandy and clayey brown soils on lime and on marl dominate the eastern study area, the northern area is characterized by stony and clayey brown soils on slate bedrock (Administration des ponts et chaussées, Service géologique 2006). In both regions, (semi-) open landscapes amount to roughly 60 % of the total surface area and are constituted chiefly by small to medium-sized agricultural fields. In the eastern region, higher portions in grassland (52 %) than arable land (43 %) of total agricultural land occur, compared to

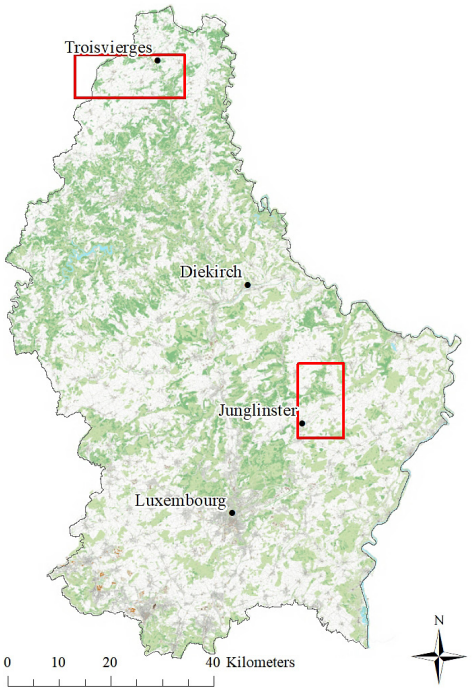


Fig. 1. Locations of the five analysed great grey shrike breeding pairs around Junglinster and Troisvierges (Source map background: Administration du Cadastre et de la Topographie, 2018).

the northern one where arable land is the dominating agricultural land use (62 %) compared to grassland (38 %) (STATEC 2012).

2.2. Field observations

Occupation status of breeding territories was surveyed with the beginning of the breeding season (between 19 February and 2 April 2018) when the birds are easily detectable due to territorial display and nest building (Südbeck et al. 2005). Former records (Bastian et al. 2013, Biver et al. 2009) as well as the nationwide shrike survey organized by the "Centrale ornithologique du Luxembourg" (COL) in the same spring of 2018 helped in finding occupied territories. The two clusters contained all for 2018 recorded breeding territories of great grey shrikes in Luxembourg and thus probably most of the remaining national population. Each cluster was made up of three territories (Fig. 1). Of all six pairs recorded, five met the requirements for further analysis: the territory was accessible and easy to survey and the birds could be observed with only minimal disturbance (Table 1). To assess the quantitative use of habitats and perching structures, the five pairs were observed in adherence to the focal animal sampling method throughout the main breeding months April, May and early June 2018 (28.03. – 12.06.2018) (Südbeck et al. 2005). Focal animal sampling involves a standardized protocol in which the observer follows an individual and records its activity during a given timespan (Altmann 1974). Every observation set lasted at least 30 minutes and was conducted



Fig. 2. Great grey shrike perching on a young tree in the territory of Heffingen, 21.05.18. Photo: Max Steinmetz.

Table 1. Overview of all analysed breeding territories of great grey shrikes with location information, time spent sampling, number of observation sets, the time span during which sampling took place and former records in the same territory (Bastian et al. 2013, Biver et al. 2009).

Territory name	Altitude (m a.s.l.)	Effective sampling time (min)	Observation sets	Time period of sampling	Former records
Beidweiler	310	366	7	03.04. - 16.05.2018	2004 -2005, 2006, 2012
Heffingen	330	368	9	03.04. - 30.05.2018	2004-2005, 2007, 2012
Rippig	285	161	4	28.04. - 23.05.2018	2004-2005, 2006, 2012
Binsfeld	475	315	9	10.04. - 06.06.2018	2000-2003, 2004-2005
Troine	450	247	6	05.05. - 06.06.2018	2000-2003, 2012

Table 2. Vegetation height categories of hunting habitats used during the focal animal and habitat sampling.

Description	Height
Bare soil	0
Low and sparse vegetation	< 10 cm
Low and covering vegetation	< 10 cm
Medium high and covering vegetation	10-50 cm
High covering vegetation	> 50 cm

Table 3. Perch height categories used during the focal animal and habitat sampling.

Perch height	Perch type
Low < 1.5 m	Fence
	Pole
	Hedge (linear)
	Bush (solitary)
	Woodpile
Medium 1.5-3 m	Hedge
	Bush
	Pole
High 3-5 m	Hedge
	Bush
	Tree
Very high > 5 m	Tree

in mornings from 8 a.m. onwards or in afternoons from 3 p.m. onwards. To minimize disturbances and behavioural alterations, observations were made mainly out of a stationary car. Due to their natural behaviour of perching on elevated posts and their shining white breast feathers, great grey shrikes are spotted relatively easily in a known territory (Fig. 2). In total 35 observation sets add up to 1,457 minutes of recording time. Recorded factors were habitat type at landing point for each hunting attempt (hunting point) together with the respective vegetation height and structure (Table 2), perching heights used prior to hunting attempts (Table 3), as well as the horizontal distance from perch to hunting point and from hunting point to nest location.

2.3. Habitat sampling and data preparation

Using all observations, home ranges ("Aktionsräume") in the form of minimum convex polygons were calculated. In a next step, habitat and perch availability within each home range were mapped over the months of May and June 2018. Forms of land use such as hay meadows, pastures and arable land as well as structures such as hedges, trees or fence rows were categorized using a key (Table 4; Fig. 3-7). The attribution to different management intensities was based on management dates, the diversity of plant species occurring on site and, where applicable, the listing of the habitat as a national or European protected biotope (Mémorial 2018). In order to take vegetation growth into account, vegetation heights of all habitats within the home ranges were sampled regularly from April to June 2018. All mapped hunting points, habitats and corresponding perching structures as well as the home range polygons were digitized in Esri ArcGIS Desktop 10.6 and Excel 2016

Table 4. Summary of different habitats found in great grey shrike breeding territories classified by management intensity grade and by classes with the description to identify them in the field. LSU = Livestock Unit, biotope designations from Mémorial (2004).

Class	Habitats	Description
Extensive grassland	Extensive pasture	Stocking rates 0.1-1 LSU/ha
	Extensive meadow	Unimproved flower rich lowland meadows cut no earlier than 15 June; biotopes 6510 lowland hay meadow and BK10 Calthion wet meadows
	Dry grassland	Nutrient poor grasslands; biotope BK07 semi terrestrial silicate and sand grassland
Structural habitats	Hedge/Bush	Any size and form
	Margin	In between fields or alongside roads with a width ≥ 0.5 m
	Dirt track	Small road with mud and vegetation
	Paved track	Small paved road without vegetation
	Woodpile	Piled up branches and timber
Intermediate grassland	Intermediate meadow	Improved meadows cut no earlier than 15 June; low plant diversity and abundance
	Intermediate pasture	Stocking rates 1-3 LSU/ha
Intensive grassland	Intensive meadow	Meadows being cut at least once before 15 June; no plant diversity
	Intensive pasture	Stocking rates > 3 LSU/ha
Arable land	Spring crop	Sown in spring and harvested in September-October; corn, oat, springbarley and -wheat
	Winter crop	Sown in winter and harvested in June-July; barley, rapeseed, rye, winterbarley and -wheat

(Microsoft Corporation). Graphs and tables were created in Excel, whereas Kernel density maps of all five shrike pairs were produced with the relevant ArcGIS tool. To analyse habitat use, we adopted a use versus availability design. Locations where a great grey shrike had been observed hunting, i.e. actual hunting points, were compared with randomly generated points. Since in the case of perch hunters such as great grey shrikes, hunting habitat availability is dictated by the presence of elevated structures, random points were generated only within an appropriate distance to perches. Therefore, only areas situated within a distance of 20 meters around low to medium perches (< 3 m) and 50 meters around high to very high perches (> 3 m) were referred to as available hunting area and used in the generation of random points. Those distances correspond to the maximum hunting distances observed for the different perch heights. Relevant variables such as the habitat type, vegetation height at a given date (randomly generated) or the height of the closest perch, which were previously collected in the field, were assigned to each of the random points. Finally, maps containing the home range, the available hunting area, all occurring habitats, the nest site location as well as actual, observed hunting points and random points were produced with ArcGIS for all five great grey shrike pairs. Due to the unfavourable status of the great grey shrike population in Luxembourg, we omitted publishing more precise descriptions and coordinates of the five territories and only show the map of one territory.

2.4. Statistical analysis

Statistical analysis was performed by means of a multivariate generalized linear mixed model (GLMM) in the software R, using the function glmer() of the package *lme4* (Bates et al. 2015), in order to compare the binomi-



Fig. 3. Extensively managed lowland hay meadows are scarce in Rippig, Heffingen and Beidweiler, 28.05.2018. Photo: Max Steinmetz.



Fig. 4. Semi-terrestrial sand and silicate grassland in early stages of succession and rich in structures in Troine, 03.06.2018. Photo: Max Steinmetz.



Fig. 5. Intensively managed meadows are the most abundant form of land use found throughout all territories, 03.06.2018. Photo: Max Steinmetz.



Fig. 6. Dirt roads with bordering margins combined with low perching possibilities such as fencerows are important hunting habitats, 03.06.2018. Photo: Max Steinmetz.



Fig. 7. Frequently used woodpile bordering onto a spring crop in Heffingen, 17.05.2018. Photo: Max Steinmetz.

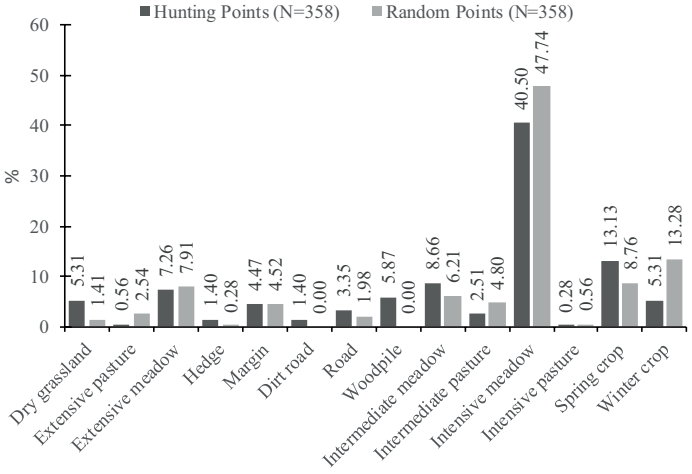


Fig. 8. Distribution of observed and random hunting points in specific habitats. Whereas the proportion of hunting points represents the actual use, the proportion of random points represents the availability of a habitat.

Table 5. Results of the generalized linear mixed model fit by maximum likelihood (Laplace approximation), testing the effects of the various predicting variables on the response variable of shrike presence (hunting or random point).

Predictor	Estimate	SE	p value
Intercept	1.888	0.37	< 0.001***
Use_Structural habitats	1.004	0.466	0.031*
Use_Intermediate grassland	-0.598	0.393	0.1261
Use_Intensive grassland	-0.598	0.393	0.1276
Use_Arable land	-0.747	0.352	0.034*
Vegetation height	-0.114	0.011	< 0.001***
Perch height	-0.122	0.051	0.017*
Distance to nest	<-0.001	0.011	0.246

nal response variable great grey shrike presence in the form of hunting and random points and including the different territories as a random effect (Bolker et al. 2009). The multivariate model utilizes the fixed predicting factors of habitat at hunting point as a categorical variable, vegetation and perch height as a continuous variable with averaged heights and the distance of the hunting point to the nest as a continuous variable. Additionally, the icc() function of the package *sjstats* (Wu et al. 2012) was used to calculate an intraclass correlation coefficient (ICC) to assess how much variation is explained by grouping into territories.

3. Results

The intraclass correlation coefficient, depicting the amount of variation which can be explained by grouping the data, in this case into five territories, depicts a low value of (ICC=0.0047). Thus, observations from within territories are no more similar than those between territories, and little variation can be explained by grouping into territories.

3.1. Hunting habitat selection

A total of 358 observations of hunting behaviour could be included in the analysis. Of these, 140 were located in Beidweiler, 113 in Heffingen, 61 in Binsfeld, 34 in Troine and only 10 in Rippig. Great grey shrikes significantly preferred to hunt in the habitat class "structural habitats", compared to "extensive grassland" (Table 5). On the other hand, they preferred "extensive grassland" to "intermediate grassland" or "intensive grassland" as well as "arable land". However, only the comparative dislike of "arable land" proved to be statistically significant ($p < 0.05$).

When looking at the quantitative distribution of hunting and random points within different habitats in Fig. 8, the high proportions of 40.5 % of hunting and even 47.74 % of random points are located in intensive meadows. Whereas hunting points are located less frequently on winter crops proportionally, containing less than half the amount of hunting compared to random points, spring crops host proportionally more hunting points (13.13 %) than random points (8.76 %). Extensive, intermediate and intensive pastures hold very few hunting and random points and in all three habitats, random points are slightly more frequent. Even though all structural habitats are used only occasionally (1.40-5.87 %), the frequency of hunting points in these habitats is much higher than that of randomly generated points, except for margins. Last but not least, 5.31 % and 7.26 % of hunting points are located on dry grassland and extensive hay meadows respectively. Whereas dry grassland hosts many more hunting than random points, proportions on extensive meadows are nearly equal. The maps of great grey shrike breeding territories, such as the one created for the territory of Heffingen (Fig. 9) give a complete picture of the birds´ spatial use within their home range. Besides indicating the different habitats and land

uses overall, the map also clearly visualises habitat use in relation to the availability of perches as well as distance to the nesting site.

The results from the mixed model (Table 5) show a highly significant negative effect of increasing vegetation height on great grey shrike presence or, differently put great grey shrikes preferred to hunt on areas with low vegetation ($p < 0.001$). When comparing the frequency of hunting and random points at varying vegetation heights (Fig. 10), it becomes apparent that bare soil and the two low vegetation classes (below 10 cm) host proportionally more hunting points. The divergence between hunting and random points is particularly pronounced in the category "low and sparse vegetation". Quantitatively, great grey shrikes have predominantly been observed hunting on low and covering vegetation (49.41 %), followed by low and sparse vegetation (31.47 %), bare soil (13.24 %), yet have hunted very little on medium high and covering vegetation (5.88 %), despite the category's high availability. High covering vegetation was entirely avoided.

Model results showed no significant difference of distances to nest sites between random and actual hunting points in the home ranges (Table 5).

3.2. Perch height selection

Decreasing perch height proved to have a significantly positive effect on great grey shrike presence or, differently put, great grey shrikes significantly preferred hunting from low perches (Table 5). Whereas random points are more frequently located close to medium (1.5-3 m), high (3-5 m) and very high (> 5 m) perches than hunting points, low perching structures up to 1.5 m are used proportionally more often by hunting great grey shrikes than expected by their availability (64.57 % vs. 46.22 %) (Fig. 11).

4. Discussion

To our knowledge, our study is the first to systematically analyse habitat selection by great grey shrikes during the breeding season in form of a use vs. availability design. Our results on hunting habitat selection reveal concrete conservation and habitat improvement measures for the locally threatened species.

Even though we could include only five breeding territories in our study, due to low breeding densities and time-consuming data collection, we managed to gather 358 hunting locations. We were therefore able to draw a number of conclusions that are statistically robust, yet remain limited to our five territories. The low ICC value reveals differences within the territories, stressing the large variation in habitat use and availability found in each of the territories. This indicates that great grey shrikes might be flexible in their hunting behaviour depending on local conditions, therefore one should be careful to extrapolate our results on a wide geographical scale. By including only areas within perch reach, the habitat selection analysis is refined and adapted to the perch and pouncing behaviour of great grey shrikes. Thus, the effect of perch presence can be excluded when analysing the selection for a certain habitat for hunting. This choice is then more likely to be based only upon the abundance of a resource itself found on the habitat (Jones 2001). Areas outside of the defined buffer ranges in the middle of plots where accessed only rarely in this study. Although hunting methods different to perch and pouncing have been observed in this study and are recorded for great grey shrikes in general (such as hovering, longer ground or aerial pursuits), perch and pouncing is the most common method (Lefranc & Worfolk 1997, Cade 1995).

4.1. Hunting habitat selection

We studied hunting habitat selection within territories as a third order of habitat selection (Johnson 1980) during the breeding season. Since great grey shrikes are highly territorial and exhibit perch hunting behaviour, habitat availability was defined as the intersection of home range and area within perch reach. As the distance to the nest had no significant effect on hunting habitat selection (Table 5), a strong gradual likelihood of use depending on nest distance can be excluded. We found the selection of hunting habitats to be



Fig. 9. Aerial images of the territory in Heffingen with both observed hunting (N = 113) and random points (N = 113). Many different forms of land use are found within this home range, such as intensive to extensive meadows, spring as well as winter crops. Surprisingly, this great grey shrike pair had their nest location in a hedge in the direct vicinity of an intensively frequented road and was recurrently using the woodpile south east of the nest as a hunting perch. ExMe = extensive meadow, IntMe = intensive meadow, InterMe = intermediate meadow, SpCr = spring crop, WiCr = winter crop (Source map background: Administration du Cadastre et de la Topographie du Luxembourg, 2018).

affected by land use as well as specific habitat structures (Table 5). For example, the rare biotope type of dry grassland, with low vegetation throughout most of the breeding season and a high structural diversity on the micro-scale was a preferred hunting ground. The abundance of bare soil patches makes it easy to spot prey in this type of habitat, which, furthermore, is generally available in high numbers as well as diversity (Siegrist et al. 2017, Schirmel et al. 2015, Vickery et al. 2001). Although extensive meadows may also host relatively high prey abundances and diversity, especially in relation to invertebrates (Vickery et al. 2001, Fenner & Palmer 1998, Yosef & Deyrup 1998, Blake 1996, Van Wingerden et al. 1992) and voles (Benedek & Sîrbu 2018, Fischer & Schröder 2014, Butet et al. 2010, Koks et al. 2007, Spehn et al. 2000), the vegetation grew to a height in which great grey shrikes may find it difficult to spot and access ground dwelling prey before the fledgling period (end of April). This stands in stark contrast to intensive meadows, which were mown already once before the end of April and kept relatively short after.

Furthermore, great grey shrikes are selecting for structural habitats as hunting grounds (Table 5). As can be seen by comparing use with availability, this is especially the case for woodpiles, hedges, dirt and paved tracks (Fig. 8). Margins, on the other hand, have been used in equal proportion to their availability. Woodpiles as well as hedges constitute small structures which provide perching opportunities as well as habitat for a range of prey taxa such as birds, insects and small mammals. While both dirt and paved tracks types offer easily accessible, open hunting grounds, their use may be amplified by prey abundance in bordering side strips.

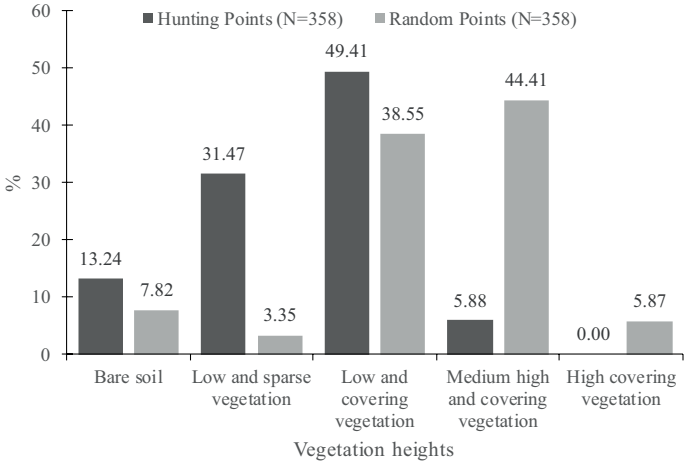


Fig. 10. Distribution of hunting and random points at different vegetation heights, averaged over the sampling period and over habitats.

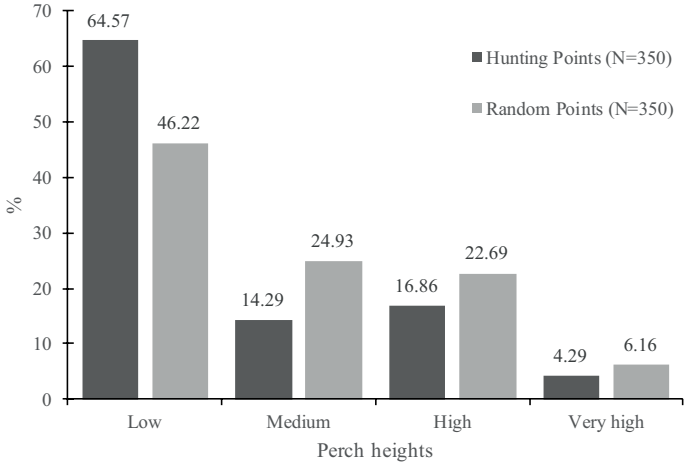


Fig. 11. Distribution of hunting and random points in relation to perch heights. The dark grey bars represent perches used prior to hunting pounces during focal animal sampling, the light grey bars represent perches situated closest to random points.

Such strips as well as margins dividing different land uses are shown by many studies to be an important habitat for several great grey shrike prey taxa (Westbury et al. 2017, Broughton et al. 2014, Fischer & Schröder 2014, Ernoult et al. 2013, Thomas & Marshall 1999). Nonetheless, these structures have been given no direct preferential treatment by great grey shrikes, possibly due to their high vegetation character. However, great grey shrikes have been observed pouncing down directly besides margins, indicating a certain spillover of prey from margins into easily accessible areas. Large scale agricultural intensification is often related to an increase in field sizes through land consolidation and by consequence a reduction in structural edge habitats such as margins, hedges, wood- or stonepiles and other edge lines. Since great grey shrikes prefer using those habitats, their reduction within territories decreases the amount of high-quality foraging habitat and could negatively affect a local great grey shrike couple.

The results further show that spring crops are used as hunting grounds by great grey shrikes more frequently as would be expected by their availability (Fig. 8). The selection for spring crops may be largely attributed to the thoroughly optimized accessibility of prey on bare soil through May and June, before the growing season. Due to the intensified cultivation of spring crops, mostly in form of uniform corn and spring wheat, their benefit

in terms of food supply may be only temporary. Food abundance in terms of insects and rodents is shown to be reduced by increased labour intensity, pesticide use and erosion (Newton 2017, Morris et al. 2005) often practised respectively found on intensive spring crops. Nevertheless, the importance of spring crops as great grey shrike hunting habitat must not be underestimated (Tryjanowski et al. 1999), all the more if cultivated extensively.

In contrast, intensive meadows as well as winter crops are used disproportionately little for hunting (Fig. 8). The fact that, quantitatively, intensive meadows remain the most used hunting ground within the analysed territories could be explained by their absolute predominance as a land use type as well as their attractive low vegetation character. Since intensive meadows are mown regularly from April onwards, vegetation heights are constantly kept low. The fact that they are still avoided as hunting grounds may be further proof of limited food supply (Jacob 2003, Vickery et al. 2001, Spehn et al. 2000, Fenner & Palmer 1998, Van Wingerden et al. 1992). The high proportions of intensive meadows found within the territories reflect the ongoing intensification of grassland and meadow management in Luxembourg. Where grasslands were once managed extensively as hay meadows or extensive pastures and produced abundant food supply, sedentary great grey shrikes now find themselves surrounded increasingly by intensive silage meadows fertilized artificially and mown frequently and thus with poor insect populations (G. Bechet, personal communication, March 2018). Winter crops are largely avoided in hunting because the prerequisite of easy access is not given: these habitats are characterized by medium high vegetation height already at the beginning of the breeding season and become increasingly inaccessible for ground hunting birds such as great grey shrikes.

Lastly neither extensive nor intermediate nor intensive pastures were given preferential use as hunting habitats by great grey shrikes (Fig. 8). Further differences in selection between the three intensity categories are hard to assess and interpret, especially because pastures are not strongly represented in the territories. It may be more suitable to categorize pastures based on vegetation structure, diversity and composition, rather than on actual stocking rates. Still browsing keeps vegetation heights low and thus guarantees accessibility for great grey shrikes, the more so the higher the stock intensity. In any case, the reason behind a non-selective use may be low prey availability. Some studies point out a decreasing abundance of invertebrates and small rodents in intensively stocked homogeneous pastures (Vickery et al. 2001, Strong & Wall 1994, Brandl et al. 1986); in others, high vole abundance is linked directly to high and dense vegetation (Koks et al. 2007). Diverse dung bound invertebrates, amongst other many large *Scarabaeidae*, possibly supplying great grey shrikes on pastures, are shown to have been greatly reduced by the large-scale use of pharmaceutical avermectins (Strong & Wall 1994, Brandl et al. 1986).

Our results show that in the main breeding period between April and June great grey shrikes prefer to hunt in areas with bare soil or low vegetation of up to 10 cm in general (Table 5 and Fig. 10) and display a particularly strong preference for low and sparsely vegetated habitats, the second class shown in table 2. A similar preference for low and/or sparse vegetation is documented in previous studies (Antczak et al. 2004, Tryjanowski et al. 1999, Rothhaupt 1997, Panow 1996, Gawlik & Bildstein 1995, Guerrieri et al. 1995, Novak 1995) and can be explained by the effective accessibility of such habitats. Both factors make it comparatively easy to detect and catch ground dwelling prey, thus even negating the effect of high or low prey abundance to a certain extent. No variation in hunting habitat and vegetation height selection through the breeding period could be detected.

4.2. Perch height selection

The analysis of hunting perch selection of great grey shrikes indicates that there is a strong preference towards low structures up to 1.5 m in height (Table 5 and Fig. 11). From a cost – benefit point of view (Krebs 2002), it is beneficial for sit and wait predators spe-

cialized on ground dwelling prey to perch on low structures since the flying distance is minimized. Thus, time and energy spent for each pounce are decreased, increasing the overall hunting efficiency. While higher perches provide ground vision to a wider area (Rothhaupt 1995), low perches may be especially suitable when hunting small ground invertebrates, which constitute important prey during the breeding season (Grimm 2009). Catching insects from high perches may not be as cost efficient as catching them from low perches. Furthermore, the quantitative dominance of low to medium high (< 3 m) perching structures available within the territories and their disproportionate high use indicate that the analysed individuals used well oversee-able areas in early successional stages. Here, great grey shrikes may encounter fewer competing corvids, which rather prefer areas with medium to high vertical structures and elder shrubs and trees (Newton 2017, Diehl 1995).

Habitat selection is a decision-making process, during which the disproportionate use of a certain habitat is based upon a selective choice (Jones 2001) which itself is not necessarily only based upon habitat quality, but more likely the result of a cost and benefit evaluation (Krebs 2002). Further non-habitat related and extrinsic factors affecting selection in birds and cost-benefit evaluations are intraspecific attraction, competition and nest and adult predation risk. These factors are well known for affecting shrikes constantly in many situations and on many scales (Lefranc & Worfolk 1997, Panow 1996, Cade 1995, Cade & Swem 1995, Yosef & Grubb 1993, Cody 1981).

Although intraspecific attraction and competition generally play an important role for cluster breeding shrikes when occupying territories (Diehl 1995, Lorek 1995, Massa et al. 1995, Schön 1994), they should hardly affect hunting habitat selection within territories. Especially not in Luxembourg, where great grey shrikes are found at low densities and in this case occupied territories did not touch directly.

Although avoidance patterns of shrikes towards corvids are recorded (Roos 2004), those are shown for red-backed shrikes to influence breeding related choices and habitat selection on a landscape scale, however not directly hunting habitat choices. This last assumption may be supported by our observations of great grey shrikes hunting close to perching magpies or carrion crows and showing no apparent avoidance or defensive behaviour. Great grey shrikes guarding a nest with fledglings, however, were harassing passing magpies, carrion crows, common buzzards as well as kestrels. Nest predation pressure may influence nest site selection in great grey shrikes but seems to have little effect on hunting habitat selection. Further do great grey shrike pairs hunt by turns and over short intervals only, minimizing the risk of nest predation while hunting (Panow 1996, Schön 1994). More consideration has to be given to potential spatial changes in hunting habitat selection during the breeding period.

As a last factor, adult great grey shrikes themselves are always at risk of getting preyed on, the most important predators probably being sparrowhawks (*Accipiter nisus*), falcons (*Falco* spp.) and goshawks (*Accipiter gentilis*). Many aerial raptors rely on structures such as hedges, tree belts or forest edges for surprise attacks (Newton 2010, Selås 1993). The fact that shrikes are generally occupying high-visibility territories commonly situated away from forests could point to a selective adaptation against adult predation.

4.3. Conclusion and recommendations for species conservation

The Luxembourgish great grey shrike population underwent a substantial population decline in recent years (Bastian et al. 2013), presumably largely due to land use intensification, as it is the case in the rest of Western Europe, but also to splinter development of housing and leisure activities. Habitats which are demonstrably much sought after by great grey shrikes such as structural border habitats and extensively managed and/or nutrient poor surfaces are being improved or completely abandoned (Emmerson et al. 2016). Additionally, land consolidation into bigger field sizes reduces border habitats and structural complexity

on a landscape scale (Landis 2017, Benton et al. 2003). Our results consolidate the importance of structural border habitats and extensively managed and/or nutrient poor surfaces for the preservation of great grey shrikes specifically and perhaps farmland biodiversity generally.

This study highlights the important role of low vegetation and low perching opportunities in providing hunting habitats for great grey shrikes during the breeding season. A predilection for extensively managed grassland habitats, spring crops and structural habitats (e.g. tracks, hedges, margins and woodpiles) was observed, predominantly those accessible in terms of vegetation height and perching opportunities. While intensive silage meadows and winter crop are used disproportionately little, extensively managed as well as short vegetated habitats are valuable in providing great grey shrikes with food supply all through the main breeding months April and May. Despite a low sample size of five analysed pairs, our results compensate in data completeness. They should foremost be transferable onto Central-European great grey shrike populations living in cultural landscapes.

The conservation as well as the restoration of semi-open habitats within (recently) occupied great grey shrike territories could be an effective tool not only in restoring a viable great grey shrike population, but also in supporting diverse other rare organisms of semi-open habitats. The national biodiversity regulation (Mémorial 2017b) provides financial compensation for many conservation and restoration measures in extensive grasslands and arable fields. Implementation of those programmes relies largely on the willingness of farmers as well as negotiation achievements of the concerned biological stations. For the great grey shrike, the action plan for the species in Luxembourg (Biver et al. 2009) can serve as an important basis for planning, sensitization and negotiation. Based on our study, we propose following additional management actions to increase habitat quality not only in and around currently occupied breeding areas, but also in former breeding areas of the great grey shrike in Luxembourg:

- Conservation and restoration of extensively managed grassland (Schön 2000, Rothhaupt 1997) possibly via the national biodiversity regulation for grassland habitats (Mémorial 2017b).
- Ecological improvement of arable land, particularly through the promotion of spring crops, set asides, wildflower strips and field margins via biodiversity programs for arable land (Mémorial 2017b) in combination with the provision of additional perches.
- Conservation and restoration of specific grassland habitats which combine vertical structures with rich food supply and low as well as sparse vegetation, such as sand and silicate dry grasslands (nationally protected habitat BK07), dry calcareous grasslands (European protected habitat 6210), Calluna heathland (European protected habitat 4030), very nutrient poor lowland hay meadows (European protected habitat 6510), rare Juniper formations (European protected habitat 5130) and orchards (nationally protected habitat BK09) via national biodiversity programmes (Mémorial 2017b). Optional biodiversity programmes support favourable management such as itinerant sheep grazing or no mowing before 15 June.
- Creation of feeding hotspots such as small woodpiles (< 2 m high), stone piles, sparsely vegetated margins alongside tracks or between fields, and always in combination with perches which help increase the visibility of prey, particularly in high vegetation on fields and meadows.
- Restoration of semi-open landscapes with early successional stages by providing natural or artificial, low and solitary structures up to 1.5-3 m such as poles, shrubs or young fruit trees for perching, especially in areas where such structures are rare or missing completely (Rothhaupt 1997). As a guideline, Schön (2000) calculated a mean distance of 35 meters between single woody plants including hedges as well as trees and a mean density of 5 single woody plants per hectare in core areas of occupied great grey shrike territories on the Swabian Alb.

- Implementation of an adapted woody plant management plan which provides breeding great grey shrikes with higher visibility throughout their territories, including consequential but selective trimming of higher (> 5 m) and older hedge and tree complexes and preventing an excessive scrub encroachment (Schön 2000, Diehl 1995), this foremost in areas, rich in perching structures. Furthermore, long continuous hedges should be interrupted at regular intervals. This trimming can be spread over several years to help maintain a constant vertical diversity; trimming should only be carried out from the beginning of October until the beginning of March to avoid the breeding season. Cut branches can be used to create woodpiles; for details see Schön (2000).

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