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Effects of forest management practices in clearings on breeding performance of the Red-backed Shrike (*Lanius collurio*)

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The structure and quality of breeding habitats play an essential role for breeding success of individuals and thus, the viability of populations. Knowledge on habitat requirements can guide management practises to ensure optimal conditions for breeding. In this study, we investigate the effect of different habitat features and forest management strategies on the breeding performance of Red-backed Shrikes (*Lanius collurio*) breeding in Gribskov forest, Denmark. We found that the availability of available perches for hunting is the main predictor having a positive effect on number of breeding pairs and fledglings. It was also positively associated with the number of years that the clearing has been occupied by breeding pairs. Furthermore, clearings with grazing animals contained breeding pairs for more years than clearings without grazing, suggesting improved foraging conditions in clearings with low vegetation. Our results provide direct applications for forestry management for improving the conservation status of this species.

1. Introduction

The last century's conversion of the European landscape, from small scale farming practices with grazing animals to large scale agricultural monocultures, has been detrimental to many populations of open land bird species, such as the Red-backed Shrike (*Lanius collurio*) (Chamberlain *et al*. 1999). Although the overall European conservation status of Red-backed Shrikes is now considered stable (BirdLife International 2016), several Western European populations of Red-backed Shrike have been declining during the last 30–50 years and the species has been nearly extirpated from the British Isles (Yosef 1994, BirdLife International 2004, Tellería 2018). The Danish population has been estimated to number 1,500–3,000 breeding pairs, with a shift in distribution since the 1970s from eastern to more western parts of the country (Grell 1998). This, mainly insectivorous long-distance migrant (Cramp & Perrins 1994, Tøttrup *et al*. 2012a) occurs over a broad range of habitats throughout its breeding range, including low-intensity farmland with a mosaic-like landscape of pastures, fallows and scattered trees, bushes, small woods as well as forest clearings (Cramp & Perrins 1994, Titeux *et al*. 2007, Tryjanowski *et al*. 2007, Hollander *et al*. 2011, Ajder &

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Baltag 2017). Although, Red-backed Shrikes may be flexible in habitat choice (Svendsen *et al*. 2015, Pestka *et al*. 2018), the main factors determining habitat suitability are likely a combination of dense shrubs for nesting, open sunny areas for hunting, and the presence of freestanding and evenly distributed perches (Olsson 1995a, Titeux *et al*. 2007). Studies have also shown a strong association with scrublands, hedgerows, and forest edges (Olsson 1995a, Vanhinsbergh & Evans 2002, Brambilla *et al*. 2007, 2009), as well as with the abundance of large invertebrates (Titeux *et al*. 2007, Goławski & Goławska 2008, Pedersen *et al*. 2012). Furthermore, local weather conditions during the breeding season may affect breeding success (reviewed by Jørgensen *et al*. 2013).

The main causes of population declines across Europe are likely associated with intensification of agricultural regimes over the last five decades with the conversion of pastures and meadows into large-scale monoculture fields and the use of pesticides (Tucker & Heath 1994, Chamberlain *et al*. 1999). However, conditions during migration and on wintering grounds may likewise influence population size (Pasinelli *et al*. 2011, Tøttrup *et al*. 2012b). As the availability of preferred habitat declines, Red-backed Shrike populations may be increasingly confined to other, more temporary habitat types, such as forest clear-cuts (Olsson 1995a, Hollander *et al*. 2011, Söderström & Karlsson 2011).

The overall aim of the present study is to derive evidence-based recommendations for forest management practices, in order to maintain and potentially improve conservation status for the Red-backed Shrike. Our objective is to identify key habitat features and the effects of different forest management practises important for breeding success and population viability in the Red-backed Shrike. We approach these questions by investigating breeding performance in forest clearings in relation to five forest clearing features describing different forest management practises and levels of succession.

2. Material and methods

Our study was carried out in Gribskov (56°0’ N, 12°20’ E), one of the largest forested areas in Denmark covering ca. 5,600 ha. The breeding population of Red-backed Shrikes in Gribskov numbers approximately 100 pairs found on recent clear-cuts and on permanent clearings with grazing (Pedersen *et al*. 2011). We included all clearings in the southern part of Gribskov making up a total forested area of ca. 2,000 ha. This comprises a total of 40 clearings covering 116 ha (average clearing size ± SD: 3.2 ± 2.8 ha). In two cases, multiple clearings could be considered part of an overall site sharing some similarities in habitat characteristics. The clearings were monitored for breeding occurrence of Red-backed Shrikes during six years (2004–2009) and for breeding success during four years (2006–2009).

From these efforts, three measures of habitat suitability were applied: (1) number of fledglings (2006–2009), (2) number of breeding pairs (2006–2009), and (3) total number of years with breeding pairs during the six-year monitoring period (2004–2009). The basic unit of our investigation is clearing rather than territory for the following reasons: (1) actual territories of the individual breeding pairs are difficult to assess because of a high degree of overlap, (2) each clearing form a uniform habitat easily characterised, (3) birds are assumed to utilize the clearing and not move to neighbouring clearings or into the forested areas during breeding, and (4) data on breeding success are available as total number of fledged chicks as the family flocks spread out within the clearing after fledging making assessment of chicks per breeding pair impossible (details in Pedersen *et al*. 2011).

To investigate the effects of different forest management practices on breeding performance, we collected data on five habitat parameters in the year 2010: (1) presence of forestry slash (i.e., coarse and fine woody debris) left on clearings (could serve as perches, caches and/or nesting sites), (2) abundance of suitable perches divided into three categories; scarce (open with very few trees along clearing edge), frequent (few trees also in clearing center), or abundant (single trees found throughout the clearing), (3) presence of nesting trees in terms of young Beech (*Fagus sylvatica*) and/or Spruce (*Picea abies*) in the clearing as these are the preferred tree species used for nesting by Red-backed Shrikes at this breeding site (Pedersen *et al*. 2011), (4) whether the clearing was replanted

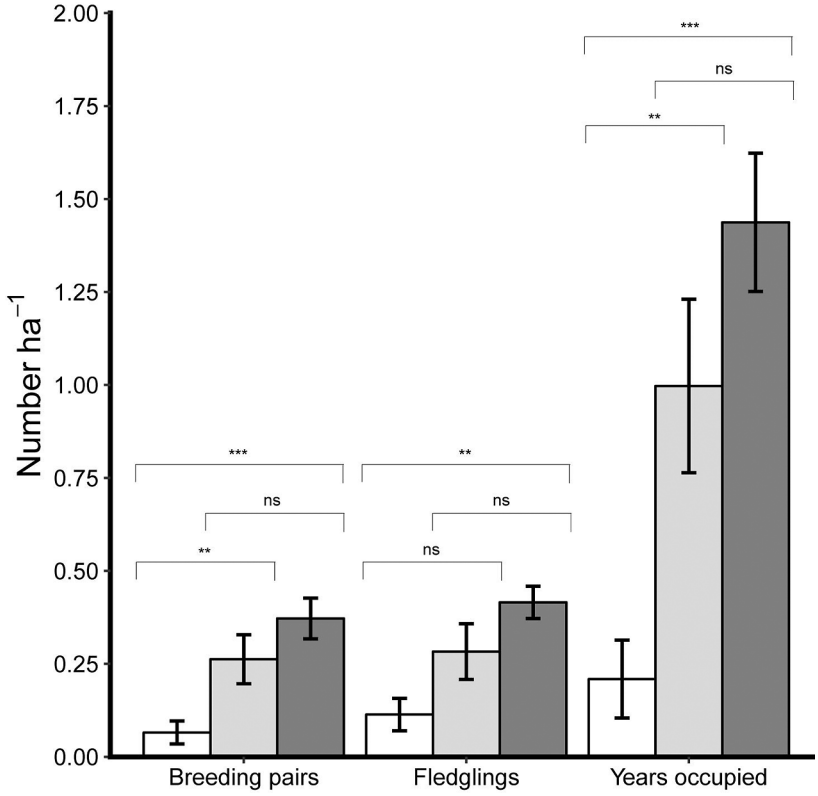

Fig. 1. Model estimated marginal means (EMMs) with standard errors of number of breeding pairs, fledglings and years occupied per hectare (ha) of clearings with scarce (white), frequent (light grey) and abundant (dark grey) availability of perches. Stars indicate significance of pairwise comparisons (*** $p \leq 0.001$, ** $p \leq 0.01$, * $p \leq 0.05$, ns: non-significant). Estimates are back-transformed from the log-scale on which original estimates and standard errors were computed.

after logging, and (5) whether the clearing was regularly grazed by livestock. Although local changes may have occurred over the study period in clearings due to succession, all habitat variables were representative of clearings going back to 2004.

2.1. Statistical analyses

We modelled the effect of all habitat parameters on the number of breeding pairs and fledglings using a Generalized Linear Mixed Model (GLMM) with a poisson distribution, an offset of the natural logarithm of area to account for clearings of different sizes as well as a random effects of year and site to account for the fact that data had been collected over multiple years (2006–2009) and that some clearings belonged to the same overall site. The models were run using the R-package *lme4* version 1.1–17 (Bates *et al*. 2015).

We checked for overdispersion using the *dispersion_glmer* function from the R-package *blmeco* version 1.1 (Korner-Nievergelt *et al*. 2015). Dispersion parameters were estimated as 0.82 and 0.94 for the models of breeding pairs and fledglings, respectively, thus, indicating no serious sign of over or under-dispersion. We modelled number of years with breeding pairs using a Generalized Linear Model (GLM) with a poisson distribution as we detected no sign of overdispersion (residual deviance 34 compared to 29 degrees of freedom).

The model included fixed effects of all habitat parameters and an offset of the natural logarithm of area. Visual inspection of residual plots revealed no violations of model assumptions for any of the above-mentioned models, and none of the habitat parameters included in the models were highly correlated (Generalized Variance Inflation Factor = 1.06–1.21). Inference was based on a backwards stepwise model selection procedure (function: *drop1*) with a χ^2-test to determine the final model parameters. From the final models, we derived estimated marginal means for a pairwise comparison of factor levels using the R-package *emmeans* version 1.2.4 (Lenth 2016). All analyses

were conducted in the statistical software R version 3.5.1 (R Core Team 2018).

3. Results

We found a strong positive association between the availability of perches in clearings and the number of breeding pairs, fledglings and total number of years occupied by Red-backed Shrikes (Table 1, Fig. 1). Increasing the level from scarce to frequent availability of perches significantly increased the number of breeding pairs and years occupied, while increasing the level from scarce to abundant generated an increase in all response variables. Furthermore, we found a strong significant positive association between occurrence of grazing and the number of years clearings were occupied by breeding Red-backed Shrikes, while none of the other variables included in the model had significant effects on breeding occurrence or success (Table 1).

4. Discussion

We show that specific forest management practices during and after clear-cutting strongly affect subsequent breeding habitat quality for Red-backed Shrike. Most importantly, the abundance of perches available for Red-backed Shrikes in clearings was positively related to both breeding performance and occurrence of breeding pairs in the clear-cut. However, the presence of grazing animals on clearings, in addition to abundance of perches, likewise seemed to be positively associated with the number of years occupied by breeding Red-backed Shrikes.

Perches are likely highly important to Red-backed Shrikes as they facilitate hunting opportunities. Thus, a high availability of perches providing good look-outs across the clearing may increase the probability of successful hunting attempts. The height of perches may also affect the likelihood of detecting prey, and heights within the range of 1.5–3.5 meters has been shown to be preferred by Red-backed Shrikes (Carlson 1985, Olsson 1995a, Titeux *et al*. 2007). In addition, perches with thorns may provide opportunities for caching, a common strategy for storing food in Red-backed Shrikes (Hernández 1995). In a previous experimental study on Loggerhead Shrikes (*Lanius ludovicianus*), artificial perches were placed in territories with only few look-out posts (Yosef & Grubb 1994). This resulted in a decreased territory size and an increase in local population size. Thus, future studies could explore the importance of different types of perches and heights experimentally by manipulating clearings.

Our results confirm previous studies showing a positive effect of grazing (Vanhinsbergh & Evans 2002, Brambilla *et al*. 2007, Goławski & Meissner 2008) on abundance and breeding success of Red-backed Shrikes in forest clearings. Grazing prevents tall grasses from dominating clearings, securing short vegetation and exposed ground, which facilitate hunting opportunities for Red-backed Shrikes. In addition, dung from the grazing animals may attract insects that increase food availability and thus, habitat suitability (see also Goławski & Meissner 2008).

Surprisingly, we found no significant effects of other habitat parameters on breeding performance or occupation of clearings by Red-backed Shrikes. The lack of an effect of nest tree availability, could potentially be explained by the fact that Red-backed Shrikes use a variety of nesting places (Olsson 1995b, Söderström 2001, Pedersen *et al*. 2011; but see: Svendsen *et al*. 2015). Thus, availability of e.g., bushes or slash heaps may have provided equally good breeding opportunities for individuals in clearings without conifer and beech trees as considered suitable nest trees in this study. The parameters investigated here might also to an unknown degree be confounded with each other, which could cause a potential bias to our results. For instance, slash left in heaps may explain some of the variation caused by perches, as these can likewise be used for perching and caching of prey items.

Other habitat parameters, besides the ones investigated here could also affect the breeding populations in forested areas. We were not able to include different logging practices, original forest type, and different growth rates for different replanted trees in the present study. These are potentially important aspects that should be included in future research on habitat suitability in forest clearings. Our results indicate that maintenance of open habitats with perches, along with grazing

Table 1. Estimates, standard errors and p-values of fixed effects of initial full models and of post-hoc pairwise comparisons of final reduced model parameters explaining number of breeding pairs, number of fledglings and number of years occupied by Red-backed Shrikes. Fixed effects consisted of slash (present / not present), perches (abundant / frequent / scarce), nesttree (present / not present), clearing replanted after clear-cutting (yes / no), grazing animals (present / not present).

Number of breeding pairs			
Initial GLMM (AICc = 326.3)			
Fixed effects	Estimate	*SE*	*p*
Slash	0.27	0.22	0.227
Perches (frequent)	1.45	0.54	0.007
Perches (abundant)	1.83	0.51	<0.001
Nesttree	–0.14	0.4	0.725
Replanted	0.11	0.24	0.63
Grazing	0.27	0.33	0.419
Final GLMM (AICc = 319.7)			
Perches			
Frequent–Scarce	1.39	0.52	0.021
Abundant–Scarce	1.74	0.48	<0.001
Abundant–Frequent	0.35	0.26	0.359
Number of fledglings			
Initial GLMM (AICc = 288.4)			
Fixed effects	Estimate	*SE*	*p*
Slash	0.09	0.19	0.653
Perches (frequent)	0.88	0.52	0.093
Perches (abundant)	1.27	0.44	0.004
Nesttree	0.00	0.56	0.994
Replanted	–0.02	0.20	0.934
Grazing	–0.05	0.29	0.870
Final GLMM (AICc = 279.5)			
Perches			
Frequent–Scarce	0.91	0.46	0.117
Abundant–Scarce	1.29	0.39	0.003
Abundant–Frequent	0.38	0.27	0.339
Years occupied			
Initial GLM (AICc = 142.2)			
Fixed effects	Estimate	*SE*	*p*
Slash	–1.18	0.23	0.422
Perches (frequent)	1.50	0.56	0.007
Perches (abundant)	2.04	0.54	<0.001
Nesttree	–0.50	0.40	0.211
Replanted	0.12	0.23	0.609
Grazing	0.41	0.28	0.146
Final GLM (AICc = 135.6)			
Perches			
Frequent–Scarce	1.56	0.56	0.014
Abundant–Scarce	1.93	0.52	<0.001
Abundant–Frequent	0.37	0.25	0.323
Grazing	0.56	0.23	0.016

within forested areas provide profitable habitat for Red-backed Shrikes. Thus, the retention of single standing trees, tree stumps and bushes scattered across the clearing and along the clearing edge during clear-cutting may benefit Red-backed Shrike occurrence and breeding success. Likewise, the maintenance of clear-cuts, preventing them from becoming overgrown is essential to ensure Red-backed Shrike occurrence. Overall, such forest management practises may offer habitat mitigation for bird species associated with low-intensity farmland being lost in recent decades.

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Hakkuuaukkojen metsänhoitotoimien vaikutukset pikkulepinkäisen (*Lanius collurio*) lisääntymiseen

Elinympäristön laatu vaikuttaa lisääntymismenestykseen ja sitä kautta populatioiden elinkelpoisuuteen. Lajin elinympäristovaatimusten parempi kartoittaminen mahdollistaa valitsemaan metsänhoitotoimet, jotka tukevat lajin säilymistä. Tutkimme habitaatin ja metsänhoitotoimien vaikutusta pikkulepinkäisen lisääntymismenestykseen Tanskassa. Havaitsimme, että saalistuksessa tarvittavien oksien saatavuus oli tärkein pesivien parien ja lentopoikasten määrää lisäävä tekijä. Se korreloi myös positiivisesti hakkuuaukoilla pesintöjen kanssa. Hakkuuaukoilla, joita oli laidunnettu, tavattiin pesiviä pareja useammin kuin laiduntamattomilla alueilla. Tämä viittaa siihen, että ravinnonsaatavuus on parempi kun hakkuuaukkojen kasvillisuus on matalampaa. Tuloksemme tarjoavat suosituksia metsänhoitotoimenpiteistä, joilla voidaan parantaa lajin säilymistä.

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