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ORIGINAL ARTICLE

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The influence of territory characteristics and food supply on the breeding performance of the Red-backed Shrike (*Lanius collurio*) in an extensively farmed region of eastern Poland

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Abstract The breeding performance of the Red-backed Shrike (*Lanius collurio*) in relation to the territory characteristics was investigated. The study was conducted in an area of high agricultural land use, characterised by small field size, a more mosaic habitat and low use of mineral fertilisers in comparison to Western European countries. The influence of habitat structure and composition in the territory on the date of clutch initiation, nest predation and clutch size in the Red-backed Shrike was not found, but such an influence on the number of nestlings was shown. The minimum adequate model explained 18.3% of the variation between territories in nestling's number. The number of fledglings was positively correlated with the area of pastures, meadows, orchards and fallows within territories, and negatively correlated with length of overhead transmission lines. The number of fledglings was correlated with food abundance within territories, based on to the results from pitfall traps. There was no correlation between territory food abundance and the size of clutch. The presence of pastures, meadows and fallows, which are foraging places, thus seems to be crucial for the protection of the Red-backed Shrike.

Keywords Territory characteristics · Farmland ecology · Extensive farmland · Agri-environment

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Introduction

Breeding success in birds can result from differences in the quality of habitats they use as breeding places (Newton 1998). Many factors may influence the selection of breeding territory. Among these, two are very important: minimization of predation, which is the main reason of clutch losses (Ricklefs 1969; Martin 1995) and sufficient food abundance (Martin 1987). Access to suitable food may decrease nesting length, and has been shown to increase both clutch and eggs size, as well as increase nestling and fledgling survival (Arcese and Smith 1988; Verhulst and Tinbergen 1991).

Decreased quantity and species diversity of invertebrates (as a consequence of agriculture development) has been shown to reduce the number and breeding range of many birds in agricultural landscape of Western Europe (Tucker and Heath 1994; Siriwardena et al. 1998). In Poland, the quantity of Red-backed Shrikes increased from 1980 to 2000, which was probably due to the reduction of intensive farming after the systemic change in 1989 (Dombrowski et al. 2000). However, following Poland's admittance to the European Union, farming practice will likely increase and potentially adversely affect the Red-backed Shrike. Identification of the relation between the present agricultural land use and reproduction of birds can be fundamental for their protection. Extensive farming practice may influence reproduction in birds, mainly by modifying food abundance (Tryjanowski et al. 2003a, 2003b). Intensification of agricultural production by the use of insecticides can cause changes in species composition of insect assemblages, which are food for many species of birds (Matson et al. 1997; Krooss and Schaefer 1998; Brickle et al. 2000; Hart et al. 2006).

The main aim of this study was to define the influence of habitat composition and food abundance within breeding territories on breeding performance of the

Red-backed Shrike in the extensively farmed agricultural landscape of eastern Poland.

Methods

The study species

The Red-backed Shrike is widespread in Europe with population estimates ranging from 6,300 to 13,000 million breeding pairs (BirdLife International 2004). During the breeding period, it occurs in various habitats, such as woodland edges, forest plantations, and orchards. However, the largest numbers of breeding pairs occur in farmland (Cramp and Perrins 1993). The territory characteristics of the Red-backed Shrike has been described in many papers (summary in: Cramp and Perrins 1993; Lefranc and Worfolk 1997; Harris and Franklin 2000), but studies on differences in reproductive performance in relation to the territory characteristics have rarely been conducted for this species (Sőderstrőm 2001; Müller et al. 2005). Territories of this shrike have usually been assigned to only one habitat type (e.g., pasture, forest clearing) and possible differences in the clutch size and the number of fledglings were analysed in territories described in this way (Brandl et al. 1986; Leugger-Eggimann 1997). However, a territory of the Red-backed Shrike may comprise several different habitats and other elements, such as fences, which serve as observation points and which may affect the hunting success, thus modify breeding success. Besides the characteristics of the territory, food abundance within the territory may have a remarkable influence on breeding success.

Study area

This study was carried out in eastern Poland, near Siedlce (52°12'N; 22°17'E) in 1999–2003. A characteristic feature of this region is a distinct division of arable land into smaller fields with a great number of wide balks and ground roads. In 2004, the mean area per farm was 7.3 ha, with 73.6% of arable land, 16.3% meadows, 6.8% pastures, 8.7% fallow land, and 4.6% orchards. During this period, the use of mineral fertilisers (NPK) was 78 kg/ha, cereal yield was 2.8 t/ha, and yearly milk production was 3,666 l/dairy cow (Voivodship Statistical Office 2005). For comparison, a few years earlier in the EU, cereal yield was 5.0 t/ha, milk production was 5,020 l/dairy cow/year and fertilizer use reached 140 kg/ha (Donald et al. 2002).

The study area consisted of 855 ha of extensive agricultural land use. Arable fields predominated in this area, mainly with crops of rye and potatoes (Table 1). The structure of the land use did not change during the period of the study.

Table 1 Habitat structure of the studied area in eastern Poland

Territories elements	Length/area	(%)
Fences (linear elements, m)	32,524	–
Overhead transmission lines	11,025	–
Roads (area, a)	18	2.1
Ditches	3	0.4
Rows of trees and bushes	4	0.5
Woodlands	105	12.3
Meadows and pastures	179	21.1
Fallow land	19	2.2
Arable lands	457	53.5
Orchards and currant plantations	48	5.5
Buildings	22	2.6
Total area	855	100.0

Bird data

From mid-May to the end of July, nests of the Red-backed Shrike were found by checking all possible places where nests could be located, including the edges of woodlands, rows of trees and bushes, orchards, plantations of currant (*Ribes nigrum*), and single trees and bushes among arable land. Broods were controlled every 5–8 days. The size of clutch was determined during the initial stage of incubation. Among 150 broods, 30 were found with nestlings. In such cases, the nestlings were weighed and their age was estimated according to the relationship between the age and the body mass, described for this species on the basis of data collected in natural conditions (Diehl 1971). The number of 8–9 days old nestlings was accepted as the number of fledglings, because later clutch size may be affect by chicks jumping out of the nest, and nests that fledged at least one young were recorded as successful (Tryjanowski and Kuźniak 1999). The date of clutch initiation was estimated by back-calculation, assuming that one egg was laid per day and that incubation lasted 15 days from the laying of the penultimate egg. Laying date was standardized within years (mean = 0) to allow pooling of all years into one data set. Because the clutch size, and thus the number of nestlings in a brood, decreased over the course of the breeding season (Goławski 2006a), only clutches started up to 14 June were considered for this study. According to studies conducted in western Poland, after 14 June only pairs which had lost their first clutches bred later in the season, and had significantly smaller broods (Kuźniak 1991). Similarly, as Simons and Martin (1990), and Whittingham et al. (2001) found that partial losses in broods not caused by predation but on the amount of food provided by the parents to the nestlings.

Territory description

The territory size for this species is 1.5 ha, based on studies of its biology and breeding ecology conducted throughout in many countries of Europe (Cramp and

Perrins 1993; Lefranc and Worfolk 1997). Thus, in the present study this territory size was utilized using the method described and previously used by Sőderstrőm (2001). Around each nest, a hypothetical territory of 70-m radius was drawn and a circle of 1.54 ha area was obtained. Because the Red-backed Shrike does not use the inside of woodlands, established territories that included woodlands were limited to a 7-m-wide strip of the woodland edge (the greatest distance from the woodland edge in which a nest was found). In such a territory, other habitat components were included in its area and its radius was enlarged to obtain the territory size equal to 1.54 ha. Drawings in field were done only after the fledglings had left their nest. Description of the territories by one person (AG) guaranteed the same precision in drawing sketches of the territory characteristics (Block et al. 1987).

Amount and biomass of food

It was assumed that the factor which may cause differences in the quality of territories was, among others, their abundance in food. The Red-backed Shrike feeds mainly on terrestrial invertebrates (Tryjanowski et al. 2003a). In the study area, invertebrates comprised 99.5%, and vertebrates about 0.5% of all prey items of this species (Goławski 2006b). The Red-backed Shrike hunts invertebrates moving mainly on the ground surface (Moskát 2001), thus pitfall traps were used inventory their potential prey. In each territory, ten pitfall traps were used. The size of the trap entrance was 50 cm^2, for a total trapping area of 500 cm^2 for each sample. In 2003, trapping was conducted in four types of open habitats - main foraging areas of Red-backed Shrikes: meadows, pastures, fallows and arable land (crops of cereals and potatoes). In each of these habitats, four trapping sites were established 250–1,500 m apart, where invertebrates were trapped five times during the breeding season, between 27 May and 15 July. These trapping sites were located within Red-backed Shire territories. Trapped invertebrates were classified into orders. Among the invertebrates a separate category designated "larvae" was distinguished, (i.e., larval stages of all invertebrates jointly combined into one group). Animals smaller than 4 mm were omitted because other research has shown that the Red-backed Shrike does not feed on animals smaller than 4 mm (Hernández et al. 1993; Lefranc and Worfolk 1997). To determine the average biomass of prey items of the Red-backed Shrike, a representative sample of identified prey were trapped and weighed. These animals were trapped at the same sites where the potential prey was collected, and after killing them with ether they were weighed (up to 3 h after catching) on a laboratory balance (MELTER AE 200) with the accuracy of 1 mg.

Influence of territory food abundance on breeding success

The number and biomass of the potential prey items of the Red-backed Shrike from each of the study territories was based on the number and biomass of all invertebrate taxon collected from the four habitat types in each territory. Additionally, the number and biomass of the potential prey items of the Red-backed Shrike in each territory was correlated with the clutch size and the number of fledglings in a given territory.

Statistical analysis

The influence of the territory characteristics on breeding success was tested using logistical regression. The impact of territory characteristics on date of clutch commencement, number of eggs and number of fledglings 8–9 days old was analyzed using multiple linear regression. The model that explained the largest variability of breeding parameters was chosen. Because distributions of variables departed significantly from the normal distribution and in some cases a variable had zero values, the variables (linear elements, number of single trees) were logarithmically transformed by the function $\log_{10}(x+1)$. The data which were in the form of proportions (proportions of habitats in a territory) were transformed by the function $(\arcsin\sqrt{p})$. The difference in numbers of invertebrates between the four habitat types was compared using one-way ANOVA. When a statistically significant value of the test was obtained, differences in the number of prey items between habitats were compared with post-hoc Newman-Keuls test. The number of animals was logarithmically transformed in the form $\log_{10}(x)$. For the comparison of biomass of invertebrates occurring in the four habitats types, the Kruskal-Wallis test and post-hoc Dunn test were used (Zar 1996). The results were considered significant when the probability of $P < 0.050$. Statistica 6.0 software was used to run the statistical analysis (StatSoft 2003).

Results

Territory characteristics and the date of clutch initiation

In the studied region, meadows and arable land predominated the Red-backed Shrike territories, and each of these habitats comprised over 33% of the average area of each territory. The proportion of orchards (9.4%) and currant plantations (8.6%) was higher than expected for the territory areas. The lowest proportions of land use within the territories were drainage ditches. Among the linear elements in territories, fences were twice as long as overhead transmission lines (Table 2).

The correlation between the habitat structure within the territory and the date of the first eggs laid was not significant (ANOVA, $F_{1,141} = 1.14$, $P = 0.231$). In the multiple regression analysis no variables were found to be statistically significant in relation to date of the clutch commencement.

Reproductive performance

The breeding success reached 50.6% ($n = 154$). The territory characteristics had no significant correlation with breeding success (logistic regression; $\chi^2_{13} = 9{,}63$, $p = 0{,}724$; all variables $p > 0.175$). The vast majority of nests were predated before the 8th- 9th day of fledglings life, when the number of fledglings was assessed. After this date only 6 of 76 nests (7.9%) were predated.

The mean clutch size of the Red-backed Shrike was 5.6 eggs (SD = 0.73, $N = 119$). The influence of the habitat structure within territories on the clutch size was nearly significant (ANOVA, $F_{1,117} = 3.40$, $P = 0.068$). In the multiple regression analysis no statistically significant variables were found, which would influence the number of eggs in a clutch.

There were 4.7 fledglings on average in broods at the age of 8–9 days (SD = 1.16, $N = 81$). The area of habitats and the length of linear elements in territories were correlated with the number of nestlings (ANOVA, $F_{5,75} = 4.57$, $P = 0.001$). The obtained model explained 18.3% of the variation in the number of fledglings between clutches laid in territories of different structures. Using coefficients of partial correlations, values that explain the influence of subsequent independent variables on the number of fledglings were obtained, and ranged between 8.4 and 13.0%. The area of pastures and meadows in territories were the most positively correlated with number of fledglings. The area of orchards and currant plantations in territories were the weakest positive correlations with the number of fledglings (Table 3).

Table 2 Descriptive statistics (mean, SE, minimum and maximum) for 13 habitat variables within hypothetical territories (area around nests) of the Red-backed Shrike (1.54 ha) in eastern Poland ($n = 154$ territories)

Variable	Mean	SE	Minimum	Maximum
Roads (area, a)	3.1	0.312	0	13
Ditches	0.8	0.114	0	6
Rows of trees and bushes	1.5	0.169	0	8
Woodland edges	5.0	0.497	0	25
Meadows	52.1	4.849	0	154
Pastures	13.2	2.552	0	144
Fallow land	10.5	1.820	0	154
Arable lands	50.8	4.272	0	154
Orchards and currant plantations	14.4	2.638	0	154
Buildings	2.7	0.935	0	85
Fences (linear elements m)	71.1	8.489	0	508
Overhead transmission lines	35.0	5.054	0	315
Single trees (indiv.)	0.8	0.120	0	7

Number and biomass of food items

There were 5,280 invertebrates from 12 orders and a separate category "larvae" trapped from all habitats covered in the study. The highest numbers of animals were trapped within meadows, followed by pastures and fallows. Spiders (*Araneae*), beetles (*Coleoptera*) and orthopterans (*Orthoptera*) predominated, comprising 86.5% of all trapped invertebrates (Fig. 1). Megalopterans (*Megaloptera*) and dermapterans (*Dermaptera*) were below 0.1% of the all animals captured. Habitats differed in the total number of potential prey items of the Red-backed Shrike (ANOVA, $F_{3,76} = 5.02$, $P = 0.003$). Significant differences occurred in the number of invertebrates between meadows and arable land, and meadows and fallows (post-hoc Newman-Keuls test, respectively: $P = 0.003$ and $P = 0.012$). The total biomass of trapped animals was 209,672 mg. The pattern of differences between habitats in the biomass of invertebrates was similar numbers of trapped invertebrates, but beetles comprised as much as 56.6% of the total biomass of invertebrates (Fig. 2). The biomass of trapped animals differed among habitats (Kruskal-Wallis test, $H_{3,76} = 17.77$, $P < 0.001$). This was due to the statistically significantly difference

Table 3 Results of regression analysis explaining the influence of the habitat structure of hypothetical territories on the number of the Red-backed Shrike fledglings ($n = 81$ territories), only statistically significant variables are presented

Variable	B	SE	Coefficients of partial correlations	p-value
Area of pastures	0.187	0.055	13.0	0.001
Length of overhead transmission lines	−0.041	0.014	10.2	0.004
Area of orchards and currant plantations	0.122	0.045	9.0	0.008
Area of meadows	0.089	0.029	10.9	0.003
Area of fallow land	0.174	0.065	8.4	0.009
Constant	0.603	0.022	–	< 0.001

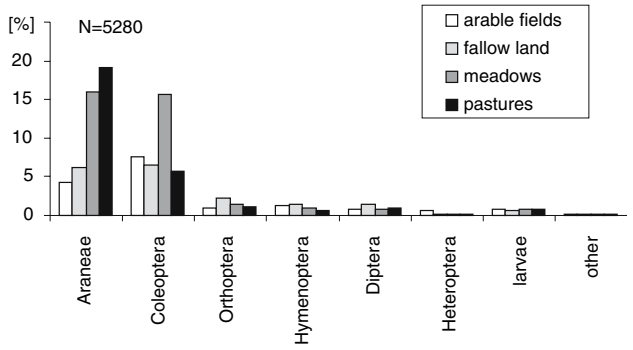

Fig. 1 Percentage of the number of important invertebrate taxa from pitfall traps in four types of open habitats in eastern Poland

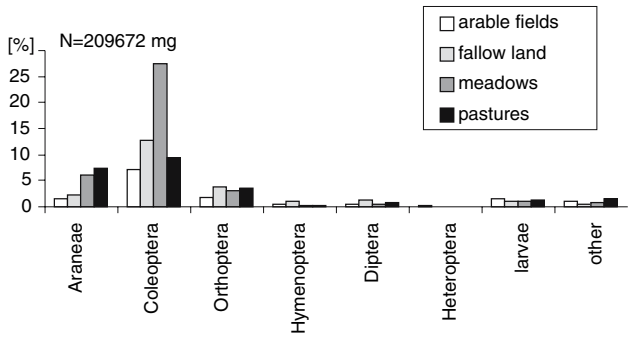

Fig. 2 Percentage of the biomass of important invertebrate taxa from pitfall traps in four types of open habitats in eastern Poland

between meadows and arable land (post-hoc Dunn test, $P < 0.001$).

Influence of territory food abundance on brood size and success

The estimated average number of invertebrates per territory of the Red-backed Shrike was 86.5 individuals (SD = 35.22, range: 17–146, $N = 72$ territories). A correlation between the number of invertebrates and the number of fledglings in a territory was found (Spearman rank correlation, $r_s = 0.35$, $P = 0.003$, $N = 72$). The mean biomass of prey in a territory was 3,417.4 mg (SD = 1,628.48 mg, range: 714–6,309 mg, $N = 72$ territories). A correlation was found between the biomass and the number of fledglings in a territory (Spearman rank correlation, $r_s = 0.35$, $P = 0.003$. $N = 72$). There was no correlation between the number and the biomass of invertebrates trapped in territories and the clutch size (Spearman rank correlation, in both cases $P > 0.975$, $N = 116$).

Discussion

The study showed that the number of fledglings at 8–9 days after hatching was related to the habitat characteristics of a territory. The area of open habitats in the territory, such as pastures, meadows and fallows had a positive effect on number of fledglings, as well as the area of orchards and current plantations. The number of fledglings was negative correlation with only the length of overhead transmission lines. The influence of these variables was partially correlated by the number and biomass of invertebrates which were potential prey occurring in territories of the Red-backed Shrike. Differences in the number and biomass of invertebrates between four open habitats of the Red-backed Shrike also support a positive correlation between some open habitats and the number of fledglings. At the same time, there was no correlation found between the territory characteristics and clutch size of the Red-backed Shrike.

The positive correlations of some habitats in territories of the Red-backed Shrike with the number of fledglings can be explained mainly by the amount of potential prey. Meadows supported the highest number and biomass of invertebrates in comparison with other habitats. The predomination of meadows over other habitats was reflected particularly by the proportional number and biomass of beetles. During other studies conducted in this area, it was found that beetles were the most preferred order of insects in the food of the Red-backed Shrike (Goławski 2006b). Meadows were mowed during the period of hatching of the Red-backed Shrike nestlings. This activity may have improved the access for the shrike to potential prey items. In addition, the birds fed on injured (not entirely fit) invertebrates which were more common after mowing. This supports observations of Van Nieuwenhuyse and Vandekerkhove (1992) of Red-backed Shrikes using animals killed during farming activities. Also, in the Lesser Grey Shrike, a distinct increase in feeding intensity was observed on mowed meadows, while those not mowed were used more rarely than was expected based on result from their proportion in the studied area (Wirtitsch et al. 2001). It should be added that in meadows many more large insects occurred in comparison with other habitats (Goławski – unpubl.), and it has been shown that the Red-backed Shrike prefers larger prey items (Wagner 1993; Tryjanowski et al. 2003b).

The presence of pastures in a territory had a favourable effect on the number of fledglings of the Red-backed Shrike, which was probably due mainly to the presence of low vegetation and not the number of the potential prey. In the studied area, cattle, and in much lower numbers horses and sheep, were allowed to graze. In the breeding period of the Red-backed Shrike the height of the grass in these habitats did not exceed a few centimetres. In such conditions, detection of potential prey can be high. In Germany, it was found that the number of Red-backed Shrike fledglings was higher in territories located on pastures than in territories comprised of meadows and fallows (Brandl et al. 1986). These authors stated that this was caused by good availability of prey in low vegetation. Along fences there remained strips of un-mowed or un-grazed grass, which

has been suggested to be a source for recolonization of pastures after mowing of hay has finished (Van Nieuwenhuyse and Vandekerkhove 1992). Additionally, pastures contain large amounts of dung from grazing animals, which attracts many species of invertebrates, especially beetles. In the food of the Red-backed Shrike there is a high number are beetles from the family *Silphidae* and the genus *Geotrupes*, which are strongly associated with faeces of animals (Goławski 2006c). The importance of coprophilic insects in the diet of Red-backed Shrikes was confirmed by Lefranc (1997) and Vanhinsbergh (2000). All these factors suggest that pastures are the most favourable habitat for Red-backed Shrikes to forage within.

Fallows appear to be the second most important habitat with respect to the number and the biomass of invertebrates. Fallows probably provided good living conditions to invertebrates, because tall vegetation exists from the previous year, which may provide good cover for invertebrates. At the same time, fragments with low vegetation may allow the Red-backed Shrike to more easily spot potential prey. Additionally, a high number of insect species of a large size occurred within this habitat. In Finland, during captures with pitfall traps, much greater species diversity and numbers of invertebrates were found on fallows in comparison with arable land sowed with different crops (Kinnunen and Tiainen 1999).

In this study, territory characteristics had no effect on other breeding success measures (e.g. the date of clutch initiation, nest predation and clutch size). However, the date of clutch initiation and nest predation may depend on the territory characteristics in the Red-backed Shrike (Sőderstrőm 2001). In Sweden, the contribution of Sole (*Prunus spinosa*) within breeding territories had a significant influence on the date of clutch initiation and nest losses caused by predators (Sőderstrőm 2001). In the research carried out in eastern Poland, near Siedlce, the characteristics of the territory did not include evaluation of the representation of each tree and shrub species within a territory. Perhaps, a general description of the territory did not allow us to find factors that would affect the time of required to select a territory (the beginning of nesting) and the breeding success. Also Müller et al. (2005) did not find any elements of territory characteristics that would influence the breeding success of this species. Still, it is not out of the question that occurrence of potential predators, especially magpie (*Pica pica*) and jay (*Garrulus glandarius*) might result in avoiding their territories by the Red-backed Shrike and in consequence may also influence the territory characteristics of the Red-backed Shrike. Such relationships between Red-backed Shrike and magpie were noted by Roos and Pärt (2004).

The territory characteristics had only a weak correlation with the number of fledglings, therefore, there must be other factors affecting the number of fledglings. Undoubtedly, one of them is the quality of parents, which may compensate for the influence of territory quality (Goodburn 1991). Birds may differ in hunting skills and this may result in some individuals being more successful at breeding. The ability to collect a sufficient amount of food is particularly important (e.g. during unfavourable weather). In the study area, weather conditions explained about 11% of variation in partial losses of broods (Goławski 2006d). However, it remains unexplained what is the factor (or factors) that are decisive for the breeding performance in the extensively farmed agricultural landscape of the eastern Poland.

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