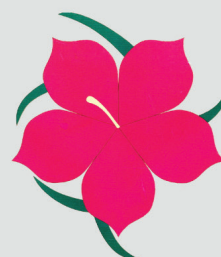


JOURNAL FOR SCIENCE AND
POPULAR SCIENCE



JU Prirodnjački muzej
Crne Gore **Natural History**
Museum of Montenegro



NATURA

MONTENEGRINA

ISSN 1800-7155 On line edition

15/2026



PODGORICA



ORIGINAL RESEARCH PAPER

HABITAT SUCCESSION AND POPULATION DENSITY OF BREEDING *Lanius collurio* IN PAŠIĆA POLJE, BOSNIA AND HERZEGOVINA

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Key words:

Red-backed Shrike,
karst polje,
population density,
shrub cover,
Bosnia and Herzegovina.

Ključne riječi:

Rusi svračak,
kraško polje,
gustina populacije,
pokrivenost žbunjem,
Bosna i Hercegovina.

SYNOPSIS

This study provides the first comprehensive information on the habitat preferences of the Red-backed Shrike (*Lanius collurio*) in Pašića polje, Bosnia and Herzegovina. The research was conducted in an area of approximately 100 ha in the municipality of Bosansko Grahovo. Population density varied depending on the ratio of trees to shrubs. The results show that the most suitable habitats for this species are mosaic landscapes with 10% to 50% shrub cover. Significantly higher abundance was observed in habitats with 10% to 30% shrub cover compared to forests or pastures. These findings highlight the influence of habitat type on Red-backed Shrike abundance in Pašića polje. The study also presents population estimates and habitat associations across eight habitat types, demonstrating that shrub cover and habitat heterogeneity are key factors for conservation planning.

SINOPSIS

SUKCESIJA STANIŠTA I UTICAJ NA GUSTINU POPULACIJE SVRAČKA (*Lanius collurio*) U PAŠIĆA POLJU, BOSNA I HERCEGOVINA

Ova studija pruža prve sveobuhvatne podatke o stanišnim preferencijama crvenoleđeg svračka (*Lanius collurio*) u Pašića polju, Bosna i Hercegovina. Istraživanje je sprovedeno na području od približno 100 ha u opštini Bosansko Grahovo. Gustina populacije varirala je u zavisnosti od odnosa drveća i žbunja. Rezultati pokazuju da su najpogodnija staništa za ovu vrstu mozaični pejzaži sa 10% do 50% pokrivenosti žbunjem. Znatno veća brojnost zabeležena je u staništima sa 10% do 30% pokrivenosti žbunjem u poređenju sa šumama ili pašnjacima. Ovi nalazi ističu uticaj tipa staništa na brojnost crvenoleđeg svračka u Pašića polju. Studija takođe prikazuje procene brojnosti i povezanost vrste sa osam različitih tipova staništa, ukazujući na to da su pokrivenost žbunjem i stanišna heterogenost ključni faktori za planiranje očuvanja.

INTRODUCTION

The Red-backed Shrike (*Lanius collurio*) breeds across most parts of Europe and western Asia and winters in tropical Africa. According to the IUCN Red List (2024), it is classified as Least Concern (LC), with a stable population trend. However, some parts of its range have experienced significant population declines, making its status less secure in certain areas. According to Lefranc & Worfolk (1997), the Red-backed Shrike breeds in temperate and Mediterranean climates. It requires sunny, warm, usually dry, and

level or gently sloping terrain, with scattered bushes, shrubs, or low trees that provide hunting perches overlooking areas of short grass, heath, or bare soil. The species generally breeds between 500 and 1,500 meters above sea level but can occasionally be found up to 1,700 meters. Locally, it may also occur at sea level and in low hills.

High-quality habitats typically feature a mosaic of grassy vegetation, alternating between tall and short growth, with bare patches and available perches. In agricultural landscapes, the species occupies neglected overgrown patches, heaths, open downs, abandoned

orchards and gardens, hedgerows, and scrub along railways or roadsides. It is also found in temporary steppe-like habitats, such as military training grounds, burned forests, forest clearings, and spruce (*Picea* spp.) plantations (Lefranc & Worfolk, 1997; Brambilla et al., 2007; Yosef et al., 2012; Polak & Filipiuk, 2014). Additionally, it breeds in forest clearcuts, particularly in northern Europe (Hollander et al., 2011; Söderström & Karlsson, 2011; Lislevand, 2012).

Nesting habitat selection depends on breeding requirements, while habitat use outside the breeding season is determined by food availability (Block & Brennan, 1993). The Red-backed Shrike is particularly sensitive to agricultural intensification and land abandonment, both of which can significantly impact its population (Brambilla et al., 2007).

Nesting territory characteristics have been described in numerous studies (Cramp & Perrins, 1993; Olsson, 1995a; Lefranc & Worfolk, 1997; Kuper et al., 2000; Harris & Franklin, 2000a; Guerriere & Castaldi, 2006; Casale & Brambilla, 2009; Polak, 2012; Morelli et al., 2016, among others). The highest densities of breeding pairs in Europe are found in farmland, forest edges, grasslands, dense hedgerows along roadsides, and open areas with bushes or small tree patches, as well as in parks and open gardens (Tryjanowski et al., 2000; Morelli, 2012; Kwieciński & Pawlak, 2015).

Research in the Western Balkans remains limited, with most studies focused on Central or Northern Europe (Kuzniak & Tryjanowski, 2000; Vanhinsbergh & Evans, 2002; Roos & Pärt, 2004; Tryjanowski et al., 2006; Baláž, 2007; Titeux et al., 2007; Goławski & Meissner, 2007; Brambilla et al., 2009; Svendsen et al., 2015). This species is also present in the karst poljes of Bosnia and Herzegovina (Obratil 1984, 1987 & 2006; Kotrošan et al., 2013; Marić 2022a, 2022b, 2023), although data on its biology remain scarce and fragmented. Further research into the reproductive characteristics and ecological requirements of this species in karst poljes under different land management regimes is crucial to understanding the factors affecting its survival.

According to Marić (2022a), nesting of *L. collurio* was recorded in six habitat types: 1) forests along the banks of creeks and rivers, 2) tall deciduous and evergreen shrubs (up to 7–10 m) or degraded forests with large clearings in various stages of degradation, 3) deciduous shrubs: bushes, low trees, and shrubs (mostly up to 3 m high) with large clearings (20–70%), 4) dry calcareous grasslands, from karst poljes to the montane zone (habitats 3 and 4 have undergone

afforestation in the last 20 years), 5) meadows and agricultural lands (arable fields, grasslands, and wet meadows of karst poljes), 6) settlements (villages and towns) with orchards.

My aim was to study the population density of Red-backed Shrikes nesting in different habitats to compare species abundance across nine habitat types and determine habitat suitability in karst poljes. Identifying suitable habitats is essential for the effective conservation of this species.

METHOD

1. Study area

The study was conducted in the municipality of Bosansko Grahovo, in a karst polje (Pašića) in western Bosnia and Herzegovina. A 100-hectare study site was selected, extending approximately 6 km in length. The research area (44°07'N / 16°25'E) is located southeast of the village of Luka. The study area is situated at an elevation of 820–900 m above sea level and is covered by a mosaic of continental habitats that includes grasslands, shrublands, and woodlands. The central parts of karst poljes are generally marshy or cultivated areas, although each field has its own distinct landscape characteristics. Pašića Polje exhibits these features (Fig. 1). The central part of the polje (around 800 m a.s.l.) is classified as a Meadows & Agricultural land habitat type, through which the Korana River flows.

The dry, elevated areas are predominantly grasslands (DCG = Dry calcareous grasslands). Shrublands (SCH = deciduous bushes) typically border the grasslands (shrubs covered much of the study site), transitioning into tall shrublands (HSCH = high deciduous and evergreen shrubs), which at higher elevations develop into deciduous forests (For = forests, deciduous and evergreen) (habitat types according to Marić 2022). Most of the area is covered by human-modified natural vegetation. For more details on the characteristics of the study area, see Marić (2022a).

The selected sites

In 2019, I defined eight vegetation types based on vegetation structure and the percentage ratio between grassy vegetation vs bushes and forests. The selected sites include: one typical forest habitat, two habitats with predominantly shrub/forest vegetation, two habitats with an equal proportion of open areas and shrub/forest vegetation, and three habitats where pastures dominate. Pastures with scattered shrubs were studied in Marić (2022b).

The eight studied plots consist of: study plot consisted of: **1.** up to 10% open areas, 2% bushes and 88% woods-trees; **2.** about 30% open areas, 10% bushes (around open areas or around glades) and 60% woods; **3.** about 30% open areas, 50% bushes and 20% woods; **4.** about 50% open areas, 25% bushes and 25% woods; **5.** about 50% open areas, 45% bushes and 5% trees; **6.** about 70% open areas, 10% trees and 20% bushes; **7.** about 70% open areas, 30% bushes; **8.** about 90% open areas, 10% bushes. Rocky formations occur in all habitats and sometimes make up more than 5% of the habitat area.

1. For = forest (woods), deciduous and evergreen. The forest in the municipality of B. Grahovo is represented by several phytocoenoses (Marić, 2022a). In this area, one habitat type was defined: 91K0 - *Aremonio-Fagion* (according to the NATURA 2000 classification). Relatively well-preserved forests are rare, while degraded and sprout forests in various developmental stages are more common. Key species: *Fagus sylvatica*, *Acer obtusatum*, *Acer campestre*, *Fraxinus ornus*, *Carpinus betulus*, *Betula pendula*.

2. Degraded deciduous forests (ranging from 7 to 15 meters in height) with tall shrubs (up to 7m) and bushes, covering approximately 70% of the area (50% woods and 20% shrubs), with large forests

clearings. Key species: *F. sylvatica*, *Acer spp.*, *Quercus spp.*, *Sorbus aria*, *F. ornus*, *C. betulus*, *B. pendula*, *Populus tremula*. Shrubs are mainly dominated by *Corylus avellana* and *Crataegus spp.* Two habitat types were identified according to the NATURA 2000 classification: 9140 (*Aceri-Fagetum* – degraded stages) and 91K0 (*Ostrya-Fagetum* – degraded stages)

3. HSCH Forests with large clearings, consisting of deciduous tall shrubs and bushes, covering approximately 70% of the area (50% shrubs and 20% woods). NATURA 2000 habitat type: 9140 (*Aceri-Fagetum* – degraded stages) Key species: Trees: *C. betulus*, *Carpinus orientalis*, *Sorbus aucuparia*, *F. ornus*, *B. pendula*, *P. tremula*, *Pyrus pyraeaster*, Shrubs: *Rosa spp.*, *Crataegus spp.*, *C. avellana*, *Cornus mas*, *Cornus sanguinea*, *Ostrya carpinifolia*, Grasslands and grassy layers: Primarily classified under 6210, with some areas corresponding to 62A0 (according to NATURA 2000).

4. SCH = Deciduous bushes and shrubs, consisting of low trees and shrubs (mostly up to 5 meters in height), with large clearings (50%). Habitat composition: 50% open areas, 25% bushes, 25% woods. The grasslands and grassy layer correspond to the NATURA 2000 habitat types 6110, 6210, and 62A0. Key species: *Crataegus spp.* and *C. avellana* are dominates (approximately 50% vs others) followed by *Rosa spp.*, *C. mas*, *C. sanguinea*, *C. orientalis*, *O.*

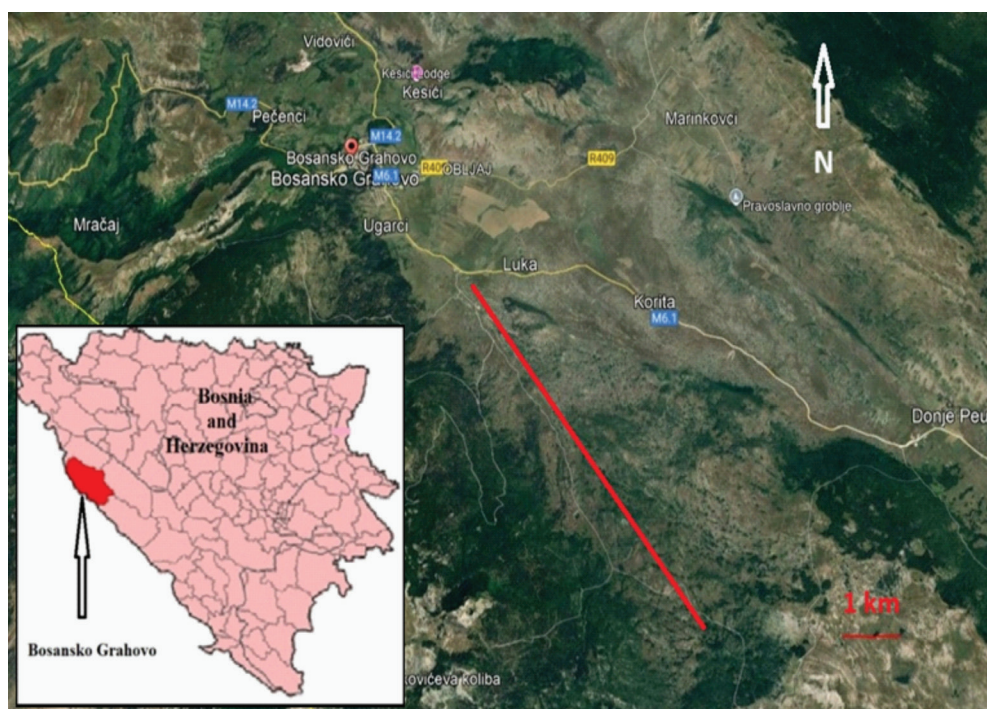


Figure 1: Position of investigated areas in the municipality of Bosansko Grahovo (localities): red line transects position.

carpinifolia, *F. ornus*, *S. aucuparia*, *P. tremula*, *Pyrus spinosa*, etc. These vegetation types represent common forms of succession, occurring in the progradation line as an intermediate developmental stage between pastures and permanent forest formations.

5. SCH = Deciduous Bushlands, Deciduous bushes and shrubs, consisting of low trees and shrubs (mostly up to 5 meters in height), with large clearings. Habitat composition: 50% open areas, 45% bushes, 5% trees. Key species: *C. avellana* (dominated), followed by *Rosa* spp., *Crataegus* spp., *Oreohertzogia* spp., *Amelanchier ovalis*, *C. mas*, *C. sanguinea*, *F. ornus*, *O. carpinifolia*, etc. These vegetation types are common forms of succession, occurring in the progradation line as an intermediate developmental stage between pastures and permanent forest formations. In all the previously described habitats, *Sesleria autumnalis* is the dominant grass.

6. DCG = Dry calcareous grasslands, these habitats are characterized by approximately 70% open areas, 20% bushes, and 10% trees. The tree layer mainly consists of *O. carpinifolia*, *F. ornus*, and *Prunus mahaleb*, while the shrub layer is predominantly composed of *C. avellana*=50%, and then follows *Crataegus* spp., *C. mas*, *C. sanguinea*, *Euonymus* spp., and *Oreohertzogia* spp. In open areas three habitat types have been defined (NATURA 2000 codes): 6110, 6210, and 62A0. The grasslands or the grassy layer are the following species: *Centaurea scabiosa*, *Eryngium campestre* and surrounding shrubs *Sesleria autumnalis* if the terrain is flat.

Habitat type 6110 is typically found around rocky outcrops and is often interspersed within other habitat types, such as 6210. The 6110 grassland vegetation consists mainly of: *Thymus* spp., *Globularia* spp., *Teucrium montanum*, *Sedum acre*, *Lotus corniculatus*, *Dorycnium germanicum*, *Potentilla* spp., and others. Vegetation of Habitat Types 6210 & 62A0 (NATURA 2000 Code) consists: *Festuca pseudovina*, *Brachypodium pinnatum*, *Bromus erectus*, *Koeleria pyramidata*, *Koeleria splendens*, *Leontodon hispidus*, *Orchis* spp. (e.g. *Orchis morio*), *Polygala comosa*, *Primula veris*, *Sanguisorba minor*, *Satureja subspicata*, *Satureja montana*, *Scorzonera villosa*, *Scabiosa leucophylla*, *Stipa bromoides*, *Teucrium montanum*, *Potentilla tomasiniana* (the dominant grassland species), than *Genista* spp., *Eryngium* spp., *Gentiana* spp., *Plantago* spp., *Trifolium* spp., *Salvia* spp., *Danthonia* spp., *Cirsium* spp., and others.

The mentioned grassland vegetation or pasture vegetation is also characteristic of the other three habitat types listed below.

7. DCG = Dry calcareous grasslands, habitats without trees, about 70% open areas and 30% bushes. A habitat with larger or smaller valleys, mostly covered in shrubs. The grassy and shrubby cover is mostly the same as in habitat 6, but tall trees are absent. Shrubs are generally up to 3 meters tall, sometimes slightly taller in the valleys.

8. DCG = Dry calcareous grasslands with small groups of shrubs or individual bushes, consisting of approximately 90% open areas and 10% shrubs. The shrub layer is mainly dominated by *C. avellana*, followed by *Crataegus* spp., *Rosa* spp., *Oreohertzogia* spp., and *C. mas*. In the past, the flat valleys were mown or ploughed, but they are now mostly overgrown with shrubs. The grass cover is generally similar to that in habitats 6 and 7.

In habitats numbered 5–8, *C. avellana* dominates with approximately 50–60%, followed by *Crataegus* spp., *Rosa* spp., and *C. mas* with around 30%, while all other shrub species account for about 10%.

2. Census method

Bird (Red-backed Shrikes) counts were conducted between May 20 and June 30 during the years 2019–2024 by the author. This period coincides with the breeding season of the studied species. Surveys were carried out at five-day intervals using the transect method, under favorable weather conditions—without rain and with wind not exceeding level 4 on the Beaufort scale—as such conditions hinder the detection of birds by sight and sound.

The abundance of Red-backed Shrikes was assessed within a 100-meter-wide strip on both sides of a 500-meter-long transect (10 ha). The selection of transect width was based on years of field experience (see Marić, 2021), indicating that a distance of 100 meters from individuals does not cause them to leave their perches. Eight transects were established in the study area, arranged in a single southeast–northwest sequence, with a minimum distance of 150 meters between them (as the distance between nests was usually less than 100 meters). A total of 142 systematic transect surveys were conducted. Each study site was surveyed at a slow walking pace, two to three times in the morning (06:00–12:00 h), during each study year. The route was approximately linear (totaling 5.7 km) to avoid overlap and minimize the risk of double counting. Each transect was walked in 20–25 minutes.

The survey unit was “the pair”, which meant a singing or otherwise observed male, observed female, a group of fledglings or inhabited nest (Koskimies

& Väisänen, 1988). The majority of the pairs were represented by singing males.

Vegetation structure was measured along all segments of each transect. Within these transects, the coverage of shrub vegetation, tree coverage, and the number of shrub and tree species were visually assessed.

3. Statistical analyses

The red-backed shrike abundance data gathered during the six monitoring years were compared using ANOVA and t- test. The same tests were run to compare data collected in the various breeding sites and years. The measures are presented as mean values, with max and minimum values. All statistical tests were independent and two-tailed. Results are considered significant if $P \leq 0.01$. All tests were carried out using the SPSS v. 13.0 software package.

The scores of all sampling were averaged in each line transect, and the mean scores of all transects were used for comparison because year did not affect the abundance (a short period for changes to occur), allowing us to pool across all 6 years for maximum sample size.

RESULTS

The results of *Lanius collurio* abundance across eight different habitat types, which vary in the proportion of trees and shrubs relative to grassland vegetation, are presented in Table 1. Significant differences in the

abundance of the Red-backed Shrike were found in relation to the percentage cover of woody and pasture vegetation. These differences were not statistically significant in habitats with a 50:50 ratio, nor between the two habitats with 10% and 30% tree cover, as well as between habitats 5 and 6 (i.e., 50% and 70% grassland/herbaceous vegetation), see table 2.

As the amount of open space increased, the abundance of Red-backed Shrikes significantly increased ($R = 0.92$) (Fig. 1), with the highest numbers recorded in the habitat containing only 10% shrub cover. However, no significant increase was found compared to the habitat with 30% shrub cover. The density of breeding pairs (or singing males) per 10 ha was 6.0 vs. 5.6.

The lowest abundance was observed in the forested habitat (90% tree cover), where only a single Red-backed Shrike pair was recorded during one year (with the nest found in a hawthorn bush). Nests in other habitat types were not the subject of systematic investigation.

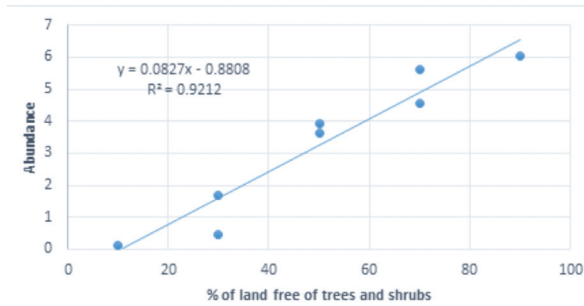
In forest habitats with small clearings, the Red-backed Shrike was not recorded at all, whereas it was observed only in areas with compact open patches of about 1 ha. In habitat type 2, with 30% open space and very few shrubs, the species was recorded at least once during the transect walk each year. In a habitat with denser shrub coverage (habitat type 3), usually one male was recorded per transect, occasionally two.

No habitats	1	2	3	4	5	6	7	8
%	10	30	30	50	50	70	70	90
Average	0.19	0.47	1.67	3.61	3.94	4.55	5.6	6.0
SD	0.403	0.515	0.485	0.70	0.72	0.62	0.698	0.594
Min	0	0	1	3	3	4	5	5
Max	1	1	2	5	5	5	7	7

Table 1: The average breeding density the population in study area (mean 10h¹), % = proportion of land uncovered by trees and shrubs.

	1 (10%)	2 (70%)	3 (70%)	4 (50%)	5 (50%)	6 (70%)	7 (70%)	8 (90%)
1	/	0.935	0.0001	0.00001	0.00001	0.00001	0.00001	0.00001
2	0.935	/	0.004	0.00001	0.00001	0.00001	0.00001	0.00001
3	0.0001	0.004	/	0.00001	0.00001	0.00001	0.00001	0.00001
4	0.00001	0.00001	0.00001	/	0.87	0.02	0.00001	0.00001
5	0.00001	0.00001	0.00001	0.87	/	0.42	0.00001	0.0001
6	0.00001	0.00001	0.00001	0.02	0.42	/	0.007	0.0001
7	0.00001	0.00001	0.00001	0.00001	0.00001	0.007	/	0.75
8	0.00001	0.00001	0.00001	0.00001	0.00001	0.0001	0.75	/

Table 2: Differences between eight groups (1–8). % = proportion of land uncovered by trees and shrubs. Numbers in bold indicate no statistical significance.



Graph 1: Abundance of *L. collurio* in eight habitats with different wood cover percentage class.

The highest number of males was recorded in the seventh and eighth habitat types (with 70% and 90% open space, respectively), most frequently totaling six males (see Table 1).

DISCUSSION

Lanius collurio (Linnaeus, 1758) is the most widespread species of the Laniidae family in Central Europe, and in the karst poljes of Bosnia and Herzegovina (Obratil, 2006; Marić, 2022). However, the habitat preferences of the Red-backed Shrike have not yet been studied in these poljes. According to Marić (2022a), the Red-backed Shrike, compared to other species, inhabits the widest range of habitats in the study area, specifically within the municipality of Bosansko Grahovo. This study provides data on the population size of the Red-backed Shrike across eight habitats differing in vegetation structure and cover. Estimating population size of any bird species is of great importance, particularly for conservation purposes. The research on *L. collurio* was conducted in an area undergoing rapid ecological transformation in the past, 15 to 20 years. These changes are largely attributed to the decline in domestic livestock, especially sheep, which historically outnumbered other types of grazing animals by a significant margin (Marić, 2022a).

The highest population densities were recorded in sites where shrub cover ranged between 10% and 30% (Graph 1). These results are consistent with previous studies conducted across various regions of Europe. According to Cramp & Perrins (1993), Farkas et al. (1997), and Goławski & Goławska (2007), the highest breeding pair densities in Europe occur in agricultural ecosystems, followed by forest edges, grasslands, dense roadside hedges, open areas with shrubs or small tree clusters, as well as parks and open gardens (Brambilla et al., 2007; Yosef et al., 2012; Morelli, 2012; Kwieciński & Pawlak, 2015; Tryjanowski et al., 2000). However, across different

parts of its range, this species shows significant variation in habitat preferences, particularly regarding vegetation cover and the specific types of shrubs present in the area (Cramp & Perrins, 1993; Olsson, 1995a; Lefranc & Worfolk, 1997; Harris & Franklin, 2000; Väli, 2005; Guerriere & Castaldi, 2006; Casale & Brambilla, 2009; Pawlak & Kwieciński, 2015).

The highest abundance found in habitats with 10% and 30% shrub cover is consistent with the findings of Brambilla et al. (2007). The height of shrubs is an important factor, usually ranging from 1 to 3 meters (Lefranc & Worfolk, 1997), while Morelli (2011) set the minimum suitable height at 0.5 meters. According to Väli (2005), the most frequent nesting sites are in human settlements, and the occurrence of this habitat type has been increasing over time. The same author also notes that nesting is relatively common in cleared forest areas, meadows with trees, other grassy landscapes, as well as in shrubland habitats and young forests. In the studied area, the highest abundance was recorded in human settlements (Marić, 2022b). According to research (Baláz, 2007; Svendsen et al., 2015; Morelli et al., 2016), the Red-backed Shrike is adapted to forest-steppe habitats with suitable perches and open areas, which are crucial for its hunting strategy. The choice of nesting habitat depends on breeding requirements, while habitat use outside the breeding season is determined by food availability (Block & Brennan, 1993).

In habitats with the most favorable conditions, an abundance of about 6 singing males/pairs was recorded (Table 1). A similar density of 5.4 pairs per 10 hectares was reported in southeastern Switzerland (Engadin) (Pasinelli et al., 2007), while Némethová (2002) recorded slightly higher values (up to 6.6 pairs per 10 hectares). The abundance of Red-backed Shrikes in this study was higher than the average values reported from most regions in Poland and several other European countries (Kuźniak, 1991; Winiecki et al., 1997; Guerrieri & Castaldi, 2006; Sikora, 2007; Morelli, 2012; Brambilla et al., 2009; Goławski et al., 2023). However, data from Hungary (Farkas et al., 1997) show higher values than in this work, then Casale and Brambilla (2009) reported a density of up to 10 pairs per hectare (from Italy) and Denac (2003) over 20 pairs per hectare from Slovenia.

The lowest abundance was recorded in forest ecosystems, which is consistent with findings from the literature (Brambilla et al., 2009; Ceresa et al., 2012 and all aforementioned authors). According to earlier research (Marić, 2022b), the abundance of the Red-backed Shrike in pastures with isolated shrubs



Figure 2: A typical habitat in a karst polje for *Lanius collurio* (approximately 10% shrub cover).

is significantly lower than in habitats with a greater number of individual shrubs or shrub groups (10–50% cover). In pastures without any shrubs or bushes, this species was not found in the past (unpublished data). Pasture habitats are often considered optimal for the Red-backed Shrike due to the abundance of food and suitable nesting sites, but only when there is a significant presence of shrubs (Lefranc & Worfolk, 1997; Brambilla et al., 2007).

A typical *L. collurio* territory covers an area from 1–2 ha up to 5–6 ha (Cramp & Perrins, 1993; Lefranc, 1993; Olsson, 1995b; Harris & Franklin, 2000; Svendsen et al., 2015), while this result indicates a territory size ranging from a minimum of 1 ha to 3 ha in areas without shrubs and trees, though these areas must be compact. According to Moes (1993) and Kuźniak & Tryjanowski (2000), a single pair's territory may reach up to 25 ha, which in this area would correspond to the density found in pastures with sparse individual shrubs and meadow/agricultural land (Marić, 2022b). Based on all the above, it can be concluded that the abundance of *Lanius collurio* varies depending on many factors and differs significantly across habitats in different geographical regions.

Changes over the past 30 years have led to the significant transformation of pastures that were once adjacent to forest ecosystems, which are now mostly converted into low woodlands. These pastures with sparse shrub cover now have more tall trees than shrubs, while open or small, mosaic-like areas remain only in shallow and rocky terrain. In the wider area of the study site, 20–30% of pastures—specifically areas where shrub cover was less than 50%—have already disappeared. As shown by the results of this study, such habitats are less suitable for this species, and its population is rapidly declining in these areas.

It has also been established that the gradual

encroachment of shrubs in pastures contributes to an increase in the abundance of *Lanius collurio* (Marić, 2022b). However, the results indicate that when shrub cover in pasturelands reaches approximately 50%, it significantly reduces the abundance of this species. Since the pastures in the karst fields, as well as in the surrounding habitats, have been abandoned for over 30 years, the process of succession toward shrub-dominated vegetation is already well underway. Given that natural succession is a slow process, the decline in the population of this species under such conditions is also expected to be gradual.

At the same time, many areas are being reforested with evergreen species (*Pinus* spp.), accelerating the transformation of pastures into shrubland and, ultimately, forest. Areas that were reforested 25–30 years ago have already developed into forest ecosystems (personal observation).

According to data from *Forest Management Company "Hercegbosanske šume" Ltd. Kupres*, (Šumsko gospodarsko društvo "Hercegbosanske šume" d.o.o. Kupres) approximately 100,000 hectares in Canton 10 have already been reforested, and within 20–25 years, these areas will likely become unsuitable for *L. collurio*, leading to its eventual disappearance from the region. Natural succession and reforestation, together with the disappearance of livestock (following the exodus of the human population), have likely contributed to the local extinction of *Anthus campestris* from pasture habitats (Marić, 2022b).

The Red-backed Shrike has been classified as a declining species in Europe (Tucker & Heath 1994, Brambilla et al. 2007). This trend, common across Europe (Donald et al., 2001), has led to a sharp reduction of open habitats suitable for grassland and farmland species in northern Spain (Regos et al., 2016; Tellería et al., 2008; Tellería, 2018). It is important to note that the species *Emberiza citrinella*

has also disappeared from the study area, due to habitat changes in the broader region (see Marić, 2022b).

Since this species inhabits a variety of habitats (this study and Marić, 2023), the Red-backed Shrike can be considered a good indicator species for assessing landscape change and nature management in this region, as previously suggested by Fuisz & Yosef (1998); Latus et al. (2004); Tryjanowski et al. (2011); Bech et al. (2021). The results have important implications for an effective conservation strategy for areas with large and viable populations of this threatened species. According to MacDonald et al. (2000), implementing effective conservation strategies is crucial to preventing further population decline, which requires a thorough understanding of the species' biology, including its specific ecological needs (Titeux et al., 2007; Tryjanowski et al., 2011).

CONCLUSION

The population of the Red-backed Shrike has declined across its geographical range due to habitat loss, primarily driven by intensive land use. In karst polje areas, a further decline is expected as grasslands undergo natural succession into scrub and forest, particularly in regions with minimal human activity and no domestic livestock. Additionally, intensive afforestation with *Pinus* species contributes to this process.

This study provides valuable new insights into the

ecology of this poorly known species within karst polje habitats. The results highlight the ecological plasticity of the Red-backed Shrike in selecting breeding habitats, demonstrating its ability to utilize a variety of landscapes. Through the first formal assessment of habitat selection by this species during the breeding season, we found that the Red-backed Shrike prefers habitats with lower shrub and tree cover.

The research indicates that the most suitable habitats for this species are mosaic landscapes where shrub cover ranges between 10% and 50%. In other words, preferred habitats have relatively low densities of shrubs and trees.

In conclusion, this study represents the first detailed census of Red-backed Shrikes in karst poljes. Regular monitoring across different areas of karst poljes is essential for assessing the impact of evolving agricultural practices, especially in abandoned fields. This information on habitat requirements of the studied species can be used while planning their protection and conservation.

Funding: This research received no funding.

Conflicts of Interest: The author declares no conflict of interest.

Ethical note: This study was observational and non-invasive. Data were collected in public places where no special permit was required. Our data collection caused only brief and minimal disturbance to birds which typically did not differ from standard background disturbance caused by other site visitors.

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RECEIVED: 31.07.2025.