

MULTI-SCALE HABITAT ASSOCIATION
OF THE ORTOLAN BUNTING *EMBERIZA HORTULANA*
IN A SUB-MEDITERRANEAN AREA IN SLOVENIA

ASOCIACIÓN DE HÁBITAT EN MULTIESCALA
DEL ESCRIBANO HORTELANO *EMBERIZA HORTULANA*
EN UN ÁREA SUBMEDITERRÁNEA DE ESLOVENIA

Maarten DE GROOT* **, Primož KMECL* ¹, Andrej FIGELJ*, Jernej FIGELJ*,
Tomaž MIHELČ* and Borut RUBINIČ*

SUMMARY.—*Multi-scale habitat association of the ortolan bunting* *Emberiza hortulana* in a sub-Mediterranean area in Slovenia.

The habitat selection of the ortolan bunting *Emberiza hortulana* has been examined on multiple spatial scales. Habitat variables of territories and random points were measured in the field on a 25 m radius and from GIS layers on scales of 25 m, 100 m, 500 m and 1,000 m radius. Habitat variables were analysed by a generalized linear model. The ortolan bunting was found on a 25 m radius in areas with a few black pines, with low grass and open patches within the herbaceous layer. On a 100 m radius scale, the probability of occurrence was highest in areas with meadows with large trees, permanent and partly overgrown meadows, and small areas of forests. On a 500 m radius scale, the occurrence of the ortolan bunting was negatively affected by urban areas and their infrastructure and by forests, and positively by partly overgrown meadows and permanent meadows with or without large trees. On a 1,000 m radius, permanent meadows with or without large trees, and the absence of large urban areas and infrastructure positively affected the presence of the ortolan bunting. In conclusion, factors influencing habitat selection by the ortolan bunting differ according to spatial scale. On the territorial level, its presence was only influenced by cover of open and partly overgrown meadows and by forest, while on larger scales it was also affected by the cover of urban areas. Factors influence habitat selection differently on different scales; a forest influences the probability of a territory positively on a small scale while negatively on larger scales. Factors influencing the habitat selection positively on a larger scale are becoming less common and therefore fewer suitable sites are available for the ortolan bunting in Kras.

Key words: anthropogenic disturbance, conservation, *Emberiza hortulana*, Emberizidae, habitat selection, multi-scale habitat association, ortolan bunting, succession.

RESUMEN.—*Asociación de hábitat en multiescala del escribano hortelano* *Emberiza hortulana* en un área submediterránea de Eslovenia.

La selección de hábitat del escribano hortelano *Emberiza hortulana* ha sido examinada con múltiples escalas espaciales. Las variables del hábitat de sus territorios y puntos al azar fueron medidas en el

* DOPPS BirdLife Slovenia, Tržaška 2, 1000 Ljubljana, Slovenia.

** Current address: Department of Entomology, National Institute of Biology, Večna pot 111, 1000 Ljubljana, Slovenia.

¹ Corresponding author: primoz.kmecl@dopps.si

campo en un radio de 25 m y en estratos GIS en escalas de 25 m, 100 m, 500 m y 1.000 m de radio. Las variables del hábitat fueron analizadas mediante un modelo lineal general. El escribano hortelano fue encontrado en un radio de 25 m en áreas con escasa abundancia de pino negro, de pastos bajos y zonas de claros en el estrato herbáceo. A la escala de 100 m, la probabilidad de incidencia fue mayor en áreas de pradera con árboles de gran porte, praderas permanentes y parcialmente con maleza, y en pequeñas áreas boscosas. En la escala de 500 m de radio, la incidencia de escribano hortelano se vio afectada negativamente por la presencia de áreas urbanas y sus infraestructuras y por zonas de bosque, mientras estuvo favorecida por praderas con cobertura parcial de maleza y praderas permanentes con o sin árboles de gran tamaño. En la escala de 1.000 m de radio, las praderas permanentes con o sin árboles grandes y la ausencia de zonas urbanas e infraestructuras afectaron de manera positiva la presencia de escribano hortelano. En conclusión, los factores que influyen en la selección de hábitat del escribano hortelano difieren según la escala espacial. A nivel territorial, su presencia estuvo influida únicamente por la cobertura de las praderas abiertas y con presencia de maleza, y por las zonas de bosque, mientras que a escalas mayores también se vio afectada por las zonas urbanas. Los factores influyen de manera distinta en la selección de hábitat a diferentes escalas; una zona de bosque actúa de manera positiva a pequeña escala en la probabilidad de territorio, mientras que influye de manera negativa a mayores escalas. Los factores que intervienen positivamente en la selección de hábitat a mayores escalas son menos frecuentes y, consecuentemente, hay una menor disponibilidad de lugares apropiados para el escribano hortelano en Kras.

Palabras clave: conservación, *Emberiza hortulana*, Emberizidae, escribano hortelano, molestias antropogénicas, selección de hábitat, asociación de hábitat en multiescalas, sucesión.

INTRODUCTION

Populations of birds favouring open habitats have declined rapidly over the last few decades in Europe (Siriwardena *et al.*, 1998; Evans, 2004). Land use changes, such as intensification (Evans, 2004), and abandonment of land are often cited as causes (Preiss *et al.*, 1997; Sirami *et al.*, 2007a). In the Mediterranean basin there is a strong trend of abandoning agricultural areas and, as a consequence, many meadows are becoming overgrown (Mazzoleni *et al.*, 2004). Management of vegetation in the Mediterranean basin is, therefore, a conservation priority for open habitat birds (Pain and Dixon, 1998; Whittingham *et al.*, 2007).

There is a growing awareness that, for conservation, more than one spatial scale has to be taken into account within the home range (López-López *et al.*, 2006). Birds select their habitat on different scales, ranging from the home range to the nest site scale, reflecting

decisions on critical parameters such as nest safety and proximity of food resources (López-López *et al.*, 2006). If the critical parameters at different scales do not match, this can prevent the species occupying a certain habitat.

One of the open habitat birds which have declined rapidly is the ortolan bunting *Emberiza hortulana* (BirdLife International, 2004). The ortolan bunting is a migratory bird whose breeding distribution extends over the Mediterranean basin and temperate parts of Europe and Asia (Cramp and Perrins, 1994). Habitat loss (Vepsäläinen *et al.*, 2005, Preiss *et al.*, 1997), female post-natal dispersion (Dale, 2005; Steifetten and Dale, 2006), change of wintering quarters (Stolt, 1993) and trapping (Stolt, 1993; Geister, 1992) have all been suggested as causes for the decline.

The habitat of the ortolan bunting in the temperate part of Europe is confined mainly to mixed farmland and raised peat bogs (Cramp and Perrins, 1994; Dale and Hagen,

1997). However, in the Mediterranean area the species breeds in open bushy areas mixed with meadows (Cramp and Perrins, 1994; Fonderflick *et al.*, 2005). The collapse of the ortolan bunting populations is suggested as having various causes in the different habitats in temperate and Mediterranean Europe (Vepsäläinen *et al.*, 2005; Sirami *et al.*, 2007b).

Regional differences and multidimensionality are important aspects of habitat selection and can be important for conservation of the ortolan bunting. Comparison of two extreme habitat types in different regions can reveal underlying mechanisms of habitat selection of a species (e.g. Sánchez *et al.*, 2009). Habitat preference of the ortolan bunting has been studied mainly in temperate areas (Conrads, 1969; Dale and Hagen, 1997; Vepsäläinen *et al.*, 2005, Berg, 2008), while in sub-Mediterranean areas knowledge of its habitat is restricted and mostly anecdotal (Cramp and Perrins, 1994, Fonderflick *et al.*, 2005). Most of these studies have focused only on the nesting site scale (but see Berg, 2008). Dale (2000) found that the ortolan bunting uses surrounding farmland hundreds of metres from nesting locations as feeding areas, but breeds on raised peat bogs. The answer to the question whether its habitat selection operates on different spatial scales can provide an insight into its complexity and thus, possibly, to solutions for its conservation.

In Slovenia, the ortolan bunting has its stronghold in the south-western, sub-Mediterranean area (Geister, 1995), with some possible breeding locations in other parts of the country. It was reported to be in decline in 2000, with an estimated population of 200 - 300 pairs (BirdLife International, 2004). In the Red List of Breeding Birds of Slovenia it has the status of a highly endangered species (E2; Official Gazette of the Republic of Slovenia 2002). A recent report estimated its population in 2008 to be 50 - 100 singing ma-

les, which occurred almost exclusively in the Important Bird Area (IBA) Kras (Rubinić *et al.*, 2008).

We have examined the habitat selection of the ortolan bunting on different scales. Our aim was to investigate (i) the influence of habitat type, vegetation succession stage and anthropogenic disturbance on the occurrence of the ortolan bunting, all at different spatial scales in a sub-Mediterranean area; (ii) the influence of possibly contrasting important factors at different scales on the occurrence of an ortolan bunting territory and (iii) whether there are other potentially suitable breeding areas for the ortolan bunting on Kras, besides those found during the research.

METHODS

Study area

Kras is a region with an area of 429 km² located in the south west of Slovenia (centroid coordinates: 45° 40' N / 13° 55' E). It is a mezzo region in the Mediterranean macro-region of Slovenia (Perko and Orožen Adamič, 1999) that starts south of Nova Gorica and continues southward to the Croatian border. A sub-Mediterranean climate and karstic phenomena, characteristic of most of the area, make this a dry landscape. Kras is covered by a wide variety of vegetation types, many of them the consequence of human management and exploitation. Desertification had taken place, with a peak in the 18th century. Since then, the area has gradually become overgrown, at first with grasslands, but nowadays also with scrub of a variety of species, depending on the local (and very variable) climatic conditions. Kras is largely covered with black pine *Pinus nigra*, which has been planted there since the 18th century. A similar area further south is Podgorški Kras, Čičarija and Podgrajsko podolje, with an area of 244 km², which is considered as a separate mezzo re-

gion in the Mediterranean macro-region of Slovenia (Perko and Orožen Adamič, 1999). Since 2003, the greater part of each mezzo region has the status of IBA Kras (Božič, 2003). Our study area comprised IBA Kras with some smaller adjoining areas (fig 1).

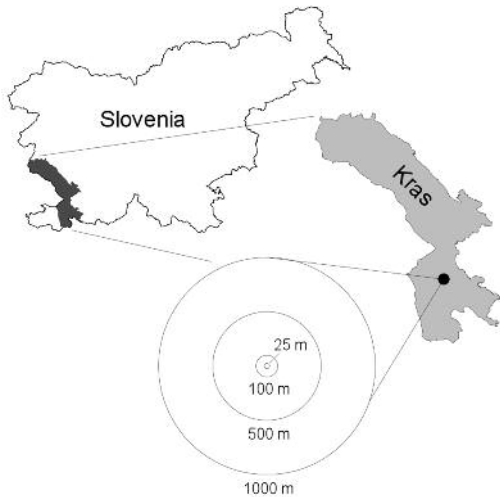


FIG. 1.—Study area Kras with an example of the different scales.

[El área de estudio en Kras, a diferentes escalas.]

Bird survey

The number of ortolan bunting male territories was defined as the number of singing males. The territories were mapped between May 15 and June 28 2006 in a single survey that covered the entire area of Kras, by visiting all non-forest habitats. Sites with open habitats were first located using aerial photos and GIS. In total, an area of 18,176 ha was searched in 66 hours of field work divided between six people. As the ortolan bunting is active during daytime (Conradts, 1969; Cramp and Perrins, 1994), the searching period was between 7:00 h and 18:00 h. Mapping took place only when it was not raining and when

the wind speed was below force 3 Beaufort. GPS coordinates were recorded for every singing post. To avoid double counting of territories, two territories were considered as different only when the neighbours were heard simultaneously.

Many territories were distinctly aggregated into subpopulations. A subpopulation was defined as a group of singing males that were at most 1,000 m from each other.

Selection of scales and habitat measurement

We distinguished four different spatial scales: singing location ($r = 25$ m), territory scale ($r = 100$) (Dale and Olsen 2002), foraging scale ($r = 500$ m) (Dale and Olsen 2002) and landscape scale ($r = 1,000$ m). For the singing location we collected only field data and for the larger scales we used only GIS data. These two data sets could not be combined since the random points of the field data overlapped on larger scales (> 500 m). The sample sizes for different scales are shown on table 1.

We compared actually used and potentially suitable breeding habitats. Literature data (Fonderflick *et al.*, 2005) and data collected through field surveys were used to describe the habitat of the ortolan bunting in sub-Mediterranean landscapes. We considered permanent meadows and partly overgrown agricultural land as potentially suitable breeding habitat. Within this habitat we chose random points that represented possibly suitable breeding habitats.

For the singing location analysis we measured field variables. Additionally we chose random points which did not overlap with the 25 m radius, although some overlapped on larger scales. The scales from 100 m upwards were investigated with the GIS data only. The singing posts and the random points were used as spatial centres in the analysis (fig 1).

TABLE 1

Sample sizes of singing posts of ortolans and random points on Kras used for analysing different scales.

[*Tamaño de muestras de los puntos de canto del escribano hortelano y puntos al azar utilizados para el análisis a diferentes escalas en la zona de Kras.*]

	Singing posts	Random points
Field data		
25 m	57	29
GIS data		
100 m	57	45
500 m	57	45
1,000 m	52	45

All singing posts were used when the 100 m and 500 m scales were analysed. For the 1,000 m scale we had to omit five of the singing posts, because these included part of the radius in Croatia, for which land use data was not available. The random points for the larger scales were positioned at distances of at least 2,000 m from the singing posts and other random points, so they would not overlap on the largest scale. Due to this constraint, the random points were equally distributed over the potentially suitable habitat and covered more than 70 % of its surface.

A total of 12 variables were investigated, of which 4 were obtained in the field and 8 from digital land use maps (<http://rkg.gov.si/GERK/>) (table 2). These variables were surveyed as categorical, which was more practical in the field. All GIS variables were obtained from a land use digital map, based on aerial photos (10 m spatial resolution) taken in 2006 (MKGP 2007). The GIS variables were measured as proportions within 100, 500 and 1,000 m radius.

Data analysis

The field data (25 m) and GIS data (100, 500, 1,000 m) sets were analysed separately. For the former, we constructed separate best fitting models using logistic regression. For the GIS data, we used logistic regression for the 100 m scale. A likelihood ratio backward stepwise procedure was used for model selection criteria (Quinn and Keough, 2002). At each step, the criterion was $P = 0.05$ for entry and $P = 0.10$ for removal of a parameter.

The land use data on larger scales were overlapping and therefore autocorrelated. We used a penalized quasi likelihood generalized linear mixed model (PQLgmm) with binomial distribution, and included an autocorrelation coefficient (Dormann *et al.*, 2007).

In the 100 m radius, 500 m radius and 1,000 m radius scales we checked for the influence of land use. The land use variables were divided between three subsets at each scale: habitat variables (hab), succession variables (suc) and anthropogenic disturbance variables (dist) (table 2). Seven global models were prepared. First, simple models were developed with variables from only one subset. Then all possible combinations of double (i.e. hab + suc) and triple subsets (i.e. hab + suc + dist) of variables were added. The most parsimonious model was prepared from each global model using logistic regression and PQLgmm for larger scales. Parameters were estimated using maximum likelihood.

For each of the seven models, the most parsimonious model for each scale was selected by calculating the second order Akaike Information Criterion (AICc), because the sample size divided by the number of variables was smaller than 40 (Johnson and Omland, 2004). For the 500 m and 1,000 m scales the second-order quasi AIC (QAIC_c) was calculated, as the PQLgmm does not calculate the actual maximum likelihood. The models within two (Q)AIC units from the most parsimonious model have comparable explana-

TABLE 2

Habitat and land use variables used for logistic regression and generalized linear mixed models.

[*Variables de hábitat y uso del suelo utilizadas en el análisis de regresión logística y en los modelos lineales generalizados.*]

Name	Description of category and variable	Radius
Field variables		
Height of black pines	No trees / trees lower than 1.8 m / trees higher than 1.8 m	25 m
Number of black pines	No trees / < 30 trees / > 30 trees	25 m
Height of the herbaceous layer	Lower than 40 cm / higher than 40 cm	25 m
Bare land between the grass patches	More than 50 % / 10-50 % bare land / 0-10 % bare land	25 m
GIS variables		
<u>Habitat</u>		
Proportion of permanent meadows	Area of meadows with less than 50 trees / ha	100 m, 500 m, 1,000 m
Proportion of bushes and trees	Area with bushes and bushes like hedges between the meadow parcels	100 m, 500 m, 1,000 m
<u>Succession</u>		
Proportion of partly overgrown arable land	Arable land in which 20-75 % is overgrown by trees larger than 10 cm and not used for more than 20 years.	100 m, 500 m, 1,000 m
Proportion of meadows with large trees	Meadows with large trees under which grass is grazed or mown once a year. Meadows have an area of around 80 % and the tree crown cover is less than 75 %	100 m, 500 m, 1,000 m
Proportion of forest	Forest cover	100 m, 500 m, 1,000 m
<u>Anthropogenic disturbance</u>		
Proportion of urban areas	Area covered with buildings and roads	100 m, 500 m, 1,000 m

tory value (Johnson and Omland, 2004) and are discussed below. The two most informative parameters with the smallest standard error in the best model per scale, were plotted against the probability of an ortolan bunting territory. Furthermore the proportion of plots in which an ortolan bunting was not obser-

ved, but predicted with the best models, was calculated to see whether or not the ortolan bunting occupied all areas with available habitats. These proportions were compared between the different scales. All analyses were done using R statistics (R Development Core Team, 2008).

RESULTS

57 singing males were recorded within the study area. Altogether we found 9 sub populations. At the smallest scale, 25 m radius, three habitat parameters were included in the most parsimonious model: black pine abundance, height of the herbaceous vegetation and bare land between the grass patches. A large part of the variability of the data was explained by this model (Nagelkerke $r^2 = 0.54$). The habitat suitability for the ortolan bunting appeared higher when there were up to 30 black pines present than when there were no trees, but statistical support was not convincing ($P = 0.069$). If there were more than 30 black pine trees, no positive effect was observed ($P = ns$) (fig 2a). The probability of territories was higher for a lower herbaceous layer (< 40 cm) than for higher vegetation (> 40 cm) ($P < 0.01$) (fig 2b). Places with a low proportion of bare ground (< 20 %) appear to be less suitable for the ortolan bunting than those with some bare patches (20 - 50 %), although this difference was not statistically significant ($P = 0.078$). There was a positive effect when there were large surfaces of bare land (> 50 %) ($P < 0.01$) (fig 2c).

The succession parameters combined with habitat parameters gave the best fit for the data of territorial habitat use in the 100 m radius scale (table 3; fig 3a). Permanent meadows, meadows with large trees, partly overgrown meadows and forest were favourable for the ortolan bunting occurrence. Permanent meadows and meadows with large trees were the most favourable.

Two models were the most parsimonious for the 500 m scale. The first included a negative effect of urban area cover and positive effects of cover of permanent meadows, cover of partly overgrown meadows and cover of meadows with large trees (table 3; fig 3b). The second model included cover of urban area, cover of permanent meadows and cover of meadows with large trees. The least expla-

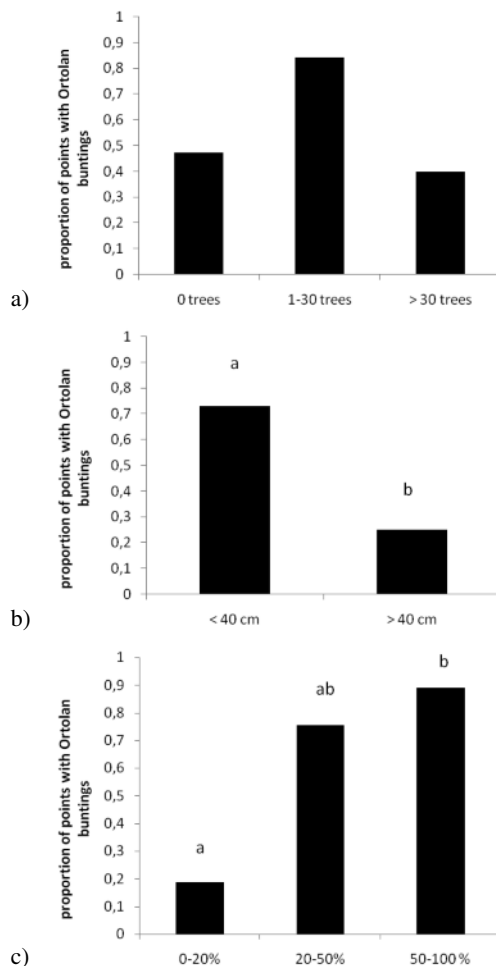


FIG. 2.—Proportion of investigated points with ortolan bunting territories for the different habitat parameter classes, within a 25 m radius area around the singing post, using logistic regression: (a) abundance of black pines, (b) height of the herbaceous layer and (c) percentage of bare land between grass patches. The letters indicate different groups.

[Probabilidad de que los puntos investigados incluyan territorios de escribano hortelano para las diferentes clases de parámetros de hábitats, en un radio de 25 m alrededor del punto de muestreo, usando regresión logística: (a) abundancia de pino negro, (b) altura del estrato herbáceo y (c) porcentaje de suelo desnudo entre parches herbáceos. Las letras indican diferentes grupos.]

TABLE 3

General linear (mixed) models examining habitat association in ortolan buntings on different scales. The models incorporate habitat (hab), succession (suc) and disturbance parameters (dist). The models within 10 AIC units from the most parsimonious model are shown. The best explanatory models are highlighted in bold. Estimates are given per parameter. ¹ AICc was used for the 100 m scale and QAICc was used for the 500 m and 1,000 m scales.

[Modelos lineales generalizados para examinar la asociación de hábitat en el escribano hortelano a diferentes escalas. Los modelos incorporan parámetros de hábitat (hab), sucesión (suc) y de molestias (dist). Se ha utilizado el criterio de información de Akaike (AIC) para seleccionar los modelos más parsimoniosos y se han escogido aquellos incluidos en 10 unidades AIC. Los modelos más explicatorios se muestran en negrita. Las estimas se dan por parámetro. ¹ El AIC con una corrección de segundo orden (AICc) se ha utilizado para escalas de 100 m y el quasi-AIC (QAICc) para escalas de 500 y 1.000 m. Véase Johnson and Omland (2004) para más detalles.]

scale	model	anthropogenic disturbance		habitat	succession			K	(Q)AICc ¹	Δ(Q)AICc	model likelihood	w _i
		% urban areas	% permanent meadows		% partly overgrown meadows	% meadows with large trees	% forest					
100m	hab+suc							5	99.97	0.00	1.00	0.50
	hab+suc+dist			0.138	0.208	0.131	0.075	5	99.97	0.00	1.00	0.50
	suc+dist	-0.223		0.138	0.088	0.131	-0.051	4	108.38	8.41	0.01	0.00
500m	hab+suc+dist							6	61.19	0.00	1.00	0.55
	suc+dist	-0.745		0.105	0.292	0.071	-0.079	5	62.84	1.65	0.44	0.45
	hab+suc	-0.779		0.391	0.696	0.391	0.263	6	63.87	2.68	0.26	0.00
1000m	hab+suc+dist							5	68.41	0.00	1.00	1.00
	suc+dist	-0.658		0.164	0.233		-0.111	5	72.79	4.38	0.11	0.00
	hab+suc+dist	-0.649		0.447	0.620	0.364	0.292	6	73.13	4.73	0.09	0.00
	hab+dist	-0.864		0.166				4	73.36	4.95	0.08	0.00

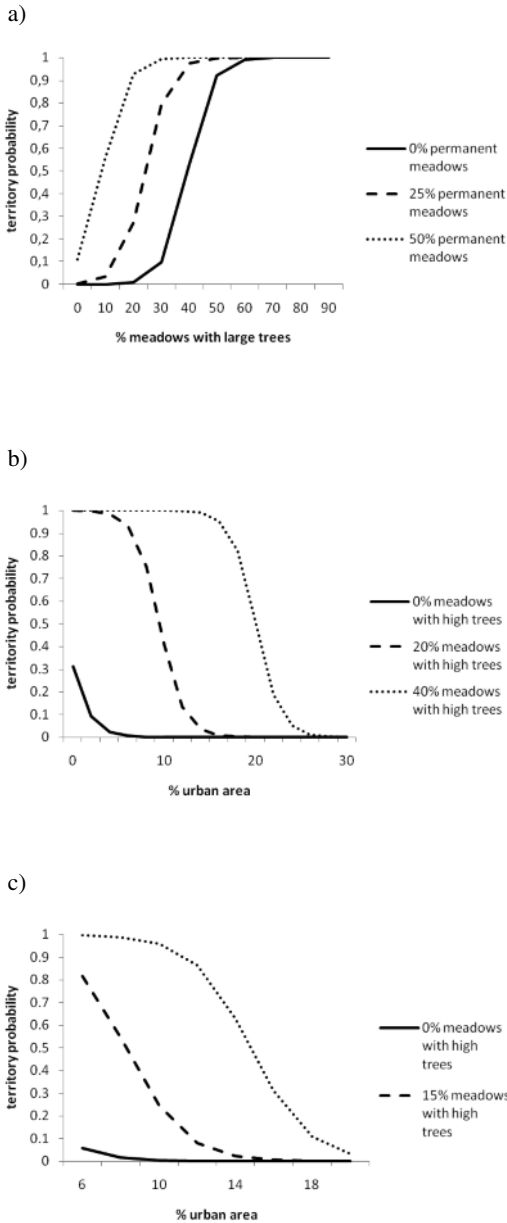


FIG. 3.—Influence of the retained variables with the largest effect in the models on the probability of an ortolan bunting to occur in a 100 m (a), 500 m (b) or 1,000 m (c) territory.
 [Influencia de las variables retenidas con mayor efecto en los modelos sobre la probabilidad de que un territorio de un radio de (a) 100 m, (b) 500 m y (c) 1.000 m contenga escribano hortelano.]

natory model shows a positive effect of forest cover in association with permanent meadows, partly overgrown meadows and permanent meadows with large trees.

On the 1,000 m scale, urban area cover exhibited a negative effect, and positive effects of permanent meadows with or without large trees were included in the most parsimonious model. In the less explanatory models, the forest cover had a negative effect when urban area cover was included, but a positive effect when the positively affecting partly overgrown meadow cover was included (fig 3c).

The percentage of random points predicted to be occupied by the ortolan bunting decreased at scales larger than 500 m but increased at 1,000 m (fig 4). The proportion of incorrectly predicted random plots at 100 m radius scale was smaller by 0.27 than at the 500 m radius ($P < 0.05$), but not different at the 1,000 m radius ($P = 0.20$). For all the scales, the proportion of random points with a suitable habitat for the ortolan bunting was less than 0.3.

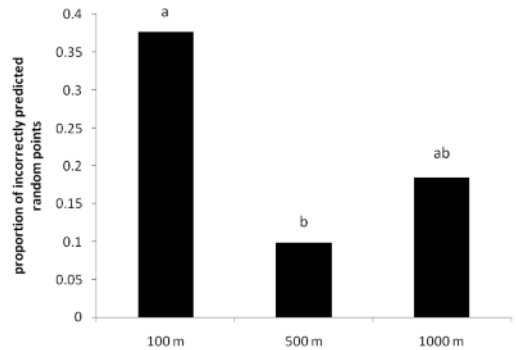


FIG. 4.—Difference in proportions of random plots with suitable habitats for ortolan bunting between different scales.

[Diferencia en las proporciones de parcelas al azar con hábitats propicios para el escribano hortelano entre escalas diferentes.]

DISCUSSION

The ortolan bunting selects its territories on the basis of different land use on different scales. This is a step-down process: on larger scales (landscape and foraging scale), the higher the proportion of meadows with or without large trees the more likely the ortolan bunting is to occur, while on the territory scale the larger proportion of meadows completely or only partly overgrown with large trees and a larger proportion of forest increased the probability of the occurrence of a territory. The number of sites which were not occupied was better predicted for the larger scales than at the territory level.

Regional differences and similarities between temperate and Mediterranean habitats

The ortolan bunting breeds in both temperate and sub-Mediterranean areas in very different habitats (Cramp and Perrins, 1994; BirdLife International, 2004). Our study shows that they occur in open grassland areas, such as grazed or unmanaged pastures, with bushes, large trees or patches of forests in the vicinity, while having less forest cover and urban area on the large scale. In temperate areas, on the other hand, it breeds in farmland and bogs with dry and open microhabitat, and feeds in farmland (Dale, 2000; Conrads, 1969). The ortolan bunting is positively related to permanent set-aside fields, short rotation coppice and grazed and unmanaged semi natural pastures on the territorial scale (Berg, 2008). On the larger scale, the probability of occurrence was higher in areas where the preferred habitat types were clustered (Berg, 2008).

The differences in selected habitat factors between temperate and sub-Mediterranean areas can be caused by several factors. First, the ortolan bunting uses different habitat attributes of the two areas for the same function.

For instance, a different array of high objects is used as singing posts (e.g. houses, electric wires and large bushes for temperate areas and trees and electric wires for sub-Mediterranean areas). Again, it needs large open areas for breeding sites, such as pastures in sub-Mediterranean areas and open peatland and farmland in temperate areas. Secondly, some land uses, for example, the use of set-aside fields or short rotation coppice, simply do not exist or are not so frequent in sub-Mediterranean areas, where pastures are much more common. Fonderflick *et al.*, (2005) found no influence of distance or proximity of agricultural land on the probability of an ortolan territory in sub-Mediterranean areas. Other factors, such as food availability, were not taken into account in the surveys but could influence the occurrence of the ortolan bunting. Further research on its general habitat requirements is needed to determine the factors influencing the occurrence of the species (Sánchez *et al.*, 2009).

Multidimensionality in habitat selection

Birds have a hierarchical approach to selecting their territories (Klopfer and Ganzhorn, 1985). This means that certain habitat attributes are important on certain scales. In the case of the ortolan bunting, it appears to have a threshold strategy in that it visits at least two suitable habitat patches and settles at the last one (Dale *et al.*, 2006). The actual choice of its territory appears to be complex: the aggregation of individuals in a preferred habitat (Berg, 2008; this study) suggests that the large size of areas with preferred habitat is an indication for selection, but conspecific attraction can also play a large role (Vepsäläinen *et al.*, 2007). It is likely that a mixture of conspecific attraction and environmental effects are involved in its habitat selection.

Different ecological attributes are important on different scales in habitat selection by

the ortolan bunting. On the 100 m scale, the territory level, patches of forests, high trees and partly overgrown meadows are preferred. High trees and patches of forest are used for singing posts (Fonderflick *et al.*, 2005). The trees on permanent meadows might also be used as a breeding site because, although the ortolan bunting is a ground breeder, it also breeds occasionally in trees (Glutz von Blotzheim and Bauer, 1997). However, this study only focused on territories and it cannot be affirmed where actual nesting sites were located. Finally, the ortolan bunting is found to feed on agricultural land at least 46 m from the nest (Dale, 2000). In Kras, where there are many insects, they could also use pastures as a feeding ground.

On both 500 m and 1,000 m scales, road and urban area cover, permanent meadows, and permanent meadows with large trees, were the parameters that best account for the probability of a territory. The availability of feeding habitats near breeding habitats could be another reason for habitat selection of the ortolan bunting (Dale, 2000). The ortolan bunting, which is generally granivorous, switches to invertebrate food during the breeding season (Cramp and Perrins, 1994). It usually prefers bare ground between the vegetation, where food can be collected more easily (Claessens, 1994; Glutz von Blotzheim and Bauer, 1997), although they are sometimes also seen feeding in trees. They are known to collect food up to 2.7 km outside the territory (e.g. Dale, 2000). However, in this study only a scale up to 1,000 m was used. The feeding habitat use of the ortolan bunting in Kras should be further investigated.

Interestingly, the effects of forest cover on the occurrence of the ortolan bunting contrasts between best and less explanatory models on all scales. On the territorial scale, the forest has a positive effect in the best explanatory model and a negative effect in a poorer explanatory model, while on the foraging level the effect is opposite. On the landscape level, there are also contrasting effects, but all in the

poorer explanatory models. These effects are associated with other parameters in the models. Where there is a much preferred habitat (permanent meadows with or without large trees), the ortolan bunting is positively affected, as the trees not only provide resources such as insects, but also singing posts (Cramp and Perrins, 1994). However, when disturbing factors are included, the effect of forest is negative. The strong negative effect of forest cover indicates the influence of the final stage of succession. Due to the loss of preferred habitat, like permanent meadows, the ortolan bunting is likely to avoid such areas.

This study shows the connection between different habitats on different scales. The importance of the connection between feeding habitat and breeding habitat has been highlighted, for example, by Chalfoun and Martin (2007). They found that the presence of different habitat attributes, such as density of potential nest shrubs, that reduced predation rate at the territorial scale and food availability at the landscape level, can affect the survival rate of the birds (Chalfoun and Martin, 2007).

Anthropogenic factors

The decrease of territory probability in the vicinity of villages, settlements and infrastructure can be explained from a socio-historical perspective and by direct anthropogenic disturbance.

Concerning the former, past overexploitation in Kras has resulted in desertification. Climate conditions in Kras are harsh and settlements have been aggregated in the lower altitudes, while pastures, the preferred habitat of the ortolan bunting, were in the open areas. Farmers have been abandoning their land for some decades, since pasturing on these poor grounds was not sufficiently profitable. The former pastures thus became overgrown by trees and bushes. However, the remaining farmers still use pastures and permanent

meadows, most of them being more than one kilometre away from the settlements.

There is, however, the additional possibility of direct anthropogenic disturbance. Roads make areas more accessible for people, enhancing disturbance in breeding and feeding areas during the breeding season. Additionally, pets, especially cats, increase in numbers in the vicinity of settlements and predate on the local bird fauna (Woods *et al.*, 2002). Bird and nest predation was beyond the scope of this survey, but needs to be studied to ascertain whether the absence is due to predation by pets or other animals or to direct disturbance by humans, or is the result of socio-historical factors.

Implications for conservation

Many reasons have been suggested for the decline of the ortolan bunting (Preiss *et al.*, 1997; Steifetten and Dale, 2006; Stolt, 1993). In this study we found that habitat loss is one of the main drivers of the rarity of the ortolan bunting, which is now confined to only a very few sites in Kras. These sites are characterised by large stretches of permanent meadows with occasional patches of forest and bushes. Due to abandonment of agriculture on the permanent meadows and subsequent succession, they are disappearing. Overgrown meadows, or areas with large forest covers in the proximity, are usually avoided on a larger scale. Thus the preferred habitat types are becoming increasingly rare in Kras. It has been found that, when the patch size with preferred habitat is maintained or increased, the population of the ortolan bunting has the potential to increase in sub Mediterranean areas (Brotons *et al.*, 2005, Brotons *et al.*, 2008). Conservation effort should therefore be directed to the increase of meadows in these and surrounding areas.

In conclusion, our study shows first of all that at territorial level habitat type and vege-

tation succession stages have a positive influence on the presence of the ortolan bunting, while on larger scales the succession stages, habitat types and anthropogenic disturbance influence the presence of the ortolan bunting. Second, the final succession stage, forest, has a positive influence on territorial level while a negative influence on larger level. Third, there are less suitable sites, due to habitat selection on the larger scales. This study shows that habitat selection operates over different spatial scales for the ortolan bunting. It is therefore important, for the purpose of conservation, to incorporate this in species conservation plans.

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