Factors affecting occurrence at the territory scale in the drastically declining Ortolan Bunting *Emberiza hortulana*

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agri-environmental schemes; bare ground; conservation; crop type; farmland birds; habitat management; MARS

Summary

Capsule Ortolan Bunting is associated with bare ground, lucerne, shrub cover and hedgerows/tree rows.

Aims To assess habitat features affecting habitat selection by Ortolan Buntings at the territory level in semi-open landscapes, in northern Apennines (Italy).

Methods We mapped bunting territories in 10 different plots and built a habitat selection model comparing 52 occupied cells with 52 unoccupied ones (cell size: 1 ha). We built MARS (multi-adaptive regression splines) models based on ground-measured variables.

Results Model (R^2 0.38, AUC 0.80 ± 0.08 SD) revealed an association with intermediate lucerne cover (50% of the cell), high shrub cover, bare ground (≥5%), hedgerows/tree rows (≥25 m/ha). The most important driver of species occurrence was bare ground (optimum at 5-20%).

Conclusion The maintenance of the mosaic and low-intensity farmed landscape, the promotion of lucerne and the conservation/restoration of hedgerows/tree rows, may be promoted by measures of the Rural Development Programme. The conservation of bare soil, grassland and shrubs at optimum amount at fine-scale could be the object of an agri-environmental scheme targeted at the species.

INTRODUCTION

The Ortolan Bunting *Emberiza hortulana* is sharply declining. In the period 1980-2009, it underwent a dramatic decrease (-89% at the pan-European level), displaying the largest decline in a set comprising 38 widespread Afro-Palearctic migrant species (Vickery et al. 2014).

This granivorous species is concentrated in Europe (which includes 50-74% of its range) and has an unfavourable conservation status in most of European countries (BirdLife International 2004). It largely inhabits open or semi-open habitats, in rather warm and dry areas occupying a variety of breeding habitats, with apparently different preferences in different parts of its distribution (Cramp and Perrins 1994). In central and northern Europe Ortolan Buntings mostly occur in heterogeneous and semi-open farmlands (Cramp and Perrins 1994; Dale and Olsen 2002; Goławski and Dombrowski 2002; Berg 2008); in southern Europe the species may occupy also (and often predominantly) open and semi-open shrubland or steppe-like habitats (Cramp and Perrins 1994; Guerrieri et al. 2006; Brotons et al. 2008; Menz et al. 2009), although farmed habitats may still be important in some temperate areas (Morelli 2012).

In general, Ortolan Buntings in the Mediterranean region are associated to areas with sparse vegetation and scattered trees (Cramp and Perrins 1994), whereas they are excluded by later stages of vegetation succession (Bogliani et al. 2003; Sirami et al. 2007). Both in southern and northern Europe, the species is often associated with burnt areas (e.g. Dale and Manceau 2003; Brotons et al. 2008; Menz et al. 2009). Therefore, Ortolan Bunting may be considered a colonizer of the early vegetation stages (Menz et al. 2009). The species predominantly forages on sparsely vegetated ground or in bare patches, whereas it nests mainly on the ground (Menz and Arlettaz 2012), rarely also in low bushes (Cramp & Perrins 1994). Trees (often in rows), rocks or bushes are required as songposts (Cramp & Perrins 1994).

Several factors can affect the status of this declining species. Conditions experienced during migration and wintering periods may be important for this Afro-Palaearctic migrant, and in particular climate or anthropogenic changes in wintering grounds and illegal trapping during

migration may exert notable effects (Menz and Arlettaz 2012 and references therein). However, the huge decline of the species had been largely ascribed to changes that have occurred in its breeding habitats. Detrimental changes include several type of modifications in agricultural practices and intensification (Goławski and Dombrowski 2002; Revaz et al. 2005; Vepsäläinen et al. 2005) and the conversion of oat and rye into maize fields (Menz and Arlettaz 2012). The loss of patches of bare ground is particularly detrimental to the species, given its foraging ecology (Menz and Arlettaz 2012), and can be caused by vegetation closure through natural succession on abandoned areas (Sirami et al. 2007; Sondell et al. 2011), as well as by agricultural intensification and in particular by the heavy use of fertilizers (Menz and Arlettaz 2012). In general, an indirect evidence for the key importance of the breeding habitat for the species status is represented by the fact that in areas where the breeding habitat of the species is increasing (e.g. Spain, due to to wildfires, Pons 2004; Brotons et al. 2008; Menz et al. 2009) or stable (e.g. central-eastern Italy, Morelli 2012), the species' population trend is positive (Brotons et al. 2008; Menz and Arlettaz 2012; Morelli 2012).
Therefore, a good understanding of the species' ecological needs during the breeding period is of basic importance for its conservation, and given the different habitat associations reported from different parts of the species range, it is essential to develop region-specific approaches.
With this study, we aim to assess at the territory level what habitat features affect habitat selection by Ortolan Buntings. On the basis of the common traits of habitat preferences and habitat use in Ortolan Buntings in different areas, we hypothesize that the species could be associated with bare ground, shrubs and selected crop types at the territory level (Golawski and Dombrowski 2002; Brotons et al. 2008; Menz et al. 2009; Morelli 2012).

METHODS

Study area

Our study took place in Oltrepò pavese (southern Lombardy, province of Pavia, northern Italy). The whole area extends over ~1100 km^2 and is characterized, from north to south, by a gradient of increasing elevation, from c. 50 m above sea level (a.s.l.) at the Po River, to 1700 m a.s.l. of the highest mountain in the area. Lowland is dominated by cereal cultivation with small woodlots and other habitats, foothill by vineyards, low-elevation mountainsides by non-intensive cultivations and woodlands, middle and especially upper elevations by woodlands with scattered pastures, partly subjected to abandonment (Brambilla et al. 2012).

In Lombardy, as well as in Italy in general (Gustin et al. 2009), the species has an unfavourable status ("bad" conservation status; cf. Brambilla et al. 2013).

Fieldwork

In April-June 2011, we carried out territory mapping of the species in 10 plots (average size 116 ha ± 37 ha; see Supplemental data for further information), which were visited at least four time. Those plots were all dominated by open or semi-open landscapes, although the proportion of fields, grassland, vineyards and other habitats varied among plots. Bunting territories were defined at the end of the fieldwork on the basis of simultaneous contacts and repeated observations as usually done in mapping studies (see e.g. Birrer et al. 2007, or Brambilla et al. 2009 and references therein for other studies on buntings in the same area adopting the same method).

Habitat-selection model

To build a habitat-selection model, we measured some habitat variables (at all territories and at an equal number of unoccupied sites) directly on the ground and representing fine-scaled land-use cover and habitat structure (Table 1). Variables were measured within a grid consisting of 100 m x 100 m square cells (1 ha), which was superimposed to the study area. The size of the grid cells was established to match the approximate size of territories at high density and the size of the 'core area' mostly used by individuals during the breeding season; Ortolan Bunting pairs may sometimes show a weak territorial behaviour (Cramp and Perrins 1994), and they can occur a few tens of meters apart (Cramp and Perrins 1994; our own observation); densities up to 8 pairs per 10 ha and 2 males per 2 ha have been reported from central and northern Italy (Gustin et al. 2009). When a single territory was spread across two neighbouring cells, its associated habitat variables were defined as the average features of the two cells. We found 52 territories and considered all them for analyses, together with an equal number of control cells, randomly chosen with the only constrain that the number of control and territory cells within each sub-area should be the same.

The habitat-selection model was built using multi-adaptive regression splines (MARS), which related bunting occurrence to the habitat variables reported in Table 1. MARS is a flexible machine-learning technique (Friedman 1991; Hastie et al. 2009) often used in ecological studies (e.g. Leathwick et al. 2005; Elith and Leathwick 2007; Mac Nally et al. 2008; Heinanen and von Numers 2009). Its ability to cope with non-linear effects makes it particularly suitable for investigating the habitat selection of a species like the Ortolan Bunting, which inhabits mosaic, complex habitats and thus may be associated with different variables according to different patterns, with specific thresholds or preferred intervals for each relevant habitat type. Prior to MARS analyses, variable correlations were checked; no pair of variables was highly intercorrelated ($|r| < 0.7$ for all pairs). The earth package version 3.2-1 (http://cran.r-project.org/web/packages/earth/index.html; Milborrow 2011a) in R 3.0.1 (R Development Core Team, 2013) was used. The following settings were used for model selection: threshold = 0.001, penalty = 3, degree of interactions = 1 (no interaction allowed among variables). We used a penalty value of 3 instead of the commonly adopted 2 for models without interactions, because the results were identical for the two values (same variables and same species-habitat relationships), apart for a drop in the occurrence probability at intermediate-low level of shrub cover with penalty 2, which was biologically meaningless and likely due to overfitting; therefore, we used a penalty equal to 3, which provided the same results without such a drop. The model was subjected to a five-fold cross validation to estimate the model performance over different subsets of the original data.

Model discriminatory ability was evaluated by means of the area under the curve (AUC) calculated on the the cross-validation, whereas variable importance was estimated by means of the evimp command (Milborrow 2011a). The latter is performed with the earth package and uses three different criteria to estimates variable importance in MARS models (see Milborrow 2011a and

Jedlikowski et al. 2014 for details). The plotmo package version 1.3-1 (http://cran.r-project.org/web/packages/plotmo/index.html) was used to plot the fitted functions (Milborrow 2011b).

RESULTS

The MARS model for habitat selection selected as the most important four habitat variables: lucerne cover, shrub cover, cover of bare soil, total length of hedgerows and tree rows. Ortolan Buntings were associated with intermediate lucerne cover (around 50% of the cell), high shrub cover, bare ground (at least 5% of the cell), length of hedgerows or tree rows (at least 25 m / ha) (Table 2, Fig. 1).

The MARS model explained a fairly good portion of the initial deviance, with an R^2 equal to 0.38. The five-fold cross-validated model had an R^2 equal to 0.22 and an AUC equal to 0.80 ± 0.08 SD. The 'evimp' function for MARS model suggested the following ranking of variable importance (factors listed from the most to the less important): bare ground, lucerne cover, shrub cover, tree rows and hedgerows.

DISCUSSION

The Ortolan Bunting decline had been related to changes occurred to its breeding habitat, thus an understanding of the ecological requirements of the species in the breeding period is crucial for its conservation.

Our results further confirmed the the primary importance of bare ground. Bare ground has been repeatedly reported as fundamental for Ortolan Bunting, being its preferred foraging habitat (Menz and Arlettaz 2012 and references therein). At the small scale we investigated, the model suggested that high occurrence probabilities are associated with a 5-20% cover of bare ground. Moreover, the occurrence probability peaked with an intermediate cover of lucerne and a good cover of shrubs (60-70%), and with at least 25 m/ha of tree rows and hedgerows. Both lucerne availability and hedgerow abundance are known to promote the occurrence of some species of conservation concern in the same area (e.g. Brambilla and Rubolini 2009; Brambilla et al. 2009). Lucerne is likely appreciated by species foraging in bare ground or sparse vegetation, such as Ortolan Bunting (Menz and Arlettaz 2012; Morelli 2012) or Woodlark *Lullula arborea* (Brambilla and Rubolini 2009), because it is often seeded at a relatively low density, and usually lucerne fields in these hilly areas offer an easily accessible ground for this kind of foragers for several weeks during the breeding period (Brambilla and Rubolini 2009). Shrubland may offer plenty of song-posts, shelter to nests and also alternative nesting sites (lower bushes; Cramp & Perrins 1994). Most of the shrubland included in territories is characterized by fairly low species (e.g. *Juniperus communis*, *Genista pilosa*, *Spartium junceum*, *Cytisus sessilifolius*), with some scattered taller bushes (e.g. *Prunus* sp.), which are often used as song-posts. The association with a good cover of shrubs may be further promoted by the rather loose structure that shrublands often have in sloping areas, where soil erosion may increase the availability of very small patches of bare ground, sometimes not fully discernible at sight but occurring among shrubs and potentially exploited by foraging Ortolan Buntings.

The lack of association with grassland was potentially due to the fact that we carried out the territory-level analysis within plots hosting Ortolan Buntings, characterised by an overall suitable landscapes, within which grasslands were well represented, averagely covering 21 and 26% of cells with and without Ortolan Buntings, respectively.

No association (positive or negative) was found with other type of cultivation: although relatively common in the area, cereal fields, vineyards, and the less widespread mixed fodder and orchards, had no tangible effect on the occurrence probability of Ortolan Buntings.

Given the likely overwhelming importance of conserving suitable habitats in the breeding grounds of Ortolan Bunting, the conclusions of our study could be used to inform management recommendations for the species' conservation, at least in this portion of its range.

The first implication is the maintenance of the typical low intensity farming mosaic of Apennines. The heterogeneous landscape of hilly and low-mountain sites in this area is characterized by a mix of relatively small fields separated by hedgerows, vineyards, grassland, shrublands, woodlots and calanques (sandy or rocky mountainsides strongly subjected to erosion), which offer complimentary resources such as song-posts, foraging and nesting habitats, to Ortolan Bunting (cf. Menz and Arlettaz 2012) and other species, including several species of conservation concern (e.g. Bogliani et al. 2003, Brambilla et al. 2012 and references therein). The main threats to this mosaic landscape are represented by abandonment (Brambilla et al. 2010) and secondarily by agricultural intensification, with especially vineyard expansion at the expense of semi-natural grassland and shrubland (Bogliani et al. 2003), but also by interventions targeted at stabilising slopes. In the past decades, the latter interventions have consisted in planting trees (mostly belonging to non-native species) over grassland with scattered shrubs to prevent soil erosion and calanque formation, reducing a highly suitable habitats characterized by the availability of grassland, shrubs and bare soil close to each other in a fine-scaled mosaic particularly suitable for the species.

The maintenance of the mosaic landscape associated with low-intensity farming (with particular emphasis on grassland, strongly declining in the area; Brambilla et al. 2010 and references therein), as well as the promotion of lucerne and the conservation or restoration of hedgerows and tree rows, may be promoted by a correct definition of the measures included in the Rural Development Programme, which in Italy is defined at the regional level. The creation of patches of bare soil and the relative amount of this and other specific habitat features in compact habitat mosaics including grassland, shrubs and bare ground, could be the object of a dedicated agri-environmental scheme targeted at the species (e.g. dedicated planning and interventions within the framework of the sub-measure 16.5 of the Rural Development Programme), that should be implemented within the portions of northern Apennines inhabited by Ortolan Buntings.

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SUPPLEMENTAL DATA

Supplementary online material describing characteristics of study areas and their location can be accessed at .

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Table 1. Habitat variables used to model fine-scaled habitat selection in Ortolan Buntings in northern Italy.

Variable	Description
lucerne	cover of lucerne (alfalfa; *Medicago sativa*)
mixed fodder	cover of fields with mixed fodder crops (e.g. oat grasses with some lucerne and wild grass)
forest	total cover of forest habitats
vineyard	cover of vineyards
orchard	cover of orchards
bare ground	cover of bare ground
hedgerows and tree rows	total length (m) of hedgerows and tree rows within the 1-ha cell
shrub cover	cover of shrubs (e.g. *Juniperus* sp., *Rosa* sp. *Prunus* sp., *Genista* sp., *Spartium* sp., *Cytisus* sp., *Cornus* sp., *Crataegus* sp.)
grassland	cover of grassland
cereal cover	cover of cereal crops
mowing (factorial)	1 for mown grasslands, 0 for unmown ones

Table 2. Summary of the MARS model for fine-scaled habitat selection. For a correct interpretation of variable effect on the occurrence probability of Ortolan Bunting, refer to Fig. 1. RSS: decrease in the residual sum of squares; GCV: generalized cross-validation of the model.

<table>
<tr><th>Coefficient</th><th>Coefficient</th><th>No. of subsets</th><th>RSS</th><th>GCV</th></tr>
<tr><td>Intercept</td><td>6.43</td><td></td><td></td><td></td></tr>
<tr><td>bare ground (below 5%)</td><td>0.60</td><td>5</td><td>100.0</td><td>100.0</td></tr>
<tr><td>lucerne cover (below 50%)</td><td>0.07</td><td rowspan="2">4</td><td rowspan="2">90.4</td><td rowspan="2">88.5</td></tr>
<tr><td>lucerne cover (above 50%)</td><td>-0.07</td></tr>
<tr><td>shrub cover (above 45%)</td><td>0.16</td><td>2</td><td>26.2</td><td>46.6</td></tr>
<tr><td>tree rows and hedgerows (below 25 m)</td><td>0.07</td><td>1</td><td>19.4</td><td>32.8</td></tr>
</table>

Figure 1. Graphical summary of the selected MARS model for habitat-selection in Ortolan Bunting at the territory level. The species-habitat relationships represent the probability of species occurrence (on Y axis) in relation to habitat variables (on X axis; unit: percentage cover for the three cover variables, linear meters for length of hedgerows and tree rows) within the 1-ha cell.