Ornis Fennica 89:264–272. 2012

Correlations between landscape features and crop type and the occurrence of the Ortolan Bunting *Emberiza hortulana* in farmlands of Central Italy

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Received 21 December 2011, accepted 11 April 2012

The occurrence of Ortolan Bunting, a declining species in Europe, was investigated in relation to environmental characteristics of agricultural landscapes in Central Italy. The present work evaluated the significance of landscape features, land-use composition and crop type at the 7-ha scale, in predicting the presence of the Ortolan Bunting. The presence of the species was not strongly linked with measures of habitat heterogeneity, but was related to certain crop types: sunflower, oats and alfalfa, and also to the availability of bare soil. Patches of bare soil may be characteristic for important foraging sites of the focal species. These results may help to predict Ortolan Bunting responses to changes in farming practices, and improve farmland management for the maintenance of the Ortolan Bunting populations in Italy.

1. Introduction

Currently most farmland bird populations are undergoing steep declines in Europe (Donald *et al.* 2001, 2002, Newton 2004), and the intensification of agricultural activities worldwide is one of the main drivers of this decline in diversity and abundance of these species (Chamberlain *et al.* 2000, Donald *et al.* 2006). The decline of farmland birds in Western Europe has particularly affected seed-eating species (Petersen 1994, Tucker & Heath 1994, Saris *et al.* 1995). Several factors have been related to this phenomenon, involving direct effects, such as afforestation, urbanization and habitat loss (O'Connor *et al.* 1986, Lack 1992, Siriwardena *et al.* 2000), and indirect effects, such as climate variation and increased predation (Newton 1993, Suhonen *et al.* 1994, Gregory & Marchant 1995). However, recent studies suggest that changes in agricultural practices are probably the major cause of decline for most granivorous or insectivorous farmland species (Donald & Forrest 1995, Wilson *et al.* 1999, Dale 2000, Siriwardena *et al.* 2000, Atkinson *et al.* 2005, Vepsäläinen *et al.* 2005, Brotons *et al.* 2008).

The present study focused mainly on the occurrence of the Ortolan Bunting *Emberiza hortulana* in different crop types for three reasons. Firstly, crop types are subject to rotation cycles according to the common Agricultural Policy of the European Union (CAP; Donald *et al.* 2002). Secondly, farmland is an important breeding-season foraging habitat for the species (Dale 2000, Dale & Olsen 2002, Menz *et al.* 2009). Thirdly, although similar studies on the relationship between crop types and habitat selection of this species have been conducted in Germany (Lang *et al.* 1990, Deustch 2007, Gues & Pürckhauer 2011) and

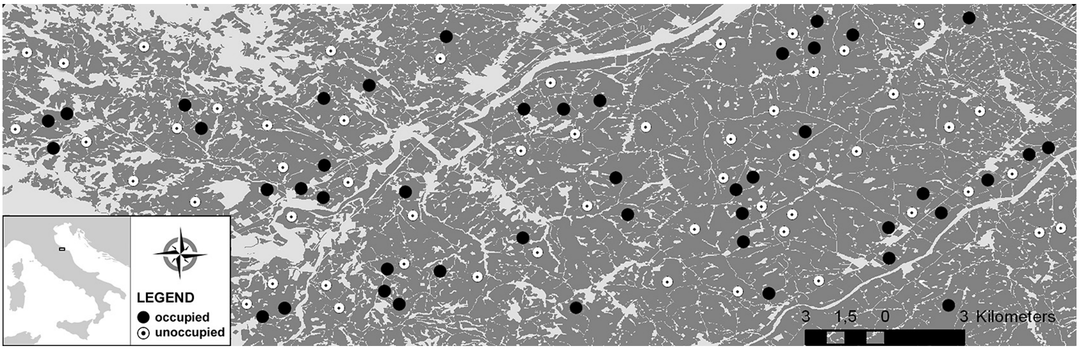

Fig. 1. Study area in Central Italy, sampling plots, and the occurrence of the Ortolan Bunting among these plots (filled circle = presence, open circle = absence).

Switzerland (Revaz *et al.* 2005, Menz *et al.* 2009), the relationship is insufficiently understood at the Mediterranean region.

The Ortolan Bunting is a long-distance migratory passerine, which breeds in Europe and Central Asia and over-winters in Africa, south of the Sahara (Cramp & Perrins 1994). It is primarily considered an open-habitat species (Brotons *et al.* 2008), often associated with farmland (Dale 2000, Berg 2008). In some countries, such as Finland, Ortolan Bunting populations have declined as much as 72% over the last 20 years (Vepsäläinen *et al.* 2005), and the species has apparently declined across most, if not all, of its European distribution. However, increasing populations have occasionally been reported, such as in Catalonia, Spain (Brotons *et al.* 2008). In Italy, the species is considered to be "under threat" because the Italian peninsula presently hosts only 4,000–8,000 breeding pairs, and estimates of a decrease vary from 20% to 49% between 1988–1997 (Calvario *et al.* 1999). Nevertheless, in the past few years the species may have slightly increased in some regions of Central Italy (Fornasari *et al.* 2004, Morelli *et al.* 2007).

The distributional range of the Ortolan Bunting covers several types of habitat. The breeding areas in temperate Northern and Central Europe are closely associated with heterogeneous agro-ecosystems with open and semi-open areas (Cramp & Perrins 1994, Dale & Olsen 2002, Goawski & Dombrowski 2002, Berg 2008, De Groot *et al.* 2010). In the Mediterranean region, however, the species' occurrence is related to open and semi-open shrublands and steppes (Cramp & Perrins 1994, Glutz von Blotzheim & Bauer 1997, Pons 2004), and in Italy it is mainly associated with agricultural landscapes (Laiolo 2005, Guerrieri *et al.* 2006).

Assessing the relative importance of farmland types in agro-landscapes is important, as recent studies suggest the crucial role of arable farmland, crop type and composition of different land-use types in determining the suitability of an area for some bird species (Thomas *et al.* 1991, Wilson *et al.* 1996, Buckingham *et al.* 1999, Moguel & Toledo 1999, Hole *et al.* 2005, Geiger *et al.* 2010). Changes in crop composition, vegetation structure and food resources associated with agricultural intensification are among key drivers of farmland-bird population declines (Wilson *et al.* 1999, 2005, Chamberlain *et al.* 2000).

In the present work, the presence of Ortolan Buntings in relation to crop composition and landscape features was investigated at a farmland area in Central Italy. The species may have recently increased at the study area (Morelli *et al.* 2012). The relative significance of structural landscape characteristics, land-use coverage and crop types in determining the probability of occurrence of the Ortolan Bunting was studied.

2. Material and methods

2.1. Study area and bird data collection

This study was carried out in Central Italy, at the foothills of the Northern Apennines (43°49.3' N, 12°26.8' E; Fig. 1), at an altitude ranging between 0 and 700 m a.s.l. The climate is mainly temperate and characterized by high spring and summer tem-

Table 1. Landscape and land-use characteristics collected in the present study.

Variable	Description
Landscape-scale variables	
Altitude	Mean altitude (m a.s.l.) of a sampling plot
Total land use types	Landscape, number of land-use types at a sampling plot
Habitat diversity	Shannon-Wiener index for plot-level habitat-type heterogeneity
Electricity wires	Number of electric wires present at a sampling plot
Slope	No slope (<3°) = 0, slight slope (3–8°) = 1, steep slope (>8°) = 2
Roads	Road types: unpaved = 0, paved = 1, mixed = 2
Land-use variables	
Cultivated	Percentage cover over a sampling plot
Shrubs	Percentage
Forest	Percentage
Reforested	Percentage
Uncultivated	Percentage
Badland	Percentage
Bare soil	Percentage
Grassland	Percentage
Hedge	Percentage
Urban	Percentage

peratures and a marked summer drought (Tomaselli *et al.* 1972). The area is a mosaic of agricultural landscapes, mostly not subjected to intensive agriculture. The Ortolan Bunting uses the open farmland areas as foraging sites during the breeding season, and trees or shrubs for perching and singing (Cramp & Perrins 1994, Glutz von Blotzheim & Bauer 1997, Berg 2008).

One hundred sampling plots, each 7 ha in size (r = 150 m), were randomly selected in farmland landscapes using regional maps. Each sampling plot is more than twice the average territory size of the Ortolan Bunting (3.14 ha; Cramp & Perrins 1994, Dale & Olsen 2002), and were surveyed by means of 15-min point counts (listening and watching) taken from the centre of each plot (Bibby *et al.* 1997). The point-count locations (plot centers) were at least 1500 m apart. All bird counts were carried out within five hours from the sunrise, in good weather conditions (no or only light wind, no precipitation).

In order to establish accurately the presence or absence of the species, all point-count locations were visited four times during the 2010 breeding season, between mid-April and end-July. For the analysis, a given plot (each with a point-count location) was considered occupied if the species was encountered there at least twice, performing breeding activities, singing or defending a territory.

2.2. Environmental parameters

The environmental structure of each sampling plot was recorded during each survey (Tables 1–3). A detailed environmental analysis performed *in situ* was considered more accurate than a GIS approach (intersect between the 7-ha buffer and a 1:10,000 land-use map) because many spatial variables could not be described accurately with the latter technique, such as hedgerows and shrubs (Brambilla *et al.* 2009) or the crop types present at the sampling sites. The percentage areas of land-use composition estimated *in situ* were later adjusted by overlaying aerial photographs, with a buffer of 150-m radius (ArcGIS 10). Habitat diversity at each plot was calculated using the Shannon-Wiener diversity index, $H' = -\Sigma\, p_i \times \log p_i$, where p_i is the relative proportion of land-use type i (Donald & Forrest 1995). This index can express fragmentation of habitat types by accounting for the number and coverage of detected habitat types at a given scale.

For each sampling plot, landscape structure (coarse habitat types), certain elements of the landscape and crop types detected were recorded (Tables 1.3). The "bare soil" category was obtained by estimating by eye the sum of all soil-surface types devoid of plant material, such as uncultivated soil without herbs and bare-soil space be-

Table 2. Habitat characteristics of farmland plots occupied (n = 46) or unoccupied (n = 54) by the Ortolan Bunting in Central Italy.

Variable	Abbreviation	Occupied, mean ± SD	Unoccupied, mean ± SD
Landscape variables			
Altitude	alt	273.0 ± 124.9	301.7 ± 186.7
No. land-use types	lus	5.3 ± 1.0	5.1 ± 1.0
Habitat diversity (H)	hdi	1.988 ± 0.6	1.542 ± 0.5
Electric wires	ele	2.9 ± 2.0	3.2 ± 2.4
Land-use variables			
Cultivated land	cul	69.1 ± 11.5	65.7 ± 14.4
Shrub land	shr	5.7 ± 2.7	3.5 ± 2.6
Forest	for	3.1 ± 2.8	5.4 ± 4.0
Reforested	ref	0.2 ± 0.9	0.6 ± 2.0
Uncultivated	unc	2.3 ± 1.4	3.2 ± 8.5
Badland	bad	0.1 ± 0.2	2.2 ± 1.7
Bare soil	bar	0.6 ± 0.5	0.2 ± 0.1
Grassland	gra	0.5 ± 0.2	0.6 ± 0.3
Hedges	hed	14.1 ± 6.6	14.8 ± 7.9
Urban	urb	4.3 ± 4.0	3.8 ± 4.0
Crop-type variables			
Oats	oat	1.5 ± 7.8	0.4 ± 2.7
Alfalfa	alf	16.3 ± 24.7	17.4 ± 27.7
Hay	hay	17.2 ± 27.1	15.4 ± 28.4
Other crops	ofo	10.0 ± 15.5	9.0 ± 18.5
Brassicacea	bra	1.0 ± 3.5	0.6 ± 4.1
Sunflower	sun	17.5 ± 28.6	5.8 ± 17.3
Wheat	whe	33.6 ± 26.6	40.0 ± 36.3
Corn	cor	1.7 ± 6.2	2.8 ± 11.1
Olive	oli	0.6 ± 1.9	4.1 ± 10.7
Vineyard	vin	0.6 ± 1.9	4.5 ± 10.8

tween crops. The categories of crop types were Oats, Alfalfa, Hay, Brassicacea, Sunflower, Wheat, Corn, Other crops (i.e., plants not identified or forage remaining on the ground as a consequence of harvest), Olive, and Vineyard. Furthermore, the relative coverage of each crop type was calculated as the proportion for each 7-ha plot.

2.3. Statistical analysis

Landscape characteristics were compared between occupied and unoccupied sampling plots by means of a Generalized Linear Modeling (GLM; McCullagh & Nelder 1989). Logistic regression was used to identify which variables best explained the presence/absence of the species as a binomial response variable, while the landscape, land-use and crop-composition variables were explanatory variables. For percent data, predictor variables were transformed with arcsin radq.

In order to avoid multi-collinearity problems, a correlation matrix among the predictor variables was constructed, and subsequently the most strongly correlated parameters were manually removed. By using this approach, point-count plots were treated as independent units, because they were only moderately spatially autocorrelated (relationship between geographic distance and landscapes dissimilarity: Mantel test $r = 0.16$, $n = 100$, $p > 0.05$; Betts *et al.* 2006). The Mantel test evaluates the similarity between matrices of ecological and geometric distance. Dissimilarities among plots were calculated with the vegdist function of the vegan package in R (R Development Core Team 2011).

A stepwise backward procedure with Akaike's Information Criterion (AIC) was used to select the most significant variables (Akaike 1974, Burnham & Anderson 2002) from all the 22 variables initially included as predictors. Some variables were removed manually, verifying the loss of signifi-

Table 3. Crop-type composition and frequency over all sampling plots (percent and frequency over a pooled 100-plot sample).

Crop type	Cover (%)	Frequency
Wheat	38.1	67.5
Alfalfa	17.2	35.0
Hay	16.1	30.0
Sunflower	9.1	17.5
Other crops	5.9	11.3
Vineyards	3.1	13.8
Olive	2.9	12.5
Corn	2.4	6.3
Oats	1.2	2.5
Brassicacea	1.1	3.8
All other categories	3.0	12.5

cance of the models against the previous model with ANOVA and comparing the AIC values of new models. The best model had the lowest AIC score (Johnson & Omland 2004). Internal validation of the model was performed using bootstrap resampling procedure (n = 999) and using the pseudo-R-squared of models as a goodness-of-fit measure. All tests and elaborations were performed with R (R Development Core Team 2011).

3. Results

3.1. Landscape description

Of the 100 sampling plots, 46 were occupied by the Ortolan Bunting (Fig. 1). Altitudes ranged from 6 to 680 m, and did not significantly differ between occupied and unoccupied plots. The slopes were usually slight. Within the occupied sampling plots, the main road type was paved or mixed (paved and unpaved combined). All the roads had low vehicle traffic. In 88% of occupied plots, electric wires were recorded (the mode was three wires). On six occasions, Ortolan Buntings were recorded using the wires as perches or song posts.

Mostly, the values of landscapes variables (land-use types, habitat diversity, electric wires, slope and road type) did not significantly differ between occupied and unoccupied plots. The different land-use categories were similar in composition between occupied and unoccupied areas and only bare soil was significantly associated with the presence/absence of Ortolan Buntings (Table 2).

3.2. Crop-type effects on Ortolan Bunting occurrence

The sampling plots were characterized by the presence of 4–5 main crop types, with the highest cover by wheat, alfalfa and hay (Table 3; all 100 plots combined). Crop types with the highest cover at plots occupied by the Ortolan Bunting were wheat (33.6%), sunflower (17.5%), hay (17.2%) and alfalfa (16.3%). These numbers correspond with many of the most frequent crop types in the farmlands of Central Italy (Table 3).

The occurrence of the Ortolan Bunting was significantly associated with seven variables, among which bare soil was the most important land-use variable. The other variables were crop types: sunflower, alfalfa and oat, but also hay, wheat and other crops (Tables 4–5). The pseudo-R-squared of the best model was 0.61, suggesting a good predictive power of that model. The AIC progressively decreased up to the best model with 10 predictors (mixed from land-use and crop-type predictors; Table 4).

Table 4. Example candidate models ranked according to AIC, used to select the best models explaining the occurrence of the Ortolan Bunting to landscape, land-use and crop-type variables (see Tables 1–3).

Model variables	Spatial scale	AIC
alt+ele+hdi	Landscape	107.50
oat+alf+hay+ofo+bra+sun+whe+cor+oli+vin	Crop type	95.57
cul+shr+for+ref+bar+bad+gra+hed+urb	Land use	91.51
shr+bar+bad+oat+alf+hay+ofo+bra+sun+whe	Land use/Crop type	63.18
all variables	Mixed	81.93

Table 5. Results of logistic regression for the best model, relating the occurrence of the Ortolan Bunting to landscape, land-use and crop-type variables (see Tables 1–3). Only statistically significant variables, selected according to a stepwise backward procedure using AIC, are shown.

Variable	Spatial scale	Estimate	SE	*Z*	*p*
Intercept	–	–13.442	3.912	–3.431	<0.003
Bare soil	Landscape	36.810	10.073	3.654	<0.001
Sunflower	Crop type	12.853	3.914	3.284	<0.001
Oat	Crop type	–17.324	7.959	–2.177	0.029
Alfalfa	Crop type	12.242	4.038	3.032	<0.002
Hay	Crop type	13.118	4.083	3.213	0.001
Other crops	Crop type	25.767	9.104	2.830	0.005
Wheat	Crop type	7.766	2.426	3.201	0.002

4. Discussion

The Ortolan Bunting has suffered one of the most severe declines among farmland bird species during the last decades (Dale 2001, Fonderflick *et al.* 2005, Vepsläinen *et al.* 2005). As in the present study, studies conducted in Germany and Switzerland have demonstrated that the crop types and bare soil are important during the breeding period, as foraging habitat for both pairs and unpaired males of the focal species (Lang *et al.* 1990, Revaz *et al.* 2005, Menz *et al.* 2009). Other studies, also carried out in areas where the species has declined, have found a strong relationship between the species' presence and habitat heterogeneity. Berg (2008) defined habitat heterogeneity through the presence of shrubby edges, field islets, electric wires and urban structures. These were confronted with the variables used in the present work (habitat diversity, electric wires, slope and road type). Heterogeneity in habitat features increased the occurrence probability of Ortolan Bunting in Central Sweden (Berg 2008).

However, the present results suggest that the occurrence of the species was not clearly linked with structural heterogeneity of the farmland, at least at the 7-ha scale used in this study. Anyway, both the scale of observation and the level of precision used to measure habitat (and micro-habitat) variables could potentially partly explain the differences between the two studies. The Swedish environmental data were analyzed at a spatial scale of 100- and 300-m radii from the center of each plot, but only by intersections of a 1:10,000 land-use map. The data of the present study, however, were obtained with accurate *in situ* descriptions, subsequently adjusted by means of aerial photographs.

The present results suggest that, at the measured scale of observation, only few differences were detected between occupied and unoccupied farmlands at the landscape level or within the land-use analysis. An increase in bare soil was related to an increase in occurrence probability, which may indicate the availability of foraging areas (Vepsäläinen 2005, Berg 2008, Menz *et al.* 2009, Schaub *et al.* 2010). Furthermore, the fact that the presence of the Ortolan Bunting was only weakly related to habitat diversity could suggest that, at out scale of determination, in the farmlands of Central Italy the species may not be closely linked to habitat heterogeneity *per se*. Alternatively but not necessarily mutually exclusive, the species may not be selective in terms of landscape features. Potential explanations are that habitats at the study area may be sub-optimal and/or the availability of food resources may be different to those in Northern Europe.

The present results also suggest a positive relationship between the Ortolan Bunting and six crop types. The species seemed to be associated with sunflower fields, oats and alfalfa, but also hay and wheat. These crop types, mainly sunflower and alfalfa, may be preferred because of certain structural characteristics that may increase space with bare soil. Although measured in the present study, in effect, the relationship between the occurrence of the Ortolan Bunting and crop types and bare soil might be explained, as in some other species, by a variety of reasons including the structure of vegetation or the occurrence of leaf litter, food availability, food detectability or perceived risks from predation (Ydenberg & Dill 1986, Butler & Gillings 2004,Whittingham & Evans 2004, Whittingham *et al.* 2006). In theory, detailed information about the relative proportion of bare ground between crop types, in terms of space between planting rows (Morris *et al.* 2004), might help explain why Ortolan Buntings were associated with particular crop types in the present study. However, because the Ortolan Bunting is also philopatric, with older males showing higher site fidelity (Dale *et al.* 2005), extensive studies conducted over several years might help disentangle the importance of specific rotational crop types compared to static semi-natural habitat characteristics.

Based on a comparison of the crop types used by the Ortolan Bunting in this study, and on its association with bare ground, certain conservation measures can be suggested for agro-ecosystem management. For example, uncultivated patches with bare soil could be retained to increase the area and number of open patches, suitable to foraging activities of the species (Brotons *et al.* 2008). Furthermore, sunflower crops were correlated with the occurrence of the species and could be more frequently preferred at field boundaries of farmlands to separate crop fields, because such vegetation might increase prey availability (Jones & Sieving 2006). Thus, the application of these sorts of strategies can increase habitat heterogeneity and niche availability within farmland areas for several farmland bird species (Benton *et al.* 2003, Whittingham *et al.* 2006) but also increase the suitability of feeding habitat for the Ortolan Bunting.

Acknowledgements. I am grateful to Maria Balsamo, Alessandro Andreotti, Fabio Pruscini, Mario D'Atri and Simone Asprea for various sorts of support during this study. I also thank the anonymous reviewers for their constructive comments in order to improve the manuscript.

Maisemarakenteen, viljelykasvin ja peltosirkun esiintyvyyden suhde Keski-Italian maaseudulla

Peltosirkku (*Emberiza hortulana*) on Euroopassa vähenevä laji, jonka esiintyvyyttä tutkittiin suhteessa eri ympäristömuuttujiin Keski-Italian maaseutumaisemassa. Työssä selvitettiin maiseman piirteiden, maankäytön muotojen ja viljelykasvin vaikutuksia lajin esiintyvyyteen seitsemän hehtaarin mittakaavassa. Esiintyvyys ei ollut selvästi yhteydessä useisiin ympäristön rakenteen monimuotoisuutta kuvaaviin mittareihin, mutta oli positiivisesssa suhteessa viljelykasvilajiin (auringonkukka, kaura ja alfalfa) sekä paljastuneen maan määrään. Paljaan maan laikut saattavat heijastaa lajille tärkeitä ruokailupaikkoja. Tulokset auttavat ennustamaan peltosirkun vastetta maatalouden muutoksiin sekä kehittämään maaseutuympäristön hoitoa peltosirkun säilymisen kannalta suotuisammaksi lajin italialaisissa populaatioissa.

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