Ornis Fennica 86:41–50. 2009

Breeding-season habitat associations of the declining Corn Bunting *Emberiza calandra* – a potential indicator of the overall bunting richness

Mattia Brambilla*, Franca Guidali & Irene Negri

*Brambilla, M., Fondazione Lombardia per l'Ambiente, Settore Biodiversità e Aree protette, Piazza Diaz 7, I-20123 Milano, Italy. E-mail: brambilla.mattia@gmail.com (*Corresponding author)*
Guidali, F., Dipartimento di Biologia, Sezione di Ecologia, Università degli Studi di Milano, via Celoria 26, I-20133 Milano, Italy. E-mail: franca.guidali@unimi.it
Negri, I., Dipartimento di Biologia, Sezione di Ecologia, Università degli Studi di Milano, via Celoria 26, I-20133 Milano, Italy. E-mail: negriranera@libero.it

Received 14 March 2008, accepted 9 February 2009

The aim of the present study was to assess factors affecting Corn Bunting occurrence and abundance, and to evaluate its potential to indicate the diversity and abundance of other buntings. The study was conducted in Lombardy, N Italy, at 40 sites in a low-intensity agricultural landscape. Corn Bunting occurrence depended on the availability of arable land and, secondarily, of rocky areas. Its abundance was affected by the extent of arable land and length of continuous hedgerows. The number of species and territories of other buntings was higher at sites where Corn Buntings were more abundant. Measures aiming at species' conservation should primarily promote the maintenance of arable lands and hedgerows in low-intensity agricultural areas. These landscape features are threatened in the Mediterranean region by both agricultural intensification and land abandonment. Conservation measures for Corn Buntings may also benefit the other bunting species.

1. Introduction

The decline of farmland birds has remained one of the main concerns in bird conservation during the last decades (Tucker & Heath 1994). Many typical farmland species in Europe are declining (BirdLife International 2004a). The most important factors potentially determining the widespread and dramatic decline of farmland species are agricultural intensification and land abandonment (O'Connor & Shrubb 1986, Fuller *et al.* 1995, Bignal & McCracken 1996, Pain & Pienkowski 1997, Preiss *et al.* 1997, Donald *et al.* 2001, Donald *et al.* 2002, Suárez-Seoane *et al.* 2002, Müller *et al.* 2005, Scozzafava & De Sanctis 2006, Brambilla *et al.* 2007a). This negative trend shown by farmland birds has been linked to increased yields driven by the Common Agricultural Policy of the European Union (Pain & Pienkowski 1997, Donald *et al.* 2002, BirdLife International 2004a). Agricultural intensification has led both to detrimental changes in cultivated areas and to widespread abandonment of traditional extensive agricultural landscapes, especially in mountainous regions in Western Europe, which have become economically unattractive. These changes have determined

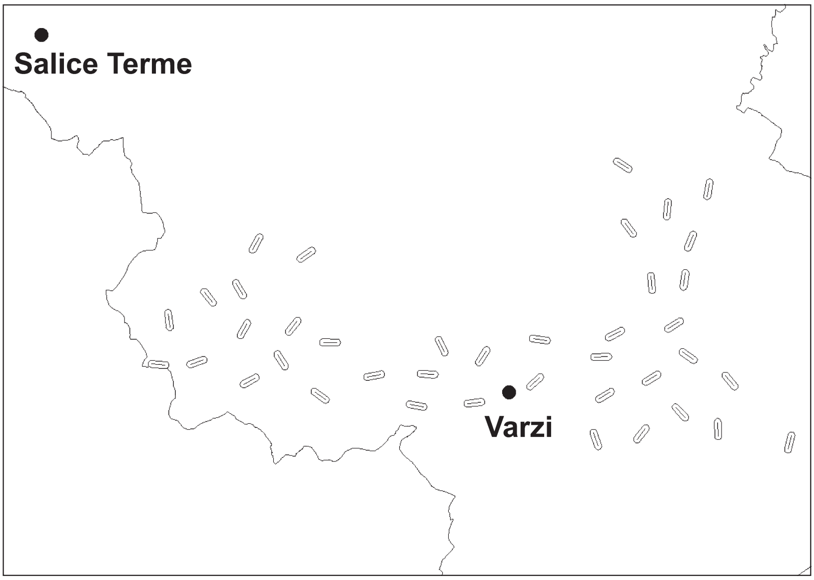

Fig. 1. Map of the study area, with the location of census transects (with a 100-m buffer), major towns and regional boundaries.

deep environmental and social changes (Baudry & Bunce 1991, Tucker & Evans 1997). Among farmland birds, passerines have perhaps been most negatively affected by this process. A few species are recovering after steep declines, but several are still declining (BirdLife International 2004a).

The Corn Bunting *Miliaria calandra* was classified as secure in 1994 (Tucker & Heath 1994), but it is currently considered declining (BirdLife International 2004a). This species was once a widespread breeder in open or cultivated landscapes throughout most of the European countries. Following the intensification and mechanization of traditional agriculture in the past decades, the species progressively declined and disappeared almost completely from large areas (BirdLife International 2004b). The decline started earlier in Western Europe (e.g., in 1930s in the UK) and later in Eastern Europe (e.g., in 1980s in Lithuania) (Cramp 1998). The Corn Bunting is currently classified as a SPEC 2 species by BirdLife International (2004a), being a species concentrated in Europe with an unfavourable conservation status. Additionally, more than 75% of the European population use arable and improved grassland; hence it should be considered a 'Priority A' species, i.e., those with the highest conservation priority, for this habitat (Tucker & Evans 1997). Most of the studies on Corn Bunting ecology have been carried out in Central and Northern Europe especially and in the UK, with few exceptions (e.g., Stoate *et al.* 2000, Golawski & Dombrowski 2002).

In Britain, the population size of Corn Bunting in different regions appeared positively correlated with the proportion of total farmland under tillage and cereals, and with the total areas of tillage and cereals (Donald & Evans 1995). In a sample of individual farms, cereals were preferred over grassland and temporary grassland was preferred over permanent pasture (Donald & Forrest 1995). Hartley *et al.* (1995) reported a preference for foraging in cereal crops by females provisioning nestlings. The decline of the Corn Bunting in Britain has been attributed to reduced over-winter survival, possibly caused by the decreased availability of stubble fields (Donald *et al.* 1994, Donald & Evans 1994, 1995, Siriwardena *et al.* 1999). Moreover, Brickle *et al.* (2000) suggested that agricultural intensification could reduce the breeding success of Corn Buntings and might therefore have contributed to the species decline in Britain.

Despite their importance (cf. BirdLife International 2004b), southern European Corn Bunting populations have been poorly studied. Most studies on Corn Buntings have focused on a larger set of birds (e.g., De Juana & Garcia 2005, Mezquida *et al.* 2005, Scozzafava & De Sanctis 2006), and very few have dealt with its breeding ecology. Little information is thus available about environmental factors determining the settlement and breeding density in Southern Europe. For example, even though Italy holds a large Corn Bunting population, studies on its breeding biology and ecology have remained scarce (Gustin & Sorace 2005, Scozzafava & De Sanctis 2006), and a quantitative report of its habitat requirements is still lacking. Knowledge about factors affecting habitat selection and territory density is essential to provide the basis for effective management strategies for bunting conservation in this important portion of Corn Bunting range. Several areas hosting Corn Bunting populations are currently undergoing dramatic land-use changes: lowland sites are subjected to agricultural intensification, while hilly and mountainous sites are largely affected by land abandonment with woodland recovery and likely negative effects on the species (Scozzafava & De Sanctis 2006).

Other species of the family Emberizidae have an unfavourable conservation status or are considered among priority conservation species under the auspices of the EU "Bird Directive" (79/409/EEC). As conservation efforts focusing on a single species may be rather cost-ineffective within a broader conservation strategy, we studied whether Corn Bunting could be adopted as an indicator of the abundance and diversity of other bunting species, thus acting as a surrogate for overall bunting conservation.

Our research aims were (1) to provide an assessment of the factors affecting Corn Bunting settlement and abundance at the landscape level, focusing on a key population in southern Lombardy, and (2) to test whether the presence of Corn Buntings could be used as an indicator of the abundance and diversity of other bunting species.

2. Material and methods

2.1. Study area

The study area was located in the Northern Apennines (Italy, Lombardy, province of Pavia), roughly at the boundary between the Mediterranean and Euro-Siberian regions. This area holds the largest bunting diversity in Italy (Bogliani *et al.* 2003) and the most important Corn Bunting population in Lombardy (Canova 1990). The area covers 66.2 km^2 and holds one of the few low-intensity agricultural systems remaining in Central and Northern Italy. Moreover, the area is located at the western boundary of another important area of low-intensity agriculture, the Trebbia valley (see Brambilla *et al.* 2007a). The same study area has been used to investigate the breeding ecology of the Cirl Bunting *Emberiza cirlus* (Brambilla *et al.* 2008). Elevation ranges between 250 and 1,200 m a.s.l. Main habitats of the site are fields (generally of a few hectares), consisting of arable land mainly seeded with cereals and Lucerne *Medicago sativa*, and of fodder and fallow lands, vineyards, villages and small towns, rocky outcrops, broad-leaved woodlands, pine plantations, small rivers, calanques (mountain-sides with sandy or rocky soil strongly subjected to erosion), sub-Mediterranean garigues, and extensive areas of recently-abandoned fields and pastures progressively covered by shrubs and small trees. Agricultural and pastoral activities are decreasing in the area, with consequent loss of cultivated and grazed areas, mainly in favour of woodland, and urban areas are mainly located at the bottom of the valleys (Bogliani *et al.* 2003).

2.2. Sampling design

We sampled buntings at 40 plots including all main habitat types and characterised by different land-use and elevation. These plots represented the main landscape types found in the valley (Brambilla *et al.* 2008), were uniformly scattered over the study area (Fig. 1), and covered varying conditions in orientation, altitude and proximity to water courses and human settlement. At each plot, we counted all the bunting species breeding in the area, i.e., Yellowhammer *Emberiza citrinella*, Cirl Bunting, Rock Bunting *Emberiza cia*, Ortolan Bunting *Emberiza hortulana* and Black-headed Bunting *Emberiza melanocephala*, along 400 m-long linear transects within a 100-m buffer from the transect line. Thus, the censused surface for each plot was approximately 11 ha (see Brambilla *et al.* 2008 for further details). Each transect was censused by two observers at slow-walking pace, three times between 28 April and 12 June 2004, between 6:00 and 11:00 AM. Starting times of transects were shifted among visits. The records were spatially-referenced within the 100-m band

Table 1. Variable definitions and mean ± SE for habitat and bird variables in occupied and unoccupied transects. For all the land-cover variables, all tests were performed on square-root-arcsin transformed variable (see also Brambilla *et al.* 2008).

Variable	Definition	Occupied	Unoccupied
Woodland	% cover of woodland	10.06 ± 3.31	38.85 ± 6.89
Perennial crop	% cover of orchards, vineyards and other perennial (arboreal) crops	3.37 ± 1.11	3.33 ± 1.60
Shrubland	% cover of shrubs and scrubland	5.73 ± 1.90	5.14 ± 1.72
Grassland	% cover of mowed or grazed grassland	4.32 ± 2.08	3.87 ± 1.49
Rocks	% cover of rocky surface and bare soil (vegetation cover < 20%)	0.91 ± 0.54	0.09 ± 0.09
Other rocky habitats	% cover of quarries, sand- or gravel-covered areas	0.00 ± 0.00	1.84 ± 1.50
Urbanized	% cover of urban areas	1.28 ± 0.41	3.92 ± 2.38
Arable land	% cover of arable and improved herbaceous cultivations	74.33 ± 3.73	42.95 ± 6.28
Hedgerows (1)	length (m. of continuous hedgerows; continuity refers to the field that the hedge is within or along)	237.25±66.69	102.64±39.16
Hedgerows (2)	length (m of hedgerows; scattered trees or shrubs within/along fields)	162.22±40.17	37.85±21.80
Other buntings (1)	number of territories	2.30 ± 0.37	0.70 ± 0.29
Other buntings (2)	number of species	1.15 ± 0.59	0.35 ± 0.49

to aerial photographs (1:2,000), discriminating between 'reproductive' (singing males, feeding of chicks, newly-fledged young) and 'other' behaviour. We used these count data to define breeding territories based on simultaneous contacts and distribution of observations, as in the territory-mapping method, to obtain the number of territories for each transect. Estimates for territories have previously been used in bird ecology studies for a wide variety of territorial species, including buntings (Brambilla *et al.* 2008) and other avian taxa (e.g., Toepfer & Stubbe 2001, Brambilla & Rubolini 2004, 2009, Brambilla *et al.* 2007a).

2.3. Data analysis

To analyse the effect of different land-uses (resulting in different landscape traits or vegetation types) on bunting occurrence and abundance, we measured a set of habitat variables potentially influencing the species (based on available knowledge) within the 100-m buffer of each transect (Table 1). We measured variables using a high-definition digital land-use map (DUSAF, ERSAF Lombardia; scale 1:10,000). Given the low sample, some of the original habitat variables of the DUSAF database were grouped together. We square-root-arcsine transformed habitat-cover variables to approach a normal distribution.

Prior to statistical analyses, we checked for correlations among variables. All variables showed weak inter-correlations ($r < 0.5$) except woodland and arable-land cover ($r = -0.84$). We removed woodland cover from regression analyses, based on the potentially important effect of arable lands on the focal species (Tucker & Evans 1997, Cramp 1998). We also removed from analyses other rocky habitats, as this habitat-type was only found in three plots (with scarce cover). Thus, we included eight variables in the regression analyses.

We then assessed the combined effect of habitat factors on the likelihood of whether a given transect hosted Corn Buntings by means of a logistic regression. In this analysis, we included also the square term of each land-cover variable in order to test for quadratic relationships. We calculated the area under the Receiver Operating Characteristic (ROC) curve (± its standard error) on 1,000 bootstraps, based on a non-parametric assumption. This area provides a measure of discrimination ability, varying from 0.5 for a model with discrimination ability indifferent from random, to 1.0 for a model with perfect discriminatory ability (Pearce & Ferrier 2000). In the final models, standardised residuals approached a normal distribution, and the data were not over-dispersed.

To assess which variables best explain bunting breeding abundance, we built a general linear model (GLM) with the number of Corn Bunting territories per plot as a discrete (Poisson) response variable. All the recorded habitat measures were thus potential predictor variables (see also Brambilla *et al.* 2006c).

We based the model selection for both regression procedures on the AIC_c value, which relies on an information-theoretic approach, without carrying out explicit statistical tests (Mac Nally 2000). We performed the AIC-based model selection by means of the 'stepAIC' function available in R software, setting the direction of the search on 'both' (which involves fitting all possible permutations of predictor variables; Venables & Ripley 2002). We then manually calculated AIC_c values from the AIC values provided by the program. It should be noted that stepwise procedures (either forward or backward), carried out by including only those predictors whose entry contributed to decrease significantly ($p < 0.05$) its deviance that was based on the likelihood-ratio test, provided identical results with respect to AIC_c selection.

We checked the consistency in model selection, and choice among comparable models according to the AIC_c ranking, using a hierarchical partitioning analysis. This method provides estimates of the independent and joint explanatory power of each predictor by considering all possible models in a multivariate regression setting (Chevan & Sutherland 1991, Mac Nally 1996, 2000). Variables with large independent values are most likely to be causal (Mac Nally 2000) and consequently relevant for management when models are used as practical tools (Brambilla & Rubolini 2005). The results of the model selection could be usefully checked by looking at the guidance generated through hierarchical partitioning (cf. Mac Nally 2000, Heikkinen *et al.* 2004, Brambilla *et al.* 2006a). The independent contribution (expressed as % of the total independent contributions) of each explanatory variable may be used to validate the results of regression analyses (Radford & Bennett 2004). This analysis was performed by means of the "hier.part" package available for R software (Walsh & Mac Nally 2003).

To assess whether Corn Bunting occurrence and abundance can be adopted as estimators of overall bunting richness, a three-step analysis was performed. Firstly, we compared the number of other bunting territories and species between plots hosting and those not hosting Corn Buntings using a *t*-test. Secondly, we correlated the number of Corn Bunting territories with the number of territories of all the other bunting species (within the 100-m buffer; overall, 60 additional territories) and with the number of other bunting species. Thirdly, we compared the mean number of territories of other buntings, and the nymber of other bunting species among plots hosting 0, 1, 2, 3, 4 or 5 Corn Bunting territories, adopting different methods according to the homogeneity of variances (assessed using the Levene statistic). We report the means and parameter estimates together with their standard errors, unless stated otherwise.

3. Results

3.1. Habitat associations of breeding Corn Buntings

We found 36 Corn Bunting territories at a total of 20 transects. We detected another 27 territories outside the 100-m buffer but discarded these from the analyses. The likelihood of Corn Bunting occurrence was positively affected by the proportional cover of arable land (b ± SE = 6.58 ± 2.12) and, secondarily, rocky surface (b ± SE = 35.02 ± 20.24), together with the model intercept (b ± SE = –6.44 ± 2.11). This model showed a minimum difference of AIC_c of 1.04 in comparison with other models. The hierarchical partitioning analysis supported the validity of that model, as the two most important factors according to the independent explanatory power were included (arable land and rocky surface, in this order). The discriminatory ability, according to the AUC of the ROC plot, calculated over 1,000 bootstrapping replicates, was 0.90 ± 0.01.

Corn Bunting abundance was positively affected by both the cover of arable land (b ± SE = 2.09 ± 0.68) and the length of continuous hedge-

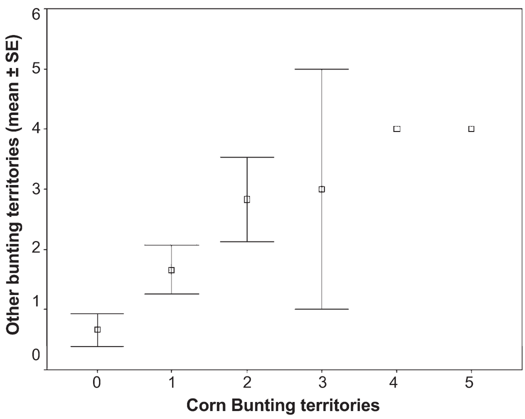

Fig. 2. Abundance of bunting species other than Corn Bunting as overall number of territories in relation to Corn Bunting abundance.

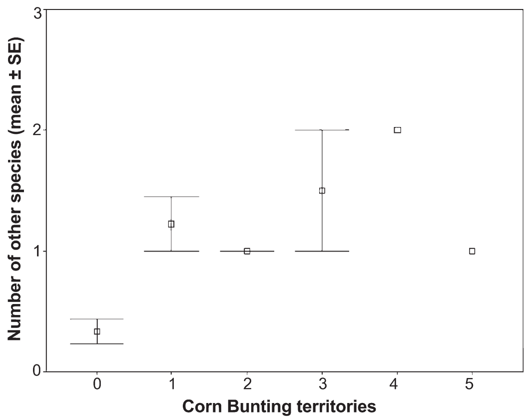

Fig. 3. Number of bunting species other than Corn Bunting, in relation to Corn Bunting abundance.

rows (b ± SE = $1.34*10^{-3} \pm 5.07*10^{-4}$) (model intercept: b ± SE = –2.58 ± 0.76). Hierarchical partitioning supported this model, as the two variables included were the ones with the highest independent power. However, the second 'best' model, according to AIC_c, showed a difference of AIC_c value of only 0.053. This model still included arable land (b ± SE = 2.28 ± 0.72), the length of continuous hedgerows (b ± SE = $1.58*10^{-3} \pm 5.16*10^{-4}$), but also rocks (b ± SE = 4.03 ± 2.38) (model intercept: b ± SE = –2.93 ± 0.83). Despite the importance of rocks for Corn Bunting settlement (see above), arable land and the length of continuous hedgerows together accounted for nearly 86% of the independent explanatory power, as shown by hierarchical partitioning, with all the other variables having independent power ≤ 6% (rocks only 3.36%). We chose the first model because of the low independent power shown by rocks. The ratio between the explained and initial deviance of the final model was 0.79.

3.2. Correlations between Corn Bunting abundance and richness of other bunting species

The number of territories of the other buntings (2.30 ± 0.37 vs. 0.70 ± 0.29, t = –3.40, df = 38, p = 0.002) and the number of the other bunting species (1.15 ± 0.59 vs. 0.35 ± 0.49, t = –4.68, df = 38, p < 0.001) were higher for transects hosting Corn Bunting. The overall bunting abundance was higher in transects hosting more Corn Buntings, and the territories of Corn Bunting significantly correlated with the number of territories of other buntings (r = 0.61, p < 0.001). Similarly, bunting species richness was correlated with the number of Corn Bunting territories (r = 0.56, p < 0.001). The mean number of territories of other species was consistently higher the more the plots hosted Corn Buntings (Fig. 2; Levene statistic = 1.86, p = 0.127; one-way ANOVA, $F_{5,34}$ = 4.28, p = 0.004). The same applied to the number of bunting species, which showed significantly higher values for plots with more Corn Buntings (Fig. 3; variances not homogeneous; Kruskall-Wallis test, χ^2 = 19.05, p = 0.002).

4. Discussion

This study provides a quantitative assessment of the habitat preference of Corn Buntings in Southern Europe. The efforts of researchers and managers in the conservation of living species often focus on identifying and protecting (or increasing) suitable habitat and limiting adverse factors, such as excessive anthropogenic pressure on habitat structure or composition (Loehle & Li 1996, Moss 2001, Ceballos & Ehrlich 2002, Johnson *et al.* 2004). This work provides evidence for landscape traits influencing the occurrence and abundance of Corn Bunting in Italy, which is one of the species' strongholds in Europe (BirdLife International 2004b). Italy holds a large Corn Bunting population within the core of the species' range in a west-east direction, thus being an area of critical importance for the conservation of this declining species. In the studied Lombardy region, Corn Bunting populations have dramatically declined over the last forty years in lowland plains (Canova 1990; see also BirdLife International 2004b), and the species is virtually extinct from most lowland areas. The bulk of the regional populations is currently confined to the Apennine foothills – where the present study took place – that still holds high densities of the species (cf. Cramp 1998). However, in nearby areas of intensive agriculture the species is much rarer and almost extinct in many large areas, such as the Po Plain between the Po river and Milan (see Canova 1990). Conservation of the Apennine population is therefore crucial also for maintaining a source population for the possible re-colonization of more northern areas, where the species has experienced population decline in the past decades. The present study demonstrates the importance of suitable low-intensity agricultural landscapes that are still common in Central-southern Italy. In these areas, and in other parts of Southern Europe, Corn Bunting mainly inhabits arable lands (Tucker & Heath 1997, Gustin & Sorace 2005). The status of the species in Lombardy shows how low-intensity agricultural systems can host viable Corn Bunting populations even when the nearby high-intensity agricultural areas do not.

Corn Bunting inhabits both natural and anthropogenic herbaceous habitats, such as grasslands and cereal fields. The species may particularly inhabit low-crop cultivations in Western and steppe habitats in the Eastern Europe (Cramp 1998). When both these habitats are available, Corn Bunting densities are higher in arable lands than in steppes, at least in Southern Europe (Gustin & Sorace 2005). We showed that the availability of arable lands is the most important factor driving the occurrence and affecting the abundance of Corn Buntings. Indeed, the reported discriminatory and explanatory power of models suggest that the main factors affecting Corn Bunting presence and abundance at the landscape level were included in our models. These results agree with earlier reports (Donald & Evans 1995, Donald & Forrest 1995, Hartley *et al.* 1995, Cramp 1998) and highlights the ecological importance of maintaining low-intensity agricultural practices (Brickle *et al.* 2000). In fact, the decline of the Corn Bunting seems to be mainly due to the intensification and other changes in farming methods (e.g., Cramp 1998, Brickle *et al.* 2000, Brickle & Harper 2002), including reduction of certain types of crop plantation, switch towards autumn-growing cereals, replacement of hay by silage, decline in traditional rotations and mixed farming practices, removal of stubbles, increased use of pesticides, and removal of hedgerows. All these factors may have reduced food supply and suitable habitat for the Corn Bunting (Donald & Evans 1994, Donald *et al.* 1994, Donald & Evans 1995, Cramp 1998, Brickle *et al.* 2000). Our results agree with Scozzafava and De Sanctis (2006) in that the availability of hedgerows positively affects bunting abundance. Thus, the role of hedgerows in agricultural landscapes for bird conservation should be unambiguously stressed (see also Brambilla *et al.* 2007a, 2007b).

The presence of rocky areas may also favour the occurrence of Corn Buntings, but they may not be as important as arable land in determining the species occurrence, as suggested by the very limited amount of bare and broken soils in the study area. Moreover, the quality of winter habitats, not analysed here, could also affect the occurrence and abundance of this species that appears strongly tied to stubbles (Donald *et al.* 1994, Donald & Evans 1994, Mason & MacDonald 2000, Newton 2004).

The availability of arable land is seriously compromised by the long-term land abandonment that is occurring in vast areas throughout the Mediterranean region (Beaufoy *et al.* 1994). This process could dramatically affect the population of Corn Buntings at its South European stronghold. The lack of selection for other herbaceous habitats (mowed or grazed grassland) further shows that the abandonment of arable fields cannot be compensated by the availability of other habitats. The other side of the coin is that farming intensification, with its negative consequences (Brickle *et al.* 2000, Brickle & Harper 2002), and elimination of hedgerows (see Results) occurring in lowland areas further decrease the habitat suitability for Corn Buntings, leading to general population decreases and local extinctions even though arable lands would remain available (e.g., Canova 1990). Therefore, we suggest that the quality of arable habitats is a key-factor in determining habitat suitability for the species.

The wide-spread abandonment of farming in peninsular Italy, in the entire Apennines and the hilly and mountainous areas in particular, is often reported as being beneficial for biodiversity. This process might indeed increase the abundance and enlarge the distribution of at least some woodland species, but secondary woodlands often have impoverished avifauna due to the poor quality of habitats created by overgrowth of shrub and trees on human-altered soils (Tucker & Evans 1997). Moreover, the retreat of farmland habitats appears highly detrimental to a wide range of open-land species. These include species that have their strongholds in the Apennines and are dependent on mosaics of wooded and open areas, such as buntings (Negri *et al.* 2005, Brambilla *et al.* 2008, this study), shrikes (Brambilla *et al.* 2007a), warblers (Brambilla *et al.* 2006b, 2007b) and many raptor species (Tucker & Evans 1997).

5. Conclusions

The occurrence and abundance of Corn Buntings appear to be good indicators of the abundance and diversity of the bunting assemblage. Our analyses on bunting abundance and diversity, according to the occurrence and abundance of Corn Buntings clearly showed that bunting richness peaks at sites hosting abundant Corn Buntings. The most important habitat characteristics affecting Corn Bunting abundance appeared to be the availability of arable land and the length of hedgerows length. These factors may well be positively linked with the occurrence and abundance of the other bunting species too. This finding is consistent with studies on other species that are tied to low-intensity farming, arable lands and hedgerow occurrence (Cramp 1998, Golawski & Dombrowski 2002, Negri *et al.* 2005, Brambilla *et al.* 2008).

Traditional low-intensity farming creates and maintains open and semi-open landscapes, which support high biodiversity and are suitable for a large number of bird species of high conservation interest (Tucker & Evans 1997). These include, for example, Corn Bunting, other Emberizidae and other passerines tied to intermediate levels of ecological disturbance, such as the Red-backed Shrike *Lanius collurio* (Brambilla *et al.* 2007a). The conservation of traditional rural landscapes in the low relieves of the Mediterranean region should be encouraged and promoted by policies favourable for conservation. The complete loss of open habitats due to secondary woodland recovery should be avoided through active habitat management.

Acknowledgments. We are grateful to F. Reginato, F. Zucca, E. Vigo and P. Alberti for their help in different phases of the work. O. Janni, R. Jenkins, M. Koivula, P. Volonterio, two anonymous reviewers and an associated editor provided helpful comments on a first version of the manuscript. This study was partially funded with FIRST funds.

Pesimäympäristön piirteet vähenevällä harmaasirkulla *Emberiza calandra* – lajilla, joka voi indikoida yleistä sirkkujen rikkautta

Tutkimuksessa selvitettiin harmaasirkun esiintymisen ja runsauden määrääviä tekijöitä ja arvioitiin lajin toimivuutta muiden sirkkujen monimuotoisuuden ja runsauden indikaattorina. Tutkimus tehtiin Lombardiassa, Pohjois-Italiassa, 40 alhaisen maatalousintensiteetin alueella. Harmaasirkun esiintyvyys riippui viljelymaan ja toissijaisesti kivikkoalueiden saatavuudesta. Lajin runsauteen taas vaikuttivat viljelymaan laajuus ja yhtenäisten pensasrivien jatkuvuus.

Muiden sirkkujen laji- ja reviirimäärä olivat korkeampia paikoilla, missä harmaasirkku oli runsas. Lajien suojelussa täytyisi huolehtia viljelymaiden ja pensasrivien säilymisestä alhaisen intensiteetin maatalousmaisemissa (nämä maiseman piirteet ovat Välimeren seudulla uhattuja maatalouden tehostumisen ja maiden hylkäämisen vuoksi). Harmaasirkun suojelu saattaa auttaa muidenkin sirkkulajien suojelua.

References

Baudry, J. & Bunce, R.G.H. 1991: Conclusion: round table discussion. Options Méditerranéennes. — Série Séminaires 15: 13–19.

Beaufoy, G., Baldock, D. & Clark, J. 1994: The Nature of Farming. Low Intensity Farming Systems in Nine European Countries. — Institute for European Policy, London.

Bignal, E.M. & McCracken, D.I. 1996: Low-intensity farming systems in the conservation of the countryside. — J. Appl. Ecol. 33: 413–424.

BirdLife International 2004a: Birds in the European Union: a status assessment. — BirdLife International, Wageningen.

BirdLife International 2004b: Corn Bunting *Miliaria calandra*. — Species factsheet.

Bogliani, G., Cova, C. & Polani, F. 2003: La natura tra Nure e Scrivia. Il territorio del Giardino di Pietra Corva. — Provincia di Pavia, Pavia.

Brambilla M., Tellini Florenzano, G., Sorace, A. & Guidali, F. 2006b: Geographical distribution of Subalpine Warbler *Sylvia cantillans* subspecies in mainland Italy. — Ibis 148: 568–571.

Brambilla, M. & Rubolini, D. 2004: Water Rail *Rallus aquaticus* breeding density and habitat preferences in northern Italy. — Ardea 92: 11–18.

Brambilla, M. & Rubolini, D. 2005: Hierarchical partitioning ed ecologia di specie ornitiche. — Avocetta 29: 139.

Brambilla, M., Rubolini, D. & Guidali, F. 2006c: Eagle Owl *Bubo bubo* proximity can lower productivity of cliff-nesting Peregrines *Falco peregrinus*. — Ornis Fennica 83: 20–26.

Brambilla, M., Guidali, F. & Negri, F. 2008. The importance of an agricultural mosaic for Cirl Buntings *Emberiza cirlus* in Italy. — Ibis 150: 628–632.

Brambilla, M., Reginato, F. & Guidali, F. 2007b: Habitat use by Moltoni's Warbler *Sylvia cantillans moltonii* in Italy. — Ornis Fennica 84: 91–96.

Brambilla, M. & Rubolini, D. In press: Intra-seasonal changes in distribution and habitat associations of a multi-brooded bird species: implications for conservation planning. — Animal Conservation 12: 71–77.

Brambilla, M., Rubolini, D. & Guidali, F. 2006a: Factors affecting breeding habitat selection in a cliff-nesting peregrine *Falco peregrinus* population. — J. Ornithol. 147: 428–435.

Brambilla, M., Rubolini, D. & Guidali, F. 2007a: Between land abandonment and agricultural intensification: habitat preferences of Red-backed Shrikes *Lanius collurio* in low-intensity farming conditions. — Bird Study 54: 160–167.

Brickle, N.W. & Harper, D.G.C. 2002: Agricultural intensification and the timing of breeding of Corn Buntings *Miliaria calandra*. — Bird Study 49: 219–228.

Brickle, N.W., Harper, D.G.C., Aebischer, N.J. & Cockayne, S.H. 2000: Effects of agricultural intensification on the breeding success of corn buntings *Miliaria calandra*. — J. Appl. Ecol. 37: 742–755.

Campbell, L.H., Avery, M.I., Donald, P.F., Evans, A.D., Green, R.E. & Wilson, J.D. 1997: A review of the indirect effects of pesticides on birds. Joint Nature Conservation Committee Report 227. — Joint Nature Conservation Committee, Peterborough.

Canova, L. 1990: Strillozzo *Miliaria calandra*. — In Atlante degli uccelli nidificanti in Lombardia (ed. Brichetti, P. & Fasola, M.): 231. Ramperto, Brescia.

Ceballos, G. & Ehrlich, P.R. 2002: Mammal population losses and the extinction crisis. — Science 296: 904–907.

Chevan, A. & Sutherland, M. 1991: Hierarchical partitioning. — The American Statistician 45: 90–96.

Cramp, S. 1998: The Birds of the Western Palearctic. — Oxford University Press, Oxford.

De Juana, E. & Garcia, A.M. 2005: Fluctuations related to rainfall in richness and abundance in birds of steppic Mediterranean habitats. — Ardeola 52: 53–66.

Donald, P.F. & Evans, A.D. 1994: Habitat selection by corn buntings *Miliaria calandra* in winter. — Bird Study 41: 199–210.

Donald, P.F. & Evans, A.D. 1995: Habitat selection and population size of corn buntings *Miliaria calandra* breeding in Britain in 1993. — Bird Study 42: 190–204.

Donald, P.F., Green, R.E. & Heath, M.F. 2001: Agricultural intensification and the collapse of Europe's farmland bird populations. — Proc. R. Soc. Lond. B 268: 25–29.

Donald, P.F., Pisano, G., Rayment, M.D. & Pain, D.J. 2002: The Common Agricultural Policy, EU enlargement and the conservation of Europe's farmland birds. — Agr. Ecosyst. Environ. 89: 167–182.

Donald, P.F., Wilson, J.D. & Shepherd, M. 1994: The decline of the corn bunting. — British Birds 87: 106–132.

Flack, V.F. & Chang, P.C. 1987: Frequency of selecting noise variables in subset regression analysis: a simulation study. — American Statistician 41: 84–86.

Fuller, R.J., Gregory, R.D., Gibbons, D.W., Marchant, J.H., Wilson, J.D. & Carter, N. 1995: Population declines and range contractions among lowland farmland birds in Britain. — Conserv. Biol. 9: 1425–1441.

Golawski, A. & Dombrowski, A. 2002: Habitat use of Yellowhammers *Emberiza citrinella*, Ortolan Buntings *E. hortulana*, and Corn Bunting *Miliaria calandra* in farmland of east-central Poland. — Ornis Fennica 79: 164–172.

Gustin, M. & Sorace, A. 2005: La comunità di Alaudidi ed Emberizidi negli ambienti di steppa e seminativi della ZPS Gravina di Laterza (TA). — Avocetta 29: 80.

Heikkinen, R.K., Luoto, M., Virkkala, R. & Rainio, K. 2004: Effects of habitat cover, landscape structure and spatial variables on the abundance of birds in an agricultural–forest mosaic. — J. Appl. Ecol. 41: 824–835.

Johnson, C.J., Seip, D.R. & Boyce, M.S. 2004: A quantitative approach to conservation planning: using resource selection functions to map the distribution of mountain caribou at multiple spatial scales. — J. Appl. Ecol. 41: 238–251.

Loehle, C. & Li, B.-L. 1996: Habitat destruction and the extinction debate revisited. — Ecol. Appl. 6: 784–789.

Mac Nally, R. 1996: Hierarchical partitioning as an inter-

pretative tool in multivariate inference. — Australian Journal of Ecology 21: 224–228.
Mac Nally, R. 2000: Regression and model-building in conservation biology, biogeography and ecology: the distinction between and reconciliation of 'predictive' and 'explanatory' models. — Biodiversity and Conservation 9: 655–671.
Mason & MacDonald 2000: Corn Bunting *Miliaria calandra* populations, landscape and land-use in an arable district of eastern England. — Bird Conservation International10 (2): 169–186.
Mezquida, E.T., Villaran, A. & Pascual-Parra, J. 2005: Microhabitat use and social structure in Linnet *Carduelis cannabina* and Corn Bunting *Miliaria calandra* at a winter roost in central Spain. — Bird Study : 323–329.
Moss, R. 2001: Second extinction of capercaillie (*Tetrao urogallus*) in Scotland? — Biol. Conserv. 101: 255–257.
Müller, M., Spaar, R., Schifferli, L. & Jenni, L. 2005: Effects of changes in farming of subalpine meadows on a grassland bird, the whinchat (*Saxicola rubetra*). — J. Ornithol. 146: 14–23.
Negri, I., Brambilla, M & Guidali, F. 2005: Abbondanza degli zigoli (Emberizidae) in relazione all'uso del suolo nell'Appennino settentrionale. — Avocetta 29: 95.
Newton, I. 2004: The recent declines of farmland bird populations in Britain: an appraisal of causal factors and conservation actions. — Ibis 146: 579–600.
O'Connor, R.J. & Shrubb, M. 1986: Farming and Birds. — Cambridge University Press, Cambridge.
Pain, D.J. & Pienkowski, M.W. 1997: Farming and Birds in Europe. The Common Agricultural Policy and its Implications for Bird Conservation. — Academic Press, London.
Pearce, J. & Ferrier, S. 2000: Evaluating the predictive performance of habitat models developed using logistic regression. — Ecological Modelling 133: 225–245.
Preiss, E., Martín, J.L. & Debussche, M. 1997: Rural depopulation and recent landscape changes in a Mediterranean region: consequences to the breeding avifauna. — Landscape Ecology 12: 51–61.
Radford, J.Q. & Bennett, A.F. 2004: Thresholds in landscape parameters: occurrence of the white-browed treecreeper *Climacteris affinis* in Victoria, Australia. — Biol. Conserv. 117: 375–391.
Rencher, A.C. & Pun, F.C. 1980: Inflation of R^2 in best subset regression. — Technometrics 22: 49–53.
Scozzafava, S. & De Sanctis, A. 2006: Exploring the effects of land abandonment on habitat structures and on habitat suitability for three passerine species in a highland of Central Italy. — Landscape and Urban Planning 75: 23–33.
Siriwardena, G.M., Baillie, S.R., Crick, H.Q.P. & Wilson, J.D. 1999: The importance of variation in the breeding performance of seed-eating birds in determining their population trends on farmland. — Journal of Applied Ecology 37: 1–22.
Stoate, C., Borralho, R. & Araujo, M. 2000: Factors affecting corn bunting *Miliaria calandra* abundance in a Portuguese agricultural landscape.— Agriculture Ecosystems & Environment 77: 219–226.
Suárez-Seoane, S., Osborne, P.E. & Baudry, J. 2002: Responses of birds of different biogeographic origins and habitat requirements to agricultural land abandonment in northern Spain. — Biol. Conserv. 105: 333–344.
Toepfer, S. & Stubbe, M. 2001: Territory density of the Skylark (*Alauda arvensis*) in relation to field vegetation in central Germany. — J. Ornithol. 142: 184–194.
Tucker, G.M. & Evans, M.I. 1997: Habitats for Birds in Europe: a conservation strategy for the wider environment. — Birdlife International, Cambridge.
Tucker, G.M. & Heath, M.F. 1994: Birds in Europe: their conservation status. — BirdLife International, Cambridge.
Venables, W.N. & Ripley, B.D. 2002: Modern Applied Statistics with S, 4th edition. — Springer, Berlin.
Walsh, C. & Mac Nally, R. 2003: Hierarchical partitioning. — R Project for Statistical Computing. http://cran.r-project.org/.