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Explicit nation-wide habitat models for Italian larks (Alaudidae)

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Abstract – The aim of this paper is to assess the effect of broad-scale environmental and geographical variables on the distribution of Italian breeding larks (Alaudidae). Using the data of MITO2000 (2000-2003), logistic regression models were built, relating species-presence with the area occupied by Corine land-use categories, habitat diversity, morphological and elevation-range variables, latitude and longitude. In all models, except for that of Calandra Lark, geographical variables were included and, in particular, latitude seems the most important. The steppic nature of Alaudidae is underlined by their negative response to environmental diversity (for Calandra and Crested Lark) and to woodland (for Crested Lark and Skylark); the Woodlark, on the contrary, shows a preference for heterogeneous landscapes. Large scale assessment of species ecology, besides assessing habitat suitability at large-scale level, give some basic insight about the ecology of the species.

INTRODUCTION

Larks are typical species of grassland and steppe (Tieleman 2005). However, in Europe, in particular in the Mediterranean basin, they have widely adapted to agricutural and pastoral environments (e.g., Blondel 1988). Due to a complex series of factors, today these environments are quickly disappearing or changing (Falcucci *et al*. 2007). This leads larks to have an unfavourable conservation status in Italy (Calvario *et al*. 1999) and in general in Europe (Burfield and Van Bommel 2004).

Mathematical models are useful tools to describe species ecology and they are widely used in ornithology (Osborne *et al*. 2001, Ambrosini *et al*. 2002, Seoane *et al*. 2003, Brotons *et al*. 2004a, Rushton *et al*. 2004). Although some doubts on their effectiveness still remain (Gutzwiller and Barrow 2003, Chamberlain *et al*. 2004), these techniques, if correctly applied, have proved to be valuable tools for the knowledge of the actual distribution of species and to obtain objective information on the main ecological factors affecting their presence (Guisan and Zimmerman 2000, Scott *et al*. 2002, Bustamante and Seoane 2004).

The availability of ornithological data originating from national monitoring schemes, that may be related to high-scale variables, enables to build habitat suitability models with great geographical value, by means of GIS application (Scott *et al*. 2002, Brotons *et al*. 2004a, Suarez-Seoane *et al*. 2004). Due to their objectivity, these models can be used as reliable tools supporting the decisions for biodiversity conservation (Naesset 1997, Woodhouse *et al*. 2000, Osborne 2005).

Apart from information describing their habitat (e.g. Tellini 1987, Pesente 1991, Bani and De Carli 1999, Maritan *et al*. 2002, Pedrini *et al*. 2005), the ecological requirements of Italian larks are reported only for few species at local scale (e.g. Sposimo and Tellini 1988, Lapini 1991, Tellini Florenzano 1996, Guerrieri *et al*. 2001, Gustin 2004). The only attempt of ecological analysis at national scale concerns the definition of deterministic models for Italian vertebrates (Boitani *et al*. 2002), that are based on subjective evaluation by specialists.

Since a national synthesis based on field observation data is missing, and due to the availability of a large amount of information on breeding lark localizations in Italian territory arising from the database of MITO2000 project (Fornasari *et al*. 2004), we have calculated stochastic models at national scale for the occurrence of each breeding lark species. In particular, we aimed to assess the effect both of large-scale environmental (land use and topography) and geographical variables. The effects of the latter group of variables can be likely ascribed to changes in climatic conditions and seem to play a decisive role in explaining the distribution of the investigated species, greatly improving the validity of the models (Hawkins and Diniz-Filho 2004). These variables, largely used in the past to describe the ecogeography of birds (e.g. Voous 1960), were subsequently scarcely taken into account since their effect was considered difficult to prove (see Fasola 1985). In recent years, due to the aid of more reliable and robust statistical techniques, variables such as latitude are newly considered of capital importance to define the ecology of bird species, at least at large scale (e.g. Forsman and Mönkkönen 2003).

STUDY AREA AND METHODS

The data on bird occurrence were obtained from MITO2000 database, the Italian Bird Monitoring Scheme, that consists of randomly selected 10-min point counts (Fornasari *et al*. 2002). We took into account data collected in 2000-2003 years for the lark species breeding in Italy, i.e. *Melanocorypha calandra*, *Calandrella brachydactyla*, *Galerida cristata*, *Lullula arborea*, *Alauda arvensis.* We overlapped a 2.5 x 2.5 km grid on the whole Italian territory, excluding small islands. The grid mesh was empirically selected considering the structure of the available database and the ecology of the investigated species. For each grid cell, we defined the presence or absence of each investigated species and we calculated the values of several environmental and geographical variables. Models have been built using logistic regression (software Statistica 7.0) because, at the time when the analyses were processed (autumn 2006), presence-only methods were not yet available.

Each species was considered present in every grid cell in which it was recorded at least one time; to what concern the absence, due to the well known problems in coping with false-absence cases (Kerr *et al.* 2000), and considering the characteristics of our sampling design, in order to limit this problem we have excluded all grid cells with only one point count, considering each species absent in every grid cell in which at least two point counts were carried out without finding it.

The environmental and geographical variables used to build the models are reported in Table 1. Besides the classic geographical variables (e.g. longitude), we individuated some areas characterised by biogeographical specificity (i.e. river Po flood plain, Sicilia, Sardegna, see Minelli *et al*. 2002) that were analysed as factorial variables (Waite 2000). In each 2.5 x 2.5 km grid cell, we calculated the median altitude using the data obtained from a DTM (Digital Terrain Model; cell size 300 m^2). Standard deviation of altitude values was used to describe the ground morphology (as altitude is more changeable as the morphology is more uneven). For the environmental variables we used the Corine Land Cover map (third level; Büttner *et al*. 1998) extracting the surface of different land use category in each 2.5 x 2.5 km mesh. As a measure of environmental diversity, we calculated Shannon index on land-use Corine categories.

By interpolating the point-abundance data (IDW method; see Fortin and Dale 2005), we defined the range of each species assuming as its boundaries the isoline that excludes less than 1% of species presence. Subsequent analyses were conducted only on the meshes included in this range. The IDW method (Inverse Distance Weighting) calculates a value for each grid cell from data points within a specified search radius, weighting closer point more than those farther away.

We analysed the presence/absence data looking for first-, second- and third- order effects, for every variable and their possible interactions (Draper and Smith 1998). To obtain the most informative models of descriptive nature (McNally 2000), they were built selecting the best combination of variables according to the AIC (Akaike Information Criterion, McQuarrie and Tsai 1998) values. Models with lower AIC stress a greater degree of parsimony (greater variance explained per parameter). The model effectiveness was measured considering the AUC value (*Area Under the ROC Curve*, Hosmer and Lemeshow 2000); in all cases, we included in the models only the variables, or their interactions, whose marginal contribution was significant ($p<0.05$). For *G. cristata*, *L. arborea*, and *A. arvensis*, due to the large amount of available data, we validated the effects of each variables using randomly selected data subset (corresponding to 20%; Massolo and Meriggi 1995). For each investigated species, the selected model gave the probability of presence in each 2.5 x 2.5 km grid cell of the species range. Thus, it was possible to spatially explicit the model in its entire Italian range.

RESULTS

The variables included in the selected models for each species are reported in Table 1 and the statistics of the models are summarized in Tables 2-6; the probability of species presence in their range are mapped in Figures 1-5.

In all models, except for that of *M. calandra*, geographical variables were included. Among them, Wald statistics indicates the great importance of latitude. With the exception of *C. brachydactyla* and, partially, of *L. arborea* models, this variable, alone or in interaction with other factors, showed the highest weights. This result is clearly related to the high abundance of *A. arvensis* in northern regions and of *G. cristata* in southern regions (Meschini and Frugis 1993). The *C. brachydactyla* model does not include the latitude, even if the preference for the southern regions is clear as well, stressed by the negative relationship with PAD variable and, less significantly, with the TOS_LAZ one.

Standard deviation of altitude was included in all models excluding the *C. brachydactyla* one; altitude was included in all models (excluding *M. calandra*). *G. cristata* clearly preferred plain areas, described by the negative relationship with the standard deviation of altitude. For *C. brachydactyla* and *G. cristata*, a marked preference for the lowest altitudes was highlighted. Conversely, for *A. arvensis*, a positive relationship with the altitude was observed. Nevertheless, in the same model a negative relationship with the interaction latitude x altitude was included. This indicates that the *A. arvensis* preference for high altitudes decreases with increased latitude. In other words, moving northwards *A. arvensis* is more often recorded at low altitude.

More complex relationships with altitude are included in *L. arborea* model. This species shows peaks, both for altitude and its s.d., highlighted by second order polynomial relationships, showing therefore preferences for medium-height terrains, characterized by slightly uneven morphology.

As far as the land use variables are concerned, positive relationships were observed with 'grassland and pasture' categories for all species (for *A. arvensis* an interaction between this variable and both altitude and latitude was also recorded) and with "arable land" for all species except *L. arborea*.

This characteristic is confirmed for *G. cristata* and *A. arvensis* by the negative response to environmental diversity, although this variable is never among those with higher weight. The peculiarity of *L. arborea* as compared to the other four species also resulted by the positive relationships between the frequency of this species and both the environmental diversity and woodland surface. According to the literature on habitat choices of *L. arborea* (Sposi-

Table 1. List of variables that were considered to build the habitat models. For each variable, the abbreviation used in the Tables 2-6 is reported. With 'X' are indicated variables entered in the corresponding species models.

variables		*Melanocorypha calandra*	*Calandrella brachydactyla*	*Galerida cristata*	*Lullula arborea*	*Alauda arvensis*
LAT	Latitude			X	X	X
LON	Longitude					
PAD	river Po flood plain		X	X		
SAR	Sardegna					
SIC	Sicilia		X			
TOS_LAZ	Toscana and Lazio		X			
PUG	Puglia		X			
ALT_MDN	Altitude		X	X	X	X
ALT_DS	S.D. of altitude	X		X	X	X
URBAN	urban areas			X	X	X
CROP	herbaceous crops	X	X	X		X
PERM_CROP	permanent crops					
PASTURE	grassland and pastures	X	X	X	X	X
HETER_CROP	heterogeneus crops					
WOODLAND	Woodland				X	X
SHRUB	Shrubland					
BEACH	Seashore					
ROCK	rocks and cliffs					
WETLAND	Wetlands					
WATER	Freewater					
D_SHANNON	Corine Land-use Shannon index			X	X	X

Table 2. List of the variables entered in the *Melanocorypha calandra* model; for each of them the Wald statistic and the p value is reported. N indicates the number of positive cases.

Calandra Lark (*Melanocorypha calandra*)		N = 83
Variables	*wald*	*p*
CROP (+)	25.16	0.000
PASTURE (+)	11.47	0.001
ALT_DS (-)	5.89	0.015
Area Under the ROC Curve	**0.828**	

Table 3. List of the variables entered in the *Calandrella brachydactyla* model; for each of them the Wald statistic and the p value is reported. N indicates the number of positive cases. * means that there is an interaction between two different variables (es. CROP*SIC, interaction between herbaceous crops and Sicily).

Short-toed Lark (*Calandrella brachydactyla*)		N = 159
Variables	*wald*	*p*
PAD (-)	36.97	0.000
ALT_MDN (-)	26.10	0.000
CROP (+)	18.99	0.000
CROP*SIC (+)	11.02	0.001
TOS_LAZ (-)	8.23	0.004
ALT_MDN*PUG (+)	7.80	0.005
PASTURE (+)	7.17	0.007
Area Under the ROC Curve	**0.892**	

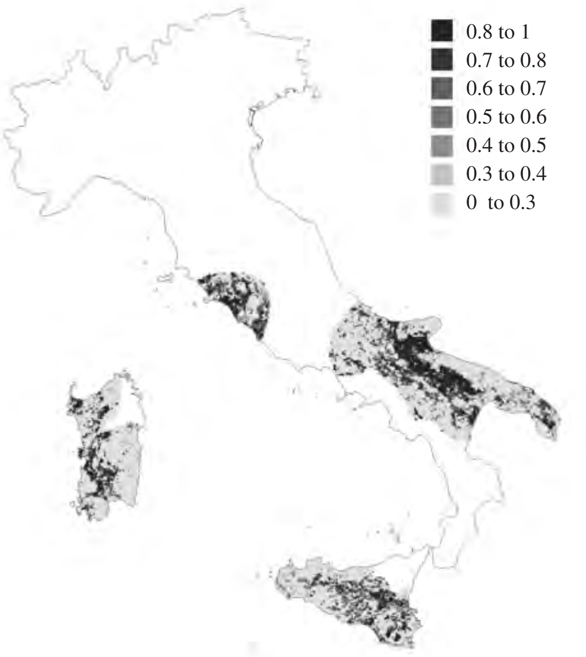

Figure 1. Map showing the result of projecting the *Melanocorypha calandra* habitat model (see Tab. 2) on the whole Italian territory. Values refer to presence probability.

mo and Tellini 1988, Schaefer and Vogel 2000), this species requires the presence of a portion of wood in its own breeding territory (our relationship includes the second order polynomial showing, also in this case, the presence of a threshold value).

Among the land use variables, urban areas play an important role affecting negatively the presence of several lark species. This variable was the most important one in *L. arborea* model, and it showed a high weight also in the models of *G. cristata* and *A. arvensis*. For the last species urban areas were included in the model as an interaction with latitude i.e., his negative effect increases at higher latitudes. This may be explained by the consideration that in north Italy, environments potentially suitable for *A. arvensis* (mainly the river Po flood plain) are often occupied by urban areas. From a conservationistic perspective, the negative importance of urban areas, whose growth in Italy is still a distinctive element of landscape dynamics (Rombai 2002, Falcucci *et al*. 2007), has to be stressed. The validation of the *G. cristata*, *L. arborea*, and *A. arvensis* models have confirmed, in all cases, the significance of the originally selected variables.

DISCUSSION AND CONCLUSION

The models, except that one of *M. calandra*, resulted quite complex and the inclusion of some variables does not enable an easy ecological interpretation. This is due to the fact that variables with lowest Wald statistics (i.e., with minor weight in the model) act like a corrective of more important ones and the two kinds of variables should not be interpreted separately. For example, *A. arvensis* model included also a negative relationship with pastures. This seeming incongruence depends on the fact that in the same model is included, with higher weight, a positive relationship with the latitude x pasture interaction. It is supposable that the negative relationship is a corrective due to the fact that at the highest latitude the species is scarce or absent on pastures (e.g., in the majority of alpine grassland, Bocca and Maffei 1997, Pedrini *et al*. 2005). The contribution of variables with minor weight to the efficiency of the models appears important, and permits, for some species (*C. brachydactyla*, *G. cristata* and *A. arvensis*) to reach high AUC values (> 0.850). Taking into account the reduced sample and the low number of included variables, also the

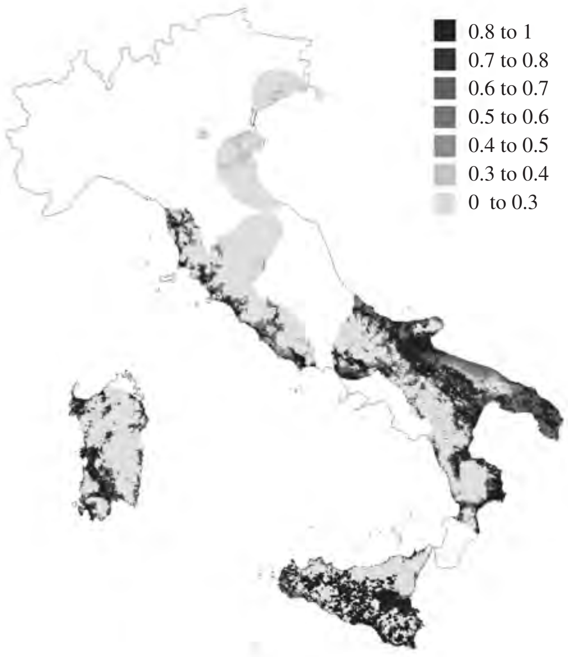

Figure 2. Map showing the result of projecting the *Calandrella brachydactyla* habitat model (see Tab. 3) on the whole Italian territory. Values refer to presence probability.

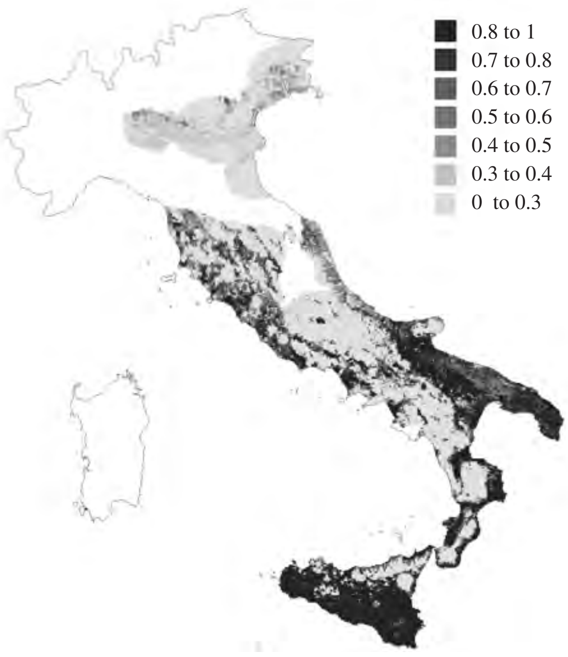

Figure 3. Map showing the result of projecting the *Galerida cristata* habitat model (see Tab. 4) on the whole Italian territory. Values refer to presence probability.

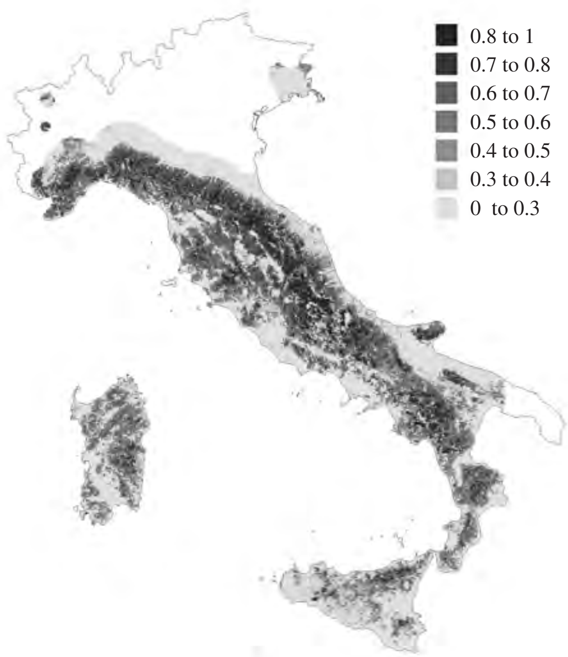

Figure 4. Map showing the result of projecting the *Lullula arborea* habitat model (see Tab. 5) on the whole Italian territory. Values refer to presence probability.

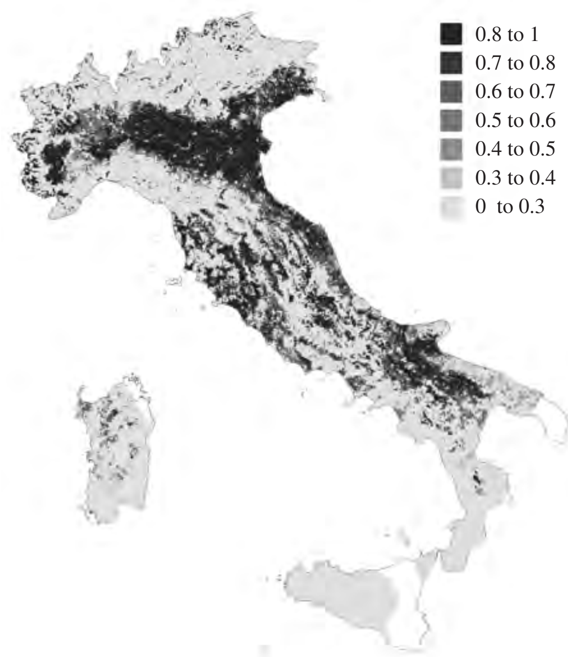

Figure 5. Map showing the result of projecting the *Alauda arvensis* habitat model (see Tab. 6) on the whole Italian territory. Values refer to presence probability.

Table 4. List of the variables entered in the *Galerida cristata* model; for each of them the Wald statistic and the p value is reported. N indicates the number of positive cases. * means that there is an interaction between two different variables (es. ALT_MDN*CROP, interaction between the median value of altitude and herbaceous crop).

Crested Lark (*Galerida cristata*)		**N = 1414**
Variables	*wald*	*p*
LAT^2 (-)	146.20	0.000
LAT^3 (+)	97.08	0.000
ALT_DS (-)	80.19	0.000
ALT_MDN^2 (-)	67.92	0.000
PAD (-)	45.81	0.000
PASTURE (+)	31.93	0.000
URBAN (-)	22.75	0.000
D_SHANNON (-)	13.70	0.000
CROP (+)	9.76	0.002
ALT_MDN*CROP (+)	4.87	0.027
LAT*CROP (-)	4.49	0.034
Area Under the ROC Curve	**0.868**	

Table 5. List of the variables entered in the *Lullula arborea* model; for each of them the Wald statistic and the p value is reported. N indicates the number of positive cases.

Woodlark (*Lullula arborea*)		**N = 711**
Variables	*wald*	*p*
URBAN (-)	23.13	0.000
ALT_DS^2 (-)	18.09	0.000
ALT_MDN (+)	17.29	0.000
ALT_DS (+)	15.87	0.000
ALT_DS^3 (+)	12.07	0.001
ALT_MDN ^2 (-)	10.10	0.001
PASTURE (+)	9.61	0.002
LAT^2 (+)	6.57	0.010
WOODLAND (+)	5.01	0.025
LAT^3 (-)	4.49	0.034
WOODLAND^2 (-)	3.78	0.050
D_SHANNON (+)	3.10	0.048
Area Under the ROC Curve	**0.756**	

value obtained for *M. calandra* model (0.828) is a good result (Hosmer and Lemeshow 2000). In spite of the AUC value for *L. arborea* model (0.756) is considered satisfactory (Hosmer and Lemeshow 2000), this model is less informative than those for the other Italian larks.

The models allow to highlight some interesting aspects of the broad scale species ecology, confirming, except for *L. arborea*, their 'steppic' nature. Among variables, the geographical ones have the most important effects, except for *M. calandra* where, due to the small distributional range, concentrated mainly in the south regions, the model does not highlight geographical gradients. In *L. arborea* model, although latitude shows a weight lower than other variables, it enables to emphasize the highest frequencies of the species in Central Italy regions, that represent the national core area (Fornasari *et al*. 2002). The good model effectiveness seems to stress that the use of IDW method could be a useful preliminary tool to investigate and define species distribution range.

Our results point out that, at least for the examined species, the elaboration of habitat suitability models at large scale has absolutely to consider these variables (Hawkins and Diniz-Filho 2004; Suarez-Seoane *et al*. 2004).

Table 6. List of the variables entered in the *Alauda arvensis* model; for each of them the Wald statistic and the p value is reported. N indicates the number of positive cases. * means that there i san interaction between two different variables (es. ALT_MDN*WOODLAND, interaction between the median value of altitude and woodland).

Skylark (*Alauda arvensis*)		**N = 2064**
Variables	*wald*	*p*
LAT (+)	155.21	0.000
LAT^2 (-)	100.36	0.000
LAT*ALT_MDN (-)	72.23	0.000
ALT_MDN (+)	66.49	0.000
CROP (+)	57.08	0.000
LAT*URBAN (-)	43.85	0.000
WOODLAND (-)	25.86	0.000
ALT_DS (-)	20.14	0.000
CROP^2 (-)	15.51	0.000
URBAN^2 (-)	13.64	0.000
LAT *PASTURE (+)	10.73	0.001
ALT_MDN*WOODLAND (+)	8.50	0.004
ALT_DS^2 (+)	8.44	0.004
ALT_MDN*PASTURE (+)	6.93	0.008
D_SHANNON (-)	6.90	0.009
D_SHANNON^2 (+)	5.13	0.023
PASTURE (-)	4.08	0.043
Area Under the ROC Curve	**0.850**	

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