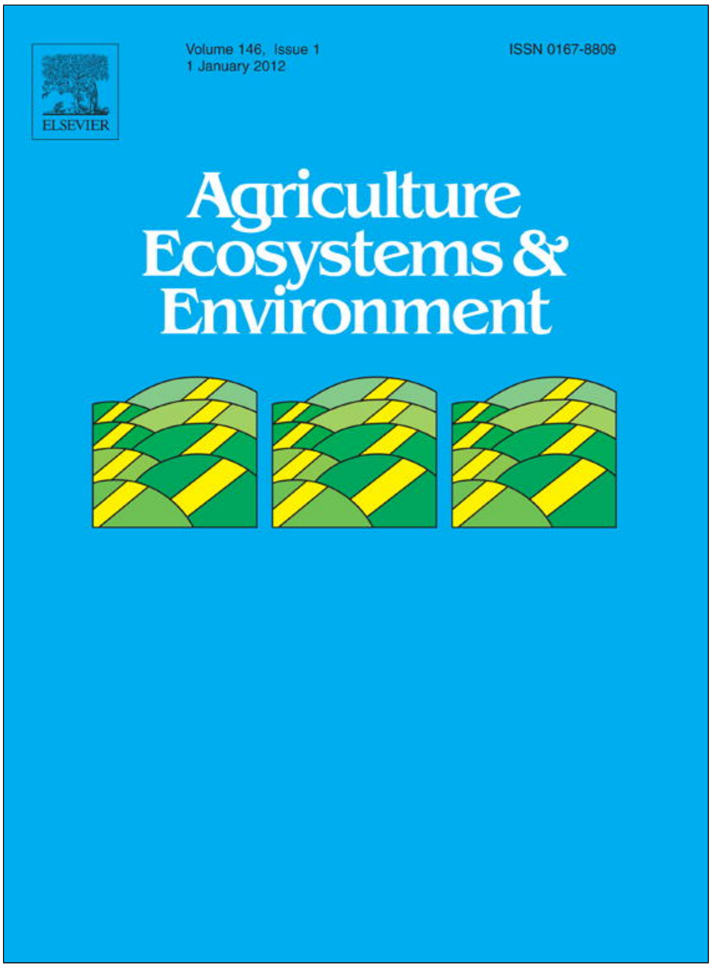
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Habitat preferences of Corncrake (*Crex crex*) males in agricultural meadows

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ABSTRACT

A dramatic decline in the Corncrake (*Crex crex*) population has been observed in Western Europe over the last century. This species is still widespread and occurs at high densities in Eastern and Central Europe. In the present study, we focused on the habitat preferences of Corncrake males in agricultural meadows of Eastern Poland, where large areas are managed by mowing. We counted calling males two times during the same breeding season and noted habitat features within the territory and at the calling location. Our study revealed that Corncrake males were abundant in agricultural meadows. We recorded 59% of the studied populations in meadows which are mowed at least one time during breeding season. We also found differences in the habitat preferences of Corncrakes between the first and second parts of the breeding season. In the first part of the season, when territories are established, males preferred abandoned meadows as the primary habitat type within their territory and as the habitat type of their calling location. The proximity of shrubs or abandoned meadows positively affected the probability of Corncrake occurrence. In the second part of the season, males significantly increased their mean distance from shrubs, ditches and abandoned meadows. Calling places were mainly situated in abandoned or extensively mowed meadows, while extensively mowed meadows was the most common habitat at the larger territory scale. In addition, the distances to the nearest (negatively) and second nearest (positively) neighbours significantly affected the probability of Corncrake occurrence. Regarding the management and protection of Corncrake populations in agricultural meadows, we propose leaving even small uncultivated fragments of meadows around ditches or shrubs as refuges. These uncultivated areas could be sufficient for Corncrakes during the period of territory occupancy. The "Corncrake-friendly" mowing should be done not earlier than after the first hatch and unmowed meadows areas should be left.

1. Introduction

Reductions in many farmland bird populations have been observed in Europe over the last half of the 20th century (Tucker and Heath, 1994; Donald et al., 2006). The most spectacular declines have primarily been reported from Western Europe (Stowe et al., 1993; Fuller et al., 1995; Siriwardena et al., 1998; van Strien et al., 2001; Wilson et al., 2004). Numerous studies have identified agricultural intensification and modernisation as the main driver of population decline (Chamberlain et al., 2000; Newton, 2004; Wilson et al., 2004; Donald et al., 2006). However, some species that are rare or declining in Western Europe are numerous and have stable populations in Central and Eastern Europe (Schäffer and Green, 2001; van Strien et al., 2001; Burfield and van Bommel, 2004; Heath et al., 2000; Voříšek et al., 2010). The more traditional farming practices in the latter regions are usually reported as a cause of this pattern (Donald et al., 2001, 2006). However, unfavourable changes in agriculture are also occurring in Central and Eastern Europe, albeit more slowly (Lerman, 2001; Reif et al., 2008; Swinnen and Vranken, 2010; Tryjanowski et al., 2011). Therefore, recognition of habitat features and the ability of birds to adapt to the habitat changes in these regions appear to be extremely important for the effective management and protection of bird populations across the varied landscapes of Europe (Reif et al., 2008; Báldi and Batáry, 2011).

Here, we focus on a farmland bird species – the Corncrake, *Crex crex* – in the agricultural landscape of Eastern Poland. A dramatic decline in the Corncrake population has been observed in Western Europe over the last century (Green et al., 1997; Schäffer and Green, 2001). Numerous studies have shown that males prefer marshes, abandoned meadows, and grasslands with extensive grazing, with

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tall and not very dense vegetation (Green et al., 1997; Schäffer, 1999; Wettstein et al., 2001; Keišs, 2005; Berg and Gustafson, 2007; Berg and Hiron, 2012). The intensification of agriculture (Schäffer and Green, 2001), mechanised mowing earlier in the season and ensuing loss of suitable breeding areas (Green and Stowe, 1993) are considered to be the primary factors responsible for the population decline. In contrast with Western Europe, in Central and Eastern Europe, the Corncrake is still more widespread and occurs at high densities in suitable habitats (Green et al., 1997; Keišs, 2005; Budka et al., 2012). Stable populations are observed despite the fact that a large part of the breeding area is mowed each year. The slower changes in the habitat, the less intensive cultivation of meadows and ability of birds to adapt to these specific management may be the reasons for this pattern in Central and Eastern Europe.

In the present study, we focused on habitat preferences of Corncrake males in the agricultural meadows of Eastern Poland, where large areas are managed by mowing. We aimed at identifying the most important habitat features for calling Corncrake males during early and late parts of the breeding season. We also considered spatial distribution of calling males, as a potential factor which may affect the attractiveness of territories. The results are discussed in light of the improvement of management strategies for Corncrake populations.

2. Methods

2.1. Study area

Our study was conducted in the Upper Nurzec River Valley (centre coordinates: 52°36′ N, 23°14′ E), a bird area of international importance in Eastern Poland (BirdLife International, 2012). About 145 bird species have been observed here, including 111 breeding. Among them are: Corncrake (206–229 singing males) Montagu's Harrier *Circus pygargus* (9–18 pairs), Lapwing *Vanellus vanellus* (50–63 pairs), Black-tailed Godwit *Limosa limosa* (13–31 pairs), Common Grasshopper Warbler *Locustella neavia* (ca. 100 pairs), River Warbler *Locustella fluviatilis* (ca. 75 pairs), Red-backed Shrike *Lanius collurio* (ca. 250 pairs; Budka, 2010). The study area comprises 46 km^2 of drained agricultural meadows situated along a small river. The river valley is from 0.5 to 5.5 km wide. The valley has been drained in the 1950s by the dense net of channels. Drainage works contributed to the lowering of the local ground water table and have caused the replacement of natural peatlands and marshes by agricultural used meadows and pastures. Now the various semi-natural communities of meadows are the most common habitat type within study area. Forests occupy 17% of the study area, arable fields 7%, and pastures 2%. Forests and arable fields are located mainly on the edges of the valley or in small dunes forming islands. Shrubs grow mainly along the channels and in low densities on unmanaged meadows. A considerable part of the meadows (ca. 60–70%) is mowed each year. Mowing begins at the end of May and lasts to the end of September. Meadows are mowed 1–3 times during the year. Due to artificial drainage, flooding by the river occurs very rarely, is very short and covers only areas located close to the river. However, during the study period we did not observe flooding caused by the river. Snow thawing in the spring, rains during the rest part of the year and flooding by European Beaver *Castor fiber* are the primary reasons for local floods.

2.2. Bird census

Corncrake males are vocally active at night, when they intensively utter their characteristic loud and monotonous disyllabic call (Schäffer, 1999). The call can be heard even from a distance of 0.5–1.0 km, depending on weather conditions and habitat features (Wettstein et al., 2001). We counted calling males at night (from 23.00 to 04.00, local time). The study area was surveyed two times during the single breeding season, from 18 to 25 May and from 8 to 30 June 2012. These dates correspond with the time for the first and the second brood in Poland (Schäffer, 1999). Fieldworkers surveyed the study area on foot. When a Corncrake male was heard, the observer approached the bird and recorded his position using a Garmin GPSmap 62 s GPS receiver. To avoid scaring the birds, observers approached to ca. 5 m to calling male. The survey routes covered the entire area, i.e., no suitable areas were situated more than 500 m from these routes.

2.3. Selection of random sites and habitat mapping

The habitat selection of Corncrake males was analysed by comparing habitat features within Corncrake territories to those within randomly selected sites. The males' spatial distribution was established during the first and second counts. After each count, we randomly selected a set of random points. Random points represented a random distribution of males within the study area and reflected the number of males recorded during each count: 144 during the first and 112 during the second count. Random points were generated using Hawth's Analysis Tools for ArcGIS software (Beyer, 2004). No minimum or maximum distance between random points was defined. Points could not be generated within habitats that are not inhabited by Corncrakes within our study area, i.e., forests, rivers and other water bodies and villages. We classified habitat types separately for the location at which the bird was observed calling and for the male's territory. During the first count, the mean distance to the nearest neighbour was 245 m. Therefore we assumed that the area within 100 m of each male (or random point) represented their territory. The exact location at which a male was observed calling was defined as a 'calling place'. The primary habitat type within each territory and at each calling place was classified as arable field, pasture, intensely mowed meadows, extensively mowed meadows or abandoned meadows. Arable fields were primarily sown with annual cereals in the spring or autumn, or rarely with maize or root vegetables. Intensely mowed meadows were cut two or three times per year between the end of May and the end of September. Extensively mowed meadows were cut once per year beginning after the end of June, but most areas were cut in August. The abandoned meadows had been abandoned for at least two years. The water level within the territory was measured using a three-point scale: dry (water level below ground level), moist (water level oscillates around ground level) and wet (water level exceeds 5 cm). For both occupied and random points, we measured the distances to the nearest representatives of various habitat features that could potentially be important for Corncrakes (Table 1), i.e., forests, shrubs, ditches and abandoned meadows. We also calculated the size of the nearest abandoned meadow. The presence of neighbours, expressed as the distances to the two nearest neighbours, was considered to be a potential factor in a territory's attractiveness. ArcGIS software connected with orthophotomap (http://www.geoportal.gov.pl) was used for all spatial analyses. Additionally, all habitat data were verified in the field.

2.4. Data analysis

We analysed the probability of male Corncrake occurrence in relation to habitat features and the presence of neighbours using stepwise logistic regression models with forward selection. A binominal dependent variable was coded as 1 (male's territory) or 0 (random point). The primary habitat type within the territory, habitat type at the calling place, water level, distances to the

Table 1
Descriptive statistics of habitat features at males calling places and pseudo-absence points during first (from 18 to 25 May) and second (from 8 to 30 June) part of the breeding season. Mean values and standard deviations are given.

Variable description	First part of season		Second part of season	
	Calling places (n = 144)	Random points (n = 144)	Calling places (n = 112)	Random points (n = 112)
Habitat features				
Distance to forest (m)	290 (226.4)	356 (299.7)	329 (278.2)	321 (254.0)
Distance to shrub (m)	34 (31.8)	59 (53.4)	52 (41.8)	55 (43.1)
Distance to ditch (m)	35 (48.9)	70 (92.9)	57 (73.3)	65 (85.7)
Distance to nearest abandoned meadow (m)	36 (69.5)	88 (101.1)	74 (134.4)	81 (100.3)
Nearest abandoned meadow area (ha)	12 (14.9)	5 (8.0)	11 (16.2)	8 (12.4)
Males' clustering				
Distance to the nearest neighbour (m)	245 (172.3)	261 (159.4)	273 (187.0)	292 (183.1)
Distance to the second neighbour (m)	389 (241.9)	447 (178.0)	397 (234.2)	496 (248.6)

nearest shrub, ditch, forest, abandoned meadow and first and second neighbour, and the area of the nearest abandoned meadow were included as covariates. The primary habitat type within a territory and the habitat type at the calling place were categorical covariates. Therefore, we used "simple contrast" to compare each category of the predictor variable to the reference category (abandoned meadows). Separate models were constructed for the males' distributions during the first and second counts. All possible combinations of variables were considered, and a constant was included in the models. To choose the best model, we used Akaike's information criterion (AIC). AIC was calculated as AIC = $-2\ln(L) + 2k$, where k is the number of fitted parameters in the model including the intercept and L is the maximum likelihood estimated for the model (Burnham and Anderson, 2002). Because the ratio between the number of observations (n) and the number of fitted parameters in the most complex model (k) was less than 40, we used a modified version of AIC_c for small sample sizes (Burnham and Anderson, 2002; Symonds and Moussalli, 2011). AIC_c was calculated by the equation:

$$AIC_C = AIC + \frac{2(k(k+1)}{n-k-1}$$

To compare the best-fitted model (AIC_{Cmin}) to the next-best model (AIC_{Ci}), we calculated ΔAIC_{Ci}, where $\Delta AIC_{Ci} = AIC_{Ci} - AIC_{Cmin}$. We did not select one best model, but instead considered all models which had ΔAIC values of less than 9 (Arnold, 2010; Burnham et al., 2011). For these models, we calculated Akaike's weights (w_i):

$$w_i = \frac{\exp\left(-(1/2)\Delta_i\right)}{\sum_{r=1}^{R} \exp\left(-(1/2)\Delta_r\right)}$$

which could be interpreted as the probability that a given model is the best at approximating the data. Finally, we interpreted the most probable models from the models best fitted to the data.

Moreover, we have performed additional analyses to test more specific hypotheses. Differences in habitat features within males' territories between the first and second parts of the breeding season were tested with the nonparametric Mann–Whitney *U* test. Because the water level was higher throughout the study area during the first part of the season, we excluded this variable from the comparison. The primary habitat type within the territory, the habitat type at the calling place and the water level were compared among territories and random points with Chi-square tests (χ^2). These tests allowed to better understand the habitat features which enable occurrence of Corncrakes in agricultural meadows. All *p*-values were two-tailed. All of the statistical analyses were performed in IBM SPSS Statistics 20.

3. Results

3.1. Habitat preferences

We recorded 144 Corncrake males during the first part and 112 during the second part of the breeding season. The mean densities of birds within the study area in the two periods were, respectively, 3.1 and 2.4 calling males/1 km^2. Males were observed primarily in moist abandoned meadows, extensively mowed meadows and intensely mowed meadows. Arable fields and pastures were rarely occupied (less than 8% observations together; see Fig. 1). A comparison of the Corncrake territories with the random sites indicated that males' habitat preferences differ a little between the first and second parts of the breeding season. In the first part of the season, as both the primary habitat type within the territory (PH) and as the habitat type at the calling place (CP), males preferred abandoned meadows (PH: $\chi^2 = 22.3$, CP: $\chi^2 = 110.6$; d.f. = 1, $p < 0.001$), and avoided arable fields (PH: $\chi^2 = 7.9$, $p < 0.01$; CP: $\chi^2 = 16.7$, $p < 0.001$; d.f. = 1) and intensely mowed meadows (PH: $\chi^2 = 14.9$; CP: $\chi^2 = 32.7$; d.f. = 1, $p < 0.001$). In the second part of the breeding season, males preferred extensively mowed meadows ($\chi^2 = 23.6$, d.f. = 1, $p < 0.001$) as the primary habitat type within the territory, whereas abandoned meadows were occupied in proportion to the cover ($\chi^2 = 0.4$, d.f. = 1, $p = 0.53$). Arable fields ($\chi^2 = 5.1$, d.f. = 1, $p < 0.05$) and intensely mowed meadows ($\chi^2 = 6.1$, d.f. = 1, $p < 0.05$) were still avoided. For calling places, similarly to the first part of the season, males avoided arable fields ($\chi^2 = 7.0$, d.f. = 1, $p < 0.01$) and intensely mowed meadows ($\chi^2 = 36.6$, d.f. = 1, $p < 0.001$) and preferred abandoned meadows ($\chi^2 = 12.6$; d.f. = 1, $p < 0.001$) and extensively mowed meadows ($\chi^2 = 63.2$, d.f. = 1, $p < 0.001$). In both parts of the season, males preferred moist habitats (first: $\chi^2 = 42.7$; second: $\chi^2 = 32.0$; d.f. = 1, $p < 0.001$) and avoided dry ones (first: $\chi^2 = 67.3$; second: $\chi^2 = 34.4$; d.f. = 1, $p < 0.001$). Wet habitats were preferred only in the first part of the season ($\chi^2 = 9.6$, d.f. = 1, $p < 0.01$). For more details, see Fig. 1.

3.2. Modelling habitat associations

Descriptive statistics on the habitat characteristics in the occupied and random territories are shown in Table 1 and Fig. 1. Stepwise logistic regression models showed that slightly different habitat features explain the probability of Corncrake occurrence during the first and second parts of the breeding season (Table 2). In our analysis, the primary habitat type within the territory and the habitat type at the calling place were categorical variables. Therefore, the negative or positive effects of these variables are always in reference to abandoned meadows. In the first part of the season, the two best-fitted models had high probabilities of being the best models to represent the data ($\Sigma w_i = 0.91$). In these models, the probability of Corncrake occurrence was positively correlated

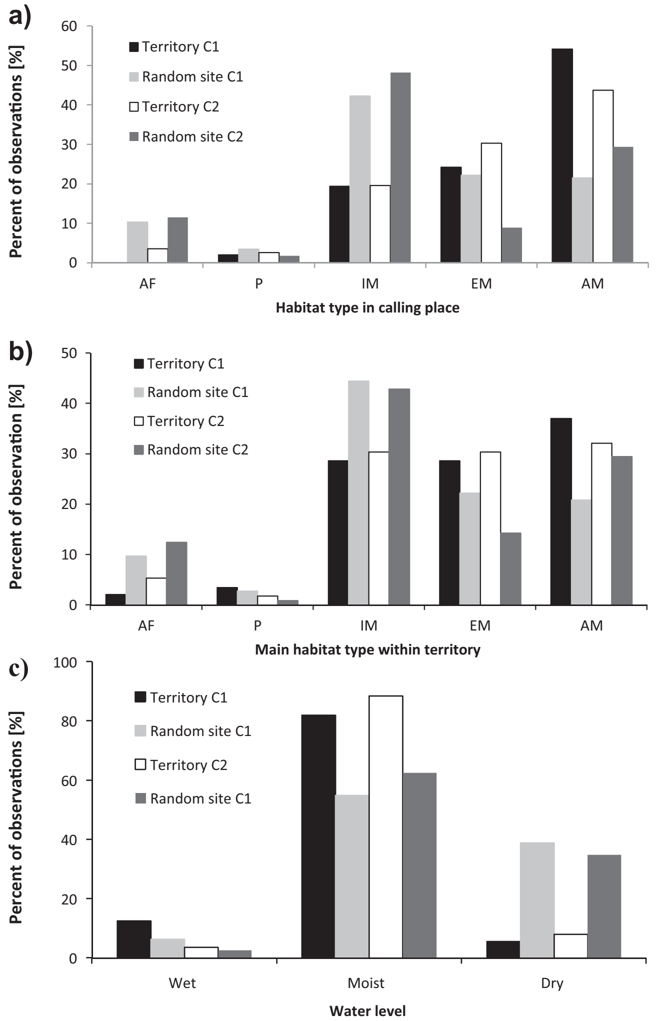

Fig. 1. Comparison of habitat type at the calling place (a), primary habitat type within a territory (b) and water level within a territory (c) among males territory (Territory) and random sites (Random site) during first (C1) and second (C2) count. Habitats were classified as: arable field (AF), pasture (P), intensely mowed meadows (IM), extensively mowed meadows (EM) and abandoned meadows (AM).

with water level and the area of the nearest abandoned meadow. The distance to the nearest shrub and abandoned meadow and the habitat type in the calling place were negatively associated with the probability of Corncrake occurrence (Tables 2 and 3). In the second part of the breeding season, similarly, the two best models had an 83% probability of being the best models to represent the data. In these models, the probability of Corncrake occurrence was positively correlated with water level, the distances to the nearest abandoned meadow and nearest neighbour, and the primary habitat type within the territory. The distance to the second-nearest neighbour and the habitat type at the calling place were negatively correlated to Corncrake occurrence (Tables 2 and 3).

3.3. Seasonal variation in habitat preferences

We found significant differences in the habitat features of male Corncrake territories between the first and second parts of the breeding season. In the second part of the season, males significantly increased their average distance from the nearest shrub ($Z = -4.07$, $p < 0.001$), ditch ($Z = -3.93$, $p < 0.001$) and abandoned meadow ($Z = -2.48$, $p < 0.05$). The area of the nearest abandoned meadow, primary habitat type within the territory, habitat type of the calling place and distances from the two nearest neighbours and nearest forest were not significantly different (in all cases $p > 0.10$) between the first and second parts of the season (Table 1, Fig. 1).

4. Discussion

4.1. Habitat preferences

A preference of Corncrake males for uncultivated or extensively mowed, moist meadows has been reported in a few studies (e.g., Berg and Gustafson, 2007; Moga et al., 2010; Berg and Hiron, 2012). However, the area of such habitats in a landscape with active meadow management is usually limited. Our study revealed that Corncrake males may also densely inhabit agricultural meadows. We recorded 59% of the studied population in intensely and extensively management meadows, which are mowed at least one time during the breeding season (Fig. 1). To analyse factors associated with Corncrake occurrence in more details, we divided the breeding season into two parts. Such an approach allowed a consideration of a typical within-season changes in habitat features in an agricultural landscape (Brambilla and Pedrini, 2011). When males establish territories in the first part of the season, most of their breeding grounds are devoid of vegetation or have very short vegetation that is unsuitable for Corncrakes (Green et al., 1997).

Table 2
Best-ranked logistic regression models, predicted Corncrake habitat preferences (used vs. random point) during first and second part of the breeding season. Corrected Akaike's Information Criterion for a small sample size (AIC_c) were calculated by using −2 log-likelihood values (L) and the total number of parameters used in the model (K). Listed are all models which had ΔAIC_c values less than 9. Akaike's weights (w_i) were calculated for ranked models. Negative (−) or positive (+) relationship among variable and Corncrake presence was showed. Predictors codes indicated: PH, primary habitat type within territory; HCP, habitat type at calling place; WL, water level; SD, distance to the nearest shrub; UMD, distance to the abandoned meadow; NN, distance to the nearest neighbour; SN, distance to the second neighbour; UMA, nearest abandoned meadow area.

Model	L	K	AIC_c	ΔAIC_c	W_i
First part of the breeding season					
HCP(−) + WL(+) + SD(−)	318.42	7	332.94	0	0.54
WL(+) + SD(−) + UMD(−) + UMA(+)	323.46	5	333.74	0.80	0.37
WL(+) + SD(−) + UMD(−)	329.42	4	337.61	4.66	0.05
WL(+) + SD(−) + UMA(+)	330.42	4	338.60	5.66	0.03
HCP(−) + WL(+) + UMA(+)	326.70	7	341.2	8.28	0.01
Second part of the breeding season					
PH(+) + HCP(−) + WL(+) + UMD(+) + NN(+) + SN(−)	234.51	13	262.09	0	0.65
PH(+) + HCP(−) + WL(+) + UMD(+) + SN(−)	239.30	12	264.65	2.56	0.18
PH(+) + HCP(−) + WL(+) + NN(+) + SN(−)	241.02	12	266.37	4.29	0.08
HCP(−) + WL(+) + UMD(+) + SN(+)	250.66	8	267.28	5.19	0.05
PH(+) + HCP(+) + WL(+) + SN(−)	245.12	11	268.26	6.17	0.03
PH(+) + HCP(−) + UMD(+) + NN(+) + SN(−)	244.67	12	270.02	7.93	0.01

Table 3
Results from two best-ranked logistic regression models (with the lowest AIC_c), predicted Corncrake habitat preferences (used vs. random points) during first and second part of the breeding season. Codes of predictors are explained in Table 2. HSP and PH are categorical covariates. In all models we used abandoned meadows as a references category, numbers indicate remaining habitat types: (1) arable field, (2) pasture, (3) intensely mowed meadows, and (4) extensively mowed meadows.

Predictor	*B*	S.E.	Wald	d.f.	*P*	Exp(*B*)
The best model for first part of the season						
HCP			13.029	4	0.011	
HCP (1)	−20.502	9783.924	0.001	1	0.998	0.001
HCP (2)	−0.967	0.792	1.492	1	0.222	0.380
HCP (3)	−1.199	0.335	12.769	1	0.001	0.302
HCP (4)	−0.524	0.346	2.301	1	0.129	0.592
WL	1.098	0.303	13.009	1	0.001	2.997
SD	−0.130	0.004	10.798	1	0.001	0.987
Constant	−5.528	1956.785	0.001	1	0.998	0.004
The best model for second part of the season						
PH			9.013	4	0.061	
PH (1)	2.129	1.539	1.914	1	0.167	8.408
PH (2)	3.523	2.444	2.078	1	0.149	33.901
PH (3)	1.797	0.809	4.938	1	0.026	6.033
PH (4)	−1.090	0.773	1.985	1	0.159	0.336
HCP			20.875	4	0.001	
HCP (1)	−3.432	1.504	5.207	1	0.022	0.032
HCP (2)	−2.435	1.963	1.539	1	0.215	0.088
HCP (3)	−3.308	0.836	15.644	1	0.001	0.037
HCP (4)	1.305	0.806	2.623	1	0.105	3.688
WL	1.436	0.491	8.565	1	0.003	4.202
UMD	0.005	0.002	6.128	1	0.013	1.005
NN	0.003	0.001	4.544	1	0.033	1.003
SN	−0.004	0.001	11.581	1	0.001	0.996
Constant	−1.930	0.972	3.946	1	0.047	0.145

We found that the presence of patches of tall vegetation from previous years, such as abandoned meadows or shrubs, is a primary factor influencing the probability of Corncrake occurrence (Tables 2 and 3). In addition, the distance to the nearest ditch was significantly shorter for occupied territories compared to random areas (Table 1). The ditches in our study site were linear elements of uncultivated land. They had widths of 0.5–1.5 m and depths of ca. 0.5–2.0 m and were overgrown by grasses, herbs and shrubs. These strips along the ditches were not cut during mowing. Our findings revealed that in agricultural meadows, even small, uncultivated fragments around shrubs or ditches could be sufficient for Corncrake males during the early breeding season. Moreover, shrubs could be true and easily visible indicators of the lack of management for at least a few years.

In the second part of the season, tall and dense vegetation suitable for Corncrakes covered larger parts of the study area. Males responded to this change in habitat by increasing their distance from uncultivated features such as shrubs, ditches and abandoned meadows (Table 1). Extensively mowed meadows were occupied significantly more often than expected by their area in random points, whereas abandoned meadows were occupied in proportion to their area. Such changes in the habitat preferences of male Corncrakes within the breeding season have been poorly studied so far. We note that changes in the spatial distribution of suitable habitats are the main driver of such behaviour. The growth of vegetation and mowing of some parts of the study area caused males to change their territory boundaries or abandon their territory and occupy a new one. Similar pattern of within-season movement of Corncrake males was observed by Brambilla and Pedrini (2011) in Italy.

Most studies of habitat preferences overlook the spatial distribution of territories. However, the presence of neighbours can be a good indicator of habitat quality (Dale and Steifetten, 2011; Farrell et al., 2012). Our study showed that the presence of neighbours is an important factor in the second part of the season (Tables 2 and 3). This outcome is not surprising when we examine the breeding biology of the Corncrake in detail. Corncrakes are sequentially polygamous; hence, both males and females change partners between breeding attempts (Green et al., 1997). Males defend their territories and therefore, the distance to the nearest neighbour must be above some minimum value. However, males often form aggregations of a few individuals, even within homogenous habitat (Schäffer, 1995). Singing in a group may enhance males' ability to attract females, as in typical lek-forming species. Therefore, an increasing distance to the second-nearest neighbour had a negative effect on the probability of male occurrence (Tables 2 and 3). Such a spatial distribution of males may confirm the role of social attraction in singing and the tendency to form small groups. On the other hand, such aggregations of males also may be result of occurrence of suitable habitat in the neighbourhood.

4.2. Implications for conservation and management

Vast, uncultivated meadows or meadows that are cultivated every few years are one of the main breeding habitats for the Corncrake (Berg and Gustafson, 2007; Moga et al., 2010). However, these habitats are rare in farmland landscapes, where cultivated meadows are the most widespread. In the present study, we showed that Corncrake males may also occur at high densities in mowed meadows if some specific habitat components are present.

In the first part of the breeding season, when males first occupy their territories, the presence of refuges with tall and dense vegetation remaining from the previous year appears to be a key factor influencing a potential territory's attractiveness. Therefore, in agricultural landscapes, we propose leaving even small uncultivated fragments of meadows around ditches or shrubs. These uncultivated areas could be sufficient for Corncrakes during the period of territory occupancy. In the later part of the breeding season, males significantly increase their distance from uncultivated fragments of land. These habitat features become less important as the surrounding vegetation becomes tall and dense. However, mowing of the breeding area at this time could be destructive, especially for nests and flightless chicks. Adult males and females are rarely killed by mowing and are able to escape from mowing activity, especially when mowing is done from the centre of the meadow outwards (Tyler et al., 1998). The best solution for Corncrake protection appears to be to mow after the breeding season (Schäffer and Weisser, 1996). However, such an approach is unrealistic for large agricultural meadows, for which the biomass harvesting pressure is high. Therefore, as a compromise solution, we propose mowing not earlier than after first hatch. The approximate time of hatching should be determined separately for each population because geographical differences can be significant (Green et al., 1997). Meadows should be mowed by Corncrake's friendly methods, and area of unmowed meadow should be left as refuge (Stowe and Green, 1997; Tyler et al., 1998). The refuges should be left around ditches and shrubs or in places with denser and higher vegetation. The important role of areas with positively managed non-crop cover vegetation was also showed by Corbett and Hudson (2010). The within-season movements of males and their changing habitat preferences suggest that the sustainable management of large breeding areas appears to be the best solution. Our proposed approach to Corncrake protection and management in agricultural meadows appears to be appropriate given the actual knowledge of the ecology of this species. Simultaneously, such agricultural practices may satisfy the needs of agriculture for hay or silage and be advantageous for other animals inhabiting agricultural meadows (Wilkinson et al., 2012). Our study, as with a great majority of papers on the Corncrake, is based only on the distribution of males. Females are very secretive, and their behaviour is poorly studied. Therefore, for the effective management and protection of Corncrake populations, better recognition of nest site selection and female behaviour in agricultural meadows is necessary. However, if females in agricultural meadows prefer small patches of uncultivated or extensively cultivated land (Green et al., 1997; Schäffer, 1999), then the proposed approach to the protection and management of Corncrake populations should be verified for a global scale.

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