

HABITAT PREFERENCE OF THE SOLE WILD POPULATION OF *FRANCOLINUS BICALCARATUS AYESHA* IN THE PALEARCTIC: IMPLICATIONS FOR CONSERVATION AND MANAGEMENT

Saâd HANANE^{1*}, Nabil ALAHYANE², Najib MAGRI¹, Mohamed-Aziz EL AGBANI³
& Abdeljebbar QNINBA³

¹ Forest Research Center, High Commission for Water, Forests and Desertification Control, Avenue Omar Ibn El Khattab, BP 763, 10050, Rabat-Agdal, Morocco.

² Faculté des Sciences de Rabat, 4 Avenue Ibn Battouta, BP 1014 RP, 10090, Agdal-Rabat, Morocco.

³ Université Mohammed V-Agdal, Institut Scientifique de Rabat, Avenue Ibn Battouta, BP 703, 10090, Agdal-Rabat, Morocco.

* Corresponding author. E-mail : sdhan333@gmail.com ; phone: +212 660 125799 ; Fax: +212 537 671151

RÉSUMÉ.— *Préférence d'habitat de la seule population sauvage de Francolinus bicalcaratus ayesha dans le Paléarctique : implications pour sa conservation et sa gestion.*— Le Francolin à double éperon (*Francolinus bicalcaratus ayesha*) est un oiseau en danger critique d'extinction et endémique du Maroc, où il habite les forêts de chêne-liège. Ses populations ont été réduites principalement en raison de la chasse et de la destruction des habitats. La caractérisation de l'habitat utilisé par ces oiseaux indigènes peut optimiser les programmes futurs de réintroduction. La méthode de détection auditive a été utilisée sur des transects pour localiser les mâles chanteurs. Nous avons analysé les facteurs qui déterminent la présence du Francolin à double éperon dans le Nord-Ouest du Maroc en considérant 13 variables explicatives. Ces prédicteurs ont été regroupés par Analyse en Composante Principale (ACP) et les données associées à la présence/aléatoire de l'espèce ont été traitées par des GLMs. Le meilleur modèle, sélectionné sur la base du critère d'Akaike, a montré les effets combinés, en additif, des axes ACP_{Taille des arbres}, ACP_{Proximité aux parcelles de céréales} et ACP_{Densité des arbres} (AIC_{weight} = 0,75). Les Francolins ont montré une préférence pour les grands arbres à faible densité et pour la proximité de champs de céréales. Cela suggère que la sélection de l'habitat chez les francolins est un compromis entre la nécessité de se nourrir et celle d'éviter les prédateurs. D'autres études sont nécessaires pour améliorer notre compréhension des effets des facteurs écologiques sur la sélection de l'habitat de nidification, la productivité et la survie de ce Gallinacé.

SUMMARY.— The critically endangered Double-spurred Francolin (*Francolinus bicalcaratus ayesha*) is endemic to Morocco, where it inhabits cork oak forests. Its populations have been reduced chiefly due to hunting and habitat destruction. Characterizing the habitat use of native-bred birds is a tool which can optimize recovery programs. Auditory detection was used during transect surveys of calling males to locate breeding birds. We analysed factors determining the occurrence of native Double-spurred Francolins in North-western Morocco using a set of 13 environmental variables. Predictors were aggregated using PCAs and related to species presence/random data using GLMs. The best-supported model of the species' occurrence included three PCA axes and was clearly better (AIC weight = 0.75) than other models. Francolins showed a preference for large trees with low density, and a proximity to cereal fields. This suggests a trade-off between the need to forage efficiently and that to avoid predators. Further studies are needed to improve our understanding of the effects of ecological factors on nest habitat selection, productivity and survival of Double-spurred Francolin.

Conservation priorities are most often related to the extinction risk of species (Vane-Wright, 2009; IUCN, 2013; Dunn *et al.*, 2015). Such species are often low in numbers (Gaston, 1994), which makes them difficult to detect and thereby to monitor. Determining which habitat types are selected by these animals can provide basic information about how they meet their requirements for survival and reproduction (Block & Brennan, 1993). This kind of study is the most effective way to assess the ecological requirements of a species and to set management guidelines to assist in conservation of populations. Indeed, knowing habitat factors is an important step in the development of effective conservation strategies, particularly for endangered species (Conway & Martin, 1993; Pasinelli, 2000). A number of factors can contribute to habitat selection, including

availability of food and adequate breeding sites, vegetation structure, intra- and interspecific competition, the presence of predators which can be affected by the attributes of the habitat occupied by the prey and human presence (Manly *et al.*, 1993; Warfe & Barmuta, 2004; Chalfoun & Martin, 2009; Hanane, 2015).

The Double-spurred Francolin *Francolinus bicalcaratus* (Linnaeus, 1766) is found in tropical West Africa and also in Morocco where an isolated subpopulation occurs as a local resident (Thévenot *et al.*, 2003). *Francolinus bicalcaratus ayesha* is a galliform subspecies that is endemic to Morocco. While *Francolinus bicalcaratus* has a conservation status of Least Concern in the IUCN Red List (Birdlife International, 2012; IUCN, 2013), the Moroccan subspecies *ayesha* is reported as Critically Endangered (Thévenot *et al.*, 2003; McGowan *et al.*, 1995; El Agbani *et al.*, 2011; Hanane & Qninba, 2014; Hanane & Magri, 2015). Currently, this subspecies occurs in the zone surrounded by the agglomerations of Sidi Yahia des Zaër, Sidi Bettache and Ben-Slimane (Thévenot *et al.*, 2003). However, it seems to have vanished from Souss (southwestern Morocco) where it was common in the early 1920s (Thévenot *et al.*, 2003), and for which, the most recent record was of 1-2 birds in 1987 (Thévenot *et al.*, 2003). Its diet consists mainly of grains, seeds, berries and insects (Alaoui, 2001). The population of *F. b. ayesha* has been reduced due to hunting and habitat destruction (Thévenot *et al.*, 2003; Hanane & Magri, 2015). Out of the 300 Galliformes species found worldwide, 26 % are classified as “threatened”, largely due to habitat loss and degradation, hunting and human disturbance (IUCN, 2013). Given this situation, the reestablishment of a viable breeding population of this francolin is desired to restore its status. Consequently, as part of its strategic efforts to strengthen wild populations, Morocco’s High Commission for Water, Forests and Desertification Control in collaboration with the Captive Breeding Center ‘Domaine la Gazelle-Gibiers’ and the Royal Moroccan Federation of Hunting have decided to implement a Double-spurred Francolin reintroduction program. Thus, a first experience was performed, in 2011, within an historical range of the species (Thévenot *et al.*, 2003) consisting of a didactic reserve at Sidi Allal Al Bahraoui (SABGR; 34°00’52”N-6°28’18”W) in which 300 Double-spurred Francolins were released (Hanane & Qninba, 2014; Hanane & Magri, 2015). This choice was also dictated because there were no longer any Double-spurred Francolins in the Ma’amora forest (Thévenot, 1991; Cherkaoui *et al.*, 2007, 2009). To enhance our knowledge and to consolidate our findings, it has been useful and even necessary to carry out another comprehensive study on habitat selection by wild birds.

In Morocco, the habitat preferences of the Double-spurred Francolin are poorly known. Historically, a variety of habitats are reported to have been occupied by the subspecies *ayesha* (De la Perche, 1992; Thévenot *et al.*, 2003), among them, dense matorral (thickets) of wild olive (*Olea europaea*) and lentisc (*Pistacia lentiscus*), open woodlands of Thuya (*Tetraclinis articulata*), and Holm and Cork oak (*Quercus ilex* and *Q. suber*), but no clear pattern has emerged. Moreover, there is a complete lack of quantitative data relating to the habitats used by this Critically Endangered subspecies.

We therefore studied data from a North-Western Moroccan woodland, known to support the last native Double-spurred Francolin population. This choice meets the needs of this study and turns out consistent with studies on rare species, which are often undertaken in areas of the most suitable habitat to maximize the likelihood of detection (Dunn *et al.*, 2015). Occupied/random data were recorded during planned surveys, because they are clearly preferable to occupied-only data in habitat modelling studies aimed at delineating niche boundaries (Franklin, 2009).

In so far the knowledge of specific habitat requirements of the species in breeding season is of major importance, our main aim was thus to identify and quantify those characteristics of forest structure associated with the habitats chosen by *F. b. ayesha*. In this way we sought to provide reliable recommendations for future reintroductions adequate to meet the conservation needs of the subspecies. We therefore aimed to determine its precise habitat requirements. We anticipate that,

in future, the results of this investigation will serve as an invaluable basis for recovery and conservation of this critically endangered subspecies.

We generated two related hypotheses: (1) that the Double-spurred Francolin will use forest areas with a high density of Cork oak and a high shrub cover, and (2) that birds will remain around water points and cereal fields in this region.

METHODS

STUDY AREA

Double-spurred Francolins were monitored at the Royal Reserve of Ain Sferjla (RRAS) ($33^{\circ}69'55''\text{N}$ - $6^{\circ}91'87''\text{W}$) (Fig. 1), which is located within the Benslimane forest, Morocco. The RRAS is a fenced area of about 87 ha. It is situated near the city of Sidi Bettach, at an altitude range between 240 and 322 m a.s.l. Annual precipitation averages 417 mm, and monthly average temperatures vary from 12°C (January) to 28°C (July-August). This region is characterized by hot summers and mild winters (a semi-arid bioclimate). The study site is managed and controlled; livestock such as sheep that are common in the region are not permitted.

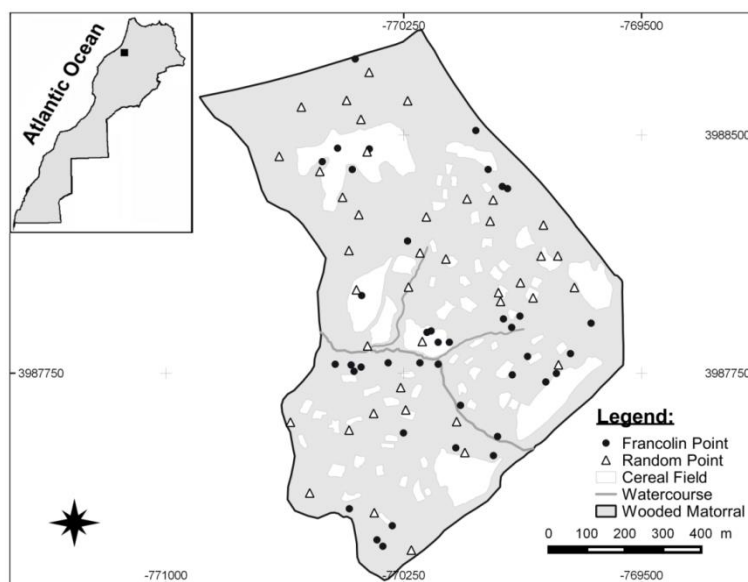


Figure 1.— Map showing the location of the Royal Reserve of Ain Sferjla (RRAS) in Northwestern Morocco. Black points represent the location of francolins and white delta points represent the location of random points.

The vegetation of this forest area is characterized by Anacardiaceae, Cistaceae, Ericaceae, Fabaceae, Lamiaceae and Poaceae. The tree-layer consists mainly of cork oak in association with lentisc, strawberry tree (*Arbutus unedo*), and tizra tree (*Rhus pentaphylla*). The shrub layer is dominated by Montpellier cistus (*Cistus monspeliensis*), needle-leaved broom (*Teline linifolia*), hairy broom (*Cistus triflorus*) and Spanish lavender (*Lavandula stoechas*). The forest landscape is dominated by a single habitat: the wooded matorral (74 ha), inside which small cereal patches, especially of wheat (*Triticum aestivum*) (min-max = 0.029-1.64 ha, n = 67), are distributed. This management action was performed in order to improve feeding conditions of Double-Spurred Francolins particularly in summer when natural food resources become extremely rare. Game management in this protected zone aims mainly at Double-spurred Francolin conservation.

SAMPLING DESIGN

Determination of Double-spurred Francolin territories

We conducted breeding season surveys in April 2015. As the Double-spurred Francolin is territorial (the male sings to attract the female and to defend its territory), we used the point count method enhanced by the playback technique (Hanane

& Qninba, 2014; Hanane & Magri, 2015). Nowadays this technique is commonly used to increase the detection of many secretive bird species (Conway *et al.*, 1993; Zuberogoitia & Campos, 1998; Brambilla & Rubolini, 2004), such as Galliformes (Evans *et al.*, 2007; Ponce-Boutin, 1992; Kasprzykowski & Gołowski, 2009; Jakob *et al.*, 2010, 2014; Fuller *et al.*, 2012).

Three permanent transects (1.0-1.2 km) were established from random start points. On each of these transects, 4 to 5 points were identified as being sufficiently far apart (0.2-0.3 km) to avoid double counting. Counts were conducted at these points 5 times during April 2015. Each survey started between dawn and 10:00 am. We played Double-spurred Francolin calls from a notebook via a VLC media player and two speakers (5W each). One cycle of Double-spurred Francolin male territorial calls was played for 10 s, and any response noted in the ensuing 60 s. At each point, this process was repeated three times in each cardinal direction, to locate calling males.

Less than half of the francolins recorded were located visually by finding a roost site or by directly observing a breeding pair. Such visual locations give the strongest indication of the core of each territory. When we heard calls from a francolin, often in response to playback, and we could not locate it visually because, generally, of dense vegetation, we used triangulation to determine its location with the help of three observers surrounding the calling bird and taking bearings. All Double-spurred Francolins' positions were geo-referenced using a portable GPS (Magellan eXplorist XL) and then reported in an Open Source GIS (Quantum GIS v2.8.1). When a male was heard, calling either without using playback or immediately after playback was first used, it was assumed that it was actively defending its territory, and thus its location was indicative of the territory core (*F. b. ayesha* has distinct far-carrying vocalizations). We performed point counts only in good weather conditions (not excessively hot and no wind or rain) for two reasons: (1) to make it easier to hear birds at a greater distance, (2) to facilitate collecting the most accurate localizations of birds and random points through using GPS instruments in the best conditions (Trimble GNSS Planning online tools).

Selection of random points

In the first step, we excluded all points at which Double-spurred Francolins were recorded. In the second step, points were selected by drawing 40 random points using the QGIS random selection tool. The random and the presence points were equal in number to give a balanced design.

Measurement of habitat characteristics

Forest structure was quantified either at the locations where francolins were recorded (hereafter 'Francolin points') or for random points in circular plots with an 11.3 m radius (0.04 ha). We assumed that this radius was sufficient to characterize the francolins' habitat use because (1) the study area is well protected and is not affected by such human activities as grazing, clearing and logging, which are known to affect the habitat structure (Kie *et al.*, 1996; Fimbel *et al.*, 2001; Hanane, 2014; Hanane & Magri, 2015); and (2) the minimum distance recorded between the singing Double-spurred Francolin males was 11.5 m.

We considered: 1) geomorphological variables as altitude (m a.s.l., *Alt* using a GPS) and slope [%_Slo using a clinometer (± 0.05 m)]; 2) vegetation variables, as tree cover [%_tree with visual estimation), height (m) of the tallest tree (*H_tree* using a clinometer), diameter (cm) at breast height [*DBH* with a measuring tape (± 0.01 m)] of the tallest tree, density of trees (*D_trees*) by counting the number of trees within the 11.3 m radius, species richness of trees (*SR_tree*) by counting the number of tree species within this same area, shrub cover [%_mat using Gayton (2003) method], average height (m) of the shrub (*H_mat* using a clinometer), herbaceous cover [%_her using Gayton (2003) method] and average height (m) of the herbaceous layer (*H_her* using a clinometer); and 3) variables related to the proximity of food resources at RRAS as distance (m) to the closest cereal patch (*D_cro*) and distance (m) to the closest water point (*D_wat*) through the application of Geographic Information Systems (QGIS, v2.8.1) to measure distances. Climatic factors were not taken into account due to the small study area (87 ha), which means that we assume similar values for temperature, precipitation, and humidity across the studied landscape.

Statistical analysis

Before performing statistical analyses, we checked for normality and homogeneity of variance of all the variables. Variables that did not conform to the requirements for parametric tests were log or square-root transformed prior to all analyses (Zar, 1984; Quinn & Keough, 2002). We also checked for possible correlations among variables by using Pearson's rank correlation (r) index. We collapsed habitat structure variables into independent vectors using Principle Component Analysis (PCA), since this analysis allowed us to: (i) reduce the dimensionality of the set of variables ($n = 13$) to a smaller number of synthetic orthogonal gradients ($n = 4$); (ii) investigate multicollinearity; and (iii) describe dominant ecological gradients (Legendre & Legendre, 1998). For each PCA, a varimax normalized rotation was applied to the set of principal components with eigenvalues > 1.0 , to obtain simpler and more interpretable gradients (Legendre and Legendre 1998). We interpreted the biological meaning of the principal components, which explain the greatest amount of combined variation within the habitat structure data, by examining the component loadings of each variable ($n > 0.70$) (McGarigal *et al.* 2000).

The PCA summarized the 13 original variables into four axes (PC) with eigenvalues > 1 , accounting together for 67.2 % of the variance in the original data set (Tab.1). The first PC (PC_{Shrub cover}) represented a gradient of increasing shrub cover and proximity to water points. The second PC (PC_{Tree size}) depicted a gradient of increasing height of trees with high DBH.

The third PC expressed the proximity to food resources on gentle slopes ($PC_{\text{Distance to the closest cereal fields}}$), and the fourth axis described gradients of increasing density of trees ($PC_{\text{Density of trees}}$) (Tab. I). These four orthogonal factors were used as independent explanatory variables in a logistic regression model to assess their significance in predicting Double-spurred Francolin occupancy probability

TABLE I

Results of the principal component analysis showing the loadings of the habitat variables within each of the principal components

Variables	Components			
	$PC_{\text{Shrub cover}}$	$PC_{\text{Tree size}}$	$PC_{\text{Proximity to cereal fields}}$	$PC_{\text{Density of trees}}$
<i>Slp</i>	-0.258	0.056	-0.721	-0.087
<i>Alt</i>	-0.105	-0.017	0.618	0.049
<i>%_mat</i>	0.732	-0.465	0.098	-0.015
<i>%_tree</i>	0.320	0.808	-0.192	0.134
<i>%_her</i>	-0.924	-0.156	0.048	-0.100
<i>H_mat</i>	0.631	0.086	0.208	-0.039
<i>H_tree</i>	0.105	0.931	-0.042	-0.052
<i>H_her</i>	-0.434	-0.203	-0.013	0.491
<i>DBH</i>	-0.149	0.823	-0.029	0.036
<i>D_trees</i>	0.271	0.245	-0.142	0.783
<i>SR_trees</i>	0.084	-0.014	0.350	0.607
<i>D_wat</i>	0.845	0.068	0.091	0.237
<i>D_cro</i>	0.173	-0.151	0.824	-0.037
<i>Eigenvalue</i>	3.013	2.577	1.826	1.323
<i>% Explained variance</i>	23.174	19.825	14.046	10.178

After this first stage of analysis, we turned to modelling the occupancy probability of the Double-spurred Francolin as a function of the orthogonal predictor factors of habitat structure using the Generalized Linear Model (GLM) with binomial response variable distribution (logistic regression: presence vs. random). In order to select the best GLM models, we developed an all-inclusive design by using multi-model inference (Burnham & Anderson, 2002): 15 possible combination models were tested (see Tab. II). For each model, Akaike Information Criteria (AICc) were calculated. The model with the lowest AICc was selected as the best fitting model. We corrected AICc for small sample size ($n = 80$) using AICc (Burnham & Anderson, 2002).

TABLE II

Models with the number of parameters used (K), the Akaike information criterion for small samples size ($AICc$), the difference between each selected model and the best model ($\Delta AICc$), and the Akaike weight ($AICc_{wi}$)

	K	$AICc$	$\Delta AICc$	$AICc_{wi}$
$PC_{\text{Tree size}} + PC_{\text{Distance to the closest cereal fields}} + PC_{\text{Density of trees}}$	4	67.97	0.00	0.75
$PC_{\text{Shrub cover}} + PC_{\text{Tree size}} + PC_{\text{Distance to the closest cereal fields}} + PC_{\text{Density of trees}}$	5	70.24	2.27	0.24
$PC_{\text{Tree size}} + PC_{\text{Density of trees}}$	3	75.72	7.75	0.02
$PC_{\text{Distance to the closest cereal fields}} + PC_{\text{Density of trees}}$	3	87.23	19.26	0.00
$PC_{\text{Shrub cover}} + PC_{\text{Distance to the closest cereal fields}} + PC_{\text{Density of trees}}$	4	89.35	21.38	0.00
$PC_{\text{Tree size}} + PC_{\text{Distance to the closest cereal fields}}$	3	92.50	24.53	0.00
$PC_{\text{Density of trees}}$	2	93.52	25.55	0.00
$PC_{\text{Shrub cover}} + PC_{\text{Tree size}} + PC_{\text{Density of trees}}$	4	94.69	26.72	0.00
$PC_{\text{Shrub cover}} + PC_{\text{Density of trees}}$	3	95.52	27.55	0.00
$PC_{\text{Tree size}}$	2	99.19	31.22	0.00
$PC_{\text{Shrub cover}} + PC_{\text{Tree size}}$	3	101.32	33.35	0.00
$PC_{\text{Distance to the closest cereal fields}}$	2	107.81	39.84	0.00
$PC_{\text{Shrub cover}} + PC_{\text{Distance to the closest cereal fields}}$	3	109.93	41.96	0.00
Null	1	112.95	44.98	0.00
$PC_{\text{Shrub cover}}$	2	115.03	47.06	0.00

One of the assumptions of parametric statistics is that observations are independent of each other. This assumption is often violated with spatial data. As a result, it is important to test for and subsequently address spatial autocorrelation in data prior to data analysis. Due to the small size of study area, the spatial structure of Francolin's presence was quantified by the indicator semi-variogram (Goovaerts, 1998) by using the residual of the best model in terms of AICc value.

All statistical analyses were performed in R-3.1.0 software (R Development Core Team 2013). We used the package "ade4" for Principal Component Analysis (Dray & Dufour, 2007) and the packages "sp", "lattice" and "gstat" to draw semi-variograms (Pebesma, 2006). Means are quoted \pm standard errors.

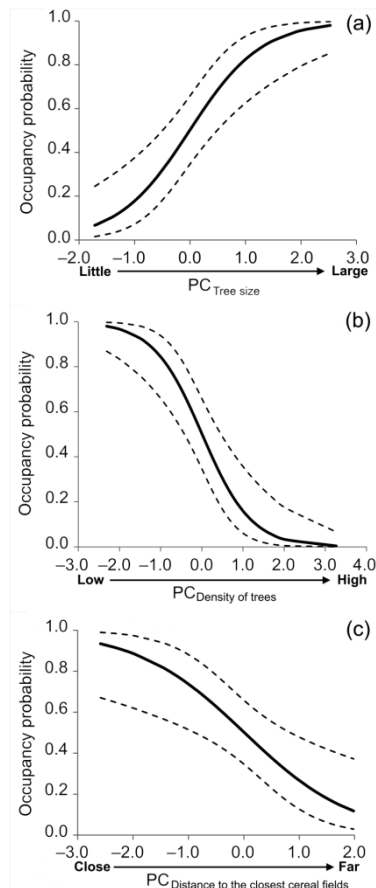


Figure 2.— Occupancy probability of Double-spurred Francolins at the RRAS, Northwestern Morocco, 2015, according to tree size (a), density of trees (b), and proximity to cereal fields (c).

RESULTS

Fifteen candidate models were obtained with the four PCA components. In accordance with the Δ AICc values, the most parsimonious model of Double-spurred Francolin habitat occupancy included a GLM fit to $PC_{Tree\ size}$, $PC_{Distance\ to\ the\ closest\ cereal\ fields}$, and $PC_{Density\ of\ trees}$ (Tab. II).

There is no competitor to this model with a delta AICc < 2 (Tab. II). The goodness-of-fit test indicated acceptable fit ($z = 0.712$, $P = 0.153$). The error rate based on the ROC function was 0.15. The model explained 75 % of the deviance in the Double-spurred Francolin occupancy and 47 % of their variance. In addition, we did not find evidence of spatial autocorrelation in models' residuals between plots. The semi-variogram of residuals from the top AICc ranked GLM shows no significant spatial autocorrelation. Indeed, Nugget to total sill ratio (NSR) is equal to 1 which

suggests that the results of this non-spatial GLM model were not biased by possible spatial covariance in the data.

Francolin occupancy probabilities were negatively related to PC_{Density of trees} ($\beta = -1.677 \pm 0.42$; 95% CI: -2.50– -0.85, $z = -3.958$, $P < 0.001$) and PC_{Distance to the closest cereal fields} ($\beta = -1.022 \pm 0.35$; 95% CI: -1.71– -0.34, $z = -2.879$, $P = 0.003$) (Fig. 2b,c) and positively related to PC_{Tree size} ($\beta = 1.541 \pm 0.41$; 95% CI: 0.74–2.34, $z = 3.764$, $P < 0.001$) (Fig. 2a).

DISCUSSION

The aim of our study in RRAS was to explore some environmental factors and identify variables responsible for habitat occupancy by the only native population of Double-spurred Francolin installed in North-Western forest of Morocco.

This population showed a preference for large trees with low density, and a proximity to cereal fields. This suggests that the distribution of the subspecies is related with the size and density of trees. This is not surprising to the extent that large trees are widely known to be useful to the birds as they provide a place to roost (20 % of observed francolins) (Ceballos & Donazar, 1990; Gibbons & Boak, 2002; Manning *et al.*, 2009; Mahmood *et al.*, 2010; Xu *et al.*, 2010), and a refuge from predators (Xu *et al.*, 2010). At RRAS, Double-spurred Francolins occupied also the wooded matorral (with the vegetation characteristics mentioned above) near places where cereals are available. Indeed, half of francolin locations were within 100 m from these fields. The cereals are undoubtedly important as food resources. Our result highlights the fact that the selection of large trees in close proximity of cereal fields would be beneficial for this galliform species. This seems logical given that, during spring and summer seasons, wheat is the main food resource for Double-spurred Francolins (see Mbinkar *et al.* 2005), as also the case for other francolin's species such as the Black Francolin (Paralikiidis *et al.* 2010). Contrary to our expectations, this endemic subspecies is the most often detected in low density of trees. A preference for a relatively open forest structure is overall related to better flight conditions. Indeed, Quevedo *et al.* (2006) and Carneiri *et al.* (2012), in working respectively on habitat selection of the Cantabrian Capercaillie (*Tetrao urogallus cantabricus*) and the Slender-billed Parakeet (*Enicognathus leptorhynchus*), have demonstrated that it facilitates movement through the open forest landscape. We also suspect that this choice may be due to the necessity of overseeing the surroundings without having to make much effort.

Although not significant, Double-spurred Francolins use areas that are far from water sources. This was also the case for the Brown Eared-pheasants (*Crossoptilon mantchuricum*) in a Chinese National Nature Reserve (Li *et al.* 2009). An explanation of this behaviour is that francolins do not probably find important resources around water points.

Surprisingly, our results contrast in some measures with those of Hanane & Magri (2015), who have highlighted that released Double-spurred Francolins at SABGR showed a preference for a dense and high shrub layer, and dense cork oak trees. So, why this occupancy difference between the two study zones? In our opinion, this pattern would be related to the type of predators that occurs within each of the two areas. At RRAS, it seems likely that Double-spurred Francolins' habitat selection would be a trade-off between the need to forage efficiently and that to avoid predators. This is consistent with previous studies (Warfe & Barmuta, 2004; Chalfoun & Martin, 2009), and who suggest that predation risk can be affected by the attributes of the habitat occupied by the prey, while predators can have indirect effects on their prey, including influencing where they choose to feed, breed and sleep (Whittingham & Evans, 2004).

IMPLICATIONS FOR CONSERVATION AND MANAGEMENT

The investigation of habitat-animal associations relies on a manager's ability to understand the scale at which wildlife responds to and interacts with their environment (Pastor *et al.*, 1996;

Guerena *et al.*, 2014). It is for this reason that the results of this study should be taken into account in planning future releases of the Critically Endangered *ayesha* subspecies. In addition to desirability of choosing a release site that is within the historical range of the subspecies (IUCN, 1998), it is also important to choose forest release sites that offer sufficient cover from large trees and shrubs (e.g. the Montpellier cistus and needle-leaved broom). This appears to be essential in helping to protect Double-spurred Francolins from both aerial and terrestrial predators. According to our results, cereal fields, but also water points, should be near or within suitable wooded matorral as already reported by Whittingham & Evans (2004). Such conservation prescriptions would enable the birds to adapt rapidly to prevailing conditions within release sites.

To our knowledge, this is the first study that highlights the association of Double-spurred Francolins with cereal fields. It will therefore be interesting to continue monitoring the Double-spurred Francolins at RRAS, especially to discover more about their ecology and dynamics. Further multi-scale studies will also be valuable to improve our understanding of landscape-level processes and the effects of biotic factors on the processes of habitat selection and especially on population viability. As suggested by Winnard *et al.* (2013) knowledge of habitat suitability thresholds at predator-free locations will also be important for selecting appropriate reintroduction sites in the future. Finally, in view of the fact that francolins breed in RRAS, we believe it is important to continue our work in order to enhance our knowledge on habitat use, nest habitat selection, productivity and survival of Double-spurred Francolins.

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