



What species-specific traits make a bird a better surrogate of native species richness? A test with insular avifauna

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ABSTRACT

Identification of species-specific traits that make a species a better surrogate of biodiversity is a need in order to implement successful conservation programmes in the face of limited data and resources. This study analyzes the relationship between the abundance of different surrogate species and species richness for terrestrial native avifauna of autochthonous steppe and semiarid environments in Fuerteventura Island (Spain) at different spatial grains, and explores which species-specific ecological traits (body mass, ecological density, habitat breadth, coverage of urban and agricultural environments) and conservation features (endemicity, conservation status) make a species more efficient as a surrogate. Results indicate that abundance of those surrogate species which are typically targeted by local conservation managers (according to their rarity and increase public awareness) proves to be a poor predictor of three different measures of species richness of the native terrestrial avifauna of Fuerteventura at all spatial resolutions. Nonetheless, some species were found to perform better than others according to partial least squares regression analyses applied to relate species-specific ecological traits and conservation features with correlation coefficients between abundance of each bird species and total bird richness. The best surrogates for global bird species richness are those smaller birds of medium–high abundances, broad habitat preferences, less threatened status, and with a high degree of endemicity. No scale-dependency was observed in the surrogacy power of species. Conservation planners in island scenarios should use a selection of bird species with these characteristics to identify conservation target areas in order to maximize the efficiency of surrogacy approaches.

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1. Introduction

Surrogate species approaches, including flagship, focal, key-stone, indicator, and umbrella, allow conservationists to identify land needing protection based on the requirements of a small number of species (Caro, 2010; Caro and O'Doherty, 1999; Favreau et al., 2006; Lambeck, 1997; Verissimo et al., 2010). In practice, surrogates are typically used as aids to identifying areas of species richness at a large geographic scale and as a mean of encompassing populations of co-occurring species at a local scale.

Despite being introduced decades ago, the effectiveness of different types of surrogate species approaches is still debated (Bried et al., 2007; Favreau et al., 2006; Rodrigues and Brooks, 2007; Wiens et al., 2008), and some authors claim that their utility in conservation planning may be limited (Andelman and Fagan, 2000; Caro et al., 2004). Roberge and Angelstam (2004) evaluated

eighteen research papers and concluded that single-species umbrellas cannot ensure the conservation of all co-occurring species because some species are inevitably limited by ecological factors that are not relevant to the umbrella species. Favreau et al. (2006) tried to develop guidelines for recognizing conditions under which surrogate species approaches could be effective. They concluded that no consensus exists on what species are protected by surrogate approaches and what attributes make good surrogate species, although potential criteria for selection of surrogate species include rarity, sensitivity to human disturbance, and high percentages of co-occurrence with other species. They also propose that the science of surrogate species can progress by taking advantage of data-rich regions with exhaustive data, incorporating spatial scale as an explanatory variable and seeking patterns that will lead to hypothesis driven research. Moreover, in a recent review of the state of the art, Rodrigues and Brooks (2007) compared results of surrogate effectiveness from 575 tests in 27 studies and found an overall positive, but relatively weak, surrogacy power, although some studies reported no surrogacy power at all.

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This study aims to explore the relationship between the abundance of different surrogate species and species richness for terrestrial insular avifauna in Fuerteventura Island (Spain), at different spatial grains. Instead of suggesting a new definition of flagship species based on methodologies from social marketing or environmental economics (e.g., Verissimo et al., 2010), we focus on which species-specific ecological traits (body mass, ecological density, habitat breadth, coverage of urban and agricultural environments) and conservation features (endemism, conservation status) make a species more efficient as a surrogate. Fuerteventura island provides an appropriate scenario to examine the biological characteristics of good surrogate species of local avian biodiversity, due to its combination of: (a) relatively high environmental homogeneity of the study area in terms of topography, climate, soil or vegetation across the island, but with geographical areas differentially threatened by urban sprawl (depending on tourism interests); and (b) an impoverished avifauna with a broad spectrum of ecological characteristics, ranging from extremely common species present throughout the Western Palaearctic, to local endemics only present in this island. Specifically, we addressed the following questions: (1) is the abundance of specific surrogate species a good predictor of native bird species richness? (2) which species-specific ecological traits and conservation features make a species more efficient in representing overall species richness? and (3) is the surrogacy power affected by the spatial scale at which a study is conducted? Our study provides a unique set up to test the effectiveness of surrogate species in representing overall species richness within

insular environments with high levels of endemism. Furthermore, questions (2) and (3) have been scarcely investigated in the literature (but see Bani et al., 2006; Banks-Leite et al., 2011; Fleishman et al., 2000; Gaspar et al., 2010). To our knowledge, this is the first study that explores in depth the species-specific attributes that make species better surrogates to be used as shortcuts to help ensure good bird biodiversity measurements with minimal expenditures.

2. Material and methods

2.1. Study area and organisms

Fuerteventura lies in the eastern part of the Canary archipelago (the second largest island: 1730 km²; 28°27'N, 14°00'W), only 100 km far from the North-African coast (Fig. 1). Its smooth relief (highest altitude: 807 m) is in accordance with its ancient geological history (20–22 million years) and subsequent erosion, since the volcanic activity of the island is almost extinct. The degree of development of vegetated areas is determined by local conditions, such as humidity, slope of terrain, soil characteristics (from stony lava fields to loose sand dunes), goat grazing, and human uses (Fernández-Palacios and Martín, 2001). The plant communities mostly consist of a few species of xerophytic shrubs (*Launaea arborescens*, *Lycium intricatum*, *Salsola vermiculata*, *Suaeda* spp. and *Euphorbia* spp.), therophytic forbs and several perennial grass species. The only natural woodlands are small and patchily located

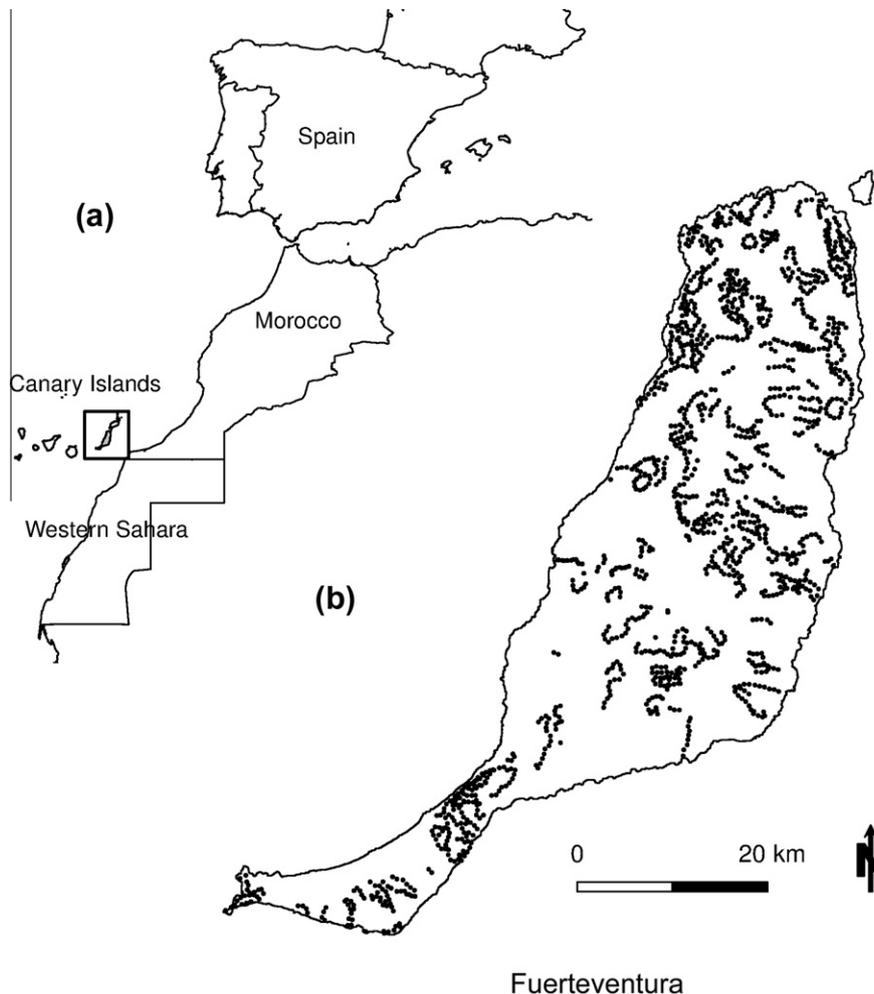


Fig. 1. (a) Location of Fuerteventura Island (Canary archipelago) and; (b) locations of the center of each 0.5-km line transect within the island.

Table 1
Species data for the terrestrial birds in Fuerteventura island including correlations between densities of each study species and total species richness at three spatial grain categories (0.5-km line transect, and spatial units of 2 × 2 and 4 × 4 km²), species-specific traits and conservation features. Data obtained from Seoane et al. (2011).

Species	CODSPP	SRDB ^a	Surrogate ^b	r spp. abundance – spp. richness			ENDEM ^c	MASS ^d	DENS ^e	HB ^f	URBAN ^g	AGRIC ^h
				0.5 km	2 × 2 km	4 × 4 km						
<i>Anthus berthelotii</i>	ANTBER	0		0.51	0.40	0.35	3	16.5	50.4	0.77	0.3	15.9
<i>Bucanetes githagineus</i>	BUCGIT	3		0.35	0.18	0.36	1	18.1	46.0	0.62	0.5	22.3
<i>Burhinus oedicnemus</i>	BUROED	3		0.15	0.18	−0.01	2	461.0	3.5	0.51	0.0	35.7
<i>Buteo buteo</i>	BUTBUT	1		0.15	0.23	0.32	2	806.5	0.8	0.44	0.0	21.0
<i>Calandrella rufescens</i>	CALRUF	3		0.18	0.27	0.16	1	23.3	94.0	0.54	0.0	35.4
<i>Carduelis cannabina</i>	CARCAN	0		0.29	0.21	0.01	2	17.6	22.5	0.55	8.7	9.8
<i>Chlamydotis undulata</i>	CHLUND	3	X	0.08	0.19	0.01	1	1245.0	1.0	0.23	0.0	29.6
<i>Corvus corax</i>	CORCOX	3		0.23	0.31	0.46	2	1250.0	0.7	0.81	0.0	18.9
<i>Cursorius cursor</i>	CURCUR	3	X	0.04	0.04	−0.13	1	108.0	5.4	0.20	0.0	0.0
<i>Cyanistes teneriffae</i>	CYATEN	3		0.18	0.22	0.18	3	11.3	16.8	0.34	4.1	33.0
<i>Falco tinnunculus</i>	FALTIN	2		0.15	0.21	0.34	2	174.5	2.9	0.32	0.0	42.5
<i>Lanius meridionalis</i>	LANEXC	0		0.33	0.28	0.33	1	63.5	6.8	0.80	1.4	15.7
<i>Neophron percnopterus</i>	NEOPER	3	X	0.08	0.31	0.16	2	2035.0	0.3	0.39	0.0	24.3
<i>Pterocles orientalis</i>	PTEORI	2	X	0.08	0.20	0.01	1	474.0	6.7	0.43	0.0	14.6
<i>Saxicola dacotiae</i>	SAXDAC	3	X	0.38	0.19	0.23	3	16.5	26.4	0.39	0.0	7.3
<i>Serinus canarius</i>	SERCAN	0		0.08	0.17	0.33	3	15.3	4.0	0.33	4.0	55.4
<i>Streptopelia turtur</i>	STRTUR	2		0.14	0.19	0.25	1	125.0	39.6	0.18	1.4	32.6
<i>Sylvia conspicillata</i>	SYLCON	0		0.50	0.47	0.44	2	9.5	37.7	0.57	0.2	16.9
<i>Sylvia melanocephala</i>	SYLMEL	0		0.20	0.17	0.31	1	11.2	46.8	0.21	0.6	23.2
<i>Upupa epops</i>	UPUEPO	0		0.34	0.29	0.26	1	59.8	3.8	0.81	1.3	21.2

^a Categories of the Spanish Red Data Book (Madroño et al., 2005): 3 = “endangered”; 2 = “vulnerable”; 1 = “near threatened”; 0 = “non-threatened”.

^b X denotes those surrogate species of autochthonous Fuerteventura steppe and semiarid lands according to their emblematic character, stenotopic habitat preferences, rarity and conservation status.

^c Degree of endemism: 1 = autochthonous taxa shared with continental areas; 2 = endemic subspecies for the Canary Islands or the larger Macaronesia region; 3 = endemic species for the Canary Islands or Macaronesia.

^d Body mass (g).

^e Maximum ecological density (in birds/km²) in the major habitat types was used as a measure of the maximum ecological abundance a species can attain in its most favorable environment in Fuerteventura.

^f Habitat breadth of habitat distribution was calculated using the Levins index in the 12 main habitats of the island.

^g Weighted average of the coverage of urban areas (%) in those sampling units where each species was detected.

^h Weighted average of the coverage of agricultural environments (%) in those sampling units where each species was detected.

tamarisk (*Tamarix canariensis*) and palm (*Phoenix canariensis*) groves. The landscape has been extensively grazed (mainly by goat herds) and cultivated for many years, although in many areas the agricultural and farming activities have been progressively abandoned during last decades.

This paper refers to the native terrestrial avifauna inhabiting the autochthonous steppe and semiarid environments of Fuerteventura. Thus, we have discarded from our analyses introduced species (*Alectoris barbara*, *Myiopsitta monachus*, *Psittacula krameri*, *Streptopelia roseogrisea*), or those mainly restricted to urban (*Streptopelia decaocto*, *Carduelis carduelis*, *Passer hispanicus*, *Columba livia* var. *domestica*) or agricultural areas (*Coturnix coturnix*, *Miliaria calandra*). Twenty species of native terrestrial avifauna, with enough data to estimate absolute densities (see below), were finally considered (Table 1).

Several parameters describing their body size, habitat preferences (habitat breadth, occupation of anthropogenic environments), maximum ecological abundance, degree of endemism and Spanish conservation status were obtained from a revision of the ecological rarity and conservation status of the avifauna of the Canary archipelago (Seoane et al., 2011; Table 1).

Surrogate species can be defined in a variety of ways, including species with legal protection (Favreau et al., 2006). For the purpose of this paper, we defined as surrogates those species which are typically targeted by local conservation managers because of their stenotopic habitat preferences, needs of large tracts of well preserved habitat, rarity, increase public awareness of conservation issues, or rally support for the protection of the steppe and semi-arid habitats in Fuerteventura. According to this definition, five species were selected as potential surrogates of bird biodiversity in Fuerteventura island (see Table 1).

2.2. Bird field data

Breeding bird surveys were carried out in March 2005 and 2006. A total number of 1184 line transects of 0.5-km (geolocated and measured by means of portable GPSs) were performed across the whole island (Fig. 1), including all of the main non-urban habitats present in the island: barren lava fields, shrubby steppe-like plains, stony/sandy desert areas, traditional cultivations, hilly/mountain slopes, and gullies/valleys. The survey method was the line transect, frequently used in extensive assessments of abundance, general distribution patterns and habitat preferences of birds (Bibby et al., 2000). Line transects were carried out on windless and rainless days, walking cross-country or on dirt tracks at a low speed (1–3 km/h approximately), during the first 4 h after dawn and the two and a half hours before dusk. Bird censuses were carried out by LMC, DP, JS and César Alonso in 2005, and by LMC, DP, JS in 2006. The starting point of the first transect was randomly determined and then the rest of transects were performed successively (from 3 to 10).

Population densities were estimated using distance sampling (Thomas et al., 2002; Buckland et al., 2004). For each bird heard or seen belonging to the studied 20 species, the perpendicular distances from the transect line at which birds were detected was estimated (overflying birds were disregarded). Previous training with a laser range-finder helped to reduce inter-observer variability in distance estimates. The number of individuals was estimated with distance sampling methods, first building a model for the detectability of the species, and then considering the actual counts adjusted for this previous model. For calculating the detection models, outliers of the frequency distribution of detection distances were excluded as recommended by Buckland et al. (2004;

i.e., deleting 1–5% of most distant birds detected). Several distribution models were fitted, all of them commonly used to explain the loss of detectability as a function of the distance from the transect line (the further the distance, the lower the probability of detecting a given individual), and the respective probabilities of detection within strips of width equal to the truncated distance were estimated. Models were evaluated according to AICc and derived Akaike weights (Burnham and Anderson, 2002). Detectability models were built with Distance 5.0 software (<http://www.ruwpa.st-and.ac.uk/distance/>). There were no significant differences among researches in detectability patterns for the 20 studied species ($p > 0.1$ after applying Bonferroni correction). Population densities for each species were expressed in birds/km².

Line transects were aggregated into two different spatial grains: 2×2 km and 4×4 km. The number of 0.5-km transects included in each 2×2 km and 4×4 km cell-size grid was not the same for all the cell units due to logistic and accessibility problems. A minimum number of transects of five was considered in order to estimate reliable average measures of bird density within each cell.

2.3. Statistical data analyses

2.3.1. Association between species richness and species-specific densities

Three different measures of species richness have been considered: total species richness of native terrestrial avifauna inhabiting the autochthonous steppe and semiarid environments of Fuerteventura (maximum of 20 spp.); richness of endemic taxa (endemic species or subspecies for the Canary Islands or Macaronesia; maximum of 11 spp.); and richness of endemic + threatened taxa (endemic species or subspecies and considered as endangered or vulnerable by the Spanish Red Data Book, Madroño et al., 2005; maximum of 6 spp.). The groups of endemic and endemic + threatened taxa have been constructed considering their functional traits in the light of management purposes (endemicity and conservation status; see Bishop and Myers, 2005, and Caprio et al., 2009 for a similar approach using specific guilds). On the other hand, total bird species richness might not be inversely related to environmental degradation or perturbation gradients, but only the richness of some particular groups of species (Devictor et al., 2008; Maas et al., 2009).

The intensity of association between the abundance of each species and the three measures of species richness was examined by means of Pearson's correlations at different spatial resolutions: 0.5-km transects, 2×2 km and 4×4 cell-size grids (richness values do not include the presence of the targeted species). Partial correlations were obtained between species abundances and species richness controlling for the effect of number of transects made within each cell unit (in log; considering the widely recognized logarithmic relationship between the number of species registered and the sampling effort). This was not necessary for the spatial resolution of 0.5-km transects, as every sample unit had exactly the same size. Significance of these correlations was not obtained considering the inflation of error type-I when estimating a large amount of correlations ($20 \text{ spp.} \times 3 \text{ measures of species richness} \times 3 \text{ spatial resolutions} = 180 \text{ correlations}$), and that we were only interested in an index of the intensity of association between the abundance of each species and species richness.

2.3.2. Species-specific variation in prediction success of total bird species richness

Interspecific differences in the intensity of association between the abundance of each species and total species richness at three different spatial grains were related to species-specific ecological traits and conservation features by means of partial least squares regressions (hereafter PLSR; Garthwaite, 1994) using the species

as the sample unit ($n = 20$). Results obtained with PLSR are similar to those from conventional multiple regression techniques; however, it is extremely robust to the effects of sample size and degree of correlation between predictor variables, which makes PLSR especially useful in cases of low sample size and severe multicollinearity (Carrascal et al., 2009). Associations with the response variable are established with factors extracted from predictor variables that maximize the explained variance in the dependent variable. These factors are defined as linear combinations of independent variables, so the original multidimensionality is reduced to a lower number of orthogonal factors, and they can be interpreted as weighted averages of predictors, where each predictor holds the residual information in an explanatory variable that is not contained in earlier factors. The meaning of each component was interpreted considering the weights (w_i) attained by the predictor variables. Weights of predictor variables indicate the sign of association, and the magnitude effect, of each predictor within each analyzed spatial grain. The addition of the squares of the weights within each component adds up to one, so the contribution of each predictor variable to the meaning of each component can be easily estimated. Only those components significant after a fivefold validation procedure were retained (only the first PLSR component for each spatial grain attained significance – $p < 0.05$). The comparison of the relative contribution of each predictor variable across the three spatial grains was made using the product of the square of predictor weights by the explained variance of each component (R^2 ; relative contribution within each component = $R^2 \cdot w_i^2$).

All statistical analyses were carried out using Statistica 9.1 (StatSoft, 2010).

3. Results

3.1. Association between species richness and species-specific densities

Correlations between densities of each study species and total species richness at three spatial grains show a very large interspecific variation, ranging from -0.13 to $+0.51$ (Table 1). Average correlations for the 20 studied species are very similar across the three spatial grains (ranging between 0.22 and 0.24; repeated measures ANOVA: $F = 0.18$, $df = 2, 38$, $p = 0.833$). *Anthus berthelotii* (an endemic Macaronesian taxa) and *Sylvia conspicillata* (an endemic Canary subspecies) are the two species with the highest correlations between their respective abundances and total species richness at three spatial grains. Conversely, two out the five surrogates, *Cursorius cursor* and *Chlamydotis undulata*, are the species whose abundances are less correlated with total species richness of the native terrestrial avifauna inhabiting the autochthonous steppe and semiarid environments of Fuerteventura.

Correlations between species-specific abundances and total species richness in autochthonous steppe and semi-arid lands of Fuerteventura are generally lower for the five surrogate species, reaching the significance level for the 4×4 km spatial grid (one-way ANOVA test: $p = 0.006$, $df = 1, 18$, Fig. 2).

Repeating the analyses for the other two measures of species richness (endemic and endemic + threatened taxa) we obtain nearly the same results (Table 2 and Fig. 3). Average correlations for the 20 studied species are very similar across the three spatial grains and the two measures of species richness (ranging between 0.19 and 0.21 for endemic taxa, repeated measures ANOVA: $F = 0.24$, $df = 2, 38$, $p = 0.789$; ranging between 0.15 and 0.17 for endemic + threatened taxa, repeated measures ANOVA: $F = 0.27$, $df = 2, 38$, $p = 0.766$). *A. berthelotii*, *Saxicola dacotiae* (an endemic species only restricted to Fuerteventura) and *S. conspicillata* showed the highest correlations with richness of endemic taxa,

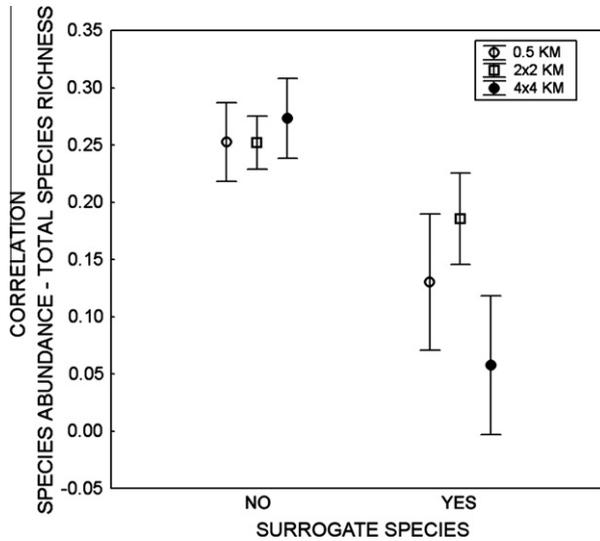


Fig. 2. Mean (\pm one standard error) of correlations between species-specific abundances and total bird species richness for 20 bird species inhabiting Fuerteventura island at three spatial scales, and using five surrogate (emblematic species representative of autochthonous steppe and semiarid lands) vs the remaining 15 species (see Table 1).

while *Corvus corax*, *Falco tinnunculus* (two subspecies endemic of the Canary Islands) and *S. dacotiae* reached the highest correlations with richness of endemic + threatened taxa. Correlations between species-specific abundances of each bird species and the species richness of endemic taxa are generally lower for the five surrogate species than for the remaining 15 species (Fig. 3a), reaching the significance level in one-way ANOVA tests for the spatial grains 2×2 km ($p = 0.046$) and 4×4 km ($p = 0.030$). No significant differences are detected when comparing surrogate vs non-surrogate species for richness of endemic + threatened taxa (one-way ANOVA tests: $p > 0.1$ for the three spatial grids, $df = 1, 18$ in all tests), although average correlations of species abundances with species richness was generally lower for surrogate species.

Table 2

Correlations between densities of each study species and species richness of endemic and endemic + threatened taxa at three spatial grain categories (0.5-km line transect, and spatial units of 2×2 and 4×4 km²). See Table 1 for endemic and threatened (endangered and vulnerable) taxa.

Species	Endemic taxa			Endemic + threatened taxa		
	0.5 km	2×2 km	4×4 km	0.5 km	2×2 km	4×4 km
<i>Anthus berthelotii</i>	0.55	0.36	0.29	0.13	0.19	0.10
<i>Bucanetes githagineus</i>	0.26	0.18	0.32	0.18	0.05	0.25
<i>Burhinus oedicnemus</i>	0.16	0.14	-0.12	0.31	0.25	0.05
<i>Buteo buteo</i>	0.21	0.22	0.32	0.03	0.07	0.12
<i>Calandrella rufescens</i>	-0.06	0.06	-0.05	-0.11	0.00	-0.01
<i>Carduelis cannabina</i>	0.35	0.22	0.11	0.11	0.03	-0.07
<i>Chlamydotis undulata</i>	-0.02	-0.08	-0.22	-0.01	-0.01	-0.15
<i>Corvus corax</i>	0.28	0.27	0.41	0.41	0.32	0.40
<i>Cursorius cursor</i>	-0.07	-0.03	-0.20	-0.05	0.04	-0.07
<i>Cyanistes teneriffae</i>	0.20	0.31	0.35	0.33	0.31	0.25
<i>Falco tinnunculus</i>	0.18	0.34	0.28	0.38	0.40	0.29
<i>Lanius meridionalis</i>	0.10	0.09	0.26	0.18	0.04	0.22
<i>Neophron percnopterus</i>	0.13	0.33	0.25	0.05	0.38	0.30
<i>Pterocles orientalis</i>	-0.09	-0.01	-0.10	-0.05	0.00	-0.11
<i>Saxicola dacotiae</i>	0.49	0.30	0.34	0.56	0.21	0.26
<i>Serinus canarius</i>	0.12	0.32	0.39	0.02	0.27	0.24
<i>Streptopelia turtur</i>	0.09	0.22	0.30	0.18	0.23	0.29
<i>Sylvia conspicillata</i>	0.56	0.39	0.34	0.19	0.20	0.16
<i>Sylvia melanocephala</i>	0.14	0.28	0.42	0.19	0.23	0.30
<i>Upupa epops</i>	0.14	0.23	0.11	0.07	0.18	0.13

3.2. Species-specific variation in prediction success of total bird species richness

There is a broad interspecific variation in several parameters describing their body size, habitat preferences (habitat breadth, occupation of anthropogenic environments), abundance, degree of endemism and conservation status (Table 1). These species-specific ecological traits significantly explain the interspecific variation in the degree of association between total bird species richness and species-specific abundance (Table 3). In general, there is a high consistency among spatial grains in the influence of species-specific traits determining high levels of association between species' abundances and total species richness. There is a positive influence of the endemism degree, and negative effects of the threat status and body mass on the ability of species' abundances to correlate with total bird species richness. Habitat breadth and maximum population density of species are positively associated with the ability of species to produce good predictions of total species richness. Other species-specific ecological traits related to occupation of environments of anthropogenic origin do not have a consistent and high influence on the ability of a particular species to be a good surrogate of total species richness. Position of the 20 studied species in the PLS components are highly correlated across the three studied spatial grains (Pearson correlations ranging from 0.61 and 0.64 for the three estimable correlations, $p < 0.004$). The potential of the species with high endemism, low threat status, broad habitat preferences and high abundance in the preferred habitats to provide good predictions of total species richness, diminishes with increasing the spatial grain, as R^2 of the PLS models diminishes from 0.5 km transects to 4×4 km grid (Table 3). The five surrogate species selected *a priori* are not included within the five species that attain the highest scores in the PLS components in any of the analyzed spatial grain.

4. Discussion

Relative abundance of surrogate species is a poor predictor of the whole richness of native terrestrial avifauna, or of richness of endemic or endemic-and-threatened taxa inhabiting the

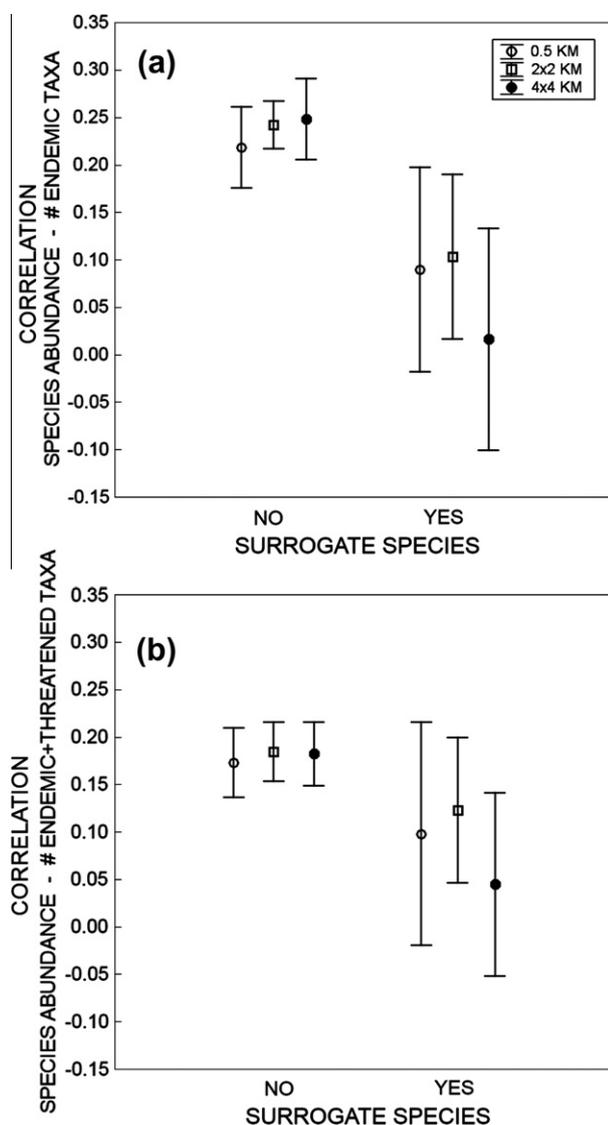


Fig. 3. Mean (\pm one standard error) of correlations between species-specific abundances and species richness of (a) endemic and (b) endemic + threatened taxa for 20 bird species inhabiting Fuerteventura island at three spatial scales, and using five surrogate (emblematic species representative of autochthonous steppe and semiarid lands) vs the remaining 15 species (see Table 1).

autochthonous steppe and semiarid environments of Fuerteventura. This result casts doubts about the usefulness of particular surrogate species as proxies for conservation programs with the whole native avifauna of semiarid lands in Fuerteventura Island. This paper reinforces the idea, supported by other papers in continental areas, that umbrella and flagship schemes are questionable as a quantitative ecological tool to guide the maximization of conservation of regional native fauna in the face of limited time, personnel and funding (Andelman and Fagan, 2000; Bried et al., 2007; Tognelli, 2005; Williams et al., 2000). Nevertheless, and although surrogates imperfectly represent overall species richness, finite resources limit the number of species that can be studied and decisions necessarily must be made with limited data (Favreau et al., 2006). As an applied aid to solve this concern, this study also shows that some species were better surrogates than others, and if any has to be used, then any criteria that helps to select surrogates will increase the chances and degree of success when implementing conservation programmes.

Among the selected surrogates, the houbara bustard (*C. undulata*) and the cream-colored courser (*C. cursor*) serve as a

Table 3

Partial least squares (PLS) regression models analyzing the interspecific variation in the correlations between species-specific abundances and total bird species richness, and several traits describing body size, habitat preferences, abundance, degree of endemism and conservation status of 20 bird species inhabiting autochthonous steppe and semiarid lands of Fuerteventura island. The analyses are carried out at three spatial grains. PLS components for each spatial scale are defined according to predictor weights (w_i ; square weights add to one within each component). Marked in bold are those variables for each spatial scale explaining more than 5% of the interspecific variation in the correlations between species-specific abundances and total bird species richness (calculated multiplying the R^2 of each model by the square of each weight: $R^2 \cdot w_i^2$). The first five species attaining the highest scores in the first component of each PLS are shown (see Table 1 for acronyms).

	0.5 km transects	2 × 2 km	4 × 4 km
Endemicity index (ENDEM)	0.22	0.29	0.34
Maximum density (DENS)	0.34	0.29	0.25
Body mass (ln; MASS)	-0.49	-0.14	-0.35
Habitat breadth (HB)	0.58	0.76	0.57
Coverage of urban areas (URBAN)	0.03	-0.15	-0.20
Coverage of agricultural environments (AGRIC)	-0.31	-0.06	0.29
Spanish Red Data Book (SRDB)	-0.40	-0.46	-0.50
R^2 for PLS	0.746	0.508	0.426
p	<0.001	<0.001	0.002
1st Highest score in PLS component	ANTBER	ANTBER	ANTBER
2nd Highest score in PLS component	SYLCON	SYLCON	SYLCON
3rd Highest score in PLS component	CARCAN	LANEXC	SERCAN
4th Highest score in PLS component	LANEXC	UPUEPO	UPUEPO
5th Highest score in PLS component	UPUEPO	CARCAN	LANEXC

wildcard for several purposes including their role as charismatic species attracting public attention, their value for monitoring conservation problems, their endangered status or their potential for identifying the habitat characteristics of the studied environment that may encapsulate the needs of other species inhabiting well preserved steppe and semiarid environments of Fuerteventura (see Carrascal et al., 2008a; Palomino et al., 2008). Therefore, they might function as good keystone species (*sensu* Simberloff, 1998) helping in the management and conservation of native avifauna and natural landscapes. Nevertheless, their spatial variation in population density at three very different spatial grains show very low figures of correlation coefficients with the three measures of species richness of native birds (total, endemic and endemic-and-threatened species; see Table 1). Their habitat preferences are so specialized according to habitat structure and lithological characteristics (mainly the courser), they are so sensible to habitat fragmentation introduced by urban developments, agricultural activities and roads (mainly the houbara), and their regional areas of distribution are subjected to local processes of extinction-colonization (both species), that these species would unlikely offer relatively high conservation coverage for other native species, largely due to lack of commonality in land-cover affinity (see also Rowland et al., 2006). Therefore, areas of importance for these species tend to be located in different places compared to the other members of the same bird community, and thus none of *a priori* selected surrogate species should be used as an indicator or umbrella group to protect the others (see also Estrada et al., 2011 for four different vertebrate groups in the western Mediterranean region).

After analyzing a broad array of 20 native species inhabiting semi-arid environments of Fuerteventura, the best surrogate species for the global bird biodiversity are those smaller species of broad habitat preferences (opposite of the 'indicator' species concept), relatively abundant and less threatened (opposite of the 'flagship' species concept), and with a higher degree of endemism. Smaller bird species usually attain high maximum regional abundances according to the inverse allometric relationship 'body

mass–population density' (Carrascal and Tellería, 1991). Therefore, they are more easily censused, due to their higher densities, in inventories that require a thorough exploration of species present throughout a region implying a stratified or random survey of many areas (Williams et al., 2002). On the contrary, large-sized bird species are scarcer, and have greater extinction risks due to the intense allometric relationship of body mass with fecundity or age at first breeding attempt (Brown et al., 2004; Gaston and Blackburn, 1995; Hendriks, 2007), so they are more prone to local extinctions due to stochastic phenomena or human impacts which are especially adverse on small islands. Therefore, large bird species have a lower probability of being adequately recorded under temporally restricted census programs, and are less likely to co-occur with richer subsets of the whole avifauna of a region.

Habitat breadth explains a large proportion of interspecific variability in the intensity of association between total species richness and species-specific population densities. Bird species with small habitat breadth cannot tolerate a relatively wide range of ecological conditions and are restricted to some particular habitats of reduced extent, making them poor candidates for identifying a broad diversity of environmental conditions that are representative of the biota or landscape under investigation for conservation or management purposes. Moreover, stenotopic species in the Canary Islands have a low range occupancy, both measured as the number of occupied islands in the entire archipelago or as 10×10 km UTM squares occupied within each island (Carrascal et al., 2008b; see also Hurlbert and White, 2007 and Swihart et al., 2003 for continental areas). For example, three of the selected surrogates (houbara bustard, cream-colored courser, and black-bellied sandgrouse, *Pterocles orientalis*) show very striking habitat preferences for sandy or denuded soils with a low cover of stones or bare volcanic bedrock, located in areas with low slope of the terrain (Carrascal et al., 2008a; Palomino et al., 2008; Seoane et al., 2010a), while the only endemic species restricted only to Fuerteventura, the Canary stonechat, *S. dacotiae*, has opposite habitat preferences for rocky or stony soil in areas of high grade (Seoane et al., 2010b). These orographic and lithological attributes of the landscape are not shared with many other native, even endemic, species of broad habitat breadth in Fuerteventura (see Table 1). The importance of habitat breadth of species influencing total species richness of native terrestrial bird species inhabiting the steppe and semiarid environments of Fuerteventura could be interpreted as a consequence of homogenization of bird communities derived from the perturbation of autochthonous environments, or due to the fact that the region has become more similar in the landscape features (e.g., Devictor et al., 2008; van Turnhout et al., 2007). Avian homogenization is usually linked with very widespread species not showing negative responses to landscape fragmentation or disturbance associated with human activities (Olden et al., 2004; McKinney, 2006). Thus, selection of species with broad habitat breadth as surrogate of total species richness would have a negative influence on conservation prioritization (Rooney et al., 2007). Nevertheless, this is not the case with the birds of autochthonous dry environments of Fuerteventura, as species-specific ecological traits that make a species more efficient as a surrogate of total richness of native species are not positively and intensely related to cover of urban areas or agricultural environments. Moreover, three of the best surrogates of avian biodiversity in the island are taxa with an endemic status (specific, *A. berthelotii*; subspecific, *Carduelis cannabina harterti* and *S. conspicillata orbitalis*; see Table 3).

Bird species with high degree of endemism in the Canary Islands or the Macaronesian region, are good candidates as surrogates for species richness of native avifauna in the semi-arid environments of Fuerteventura Island. Their presence in the landscape may represent clear indications of evolutionary processes

generating island biodiversity (Whittaker and Fernández-Palacios, 2007), therefore enhancing their role as surrogates to build a conservation network for overall species richness. On the other hand, the conventional use of endangered taxa as surrogate species for measuring biodiversity and prioritization of conservation effort are of poor value in the avifauna of Fuerteventura (see also Ficetola et al., 2007). This lack of association probably emerges because species-specific differences in the response to the same source of disturbance are strong (see Gangoso et al., 2006). On the other hand, Martín (2009) has questioned the application of common global thresholds (and regional guidelines) to label species as threatened in the Canary Islands. Therefore, interspecific differences in the response to threatening processes and the uncertainty defining a proper threat status using national red lists, may hinder the usefulness of surrogates based upon threat status.

Scale is also an important issue because associations between surrogate taxa and species richness might depend on the grain at which these variables are measured. No scale-dependency was observed in the surrogacy power of the selected species of semi-arid and steppe environments of Fuerteventura from small spatial grains covered by 0.5 km transects to 4×4 km 'pixels'. The general consensus is that patterns of global species richness correspond less with distribution patterns of surrogate species at finer scales of resolution (Garson et al., 2002), although Laiolo et al. (2011) have recently found that the occurrence of an indicator of forest functioning and diversity (capercaillie) at a regional scale was not associated with avian community diversity of forest patches, but at the local scale of male spring territories, the sexual display arenas hosted the richest local bird communities. Consequently, conservation managers, at least in the studied insular context, do not have to worry much about the grain at which conservation planning is conducted, although finer scales will obviously provide a much better depiction of the conservation problems at hand.

In conclusion, relative abundance of surrogate species according to their threat status, emblematic or representative character is a poor predictor of the whole species richness of native bird species inhabiting steppe and semi-arid lands of Fuerteventura Island. The best surrogate taxa for species richness of native avifauna are those smaller birds of medium–high abundances, broad habitat preferences, less threatened status, and with a high degree of endemism (at the subspecific or specific level). The species with these characteristics can be easily obtained from regional works dealing with bird distribution, such as quantitative ornithological atlases. Conservation planners in island scenarios should use a selection of species with these characteristics to identify conservation target areas with the highest species richness of native avifauna, in order to avoid the stochasticity introduced by other more usual umbrella or flagship species considering their emblematic character and rarity, due to the higher costs associated to the census of scarce species, their higher probabilities of local extinctions or their specificity in habitat preferences.

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