

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

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14

15 **Abstract**

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

38

39 **Keywords:** birds; Canary Islands; interspecific differences; species-specific traits;
40 species richness; surrogate species.

41 **1 Introduction**

42 Surrogate species approaches, including flagship, focal, keystone, indicator, and
43 umbrella, allow conservationists to identify land needing protection based on the
44 requirements of a small number of species (Caro, 2010; Caro and O’Doherty, 1999;
45 Favreau et al., 2006; Lambeck, 1997; Simberloff, 1995; Verissimo et al., 2010). In
46 practice, surrogates are typically used as aids to identifying areas of species richness at a
47 large geographic scale and as a mean of encompassing populations of co-occurring
48 species at a local scale.

49 Despite being introduced decades ago, the effectiveness of different types of
50 surrogate species approaches is still debated (Bried et al., 2008; Fraveau et al., 2006;
51 Rodrigues and Brooks, 2007; Wiens et al., 2008), and some authors claim that their
52 utility in conservation planning may be limited (Andelman and Fagan, 2000; Caro et al.,
53 2004). Roberge and Angelstam (2004) evaluated eighteen research papers and
54 concluded that single-species umbrellas cannot ensure the conservation of all co-
55 occurring species because some species are inevitably limited by ecological factors that
56 are not relevant to the umbrella species. Favreau et al. (2006) tried to develop guidelines
57 for recognizing conditions under which surrogate species approaches could be effective.
58 They concluded that no consensus exists on what species are protected by surrogate
59 approaches and what attributes make good surrogate species, although potential criteria
60 for selection of surrogate species include rarity, sensitivity to human disturbance, and
61 high percentages of co-occurrence with other species. They also propose that the
62 science of surrogate species can progress by taking advantage of data-rich regions with
63 exhaustive data, incorporating spatial scale as an explanatory variable and seeking
64 patterns that will lead to hypothesis driven research. Moreover, in a recent review of the
65 state of the art, Rodrigues and Brooks (2007) compared results of surrogate

66 effectiveness from 575 tests in 27 studies and found an overall positive, but relatively
67 weak, surrogacy power, although some studies reported no surrogacy power at all.

68 This study aims to explore the relationship between the abundance of different
69 surrogate species and species richness for terrestrial insular avifauna in Fuerteventura
70 Island (Spain), at different spatial grains. Instead of suggesting a new definition of
71 flagship species based on methodologies from social marketing or environmental
72 economics (e.g., Verissimo et al., 2010), we focus on which species-specific ecological
73 traits (body mass, ecological density, habitat breadth, coverage of urban and agricultural
74 environments) and conservation features (endemicity, conservation status) make a
75 species more efficient as a surrogate. Fuerteventura island provides an appropriate
76 scenario to examine the biological characteristics of good surrogate species of local
77 avian biodiversity, due to its combination of: a) relatively high environmental
78 homogeneity of the study area in terms of topography, climate, soil or vegetation across
79 the island, but with geographical areas differentially threatened by urban sprawl
80 (depending on tourism interests); and b) an impoverished avifauna with a broad
81 spectrum of ecological characteristics, ranging from extremely common species present
82 throughout the Western Palaearctic, to local endemics only present in this island.
83 Specifically, we addressed the following questions: (1) is the abundance of specific
84 surrogate species a good predictor of native bird species richness? (2) which species-
85 specific ecological traits and conservation features make a species more efficient in
86 representing overall species richness? and (3) is the surrogacy power affected by the
87 spatial scale at which a study is conducted? Our study provides a unique set up to test
88 the effectiveness of surrogate species in representing overall species richness within
89 insular environments with high levels of endemicity. Furthermore, questions (2) and (3)
90 have been scarcely investigated in the literature (but see Bani et al., 2006; Banks-Leite

91 et al., 2011; Fleishman et al., 2000; Gaspar et al., 2010). To our knowledge, this is the
92 first study that explores in depth the species-specific attributes that make species better
93 surrogates to be used as shortcuts to help ensure good bird biodiversity measurements
94 with minimal expenditures.

95

96 **2 Material and methods**

97 **2.1 Study area and organisms**

98 Fuerteventura lies in the eastern part of the Canary archipelago (the second
99 largest island: 1730 km²; 28°27' N, 14°00' W), only 100 km far from the North-African
100 coast (Fig. 1). Its smooth relief (highest altitude: 807 m) is in accordance with its
101 ancient geological history (20-22 million years) and subsequent erosion, since the
102 volcanic activity of the island is almost extinct. The degree of development of vegetated
103 areas is determined by local conditions, such as humidity, slope of terrain, soil
104 characteristics (from stony lava fields to loose sand dunes), goat grazing, and human
105 uses (Fernández-Palacios and Martín, 2001). The plant communities mostly consist of a
106 few species of xerophytic shrubs (*Launaea arborescens*, *Lycium intricatum*, *Salsola*
107 *vermiculata*, *Suaeda* spp. and *Euphorbia* spp.), therophytic forbs and several perennial
108 grass species. The only natural woodlands are small and patchily located tamarisk
109 (*Tamarix canariensis*) and palm (*Phoenix canariensis*) groves. The landscape has been
110 extensively grazed (mainly by goat herds) and cultivated for many years, although in
111 many areas the agricultural and farming activities have been progressively abandoned
112 during last decades.

113 This paper refers to the native terrestrial avifauna inhabiting the autochthonous
114 steppe and semiarid environments of Fuerteventura. Thus, we have discarded from our

115 analyses introduced species (*Alectoris barbara*, *Myiopsitta monachus*, *Psittacula*
116 *krameri*, *Streptopelia roseogrisea*), or those mainly restricted to urban (*Streptopelia*
117 *decaocto*, *Carduelis carduelis*, *Passer hispanicus*, *Columba livia* var. *domestica*) or
118 agricultural areas (*Coturnix coturnix*, *Miliaria calandra*). Twenty species of native
119 terrestrial avifauna, with enough data to estimate absolute densities (see below), were
120 finally considered (Table 1).

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

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

134

135 **2.2 Bird field data**

136 Breeding bird surveys were carried out in March 2005 and 2006. A total number
137 of 1,184 line transects of 0.5-km (geolocated and measured by means of portable GPSs)
138 were performed across the whole island (Figure 1), including all of the main non-urban
139 habitats present in the island: barren lava fields, shrubby steppe-like plains, stony/sandy

140 desert areas, traditional cultivations, hilly/mountain slopes, and gullies/valleys. The
141 survey method was the line transect, frequently used in extensive assessments of
142 abundance, general distribution patterns and habitat preferences of birds (Bibby et al.,
143 2000). Line transects were carried out on windless and rainless days, walking cross-
144 country or on dirt tracks at a low speed (1-3 km/h approximately), during the first four
145 hours after dawn and the two and a half hours before dusk. Bird censuses were carried
146 out by LMC, DP, JS and César Alonso in 2005, and by LMC, DP, JS in 2006. The
147 starting point of the first transect was randomly determined and then the rest of transects
148 were performed successively (from 3 to 10).

149 Population densities were estimated using distance sampling (Thomas et al.,
150 2002; Buckland et al., 2004). For each bird heard or seen belonging to the studied 20
151 species, the perpendicular distances from the transect line at which birds were detected
152 was estimated (overflying birds were disregarded). Previous training with a laser range-
153 finder helped to reduce inter-observer variability in distance estimates. The number of
154 individuals was estimated with distance sampling methods, first building a model for
155 the detectability of the species, and then considering the actual counts adjusted for this
156 previous model. For calculating the detection models, outliers of the frequency
157 distribution of detection distances were excluded as recommended by Buckland et al.
158 (2004; i.e., deleting 1-5% of most distant birds detected). Several distribution models
159 were fitted, all of them commonly used to explain the loss of detectability as a function
160 of the distance from the transect line (the further the distance, the lower the probability
161 of detecting a given individual), and the respective probabilities of detection within
162 strips of width equal to the truncated distance were estimated. Models were evaluated
163 according to AICc and derived Akaike weights (Burnham and Anderson, 2002).
164 Detectability models were built with Distance 5.0 software (Thomas et al., 2004). There

165 were no significant differences among researches in detectability patterns for the 20
166 studied species ($p > 0.1$ after applying Bonferroni correction). Population densities for
167 each species were expressed in birds / km².

168 Line transects were aggregated into two different spatial grains: 2x2 km and 4x4
169 km. The number of 0.5-km transects included in each 2x2 km and 4x4 km cell-size grid
170 was not the same for all the cell units due to logistic and accessibility problems. A
171 minimum number of transects of five was considered in order to estimate reliable
172 average measures of bird density within each cell.

173

174 **2.3 Statistical data analyses**

175 *Association between species richness and species-specific densities*

176 Three different measures of species richness have been considered: total species
177 richness of native terrestrial avifauna inhabiting the autochthonous steppe and semiarid
178 environments of Fuerteventura (maximum of 20 spp); richness of endemic taxa
179 (endemic species or subspecies for the Canary Islands or Macaronesia; maximum of 11
180 spp); and richness of endemic+threatened taxa (endemic species or subspecies and
181 considered as endangered or vulnerable by the Spanish Red Data Book, Madroño et al.
182 2005; maximum of 6 spp). The groups of endemic and endemic+threatened taxa have
183 been constructed considering their functional traits in the light of management purposes
184 (endemicity and conservation status; see Bishop and Myers, 2005, and Caprio et al.,
185 2009 for a similar approach using specific guilds). On the other hand, total bird
186 species richness might not be inversely related to environmental degradation or
187 perturbation gradients, but only the richness of some particular groups of species
188 (Devictor et al., 2008; Maas et al., 2009).

189 The intensity of association between the abundance of each species and the three
190 measures of species richness was examined by means of Pearson's correlations at
191 different spatial resolutions: 0.5-km transects, 2x2 km and 4x4 cell-size grids (richness
192 values do not include the presence of the targeted species). Partial correlations were
193 obtained between species abundances and species richness controlling for the effect of
194 number of transects made within each cell unit (in log; considering the widely
195 recognized logarithmic relationship between the number of species registered and the
196 sampling effort). This was not necessary for the spatial resolution of 0.5-km transects,
197 as every sample unit had exactly the same size. Significance of these correlations was
198 not obtained considering the inflation of error type-I when estimating a large amount of
199 correlations (20 spp x 3 measures of species richness x 3 spatial resolutions =180
200 correlations), and that we were only interested in an index of the intensity of association
201 between the abundance of each species and species richness.

202

203 *Species-specific variation in prediction success of total bird species richness*

204 Interspecific differences in the intensity of association between the abundance of
205 each species and total species richness at three different spatial grains were related to
206 species-specific ecological traits and conservation features by means of partial least
207 squares regressions (hereafter PLSR; Garthwaite, 1994) using the species as the sample
208 unit (n = 20). Results obtained with PLSR are similar to those from conventional
209 multiple regression techniques; however, it is extremely robust to the effects of sample
210 size and degree of correlation between predictor variables, which makes PLSR
211 especially useful in cases of low sample size and severe multicollinearity (Carrascal et
212 al., 2009). Associations with the response variable are established with factors extracted
213 from predictor variables that maximize the explained variance in the dependent variable.

214 These factors are defined as linear combinations of independent variables, so the
215 original multidimensionality is reduced to a lower number of orthogonal factors, and
216 they can be interpreted as weighted averages of predictors, where each predictor holds
217 the residual information in an explanatory variable that is not contained in earlier
218 factors. The meaning of each component was interpreted considering the weights (w_i)
219 attained by the predictor variables. Weights of predictor variables indicate the sign of
220 association, and the magnitude effect, of each predictor within each analyzed spatial
221 grain. The addition of the squares of the weights within each component adds up to one,
222 so the contribution of each predictor variable to the meaning of each component can be
223 easily estimated. Only those components significant after a five-fold validation
224 procedure were retained (only the first PLSR component for each spatial grain attained
225 significance $-p < 0.05-$). The comparison of the relative contribution of each predictor
226 variable across the three spatial grains was made using the product of the square of
227 predictor weights by the explained variance of each component (R^2 ; relative
228 contribution within each component = $R^2 \cdot w_i^2$).

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

230

231 **3 Results**

232 **3.1 Association between species richness and species-specific densities**

233 Correlations between densities of each study species and total species richness at
234 three spatial grains show a very large interspecific variation, ranging from -0.13 to
235 +0.51 (Table 1). Average correlations for the 20 studied species are very similar across
236 the three spatial grains (ranging between 0.22 and 0.24; repeated measures ANOVA: F
237 = 0.18, $df = 2, 38$, $p = 0.833$). *Anthus berthelotii* (an endemic Macaronesian taxa) and
238 *Sylvia conspicillata* (an endemic Canary subspecies) are the two species with the

239 highest correlations between their respective abundances and total species richness at
240 three spatial grains. Conversely, two out the five surrogates, *Cursorius cursor* and
241 *Chlamydotis undulata*, are the species whose abundances are less correlated with total
242 species richness of the native terrestrial avifauna inhabiting the autochthonous steppe
243 and semiarid environments of Fuerteventura.

244 Correlations between species-specific abundances and total species richness in
245 autochthonous steppe and semi-arid lands of Fuerteventura are generally lower for the
246 five surrogate species, reaching the significance level for the 4x4 km spatial grid (one-
247 way ANOVA test: $p = 0.006$, d.f. = 1, 18).

248 Repeating the analyses for the other two measures of species richness (endemic
249 and endemic+threatened taxa) we obtain nearly the same results (Table 2 and Figure 3).
250 Average correlations for the 20 studied species are very similar across the three spatial
251 grains and the two measures of species richness (ranging between 0.19 and 0.21 for
252 endemic taxa, repeated measures ANOVA: $F = 0.24$, $df = 2, 38$, $p = 0.789$; ranging
253 between 0.15 and 0.17 for endemic+threatened taxa, repeated measures ANOVA: $F =$
254 0.27 , $df = 2, 38$, $p = 0.766$). *Anthus berthelotii*, *Saxicola dacotiae* (an endemic species
255 only restricted to Fuerteventura) and *Sylvia conspicillata* showed the highest
256 correlations with richness of endemic taxa, while *Corvus corax*, *Falco tinunculus* (two
257 subspecies endemic of the Canary islands) and *Saxicola dacotiae* reached the highest
258 correlations with richness of endemic+threatened taxa. Correlations between species-
259 specific abundances of each bird species and the species richness of endemic taxa are
260 generally lower for the five surrogate species than for the remaining 15 species (Figure
261 3a), reaching the significance level in one-way ANOVA tests for the spatial grains 2x2
262 km ($p = 0.046$) and 4x4 km ($p = 0.030$). No significant differences are detected when
263 comparing surrogate vs non-surrogate species for richness of endemic+threatened taxa

264 (one-way ANOVA tests: $p > 0.1$ for the three spatial grids, d.f. = 1, 18 in all tests),
265 although average correlations of species abundances with species richness was generally
266 lower for surrogate species.

267

268 **3.2 Species-specific variation in prediction success of total bird species richness**

269 There is a broad interspecific variation in several parameters describing their
270 body size, habitat preferences (habitat breadth, occupation of anthropogenic
271 environments), abundance, degree of endemism and conservation status (Table 1).
272 These species-specific ecological traits significantly explain the interspecific variation
273 in the degree of association between total bird species richness and species-specific
274 abundance (Table 3). In general, there is a high consistency among spatial grains in the
275 influence of species-specific traits determining high levels of association between
276 species' abundances and total species richness. There is a positive influence of the
277 endemism degree, and negative effects of the threat status and body mass on the ability
278 of species' abundances to correlate with total bird species richness. Habitat breadth and
279 maximum population density of species are positively associated with the ability of
280 species to produce good predictions of total species richness. Other species-specific
281 ecological traits related to occupation of environments of anthropogenic origin do not
282 have a consistent and high influence on the ability of a particular species to be a good
283 surrogate of total species richness. Position of the 20 studied species in the PLS
284 components are highly correlated across the three studied spatial grains (Pearson
285 correlations ranging from 0.61 and 0.64 for the three estimable correlations, $p < 0.004$).
286 The potential of the species with high endemism, low threat status, broad habitat
287 preferences and high abundance in the preferred habitats to provide good predictions of
288 total species richness, diminishes with increasing the spatial grain, as R^2 of the PLS

289 models diminishes from 0.5 km transects to 4x4 km grid (Table 3). The five surrogate
290 species selected *a priori* are not included within the five species that attain the highest
291 scores in the PLS components in any of the analyzed spatial grain.

292

293 **4 Discussion**

294 Relative abundance of surrogate species is a poor predictor of the whole richness
295 of native terrestrial avifauna, or of richness of endemic or endemic-and-threatened taxa
296 inhabiting the autochthonous steppe and semiarid environments of Fuerteventura. This
297 result casts doubts about the usefulness of particular surrogate species as proxies for
298 conservation programs with the whole native avifauna of semiarid lands in
299 Fuerteventura Island. This paper reinforces the idea, supported by other papers in
300 continental areas, that umbrella and flagship schemes are questionable as a quantitative
301 ecological tool to guide the maximization of conservation of regional native fauna in the
302 face of limited time, personnel and funding (Andelman and Fagan, 2000; Bried et al.,
303 2007; Tognelli, 2005; Williams et al., 2000). Nevertheless, and although surrogates
304 imperfectly represent overall species richness, finite resources limit the number of
305 species that can be studied and decisions necessarily must be made with limited data
306 (Favreau et al., 2006). As an applied aid to solve this concern, this study also shows that
307 some species were better surrogates than others, and if any has to be used, then any
308 criteria that helps to select surrogates will increase the chances and degree of success
309 when implementing conservation programmes.

310 Among the selected surrogates, the houbara bustard (*Chlamydotis undulata*) and
311 the cream-coloured courser (*Cursorius cursor*) serve as a wildcard for several purposes
312 including their role as charismatic species attracting public attention, their value for
313 monitoring conservation problems, their endangered status or their potential for

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

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

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

350 Habitat breadth explains a large proportion of interspecific variability in the
351 intensity of association between total species richness and species-specific population
352 densities. Bird species with small habitat breadth cannot tolerate a relatively wide range
353 of ecological conditions and are restricted to some particular habitats of reduced extent,
354 making them poor candidates for identifying a broad diversity of environmental
355 conditions that are representative of the biota or landscape under investigation for
356 conservation or management purposes. Moreover, stenotopic species in the Canary
357 islands have a low range occupancy, both measured as the number of occupied islands
358 in the entire archipelago or as 10x10 km UTM squares occupied within each island
359 (Carrascal et al., 2008b; see also Hurlbert and White, 2007 and Swihart et al., 2003 for
360 continental areas). For example, three of the selected surrogates (houbara bustard,
361 cream-coloured courser, and black-bellied sandgrouse, *Pterocles orientalis*) show very
362 striking habitat preferences for sandy or denudated soils with a low cover of stones or
363 bare volcanic bedrock, located in areas with low slope of the terrain (Carrascal et al.,

364 2008a; Palomino et al., 2008; Seoane et al., 2010a), while the only endemic species
365 restricted only to Fuerteventura, the Canary stonechat, *Saxicola dacotiae*, has opposite
366 habitat preferences for rocky or stony soil in areas of high grade (Seoane et al., 2010b).
367 These orographic and lithological attributes of the landscape are not shared with many
368 other native, even endemic, species of broad habitat breadth in Fuerteventura (see Table
369 1). The importance of habitat breadth of species influencing total species richness of
370 native terrestrial bird species inhabiting the steppe and semiarid environments of
371 Fuerteventura could be interpreted as a consequence of homogenization of bird
372 communities derived from the perturbation of autochthonous environments, or due to
373 the fact that the region has become more similar in the landscape features (e.g., Devictor
374 et al., 2008; van Turnhout et al., 2007). Avian homogenization is usually linked with
375 very widespread species not showing negative responses to landscape fragmentation or
376 disturbance associated with human activities (Olden et al., 2004; McKinney, 2006).
377 Thus, selection of species with broad habitat breadth as surrogate of total species
378 richness would have a negative influence on conservation prioritization (Rooney et al.,
379 2007). Nevertheless, this is not the case with the birds of autochthonous dry
380 environments of Fuerteventura, as species-specific ecological traits that make a species
381 more efficient as a surrogate of total richness of native species are not positively and
382 intensely related to cover of urban areas or agricultural environments. Moreover, three
383 of the best surrogates of avian biodiversity in the island are taxa with an endemic status
384 (specific, *Anthus berthelotii*; subspecific, *Carduelis cannabina harterti* and *Sylvia*
385 *conspicillata orbitalis*; see Table 3).

386 Bird species with high degree of endemism in the Canary Islands or the
387 Macaronesian region, are good candidates as surrogates for species richness of native
388 avifauna in the semi-arid environments of Fuerteventura Island. Their presence in the

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

401 Scale is also an important issue because associations between surrogate taxa and
402 species richness might depend on the grain at which these variables are measured. No
403 scale-dependency was observed in the surrogacy power of the selected species of semi-
404 arid and steppe environments of Fuerteventura from small spatial grains covered by 0.5
405 km transects to 4x4 km ‘pixels’. The general consensus is that patterns of global species
406 richness correspond less with distribution patterns of surrogate species at finer scales of
407 resolution (Garson et al., 2002), although Laiolo et al. (2011) have recently found that
408 the occurrence of an indicator of forest functioning and diversity (capercaillie) at a
409 regional scale was not associated with avian community diversity of forest patches, but
410 at the local scale of male spring territories, the sexual display arenas hosted the richest
411 local bird communities. Consequently, conservation managers, at least in the studied
412 insular context, do not have to worry much about the grain at which conservation

413 planning is conducted, although finer scales will obviously provide a much better
414 depiction of the conservation problems at hand.

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

429

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439

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585 **Table 1.** Species data for the terrestrial birds in Fuerteventura island including correlations between densities of each study species and total
586 species richness at three spatial grain categories (0.5-km line transect, and spatial units of 2x2 and 4x4 km²), species-specific traits and
587 conservation features. Data obtained from Seoane et al. (2011).

588

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	2x2 KM	4x4 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

589

590 ^a Categories of the Spanish Red Data Book (Madroño et al. 2005): 3 = “endangered”; 2 = “vulnerable”; 1 = “near threatened”; 0 = “non-threatened”.
591 ^b X denotes those surrogate species of autochthonous Fuerteventura steppe and semiarid lands according to their emblematic character, stenotopic habitat
592 preferences, rarity and conservation status.
593 ^c Degree of endemism: 1 = autochthonous taxa shared with continental areas; 2 = endemic subspecies for the Canary Islands or the larger Macaronesia region;
594 3 = endemic species for the Canary Islands or Macaronesia.
595 ^d Body mass (g).
596 ^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
597 most favourable environment in Fuerteventura.
598 ^f Habitat breadth of habitat distribution was calculated using the Levins index in the 12 main habitats of the island.
599 ^g Weighted average of the coverage of urban areas (%) in those sampling units where each species was detected.
600 ^h Weighted average of the coverage of agricultural environments (%) in those sampling units where each species was detected.
601
602

603 **Table 2.** Correlations between densities of each study species and species richness of endemic and endemic+threatened taxa at three spatial grain
 604 categories (0.5-km line transect, and spatial units of 2x2 and 4x4 km²). See Table 1 for endemic and threatened (endangered and vulnerable) taxa.

605

Species	Endemic taxa			Endemic+threatened taxa		
	0.5 KM	2x2 KM	4x4 KM	0.5 KM	2x2 KM	4x4 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 oedicephalus</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

606 **Table 3.** Partial least squares (PLS) regression models analyzing the interspecific
607 variation in the correlations between species-specific abundances and total bird species
608 richness, and several traits describing body size, habitat preferences, abundance, degree
609 of endemism and conservation status of 20 bird species inhabiting autochthonous
610 steppe and semiarid lands of Fuerteventura island. The analyses are carried out at three
611 spatial grains. PLS components for each spatial scale are defined according to predictor
612 weights (w_i ; square weights add to one within each component). Marked in bold are
613 those variables for each spatial scale explaining more than 5% of the interspecific
614 variation in the correlations between species-specific abundances and total bird species
615 richness (calculated multiplying the R^2 of each model by the square of each weight: $R^2 \cdot$
616 w_i^2). The first five species attaining the highest scores in the first component of each
617 PLS are shown (see Table 1 for acronyms).

	0.5 km transects	2x2 km	4x4 km
620 Endemism index (ENDEM)	0.22	0.29	0.34
621 Maximum density (DENS)	0.34	0.29	0.25
622 Body mass (ln; MASS)	-0.49	-0.14	-0.35
623 Habitat breadth (HB)	0.58	0.76	0.57
624 Coverage of urban areas (URBAN)	0.03	-0.15	-0.20
625 Coverage of agricultural environments (AGRIC)	-0.31	-0.06	0.29
626 Spanish Red Data Book (SRDB)	-0.40	-0.46	-0.50
627 R^2 for PLS	0.746	0.508	0.426
628 p	<0.001	<0.001	0.002
629 1 st highest score in PLS component	ANTBER	ANTBER	ANTBER
630 2 nd highest score in PLS component	SYLCON	SYLCON	SYLCON
631 3 rd highest score in PLS component	CARCAN	LANEXC	SERCAN
632 4 th highest score in PLS component	LANEXC	UPUEPO	UPUEPO
633 5 th highest score in PLS component	UPUEPO	CARCAN	LANEXC

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636 **Figure 1.** (a) Location of Fuerteventura Island (Canary archipelago) and; (b) locations
637 of the centre of each 0.5-km line transect within the island.

638

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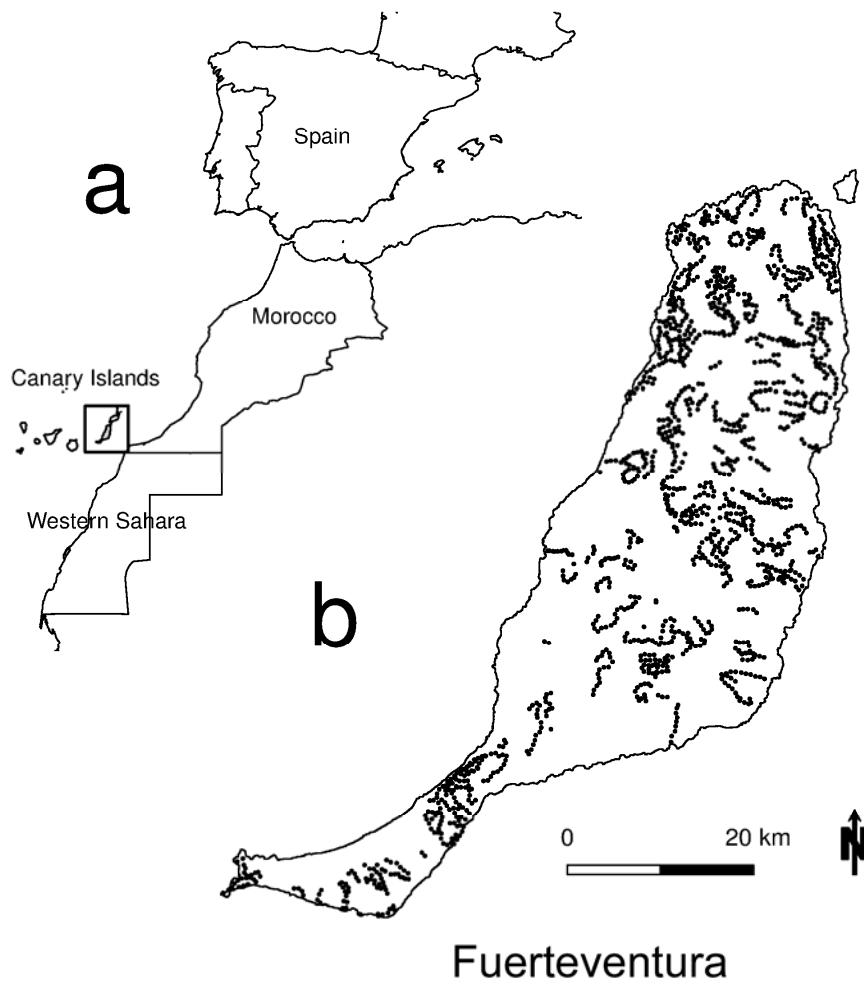
640 **Figure 2.** Mean (\pm one standard error) of correlations between species-specific
641 abundances and total bird species richness for 20 bird species inhabiting Fuerteventura
642 island at three spatial scales, and using five surrogate (emblematic species
643 representative of autochthonous steppe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

645

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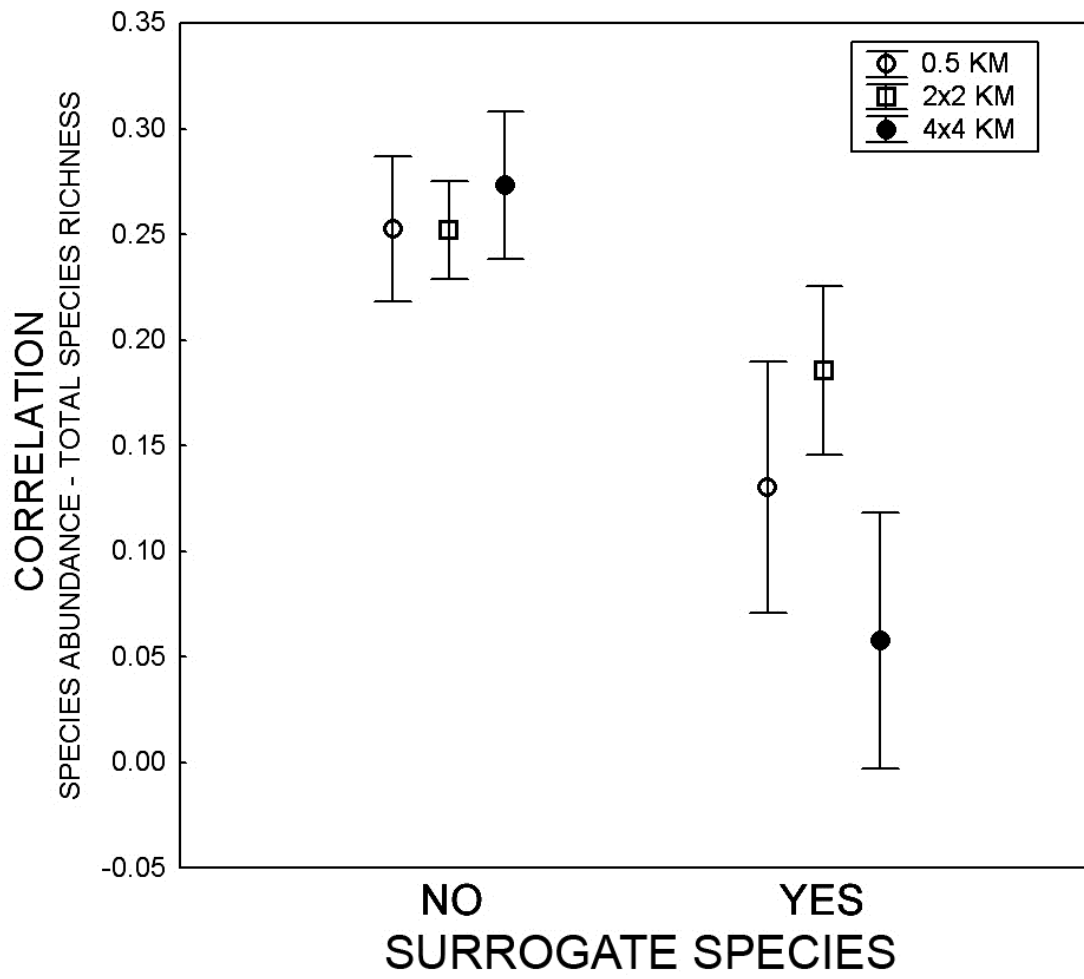
647 **Figure 3.** Mean (\pm one standard error) of correlations between species-specific
648 abundances and species richness of (a) endemic and (b) endemic+threatened taxa for 20
649 bird species inhabiting Fuerteventura island at three spatial scales, and using five
650 surrogate (emblematic species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

652



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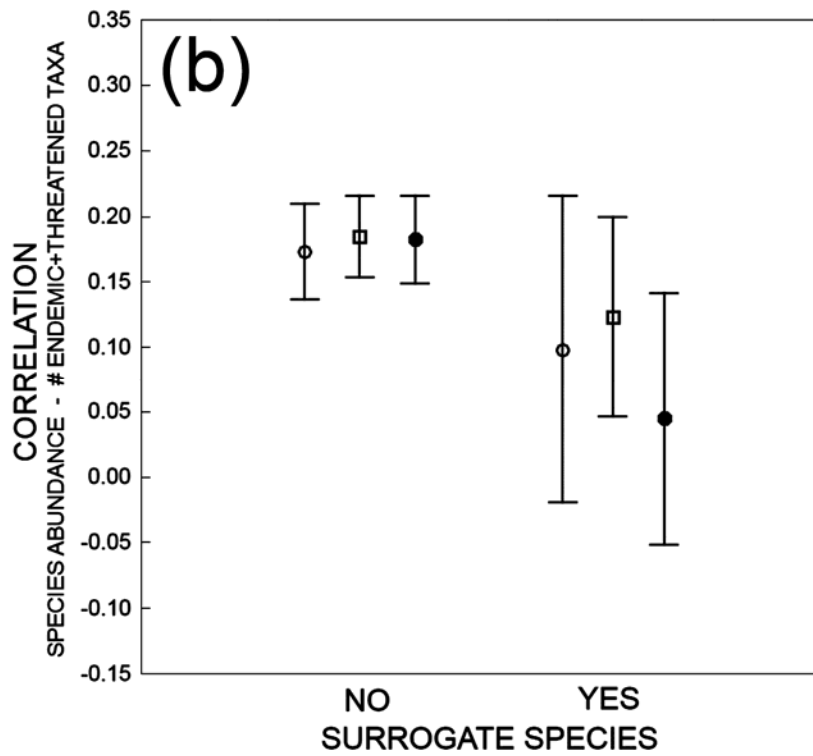
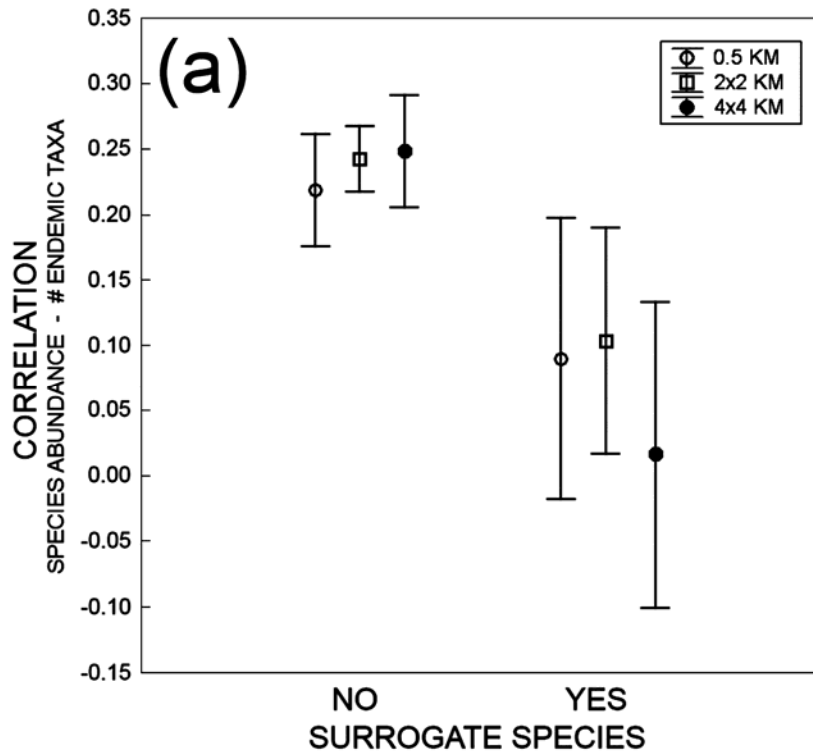
654 **Figure 1.**



655

656 **Figure 2.**

657



658

659 **Figure 3.**