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Habitat selection by the Canary Islands stonechat (*Saxicola dacotiae*) (Meade-Waldo, 1889) in Fuerteventura Island: a two-tier habitat approach with implications for its conservation

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Abstract

Habitat selection by the Canary Islands stonechat (*Saxicola dacotiae*), an endemic bird of Fuerteventura Island (Canary Islands, Spain), was studied in a two-tier habitat approach of microhabitat and landscape. Birds spent all their foraging time on stony fields and barrancos, avoiding lava and sandy fields. Slopes with high shrub coverage were the best predictors of occurrence of Canary Islands stonechats at a landscape scale. At a microhabitat scale, slopes with large boulders were selected, whilst those covered with small stones were clearly avoided. Birds used those places that supported the largest invertebrate densities. Two main threats to the species are: (1) grazing pressure (which could increase the process of desertification and decrease the availability of food), and (2) the destruction or alteration of optimal habitats, mainly owing to an increase in tourism development. Future management efforts should include the protection of large patches of stony field and barranco habitats, with slopes having at least 50% of shrub cover and large boulders. In addition, rigorous studies are needed to ascertain the maximum level of goat grazing for maintaining these optimal habitats for the Canary Island stonechat.

Keywords: Bird-habitat relationships; Canary Islands stonechat; Food availability; Fuerteventura Island; Habitat selection; *Saxicola dacotiae*

1. Introduction

To ascertain the reasons why individuals are not randomly distributed across habitats has been a major topic in animal ecology (see Cody, 1985; Wiens, 1989a for bird reviews). The studies on habitat preferences have usually examined the relationship of a species with specific characteristics of their habitats (Wiens, 1989a; Manly et al., 1993; Morrison et al., 1998). This has allowed the development of quantitative and predictive models (Morrison et al., 1998). Such models are especially important in efforts to preserve endangered species and to manage exploited populations because they can be robust over a range of habitat types (see Boyce and McDonald, 1999 for a review).

Traditionally, presence/absence and abundance of species have been assumed to be appropriately explained by studying the habitat requirements at local spatial or microhabitat scales (eg. Cody, 1985; Repasky and Schluter, 1994; Petit and Petit, 1996). However, it is now accepted that the mechanisms explaining the patterns of habitat selection depend on the scale at which the study is made (Morris, 1987; Wiens, 1989b; Kotliar and Wiens, 1990; Wiens et al., 1993). Specific factors can play a different role according to scale, and phenomena occurring at local scales are linked to factors operating at higher spatial and temporal scales. The use of a landscape perspective is specially relevant since key factors acting on population dynamics at a fine-scale can often be found (Kotliar and Wiens, 1990; Orians and Wittemberger, 1991; Rosenzweig, 1991). Despite its obvious importance for studies of habitat selection applied to the conservation of species this approach has rarely been used (Hamel et al., 1986; Lancia et al., 1986; Saab, 1999; Sánchez-Zapata and Calvo, 1999).

The purpose of the present study was to examine the patterns of habitat selection by the Canary Islands stonechat (*Saxicola dacotiae*) on Fuerteventura Island. To achieve this objective, the habitat and food availability was measured both on a local scale (microhabitat) and at a broader spatial scale (landscape). This

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two-tier habitat approach is compared with the model using a single scale developed by Bibby and Hill (1987), which predicted variations on the distribution and density of Canary Islands stonechats across Fuerteventura Island by means of topographical features. This latter approach might not predict variations in the distribution of the species if the key factors determining the habitat selection of the species were not included in the model.

This information on habitat requirements will also help to evaluate the potential threats to this species, and form the basis to define some detailed specific actions that are required to prevent deterioration in the species' conservation status.

2. Species and study area

2.1. Species

The Canary Islands stonechat (Meade-Waldo, 1889) is an endemic bird to the arid island of Fuerteventura in the eastern Canaries (Spain). Two subspecies have been described. *Saxicola dacotiae dacotiae* lives in the Fuerteventura Island, whereas *S. d. murielae*, now extinct (Martín et al., 1990), occurred in the small islands of Alegranza and Montaña Clara (north of Lanzarote). Only one population census has been carried out so far with 650–850 pairs being estimated (Bibby and Hill, 1987). The breeding period is between January and April (Martín and Lorenzo, in press). *S. dacotiae* is a Species of European Conservation Concern (SPEC, Category 2), being classified in Europe and Spain as "Vulnerable" (Tucker and Heath, 1994; Boletín Oficial del Estado, 1998), which "will demand the production of a Conservation Plan and, if necessary, the protection of its habitat" under Spanish legislation.

2.2. Study area

Fuerteventura is a volcanic island situated *c*. 100 km off the Atlantic cost of NW Africa. It has a semi-desert climate with dry summers and heavy rains (143 mm annual rainfall) in winter (Marzol-Jaén, 1984). Field work was carried out in the district of La Oliva, in the north of Fuerteventura (28°41′N, 13°52′W), covering 130 km^2 (Fig. 1). This district of La Oliva was chosen because: (1) it contains a good representation of all main habitats identified on the island, (2) it was known to be an area where Canary Islands stonechats were common (Bibby and Hill, 1987; Martín and Lorenzo, in press). The extent of all habitats was clearly shown and measured on maps (Mapa Militar de España, 1:25,000). The study area was mainly covered by stony fields (111.55 km^2; 85.81%), together with lava fields, locally called "malpaís" (10.18 km^2; 7.83%), sandy fields (7.42 km^2; 5.71%) and barrancos (ravines) (0.84 km^2; 0.65%). The vegetation consists of a sparse xerophytic shrubland, composed mainly of six species: *Launaea arborescens*, *Euphorbia regis-jubae*, *Salsola vermiculata*, *Lycium intricatum*, *Nicotiana glauca* and *Suaeda* spp.

3. Methods

3.1. Landscape structure

To understand the importance of specific landscape characteristics for *S. dacotiae*, six variables were measured, i.e. the four listed above plus the extent of slopes having $\geqslant$15% or <15% shrub cover ($\geqslant$0.25 m tall). These variables were measured during the prebreeding period (from 27 November to 12 December 1998) when birds were not attached to territories. The availability of these six habitat features was also measured throughout the study area on 50 circular sample units of 1 km radius chosen randomly from military maps (1:25,000); areas of slopes with and without shrubs were measured on the ground using GPS and the four listed above were measured on maps. The selection of these landscape features by Canary Islands stonechats was ascertained (from 5 to 17 December 1998) in a circular area of 1 km radius around each foraging bird.

3.2. Microhabitat structure

Microhabitat structure was also characterized during the prebreeding season, by measuring nine variables on 123 circular sample units of 25 m radius, which were randomly selected in each habitat. The number of sample units per habitat was established according to a logarithmic scale of size, i.e. 42 in stony fields, 31 in lava fields, 30 in sandy fields and 20 in barrancos. These variables were selected according to the most important ecological requirements of the stonechat genus (*Saxicola*) (Greig-Smith, 1983; Moreno, 1984; Bibby and Hill, 1987) (Table 1). Cover (%) variables, as well as the average height of shrubs and stones, and average slope of each sample, were estimated visually. Here, slopes are only referred to sloping ground (measured in degrees) without considering shrub cover as in landscape structure.

Microhabitat use of Canary Islands stonechats was characterised by looking for foraging birds (from 5 to 17 December 1998) within 25 m-wide belts either side of established 1 km line transects, randomly established in each major habitat type. The same microhabitat variables were measured in circular sampling stations of 25-m radius around each bird seen. The height of the bird above the ground was measured with a tape measure. Bird surveys were made in the morning, from dawn to 1300 hours (local time). The number of hours devoted to each habitat was established according to a logarithmic scale of the size of the habitat.

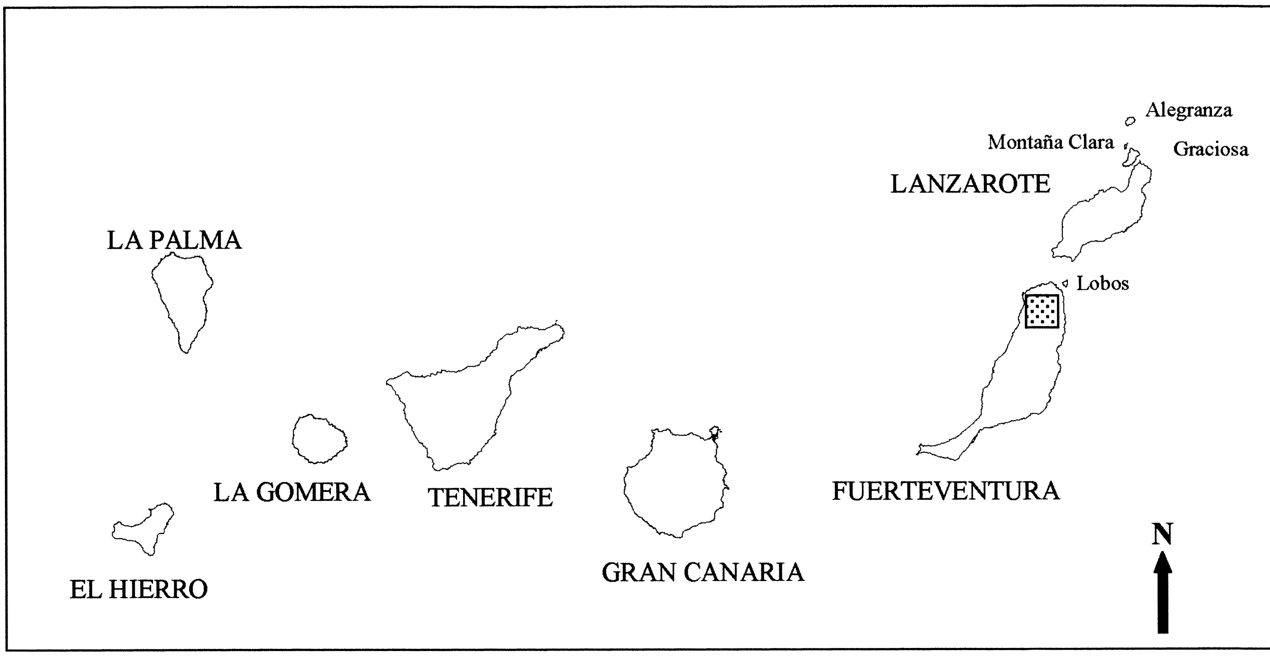

Fig. 1. Map of the Canary Islands showing the location of the study site in the Fuerteventura Island.

Table 1
Variables used to characterize the structure of microhabitat for each 25 m radius circular plot

Variable	Description
SHRUB1	Cover of shrubs < 0.25 m height (%)
SHRUB2	Cover of shrubs between 0.25 and 0.50 m height (%)
SHRUB3	Cover of shrubs >0.50 m height (%)
STONE	Cover of stones < 0.25 m height (%)
BOULDER	>0.25 m height (%)
SOIL	Bare ground cover (%)
GRASS	Grass cover (%)
SAND	Sand cover (%)
SLOPE	Average of slope (degrees)

3.3. Food availability

Food availability was measured to ascertain the possible importance of this factor on patterns of space use (landscape and microhabitat) by Canary Islands stonechats (Díaz et al., 1998). Two hypotheses were tested, (1) Do all habitats support the same food availability? (2) Considering only those habitats where birds are recorded, were they capable of distinguishing places with greater food availability than others in the same habitats? In order to ascertain these questions, food availability was assessed by two methods: pitfall traps (landscape scale) and direct observation (microhabitat scale).

Pitfall traps were used (23 November–2 December 1998) to compare the relative abundance of ground-living invertebrates between habitats. Thirty-six grids (9 in each habitat) were randomly situated throughout the study area, each consisting of five plastic jars making a total of 180 jars. The jars were 7.2 cm in diameter at the mouth, 10.4 cm deep and 36 cm apart. The traps were emptied four times over a seven day period to minimise predation.

Direct observation took place only in stony field and barranco habitats because birds were exclusively detected in those habitats. Relative abundance of invertebrates in these habitats was measured in two zones, i.e. with birds and without birds. In all, 360 random samples were taken along 500 m line transects randomly established, 180 in each zone of which half (90) were chosen in flat areas and the other 90 were in slope areas. Food availability was evaluated (18–24 January of 1999) by carefully counting all invertebrates $\geqslant 1$ mm found during 2 min searching in a square of 0.25 m^2. Since the effect of prey size on habitat use has been demonstrated with some bird species (e.g. Alonso et al., 1991; Valido et al., 1994), size of each arthropod detected was also recorded in the following length categories: 1–3, 3–6 and >6 mm.

3.4. Data analysis

Foraging site selection patterns at landscape and microhabitat scales were explored by univariate (*t* or ANOVA) tests and multivariate analyses (stepwise discriminant analysis, with the criteria of variable selection based on Wilks' lambda; Norusis, 1992) to compare foraging locations and random sampling points. Significance level was obtained after applying the sequential Bonferroni method (Rice, 1989). The original data were transformed by arcsin (cover) or square root (slope) (Zar, 1996).

Comparisons of food availability between habitats were carried out by one-way ANOVAs on log-transformed data. Significant differences ($P<0.05$) between the number of invertebrates on each habitat were determined using the Scheffé test (Sokal and Rohlf, 1981). Finally, when data were not normally distributed, Mann–Whitney and Kruskal–Wallis tests were used to explore differences between sample distributions.

4. Results

4.1. Landscape selection

At the landscape scale, stonechats foraged entirely on stony field (86%, $n=37$) and barranco (14%, $n=6$) habitats, avoiding lava fields and sand fields. Furthermore, birds were mainly found in those areas with higher proportions of stony field and barranco habitats, and on slopes with shrubs, than the average of the study area (Table 2).

Stepwise discriminant analysis of the four habitat features correctly classified 79.6% (91% of all recorded birds) of the cases (i.e. used) to their corresponding group (i.e. available) at the landscape scale. Only slopes with shrubs were in the model, that is, stonechats strongly selected areas of slopes supporting high shrub cover.

Invertebrate abundance was different in each habitat. The stony field habitats supported the largest invertebrate abundances ($n=719$; $\bar{x}=79.9\pm28.9$, where n is the total number of invertebrates collected per habitat and $\bar{x}$ the mean number of invertebrates per grid), followed by barrancos ($n=341$; $\bar{x}=37.9\pm8.3$), sandy fields ($n=294$; $\bar{x}=32.7\pm5.0$) and lava fields ($n=140$; $\bar{x}=15.6\pm3.0$). However, significant difference was only found between stony field and lava field habitats ($F_{3,32}=7.72$, $P<0.001$).

4.2. Microhabitat selection

To ascertain more accurately the key characteristics of microhabitat selection by birds, the analysis was simplified taking into account only the habitats used by Canary Islands stonechats, that is, stony field and barranco habitats. Therefore, only eight variables were analysed.

At the microhabitat scale, stonechats were observed foraging at places characterized by taller shrubs more grass cover, large boulders, steeper slopes, and fewer stones than the average (Table 3). Birds always selected the highest perches to forage from ($U=236.5$, $P<0.01$; $U=25.0$, $P<0.01$, for shrubs and boulders respectively). The stepwise discriminant analysis selected three of the eight variables introduced. The microsites selected were characterized by many large boulders and steep slopes, and low stones (Table 3). The equation obtained correctly classified 74.3% (74% of all recorded birds) of the cases to their corresponding group (i.e. sites used by foraging birds or random sample points) at the microhabitat scale.

Table 2
Mean (±S.E.) values (no transformed) for landscape variables measured (1 km radius) around each foraging bird located (used) and around random points (available) Results of t-test comparisons for each variable are also shown

Variable	Available ($n=50$)	Used ($n=43$)	t	P
Barranco (%)	4.28±0.52	7.07±0.68	−3.69	⩽0.001
Stony field (%)	81.26±3.63	92.93±0.68	−2.63	0.01
Slope without shrub (%)	4.46±1.33	2.95±1.07	1.09	0.277
Slope with shrubs[a] (%)	24.46±4.67	56.00±2.93	−5.81	⩽0.001

[a] Only slopes with shrubs were entered in the stepwise discriminant analysis.

Table 3
Mean (± S.E.) values (untransformed) for microhabitat variables measured (25 m radius) around each foraging bird located (Used) and around random points (available) of stony field and barranco habitats, both combined (S/B), Lava field habitat (Lava, L) and Sandy field habitat (Sandy, S). Results of t-test comparisons for each variable (Used versus S/B) and ANOVA tests for each variable between different habitats (S/B, Lava and Sandy) are also shown. Superscript figures indicate the order in which variables entered a stepwise discriminant analysis between foraging sites (used) and control points (S/B). See text for further details

	Means				Differences						
Variable	Used ($n=43$)	S/B ($n=62$)	Lava ($n=31$)	Sandy ($n=30$)	t (Used v S/B)	p	$F_{2,120}$ (S/B, L, S)	p	S/B v Lava	S/B v Sandy	Lava v Sandy
SHRUB1 (%)	4.28±0.55	3.37±0.33	0.74±0.09	4.37±0.60	−1.34	0.184					
SHRUB2 (%)	7.93±0.59	5.60±0.50	2.77±0.47	4.57±0.65	−3.26	0.002	7.49	0.001	0.001	0.26	0.17
SHRUB3 (%)	14.00±1.41	8.58±1.38	11.26±1.29	4.77±1.14	−3.69	⩽0.001	7.58	0.001	0.08	0.09	0.001
STONE[b] (%)	25.07±2.15	41.61±2.61	49.48±3.05	17.63±3.75	4.23	⩽0.001	26.54	⩽0.001	0.19	⩽0.001	⩽0.001
BOULDER[a] (%)	10.02±1.28	4.53±0.89	32.13±2.92	3.13±1.13	−4.55	⩽0.001	86.67	⩽0.001	⩽0.001	0.22	⩽0.001
SOIL (%)	23.65±2.40	25.24±2.08	2.26±1.09	0	0.15	0.883					
GRASS (%)	14.95±2.17	7.85±1.24	1.35±0.21	5.03±1.17	−3.29	0.001	8.81	⩽0.001	⩽0.001	0.43	0.05
SAND (%)	0	0	0	60.37±3.56							
SLOPE[c] (degrees)	30.21±3.30	17.06±2.22	11.55±2.74	11.53±2.41	−3.31	0.001	1.93	0.15	0.25	0.32	0.99

Differences in significant microhabitat variables (Table 3) were examined to see if these could entirely explain the differences between the occurrence of stonechats in the four main landscape habitats. It was clear that lava fields were distinguished by having significantly more large boulders, while sandy fields had the smallest amount of stones. Medium-sized shrubs (SHRUB2) were most prominent in stony fields and barrancos, while tall shrubs (SHRUB3) were significantly more abundant in lava fields than in sandy fields. Grass cover was least developed in lava fields. There was no difference between any of the macrohabitats in terms of slope.

In stony field and barranco habitats, birds clearly selected microsites that supported more arthropods, as measured by direct observation (Mann–Whitney test, $Z=-7.69$; $P\ll 0.001$; $n=360$) (Table 4). Within stonechat foraging zones, the overall arthropods numbers of were also significantly greater on sloping sites than on level sites (Mann–Whitney test, $Z=-3.35$; $P<0.001$; $n=180$), although they were not significantly fewer on sloping sites where birds were not foraging (Mann–Whitney test, $Z=-0.49$; $P<0.49$; $n=180$) (Table 4).

5. Discussion

5.1. Distribution of the Canary Islands stonechat

These results support the initial hyphothesis that distribution of the Canary Islands stonechat in the study area could be predicted more precisely by specific habitat factors at a two-tier spatial scale, than by a linear model based on only one scale (Bibby and Hill, 1987). Their study strongly related numbers of birds per km^2 to altitude and steepness measured on maps, but only steepness was found to be important in the present study (Table 3), and other specific landscape and microhabitat characteristics were better predictors of occurrence of stonechats. In particular, slopes with high presence of shrub cover were the main factors explaining the pattern of habitat selection at the landscape scale, while at the microhabitat scale, features of the ground surface were shown to be important. These variables can not be measured on topographic maps. At an initial stage, it would be adequate to identify just slopes with high presence of shrub cover since this variable correctly classified 79.6% of the cases.

These features of habitat use of the Canary Islands stonechat were strongly associated with its prey capture techniques, and probably these habitat features could be also related to optimal breeding places (Martin, 1993). Furthermore, the foraging strategy developed during the study period was consistent, at least from September until May (per. obs.). The Canary Islands stonechat has a typical chat feeding behaviour, which consists of scanning for potential prey from a high perch and swooping down to capture an insect (Moreno, 1984).

The fact that no bird was recorded during the prebreeding period (both at microhabitat and landscape scale) in lava and sandy fields is therefore surprising, since these habitats offered good places (perches) to perform foraging behaviour (Table 3). Likewise, in the study area the absence of birds in lava and sandy field habitats were consistent, at least, from September until May (per. obs.). Differences in the availability of food could be an important factor explaining the pattern observed. In this sense, stony field and barranco habitats supported the greatest number of prey in the study area, although this was significant only between stony fields and lava fields. Moreover, inside stony fields and barranco habitats birds were capable of identifying those zones (slopes with shrubs) which offered the larger invertebrate densities (see Illera and Atienza, 1997; Díaz et al., 1998 for similar results with other insectivorous bird species).

On the other hand, differences in prey detectability and accessibility, could be also influencing the pattern observed. This seems to be suggested by indirect evidence about the foraging behaviour of Berthelot's pipit (*Anthus berthelotii*) on lava and sandy fields Illera (unpublished data), and significant differences of soil cover found between habitats ($\chi^2=55.450$, $P\ll 0.001$). It appears that soil scarcity in sandy field and lava field habitats could play an important role in detectability and accessibility of prey to both species, which would also, explain differences in use of the habitats.

Predation risk could be another factor determining the habitat use of birds (eg. Lima and Dill, 1990; Suhonen 1993). However, the use of conspicuous places for foraging on stony field and barranco habitats, and the main abundance of their potential predators (*Falco tinnunculus* and *Lanius excubitor*) in stony fields and barrancos of the study area (pers. obs.), would not seem to support this hypothesis.

Overall, these findings would support food availability and food accessibility being the main factors affecting habitat use by insectivorous bird species

Table 4
Number, distribution and type of size of invertebrates recorded in each 0.25 m^2 sampled plot of stony field and barranco habitats, with or without presence of the Canary Islands stonechat

	With bird		Without bird	
Size	Plateau	Slope	Plateau	Slope
1–3 mm	129	196	59	27
3–6 mm	18	20	18	7
>6 mm	5	3	2	1
Total	152	219	79	35

(Holmes and Robinson, 1981; Robinson and Holmes, 1982; Díaz et al., 1998; Keane and Morrison, 1999).

5.2. Conservation implications

In the Canary Islands context three principal socio-economic activities of development have influenced the present aspect of the island landscape: agriculture, stockbreeding (goat and sheep rearing) and building development (mainly tourism) (Aguilera Klink et al., 1994). Due to the semi-desert climate in Fuerteventura Island agriculture activity is nowadays very scarce, but the other two factors are still important (Domínguez Hormiga, 1992). Grazing pressure (mainly goat grazing) is already known to have a very negative influence on the Canarian flora (Nogales et al., 1992; Rodríguez-Piñero and Rodríguez-Luengo, 1993) and may also affect Fuerteventura's bird communities (Osborne, 1986). Heavy grazing pressure in Fuerteventura could: (1) cause intensification of soil erosion by decreasing cover of grass and shrubs, which would increase the process of desertification and thus reduce the area of suitable habitat for *S. dacotiae* (Giourga et al. 1998; pers. obs.), and (2) lead to large changes in invertebrate communities and decrease the availability of food (see Fuller and Gough, 1999, for an extensive review).

On the other hand, the most important impact on bird species is probably the direct destruction or alteration of their habitats by man (Tucker and Evans, 1997). Several actions proposed on the insular development plan (PIOF) such as theme parks, highways, new residential buildings, opening of new tracks to off-road vehicles, new track-ways, etc., seem to be the principal threats to this species. Some of these actions would be developed in places with high presence of Canary Islands stonechats (e.g. building of a theme park in the barranco of Ajuy).

The absence of birds in small isolated patches of suitable habitat (i.e. with shrub covered slopes and boulders), indicates that any conservation plan for this species should include as a principal objective the maintenance of large patches with appropriate landscape and micro-habitat features (i.e. stony fields and barrancos with presence of at least 50% shrub covered slopes, presence of large boulders and low stones cover).

Management objectives for the Canary Islands stonechat should take account of all kinds of infrastructures involving the destruction or alteration of optimal habitats, by completing the network of Special Protection Areas (SPAs) and Natural Protected Areas in Fuerteventura. In addition, rigorous studies are needed to ascertain the number of goats that the Canary Island stonechat's optimal habitats can support. These actions would not only be profitable to this endemic species but also for other endangered bird species living in Fuerteventura (Martín et al., 1997).

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