The Condor 106:429–434

HOW MUCH SUITABLE HABITAT IS LEFT FOR THE LAST KNOWN POPULATION OF THE PALE-HEADED BRUSH-FINCH?

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Abstract. The Pale-headed Brush-Finch (*Atlapetes pallidiceps*) is threatened with extinction due to loss of habitat. The only remnant population consists of 30–35 pairs and is confined to a single valley in the Andes of southwestern Ecuador. We investigated the habitat types used by this species in order to quantify the amount of available suitable habitat. The species used semiopen habitat types featuring a mosaic of dense scrub 2–4 m tall and grassy patches. Low continuous scrub was also used in larger proportions than on average available; forest and open country were not included in territories. Suitable habitat covered 28% of the area, and 16% was still available for new brush-finch territories. We identified a minimum of seven coherent patches that could support eight further pairs of the species. The valley can thus potentially support 40–50 pairs. The occupied habitat as described here should serve as a guideline in searching for new habitat.

Key words: Atlapetes pallidiceps, compositional analysis, *conservation, Ecuador, habitat selection, Pale-headed Brush-Finch.*

¿Cuánto Hábitat Adecuado Está Disponible para la Ultima Población de *Atlapetes pallidiceps*?

Resumen. *Atlapetes pallidiceps* es una especie endémica a un sólo valle en el suroeste del Ecuador. La especie está en peligro de extincción debido a la pérdida del hábitat. En este estudio analizamos los tipos de hábitat ocupados de *Atlapetes pallidiceps* con la intención de evaluar la cantidad de hábitat adecuado para una expansión de la población. *Atlapetes pallidiceps* ocupó hábitats semi-abiertos con un mosaico de matorral denso (2–4 m de altura) y lugares con vegetación herbácea. La especie también ocupó matorrales bajos continuos, mientras que los territorios no incluyeron bosques ni terrenos abiertos. Los hábitats adecuados cubrieron el 28% del área de estudio, y el 16% estuvo todavía disponible para el establecimiento de territorios nuevos. Identificamos un mínimo de siete parches coherentes que podrían sostener ocho parejas más del *Atlapetes pallidiceps*. Por lo tanto, el área tiene el potencial para soportar 40–50 parejas. Sería recomendable aplicar nuestra clasificación de los tipos de hábitat ocupados como guía para la búsqueda de nuevas áreas para este especie.

The Pale-headed Brush-Finch (*Atlapetes pallidiceps*) is a critically endangered endemic bird species of a semi-arid valley in the Andes of southwestern Ecuador (Collar et al. 1992, BirdLife International 2000). It was considered extinct for 30 years until a small population of ca. 30 pairs was rediscovered in Yunguilla Valley in 1998 (Agreda et al. 1999, Krabbe 2004). The species appears to have always been confined to a limited geographic and ecological zone, but at present all of its habitat is modified by human land-use (Paynter 1972, Dercon et al. 1998). Habitat loss and degradation are therefore likely to play a prominent role in the decline of the Pale-headed Brush-Finch. A quantitative analysis of the habitat preferences of this species has not been presented so far (Paynter 1972, Ridgely and Greenfield 2001). Hence, data facilitating the identification of further extant populations are still lacking.

A land purchase has secured some habitat for the only remnant population of the Pale-headed Brush-Finch (Agreda et al. 1999), but brood parasitism by Shiny Cowbirds (*Molothrus bonariensis*) remains a threat (Oppel et al. 2004a). Cowbird shooting is being applied to reduce parasitism rates; this technique can enable host populations to grow (Hall and Rothstein 1999, Griffith and Griffith 2000), but has often failed due to the lack of suitable habitat (Whitfield et al. 1999, DeCapita 2000). It is therefore of crucial interest how much suitable habitat is left for the Pale-headed Brush-Finch in the Yunguilla Valley.

In this study, we first determined which habitat types the Pale-headed Brush-Finch occupied, using GIS to analyze used vs. available habitat features. Applying this result as a definition of suitable habitat, we calculated the amount of suitable habitat that is not currently occupied by existing territories. Size and spatial arrangement of unoccupied suitable habitat patches were then examined, in order to determine the number of potential territories providing sufficient habitat for further pairs.

Manuscript received 21 July 2003; accepted 14 January 2004.
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METHODS

STUDY AREA

The Yunguilla Valley is located ca. 50 km southwest of Cuenca in the upper Río Jubones drainage, Province Azuay, Ecuador (3°13′S, 79°16′W). It belongs to a moderately cool area situated in a transitional zone between the arid lower Río Jubones valley and the humid upper reaches of the Andean west slope (Dercon et al. 1998). In this area, stable ecoclimatic conditions likely led to high endemism and a dense human population since the times of the Incas (Fjeldså et al. 1999). Current land uses are mainly corn crops and cattle pastures (Bossuyt et al. 1997, Dercon et al. 1998). The Pale-headed Brush-Finch was rediscovered here in 1998, on two steep slopes (ca. 45°) covering ca. 80 ha and ranging from 1650–2000 m in elevation (Agreda et al. 1999). The area is now protected and largely ungrazed by livestock. A subsequently discovered population on the neighboring hill inhabits an area of approximately equal size that is still grazed by cattle (B. Carlos and F. Sornoza, unpubl. data). Both hills feature semiopen habitats with dense early successional arid scrub consisting mostly of composite and verbenaceous species (e.g., *Steiractinia sodiroi*, N. Krabbe, pers. comm.), interspersed with non-native *Melinis minutiflora* grassland of old or recent pastures. Small stands of *Acacia* sp. and lauraceous trees are found in more humid parts, and fragments of semihumid forest persist on west-facing and southern slopes. Dwarf bamboo (*Chusquea* sp.) forms large patches in small depressions, ravines, and on the western slopes. The study area comprises ca. 150 ha including the reserve and an adjacent slope. It is surrounded by agricultural lands, secondary forest, and human settlements.

TERRITORY AND HABITAT MAPPING

Birds were monitored from dawn to early afternoon every day from late March to mid-June 2002. Territory boundaries were defined by the outermost song perches connected to form a minimum convex polygon (White and Garrott 1990). Habitat features were mapped in June 2002, and units with homogenous vegetation structure were defined by three variables: (1) habitat type (1 = open grassland and crops; 2 = semiopen grassland with single bushes covering <50%; 3 = semiopen grassland with single bushes covering >50%; 4 = low deciduous scrub ≤4 m height; 5 = low bamboo scrub ≤ 4 m height; 6 = tall deciduous scrub >4 m height; 7 = tall bamboo scrub >4 m height; 8 = mature forest or woodland; 9 = solitary trees), (2) vegetation density (1 = open; 2 = semiopen; 3 = open scrub with visibility >10 m; 4 = dense scrub with visibility 5–10 m; 5 = dense scrub with visibility <5 m), and height of the woody scrub (1 = 0–2 m; 2 = 2–4 m; 3 = 4–6 m; 4 = >6 m). We created a map from photographs taken from the opposite slopes, because plane topographic maps underestimate the area on steep slopes and were not available in an appropriate scale. The obtained pictures approximate an orthophoto, but may lead to some distortion along the slope. We therefore used only relative measures of use and availability to avoid bias introduced by distorted distance measures.

ANALYTICAL APPROACH

To describe the use of habitat features by the Pale-headed Brush-Finch in the study area, we intersected the map of all territories with the habitat feature map using ArcView GIS software (ESRI 1999, Sandkühler and Schröder 1999, Osborne et al. 2001). This yielded the proportion of every variable category for both the territories (use) and the entire study area (availability). We used compositional analysis (Aebischer et al. 1993) to compare habitat used in territories and habitat available in the study area. This technique overcomes the unit-sum constraint caused by the lack of independence between proportions that sum to 100% (Johnson 1980). In compositional analysis, a log-transformed ratio of one category over a random category from the same variable results in linearly independent data (Aebischer et al. 1993). The log-ratios of utilized habitat proportions are compared with the log-ratios of available habitat proportions, and differences around zero indicate random use of the category. We replaced all zero values with 0.0001 (Aebischer et al. 1993), and computed a matrix of all log-ratio differences for every habitat category using alternate categories as denominators. Categories were then ranked by adding all log-ratio difference values; the largest positive value representing the most selected, the smallest (largest negative) value the least selected category (Aebischer et al. 1993, Graham 2001, Ratcliffe and Crowe 2001). We tested for deviation from zero of all replication units (brush-finch territories) by using one-sample randomization tests with a significance level of $\alpha = 0.05$ (Manly 1997a). This was performed with RT software (Manly 1997b).

The unoccupied habitat was calculated by subtracting the occupied areas from the study area total. We then defined optimal habitat as those polygons that featured (1) the two most selected habitat types, (2) the most selected vegetation height, and (3) the three most selected density categories. Secondary habitat was defined as the two next best habitat types featuring the same height and density categories as in optimal habitat. Based on these definitions we assigned the values *optimal*, *secondary* (both combined to constitute *suitable*) or *unsuitable* to all habitat polygons. We then calculated the mean proportion of optimal and secondary habitat in occupied territories, and used this value as a threshold to remove polygons of unoccupied suitable habitat that were too small and isolated. Optimal and secondary habitat polygons that were large enough, or adjoined with other suitable polygons to form a sufficiently sized patch, were considered suitable for the establishment of further brush-finch territories. All analyses were carried out for each slope separately, but results represent relative values averaged across the study area as well as total number of potential territories. Results are given as means ± SD.

FIELD VALIDATION

From February through June 2003, territories of Pale-headed Brush-Finches were mapped in a section of Yunguilla Valley, in order to validate predictions derived from habitat classification. We made field observations independent of habitat classification and compared territory distribution in 2003 with predicted hab-

TABLE 1. Percentage (mean ± SD) of habitat types in the study area and within 26 territories of the Pale-headed Brush-Finch in Yunguilla Valley, Ecuador, in 2002.

Habitat types	Study area	Territories
Open grassland, crops	15 ± 8	1 ± 2
Semiopen, single shrubs <50%	20 ± 11	18 ± 18
Semiopen, single shrubs >50%	18 ± 6	32 ± 21
Deciduous scrub ≤4 m tall	9 ± 5	19 ± 19
Bamboo scrub ≤4 m tall	13 ± 5	14 ± 13
Deciduous scrub >4 m tall	14 ± 5	13 ± 22
Bamboo scrub >4 m tall	4 ± 3	2 ± 7
Forest	7 ± 8	0.2 ± 0.8
Solitary trees	0.5 ± 0.5	0.5 ± 0.9

itat suitability derived from the 2002 data set. The percentage of predicted suitable habitat included in new territories was used to assess prediction success. Prediction success was averaged across all new territories and is given as mean percentage ± SD.

RESULTS

Twenty-six territories of the Pale-headed Brush-Finch were detected in the study area in 2002. They did not include habitat types in proportion to habitat abundance ($\chi^2_{18} = 240.4$, $P < 0.001$). Semiopen habitat types covered 50% of all territories, and scrub <4 m tall contributed another 33% to all territory areas (Table 1). Open country and forest remnants comprised less than 2% of territories. The scrub height in territories deviated from random use, with heights of 2–4 m being used more, and scrub <2 m and >4 m used less than available in the study area ($\chi^2_6 = 100.0$, $P < 0.001$). Seventy-three percent of the scrub in territories was 2–4 m high, and another 14% was between 4 and 6 m high. Only 2% of the scrub in territories exceeded 6 m in height. The five density categories had balanced proportions in occupied territories, ranging from 16% (category 5) to 23% (category 2). Only the category ''open'' was used significantly less than available in the study area ($\chi^2_2 = 31.9$, $P < 0.001$).

The ranking matrix obtained from compositional analysis ordered the habitat types in the following sequence: semiopen with >50% bushes > semiopen with <50% bushes and both categories of low scrub > solitary and tall deciduous scrub > tall bamboo scrub, open country, and forest (Table 2). Based on the sum of log-ratio differences, we defined three habitat pools: a selected habitat pool including semiopen and low scrub habitat types, a tolerated habitat pool containing solitary trees and tall deciduous scrub, and an avoided habitat pool comprising tall bamboo, forest, and open country. The selected habitat pool was used to calculate potential habitat still available for brush-finches in the study area.

Analysis of vegetation density yielded only that dense scrub with 5–10 m visibility was used over dense scrub with visibility less than 5 m ($P < 0.05$), but did not differ from other density categories. Defi-

TABLE 2. Simplified ranking matrix of Pale-headed Brush-Finch habitat selection in Yunguilla Valley, Ecuador, calculated from proportions of habitat types in 26 territories (Table 1). For each pair of habitat types the ratio of the area in each pair's territory was calculated. Next, the ratio of the area available in the total study area was subtracted, and the mean of this difference over all 26 territories was calculated. Matrix elements represent signs of this mean difference, 0 = no significant deviation from zero; + = $P < 0.05$; ++ = $P < 0.01$ from a one-sample randomization test. Negative values suggest avoidance; positive values suggest selection.

	Habitat type									Sum of differences	Rank
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)		
(1) Open grassland, crops		—-	—-	—-	—-	—-	0	0	—-	–31.5	9
(2) Semiopen, single shrubs <50%			0	0	0	0	++	++	0	12.5	2
(3) Semiopen, single shrubs >50%				0	0	+	++	++	++	22.6	1
(4) Deciduous scrub ≤4 m tall					0	0	++	++	0	10.4	3
(5) Bamboo scrub ≤4 m tall						0	++	++	0	8.5	4
(6) Deciduous scrub >4 m tall							+	++	0	–2.6	6
(7) Bamboo scrub >4 m tall								0	—-	–13.9	7
(8) Forest									—-	–22.4	8
(9) Solitary trees										0.3	5

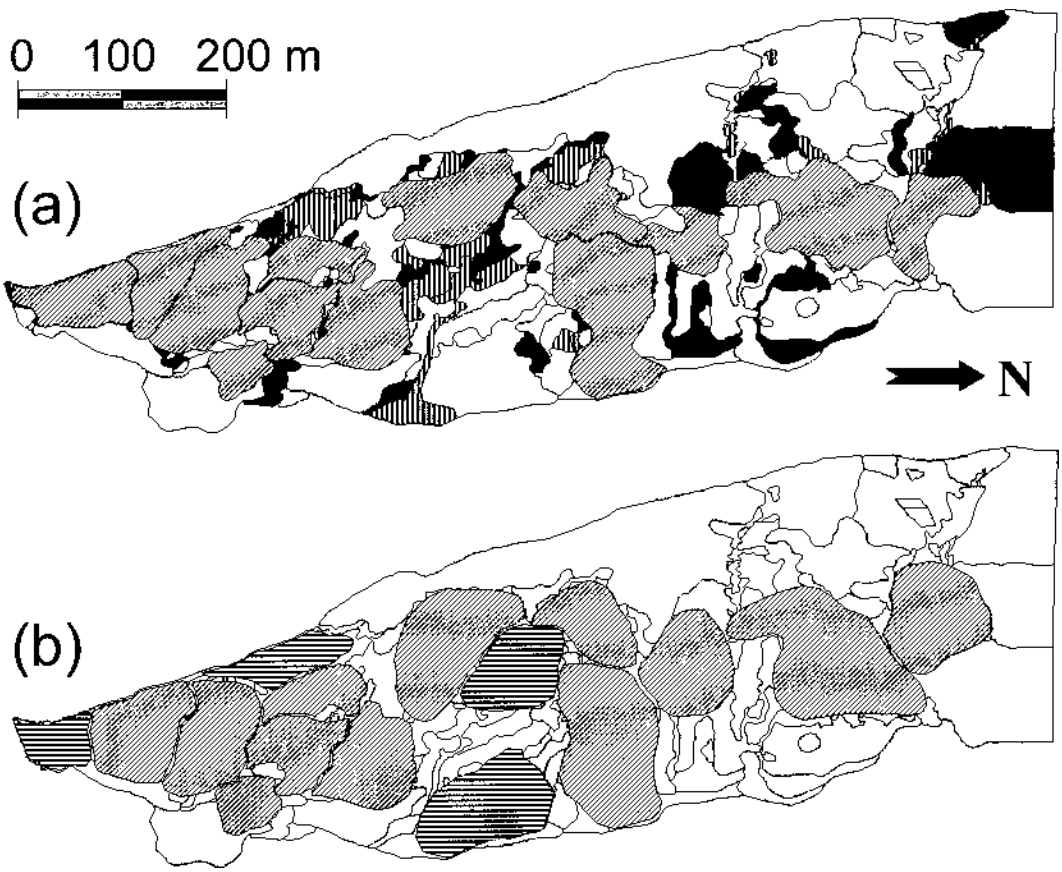

FIGURE 1. Map of the east slope of the Pale-headed Brush-Finch reserve in Yunguilla Valley, Ecuador. An additional 13 pairs were located on further slopes in and outside of the reserve in 2002. (a) Cross-hatched areas are brush-finch territories occupied in 2002, black areas indicate unoccupied ''optimal'' habitat (semiopen habitat with moderately dense scrub), vertically barred areas unoccupied ''secondary'' habitat (low, <4 m tall, moderately dense scrub). Unsuitable forest, tall bamboo, and open country habitat is unshaded. (b) Brush-finch territories found during the 2003 validation survey, divided into old pairs (cross-hatched) and pairs new to the reserve in 2003 (horizontally barred).

nition of suitable habitat was therefore based on the three remaining density categories. Optimal habitat, defined as polygons featuring both semiopen habitat types, scrub height from 2–4 m, and intermediate vegetation densities (categories 2 to 4), covered 16% of the study area. Of the total area of optimal habitat, 47% was occupied by territories in 2002, leaving an area unoccupied that equates to 9% of the study area. Optimal habitat was present in all brush-finch territories and covered on average 36% ± 21%, range (5–85%). Secondary habitat, (polygons featuring low scrub habitat types [categories 4 and 5], scrub height of 2–4 m, and intermediate vegetation densities [categories 2 to 4]), covered 12% of the study area, of which 39% was occupied in 2002. Within brush-finch territories, secondary habitat covered 21 ± 21%, range (0–65%).

Unoccupied suitable habitat covered 16% of the study area. Of this area, 34% of patches were too small (1–73% of territory mean), and isolated between either existing territories or unsuitable habitat (Fig. 1a). The remainder included seven areas with enough optimal and secondary habitat to support eight new territories. Another three areas remained with only secondary habitat, but large enough for at least one territory each, covering 11% of the study area. In sum, at present the area in Yunguilla supports suitable habitat for a minimum of eight, and possibly up to 14 further territories of the Pale-headed Brush-Finch.

In 2003, 21 territories were found in the study area, of which 17 were almost identical to territories of the previous year (Fig. 1). Three of the new territories were established in areas classified as suitable habitat, and one new territory was established in an area with little suitable habitat (Fig. 1b). Classification success was 66 ± 35%, range (15–90%). One more territory was located outside the study area and could therefore not be included in this analysis.

DISCUSSION

The Pale-headed Brush-Finch avoids forests or tall scrub vegetation. It inhabits heterogeneous semiopen scrubland, where patches of scrub with medium height are interspersed with small grassy clearings. Dense continuous scrub adjacent to open areas is present in most territories, and is considered important for nest sites (Oppel et al. 2004b). Territories were established in patches of pure deciduous or bamboo scrub. Approximately 16% of the study area provided suitable but unoccupied habitat for the species in 2002. However, more than one-third of these patches were too small and not directly connected to other suitable habitats, and were thus considered unavailable for territory establishment. Yet, territories might provide the minimum amount of cover and food supply even if they include unsuitable habitat. Some of the patches that we considered to be too small and isolated might thus be combined in a larger than average territory. Thus, our definition of available habitat for at least eight further territories is fairly conservative, as only coherent patches of suitable habitat qualified for new potential territories. We identified three further areas with sufficient secondary habitat to support another three or four pairs. The validation in 2003 indicated that the predictions derived from our habitat classification were accurate and useful. Two territories were established where expected, one new pair settled in suitable habitat that had previously been occupied, and one more pair settled adjacent to the study area.

The Pale-headed Brush-Finch is unobtrusive and difficult to detect. It is therefore possible that some of the areas described as unoccupied in this study are in reality already occupied. On the other hand, factors like predation and cowbird parasitism affecting the reproductive output of the species (Oppel et al. 2004b) might render suitable patches unoccupied. It can, however, be assumed that the study area can support at least 40–50 territories of the Pale-headed Brush-Finch. Reduction in territory size resulting from increasing pressure within an expanding population might elevate the number of pairs that the study area can accommodate. Furthermore, an adjacent slope not surveyed in 2002 held another two pairs in 2003. Since we used distribution data to define suitable habitat, it has to be cautioned that there is no guarantee that presence of individuals in a certain habitat is related to habitat quality (van Horne 1983, Pulliam 1988, Jones 2001). Cowbird parasitism or interspecific competition by other brush-finch species might reduce the availability of suitable habitat (although the sympatric Stripe-headed Brush-Finch [*Buarremon torquatus*] uses a different microhabitat, Oppel et al. 2004b).

The identification and protection of new areas with suitable habitat seems essential for the conservation of the Pale-headed Brush-Finch to reduce the risks inherent to small populations at a single site. Repeated searches in the 1990s found former localities in the Río Jubones drainage degraded and devoid of the Pale-headed Brush-Finch (Collar et al. 1992, Krabbe 2004). Though suitable habitat is rare, it persists at a few localities (N. Krabbe, pers. comm.), and succession on fallow land might create new suitable habitat. Assessing the species' presence in all suitable areas outside the Yunguilla Valley would thus yield important insight into habitat use, colonization probability, and the ability to cope with cowbird parasitism at a different locality. Our results provide an important tool for this search and also to implement successful land management in the Yunguilla reserve to counteract conversion from scrub into forests.

This study was funded by the German Academic Foreign Exchange Service (DAAD), grant number 332404010, the Royal Society for the Protection of Birds, and the Swedish Club300, and conducted in collaboration with the Institute for Avian Research in Wilhelmshaven, Germany. The research was carried out under permit No. 004-IC-FAU-DBAP/MA of the Ministerio del Ambiente, Ecuador, and supported by Fundacion Jocotoco, the landowner of the study area. J. Heathcote was of great help with field observations, habitat mapping, and data entry. C. Pohl kindly provided the Spanish abstract. F. Bairlein and P. Stoddard improved the manuscript with helpful comments.

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