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The role of cacao plantations in maintaining forest avian diversity in southeastern Costa Rica

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Abstract

We conducted 600 ten-minute, fixed-radius point counts in two climatically different seasons in forest, abandoned cacao (*Theobroma cacao*), and managed cacao habitat from September 1997 through April 1998 in the Talamanca lowlands of Costa Rica. A total of 1,464, 1,713, and 1,708 individual birds and 130, 131, and 144 total species were detected in forest, abandoned cacao, and managed cacao, respectively. Independent of season, cacao habitats had a significantly greater number of individuals and species per point than forest. Community similarity analyses based on guild categorizations revealed a significant degree of similarity among all habitats; however, habitat affinity analyses showed cacao habitats having significantly less forest specialists than forest. A multiple linear regression model for actively managed cacao habitat using habitat and landscape variables revealed density and diversity of canopy tree species to be significantly correlated with numbers of forest specialist species detected per point. Although nearest distance to forest was negatively correlated with the number of forest specialist species per point, it was not a significant variable in the model, possibly indicating the complex and unpredictable nature of bird movements within the complex habitat mosaic of Talamanca. The present forest bird community of the Talamanca lowlands is poor in forest specialist species relative to other forested Caribbean lowland sites. The broad patterns of avifaunal distribution illustrated by our results suggest, therefore, that although cacao plantations cannot substitute for forest, they provide habitat for a large number of species which depend to some degree on forests.

Introduction

Tropical deforestation for agricultural clearing continues to be a major contributor to the worldwide loss of biodiversity (Bryant et al., 1997). For example, with native forest having long since been cleared in many regions, Northern Latin America continues to lose 1 to 4% of forest cover per year due to various forms of agriculture (Greenberg and Reaser, 1995). Although eleven percent of its land area is managed for protection, Costa Rica exemplifies this trend with an annual loss of 3.2%. Historically, much of this loss has been due to conversion of forest to pasture, export agriculture or small farms (Watson et al., 1998; Sánchez-Azofeifa, 1996).

The rapid rate of deforestation has resulted in a race among conservationists to protect the remaining forested tracts. Often overlooked, however, is the fact that conversion of tropical forests for agricultural use is rarely complete, and often not permanent. Within the agricultural land-

scape, one can find a significant amount of forested area in the form of managed multistory agroforestry systems, or agroecosystems, whose features of structural complexity, microclimate buffering, and diversity of canopy food plants which retain high biodiversity and contribute to the protection of forest biota (Perfecto et al., 1996; Michon and de Foresta, 1995; Alcorn, 1990). Although no substitute for intact forest, these economically important anthropogenic habitats will have increasing conservation value as large tracts of tropical forest continue to be reduced or eliminated (Sherry and Holmes, 1996; Schelhaus and Greenberg, 1993; Pimentel et al., 1992).

In the past decade, a growing number of studies have focused on biodiversity in agroforestry systems (e.g. Wunderle and Latta, 1996, 2000; Roberts et al., 2000; Greenberg et al., 1997a, b; Parrish and Petit, 1996; Thiollay, 1995; Heinen, 1992). The studies using birds as indicators of biodiversity and forest habitat quality have dealt little with the cacao agroforestry system (but see Greenberg et al., 2000; Alves, 1990). Also receiving little attention are the roles played by shade management and landscape context in determining forest bird distribution in agroforestry systems. In addition, there has been a bias toward neotropical migratory species in these studies, virtually omitting the year-round resident avifauna, whose inclusion could greatly strengthen inferences regarding the habitat suitability of agroecosystems.

The purposes of this study were a) to provide a general assessment of the forest habitat quality found in cacao plantations using avian community structure comparisons that include both migratory and resident species; b) to compare gross vegetation structure of forest and cacao habitats; c) to examine the influence of seasonal phenological differences among canopy trees on bird community structure; and d) to determine how habitat and landscape variables affected forest bird species composition in actively managed cacao plantations.

Study site and methods

This study took place in the Caribbean lowlands of the canton of Talamanca, Costa Rica (943 km^2, center of study area 9°30′ N, 22°40′ W, Kapp, 1989). It was administered by The Nature Conservancy's Wings of the Americas program with logistical support from the organization ANAI and the Talamanca Small Producers' Association (APPTA). The average daily temperature of the region is 25.8 °C and average annual precipitation 2,370 mm, with slightly pronounced dry seasons during the March–April and September-October periods (IMN, 1998; Herrera, 1985). The study area spans the tropical humid forest and the premontane wet forest life zones (Tosi, 1969). Both zones are experiencing greatly accelerated rates of deforestation in Costa Rica primarily due to logging (most prevalent cause in Talamanca), conversion to cattle pasture, and other forms of agriculture (MIDEPLAN, 1996; Sánchez-Azofeifa 1996). Portions of the study area also lie within a relatively populated section of the Talamanca – Caribbean Biological Corridor, a 2 to 10 mile-wide band with varying protection status extending from the continental divide to the Atlantic coast.

The landscape of this region is a complex agricultural mosaic, a result of the boom and bust cycles of banana and cacao cultivation of the last century, and more recently, of increased deforestation and cattle ranching. Interspersed within the rugged topography are the huge contiguous expanses (thousands of ha) of large-scale banana cultivation in the Sixaola River valley, as well as smaller patches of bananas, cacao, subsistence crops, and cattle pasture. Larger patches of forest between 5–200 ha are also common, most of which have been selectively logged within the last 40 years.

In the late 1970s, the rapid spread of monilia pod rot disease (*Moniliophthora roreri*) resulted in conversion of cacao plantations to pasture or subsistence crops (Hernández-Auerbach, 1995). However, cacao plantations still comprise a large area within the region. There are approximately 400 cacao producers in lower Talamanca actively managing approximately 900 ha of cacao patches up to 10 ha. Shade canopy management, the most critical variable influencing avian diversity levels, varies widely from the structurally diverse combination of remnant and planted shade of older, traditionally managed plantations (> 20 years old), to younger, more intensively managed plantations

(< 20 years old) with a monoculture of planted shade trees of species such as *Cordia alliodora* and *Inga* spp. Although there are no data on the area comprised by abandoned cacao plantations, the area is at least comparable to that of managed plantations. These plantations exist in 5 to 15 ha patches, and generally contain a taller and consistently dense shade canopy composed of large remnant forest trees such as *Hura crepitans* and *Ficus* spp. The understory of both plantation types consists almost exclusively of cacao trees planted at high densities (Table 1).

Between 11 November 1997 and 17 March 1998, birds were systematically censused using the point-count visual/aural surveying technique. The point-count bird survey method is appropriate for obtaining a broad sample of bird communities in a common, region-wide habitat distributed in disjunct patches (Petit et al., 1994). A fixed radius of 25 m for point counts was used to minimize bird detection differences between habitats of different vegetation structure (Petit et al., 1994). For this reason, all points were at least 25 m from a habitat edge to minimize detection of individuals not specifically associated with the habitat being surveyed. One hundred points were sampled in each of three habitats: forest, abandoned cacao, and managed cacao. Point counts were separated by at least 100 m and were conducted between 05:30 and 08:00 hours Central Standard Time; nocturnal birds were not sampled. Within a 25 m radius of each survey point, we recorded the species, number, sex (when possible) and foraging height (when seen) of all individuals during a 10-minute period. Individuals flying over a point count circle were not recorded. As in other similar tropical avian studies, each point was sampled twice during the study period to determine the effect of seasonal phenological differences on bird distribution (Greenberg, 1997a, b). The first set of 300 points was completed within a relatively wet period from 11 November to 20 December 1997 and the second during a relatively dry period from 24 January to 20 March 1998.

Plantations were categorized as abandoned or managed based upon whether or not shade canopy pruning, cacao harvesting, weeding, and other forms of active management were practised. Points were randomly located in 25 and 19 managed and abandoned plantations, respectively. Forest points were located in both primary (n = 33) and secondary (n = 67) forest patches, since past selective logging in the region was quite extensive. Combining these points into a single forest category, however, still provided an adequate index of general forest avifauna with which to compare cacao plantation avifauna.

For bird community comparisons, managed cacao sites were classified according to their management regimes, which were classified into three types according to our observations: traditional, being those plantations with lower cacao tree densities utilizing a diverse combination of remnant forest and planted canopy tree species; intensive, referring to plantations with planted monospecific shade tree stands and greater cacao tree densities; and traditional/intensive, being plantations exhibiting a combination of the former two types.

To compare the gross habitat features and to determine the associations between bird abundance and vegetation features of managed cacao plantations, structural and floristic characteristics were quantified within the areas of the point count surveys. Vegetation data were obtained using a method modified from James and Shugart (1970). The following variables were estimated by eye at each point-count circle: herbaceous ground cover, density of cacao plants, mean canopy height, number of canopy trees larger than 15 cm diameter at breast height, percentage of ground area covered by canopy foliage, the number of morphological types of canopy tree species as a measure of canopy tree diversity, and the percent coverage of ground area comprised by flowering and fruiting canopy vegetation (recorded during both sampling periods). Shrub density and canopy tree diversity were not estimated for forest habitat.

The effect of habitat and landscape factors on bird community structure was examined only in managed cacao habitat. The only landscape variable considered was the shortest distance between the center of each managed cacao point-count circle and the next forest patch large enough to be considered as a source of forest birds. Distances were determined first by obtaining geographic coordinates of forest patch edges and point-count circles through the use of a Magellan Field Pro V Geographic Position Systems instrument. After fieldwork was completed, coordinate

data were entered into georeferencing programs to obtain distance estimates.

Ecological similarity among the three habitats was examined by first classifying each bird species into guilds based on diet and the stratum in which a given species spends most, if not all, of its time (Greenberg, 1997a; Blake and Loiselle, 1991; Stiles, 1983). After guild categorization, the Pearson's *r* correlation coefficient was determined for all habitat pairings using total numbers of individuals detected per guild for combined season data (Sokal and Rohlf, 1995).

Further comparisons among point count habitats were based on the convention of habitat affinity classification (Greenberg et al., 1997a, b; Wunderle and Latta, 1996). Habitat affinities were: forest specialists which were species found exclusively in forest; woodland generalists being species found in forest and adjacent arboreal habitats with large patches of trees; and agricultural generalists referring to species found in open agricultural habitats with scattered patches of trees. This classification was based primarily on occurrence frequencies of species detected in a similar multi-habitat point-count study done within the La Selva Biological Station, approximately 150 km to the northwest (10°25′ N, 84°01′ W, Blake and Loiselle, 2000).

A multiple regression model using vegetation and landscape measurements as independent variables and numbers of individual forest birds as the dependent variable was used to assess the vegetation and landscape influences on forest birds detected in managed cacao (SPSS, 1997). All variables entering the model were transformed appropriately to meet parametric test assumptions (Sokal and Rohlf, 1995). Vegetation variables were compared between habitats using one-way ANOVAs.

Results

Vegetation comparisons

Structural differences among the three habitats include significantly less canopy diversity, canopy coverage, and shorter canopy height in managed cacao compared to the other habitats (Table 1). Since a two-way ANOVA for habitat and season effect produced significant interaction, separate one-way ANOVAs were conducted for each habitat to determine seasonal phenological differences. All habitats had significantly more flowering and fruiting canopy vegetation in the drier season, with managed cacao exhibiting more flowering and fruiting canopy vegetation in both seasons compared to other habitats (Table 1).

Bird community comparisons

Over the two sampling periods, a total of 1,464, 1,713, and 1,708 individual birds and 130, 131, and 144 total species were detected in forest, abandoned cacao, and managed cacao, respectively. Within habitats, there were no seasonal effects on bird abundance and diversity. Abandoned and managed cacao had significantly more individual birds per point than forest, and managed cacao had significantly more species per point than the other habitats (Figure 1).

Avian similarity analyses based on a total of 35 guild descriptors revealed that niche occupation by birds in forest was more similar to abandoned cacao (Pearson's $r = 0.91$) than to managed cacao ($r = 0.75$). Nevertheless, all habitats were highly significant in their degree of similarity (Bonferroni adjusted $P < 0.001$). Habitat affinity analyses showed, however, that forest specialists were significantly less represented in the cacao habitats than in the forest (Figure 2). Managed cacao had significantly more agricultural generalist individuals than either the abandoned cacao or the forest patches and forest had significantly fewer woodland generalists than abandoned cacao (Figure 2). The three habitats did not differ significantly with respect to a combined 'forest species' category comprised of woodland generalists and forest specialists (Figure 2). The effect of management regime on managed cacao bird communities was not significant, although the number of forest species per point increased the more a plantation exemplified traditional management (Figure 3).

Vegetation and landscape effects on managed cacao bird communities

A multiple regression analysis focusing on managed cacao using the per point estimates of

Table 1. Some aspects of vegetation structure of avian habitats provided by forests and cacao plantations in southeastern Costa Rica.

Vegetation variable[a]	Habitat					
	Forest		Abandoned cacao		Managed cacao	
	Ave.	(SD)	Ave.	(SD)	Ave.	(SD)
% ground cover	49.9**	(23.3)	62.7	(24.1)	66.3	(25.9)
Cacao density (no. trees)	–		61.0*	(22.1)	71.8	(32.9)
Tree canopy cover (%)	63.6	(16.1)	66.0	(18.1)	60.0*	(16.2)
No. canopy trees (> 15 cm dbh)	26.9***	(7.3)	15.8	(5.8)	17.7	(5.9)
Canopy height (m)	22.0	(3.3)	21.1	(3.6)	17.8**	(3.5)
Number of canopy morphs	n. d.[b]		6.5	(2.2)	5.4**	(1.9)
Fruiting and flowering canopy cover (%)						
– in wet season	3.4	(4.6)	4.8	(6.3)	5.3	(9.3)
– in dry season	6.3***	(6.2)	12.3***	(10.5)	16.1***	(13.5)

[a] Based on estimates made at each point count circle; $n = 100$ for each habitat. All comparisons are between habitats, except for seasonal fruiting and flowering canopy vegetation, which were compared within habitats.
[b] Not determined.
* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

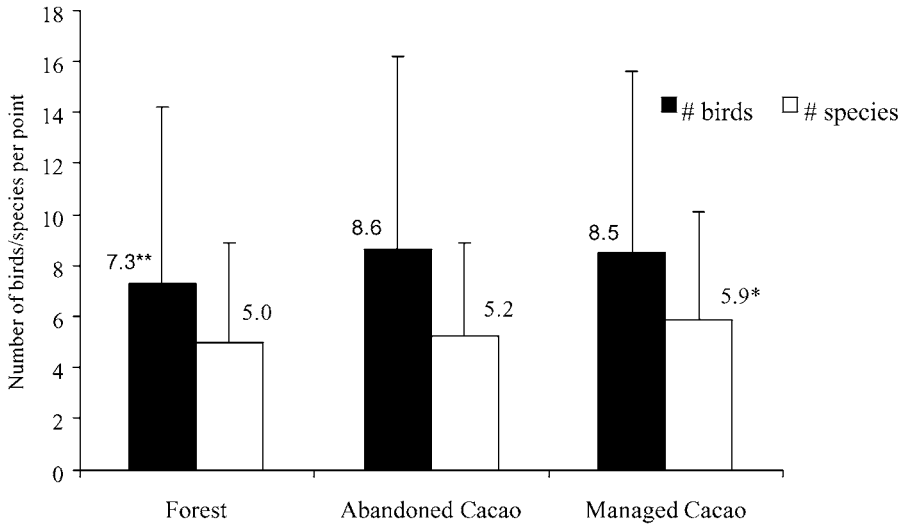

Figure 1. Average number of birds and species observed at each sample point in forest and cacao plantations in southeastern Costa Rica. ($n = 200$ for each habitat; statistical analyses refer to comparisons among habitats; * $P < 0.01$, ** $P < 0.001$; bars are standard errors).

ground cover, cacao density, canopy height, canopy coverage, number of canopy trees, number of canopy tree species, and nearest distance to forest as independent variables, and the per point number of forest bird individuals as the dependant variable explained a significant amount of variation ($P < 0.001$; $R^2 = 0.25$). All vegetation variables except herbaceous ground cover were positively correlated with the total number of forest birds per point. As expected, nearest distance to forest was negatively correlated with the number of forest birds per point, but did not

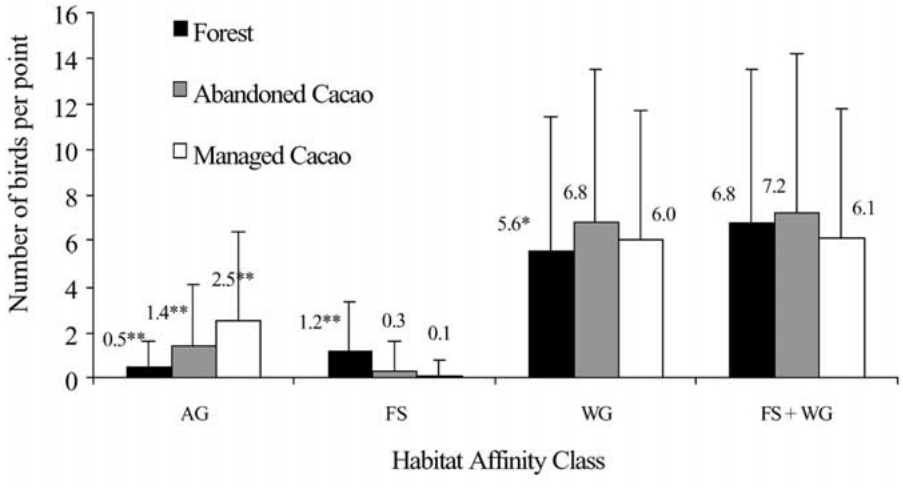

Figure 2. Average number of birds, grouped by habitat affinity classes, that were observed at each sample point in forest and cacao habitats in southeastern Costa Rica (AG = agricultural generalist, FS = forest specialist, WG = woodland generalist; statistical analyses are within-affinity comparisons, * $P < 0.05$, ** $P < 0.001$; bars are standard errors).

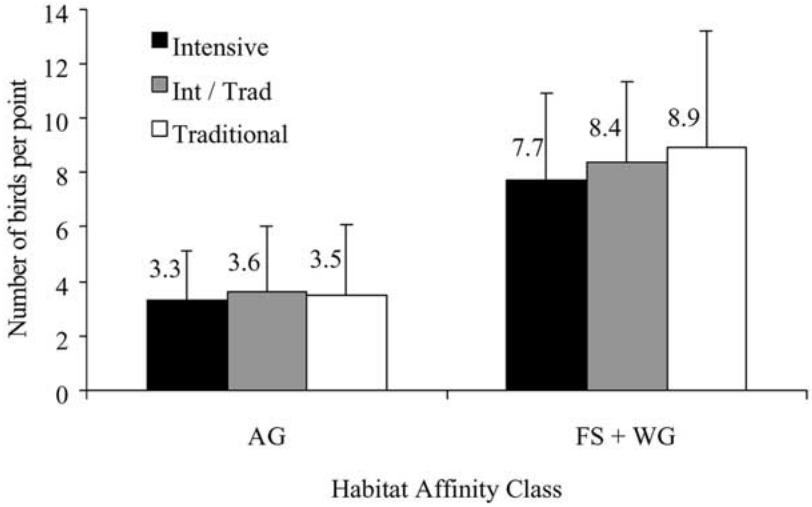

Figure 3. Average number of birds per sample point in affinity classes for different management regimes of managed cacao in southeastern Costa Rica (AG = agricultural generalists; FS+WG = forest specialists and woodland generalists combined; bars are standard errors).

explain a significant amount of the variation. The only two variables explaining significant variation were the number of canopy tree species and the number of canopy trees ($P < 0.001$, $P = 0.02$, respectively; combined $R^2 = 0.24$).

Discussion

Bird community structure in forest versus cacao habitats

Previous studies have reported regional movements among avian assemblages in response to seasonally available food resources (Levey and Stiles, 1994; Loiselle and Blake, 1991). Studies in

shaded coffee plantations have detected significant shifts in frugivore and nectarivore bird abundance from wet to dry seasons, with concurrent increases in canopy fruits and flowers (Greenberg et al., 1997a). The lack of seasonal shifts in distribution in this study despite significant increases in canopy fruits and flowers in the dry season may be explained by the prevalence of fruits which are not bird dispersed and by flowers which produce relatively little nectar (e.g. *Cordia alliodora* in managed cacao and *Pentaclethora macroloba* in forest).

It is not surprising that managed cacao harbored higher numbers of individuals and species per point than forest (Figure 1) given that it was the habitat most influenced by the edge effects of adjacent open habitats. As suggested by Figure 2, these higher levels of diversity and abundance are mostly a contribution from agricultural generalist species. In contrast, abandoned cacao, characterized by taller denser canopies and its occurrance in extensive patches, resembled more an isolated woodland; hence it contained fewer agricultural generalists than managed cacao due to their preference for open canopies and tree crowns.

Ecological similarity analyses suggested that forest and cacao habitats provide similar niches for Talamancan avifauna, but habitat affinity analyses revealed that species composition differed between habitats (Figure 2). The relatively smaller patch size and greater proximity to open habitats may explain the greater numbers of agricultural generalists in managed than in abandoned cacao plantations. The non-significant result in the combined woodland generalist – forest specialist affinity comparison indicates that cacao habitats are generally suitable to forest birds. The absence of forest specialists from cacao habitats is mainly explained by the fact that 71% of all forest specialist individuals detected in forest points were understory insectivores – a group of species not adapted to a habitat with a dense monoculture understory, such as in managed or abandoned cacao plantations.

The paucity of forest specialists in Talamancan cacao plantations should not, however, be overemphasized given the already low number of forest specialists found in Talamanca compared to other Caribbean lowland forests in Costa Rica. In the La Selva study, 30% of all individuals detected in forest were forest specialists compared to only 16% in Talamanca (adapted from Blake and Loiselle, 2000). Agricultural generalists were much more common in Talamancan forest points, comprising 7% of the total numbers of birds compared to 1.4% at La Selva. This regional comparison highlights the present depauperate condition of Talamancan forest avifauna, providing a regional perspective on the importance of Talamancan cacao plantations for maintaining forest bird diversity.

Bird species communities in different cacao management regimes

The lack of significant differences among the management regimes of managed cacao habitat may indicate the influences of the surrounding landscape on bird distribution. The expected trend of fewer agricultural generalists and more forest species along the intensive to traditional management gradient may not be clearly evident since each management regime was represented by plantations that varied with respect to their proximity to forest. Therefore, any enhancing vegetation qualities of some traditional plantations may have been offset by the relative isolation from forest. The converse may be true of some intensive plantations. As experienced in other studies, this interplay between habitat and landscape heterogeneity within Talamanca is an obstacle to a greater understanding of species distribution patterns (Greenberg et al., 2000; Wunderle and Latta, 1996).

Relationship of bird variables to habitat and landscape factors in managed cacao

Regression analysis suggested that canopy tree diversity and the number of canopy trees were the most important predictors of forest bird abundance in managed cacao; the model, however, did not explain a large proportion of the variation. These results are similar to other bird studies in agroforestry systems which demonstrate the importance of greater structural complexity, such as shade trees with bird-dispersed fruits (Greenberg et al., 1997b; 2000; Wunderle and Latta, 1996; Thiollay, 1995).

Although distance to forest was negatively

correlated with the numbers of forest specialists, the complex pattern of land use in Talamanca implicates the critical role played by forest connectivity, location of population sources and sinks, and the size, configuration, and distribution of different habitat patches (MacArthur and Wilson, 1967). If Talamancan forest patches were more extensive, there may have been a stronger relationship between distance to forest and forest bird abundance in managed cacao. This study contrasts with biodiversity studies done in landscapes that exhibit larger, more regular and non-disjunct habitat patches. In the latter, correlations between distance to forest and avian diversity were more evident (Roberts et al., 2000; Parrish and Petit, 1996; Stouffer and Bierregaard, 1995; Alves, 1990).

Conclusions and recommendations

Although lacking in forest specialist bird species, both abandoned and managed cacao plantations in the Talamancan lowlands provide habitat for large numbers of woodland generalist species. Managed plantations do not offer a dry season refuge for forest birds, but they support large numbers of forest bird species throughout the annual cycle. Given that Talamancan forests are at present relatively depauperate in forest specialists, cacao plantations in this region have definite conservation value. Our results indicate that forest bird species composition in managed cacao can be augmented by increasing the number and diversity of canopy food trees. Multi-disciplined efforts to guarantee the economic viability of cacao cultivation in conjunction with culturally accepted habitat enhancements will safeguard high levels of avian diversity in this increasingly deforested region. The forest avifauna of this region is comprised primarily of wide ranging species passing into or through different habitats in a complex patchwork landscape for varying lengths of time. Therefore, presence alone of a species in a habitat is not sufficient to indicate the degree of dependence on that habitat. For this reason, the presented findings need to be corroborated by studies which examine habitat suitability at the level of bird population processes.

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