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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 1464, 1713, and 1708 individual birds and 130, 131, and 144 total species were detected in forest, abandoned cacao, and managed cacao respectively. Cacao habitats had a significantly greater number of individuals and species per point than forest with no seasonal effect. 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 species detected per point. Although nearest distance to forest was a negatively correlated, it was non-significant, possibly indicating the complex unpredictable nature of bird movements within the complex habitat mosaic of Talamanca. The present forest bird community of the Talamanca lowlands is depauperate in forest specialist species relative to other forested Caribbean lowland sites. The broad patterns of avifaunal distribution illustrated by our results suggest, therefore, that cacao plantations are not a habitat substitute for forest, but 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 1-4% 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 (Sanchez-Azofeifa, 1996; Vandermeer and Perfecto, 1996; Watson, et al. 1998).

The rapid rate of deforestation has resulted in a race among conservationists to protect remaining forested tracts. Often overlooked, however, is that conversion of tropical forests for agricultural use is rarely complete, and often not permanent. Within the agricultural landscape, 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 retain high biodiversity and contribute to the protection of forest biota (Perfecto *et al*., 1996; Michon de Foresta, 1995; Alcorn, 1990; Beer, 1987). 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, 1994; 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, 2000; Roberts *et al*., 2000; Greenberg *et al*., 1997a, 1997b; Wunderle and Latta, 1996; Parrish and Petit, 1996; Thiollay, 1995; Estrada *et al*., 1993; 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*., in press; Robbins *et al*., 1992; 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 1) 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; 2) to compare gross vegetation structure of forest and cacao habitats; 3) to examine the influence of seasonal phenological differences in canopy trees on bird community structure; and, 4) 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 within the Caribbean lowlands of the canton of Talamanca, Costa Rica (943 km², 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 Asociación ANAI and the Talamanca Small Producers’ Association (AAPTA). The average daily temperature of the region is 25.8 °C and average annual precipitation 2370 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 –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 huge expanses of banana cultivation, 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 1970's, the rapid spread of monilia pod rot disease (*Moniliophthora roreri*) resulted in conversion from 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 of up to 10 ha. Shade canopy management, the most critical variable influencing avian diversity levels, lies within a spectrum of regimes; 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 planted shade canopy of species such as *Cordia alliodora* and *Inga sp.* 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 -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 sp*. The understory of both plantation types is almost exclusively cacao trees planted at high densities (see Table 1).

Between 11 November, 1997 and 17 March, 1998 birds were systematically censused using the point-count visual/aural surveying technique (Petit *et al*., 1994). 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 (Ralph *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 greater than 25 m from a habitat edge to minimize detection of individuals not specifically associated with the habitat being surveyed. One hundred points were conducted in each of three habitats: forest, abandoned cacao, and managed cacao. Point counts were separated by at least 100 m and were conducted between 0530 and 0800 hours CST; nocturnal birds, therefore, were not sampled. Within a 25 m radius of each stationary 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, 1997b). 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 pruining, cacao harvesting, weeding, and other forms of active management were in practice. Points were located in a total of 25 and 19 managed and abandoned plantations respectively, all selected randomly and within a practical distance from the project base. Forest points were conducted in both primary (n = 33) and secondary (n = 67) forest patches since past selective logging in the region is quite extensive. Combining these points into a single forest category, however, still provides an adequate index of general forest avifauna with which to compare cacao plantation avifauna.

Managed cacao sites were classified according to their management regime for bird community comparisons. Management regimes were classified into three types according to our observations: traditional, those plantations with lesser cacao tree density utilizing a diverse combination of remnant forest and planted canopy tree species; intensive, those utilizing monoculture planted shade canopy stands with greater cacao tree densities; and traditional/intensive, plantations exhibiting a combination of the former two types.

To compare gross habitat structure among habitats and to determine associations between bird abundance and vegetation features of managed cacao plantations, structural and floristic characteristics were quantified within all the point count surveys. Vegetation data were obtained using a method modified from James and Shugart (1970). For each point count circle the following were estimated: 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 apparent tree "morphs" as a measure of canopy tree diversity, and the percentage of ground area comprised by flowering and fruiting canopy vegetation (recorded during both sampling periods). Estimates of shrub density and canopy tree diversity were not made 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 a forest patch, large enough to be considered as a source of forest birds, and the center of the managed cacao point count circle. 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 habitats was examined by first classifying each species into guilds based on diet and the stratum in which a given species spends most, if not all, its time (Greenberg, 1997a; Remsen, 1994; Blake and Loiselle, 1991; Stiles, 1983). After guild categorization, the Pearson's *r* correlation coefficient was determined for total numbers of individuals detected per guild using 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, 1997b; Wunderle and Latta, 1996). Habitat affinities were: forest specialist, species found exclusively in forest; woodland generalist, species found in forest and adjacent arboreal habitats with large patches of trees; and agricultural generalist, 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.

Results

Vegetation Comparisons

Using appropriate transformations for parametric tests, one-way ANOVAs were conducted on each vegetation variable for between-habitat 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). Within-habitat analyses were conducted for seasonal phenological comparisons. A two-way ANOVA for habitat and season effect produced significant interaction, therefore, separate one-way ANOVAs were conducted for each habitat to determine seasonal differences. All habitats had significantly more flowering and fruiting canopy vegetation later 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

A total of 1464, 1713, and 1708 individual birds and 130, 131, and 144 total species were detected in forest, abandoned cacao, and managed cacao respectively over the two sampling periods. No season effect on bird abundance and diversity existed within habitats. 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 representation by birds in forest and abandoned cacao was highly similar (Pearson's $r = 0.91$), and that between forest and managed cacao less similar ($r = 0.75$). 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 compared to forest (Figure 2). Managed cacao, had significantly more agricultural generalist individuals than both the abandoned cacao and forest patches (Figure 2). The three habitats did not differ significantly with respect to the presence of woodland generalists, nor did they differ with respect to a combined "forest species" category comprised by woodland generalists and forest specialists (Figure 2).

The effect of management regime on managed cacao bird communities was not significant, although a trend toward increased number of forest species per point was present along the intensive/traditional gradient (Figure 3).

Vegetation and Landscape Influences on Managed Cacao Bird Communities

A multiple regression analysis focusing on managed cacao using the per point estimates of 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 ground cover were positively correlated with the total number of forest birds per point. As expected, nearest distance to forest was negatively correlated with number of forest birds per point, but did not explain a significant amount of the variation. The only two variables explaining significant variation were number of canopy tree species and number of canopy trees ($p < 0.001$, $p = 0.02$, respectively; combined $R^2 = 0.24$).

Discussion

Bird Community Structure Comparisons in Forest and 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 may be explained by the prevalence of fruits which are not bird dispersed and by flowers which do not produce relatively large quantities of 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. Occurring in patches that were more extensive with a taller more dense canopy, abandoned cacao contained far fewer agricultural generalists than managed cacao.

Ecological similarity analyses suggest that forest and cacao habitats provide similar niches for Talamancan avifauna, but habitat affinity analyses reveal that different species occupying these niches (figure 2). The relatively smaller patch size and greater proximity to open habitats may explain the greater numbers of agricultural generalists in managed cacao plantations. The lack of significance in the combined "forest species" affinity suggests general suitability of cacao habitats to forest birds. The absence of forest specialists in cacao habitats is mainly explained by the fact that 70.9% 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 a managed or abandoned cacao plantation.

The paucity of forest specialists in Talamancan cacao plantations should not be overemphasized, however, 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, 29.9% of all individuals detected in forest were forest specialists compared to only 16.2% in Talamanca (adapted from Blake and Loiselle, 2000). Agricultural generalists were much more common in Talamancan forest points, comprising 6.9% 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 role Talamancan cacao plantations play in maintaining forest bird diversity. Keeping in mind this consideration paid to the forest specialist component, the lack of significant differences between the Talamancan habitats with respect to the combined "forest species" affinity category further points to the capability of cacao habitats to harbor forest birds.

Bird Species Communities in Different Cacao Management Regimes

The lack of significant differences among management regimes of managed cacao habitat may indicate influences of landscape context on bird distribution. The expected outcome of fewer agricultural generalists and greater 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 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 confounds a greater understanding of species distribution patterns (Greenberg, 2000; Wunderle and Latta, 1996).

Relationship of Bird Variables to Habitat and Landscape Factors in Managed Cacao

Regression analysis suggests the importance of canopy tree diversity and number of canopy trees as most influential 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 suggest the incorporation of greater structural complexity, such as shade trees with bird dispersed fruits (Greenberg *et al.*, 2000; Greenberg *et al.*, 1997b; Wunderle and Latta, 1996; Thiollay, 1995).

Although distance to forest was negatively correlated to numbers of forest species, 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 forest biodiversity were more clear (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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Table 1. Some aspects of vegetation structure of avian habitats provided by forests and cacao plantations in southeastern Costa Rica.

	Habitat					
	Forest		Abandoned Cacao		Managed Cacao	
Vegetation variable[a]	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)
% Canopy cover	63.6	(16.1)	66.0	(18.1)	60.0*	(16.2)
No. canopy trees (>15cm 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)
No. 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 = 200 for each habitat. All comparisons are between habitats, except for seasonal fruiting and flowering canopy vegetation, which were compared within habitats.
[b] Not determined.
* $p < 0.05$, **$p < 0.001$, ***$p < 0.001$.

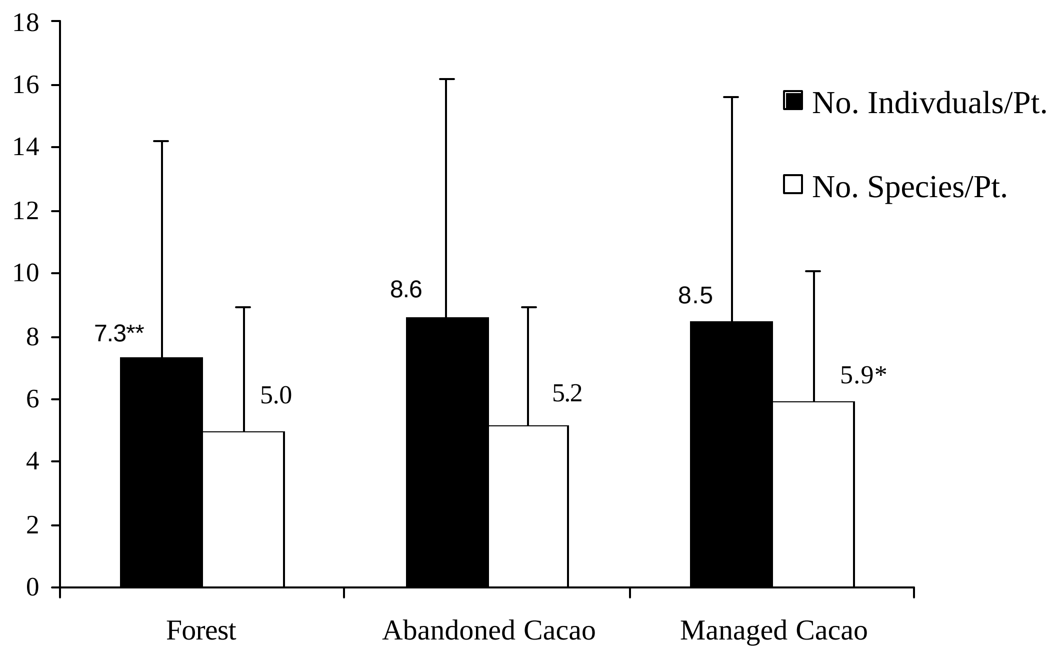

Figure 1. Average number of individuals and species detected per point (n=200 for each habitat; statistical analyses are between-habitat comparisons bird variables indicated, *p<0.01, **p<0.001; bars are standard errors).

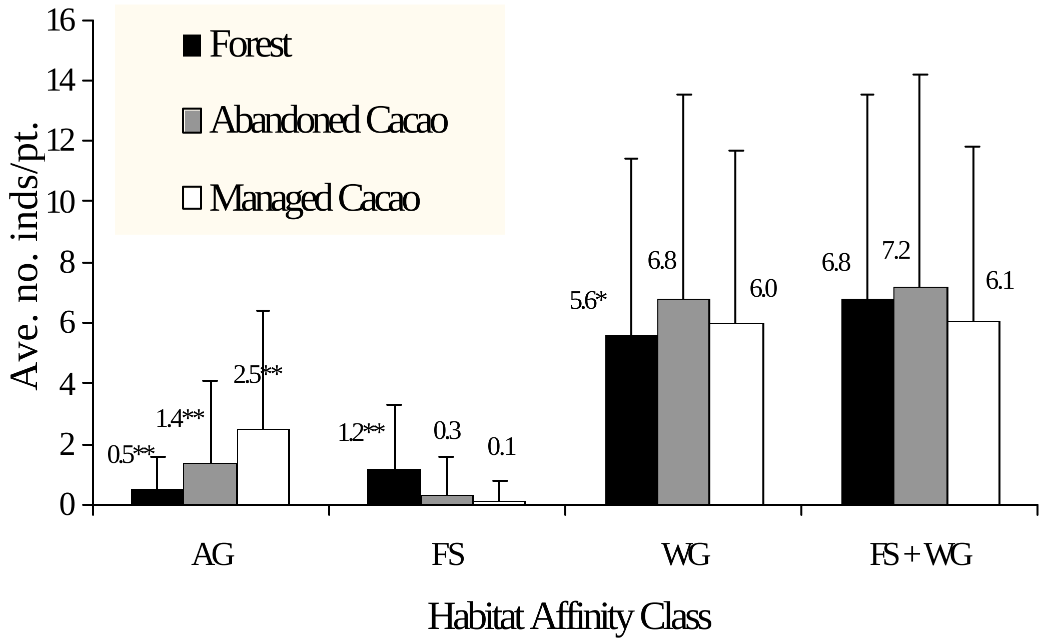

Figure 2. Average number of individuals detected per point in forest and cacao habitats for different habitat affinity classes. (AG = agricultural generalist, FS = forest specialist, WG = woodland generalist; statistical analyses are within-affinity comparisons, *p<0.05, **p<0.001; bars are standard errors).

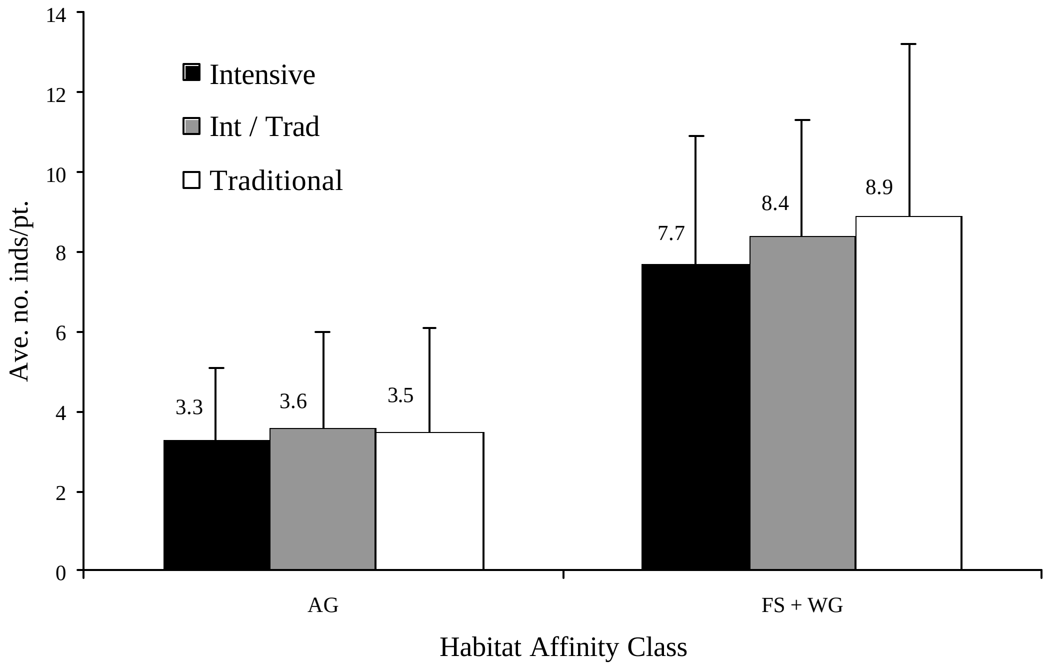

Figure 3. Average number of individuals per point in affinity classes for different management regimes of managed cacao (AG = agricultural generalists; FS+WG = forest specialists and woodland generalists combined; bars are standard errors).