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AVIAN DISTRIBUTION IN DOMINICAN SHADE COFFEE PLANTATIONS: AREA AND HABITAT RELATIONSHIPS

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Abstract.—Residents and wintering Nearctic migrants were sampled by point counts in 40 small to medium-sized (0.07–8.65 ha) shade coffee plantations with an overstory of *Inga vera* in the Cordillera Central, Dominican Republic. The purpose of the study was to determine the relative importance of plantation area, isolation, and habitat structure to avian distribution and abundance. Variation in abundance was unrelated to plantation area for all migrant species (n = 7), whereas the local abundance of four of ten resident species increased significantly with area. Elevation was the only variable that significantly contributed to the total number of species per plantation (fewer species at higher elevation), and no habitat variables significantly contributed to variation in the total number of migrant species. In contrast, significantly higher numbers of resident species were found in larger and older plantations at lower elevations, characterized by numerous stems ≥3 cm DBH, little or no pruning of overstory branches, and maximum canopy cover at 12.0–15.0 m. Coffee plantations with high levels of structural and floristic diversity should be encouraged for avian conservation, and even the smallest plantations, if not too isolated by treeless areas, can contribute to avian abundance and diversity in tropical agricultural regions.

DISTRIBUCIÓN DE AVES EN ALGUNAS PLANTACIÓNES DE CAFÉ DE SOMBRA EN LA REPÚBLICA DOMINICANA: RELACIONES ENTRE ÁREA Y HABITAT

Sinopsis.—En la Cordillera Central de la República Dominicana, se muestrearon (por conteo de puntos) 40 plantaciones de café de sombra (cuyo tamaño varió de 0.07–8.65 ha) con un docel de *Inga vera.* El propósito del estudio fué determinar la importancia relativa del área de la plantación, el aislamiento de la misma y la estructura del habitat, en relación a la distribución y abundancia de aves. La variación en abundancia no estuvo relacionada al área de la plantación para las especies migratorias estudiadas (n = 7), aunque la abundancia, de cuatro de un total de diez especies residentes, aumentó significativamente con el incremento en área. La elevación fue la única variable que contribuyó significativamente al número total de especies por plantación (a mayor elevación menos especies), y ninguna variable en el habitat contribuyó significativamente a la variación en el número total de especies migratorias. En contraste, un número significativamente mayor de especies residentes fue encontrado en plantaciones de mayor tamaño y de más tiempo, establecidas a elevaciones más bajas. Estas se caracterizaron por tener tallos > a 3 cm DBH, un sotobosque poco alterado y un docel máximo de 12.0–15.0 m. Deben promoverse plantaciones de café con altos niveles de diversidad (tanto estructural como florístico) para la conservación de las aves. Inclusive las plantaciones más pequeñas, si no estan muy aisladas de otras áreas con árboles, pueden contribuir a la abundancia y diversidad de aves en las regiones agrícolas del trópico.

Traditional coffee plantations that include an overstory of shade trees have a relatively rich avifauna (e.g., Wetmore 1916; Griscom 1932; Augilar-Ortiz 1982; Wunderle and Latta 1996; Greenberg et al. 1997a,b). The relatively high diversity of birds found in shade coffee plantations and the presence there of some forest-dwelling specialists suggest that shade coffee may provide a valuable refugia for birds and other organisms in heavily deforested agricultural regions of the tropics (Perfecto et al.

1996). However, not all shade coffee plantations may be equivalent in their attractiveness to birds, as variation in canopy structure and composition influence avian abundance and diversity in some plantations (Greenberg et al. 1997a; Calvo and Blake 1998; Johnson, in press). Demonstration of the potential value of shade coffee to birds requires identification of particular habitat characteristics of the plantations with which various bird species are associated.

Plantation area should influence avian distribution in shade coffee plantations, based on other studies of species-area effects on birds (reviewed in Burgess and Sharpe 1981; Williamson 1981; Harris 1984). Nonetheless, species differ considerably in their response to patch size. For instance, many Nearctic migrants avoid small isolated forest patches on the breeding grounds (e.g., Lynch and Whigham 1984; Robbins et al. 1989), although they may readily inhabit similar or even smaller-sized patches on the tropical wintering grounds (Robbins et al. 1987; Greenberg 1992). Although most species-area studies have been conducted in the temperate region, the few tropical studies indicate that many tropical resident species are sensitive to habitat patch size (e.g., Willis 1974, 1979; Lovejoy et al. 1986). Thus, small isolated shade coffee plantations should support fewer species per unit area of habitat.

In the Dominican Republic shade coffee plantations often constitute the only broadleaf tree cover remaining in mid-elevation agricultural areas. There plantations of different sizes are typically isolated by pastures or cropland from other plantations or forest patches of pine or mixed pine and broadleaf species. A variety of resident and migrant bird species occupy these plantations, thereby maintaining avian diversity in an otherwise inhospitable agricultural landscape (Wunderle and Latta 1996). However, the relative importance of plantation area, isolation, and habitat structure for attracting different species is unknown. The objective of this study was to examine the relative importance of these variables on species-area relationships in shade coffee plantations. A multivariate approach was used to identify the plantation characteristics associated with individual migrant and resident species.

METHODS

Study site.—Forty shade coffee plantations (mean = 1.1 ha, range 0.1–8.7 ha) were sampled in the vicinity of Constanza (18°54′N, 70°37′W), Ebano Verde (19°2′N, 70°34′W), Manabao (19°6′N, 70°48′W) and Jarabacoa (19°9′N, 70°39′W), La Vega province, at an elevation of 480–1240 m in the Cordillera Central of the Dominican Republic. The plantations are located in a zone that receives an annual rainfall of approximately 1200 mm (Hartshorn et al. 1981) and is classified as subtropical moist forest in the Holdridge life zone system (Anonymous 1967). In this region, coffee is cultivated in areas that were originally pine forest (*Pinus occidentalis*). Pine forests, most of which have been logged selectively, remain in scattered patches on the steeper slopes. These relict stands contain variable amounts of broadleaf understory that has been degraded by fire, cutting, or grazing. Broadleaf canopy trees are restricted primarily to shade coffee plantations, fruit and ornamental trees along fence rows and around homes, and in arroyos lined primarily with the exotic *Syzygium jambos*. Broadleaf forest or woodland are absent and pasture and cultivated ground crops are the predominant cover type.

Bird censuses.—Bird populations were sampled 6–19 Feb. 1992 using fixed-radius point counts (Hutto et al. 1986). An observer recorded all birds seen or heard during a 10-min period at each point. Points were placed in the center of the smallest plantations. In larger plantations, each point was set at least 100 m from each other and equidistant from the plantation edge, at least 20 m from the edge. Each point was 100 m or more from all others. Only in the ten largest shade coffee plantations was it possible to conduct more than one point count. Counts were initiated at sunrise and terminated before 1100 h, with most counts completed before 1030 h. During the count, the observer estimated the minimum distance to each bird detected within a 25-m radius. Analyses were restricted to counts of birds detected only within a 15-m radius circle ensuring that all plots, including those in the smallest plantations, contained equivalent amounts of coffee habitat. The surveys excluded swallows, swifts, and raptors.

Habitat measurements.—Vegetation was measured in 16-m diameter plots (0.02 ha) centered at each point. Stems of all standing trees and saplings ≥3 cm were measured 1.3 m above the base (DBH) and identified to species. Stem density of coffee plants at breast height was estimated along four 8-m transects running in the cardinal directions centered within the 0.02-ha circle. Shrub density was determined by an observer walking along the transect and counting all woody stems (<3 cm) touching the observer's body and outstretched arms at breast height. The contribution of coffee and other plant species was recorded separately.

Foliage-height profiles were determined at 20 points located at 1.6-m intervals along the north, south, east, and west radii of each circular plot (Schemske and Brokaw 1981). A 3-m pole (2.0-cm diameter) marked at 0.5-m intervals was placed vertically at each sample point. The presence or absence of foliage touching the pole within each height class was recorded as well as the identity of the foliage. For height intervals above 3 m, we sighted along the pole and recorded the presence/absence of foliage in each of the following height intervals: 3–4, 4–6, 6–8, 8–10, 10–12, 12–15, 15–20, and 20–25 m. Total foliage per height interval was calculated by summing the number of points (maximum = 20) with the presence of foliage at a particular height interval. Foliage density was calculated by adding the total number of height intervals with foliage at the 20 points.

The outer perimeter of all coffee plantations was measured using a hip chain and a compass to obtain bearings. The amount of various habitat types (e.g., pasture, ground crops, road, stream, trees >2 m,) adjoining the plantation was estimated in meters along each bearing of the plantation perimeter. Maps of all plantations were prepared and the error of closure measured to determine accuracy (all <5%) of field maps. A digitizer was used to estimate plantation area. As aerial photographs were unavailable, plantation isolation was estimated as either the distance to the nearest shade coffee plantation or the nearest pine forest patch (>0.25 ha).

Analysis.—In the larger plantations, where more than one point count was conducted and more than one vegetation plot was measured, the average values of bird counts or vegetation measurements were used to represent the plantation. Hence for each plantation, only one value was used for each variable, but averaging values for the large plantations adjusted for the concomitantly greater sampling effort.

Principal component analysis (PCA) was used to assess habitat differences among the plantations. Variables included in the analysis were: total stems ≥3.0 cm DBH, foliage density, number of height intervals with *Inga* foliage, total coffee stems, total number of species, and total foliage in each of the five height intervals (0–0.5 m, 1.5–2.0 m, 4.0–6.0 m, 12.0–15.0 m, and 15.0–20.0 m). All variables approximated a normal distribution as determined by visual inspection of normal probability plots in SYSTAT (SYSTAT 1992). The PCA was generated using a correlation matrix and four factors. A varimax rotation was selected because it provided better separation than did either equimax or quadramax rotations. The significance of each habitat variable with respect to the PC axes was ascertained by correlation (Pearson product moment) of the original variables back to the PC scores. In addition, Pearson product moment correlations were used to determine the degree of association between log plantation area and individual habitat variables.

A forward stepwise multiple regression was used to evaluate the influence of plantation area, isolation, and the suite of habitat variables on components of the avian community. The procedure was run on SYSTAT using the default settings for the alpha to enter (0.15) and alpha to remove (0.15) chosen on the basis of Monte Carlo studies of stepwise regression (Bendel and Afifi 1977). Independent variables included the 10 vegetation variables characterized in the PCA, as well as elevation, estimated distance (m) to nearest plantation, estimated distance to nearest pine forest, and log of plantation area (ha). All variables were entered into a multiple regression (forward selection) to obtain the Type II partial correlation coefficients to evaluate their relative contributions to R^2.

RESULTS

Vegetation.—A total of 23 plant species (height >1 m) occurred in the 0.02 ha plots in the 40 plantations. The plantations were characterized by an overstory of *Inga vera* (Mimosoideae), although mango (*Mangifera indica*), avocado (*Persea americana*), various citrus species (*Citrus* spp.), and banana or plantains (*Musa* spp.) were scattered throughout some plantations, where they provided an intermediate layer above the coffee. In a few plantations, an occasional pine (*Pinus* spp.) or palm (*Roystonea*

TABLE 1. Results of principal components analysis of vegetation structure in 40 shade coffee plantations in the Dominican Republic. Component loadings are shown with the significance levels from Pearson product moment correlation of the original variable back to the PC score.

Variable	PC1	PC2	PC3
Stems ≥3.0 cm DBH	0.733***	−0.072	−0.227
Foliage density	0.716***	0.193	0.404**
Categories with *Inga*	0.528**	0.089	0.371
Total coffee stems	−0.526**	−0.095	0.462**
Total foliage 0.0–0.5 m	0.096	−0.552	0.055
Total foliage 1.5–2.0 m	−0.232	0.266	0.791***
Total foliage 4.0–6.0 m	0.513	−0.702***	−0.038
Total foliage 12.0–15.0 m	0.437	0.662**	0.088
Total foliage 15.0–20.0 m	0.148	0.694***	−0.372*
Total plant species	−0.391	0.255	−0.353
Eigenvalue	2.30	1.91	1.47
% of variance accounted for	22.9	19.1	14.7

* $0.05 \geq P > 0.01$; ** $0.01 \geq P > 0.001$; *** $P \leq 0.001$.

spp.) extended into the overstory. The pervasive variety of coffee (*Coffea arabica*) in the shade plantations was the traditional "típica" variety, although "catorra" predominated in some of the larger plantations and was introduced to replace "típica" in some of the smaller plantations.

The first three principal components (PC 1–3) accounted for 56.7% of the variation in habitat structure among the coffee plantations (Table 1), whereas five components accounted for 78% of the variation. The first component distinguished plantations primarily on the basis of total stems ≥3.0 cm DBH, total coffee stems, foliage density, and total foliage intervals with *Inga,* The second axis separated plantations primarily on the basis of total foliage in the intervals of 4.0–6.0 m, 12.0–15.0 m, and 15.0–20.0 m, and the third axis separated plantations mostly on the basis of total foliage at 1.5–2.0 m, total coffee stems, and foliage density.

Most habitat variables were not correlated with log plantation area, though one variable (total foliage in 1.5–2.0 m) showed a weak, but statistically significant correlation ($r = -0.36$, $P = 0.02$). Correlations were not detected between plantation size and degree of isolation as measured by distance to nearest plantation ($r = -0.12$, $P = 0.47$), distance to nearest pine forest patch ($r = -0.18$, $P = 0.27$) or proportion of perimeter bounded by pasture or field ($r = -0.24$, $P = 0.14$), or elevation ($r = -0.08$, $P = 0.62$).

Although considerable variation existed among the 40 plantations in terms of different measures of isolation, most plantations were moderately isolated from each other and from woodland habitats suitable for birds. The median distance to the nearest plantation was 50 m (range 10–500 m) and the median distance to the nearest pine forest patch was 65 m (range 0–350 m). The median proportion of the plantation perimeter that was bounded by pasture or field was high (median = 0.96, range = 0.0–1.0).

Bird censuses.—A total of 28 bird species (Appendix lists scientific names) was detected during the counts including 17 resident species, 10 Nearctic migrants, and 1 Neotropical migrant that breeds in Hispaniola. The last species was included with resident species in subsequent analyses. Examination of species accumulation curves indicated that species composition (i.e., richness) of the plantations was adequately determined and recent re-surveys of 32 of these plantations have found a similar species composition (Wunderle and Latta 1996).

Plantation area (log) did not account for variation in total species richness per point in the coffee plantations ($R^2 = 0.01$, $P = 0.27$). However, area did account for some variation in species richness of resident species ($R^2 = 0.11$, $P = 0.04$), but not migrant species ($R^2 = 0.003$, $P = 0.72$). Inclusion of variables for vegetation structure, elevation, and measures of plantation isolation in the stepwise multiple regression improved the association between total resident species per point and plantation area, but not between total migrant species per point and area (Table 2).

Some variation in individual abundance was attributable to plantation area in four of the ten resident species that were adequately sampled (found in ≥5 plantations), including Rufous-throated Solitaire ($R^2 = 0.16$, $P = 0.01$), Hispaniolan Lizard Cuckoo ($R^2 = 0.15$, $P = 0.01$), Hispaniolan Woodpecker ($R^2 = 0.14$, $P = 0.02$), and Broad-billed Tody ($R^2 = 0.13$, $P = 0.04$). Inclusion of habitat variables and elevation in the stepwise multiple regression slightly improved the regression of abundance and plantation area only in the Broad-billed Tody (Table 2). Thus, plantation area had a slight effect on abundance for a few resident species, but <25% of the variation in abundance was explained by area even for these species.

Of the 14 variables included in the multiple regressions, elevation showed the most consistent relationship with abundance. Among the 17 bird species that were analyzed, this variable was significant for only six (Table 2). The next most important variables were the number of foliage intervals containing *Inga*, total foliage in 0.0–0.5 m, and plantation area, each of which were significant predictors of abundance in four species. The next most common predictors of abundance were total stems >3 cm DBH (3 bird species), total foliage 4.0–6.0 m (3), distance to nearest pine forest (2), total foliage 1.5–2.0 m (2), and total foliage 12.0–15.0 m (2). Each of the other five variables was a significant predictor in only a single species each.

Resident species differed from migrants in their responses to elevation (five resident species vs. one migrant species significantly correlated) and plantation area (four vs. zero). For migrants, at least one of the foliage height intervals was a significant predictor in six of the seven species, in contrast only three of seven residents were significantly correlated with the density of foliage at one or more height intervals.

TABLE 2. Variables identified as significant predictors of avian species richness or relative abundance for 17 species sampled by point counts in shade coffee plantations in the Dominican Republic. Variables were selected by using forward stepwise multiple regression and partial correlations calculated to indicate the importance of each variable to the overall model. Only partial correlations which are significant ($P \leq 0.05$) are shown, and negative partial correlations are indicated by (−).

Dependent variable	R^2	P	Independent variable	Partial r^2
Total species	0.25	0.005	Elevation	−0.13
Total resident species	0.56	0.001	Stems	0.38
			Log plantation area	0.21
			Foliage density	0.18
			Elevation	−0.16
			Total foliage 12.0–15.0 m	0.14
Total migrant species	0.00	N.S.		
Residents				
Hispaniolan Lizard Cuckoo	0.10	0.01	Log plantation area	0.15
Hispaniolan Emerald	0.46	0.001	Total foliage 0.0–0.5 m	0.40
			Total coffee stems	−0.39
			Distance to pine forest	−0.32
Narrow-billed Tody	0.20	0.04	Stems	−0.15
Broad-billed Tody	0.56	0.001	Elevation	−0.43
			Categories with *Inga*	−0.26
			Log plantation area	0.24
Hispaniolan Woodpecker	0.31	0.004	Elevation	−0.20
			Log plantation area	0.12
Red-legged Thrush	0.51	0.001	Elevation	−0.29
			Distance to plantation	0.21
			Total foliage 0.0–0.5 m	0.19
			Categories with *Inga*	−0.16
			Plant species	0.09
Rufous-throated Solitaire	0.22	0.01	Log plantation area	0.17
Black-whiskered Vireo	0.13	0.02	Elevation	−0.13
Hispaniolan Stripe-headed	0.11	0.04	Elevation	−0.11
Tanager	0.28	0.007	Categories with *Inga*	0.20
Black-cowled Oriole				
Migrants				
Black-and-White Warbler	0.33	0.007	Total foliage 12.0–15.0 m	0.23
			Total foliage 4.0–6.0 m	0.19
			Foliage density	−0.13
Cape May Warbler	0.58	0.001	Stems	0.42
			Total foliage 0.0–0.5 m	0.18
			Total foliage 12.0–15.0 m	−0.13
			Total plant species	−0.13
Black-throated Blue Warbler	0.26	0.004	Total foliage 1.5–2.0 m	−0.20
Black-throated Green Warbler	0.15	0.02	Total foliage 4.0–6.0 m	0.15
Ovenbird	0.17	0.04	Elevation	−0.12
Common Yellowthroat	0.37	0.001	Dist. to pine forest	0.30
			Categories with *Inga*	−0.18
			Total foliage 1.5–2.0 m	−0.11
American Redstart	0.31	0.01	Total foliage 4.0–6.0 m	0.22
			Stems	−0.19

DISCUSSION

Plantation age and intensity of management contributed to variation in the structure and composition of vegetation among the plantations. Although exact plantation ages were unavailable for most plantations, younger plantations appeared to differ from older plantations by having coffee bushes of lower stature but with denser foliage, lower overstory canopies with fewer foliage layers, and fewer stems of all species ≥3 cm. Many of these age-related differences were reflected in the first principal component. Younger plantations appeared to show less structural variation resulting from management differences than did the older plantations. The effects of intensive pruning of the shade overstory were most evident in older plantations, in which more foliage layers could potentially be eliminated, than in the young plantations with low stature overstories. The second principal component reflected many of these management differences among plantations by contrasting plantations mostly on the basis of the presence of foliage in different height intervals in the overstory. Older plantations were found at both extremes of the second principal component axis representing either intensive management or abandonment, in contrast to younger plantations where relatively little variation was observed among plantations.

Despite some variation in vegetation structure attributable to plantation age and management, the Dominican plantations I studied were relatively homogeneous in structure and composition in comparison to those that have been studied in Meso-America (Greenberg et al. 1997a,b). Although overstory height and distribution of foliage layers differed among plantations, all the Dominican plantations had an overstory composed mostly of *Inga vera,* which shaded almost all of the coffee plants (Wunderle and Latta 1996, 1998).

The Dominican coffee plantations were clearly separated from other areas of continuous forest or woodlands, as measured by distance to nearest pine forest or nearest plantation, but I did not quantify the possible "stepping stone" effects of scattered trees or small groups of trees in the vicinity of plantations. These scattered trees were used by various species to move between plantations and forest patches (Wunderle and Latta, unpublished) presumably facilitating immigration. In addition, the scattered trees between coffee plantations and woodlots may increase the likelihood that individual birds could incorporate more than one plantation or clump of trees into a single territory (e.g., Howe 1984). Moreover, the presence of nearby scattered trees may enable an individual to inhabit a plantation that by itself is too small to support a territory, as documented in some of these plantations for several species of Nearctic migrants (Wunderle and Latta, ms). Thus, scattered trees likely facilitated immigration and enabled some species to inhabit plantations smaller than their average territory size, thereby inflating species (and individual) numbers in small plantations above the values that would be expected, assuming complete isolation of plantations.

Scattered trees effectively diminished the isolation of some plantations and presumably contributed to the weak species-area effect: area accounted for only 11% of the variation in the number of resident species per point and none of the variation in total species or migrant species per point. In addition, the plantations were only moderately isolated from each other or nearby woodlands and it is likely that if the plantations were more widely separated from these sources the area effects would have been much greater. In addition, a stronger area effect is expected if a wider range of plantation sizes had been available, particularly with the addition of plantations greater than 10 ha. It is conceivable that some area-sensitive species (trogons, quail-doves) were absent or poorly represented in the study because even the largest sampled plantations were of insufficient size (maximum 8.65 ha).

The absence of an area effect on the number of Nearctic migrant species or number of individuals is consistent with some previous findings on the wintering grounds (Robbins et al. 1987, Greenberg 1992, but see Askins et al. 1992) despite the sensitivity of many of these species to area effects on the breeding ground (e.g., Lynch and Whigham 1984, Robbins et al. 1989). Even wintering migrants typical of Caribbean forests (Wunderle and Waide 1993), such as Ovenbird, Black-and-white Warbler, American Redstart, Black-throated Blue Warbler, and Black-throated Green Warbler appeared to be unaffected by the abrupt plantation-pasture edges. Additional evidence that most migrants are not adverse to using small isolated (<5 ha) woodlots is noted each spring in North America where small patches attract numerous passage migrants (e.g., Martin 1980, Blake 1986). The migrants in this study were a much more homogenous group of species than the residents in terms of taxonomic diversity (1 family vs. 7 families) and foraging ecology (mostly insectivorous, 2 highly nectarivorous vs. 4 insectivorous, 5 frugivorous, 1 nectarivorous). Therefore, it was not surprising that migrants as a group were more consistent in their response to area than were resident species.

Plantation area did influence the total number of resident species, and for four resident species, the number of individuals detected at a point. Some of this area effect may be attributed to the fact that a relatively high proportion of the plantations were undoubtedly smaller (30% less than 0.5 ha) than the average home range size of some of the larger resident species (Hispaniolan Lizard Cuckoo, Hispaniolan Woodpecker). For these species, some small plantations may have also been sufficiently isolated by inappropriate habitats so as not to be incorporated within a home range. In addition, habitat diversity usually increases with area (e.g., Williamson 1981) so that larger plantations are more likely to have a greater diversity of essential resources than do smaller plantations. In the present study, larger plantations were more likely to contain fruiting palms or shrubs attractive to frugivores (e.g., Hispaniolan Woodpecker, Rufous-throated Solitaire). Thus, some of the area effect in residents may be attributed to the extremely small size of many of the plantations relative to the larger home range sizes of some resident species and the greater likelihood that larger plantations contained critical resources.

As found in previous studies of avian distribution in coffee plantations (Greenberg et al. 1997b), species richness decreased with elevation. Six individual species significantly declined in abundance with elevation (one migrant, five residents) and none increased with elevation. Although a few plantation characteristics varied with elevation (total foliage 0–0.5 m, $r = 0.48$; coffee stems $r = -0.37$) these factors unlikely are directly responsible for observed elevational declines. More likely, the observed changes in abundance are associated with elevational changes in climate which affect the distribution of individual species directly or indirectly by affecting resource distributions in the plantations or in nearby habitats. Elevational migration or seasonal movements of some residents and wintering migrants, which are evident in some Central American coffee plantations (Greenberg et al. 1997b), are unlikely to be important factors in these plantations where little seasonal variation was detected, at least during October to April (Wunderle and Latta, in prep.).

From previous observations in these plantations (Wunderle and Latta 1996, 1998) and elsewhere (Greenberg et al. 1997a,b), it was expected that avian species richness and abundance would infrequently be associated with coffee understory characteristics. This was expected because coffee is a resource-poor habitat (i.e., low in nectar, fruit, and invertebrates) relative to the *Inga* overstory (Wunderle and Latta 1996; Greenberg et al. 1997a) and, not surprisingly, most birds forage in the plantation canopy and rarely in the understory (Greenberg et al. 1997b; Wunderle and Latta 1998). Therefore, coffee layer features were expected to be less frequently correlated with avian abundance than features relating to the shade overstory alone or shade and understory together.

As expected, features of the coffee layer were of limited utility as predictors of avian abundance, as abundance was correlated with these features in only 6 of 17 species. In four species, abundance was positively correlated with the presence of foliage at ground-level (total foliage 0–0.5 m), which was mostly an indication of weed abundance. This feature might be of direct importance to the ground-nesting Broad-billed Tody and to the Red-legged Thrush which occasionally forages on the ground, but of indirect importance to nectarivores (Hispaniolan Emerald, Cape May Warbler) which forage above this zone (foraging heights in Wunderle and Latta 1998). Abundance was negatively correlated with measures of coffee density in the two species which mostly forage above this layer (Hispaniolan Emerald, coffee stems; Black-throated Blue Warbler, total foliage 1.5–2.0 m), and in Common Yellowthroat which forages mostly below this level.

Features of the plantation overstory or those combining overstory and understory were predictors of avian abundance for only a few species. Neither total number of species nor total number of migrant species was correlated with vegetation features, in contrast to the total number of resident species. Plantations with high numbers of resident species tended to occur at low elevation, were large and relatively old, characterized by numerous stems ≥3 cm DBH, showed little or no pruning of overstory branches, and had their maximum canopy cover at 12–15 m. Similarly, Greenberg et al. (1997a) found that resident birds in contrast to migrants in Guatemalan coffee groves showed the strongest correlation with habitat variables based on multiple regression analysis. Specifically, variables related to vertical structure and taxonomic diversity of the canopy contributed most to variation in total resident species.

From a conservation standpoint, the traits that characterize plantations with large numbers of resident species should be encouraged. Although larger plantations tend to have more resident species, smaller plantations still attract some resident species as well as a full complement of migrant species, which as a group are unaffected by area in these plantations. Therefore, small plantations should be included in conservation efforts, particularly in areas where plantations are not extremely isolated by pastures, fields, or other treeless areas. In addition, small coffee producers are more likely to grow a diversity of crops in their plantations and are less likely to manage intensively for coffee production (see also Greenberg et al. 1997a), thereby providing better development of the structural and floristic diversity which is attractive to birds.

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APPENDIX. Summary of birds detected in point counts conducted in 40 shade coffee plantations in the Cordillera Central of the Dominican Republic in February 1992. Shown are the range of plantation sizes, number of plantations detected, and status (M = Nearctic migrant; R = Resident). Asterisk indicates a species treated as a resident although it migrates to South America after breeding in the Dominican Republic.

Species	Range of plantation sizes (ha)	Number of plantations	Status
Hispaniolan Parrot (*Amazona ventralis*)	0.59–8.65	2	R
Hispaniolan Lizard Cuckoo (*Saurothera longirostris*)	1.36–8.65	6	R
Hispaniolan Emerald (*Chlorostilbon swainsonii*)	0.22–1.40	6	R
Antillean Mango (*Anthrocothorax dominicus*)	0.09–8.65	30	R
Vervain Hummingbird (*Mellisuga minima*)	0.11–8.65	26	R
Narrow-billed Tody (*Todus angustirostris*)	0.09–8.65	8	R
Broad-billed Tody (*Todus subulatus*)	1.36–8.65	10	R
Hispaniolan Woodpecker (*Melanerpes striatus*)	1.36–8.65	9	R
Hispaniolan Pewee (*Contopus hispaniolensis*)	0.23–8.65	7	R
Red-legged Thrush (*Turdus plumbeus*)	0.23–4.56	6	R
Rufous-throated Solitaire (*Myadestes genibarbis*)	2.29–8.65	5	R
Palmchat (*Dulus dominicus*)	0.09–1.89	3	R
Black-whiskered Vireo (*Vireo atiloquus*)	0.10–2.45	8	R*
Black-and-white Warbler (*Mniotilta varia*)	0.10–2.29	16	M
Northern Parula (*Parula americana*)	0.18–0.59	5	M
Magnolia Warbler (*Dendroica magnolia*)	0.09–0.64	4	M
Cape May Warbler (*Dendroica tigrina*)	0.09–8.65	29	M
Black-throated Blue Warbler (*Dendroica caerulescens*)	0.09–8.65	31	M
Black-throated Green Warbler (*Dendroica virens*)	1.40–4.36	6	M
Ovenbird (*Seiurus aurocapillus*)	0.09–8.65	24	M
Common Yellowthroat (*Geothlypis trichas*)	0.09–3.83	11	M
Green-tailed Ground Warbler (*Microligia palustris*)	0.87–1.40	2	R
Hooded Warbler (*Wilsonia citrina*)	0.59	1	M
American Redstart (*Setophaga ruticilla*)	0.09–8.65	27	M
Bananaquit (*Coereba flaveola*)	0.09–8.65	40	R
Hispaniolan Stripe-headed Tanager (*Spindalis dominicensis*)	0.10–8.65	9	R
Black-crowned Palm Tanager (*Phaenicophilus palmarum*)	0.09–8.65	25	R
Black-cowled Oriole (*Icteris dominicensis*)	0.26–8.65	8	R