Bird Conservation International (1998) 8:297–308. © BirdLife International 1998

Bird diversity and abundance on two different shade coffee plantations in Guatemala

LORENA CALVO and JOHN BLAKE

Summary

Many studies have examined differences in bird communities between shade and sun coffee plantations but less is known about how different management practices within shade coffee plantations affect bird populations. This study compares diversity and abundance of resident and migrant birds in two shade coffee plantations located in Palajunoj, Quetzaltenango, Guatemala, that differ in their farming practices (e.g. pruning schedules and fertilizer regimes) and, consequently, in vegetation structure. One plantation represents a traditional, polyculture shade system whereas the second represents a more modernized, monoculture shade system. Both plantations supported many resident and migrant birds. Bird abundance and diversity were significantly greater during both wet and dry seasons on the traditional farm, due largely to the vegetation structure resulting from the different management practices. All plantations typically classified as "shade coffee" are not equivalent, much of their conservation value coming from the more diverse and structurally complex traditional polycultures rather than from the newer, monocultural systems. Coffee production techniques that affect the structural and floristic diversity of the vegetation (e.g. pruning, application of chemicals) have important consequences for birds.

Introduction

As more natural habitats are lost in tropical countries, structurally complex agricultural habitats such as plantations of shade coffee *Coffea arabica* (i.e. coffee plants grown under overstorey cover) will become increasingly important as alternative habitats for many bird species, both migrants and residents (e.g. Brash 1987). Shade coffee systems clearly support a greater diversity and abundance of birds than do plantations of sun coffee (i.e. coffee plants grown without overstorey cover) (Aguilar-Ortiz 1982, Wunderle and Latta 1996, Greenberg *et al.* 1997a). Species numbers in shade coffee plantations also can be greater than in many other agroforestry types (Greenberg *et al.* 1997b) and even comparable to those in forest patches (Corredor 1989, Wunderle and Latta 1994). However, shade coffee plantations differ in their structural diversity due to differences in overstorey cover and management practices. As a consequence, all shade coffee plantations are not equivalent, nor are they likely to be equally beneficial as habitats for birds (Greenberg *et al.* 1997a).

https://doi.org/10.1017/S0959270900001945 Published online by Cambridge University Press

Traditional polyculture shade coffee plantations have planted shade trees (e.g. *Inga* spp.) and other non-coffee products, including fruit trees (e.g. avocado *Persea americana*, banana *Musa* sp. and citrus *Citrus* sp.). Such traditional shade systems typically use little chemical herbicides and fertilizers. In contrast, monoculture shade coffee plantations have shade provided only by *Inga* (or other shade) trees that are planted at regular intervals in the coffee plots. The shade trees are pruned to achieve the size and shape desired by the coffee farmer (Leon 1966). Such plantation systems require more intensive management (i.e. intensive shade pruning), make heavy use of fertilizers and herbicides, and represent a major economic investment for the coffee farmer (Rice and Ward 1996).

Shade coffee plantations are important as refuges for biodiversity because they represent a complex vegetation system which provides benefits to birds and other organisms that are not provided by other agroecosystems (Brash 1987, Wunderle and Latta 1996). Given that not all shade systems are equivalent, it is important to evaluate how differences in farming practices affect bird populations. Such information can be useful in developing recommendations for managing plantations when there is a desire to protect species as well as grow coffee. To address this question, we compare the characteristics of bird communities in two shade coffee plantations that differ in farming practices and vegetation structure.

Methods

Study site

We conducted this study in two adjacent coffee plantations located in the western part of Guatemala in Palajunoj, Quetzaltenango (14°43′30′ N; 91°37′00′ W) at an elevation of approximately 1,000–1,100 m above sea level. Average annual precipitation is about 2,200 mm, with a six-month wet season from May until the end of October. Temperature remains relatively high throughout the year, ranging on average from 20 to 33 °C.

The landscape and vegetation surrounding the two farms are very similar. Both farms are bordered by abandoned cardamom *Elettaria cardamomum* plantations, patches of secondary forest (none larger than 2 ha) and other small plantations. The region as a whole is composed of small coffee farms and agricultural plots. The nearest block of intact forest is approximately 6 km north (~ 1,500 m elevation). The two farms were operated jointly until 25 years ago (L. C., pers. obs.), but differences in management regimes began when the property was divided. The farms are typical of most coffee farms in the region, both in terms of management and size. Thus results from this study probably apply to other farms in the area as well.

The two study farms differ in their use of chemicals (fertilizers and herbicides) and schedule of pruning of shade trees. Finca Bohemia (62 ha; hereafter called "traditional farm") uses a traditional polyculture shade system, whereas Finca Nueva Delfina (130 ha; hereafter called "modernized farm") uses a monoculture shade system. The understorey (i.e. weeds) of the traditional farm is cleared primarily with machetes, although some herbicides are used (i.e. Gramaxone, applied three times a year). In contrast, clearing in the understorey of the modernized farm is done entirely with herbicides (Gramuron, applied six times a year). As a consequence, the understorey of the modernized farm remains cleared of weeds and other non-coffee vegetation (e.g. ferns, bromeliads, other epiphytes) to a greater extent than is true on the traditional farm. Fertilizer (urea) is used on both farms but the quantities differ (28 g/plant per year on the traditional farm; 450 g/plant per year on the modernized farm). Pruning of shade trees in the traditional farm is done at the beginning of the dry season (late January) while in the modernized farm it is done in the middle of the wet season (June).

Vegetation composition

Vegetation and birds (see below) were sampled at 25 points on the traditional farm and on 24 points on the modernized farm. Points were at least 75 m apart and were distributed over comparable areas in the traditional farm (21 ha) and the modernized farm (24 ha). Vegetation was sampled in 0.03-ha circles (10-m radius) centred on each point. Presence of foliage in different height intervals was noted at 20 points/circle (10 points along both north–south and east–west transects of each circle) during the wet season (June) and during the dry season (December) of 1997. Diameter at breast height, height and identity of all trees within each 0.03-ha circle were noted; percentage of each tree trunk covered by epiphytes (e.g. ferns, bromeliads, orchids, moss) was estimated. Trees were grouped into categories based on height, diameter or percentage of epiphyte cover. We compared characteristics of vegetation between the two farms using *t*-tests (for comparisons of mean values; or Mann–Whitney tests when data did not meet assumptions of parametric tests) and chi-square tests (for comparison of categorical data).

Bird counts

All birds seen within a 25-m radius of each point were counted; birds flying by over the canopy were not included. As points were at least 75 m apart, the counting areas for adjacent points did not overlap, helping to ensure that individual birds were not counted at more than one point (i.e. points were independent with respect to birds). Each count lasted for 10 minutes with a 5-minute interval between points. Counts were initiated at sunrise and ended by 11h00. Counts were not conducted on days when wind or rain interfered with observations. Each point was sampled on four days during the wet season (June–July 1996) and on two days during the dry season (December–January 1997). The same set of points (maximum of six points on a single day) was sampled twice in a given morning, once early and once late (i.e. 12 counts in a morning). Results from the two counts at each point were combined by using the maximum number of individuals recorded for each species as an estimate of the number of individuals of that species at that point. Bird species were categorized by residency (migrant: species that breed in temperate habitats of North America and spend the non-breeding season in tropical habitats; resident: species that breed in Guatemala) and primary diet (insectivore, frugivore, nectarivore, omnivore, granivore,

Table 1. Species and individuals of trees recorded in 0.03-ha plots on a traditional (25 plots) and a modernized (24 plots) shade coffee plantation

Local name	Species	Family	Traditional	Modern
Chalum	*Inga* spp.	Leguminosae	166	128
Aguacate	*Persea americana*	Lauraceae	1	0
Guayabo	*Psidium biloculare*	Myrtaceae	7	2
Jocote silvestre	*Spondias mombin*	Anacardiaceae	1	0
Naranja	*Citrus cinensis*	Rutaceae	7	0
Palo blanco	*Tabebuia donnelli-smith*	Bignoniaceae	3	2
Banana	*Musa* sp.	Musaceae	11	0
Total			196	132

carnivore). Species names and guild designations follow Howell and Webb (1995).

We used a repeated measures analysis of variance (rmANOVA) to compare total abundance of birds/point between farms, with seasons analysed separately (Zar 1996). We used Mann–Whitney *U*-tests to compare abundances of individuals species that were common (at least 25 individuals observed) on one or both farms; analyses were done separately by season. Comparisons were based on mean abundance in each season (e.g. mean of four counts/point per farm during the wet season). All analyses were run on SPSS (version 7.0 for Windows). We used rarefaction analyses to compare number of species observed on each farm during each census (Gotelli and Graves 1996, Gotelli and Entsminger 1997).

Results

Vegetation composition

Inga was the dominant shade tree on both farms (Table 1) although mean density varied slightly (traditional farm, $\bar{x} = 6.6 \pm 2.64$ [S.E] trees/0.03 ha; modernized farm, $\bar{x} = 5.3 \pm 1.86$; Mann–Whitney $U = 204$, $P = 0.052$). The traditional farm also had a variety of other shade trees that were rare or absent on the other farm (Table 1). As a consequence, overall tree density (per 0.03 ha) was greater on the traditional farm (7.8 ± 0.53 versus 5.7 ± 0.31; $t = 3.47$, $P < 0.001$) as was total basal area (cm^2/0.03 ha) of shade trees (2876 ± 510 cm^2 versus 1294 ± 149; Mann–Whitney $U = 136$, $P < 0.001$). A greater proportion of trees on the traditional farm supported at least some epiphytic plants (61% versus 35% on the modern farm; $\chi^2 = 22$, $df = 1$, $P < 0.001$), adding to the structural diversity of the traditional plantation.

As a consequence of differences in coffee plant density and shade tree density, the vertical distribution of foliage differed between farms (Figure 1). The modernized farm had more foliage below 2 m than did the traditional farm, primarily due to higher density of coffee plants (±2,500/ha on the traditional farm; ±5,000/ha on the modern farm; C. de Martinez and C. Miron, pers. comm.). In contrast, the traditional farm had more foliage above 5–6 m during both seasons, due both to the greater density of trees on the traditional farm and to the more severe pruning of shade trees done on the modernized farm.

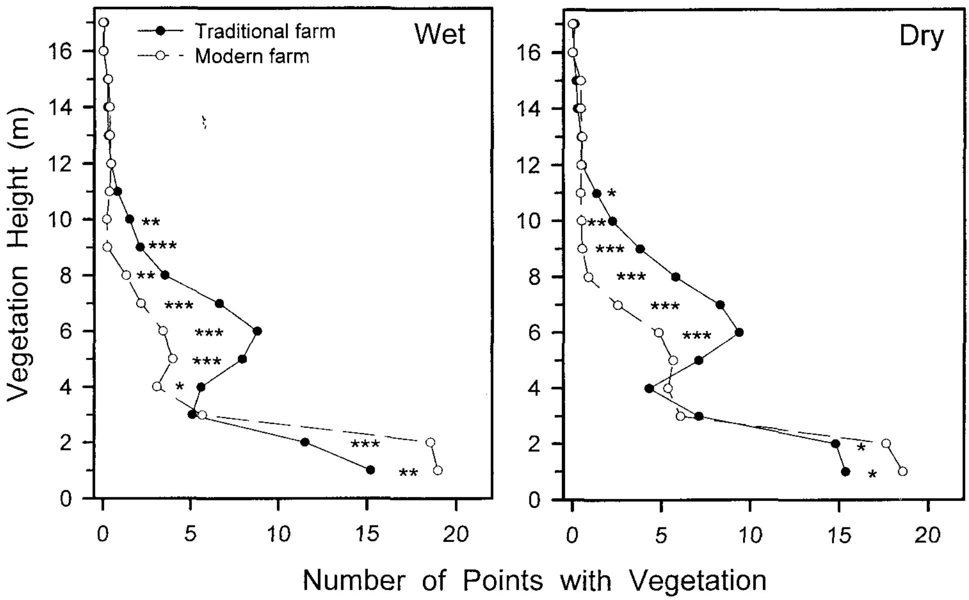

Figure 1. Distribution of foliage at different height intervals in traditional and modernized shade coffee plantations during the wet (June) and dry (December) season. Values indicate number of points (out of 20) where any vegetation was encountered in the corresponding height interval. Significant differences in amount of vegetation at different height intervals (based on Mann–Whitney *U* tests) are indicated: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Bird composition

Bird abundance was higher on the traditional farm than on the modernized farm for all censuses (Table 2). Abundance varied over time (among counts) during the wet season but the pattern of variation differed between farms (primarily due to a decline in bird abundance during the third count on the traditional farm), resulting in a significant interaction effect between count and farm (Table 2). Bird abundance did not vary between counts during the dry season but the difference between farms was still pronounced.

A total of 92 bird species was recorded, including 90 on the traditional farm and 75 on the modernized farm. More species were observed on the traditional farm during both wet (72 versus 49) and dry seasons (63 versus 51). Differences in species number might simply reflect the greater number of individuals observed on the traditional farm. Thus, we used rarefaction to compare species numbers on the basis of equal sample sizes (i.e. simulations, EcoSim, Gotelli and Entsminger 1997, calculated number of species expected in the traditional farm based on the number of individuals observed in the modernized farm during the same count period). In all comparisons, the number of species observed on the modernized farm was significantly less than the expected number on the traditional farm (Figure 2). Thus, observed differences in species richness were not simply a consequence of differences in overall bird abundance.

The most common guilds on both farms were omnivores and insectivores,

Table 2. Mean (SE) number of birds/point (25-m radius) on a traditional and a modern shade coffee plantation. Counts were conducted from early June to late July, 1996 (rainy season) and late December (1996) to early January (1997) (dry season)

	Count 1		Count 2		Count 3		Count 4		C	F	I
	Traditional	Modern	Traditional	Modern	Traditional	Modern	Traditional	Modern			
Wet season											
Total individuals	11.4 (3.73)	5.6 (1.64)	11.1 (5.88)	5.0 (1.93)	8.8 (3.12)	6.6 (1.56)	12.6 (3.85)	6.1 (2.94)	***	***	***
Nectarivores	0.9 (0.10)	0.2 (0.08)	0.5 (0.13)	0.2 (0.08)	0.8 (0.17)	0.3 (0.10)	1.2 (0.22)	0.5 (0.13)	**	***	
Frugivores	1.4 (0.36)	0.4 (0.12)	1.6 (0.37)	0.1 (0.06)	1.7 (0.32)	0.0 (0.04)	2.8 (0.44)	0.3 (0.09)		***	*
Insectivores	3.9 (0.43)	0.8 (0.15)	3.8 (0.68)	1.7 (0.18)	2.9 (0.30)	2.0 (0.24)	4.8 (0.60)	1.5 (0.26)		***	***
Omnivores	5.4 (0.53)	4.6 (0.37)	5.5 (0.53)	3.1 (0.29)	4.5 (0.40)	4.2 (0.27)	4.3 (0.27)	4.0 (0.41)		**	**
Dry season											
Total individuals	13.8 (4.15)	6.5 (2.27)	14.8 (6.78)	8.6 (5.10)						***	
Migrants	4.3 (0.60)	1.5 (0.45)	3.5 (0.68)	2.8 (0.52)						**	**
Nectarivores	1.2 (0.24)	0.8 (0.16)	1.2 (0.18)	0.3 (0.12)						***	
Frugivores	4.1 (1.33)	1.3 (0.28)	3.6 (0.56)	1.6 (0.26)						***	
Insectivores	5.0 (0.58)	2.0 (0.29)	4.2 (0.61)	2.9 (0.35)						***	
Omnivores	5.0 (0.58)	3.8 (0.42)	7.2 (0.73)	5.4 (0.76)					*	*	

Significance (* P <0.05; ** P <0.01; *** P <0.001) of rmANOVA results are shown (C, count; F, farm; I, interaction). Means <0.05 are shown as 0.0.

https://doi.org/10.1017/S0959270900001945 Published online by Cambridge University Press

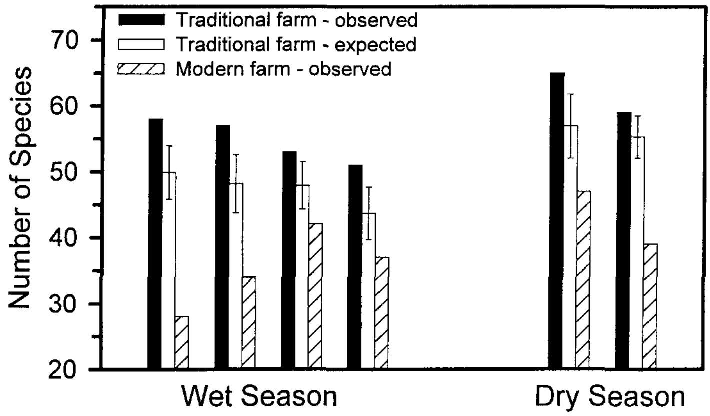

Figure 2. Results of rarefaction analyses comparing number of species observed on the two coffee farms. Total numbers of species observed on the traditional coffee farm and on the modern coffee farm during wet and dry season samples are compared to the number expected from the traditional farm based on the number of individuals observed on the modern farm. More individuals were recorded on the traditional farm during each count. Mean (and 95% confidence interval) number of species expected was based on 1,000 simulations (EcoSim; Gotelli and Entsminger 1997).

followed by frugivores and nectarivores (Table 2). All guilds were more abundant on the traditional farm during both seasons. Although changes in abundance per guild between counts were significant only for nectarivores in the wet season and for omnivores during the dry season, there were significant interaction effects (based on rmANOVA) for frugivores, insectivores, and omnivores during the wet season. These interaction effects indicate that temporal patterns of abundance differed between the two farms (Table 2). Insectivores and omnivores, for example, decreased on the traditional farm from the second to the third count period during the wet season but increased on the modern farm during the same period. Abundance nonetheless remained higher on the traditional farm. Frugivores were more abundant on both farms during the dry season, reflecting in part the arrival of such birds as the Ochre-bellied Flycatcher *Mionectes oleagineus*. Although the relative distribution of individuals per guild (all counts combined) differed between farms in both the wet ($\chi^2 = 147.6$, $df = 5$, $P < 0.001$) and dry seasons ($\chi^2 = 37.8$, $df = 4$, $P < 0.001$; carnivores excluded due to small sample size), distribution of species per guild did not (wet: $\chi^2 = 2.5$, $df = 5$, $P < 0.75$; dry: $\chi^2 = 0.28$, $df = 3$, $P > 0.95$).

A total of 14 species of migrants (birds that breed in temperate North America) was observed during the dry season, including 13 species on each farm. Although the proportion of migrant individuals relative to residents (all counts combined) did not differ between farms ($\chi^2 = 1.7$, $df = 1$, $P > 0.15$) more migrants were observed on the traditional farm than on the modern farm (Table 2). Migrants comprised from 23% to 32% of individuals per point.

During the wet season, 11 common species (i.e. species observed a minimum of 25 times on at least one farm) were more abundant on the traditional farm, two were more abundant on the modernized farm, and nine were equally abund-

Table 3. Results of comparisons (Mann–Whitney *U*) of abundance (number of individuals/point) of common species (i.e. observed a minimum of 25 times on at least one farm) during the wet season 1996

Species significantly more abundant on traditional farm

Plain Chachalaca *Ortalis vetula*, Green Parakeet *Aratinga holochlora*, White-fronted Parrot *Amazona albifrons*, Cinnamon Hummingbird *Amazilia rutila*, Golden-fronted Woodpecker *Melanerpes aurifrons*, Tropical Pewee *Contopus cinereus*, Dusky-capped Flycatcher *Myiarchus tuberculifer*, Tropical Kingbird *Tyrannus melancholicus*, White-breasted Wood-Wren *Henicorhina leucosticta*, Bananaquit *Coereba flaveola*, White-collared Seedeater *Sporophila torqueola*

Species more abundant on modernized farm

Social Flycatcher *Myiozetetes similis*, Plain Wren *Thryothorus modestus*

Species equally abundant on both farms

Yellow-olive Flycatcher *Tolmomyias sulphurescens*, Boat-billed Flycatcher *Megarhynchus pitangua*, White-throated Magpie-Jay *Calocitta formosa*, Clay-coloured Robin *Turdus grayi*, Blue-black Grassquit *Volatina jacarina*, Melodious Blackbird *Dives dives*, Great-tailed Grackle *Quiscalus mexicanus*, Yellow-backed Oriole *Icterus chrysater*, Spot-breasted Oriole *Icterus pectoralis*

Table 4. Results of comparisons (Mann–Whitney *U*) of abundance (number of individuals/point) of common species (i.e. observed a minimum of 25 times on at least one farm) during the dry season 1996–1997

Species more abundant on traditional farm

Plain Chachalaca *Ortalis vetula*, Red-billed Pigeon *Columba flavirostris*, Cinnamon Hummingbird *Amazilia rutila*, Ochre-bellied Flycatcher *Mionectes oleagineus*, Warbling Vireo *Vireo gilvus*, Magnolia Warbler *Dendroica magnolia*, Black-faced Grosbeak *Caryothraustes poligaster*

Species more abundant on modernized farm

Tropical Pewee *Contopus cinereus*, White-throated Magpie-Jay *Calocitta formosa*

Species equally abundant on both farms

White-fronted Parrot *Amazona albifrons*, Golden-fronted Woodpecker *Melanerpes aurifrons*, Boat-billed Flycatcher *Megarhynchus pitangua*, Tropical Kingbird *Tyrannus melancholicus*, Clay-coloured Robin *Turdus grayi*, Tennessee Warbler *Vermivora peregrina*, Black-throated Blue Warbler *Dendroica caerulescens*, Yellow-throated Euphonia *Euphonia hirundinacea*, Northern Oriole *Icterus galbula*

ant on both farms (Table 3). Differences also were pronounced during the dry season (Table 4). Seven species were more abundant on the traditional farm, two were more abundant on the modernized farm, and nine were equally common.

Discussion

Results of this and other studies (e.g. Greenberg *et al.* 1997a) demonstrate that shade coffee plantations can vary greatly in their suitability as habitat for birds. The majority of birds found on both farms are characteristic of forest edge, second-growth, semi-open areas, plantations, and other disturbed habitats (Howell and Webb 1995). Birds typical of humid evergreen forest were less common but, when present, typically were more abundant on the traditional farm (e.g. Ochre-bellied Flycatcher, White-breasted Wood-Wren *Henicorhina leucosticta*). Many of the 15 species that were never observed on the modernized farm (e.g. Collared Trogon *Trogon collaris*, Emerald Toucanet *Aulacorhynchus prasinus*, Ruddy Foliage-gleaner *Automolus rubiginosus*) are typically found in humid evergreen forest, suggesting that the traditional farm may provide a more suitable alternative habitat for such birds than does the modernized farm.

Although this study was based on only two farms, the results probably apply more broadly, for several reasons. First, the two farms are representative of other farms in the region, both in terms of type of plantation, management and size. Second, farms are adjacent to each other (similar elevation) and are surrounded by the same landscape. Thus, differences between the farms are not confounded by differences in elevation (see Greenberg *et al.* 1997a) or surrounding habitat. Finally, results were consistent over time (between and within seasons) and are consistent with other studies (e.g. Wunderle and Latta 1996, Greenberg *et al.* 1997a, b) that have demonstrated increased abundance and diversity of birds on structurally more complex agroforestry systems.

The two coffee farms included in this study used different management practices (use of chemicals, planting and pruning of shade trees, etc.) that affected the structural and floristic diversity of the vegetation (i.e. shade trees, epiphytes). These differences in vegetation probably account for much of the difference in bird abundance and diversity between the farms and also are likely to influence the overall biological diversity in the two systems (Perfecto *et al.* 1996). Several aspects of the plantation systems were particularly important influences on diversity.

Habitat structure

Structurally complex agricultural habitats can provide important alternative habitats for many species when natural habitats are lost (Rappole and Warner 1980, Vannini 1994, Schelhas and Greenberg 1996). The traditional farm included in this study had a greater abundance and diversity of shade trees, more epiphytes, and was more heterogeneous in distribution of foliage than was the more uniform modern farm. Differences in both floristic and structural diversity of the vegetation probably contributed to the greater abundance (twice as many birds) and diversity (e.g. birds of humid forests) of birds on the traditional farm.

Inga, the most important shade tree on both farms, provides resources for a variety of birds (Wunderle and Latta 1996, Greenberg *et al.* 1997b) and probably attracts many birds to shade coffee plantations. Many birds were observed feeding on arthropods found on the foliage of *Inga* trees. In other cases, insectivores may be influenced by the presence of *Inga* extrafloral nectaries, which attract insects (Leon 1966). Similarly, the greater occurrence of epiphytes on *Inga* and other shade trees on the traditional farm probably attract insectivores, many of which were observed feeding in epiphytes. Differences in foliage density and distribution between the farms may thus contribute to the differences in abundance of foliage-gleaning insectivores.

Frugivores and nectarivores also can be attracted by resources provided by *Inga* trees. *Inga* fruits have seeds covered by a fleshy white aril or pulp which attract many birds (e.g. White-fronted Parrot *Amazona albifrons*, Pacific Parakeet

Aratinga strenua) that were absent or uncommon on the modernized farm where pruning prevents the *Inga* trees from fruiting. *Inga* flowers attract both residents (e.g. hummingbirds, orioles) and migrants (e.g. Tennessee Warbler *Vermivora peregrina*). The Tennessee Warbler, which was common on both farms during winter, depends heavily on the mass flowering of *Inga* during the dry season (Greenberg *et al.* 1997b).

Although the abundance of *Inga* was similar on both farms, the traditional farm also had a variety of other shade plants (e.g. orange, banana) that contributed to the complexity of the vegetation structure and provided important resources for both resident and migrant species. For example, guayabo *Psidum biloculare* was more common on the traditional farm and was used by several species for nesting while many others fed on the fruits (pers. obs.).

Management techniques

Differences in management techniques (i.e. pruning schedules, fertilizer regimes) can have direct and indirect impacts on birds (Katzeff 1994, Vannini 1994). More intensive use of herbicides means that understorey vegetation (other than coffee) is absent for a longer period in the modernized farm and may account for the lower numbers of birds found there. Many birds typically forage on the ground or low in the understorey; thus elimination of vegetation at this level reduces foraging sites and insect abundance (Nestel *et al.* 1993, Greenberg *et al.* 1997a).

Application of herbicides may have other consequences for birds as well. Bird abundance during the wet season showed a significant decrease during the third count on the traditional farm conducted one week after the application of herbicide (Gramaxone). No decline was noted on the modernized farm where no herbicide had been applied recently. In fact, the slight increase in bird numbers on the modernized farm may have reflected movement of birds away from the traditional farm. Based on this and other studies (e.g. Mullie *et al.* 1991), use of agrochemicals probably has significant effects on avifauna in shade coffee plantations but such effects remain difficult to quantify.

Major differences in shade management techniques between the two farms probably affect bird populations as well. For example, pruning of shade trees in the traditional farm was done at the beginning of the dry season (late January) while in the modernized farm it was done in the middle of the wet season (June). Such differences in pruning schedules affect the seasonal distribution of foliage and contribute to differences observed between the two farms. Distribution and abundance of foliage can influence foraging patterns, abundance, and nesting success of birds (e.g. Pearson 1975, Martin 1993). Severe pruning of large branches may even affect the likelihood of cavity nesters (e.g. woodpeckers) finding suitable sites for nest construction, with consequent impacts on secondary cavity nesters as well.

Conservation implications

As Greenberg *et al.* (1997a) concluded, the use of pesticides and extensive trimming of shade are two management techniques that can reduce abundance of birds on coffee plantations. Thus, any reductions in these activities might potentially benefit bird populations. To accomplish this, coffee growers must be provided with information about how alternative management techniques (e.g. pruning schedules, types of shade trees) may help conserve biodiversity without reducing the economic returns from the coffee. Coffee is a commodity that influences the prosperity and economic stability of Guatemala. Persuading farmers to maintain shade coffee farms in the interest of conservation can only be accomplished by demonstrating that such farms are economically viable.

Acknowledgements

This research constitutes partial fulfillment of the requirements for a Masters degree in Biology (L. C.) at University of Missouri-St Louis and was supported by a Fulbright Fellowship to L. C. Research support was provided by the International Center for Tropical Ecology (Mallinckrodt Foundation Fellowship) at UM-St Louis, UM-St Louis Small Grants Fund, Wildlife Preservation Trust International, and Manomet Observatory for Conservation Sciences (Birder's Exchange Program). Valuable comments on the manuscript were provided by F. Hayes, J. Lill, B. Loiselle, R. Marquis, S. Mason, and J. Perez-Eman.

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LORENA CALVO
University of Missouri-St Louis, Department of Biology, 8001 Natural Bridge Rd., St Louis, MO 63121, U.S.A.

JOHN G. BLAKE
University of Missouri-St Louis, Department of Biology, 8001 Natural Bridge Rd., St Louis, MO 63121, U.S.A.
email: blake@jinx.umsl.edu.