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PROXIMITY TO FORESTS DRIVES BIRD CONSERVATION VALUE OF COFFEE PLANTATIONS: IMPLICATIONS FOR CERTIFICATION

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Abstract. Widespread loss of primary habitat in the tropics has led to increased interest in production landscapes for biodiversity conservation. In the Western Ghats biodiversity hotspot in India, shade coffee plantations are located in close proximity to sites of high conservation value: protected and unprotected forests. Coffee is grown here under a tree canopy that may be dominated by native tree species or by nonnative species, particularly silver oak (*Grevillea robusta*). We investigated the influence of properties at the local scale and the landscape scale in determining bird communities in coffee plantations, with particular emphasis on species of conservation priority. We used systematic point counts in 11 coffee plantation sites and analyzed data in a randomized linear modeling framework that addressed spatial autocorrelation. Greater proportion of silver oak at the local scale and distance to contiguous forests at the landscape scale were implicated as factors most strongly driving declines in bird species richness and abundance, while increased basal area of native tree species, a local-scale variable, was frequently related to increased bird species richness and abundance. The influence of local-scale variables increased at greater distances from the forest. Distance to forests emerged as the strongest predictor of declines in restricted-range species, with 92% reduction in the abundance of two commonly encountered restricted-range species (Pompadour Green Pigeon and Yellow-browed Bulbul) and a 43% reduction in richness of bird species restricted to Indian hill forests within 8 km of forests. Increase in proportion of silver oak from 33% to 55% was associated with 91% reduction in the abundance of one commonly encountered restricted-range species (Crimson-fronted Barbet). One conservation strategy is providing incentives to grow coffee in a biodiversity-friendly manner. One implication of our study is that plantations located at varying distances to the forest cannot be compared fairly for biodiversity friendliness by existing certification methodology. Another is that conservation of existing forests at the landscape scale is essential for maintaining higher biodiversity in coffee plantations. Incentive schemes that promote conservation of remnant forests at the landscape scale and biodiversity-friendly practices locally and that relate to coffee communities as a whole rather than individual planters are likely to be more effective.

Key words: biodiversity certification schemes; birds; coffee plantation; Grevillea robusta; *incentive programs; restricted range; silver oak; Western Ghats, India.*

Introduction

The expansion of production landscapes over the last two centuries has resulted in the loss and degradation of much native habitat. As a result of this, populations of several forest species are entirely resident in or dependent upon these landscapes to the extent that many biologists view the landscapes as an integral component of conservation planning (Pimentel et al. 1992, Perfecto et al. 1996, Luck and Daily 2003, Petit and Petit 2003, Fischer et al. 2006).

The economic importance of coffee, one of the most-traded commodities in the world, is matched by its ecological significance as a crop grown in high-biodiversity areas in middle elevations in the tropics (Perfecto et al. 1996, O'Brien and Kinnaird 2003). Birds, particularly Neotropical migrants, have been the primary focus of conservation in coffee plantations (Komar 2006). Studies conducted over the last decade have investigated the response of migratory and resident bird species to variation in shade-layer species composition, habitat structural complexity, and management intensity gradients. These studies have identified certain forms of coffee cultivation, such as shaded traditional polycultures, to be more conducive to biodiversity conservation than unshaded or monoculture shade plantations (Perfecto et al. 1996, Greenberg et al. 1997*a*, Calvo and Blake 1998, Tejeda-Cruz and Sutherland 2004).

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It is evident that while coffee plantations hold significant socioeconomic and ecological values, the manner in which plantations are managed can cause these values to vary widely. Maintaining these values at a high level may result in suboptimal direct economic value (Perfecto et al. 2005); hence planters are encouraged to do so through incentive schemes that supplement economic returns. These incentives are linked to certification schemes that relate to issues of fair trade and organic cultivation or, like the more-recent shade coffee movement, focus solely on environmental and biodiversity conservation (Rice and McLean 1999). A recent review of popular biodiversity certification schemes (Mas and Dietsch 2004) reflects a strong bias towards rewarding biodiversity-friendly activities at the scale of individual estates, while the role of habitat matrix structure and presence of natural forests in the surrounding landscape are given relatively less importance. At the same time, research in heterogeneous, human-dominated landscapes highlights the importance of landscape configuration, in terms of native vegetation and tree cover surrounding a site in influencing forest bird species populations and community composition at a site (Daniels 1994, Estrada et al. 1997, Daily et al. 2001, Graham and Blake 2001, Rodewald and Yahner 2001).

The influence of proximity to natural forests in the surrounding landscape on avian communities in coffee plantations may become increasingly evident in landscapes with large areas under forest cover, such as the Western Ghats in southern India, a region of high conservation importance (Olson and Dinerstein 1998, Stattersfield et al. 1998, Myers et al. 2000, Hoekstra et al. 2005). Tree-covered plantations here are reported to harbor rich bird assemblages, though these are depauperate in typical forest avifauna when compared to natural forests (Daniels et al. 1990, Shahabuddin 1997, Raman 2006). Coffee plantations here often occur in close spatial proximity to moist tropical forests and sites harboring populations of rare, threatened or endemic flora and fauna (Das et al. 2006).

In this study, we examine the importance of factors at the local scale, such as shade species composition and habitat structure, along with landscape-scale influences, such as distance to natural forests, in determining bird species richness and abundance in coffee plantations in a tropical forest coffee landscape in the Western Ghats. We pay particular attention in our analysis to bird species of high conservation priority. Finally we discuss some of the limitations of incentive schemes to promote conservation on coffee plantations and propose a few innovations that may result in more effective conservation, with reference to our results.

Methods

Study site

The fieldwork was conducted in the foothills of the Bababudan Hills in the Chikmagalur District of Karnataka, India. The site is located within the Western Ghats and Sri Lanka Biodiversity Hotspot (Myers et al. 2000). Of the ~53 400 km^2 extent of the central and southern Western Ghats landscape, coffee plantations cover ~3300 km^2 (6%) along with National Parks and Wildlife Sanctuaries (9939 km^2, 19%) and state Reserved Forests (18 291 km^2, 34%). In many cases, particularly in the central Western Ghats, coffee plantations are a major landscape element in enclaves within and areas around and in between these protected forests (Fig. 1a).

The study site, located in the central Western Ghats, comprises shade coffee plantations, tropical moist deciduous forest, open habitats such as grasslands, paddy, and mustard fields, human habitation, lakes, and reservoirs (Fig. 1b). Coffee plantations in this landscape form a large, contiguous matrix. The Bhadra Wildlife Sanctuary, a 493 km^2 tropical moist deciduous forest characterized by tree species such as *Tectona grandis*, *Dalbergia latifolia*, *Terminalia alata*, *Pterocarpus marsupium*, and *Lagerstroemia lanceolata* (Karanth 1981), forms the northern and western boundaries of the study site. The study area is flanked by two Important Bird Areas, the Bhadra Tiger Reserve and the Kemmangundi and Bababudan Hills (Islam and Rahmani 2004). Twenty-five species of birds restricted to moist tropical forests of peninsular India are reported from this area, including 13 out of the 16 species endemic to the Western Ghats (Islam and Rahmani 2004). Coffee (Arabica variety, *Coffea arabica*, and Robusta variety, *C. robusta*) plantations in the district cover over 870 km^2 and contribute close to 25% of all coffee produced from the Western Ghats (Coffee Board of India 2005). These plantations range in area from small-scale farms of ~0.1 km^2, which account for >90% of all coffee plantations, to corporate plantations of close to 5 km^2 (Coffee Board of India 2005). Coffee here is almost entirely grown under a shade layer. The shade layer, while rarely falling in the rustic (Moguel and Toledo 1999) category, may vary from one dominated by planted native shade trees to shaded monoculture of silver oak (*Grevillea robusta*), an introduced species native to Australia. The last few decades have seen a great increase in coffee plantation area under silver oak shade, largely because of the financial benefits resulting from harvesting the timber of this fast-growing species (Damodaran 2002).

Habitat and bird sampling

Eleven coffee plantation sites were selected for sampling between December 2005 and May 2006. We selected sites so as to capture gradients in habitat characteristics, particularly the proportion of silver oak trees in the shade layer, and landscape characteristics, such as the distance to contiguous forests, based on visual assessment of proportion of silver oak in the shade layer on site and on the examination of 1:25 000 Survey of India topographic maps. We ensured that no two sites were closer than 2 km apart. Within each plantation site, nine sampling stations were marked on

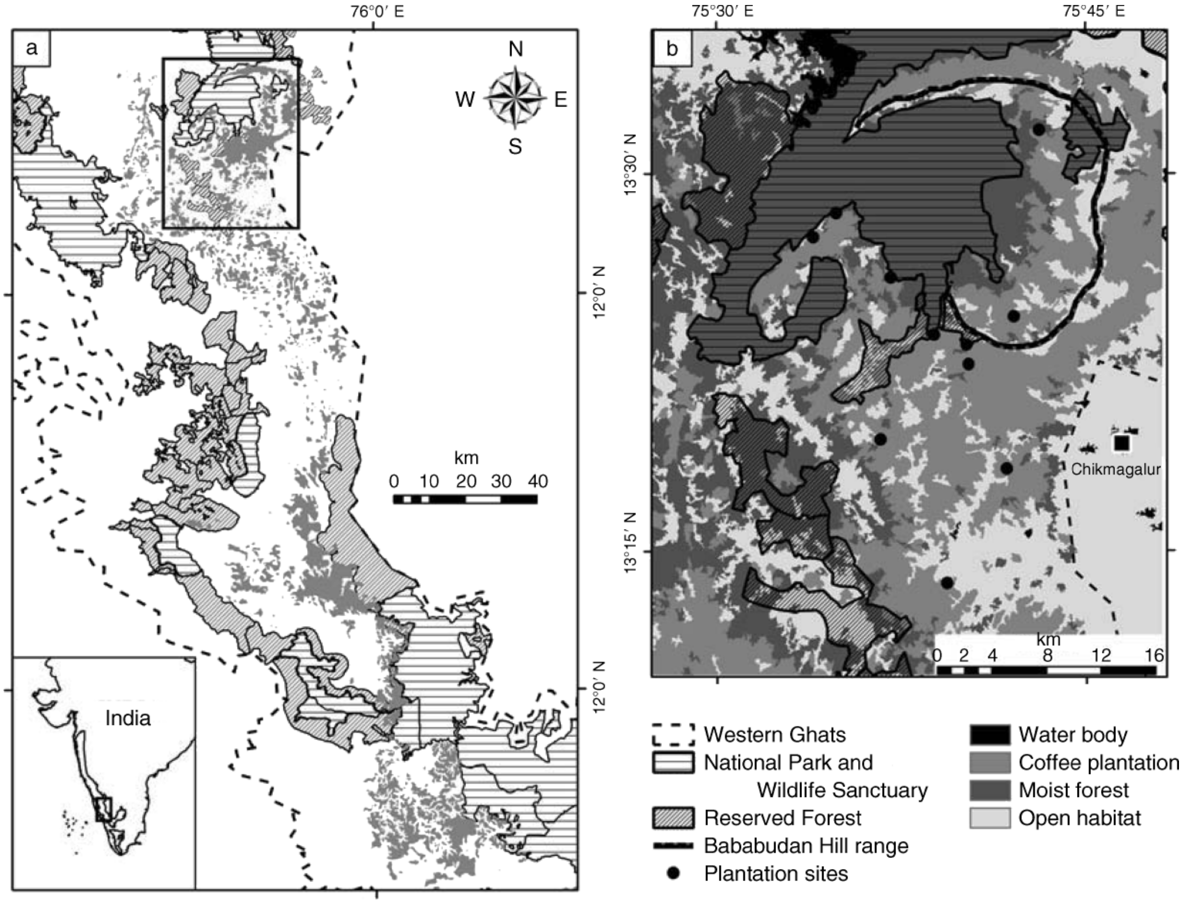

FIG. 1. Map showing (a) close spatial association between protected areas and coffee plantations in the central Western Ghats (Pascal and Ramesh 1995) and (b) the study site with major land cover types, administrative boundaries of protected areas, and 11 coffee plantation sampling sites. The fieldwork was conducted in the foothills of the Bababudan Hills in the Chikmagalur District of Karnataka, India.

the ground using paint and chalk markers and on a geographic information system (GIS) using a hand-held global positioning system (GPS; Garmin GPS 12 XL, Garmin, Olathe, Kansas, USA). A minimum distance of 150 m was maintained between sampling stations.

At each of the sampling stations, we sampled vegetation and habitat structure in concentric circular plots of 30 m and 10 m radius. Within the 30 m radius plot, we counted the total number of trees over 30 cm girth at breast height (GBH), noting the number of silver oak trees, thereby generating a proportion of silver oak (PSO) at that station. Within the 10 m radius plot, we counted and identified, to the level of species or morphospecies, all trees over 30 cm GBH. We used these data to calculate tree density (TDEN), tree species richness (TSP), basal area (BATOT), and basal area of tree species other than silver oak (BANAT), mostly native species, per plot. Also within the 10 m radius plot, we estimated canopy cover using a canopy densitometer (CDEN) and visually estimated canopy height (CHT) and the number of middle-story trees $<$10 m in height (MC). Lastly, we estimated a measure of vertical stratification by counting the number of height classes from among 11 height classes (VSTRAT, in meters: 0–1, $>$1–2, $>$2–3, $>$3–4, $>$4–5, $>$5–6, $>$6–7, $>$7–8, $>$8–16, $>$16–32, and $>$32 m) that contained leafy vegetation within an imaginary cylinder of 0.5 m radius above the observer.

We used IDRISI Kilimanjaro (Clark Labs 2003) spatial analysis software to extract two landscape-scale characteristics: the nearest linear distance of a sampling station from contiguous forest (DIST) and the proportion of area within a 1 km radius of a station that is not under tree cover (POC).

We sampled birds using variable circular plots (Williams et al. 2002) at each of the 11 sites over two seasons, with two visits per season to each of the sampling stations. Each count lasted 5 min, and all counts were conducted between 06:30 and 09:30. We recorded detections up to a maximum distance of 70 m from the sampling station. Both sightings and aural detections were recorded, and we used a laser range finder to measure distance to the bird, in case of sightings, or in the case of calls, to the tree or branch closest to its detection location. Detections were subsequently pooled into classes of 0–10, >10–20, >20–30, >30–40, >40–50, and >50 m. Data were not collected on soaring raptors, swifts, and swallows as the methods we used were not appropriate to the sampling of these groups. One nocturnal species, the Eurasian Eagle Owl (*Bubo bubo*) was recorded during sampling.

Analysis

We examined the bird data using the software DISTANCE 5 (Thomas et al. 2006) to investigate whether there were differences in detection probability of functional groups of bird species across coffee plantations. For this purpose, coffee plantations were classified based on shade composition as native shade (10–40% silver oak, five sites), mixed shade (40–60% silver oak, three sites), and exotic shade (>60% silver oak, three sites), and bird species were grouped into five detectability groups based on foraging behavior and taxonomic similarity. We confirmed by comparing 95% confidence intervals that there were no differences in the detection probability of these bird species groups within coffee plantations (Fig. 2), suggesting that any patterns observed in species richness and encounter rate across the plantation sites were not confounded by differences in detection probability. We restricted our use of DISTANCE to investigate detection probability only, as the remainder of our analysis focused on relative differences in species richness and abundance across coffee plantations and not on absolute estimates of these parameters.

We investigated the drivers of species richness of (1) all species (ALLS); (2) Western Ghats endemics and species restricted to moist tropical forests of the Indian peninsula (RR1); (3) species restricted in India to moist hill forests of the Western Ghats, Himalayas, and northeast India (RR2); (4) species distributed widely in India in forested and wooded habitats (RR3); and (5) species distributed widely in India, often occurring in non-forested habitat, degraded habitat, and human habitation (RR4) (Grimmett et al. 1999, Kazmierczak and van Perlo 2000, Islam and Rahmani 2004) (Appendix). Groups 2–5 represent independent sets of species of decreasing conservation priority based on size of distribution range. We then investigated patterns in the number of individuals detected per point (ALLD) and encounter rates of species that were detected frequently (over 20 detections) during the study. All migratory species and species that exhibited significant differences in encounter rate across seasons according to a Mann-Whitney *U* test were excluded from the analysis, except for the responses ALLS and ALLD.

We examined the response of bird species richness and encounter rate to gradients in habitat and landscape characteristics using a multiple regression. Bird species richness at a sampling station was defined as the cumulative number of species detected at that station across the four visits. For species encounter rates, we considered data from only one of two point count samples within each season. Data were suitably transformed: logit transformation of proportions (Johnson and Wichern 1988), square-root transformation ($n + 0.5$) of count variables (Zar 1999, Renjifo 2001), and log transformation of distances and basal areas (Zar 1999).

The bird sampling points located within each plantation site were close enough to each other to be spatially autocorrelated, and yet all the sampling points were required to capture local habitat variability within an estate. We used a randomization procedure to control for the effects of spatial autocorrelation within a site (Legendre 1993, Oommen and Shanker 2005), wherein 500 iterations of the multiple regressions were carried out, with only a randomly selected 33% of the total data contributing to the regression in every iteration. In every iteration, three out of nine points within each of the 11 plantation sites were chosen at random and averaged for both response variables and covariates. Thus we obtained 11 independent data points for fitting a regression model in a particular iteration and potentially covered all the point data in all the plantation sites by running 500 iterations. We used model selection, a rigorous information theoretic approach that estimates likelihood (the probability of the data given different models) as well as penalizes for model complexity or number of covariates used (Burnham and Anderson 1998, Johnson and Omland 2004, Hobbs and Hilborn 2006). Models were compared and selected using the small-sample corrected Akaike Information Criteria (AIC_c) that are now increasingly favored over the traditional regression measures such as R^2 and P values, especially in ecological applications (Johnson 1999, Hobbs and Hilborn 2006). Whereas we used AIC_c values to identify and select the best from among candidate models, we calculated R^2 values for these selected models to assess their goodness of fit (Burnham and Anderson 1998).

Linear regression models were fit and regression parameters and diagnostics (intercept, slope[s], AIC, R^2) generated. The comparative assessment of the competing regression models for a particular response variable was based on median values of the regression parameters and diagnostics from all 500 iterations.

We used a model selection approach (Burnham and Anderson 1998) to identify the model that best explained the bird community response variables. Small sample-corrected Akaike's Information Criterion and Akaike weight (w) were used as the basis for model selection (Burnham and Anderson 1998, Johnson and Omland 2004). For every bird species response, we tested the predictive power of 21 models in a model selection framework, of which 11 models comprised the 11 single covariates, while the remaining 10 comprised two covariates. In each of the latter 10 models, one of the two covariates was the covariate with the strongest predictive power from the former 11 models. All

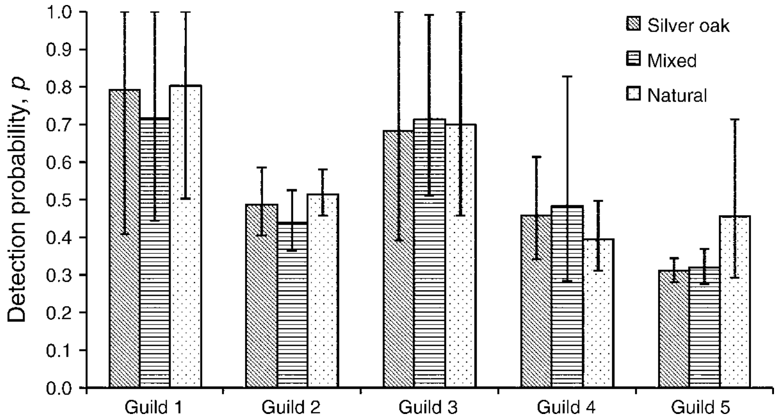

FIG. 2. Detection probabilities (mean ± 95% CI) of bird species guilds created based on taxonomic and foraging behavior similarity. These are canopy specialist species (Guild 1), canopy generalist species (Guild 2), canopy and bark-feeding species (Guild 3), terrestrial and understory species (Guild 4), and sallying insectivore species (Guild 5).

statistical analysis was carried out using the statistical software S-PLUS (Insightful Corporation 2001).

Using the above analysis, we investigated which covariates were being most frequently identified through model selection and what the direction of the relationship was between that covariate and bird species richness and abundance response. For a given bird response, by summing up the Akaike weights of all the models containing a particular covariate (covariate weight), we identified which covariate had the strongest influence on that response. Using the functional responses obtained through the linear regression and model selection, we investigated the magnitude and direction of change in bird species richness and abundance responses across the inter-quartile ranges of sampled gradients in predictor variables.

Finally, in order to verify whether the results we obtained at the level of the sampling point were comparable to those at the plantation site level, as well as to eliminate the possible effects of species evenness on the results, we compared rarefied species richness within the following treatments: (1) near forest (<3000 m) and dominated by native shade (<50% PSO), (2) near forest and dominated by silver oak shade, (3) away from forest and dominated by native shade, and (4) away from forest and dominated by silver oak shade. As the results obtained in this analysis closely matched and supported the results from the analysis described in preceding paragraphs, we have not included them in the following section.

RESULTS

We recorded a total of 102 bird species during the study, of which 12 were migratory and 90 were resident species. Twenty-one resident species were encountered 20 or more times over the course of the study, of which four belonged to RR1, two to RR2, 12 to RR3, and three to RR4.

All 11 covariates included in the analysis appeared at least once among the 81 models that constituted the three strongest predictors for each of the five species richness responses and 22 species abundance responses. Within these 81 models, for species richness and abundance, PSO, DIST, PSO, and BANAT were the covariates most frequently appearing, with PSO almost always being associated with species richness and abundance decline, BANAT almost always associated with increase in richness and abundance, and DIST being associated with declines of the more restricted-range species (Fig. 3a, b).

Single-covariate models were identified by model selection as the best predictors of all five species richness responses and 21 of 22 species abundance responses. We identified PSO as being the best predictor associated with declines of overall species richness and total abundance per point (Akaike weight of covariate [*w*] of 0.82 and 0.76, respectively).

Models containing PSO as the single strongest predictor of bird response were selected for two species richness responses and two species abundance responses (Table 1). Across the sampled interquartile range of PSO (33–55%), we recorded a 12.4% decline in ALLD and a 91.4% reduction in the abundance of Crimson-fronted Barbet (RR1). The R^2 values for the selected models were reasonably good, ranging from 0.22 to 0.36 for the five species richness responses and from 0.31 to 0.39 for the four species abundance responses.

Models that contained DIST as the only covariate or one of the two covariates were identified by model selection as the best models for three of the five species richness responses and six species abundance responses, including the abundance response of one RR1 and one RR2 species. For two species richness responses (RR1 and RR2) and abundance responses of two commonly encountered species (Yellow-browed Bulbul [RR1] and Pompadour Green Pigeon [RR2]), DIST was the single strongest predictor of decline, with covariate weight (*w*)

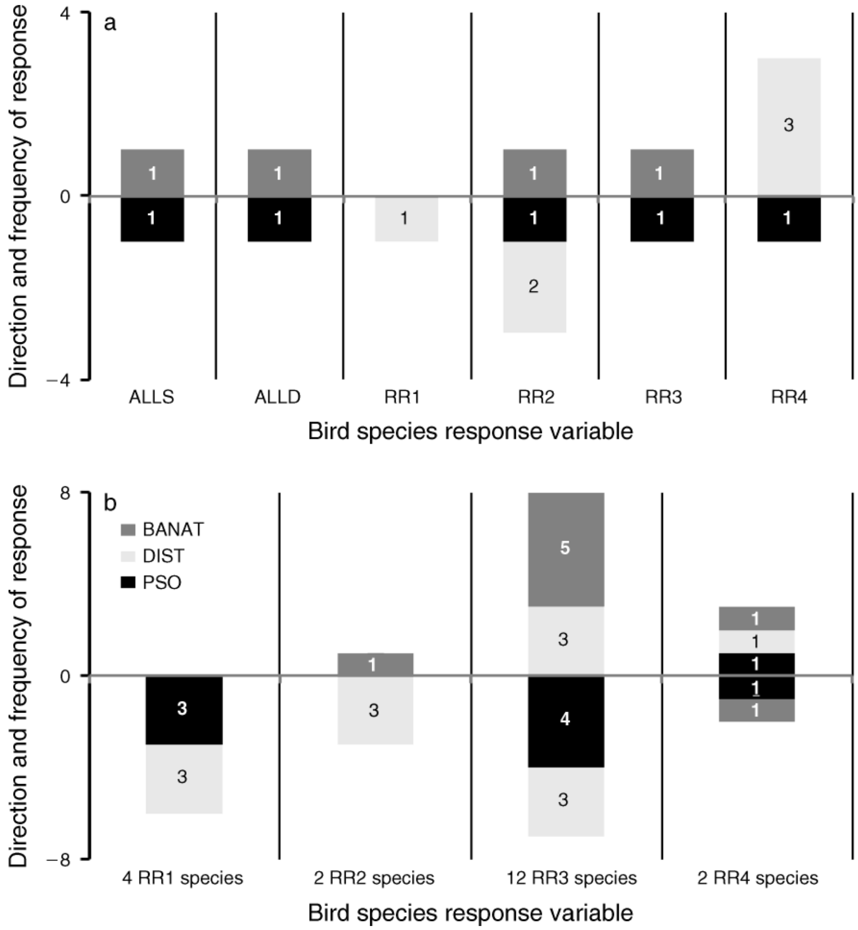

FIG. 3. Frequency of occurrence (values within bars) of three covariates (proportion of silver oak [PSO], distance to contiguous forests [DIST], and basal area of native shade trees [BANAT]), in models selected as the best predictors of (a) five species richness responses (ALLS, RR1, RR2, RR3, and RR4) and one overall abundance response (ALLD) and (b) 21 species abundance responses. Numbers within bars for each response indicate the number of times a particular covariate was present in the top three models selected for that response. In (b) these results are pooled for more than one species, and hence the values of numbers within bars may exceed 3. Bars along the positive *y*-axis indicate the frequency of positive relationships between that particular covariate and response, and bars along the negative *y*-axis indicate a negative relationship.

ranging from 0.76 to 0.92 (Table 1). Across the interquartile range of the distance gradient sampled (0.3–8.1 km) species richness declined by as much as 42.6% (RR2) and species abundance by as much as 91.9% (Pompadour Green Pigeon [RR2]; Table 1).

Extrapolation from the strongest two-covariate models for species richness responses, RR1 (DIST + PSO) and RR2 (DIST + BANAT), and for species abundance responses of Yellow-browed Bulbul (DIST + TSP) and Pompadour Green Pigeon (DIST + TSP) indicated that a change in floristic or structural properties of plantations at sites farther from the forest resulted in a greater change in the bird species response than at sites closer to the forest (Table 2).

Discussion

Rappole et al. (2003) contend that while it is important to promote coffee that is grown under a tree canopy (as opposed to coffee grown in the open), the floristic composition and structural characteristics of the shade canopy can greatly influence its suitability for biodiversity. Birds in several coffee-growing regions have been found to prefer coffee plantations under a native, mature shade layer to plantations under monocultures of nonnative shade trees (Greenberg et al. 1997*b*, Calvo and Blake 1998, Raman 2006). In this study, an increase in PSO was the local-scale property most strongly associated with declines in species richness and abundance of the overall bird community and a few subsets within it. A cause for concern in the Western Ghats is that planters are increasingly planting this species as a shade tree in preference to native tree species, encouraged by economic returns derived from the harvest and sale of silver oak wood (Damodaran 2002).

TABLE 1. Responses and covariates of bird species richness and abundance variables with model covariate strength and model explanatory power, along with magnitude of change of response over the interquartile range of the covariate sampled (proportion of silver oak per plot [PSO], 33–55%; distance to contiguous forests [DIST], 0.3–8.1 km), for five species richness responses and four species abundance responses.

Response variable	Covariate	Response direction	Magnitude of change in response (%)	Covariate weight (w)	R^2
Species richness response					
ALLS	PSO	decline	3.7	0.82	0.36
RR1	DIST	decline	20.6	0.77	0.26
RR2	DIST	decline	42.6	0.76	0.28
RR3	PSO	decline	15.9	0.46	0.22
RR4	DIST	increase	27.7	0.90	0.30
Species abundance response					
ALLD	PSO	decline	12.4	0.76	0.31
Yellow-browed Bulbul (RR1)	DIST	decline	89.7	0.92	0.35
Crimson-fronted Barbet (RR1)	PSO	decline	91.4	0.92	0.39
Pompadour Green Pigeon (RR2)	DIST	decline	91.9	0.92	0.33

Notes: In case of species abundance responses, results are reported only for those responses with covariate weights over 0.60. The fieldwork was conducted in the foothills of the Bababudan Hills in the Chikmagalur District of Karnataka, India. Abbreviations are: ALLS, all species; RR1, Western Ghats endemics and species restricted to moist tropical forests of the Indian peninsula; RR2, species restricted in India to moist hill forests of the Western Ghats, Himalayas, and northeast India; RR3, species distributed widely in India in forested and wooded habitats; and RR4, species distributed widely in India, often occurring in non-forested habitat, degraded habitat, and human habitation. RR3 and RR4 represent the overall species pool and independent sets of species based on restrictedness of distribution. ALLD is a measure of overall bird abundance per point.

In addition, the Government of India and state governments will soon implement legislation that would govern cultivated and residential areas within natural forests including protected areas. The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act 2006 entitles forest dwellers to residence, development, and forest products extraction and management rights, as well as the right to cultivate up to 4 ha of land per family conditional on such land already being cultivated as of December 2005. In such a situation, promotion of ecologically and socially sustainable coffee cultivation, wherever suitable conditions prevail, in preference to other forms of ecologically more disruptive cultivation can aid in buffering the impending loss of biodiversity habitat and reduce human–wildlife conflicts.

Given this scenario, the need to generate incentives to grow coffee under a native shade layer becomes important to conservation, a need that can be met through active promotion of incentive schemes for biodiversity conservation on coffee plantations.

Incentive schemes are also essential to buffer the economic and biodiversity losses resulting from market fluctuations that encourage planters to bring more areas under coffee cultivation and to promote yield by increasing technical intensity (Perfecto et al. 1996, 2005, O'Brien and Kinnaird 2003, Madhusudan 2005).

While on the one hand these incentive schemes are important to conservation, their potential is currently hampered by a lack of transparency with regard to price premiums and coordination among both certification principles and certifying agencies (Rice and McLean 1999). Nonlinear declines in coffee yield with increasing shade coupled with variable responses of different taxa of conservation value to changes in shade level further complicate the development of standards and incentives for shade certification (Perfecto et al. 2005).

The results of our study provide more evidence that economic incentives based on popular certification schemes in their present form may neither entirely serve the purpose of conserving species of high conservation priority nor reward planters in proportion to the benefits

TABLE 2. Changes in species richness and abundance of restricted range species across the interquartile range of proportion of silver oak [PSO] (33–55%), basal area of native shade trees [BANAT] (3.06–5.58 m^2/ha), and tree species richness per plot [TSP] (1.87–2.35 species) at 1 km (D1), 5 km (D2), and 15 km (D3), as predicted by two-covariate models for which DIST is one of the covariates (covariate 1).

Response variable	Covariate 2	Response direction	Change at 1 km (%)	Change at 2 km (%)	Change at 3 km (%)
Species richness response					
RR1	PSO	decline	7.4	7.8	8.0
RR2	BANAT	increase	28.21	30.37	32.04
Species abundance response					
Yellow-browed Bulbul (RR1)	TSP	increase	47.63	53.41	58.18
Pompadour green Pigeon (RR2)	TSP	increase	80.71	81.99	83.06

Note: See Table 1 for an explanation of abbreviations.

to conservation that their plantations provide. These schemes emphasize shade tree species composition and structure and other plantation-scale factors that distinguish shade coffee plantations from unshaded ones or from shaded monocultures (Gobbi 2000, Greenberg and Rice 2001, Mas and Dietsch 2004, Philpott et al. 2007). By focusing on these factors alone, effective conservation may be restricted to highly vagile species, ubiquitous species, and habitat generalists. These schemes cater to and are more effective in landscapes increasingly undergoing conversion from shade coffee to sun coffee (Rice and McLean 1999) or in landscapes where the almost complete destruction of native habitats has made shade coffee plantations the land cover type of highest conservation value (Perfecto et al. 1996, 2005).

In coffee-growing regions with greater amounts of forest and tree cover, the nature, configuration, and quality of the forest and tree cover in the landscape surrounding a site may have a strong influence on bird community composition at a site (Renjifo 2001, Bhagwat et al. 2005, Raman 2006). For forest-dependent species, the quality of surrounding habitats may have an even greater influence than habitat quality at the site itself (Yamaura et al. 2007). In this study, DIST consistently emerged as the strongest predictor of bird species richness and abundance, particularly so for species of high conservation priority. Plantations that were close to the contiguous forest boundary harbored higher species richness and abundance of restricted range species than those further away from the forest. Under these conditions, a plantation conforming to all shade criteria of a certification scheme but at a large distance from the forest may not be as frequently used by conservation priority species as a plantation less worthy of shade certification but located closer to natural forests. Another important implication is that conserving remnant forest will help maintain higher overall biodiversity in coffee plantations, which is also supported by two other studies in this area (Bali et al. 2007, Dolia et al. 2008).

Our results suggest that shade certification schemes, such as that of the Rainforest Alliance (Anonymous 2005), that require planters to act beyond their plantation boundaries into the conservation of natural ecosystems need to be further refined, promoted, and replicated. In a situation in which landscape configuration may determine the relative role of different predictor variables in driving conservation value, it seems insufficient to base biodiversity certification on a fixed set of criteria focused on shade alone. In coffee-growing regions that harbor remnant natural forests, there is a need for more flexible certification schemes, ones that reward efforts by planters at sites close to forests to restore and conserve the biodiversity, including discouragement or elimination of hunting in estates and within those forests, but place more emphasis on shade management at increasing distances from the forest. By explicitly encouraging the conservation of native forests in a coffee-growing landscape, these certification schemes would also address one of the major arguments against shade certification: the argument that incentives would make it economically viable to bring more land, potentially forest land, under coffee production (Rappole et al. 2003). This is a major concern in regions where coffee is still replacing natural forest and prime wildlife habitat, mostly illegally, especially in Southeast Asia.

Our results suggest that incentive schemes must also place increased emphasis on conservation at the landscape scale rather than at the scale of individual plantations. Since these remnant forests are clearly more important than plantation-scale habitat characteristics in supporting populations of conservation priority species, a result also reflected by studies on other taxa at the same study site (Bali et al. 2007, Dolia et al. 2008), incentive schemes that sufficiently reward individual planters, groups of planters, or even the entire plantation community for taking action to conserve these forests and wildlife are required. Overall biodiversity friendliness will be achieved only when, in addition to shade management, hunting is curbed or eliminated, impacts of coffee pulping discharge on aquatic ecosystems are minimized, and remnant forests are conserved. To be successful such schemes would require higher levels of coordination within the planter community; this may be achieved through greater involvement of administrative bodies associated with coffee production and formal or semiformal associations of planters.

Several authors have also suggested greater coordination between fair trade, organic, and shade certification (Philpott and Dietsch 2003, Dietsch et al. 2004), given not only the ample common ground between the objectives, but also equally important conflicts of interest (see Madhusudan [2005] for an example of conflict of interest between organic cultivation and biodiversity conservation). Such coordination could potentially increase premiums to coffee growers (Philpott et al. 2007). In the Araku Valley in peninsular India, the Coffee Board of India and the Government of India are promoting coffee grown on 50 000 ha of land that, until recently, was under degraded forest and subsistence shifting agriculture. The product is promoted as greening the degraded landscape while providing livelihood options for local communities. Whereas the coffee is certified as organic and application for fair-trade certification has been submitted, overall sustainability will not be achieved until greater attention is paid to biodiversity friendliness at the landscape scale as well.

Finally, several studies have assigned relatively less importance to remnant forests in structuring biodiversity in coffee plantation landscapes, either because of study design constraints (Greenberg et al. 1997*a*, Petit and Petit 2003) or because forest cover in the landscape is limited or highly degraded (Greenberg et al. 1997*b*, 2000, Wunderle 1999). Future research on biodiversity in coffee plantation landscapes must explicitly examine the importance of factors at the landscape scale as well as nonlinearity and thresholds in the influence of local- and landscape-level factors in structuring biodiversity. In addition, research must also look at the relationships between biodiversity and ecosystem services, most notably pest control and pollination (Perfecto et al. 2004, Ricketts 2004, Ricketts et al. 2004), that may supplement existing incentives to conserve biodiversity on coffee plantations.

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Literature Cited

Anonymous. 2005. Sustainable agriculture standard. Rainforest Alliance, San Jose, Costa Rica.

Bali, A., A. Kumar, and J. Krishnaswamy. 2007. The mammalian communities in coffee plantations around a protected area in the Western Ghats, India. Biological Conservation 139:93–102.

Bhagwat, S. A., C. G. Kushalappa, P. H. Williams, and N. D. Brown. 2005. A landscape approach to biodiversity conservation of sacred groves in the Western Ghats of India. Conservation Biology 19:1853–1862.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.

Calvo, L., and J. Blake. 1998. Bird diversity and abundance on two different shade coffee plantations in Guatemala. Bird Conservation International 8:297–308.

Clark Labs. 2003. IDRISI Kilimanjaro. Clark University, Worcester, Massachusetts, USA.

Coffee Board of India. 2005. Annual report: 2004–2005. Coffee Board of India, Bangalore, Karnataka, India.

Daily, G. C., P. R. Ehrlich, and G. A. Sanchez-Azofeifa. 2001. Countryside biogeography: use of human-dominated habitats by the avifauna of southern Costa Rica. Ecological Applications 11:1–13.

Damodaran, A. 2002. Conflict of trade-facilitating environmental regulations with biodiversity concerns: the case of coffee-farming units in India. World Development 30:1123–1135.

Daniels, R. J. R. 1994. A landscape approach to conservation of birds. Journal of Biosciences 19:503–509.

Daniels, R. J. R., M. Hegde, and M. Gadgil. 1990. Birds of the man-made ecosystems: the plantations. Proceedings of the Indian Academy of Sciences (Animal Sciences) 99:79–89.

Das, A., J. Krishnaswamy, K. S. Bawa, M. C. Kiran, V. Srinivas, N. S. Kumar, and K. U. Karanth. 2006. Prioritisation of conservation areas in the Western Ghats, India. Biological Conservation 133:16–31.

Dietsch, T. V., S. M. Philpott, R. A. Rice, and R. Greenberg. 2004. Conservation policy in coffee landscapes. Science 303: 625.

Dolia, J., M. S. Devy, N. A. Aravind, and A. Kumar. 2008. Adult butterfly communities in coffee plantations around a protected area in the Western Ghats, India. Animal Conservation 11:26–34.

Estrada, A., R. Coates-Estrada, and D. A. Meritt Jr. 1997. Anthropogenic landscape changes and avian diversity at Los Tuxtlas, Mexico. Biodiversity and Conservation 6:19–43.

Fischer, J., D. B. Lindenmayer, and A. D. Manning. 2006. Biodiversity, ecosystem function, and resilience: ten guiding principles for commodity production landscapes. Frontiers in Ecology and the Environment 4:80–86.

Gobbi, J. A. 2000. Is biodiversity-friendly coffee financially viable? An analysis of five different coffee production systems in western El Salvador. Ecological Economics 33:267–281.

Graham, C. H., and J. G. Blake. 2001. Influence of patch- and landscape-level factors on bird assemblages in a fragmented tropical landscape. Ecological Applications 11:1709–1721.

Greenberg, R., P. Bichier, and A. C. Angon. 2000. The conservation value for birds of cacao plantations with diverse planted shade in Tabasco, Mexico. Animal Conservation 3: 105–112.

Greenberg, R., P. Bichier, A. C. Angon, and R. Reitsma. 1997*a*. Bird populations in shade and sun coffee plantations in central Guatemala. Conservation Biology 11:448–459.

Greenberg, R., P. Bichier, and J. Sterling. 1997*b*. Bird populations in rustic and planted shade coffee plantations of eastern Chiapas, Mexico. Biotropica 29:501–514.

Greenberg, R., and R. Rice. 2001. Shade management criteria for "bird friendly" coffee. Smithsonian Migratory Bird Center. ⟨http://nationalzoo.si.edu/ConservationAndScience/MigratoryBirds/Coffee/Certification/criteria.pdf⟩

Grimmett, R., C. Inskipp, and T. Inskipp. 1999. Pocket guide to the birds of the Indian Subcontinent. Oxford University Press, New Delhi, India.

Hobbs, N. T., and R. Hilborn. 2006. Alternatives to statistical hypothesis testing in ecology: a guide to self teaching. Ecological Applications 16:5–19.

Hoekstra, J. M., T. M. Boucher, T. H. Ricketts, and C. Roberts. 2005. Confronting a biome crisis: global disparities of habitat loss and protection. Ecology Letters 8:23–29.

Insightful Corporation. 2001. S-PLUS 6.0. Professional Release 1. MathSoft, Seattle, Washington, USA.

Islam, M. Z., and A. R. Rahmani. 2004. Important Bird Areas in India: priority sites for conservation. Indian Bird Conservation Network, Bombay Natural History Society, Bombay, India.

Johnson, D. H. 1999. The insignificance of statistical significance testing. Journal of Wildlife Management 63:763–772.

Johnson, J. B., and K. S. Omland. 2004. Model selection in ecology and evolution. Trends in Ecology and Evolution 19: 101–108.

Johnson, R. A., and D. W. Wichern. 1988. Applied multivariate statistical analysis. Prentice-Hall, Upper Saddle River, New Jersey, USA.

Karanth, K. U. 1981. Bhadra Wildlife Sanctuary and its endangered ecosystem. Journal of the Bombay Natural History Society 79:79–86.

Kazmierczak, K., and B. van Perlo. 2000. A field guide to the birds of India, Sri Lanka, Pakistan, Nepal, Bhutan, Bangladesh, and the Maldives. Om Book Service, New Delhi, India.

Komar, O. 2006. Ecology and conservation of birds in coffee plantations: a critical review. Bird Conservation International 16:1–23.

Legendre, P. 1993. Spatial autocorrelation: Trouble or new paradigm? Ecology 74:1659–1673.
Luck, G. W., and G. C. Daily. 2003. Tropical countryside bird assemblages: richness, composition, and foraging differ by landscape context. Ecological Applications 13:235–247.
Madhusudan, M. D. 2005. The global village: linkages between international coffee markets and grazing by livestock in a south Indian wildlife reserve. Conservation Biology 19:411–420.
Mas, A. H., and T. V. Dietsch. 2004. Linking shade coffee certification to biodiversity conservation: butterflies and birds in Chiapas, Mexico. Ecological Applications 14:642–654.
Moguel, P., and V. M. Toledo. 1999. Biodiversity conservation in traditional coffee systems of Mexico. Conservation Biology 13:11–21.
Myers, N., R. A. Mittermeler, C. G. Mittermeler, G. A. B. Da Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853–858.
O'Brien, T. G., and M. F. Kinnaird. 2003. Conservation: caffeine and conservation. Science 300:587.
Olson, D. M., and E. Dinerstein. 1998. The global 200: a representation approach to conserving the earth's most biologically valuable ecoregions. Conservation Biology 12: 502–515.
Oommen, M. A., and K. Shanker. 2005. Elevational species richness patterns emerge from multiple local mechanisms in Himalayan woody plants. Ecology 86:3039–3047.
Pascal, J. P., and B. R. Ramesh. 1995. Forest map of south India. French Institute of India and Forest Department of Karnataka, Kerala and Tamil Nadu, Pondicherry, India.
Perfecto, I., R. A. Rice, R. Greenberg, and M. E. Van Der Voort. 1996. Shade coffee: a disappearing refuge for biodiversity. BioScience 46:598–608.
Perfecto, I., J. H. Vandermeer, G. L. Bautista, G. I. Nunez, R. Greenberg, P. Bichier, and S. Langridge. 2004. Greater predation in shaded coffee farms: the role of resident neotropical birds. Ecology 85:2677–2681.
Perfecto, I., J. Vandermeer, A. Mas, and L. S. Pinto. 2005. Biodiversity, yield, and shade coffee certification. Ecological Economics 54:435–446.
Petit, L. J., and D. R. Petit. 2003. Evaluating the importance of human-modified lands for Neotropical bird conservation. Conservation Biology 17:687–694.
Philpott, S. M., P. Bichier, R. Rice, and R. Greenberg. 2007. Field-testing ecological and economic benefits of coffee certification programs. Conservation Biology 21:975–985.
Philpott, S. M., and T. Dietsch. 2003. Coffee and conservation: a global context and the value of farmer involvement. Conservation Biology 17:1844–1846.
Pimentel, D., U. Stachow, D. A. Takacs, H. W. Brubaker, A. R. Dumas, J. J. Meaney, J. A. S. O'Neil, D. E. Onsi, and D. B. Corzilius. 1992. Conserving biological diversity in agricultural/forestry systems. BioScience 42:354–362.
Raman, T. R. S. 2006. Effects of habitat structure and adjacent habitats on birds in tropical rainforest fragments and shaded plantations in the Western Ghats, India. Biodiversity and Conservation 15:1577–1607.
Rappole, J. H., D. I. King, and J. H. Vega Rivera. 2003. Coffee and conservation. Conservation Biology 17:334–336.
Renjifo, L. M. 2001. Effect of natural and anthropogenic landscape matrices on the abundance of subandean bird species. Ecological Applications 11:14–31.
Rice, P. D., and J. McLean. 1999. Sustainable coffee at the crossroads. White paper prepared for the Consumer's Choice Council, Washington, D.C., USA.
Ricketts, T. H. 2004. Tropical forest fragments enhance pollinator activity in nearby coffee crops. Conservation Biology 18:1262–1271.
Ricketts, T. H., G. C. Daily, P. R. Ehrlich, and C. D. Michener. 2004. Economic value of tropical forest to coffee production. Proceedings of the National Academy of Sciences (USA) 101: 12579–12582.
Rodewald, A. D., and R. H. Yahner. 2001. Influence of landscape composition on avian community structure and associated mechanisms. Ecology 82:3493–3504.
Shahabuddin, G. 1997. Preliminary observations on the role of coffee plantations as avifaunal refuges in the Palni Hills of the Western Ghats. Journal of the Bombay Natural History Society 94:10–21.
Stattersfield, A. J., M. J. Crosby, A. J. Long, and D. C. Wege. 1998. Endemic bird areas of the world: priorities for conservation. Birdlife International, Cambridge, UK.
Tejeda-Cruz, C., and W. J. Sutherland. 2004. Bird responses to shade coffee production. Animal Conservation 7:169–179.
Thomas, L., J. L. Laake, S. Strindberg, F. F. C. Marques, S. T. Buckland, D. L. Borchers, D. R. Anderson, K. P. Burnham, S. L. Hedley, J. H. Pollard, J. R. B. Bishop, and T. A. Marques. 2006. Distance 5.0. Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, St. Andrews, UK.
Williams, B. K., J. D. Nichols, and M. J. Conroy. 2002. Analysis and management of animal populations. Academic Press, San Diego, California, USA.
Wunderle, J. M., Jr. 1999. Avian distribution in Dominican shade coffee plantations: area and habitat relationships. Journal of Field Ornithology 70:58–70.
Yamaura, Y., H. Tojo, Y. Hirata, and K. Ozaki. 2007. Landscape effects in bird assemblages differ between plantations and broadleaved forests in a rural landscape in central Japan. Journal of Forest Research 12:298–305.
Zar, H. J. 1999. Biostatistical analysis. Pearson, Singapore.

APPENDIX

Common names, scientific names, and migratory and range restriction categories for species recorded (*Ecological Archives* A018-060-A1).