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The Impact of Habitat Fragmentation on Bird Community Composition in Monteverde, Costa Rica

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ABSTRACT

Habitat fragmentation is currently the greatest threat to the avifauna of Costa Rica. To study its effects on bird species composition in the Monteverde region, I surveyed three sites of varying degrees of fragmentation. I did not detect a significant difference in the species richness and heterogeneity among the three sites. My study showed, however, that the species composition changed drastically among sites. Furthermore, the predominant feeding guilds of the species unique to each site changed between sites, suggesting that food availability is an important determinant of where a bird lives. The proportion of insectivores was inversely related to fragmentation, and omnivores are perhaps less affected by fragmentation than other feeding guilds because they are able to use a higher variety of food resources. Certain species were only found at the more continuous sites, including the Black-breasted Wood-quail (*Odontophorus leucolaemus*), which implies they may be more sensitive to habitat fragmentation.

RESUMEN

La fragmentación del hábitat es actualmente la mayor amenaza a la avifauna de Costa Rica. Para estudiar sus efectos en la composición de especies de aves en la región de Monteverde, examiné tres sitios con diferentes grados de fragmentación. Detecté no una diferencia significativa en riqueza y heterogeneidad entre los tres sitios. Mi estudio mostró, sin embargo, que la composición de especies cambió drásticamente entre sitios. Además, los gremios tróficos predominantes de las especies únicas en cada sitio cambió entre sitios, sugiriendo que la disponibilidad de comida es determinante en la presencia de las aves. La proporción de insectívoros se relacionó inversamente con la fragmentación, y los omnívoros son posiblemente menos afectados por la fragmentación que otros gremios tróficos porque son capaces de usar una variedad mayor de recusos alimenticios. Ciertas especies fueron encontradas solamente en los sitios más contínuos, incluyendo la Chirrascuá (*Odontophorus leucolaemus*), lo que implica que ellos son más suceptibles a la fragmentación del hábitat.

INTRODUCTION

Habitat loss and fragmentation are thought to be the biggest threats to animals worldwide, including birds. As habitat is destroyed at an alarming rate, largely due to human development, it greatly reduces the area available for birds to nest, roost, forage, and go about their daily activities. It also impacts the availability of prey items that birds depend on, from fig fruits to insects. Other impacts of habitat fragmentation include increasing edge effects, more isolated populations and decreased gene flow between popu-

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lations, and higher rates of local extinctions.

According to Stiles and Skutch (1), "Habitat destruction is without doubt the greatest threat to Costa Rica's avifauna as a whole." The Monteverde zone is a unique region for birds. With six out of Costa Rica's 12 life zones represented in this area, there is great spatial heterogeneity, providing an assortment of habitats for many bird species (2). However, since Monteverde was first settled, forested areas have been modified for farmland, and as a result, some primary forest has either been destroyed or is regenerating from deforestation.

Although the most severe bouts of deforestation in the Monteverde zone have passed, forest fragments of various sizes and connectivity remain. Habitat modification in Monteverde and the surrounding areas for farmland or residential development affects birds in different ways; species resilient to disturbance will thrive, but more sensitive species may not do as well (2). Past studies have examined anthropomorphic influences on avifauna diversity in the temperate zone and how conversion to farmland affects avifauna composition in Southern Costa Rica (3, 4), but there have been few studies on how human activity affects bird community structure in Monteverde (2).

Over two weeks of independent study, I surveyed bird diversity at three sites of varying degrees of fragmentation to evaluate the impact of habitat fragmentation on birds in Monteverde. In my study, I define fragmentation to be the disruption of forest continuity due to human activity. The following questions were asked: 1. Is species richness higher at less fragmented sites? 2. What unique species can be found at each site? 3. Why are unique birds not present at the other sites?

MATERIALS AND METHODS

Study Sites

I chose three sites in the Monteverde region with low, intermediate, and high degrees of forest fragmentation. My first site, ~ 500 m into the forest behind the Instituto Monteverde (IMV), is the least fragmented site. At an elevation of ~1500 m, the forest is connected to a large patch of primary forest, including the Monteverde Preserve and the Children's Eternal Rain Forest, with a total protected area of more than 220 km2 (Asociación Conservacionista de Monteverde). The coordinates, which are approximated from the program Google Earth for these sites, are 10.3087° N, 84.8044° W. My second study site was in Bajo del Tigre, a small reserve that receives a lot of ecotourists, at ~1350 m. The property is a forested region of 0.48 km2 bordered by residences and somewhat patchy forest on one side and Río Guacimal on the other (5). I consider it to be an intermediate degree of fragmentation because the surrounding area is disturbed by human activity, but beyond the river, this region is connected to another large patch of forest. Specifically, my mist net site was near Sendero Murciélagos, on the lindero (property divide) between Bajo del Tigre and the Joyce property (10.3043° N, 84.8189° W). My third study site has the highest degree of fragmentation. I conducted my study on Finca Torres in Santa Elena, in a small patch of forest surrounded by pasture on three sides and the road to the Cloud Forest School on the other side (10.3213° N, 84.8206° W). The area of the remaining forest fragment is 7000 m2 (0.07 km2) according to Don Fermin Torres, and the elevation was ~1450 m.

Data Collection

I spent three days sampling at each site using mist nets, visual observation, and identification by vocalization. I surveyed for birds at the Instituto Monteverde on 13 May, 15 May, and 25 May 2008, at Bajo del Tigre from 17-19 May 2008, and at Finca Torres from 22-24 May 2008. At each site, I operated four mist nets from 5:00-11:00 for two days, and on the third day of sampling, I operated mist nets from 5:30-11:00. The total length of the nets was 38 m, and assuming that I surveyed birds on 25 m of either side of the net, I surveyed an area of 1900 m2 at each of my study sites. Overall, I spent 17.5 hours at each site for a total of 52.5 hours in the field. I sampled for 70 mist net-hours at each site for a total of 210 mist net-hours.

While mist netting, I listened and looked for birds from the location of the nets, using 10 x 50 binoculars, an iPod music player with 95 bird calls of the Monteverde area (without using playbacks), *The Birds of Costa Rica (6)*, and *A Guide to the Birds of Costa Rica* (1). I noted the species and number of birds I detected visually as well as those caught in the nets. Of the birds that I netted, I clipped one centimeter of the rightmost retrice feather to determine recaptures. I assumed that the birds I identified by sight were distinct individuals due to the low rate of visual detection and thus rela-

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Table 1: Bird species richness and abundance at the three study sites. The M column indicates the number of birds in mist nets, S = the number seen, and V = whether the bird was heard (presence or absence data).

			IMV			Bajo			Finca		
Family	**English Common Name**	**Scientific Name**	**M**	**S**	**V**	**M**	**S**	**V**	**M**	**S**	**V**
Cracidae	Gray-headed Chachalaca	*Ortalis cinereiceps*	-	-	-	-	3	N	-	-	-
	Black Guan	*Chamaepetes unicolor*	-	-	-	-	-	-	-	3	N
	Crested Guan	*Penelope purpurascens*	-	-	-	-	-	-	-	2	N
Odontophoridae	Black-breasted Wood-quail	*Odontophorus leucolaemus*	-	2	Y	-	2	N	-	-	-
Columbidae	Red-billed Pigeon	*Patagioenas flavirostris*	-	-	-	-	-	Y	-	-	Y
	Ruddy Pigeon	*Patagioenas subvinacea*	-	-	Y	-	1	Y	-	-	Y
	White-tipped Dove	*Leptotila verreauxi*	-	-	-	-	-	Y	-	-	Y
	Chiriqui Quail-Dove	*Geotrygon chiriquensis*	-	-	-	-	1	N	-	1	N
Trochilidae	Violet Sabrewing	*Campylopterus hemileucurus*	-	1	Y	1	-	Y	-	-	-
	Steely-vented Hummingbird	*Amazilia saucerrottei*	-	-	-	1	3	N	-	-	-
	Purple-throated Mountain-gem	*Lampornis calolaemus*	5	13	N	-	-	-	-	-	-
	Stripe-tailed Hummingbird	*Eupherusa eximia*	9	-	N	1	5	N	1	-	N
Momotidae	Blue-crowned Motmot	*Momotus momota*	-	-	Y	-	5	Y	-	-	Y
Ramphastidae	Emerald Toucanet	*Aulacorhynchus prasinus*	-	4	Y	-	4	Y	-	9	Y
	Keel-billed Toucan	*Ramphastos sulfuratus*	-	6	Y	-	2	Y	-	3	Y
Picidae	Hoffman's Woodpecker	*Melanerpes hoffmannii*	-	-	-	-	1	Y	-	-	Y
	Golden-olive Woodpecker	*Piculus rubiginosus*	-	-	-	-	1	N	-	-	-
Furnariidae	Ruddy Woodcreeper	*Dendrocincla fuliginosa*	1	-	N	1	1	N	-	-	-
	Olivaceous Woodcreeper	*Sittasomus griseicapillus*	-	3	N	-	-	-	-	-	-
	Gray-throated Leaftosser	*Sclerurus albigularis*	2	-	Y	-	-	-	-	-	-
Tyrannidae	White-throated Spadebill	*Platyrinchus mystaceus*	1	-	N	-	-	-	-	-	-
	Tufted Flycatcher	*Mitrephanes phaeocercus*	1	-	N	-	-	-	-	-	-
	Great Kiskadee	*Pitangus sulphuratus*	-	-	-	-	-	-	-	2	Y
Cotingidae	Three-wattled Bellbird	*Procnias tricarunculatus*	-	-	Y	-	-	Y	-	-	-
Pipridae	Long-tailed Manakin	*Chiroxiphia linearis*	10	-	Y	1	3	Y	-	2	Y
Corvidae	Brown Jay	*Cyanocorax affinis*	-	2	Y	-	3	Y	-	20	Y
Troglodytidae	Rufous-breasted Wren	*Thryothorus rutilus*	-	-	-	1	-	N	-	-	-
	Rufous-and-white Wren	*Thryothorus rufalbus*	-	-	Y	3	8	Y	2	1	Y
	Gray-breasted Wood-wren	*Henicorhina leucophrys*	-	-	-	-	-	Y	-	-	-
Turdidae	Orange-billed Nightingale-Thrush	*Catharus aurantiirostris*	-	-	Y	3	3	Y	1	-	Y
	Clay-colored Robin	*Turdus grayi*	-	-	-	-	4	Y	-	-	-
Parulidae	Slate-throated Redstart	*Myioborus miniatus*	-	-	-	-	-	-	-	1	Y
	Rufous-capped Warbler	*Basileuterus rufifrons*	-	-	-	-	-	-	1	-	Y
	Golden-crowned Warbler	*Basileuterus culicivorus*	3	2	Y	1	4	Y	1	13	Y
Emberizidae	White-eared Ground Sparrow	*Melozone leucotis*	-	-	-	-	18	N	-	-	-
Icteridae	Chestnut-headed Oropendula	*Psarocolius wagleri*	-	-	Y	-	-	Y	-	-	-

	Number of species in nets	**Number of species seen**	**Number of species heard**	**Number of species using all methods**
Instituto Monteverde	8	8	14	**20**
Bajo del Tigre	10	19	17	**26**
Finca Torres	5	11	15	**19**

Table 2: The number of species detected at each site by the three methods. The trend that Bajo del Tigre has the highest richness is consistent regardless of survey method. There is no significant difference in species richness between sites (Chi-squared = 1.32, df = 2, P-value = 0.52).

Site	H'
Instituto Monteverde	0.98292
Bajo del Tigre	1.14490
Finca Torres	0.89847

Table 3: The Shannon-Weiner diversity index (H') for the three study sites as calculated from mist net and sight data; I did not evaluate abundance by vocalizations to avoid double-counting. H' values are comparable in my study because of consistent sampling effort in all the sites. However, there are two important conditions of using this index that my limited study may not meet: (1) All the species present are detected (if they were not in nets or seen, they were not detected), and (2) The abundance of species detected reflects the actual abundance (canopy species are not as well-represented as understory species).

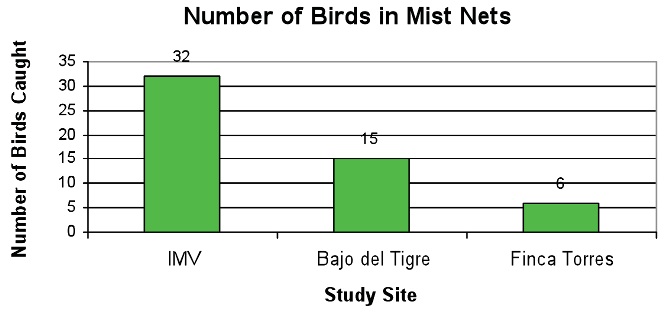

Figure 1: Number of individual birds caught in nets at the three sites. The difference between the sites is significant (Chi-square = 19.74, df = 2, P-value = 0.00005). Using this data as estimates of abundance, there are more birds at the Instituto, fewer at Bajo del Tigre, and even fewer at Finca Torres.

tively low probability of double counting. One exception is a Black Guan that I saw in Finca Torres for two days in the same tree, which I assumed to be the same individual. I used vocalization data to determine the absence/presence of a bird, but not to estimate abundance because of the high likelihood of overestimation when counting from the same spot for six hours (Rabenold, pers. comm.).

RESULTS

Over a period of nine sampling days, I observed 162 birds and caught 53 individuals in mist nets. Combining all the sampling methods, I detected a total of 36 bird species in 17 families (Table 1). There was great variation in the abundance of the species I found. For example, I saw 20 Brown Jays in Finca Torres but only one Chiriqui Quail-Dove. According to my results, the most abundant species were Brown Jays (n = 25), Golden-crowned Warblers (n = 24), and Purple-throated Mountain-gems (n = 18). In contrast, the following species were only detected once: White-throated Spadebill, Tufted Flycatcher, Golden-olive Woodpecker, Rufous-breasted Wren, and Gray-breasted Wood-wren.

With respect to the study sites, I detected 20 species at the Instituto Monteverde, 26 species at Bajo del Tigre, and 19 species at Finca Torres (Table 2, Figure 2). When I performed a Chi-square test on the species richness of the three sites, I found no significant difference between these values (Chi-square = 1.32, df = 2, P-value = 0.52).

In addition to species richness, I calculated the species evenness at the different sites using the Shannon-Weiner diversity index (Table 3). The Shannon-Weiner index of Bajo del Tigre is slightly higher than the other two sites, but a Chi-square test reveals no statistical significance (Chi-square = 0.03, df = 2, P-value = 0.98).

Mist net captures showed that the IMV had a higher abundance of birds than the other sites. The number of birds netted is inversely related to fragmentation (Figure 1). Since mist nets provide an unambiguous estimate of abundance, I extrapolated from these results and inferred that the abundance of birds, regardless of species richness, is the highest at the most continuous site. More intact forests support more birds.

Several species were common at the most continuous site but absent from the most fragmented site, and therefore may be more susceptible to habitat fragmentation: Three-Wattled Bellbird, Black-breasted Wood-quail, Purple-throated Mountain-gem, and Chestnut-headed Oropendula (Table 1). The toledo song of the Long-tailed Manakin was among the most commonly heard vocalizations at IMV and Bajo del Tigre, but I only saw two individuals at Finca Torres (Table 1). Other species showed the opposite trend and became more abundant with increasing fragmentation: Red-billed Pigeon, Hoffman's Woodpecker, Brown Jay, and Rufous-and-white Wren (Table 1).

An important finding is that all three study sites harbor unique species. I detected five species unique to the Instituto Monteverde, seven species unique to Bajo del Tigre, and five species unique to Finca Torres (Figure 2). There was also a set of ten species that were present at all the sample sites (Figure 2). Analyzing them by feeding guild may yield insight into why they are so ubiquitous (Figure 3). Indeed, the most prominent feeding guild for these species is om-

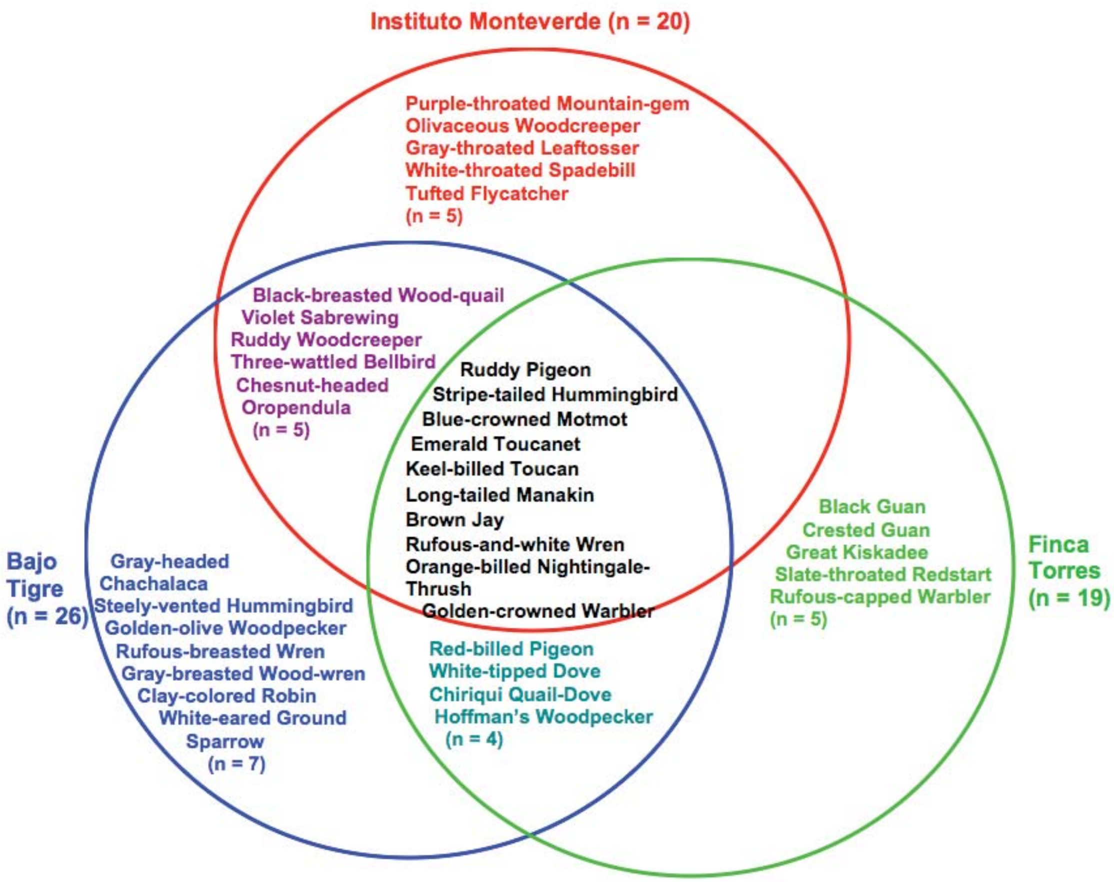

Figure 2: A Venn diagram showing the species unique to each site and the overlap between sites. Bajo del Tigre has species that overlap with the two other sites, but the Instituto Monteverde and Finca Torres do not have species that overlap except for those that are also found at Bajo del Tigre.

Sorenson similarity between the sites:
IMV and Bajo del Tigre: 65% similar
Bajo del Tigre and Finca Torres: 62% similar
Finca Torres and IMV: 44% similar

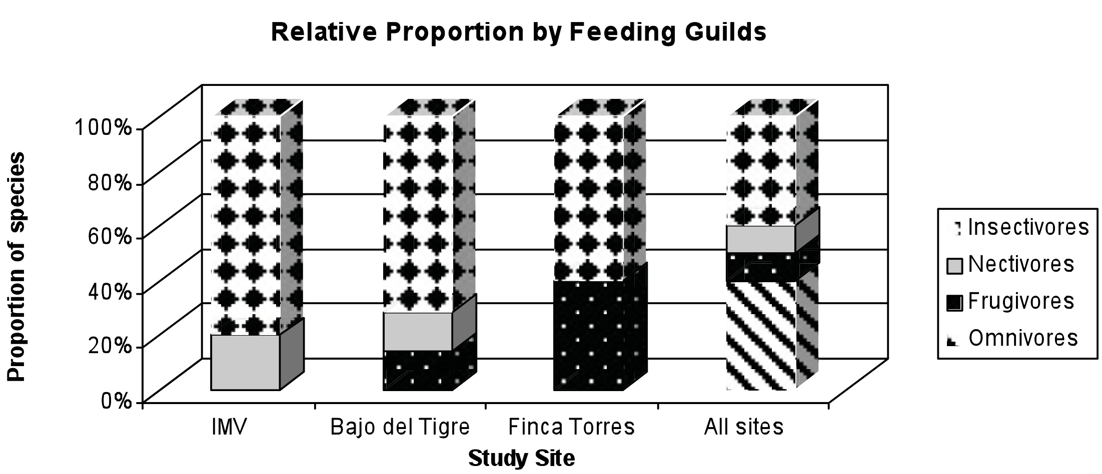

Figure 3: Shows the feeding guilds of the species unique to each site, as well as the ones ubiquitous to all the sites. A large proportion of the birds unique to IMV were insectivorous, and no omnivore was restricted to one site. The classes of feeding guilds were derived from a previous study on birds in rainforest fragments (Arriaga-Weiss *et al*. 2007), and classification into guilds was based on natural history information in the field guild by Stiles and Skutch.

nivores; birds like the Emerald Toucanet and Brown Jay can take advantage of a variety of food resources. Furthermore, no omnivore was confined only to one of my study sites.

DISCUSSION

Although I expected to see most number of species in the continuous forest, IMV, and fewer species at more fragmented sites, I found the highest richness at Bajo del Tigre, an area of intermediate fragmentation. The number of species detected does not follow the expected trend for several probable reasons. For one, species richness is not necessarily related to habitat fragmentation. Although a previous study found significantly fewer bird species in smaller fragments (7), another study found no effect of fragment size in Australia (8).

Life zones can also be a confounding factor in my study. Due to a lack of sites that both fit my fragmentation criteria and are practical to get to at 4:30 in the morning, as well as some difficulties in obtaining permission to mist net on private land, I was not able to survey three sites in the same life zone. One consequence is that variables that may be important to birds, such as temperature and rainfall, could be somewhat different between my study sites. The average temperature of 17-24 ˚C in the Premontane wet forest (Bajo del Tigre) is drastically higher than the average temperature of 12-17 ˚C in the Lower montane wet forest (IMV, 9). Finca Torres is in the transition gradient between the two lifezones. Previous research in Monteverde found that the Premontane wet forest has higher avifaunal richness the Lower montane wet forest (2). My data corroborate this finding since I found the most species in Bajo del Tigre. Furthermore, certain genera are only confined to one or two life zones and will not be present at an adjacent site regardless of fragment size (2). Such species include the Slate-throated Redstart (*Myioborus miniatus*) and Rufous-capped Warbler (*Basileuterus rufifrons)*, both of which were unique to one site in my study, Finca Torres.

Finding the more fragmented Finca Torres to harbor almost as many species (n = 19) as the Instituto Monteverde (n = 20) was not expected, there are potential explanations for this result. In the Finca forest patch, there was a large tree of the Lauraceae, or avocado, family with abundant fruits, a Moracea tree (of the fig family), and two other trees with white fruit where I saw birds foraging everyday of my study. Lack of suitable habitat nearby can also confine birds to this small patch of forest.

In addition to species richness, I found that IMV and Finca Torres were similar in terms of Shannon-Weiner heterogeneity, and Bajo del Tigre was slightly more heterogenous (Table 3). This could be because at Bajo, I was detecting more birds from different species, whereas at IMV, where the mist nets were set up seemed to be in particularly good locations for hummingbirds and manakins, so these birds were detected more frequently. Perhaps it was near flowers that the hummingbirds liked, or lek sites for manakins. This repeated detection of certain species lowers the value of the diversity index, because instead of sampling new species, new individuals were from already detected species.

I found the overall abundance of birds to be negatively correlated with habitat fragmentation (Figure 1). This makes sense because continuous forest has a larger area, and therefore more resources for birds to use. Continuous forests are essential in conservation because they support more individual birds than fragmented patches.

In my study, some species seem to be more susceptible to habitat fragmentation than others. One example is the Long-tailed Manakin, which has flagship importance in the Monteverde area and a male cooperative mating system that is unique in the world. Other species showed the opposite trend and became more abundant with increasing fragmentation. Species like Brown Jays and Emerald Toucanets, which do well in more fragmented areas, are identified as important egg predators (1, 10), so they can have devastating impacts on sensitive species as forest habitat becomes altered for human activity and they become more abundant.

Most of the species unique to the IMV are insectivorous flycatchers (Figure 3), suggesting this guild is more successful foraging in a continuous forest. This trend may be related to arthropod abundance; as student researcher Derek Mead found out in his project, there were more butterflies in primary forests than regenerating forest (Derek Mead, pers. comm.). A previous study supplements this finding and shows that insectivores are the more prone to disturbance than birds from other feeding guilds (11), and this may be related to arthropod decline in disturbed areas. To establish this effect, it would be interesting to study how arthropod abundance is related to forest fragmentation. Since these flycatchers were not detected at any of my other two sites, the IMV forest has conservational importance for them.

Five species were unique to Finca Torres, including the Black Guan, Crested Guan, Great Kiskadee, Slate-throated Redstart, and Rufous-capped Warbler. The guans, which are frugivores, generally prefer the forest interior (1), so I was not expecting to see them in such a tiny patch of forest. However, as previously mentioned, there were Lauraceae trees abundant with aguacatillos (small avocados), Moraceae trees with fig fruit, and two other trees with white fruit where I saw guans, Brown Jays, Emerald Toucanets, and Keel-billed Toucans forage on several days. The other two sites did not have such prominent fruiting trees, which most likely played a major role in attracting such birds. This finding is also corroborated by another study in Costa Rican countryside, which found that 26% of all species in agricultural habitats are forest species (4). Thus, even forest interior species may come to agricultural or fragmented habitats to use food resources (2, 4).

A large proportion of species ubiquitous to all the sites are omnivores, presumably because they can take advantage of a variety of food resources. According to my data, no omnivore was restricted to only one study site, which may signify that they are less sensitive to habitat fragmentation. On the other hand, insectivores, frugivores, and nectivores cannot exploit the same range of resources as omnivores, and insectivores in particular seem to be very sensitive to deforestation. The feeding habits of a bird species may give important insight in conservation of that species.

Overall, I found heterogeneity in community composition so that even in close proximity, different sets of species are found at different locations. According to my study, all three types of habitats that I surveyed are required for the continued survival of the 36 species I found. No one site can be eliminated without affecting at least five bird species. Furthermore, since the species unique to each site are from different feeding guilds, it suggests that food availability is an important determinant of where a species dwells. Although fragmentation wasn't directly related to species richness in my study, fragmentation impacts birds in other ways. For example, another study found that local extinctions are more common in smaller than larger fragments (12). Population dynamics in smaller fragments could also be less stable and have higher levels of colonization (13). In addition to studying arthropod abundance, future studies could investigate extinction rates or community dynamics in fragments to determine if similar patterns are found in Monteverde.

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