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Avian diversity across three distinct agricultural landscapes in Guadalupe, Chiriquí Highlands, Panama

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ABSTRACT

La deforestación de los bosques tropicales para fines agrícolas amenaza la pérdida de hábitat de las especies nativas. El valor de los diversos paisajes agrícolas en la conservación de las poblaciones de aves es útil para determinar los planes de desarrollo de diversidad consciente. Sin embargo, los resultados generalizados de los estudios a escala regional no se pueden aplicar a los hábitats de aves insulares. Este estudio sirve como el único estudio de la diversidad aviar actual de las tierras altas de Chiriquí. Para determinar el efecto del uso de la tierra agrícola dentro de un hábitat aviar insular, comparé aviar diversidad y sitio similitud población en Guadalupe, Chiriquí tierras altas de la Cordillera de Talamanca, Panamá. Punto-cuenta fijas estándar se utilizaron en tres sitios: borde bosque contiguo, tierra cultivada con cubierta arbustiva mínima, y los corredores de los bosques. En total, 734 aves, se registraron 44 especies, y 21 especies endémicas. La diversidad de aves fue mayor en el borde del bosque seguido por corredor forestal y de pastos, respectivamente. Muchas especies endémicas y amenazadas se registraron en mayor frecuencia en los hábitats de borde. Mientras que los sitios tanto de pastoreo y los corredores apoyaron casi la misma cantidad de especies endémicas, corredor forestal sostenida en la riqueza específica. Este estudio sugiere que los propietarios de Finca en Guadalupe deben maximizar el borde del bosque y las limitaciones de propiedad atados con corredores forestales. Este estudio pone de manifiesto la necesidad de un estudio más amplio de las poblaciones de aves y paisajes Guadalupian (Google Translate).

Deforestation of tropical forest for agricultural purposes threatens habitat loss of native species. The value of various agricultural landscapes in conserving avian populations is useful in determining diversity-conscious development plans. However, generalized results from regional-scale studies cannot be implemented to insular avian habitats. This study serves as the only current avian diversity study of the Chiriquí Highlands. To determine the effect of agricultural land use within an insular avian habitat, I compared avian diversity and site population similarity in Guadalupe, Chiriquí Highlands of the Talamanca Range, Panama. I hypothesized that avian diversity is greatest at forest edge followed by forest corridor and pasture sites. Standard fixed point-counts were used across three sites: contiguous forest edge, cultivated land with minimal shrubby cover, and forest corridor. In total 734 birds, 44 species, and 21 endemic species were recorded. Avian diversity was greatest at the forest edge followed by forest corridor and pasture, respectively. Many endemic and threatened species were recorded at the highest frequency at edge habitats. While both pasture and corridor sites supported nearly equal amounts of endemic species, forest corridor sustained higher species richness. This study suggests that Finca (small farm) owners within Guadalupe should maximize forest edge and bound property limitations with forest corridors. This study reveals the need for more extensive study of Guadalupian bird populations and landscapes.

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INTRODUCTION

Panama has one of the highest avian diversities of any Central American country, providing habitat for 978 species. This avian diversity is due to Panama's location at the intersection of the Pacific Ocean and Caribbean Sea and as the bridge of the Americas. Equally important to the avian diversity in Panama is the widely varying topography and insular habitat diversity, allowing for species specialization (Angehr and Dean, 2013). As Panama further develops, urban and agricultural encroachment is increasingly common in rural parts. Panama's natural areas are exploited for their economic value, and wildlife is typically the externality of these processes (Howard Ernst, Personal communication).

The western highlands of Panama exhibit especially diversified habitats as a result of its topography and insular biogeography. Consequentially, Guadalupe of Chiriquí is considered to harbor one of the highest concentrations of mammal and avian endemic species in the world (Shapiro 2001; Angehr and Dodge 2006). Albeit the vast amount of forest felled and converted for agricultural purposes, habitat loss is not the only major threat to resident avian populations. Habitat fragmentation, invasive species, and subsequent species interactions are also afflicting avian populations in Panama.

As an area that holds one of the world's highest concentrations of endemic and sensitive species, Guadalupe, Chiriquí is intrinsically valuable. Complicating the matter, Guadalupe represents an intersection between the food securities of a developing nation, lucrative business, ecotourism, and intrinsic value. The greater Cerro Punta area supplies over 80% of the vegetables for the country of Panama, hence it is a hub of agrochemical usage. In order to produce a greater profit, farm owners invest in agrochemicals which typically yield more product the following year. Agrochemical usage to attain higher yields ironically strips the soil of its fertility over time; thus the farmer needs to invest in greater amounts of agrochemicals each year to sustain production. Consequently increasing amounts agrochemicals are being spread over the Guadalupian landscape without a biological watch. Furthermore, once the land is drained of its fertility additional land can be utilized due to old claims, squatter's rights, and weak park enforcement: the process begins once more. Encroaching deforestation also removes vital habitat for endemic and sensitive species. Bird diversity observation needs to be completed in an area with such pre-mentioned practices. Despite the use of such practices there is precisely no literature present about the impacts of Guadalupian agriculture on avian populations.

Many regional-scale studies delineate the impact of various agricultural landscapes on avian populations (Galli et al. 1976; Estrada at el. 1995; Blair 1996; Turner 1996; Harvey et al. 2000; Rodewald and Yahner 2001; Luck and Daily 2003; Petit and Petit 2003; Harvey et al. 2006; Schroth and Harvey 2007; Van Bael et al. 2007; Mendenhall et al. 2013, Mendoza et al. 2014). One basic trend is present in nearly all of these studies: along a disturbance gradient, generalist species tend to exploit more disturbed areas while sensitive species thrive on stability. Despite this generalized finding, a need for a situational analysis of each also arises. Some studies focus on semi-regional biodiversity in relation to agroforestry conservation techniques (Turner 1996; Connelly and Shapiro 2006; Harvey et al. 2006; Van Bael et al. 2007), but nearly none have a Chiriquí Highlands scope, let-alone Guadalupe. In addition, these studies do not describe insular avian habitats and endemic populations found in Guadalupe.

This study estimates how avian diversity changes across three distinct agricultural landscapes in Guadalupe. Using avian diversity and similarity of species across agricultural landscapes, suggestions for avian diversity conservation can be made. Suggestion of agro-conservation techniques will be more effective the policy and park management critiques. This study will potentially lay the groundwork for future studies about the effects of deforestation and agriculture on avian populations within the Talamanca Range, Chiriquí Highlands. In a more basic sense, this study will begin long-term avian observation in Guadalupe, Chiriquí.

LITERATURE REVIEW

Location, Geology, and Ecology

The western highlands of Panama exhibit especially diversified habitats that are due to topography and equatorial proximity. Located on the Pacific drainage of the Central Cordillera, Guadalupe in nestled within a valley at nearly 2100 meters (Jones 2006). Most of Parque Internacional La Amistad (PILA) and Volcan Barú are part of the Talamanca montane forest ecoregion, containing six of the twelve Holdridge life zones within Panama (Jones 2006). Guadalupe sits atop the country and is the most agriculturally productive region in Panama. Guadalupe also exhibits many different microclimates, unique from the rest of the country. The Talamanca Range is absent of any active volcanoes and erosion rates are much greater than those of accretion. Over the quaternary period the Central Cordillera has lost elevation due to erosion, and currently each valley exhibits a vastly different microclimate than its respective mountain summit. Consequently this constantly changing and diverse topography has affected numerous species. Many cannot breed in those valleys as they represent poor habitat compared to mountain slopes. Nor can these species successfully colonize suitable habitats far distances away. Currently, the Central Cordillera has sunk significantly enough to isolate the Talamanca Range as an insular biogeographic habitat region. The species that once flourished at high altitudes throughout the Central Cordillera are now constrained by elevation ranges within the Talamanca Range (Whittaker 1960; Vuilleumier 1970; Simpson 1974). They are unable to breed within the unsuitable surrounding matrix of habitat, nor colonize distant favorable habitats (unesco.org). Due to this unique topography and climate variation, Guadalupe of Chiriquí is considered to harbor one of the highest concentrations of endemic species in the world (Angehr et al. 2006).

Along with being located within the buffer zone of PILA, Guadalupe also shares borders with Parque Nacional Volcan Barú and PILA. PILA was designated a biological reserve by UNESCO in 1982 (Chaverri & Herrera, 2003; Connelly and Shapiro, 2006). There are approximately 38 endemic species present within PILA and Volcan Barú such as the Harpy Eagle, Scintillant and Volcano Hummingbirds, Flame-throated Warbler, White-throated Mountain-gem, Black-faced Solitaire (Angher and Dean 2006; Jones 2006). This count does not include sensitive or highly evolved species, nor species of great importance within the region. Certain birds such as the Resplendent Quetzal also hold great cultural importance to many Mesoamerican cultures. The Mesoamerican biodiversity hotspot encompasses PILA and Volcan Barú, and is ranked as the second most bio-diverse region in the world including avian species (Shapiro 2001; Reid and Hanily 2003).

Threats to Biodiversity

Deforestation in the tropics is steady and increasing, and contributes to global climate change patterns (Wassenaer et al. 2007; Scanlon et al. 2007; Downing et al. 1999). Small stake holders such as cocoa, cattle, and vegetable farmers suspected to causing the greatest threat to conservation of the Buffer zone of PILA, and seem to threaten nearby marine and terrestrial diversity as well (Mehta & Leushner, 1997; Finisdore, 2002; Connelly and Shapiro, 2006). Deforestation is mainly attributed to agricultural deforestation, and proliferates due to weak governmental organization (Forrestal and Pael, 2006). Deforestation of agricultural lands is catalyzed by the presence of roads and is significantly greater than in areas without road access (Forrestal and Pael, 2006; Jones 2006). Recent accelerated deforestation correlates with increasing permanent and seasonal populations (Forrestal and Pael, 2006).

Habitat loss and fragmentation also act as a gateway for other impending threats to avian populations. Small and Hunter (1988) and King et al. (1997) also describe how forest fragmentations and clear cuts favor brood parasitism and generalist species. Deep-forest species tend to be less abundant at edges – not because of active edge avoidance, but due to the absence of a true habitat. Low species diversity may even provide higher chances of general disease (Ostfeld and Keesing 2012HANTA). In these cases, habitat loss and fragmentation act as both physical and biological threats. Albeit the vast amount of forest felled every day, habitat loss is not the only major threat to resident Panamanian birds. Habitat fragmentation is also threatening avian populations in Panama. Nearby cases have already been documented, such as the Volcan Barú wilderness road. Already surrounded by three roads, Volcan Barú National Park is threatened by a final fourth road that bridges the wilderness from Cerro Punta to Boquete (Reid and Hanily 2003; Jones 2006). It was concluded that the construction of the road would not fulfill its purpose of boosting the economy, and almost certainly cause significant ecological damage. In addition to ecological damage, it was concluded that the road would incur debt on the Panamanian Government (Reid and Hanily 2003). The government would falter on its commitment to sustainable growth and development within Chiriquí with the construction of the ecological road (Jones, 2006).

Agricultural Landscapes and Biological Consequence

Many studies have been completed about biodiversity over an environmental gradient (Formann et al. 1976; Galli et al. 1976; Blair 1996; Van Bael et al. 2007; Mendenhall et al. 2013, Mendoza et al. 2014). In general these studies highlight the detriment of anthropogenic influence on natural areas. Mendenhall (2013) studied island biogeography of bat species between the Costa Rican countryside and a habitat island in Panama. Findings confirmed the bat species diversity was lower on the habitat island, as species richness was greater within the Costa Rican country side. Agricultural landscapes anywhere describe this context well. As larger tracts of lands are deforested for agriculture and roads bisect natural areas, habitat 'islands' are created. The habitat islands are left without the defense of species flow against stochastic extinction events. Thus lower species richness and evenness are found on habitat 'islands'. There are few counter arguments to habitat fragmentation.

It cannot be refuted that the agriculturally sculpted landscape benefits some species by providing intermediate disturbance. In this sense, applications of island biogeography and intermediate disturbance may be overextending into the realm of conservation biology (Laurance 2008). Man-made landscapes often allows intermediate levels of both r- and k-selected species, also know as pioneer and late successional species. This allows for exceptionally high biodiversity in disturbed areas (Mendenhall et al., 2013). The theory of intermediate disturbance serves as a basic explanation. The ecologically beneficial argument would describe that anthropogenic expansion actually creates habitat for certain species. As contiguous habitat is fragmented into habitat islands, MacArthur and Wilson's Theory of Island Biogeography can be applied to explain consequent wildlife fluctuations (MacArthur and Wilson 1967). The theory has broad applications in current ecology, not only to true islands but also to man-made islands and areas of low habitat suitability. Mendoza et al. (2014) explored avian island biogeography exhibited throughout the agricultural countryside of Costa Rica and Panama. Despite findings that avian diversity is expectedly lower in areas cleared of native forest, it was actually higher in forest fragments. True islands exhibit lower biodiversity than contiguous habitat, which is even lower than man-made islands surrounded by low quality matrix. Complex agricultural landscapes such as Cocao exhibited high avian diversity and therefore may be of higher value in conservation strategies (Greenberg, R. 1998; Van Bael et al. 2007; Mendoza et al. 2014). By sampling the avian diversity of various agricultural landscapes, avian population importance values were attributed to land use practices. Tree cover and complexity typically holds higher diversity when compared to pastures and cleared areas (Van Bael et al. 2006; Mendenhall et al. 2013; Mendoza et al. 2014).

Further evidence and suggestions of sustainable agricultural management practices are suggested by Shah (2006). Agrochemical overuse in the Cerro Punta watershed is described by Shah, and is found to be unsustainable within the near future. Human environment interactions tend to be interdisciplinary and in order to maintain a healthy environment, a healthy relationship needs to be maintained.

RESEARCH QUESTION

How does avian diversity vary across three distinct agricultural landscapes within Guadalupe, Chiriquí Highlands, Panama?

METHODS AND MATERIALS

Study Sites

The study sites consisted of three distinct agricultural land uses located within Finca Santamaria (Figure 1). The land was once cleared for agriculture (6-8 hectares), but has assumed extensive regrowth. The remainder of the forest is a large tract of primary growth contiguous forest (Genover Santamaria personal communication, Figure 1). The contiguous forest edge can be seen at the edge at the top of Figure 1, bordered Volcan Barú National Park and is adjacent to PILA. The forest corridor is present within Figure 1, marking the boundary between Finca Santamaria and a neighboring finca. The forest corridor also represented the border with PILA, adjacent and just below the border of Volcan Barú.

Figure 1. Finca Santamaria. Notice the forest corridor, pasture sites, and the forest edge along the top of the photograph

The pasture and cultivated land site purposes with strew shrubby growth (Figure 2). Figure 1 may also be reference for the size and orientation of the pasture site. Currently six hectares of land have been cleared and are being used for agriculture. The land use is rotated to increase sustainability and soil health (Genover Santamaria, Personal Communication). During the current season, onions, celery, and potatoes are being grown on Finca Santamaria, possibly attracting a different crowd of avian species. Natural Hummingbird bushes and other vegetation is strewn throughout the pasture site. The majority of the shrubby growth is located along paths and trails within the pasture site, acting as a transect for my point-counts.

Figure 2. Middle Site, cleared land for agriculture with strewn bushes

The forest corridor site consisted of a mainly secondary growth forest corridor between two parcels of agricultural land, and connects the forest edge to the riparian zone of Rio Chiriquí Viejo (Figure 3). The forest corridor may also be seen in Figure 1, as the boundary between Finca Santamaria and a neighboring finca. The road connecting Finca Santamaria to Guadalupe was used as a transect line for the study. Rarely traveled, the road served well as a transect line for point-counts. Higher in elevation, the forest corridor connected to PILA and Volcan Barú. On the lower end, the forest corridor connected to a riparian strip surrounding Rio Chiriquí Viejo. The forest corridor was approximately 75 meters wide at its narrowest width.

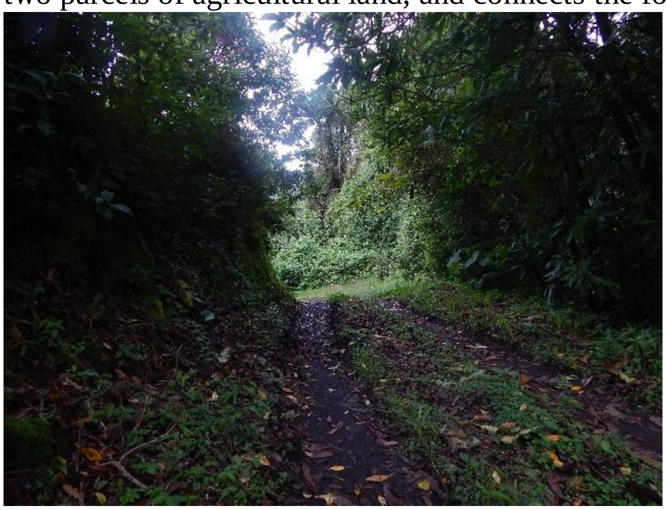

Figure 3. Lower Site, forest corridor between two parcels of agricultural land, connecting to lower riparian strip

The forest edge site is pictured in Figure 4, as the border between Finca Santamaria and Volcan Barú. Figure 1 shows the forest edge in entirety. The road that skirted the forest edge was used as the transect for point counts, ending slightly inside the cloud forest. The forest is mainly primary growth with mixed secondary growth along the edges.

Figure 4. Edge of contiguous forest. Border of Parque Volcan Barú and Parque Internacional La Amistad

The study sites were purposely located in close proximity to reduce environmental variables. Instead of adopting a linear transect, transect orientation of the pasture site was chosen to optimize coverage of the study site. While area optimization was important, point counts were be spread far enough to avoid pseudo-replication of data. The three study sites were rotated randomly but equally, in reference to time of observation. The alternation of study sites each day reduced stochastic weather patterns, and sustained more robust data.

As with any avian diversity study, there is the possibility of pseudo-replication or double counting birds within each point-count. Although each count was ten minutes, the point-counts were spaced far enough apart to avoid overlap of foraging and conspicuous birds. In addition, a large source of error could be the inflated counts of conspicuous species in relation to inconspicuous species.

Methods

With suggestions from a local guide, data collection began on November 11th using point counts along transect (Emlen 1971; Petit et al. 1994; Sutherland 2004; Van Bael et al. 2007). Data was collected from 6:30 AM – 10:30 AM, the optimal time for bird observations in the Chiriquí Highlands. The first study site was observed from 6:45 AM – 8:15 AM and the second from 8:30 AM – 10:00 AM. There were seven point counts per transect, one transect per study site. For each point count, three minutes was allowed for travel, two minutes for bird adjustment, and ten minutes for observations, totaling 15 minutes per point count. Each point count was located approximately 75 meters apart, creating transects about 500 meters long. Species and species count were recorded by audial and visual observation within a 25 meter band. A 25 meter radius was used in order to increase data resolution, despite small sample size. The narrow radius also aided in mitigating pseudo-replication of conspicuous, moving species. Each site totaled n = 8 and 9.3 sampling hours. Total study sample size n = 24, and will total 27.9 sampling hours.

Statistical Analysis

Shannon-Weiner Biodiversity, species richness and evenness, and similarity indices were used to analyze data (Petite et al. 1994; Blair 1996; Mendoza et al. 2014). Differences in diversity were tested by ANOVA and standard error overlap. The Sorenson CC similarity index was used to describe the similarity of the three sites (Jongman et al. 1996). Although the Sorenson index is typically used for ecological studies implementing quadrat data collection methods, point-counts were substituted as a similar alternative. The Sorenson Index also judges site similarity on species presence rather than abundance estimates, absent from this study.

RESULTS

Using fixed point counts I recorded a total of 734 birds, including 44 different species. Of those 44 species, 19 were endemic to the Talamanca range and another two are considered resident races (Angehr and Dean 2007, Table 1). Out of 44 species, 5, 3, and 6 species were restricted to forest corridor, pasture and forest edge, while the rest were common species among two or three sites (Table 1).

The three sites had significantly different avian diversity and the forest edge retained greatest species diversity and evenness, followed by the forest corridor and pasture site (Table 1). At the forest edge, forest corridor and pasture retained 18, 14, and 15 endemic species respectively. Forest edge and corridor populations were observed to be composed of nearly 60% endemic species, while the pasture site is only 17% (Table 2). Observed endemic species and site presence is given in Table 3. Forest edge holds most endemic species, forest corridor and pasture hold lower and nearly equal numbers. Each site was relatively distinct from one another, only preserving one-half of total species in site comparisons (Table 4).

Graphically, all sites exhibited right skewed population distributions. Forest edge holds a relatively even population distribution compared to the pasture site (Figure 5).

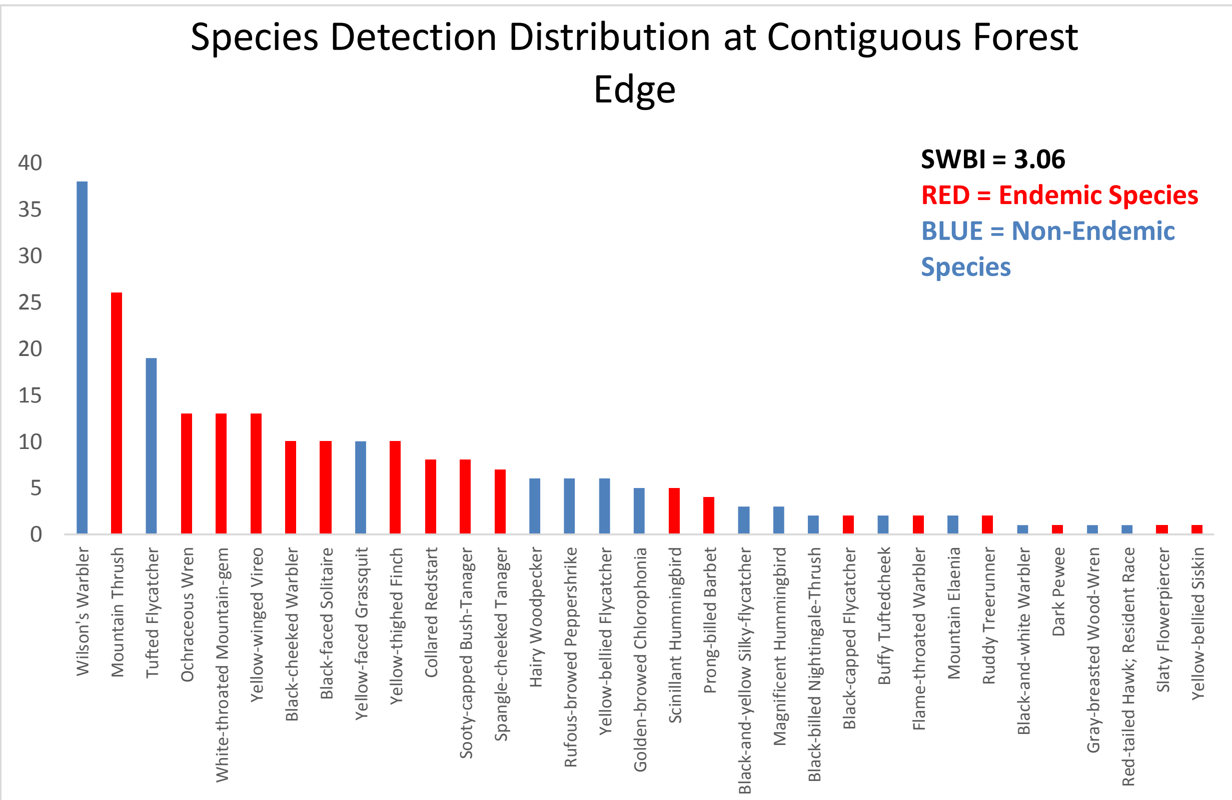

Figure 4. The forest edge retains high avian diversity and percentage of endemic species.

Forest corridor also retains even population distribution when compared to the pasture site (Figures 6,7).

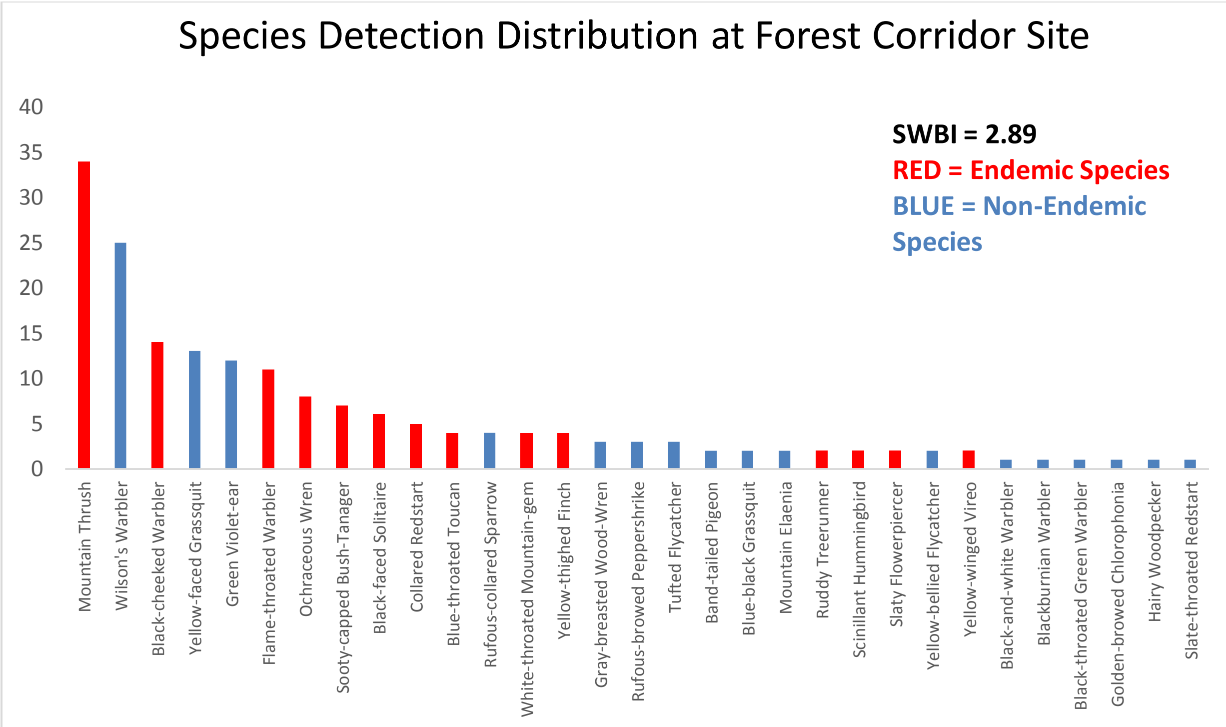

Figure 5. The forest corridor retains similar diversity to forest edge, but has less evenly distributed populations.

The population distribution of the pasture site is heavily right-skewed (Figure 7). Forest edge and corridor also hold a ten endemic species within the 15 most recorded species, while pasture holds eight (Figures 5,6,7).

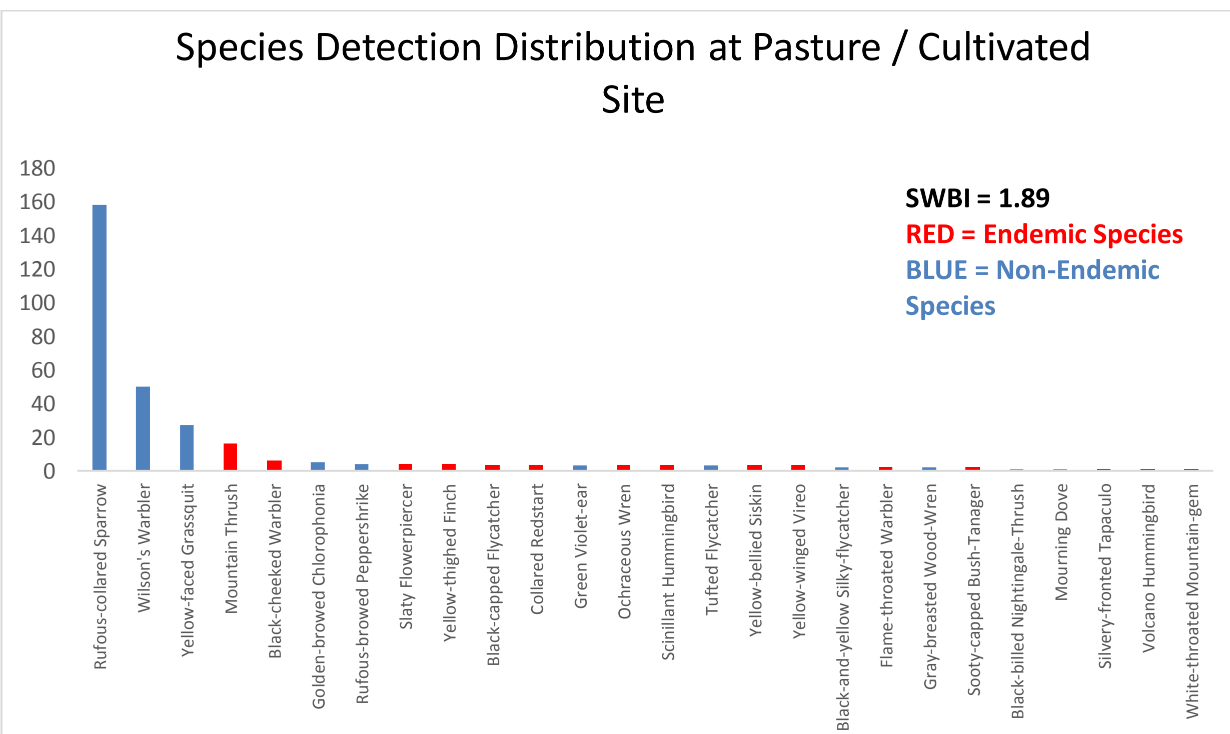

Figure 6. Pasture data is heavily right-skewed, and has little species evenness.

The pasture site poorly preserves avian species evenness and exhibits less endemic species than the forest edge.

DISCUSSION

Results and Disturbance

This study cannot explain avian diversity trends observed on a provincial, regional, or municipal scale. Due to the study's extremely restricted scale, it can describe avian diversity trends over the scale of a single finca accurately. Avian diversity on a finca with a northerly aspect in Guadalupe will have significantly different avian diversities across forest edge, forest corridors, and pasture sites. Since there is no recent literature pertaining to avian diversity in the Chiriquí Highlands, this study can be considered the inaugural study on which others can build and reference. In a more general sense, these results agree with recent studies pertaining to avian diversity elsewhere in Panama. These results along with others can be explained by the intermediate disturbance hypothesis, in which sites with an intermediate amount of disturbance typically have higher biodiversity (Galli et al. 1976; Estrada at el. 1995; Blair 1996; Turner 1996; Harvey et al. 2000; Rodewald and Yahner 2001; Luck and Daily 2003; Petit and Petit 2003; Harvey et al. 2006; Schroth and Harvey 2007; Van Bael et al. 2007; Mendenhall et al. 2013, Mendoza et al. 2014). Generally speaking, avian diversity tends to be highest where habitat edges or ecotones occur (Robbins 1989; Villard 1998), which my results also support.

Within Finca Santamaria, all sites have minimal to heavy disturbance. However according to the species richness, evenness and Shannon-Weiner Biodiversity (Table 1 and Figures 5,6,7), forest edge is the healthiest system, followed by forest corridor and pasture. Assuming the pasture site has undergone the heaviest disturbance, this coincides with its relatively low avian diversity. This deduction fits well as many common agricultural procedures are damaging and disturbing. Both the forest edge and corridor exhibited much higher diversity, indicating that the disturbance levels were lesser than that of the pasture site. Among the two forest sites, it is likely that the forest edge experiences intermediate disturbance with the highest avian diversity. The forest corridor likely experienced more disturbance than the forest edge, but less than the pasture site evidenced by its diversity. Despite sustaining low relative diversity, the pasture site holds a high species richness and relatively high numbers of endemic species. This may be attributed to a source and sink environment within the study sites (Clergeau et al. 2001). The forest edge and corridor may act as a source for bird diversity, while the pasture acts as a sink habitat. The sink habitat may explain surprisingly high levels of diversity and endemic species while providing low quality habitat.

It has been recognized that certain avian species prefer forests of different age, disturbance, and species composition (Villard 1998). As a general observation, among the 978 species recorded in Panama, there are a great amount of niches filled by these species (Angehr and Dean, 2013). These niche environments can result from mudslides, earthquakes, and tree falls, but can also result from anthropogenic interaction. Within PILA and Volcan Barú, many species thrive on the edge habitats created by human disturbance. Many of these species are endemic and endangered such as the Volcano Hummingbird, White-throated Mountain-gem, Scintillant Hummingbird, Yellow-thighed Finch, Sooty-capped Bush-Tanager, Collared Redstart, Wrenthrush, and Yellow-bellied Siskin. In this sense human interaction can be beneficial to the conservation of certain species, building on the findings of Mendenhall et al.

(2013) and Mendoza et al. (2014). Yet other species suffer reproductive failure and brood nest parasitism when within an edge habitat (Robinson et al. 2000; Davies 2011). Certain species may reproduce more effectively in areas with intermediate disturbance, while others thrive in an undisturbed, natural environment. Hence these results fit into a matrix of intermediate disturbance and conflicting evidence of avian conservation.

Management Suggestions

Management and agro-conservation suggestions can be implemented with these data. As previously stated, Cerro Punta serves as an intersection of interests in current Panama. Livelihoods, food security, and protection rights of national and international parks complicate land management options. While agricultural lands are necessary, a balanced management plan between these competing interests will hopefully help initiate a sustainable agricultural environment. Considering the context of residency and subsistence farming within the PILA buffer zone, the preservation of land use practices is expected. Slight changes in agro-conservation techniques are likely to yield more efficient and feasible results. The least feasible but seemingly easiest suggestion is to let the land recover the landscape within the PILA buffer zone. This suggestion is unfeasible for many reasons, including the livelihood of the Guadalupian and Cerro Puntian communities. Recovered secondary forest would allow many endemic species to ensure population stability (Table 3). This management would also produce a counter effect: the Scintillant Hummingbird, Volcano Hummingbird, White-throated Mountain-gem, Yellow-thighed Finch listed in Table 3 are endangered, but prefer forest clearings and edge habitats. Therefore, allowing a reforestation of the land used for agriculture would likely harm these species. For economic and environmental reasons, this option is not the best. Following this deduction, drastic management suggestions should be avoided due to unknown population consequences.

As the results suggested, forest edge and corridor sustain higher avian diversity than pasture and would be beneficial in agro-conservation techniques. Both of these landscapes should be utilized for species retention. It is recommended that a specialized observation of finca structure and location should be completed before implementing conservation techniques. Specialized observation will allow for prioritization of lands and increased effectiveness of agro-conservation techniques. Forest edge should be prioritized in the management of fincas, maximizing the interface between forest and pasture. This can easily be done by cutting and burning portions into the forest edge, which increases interface area while also creating more land for cultivation. While the pasture site maintained nearly as many endemic species as the forest corridor, the retention of corridors should be favored due to its species richness. Forest corridors should still be retained to allow species flow between fincas, and from highland to lowland. Corridors can be implemented as boundary lines between fincas and a buffer between organic farms and conventional.

CONCLUSION

This study was not unique among numerous recent studies of avian diversity across landscapes. However, the absence of previous literature in the Chiriquí Highlands gave this study novel standing. This study accomplished its objective of determining the difference of avian diversity across three distinct agricultural landscapes. Small scale limited and confined the results as well as the significance of this study. Limitations in hand, the study defined the avian diversity well as described by significant differences between each of the sites. Results confirmed the hypothesis, that avian diversity is greatest at forest edge followed by forest corridor and pasture sites. It is likely that the diversity between the three sites was due to varying levels of disturbance, and that the forested sites acted as a species source for the pasture site. In the midst of encroaching anthropogenic influence, Guadalupian fincas should preserve forest edge and forest corridors to maintain sensitive and endemic avian populations. These results should not be generalized to the Chiriquí Highlands, but may have narrow significance in the Cerro Punta area. Further studies describing avian diversity across additional landscapes is recommended, as this study stands alone. Future studies should build on previous results, but discuss avian diversity within the context of Guadalupe and its insular habitats.

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APPENDIX

Table 1 Avian population characteristics at sites observed with fixed Point-counts.

Site Characteristics*	Contiguous Forest Edge	Forest Corridor	Pasture / Cultivated Site
SW BDI** (SE)	3.05 (0.011)	2.90 (0.012)	1.89 (0.017)
Species Evenness	131.81	122.68	115.1
Species Richness	33	30	27
Birds Observed (% Total)	241 (32.8%)	182 (24.8%)	311 (42.4%)

* All site characteristics observed were gathered from Point-count data

** SW BDI stands for Shannon-Weiner Biodiversity Index, and is used for site comparison only

Table 2 Relative proportion of endemic and other species observed at each site

Relative Frequency	Contiguous Forest Edge	Forest Corridor	Pasture / Cultivated Site
Endemic (%)	137 (56.8%)	105 (57.7%)	54 (17.4%)
Others (%)	104 (43.2%)	77 (42.3%)	257 (82.6%)
Total	241	182	311

Table 3 Endemic species observed at the three study sites

Species, Common Name	Forest Edge	Forest Corridor	Pasture	Threatened
Empidonax atriceps Black-capped Flycatcher	Y	N	Y	†
Basileuterus melanogenys Black-cheeked Warbler	Y	Y	Y	†
Myadestes melanops Black-faced Solitaire	Y	Y	N	†
Aulacorhynchus caeruleogularis Blue-throated Toucanet	N	Y	N	NA
Myioborus torquatus Collared Redstart	Y	Y	Y	†
Contopus lugubris Dark Pewee	Y	N	N	†
Parula gutturalis Flame-throated Warbler	Y	Y	Y	†
Turdus plebejus Mountain Thrush*	Y	Y	Y	NA
Troglodytes ochraceus Ochraceous Wren	Y	Y	Y	†
Semnornis frantzii Prong-billed Barbet	Y	N	N	†
Buteo jamaicensis Red-tailed Hawk**	Y	N	N	NA
Margarornis rubiginosus Ruddy Treerunner	Y	Y	N	†

Selasphorus scintilla Scinillant Hummingbird	Y	Y	Y	††
Scytalopus argentifrons Silvery-fronted Tapaculo	N	N	Y	†
Diglossa plumbea Slaty Flowerpiercer	Y	Y	Y	†
Chlorospingus pileatus Sooty-capped Bush-Tanager	Y	Y	Y	†
Tangara dowii Spangle-cheeked Tanager	Y	N	N	†
Selasphorus flammula Volcano Hummingbird	N	N	Y	††
Lampornis calolaemus White-throated Mountain-gem	Y	Y	Y	††
Spinus xanthogastrus Yellow-bellied Siskin	Y	N	Y	†
Pselliophorus tibialis Yellow-thighed Finch	Y	Y	Y	††
Vireo carmioli Yellow-winged Vireo	Y	Y	Y	††

* Endemic Subspecies of Mountain Thrush — † Vulnerable Species
** Endemic western race of Red-tailed Hawk — †† Endangered Species

Table 4 The similarity indices within each unique study site comparison.

Site Comparison (1,2)	Common	Unique (1)	Unique (2)	Similarity Value (J)
Lower-Middle	19	11	8	0.50
Middle-Upper	22	5	12	0.56
Lower-Upper	23	8	10	0.56