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# Avian diversity and abundance among agricultural land, forested land, and their ecotone in Guadalupe, Cerro Punta, Chiriquí Province, Republic of Panamá.

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*SIT Study Abroad*

# Avian diversity and abundance among agricultural land, forested land, and their ecotone in Guadalupe, Cerro Punta. Chiriquí Province, Republic of Panamá.

*Ptiliogonys caudatus*/Long-tailed Silky Flycatcher (Photo: Stella Rae Kinard)

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ABSTRACT

As the human population increases, finding the balance between modifying land use for resources and protecting areas to preserve species that are threatened by anthropogenic disturbance is an evergrowing problem. Guadalupe is a town in the Western Highlands of Panamá that struggles in this balance as its primary income source is agriculture, but it is located on the border of two protected areas, Parque Nacional La Amistad and Parque Nacional Volcán Barú. By understanding the unique ways in which avifauna utilize distinct vegetative landscapes, recommendations can be made for management styles of farms in Guadalupe to implement practices that promote conservation. The purpose of this study is to quantify the different contributions to avian diversity of agricultural land, forested land, and the border between the two. Stationary point counts were used in three different sites (forest, forest edge, and cultivated land) within the town of Guadalupe to measure avian diversity and abundance. It was hypothesized that the forest edge would have the highest diversity and abundance followed by the forest and the cultivated land last. Analysis revealed no significant difference in abundance between the three sites but significantly higher Shannon-Wiener and Simpson's biodiversity indices in both the forest and forest edge sites when compared to the cultivated land. No significant difference was found between the forest and edge sites. Sorenson's coefficient of community found the highest similarity to be between the forest and edge sites. A high number of endemic species were found in the forest and edge sites compared to the cultivated site. These results show the forest and forest edge hold the highest conservation value and that the forest edge on agricultural land preserves a high percentage of the biodiversity within natural forests. Thus, conservation efforts in Guadalupe should prioritize the interface between forest edge with cultivated land, preservation of forests, and reforestation. Further recommendations include increasing tree cover throughout agricultural plots to increase connectivity in these fragmented landscapes.

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*Tangara icterocephala*/Silver-throated Tanager (Photo: Stella Rae Kinard)

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*Tiaris olivaceus*/Yellow-faced Grassquit (Photo: Stella Rae Kinard)

## INTRODUCTION

Panamá plays host to an impressive amount of biodiversity for its small size. Its role as the joint between North and South America allows for the meeting and migration of large numbers of fauna. For birds specifically, many migrants from the north and south meet their range limits here, while endemic species also find their homes among the diverse topography (Angehr & Dean, 2010). This biodiversity has become threatened by human impacts, inciting researchers to study the ways human land use affects biodiversity across the globe (Coetzee & Chown, 2016).

The specific site of this study takes place in the town of Guadalupe located within the Parque Internacional La Amistad (PILA) buffer zone. Guadalupe is part of the Cerro Punta corregimiento of the Chiriquí province at an altitude of between 1600 and 1800 masl (Shah, 2006). This region of Panamá experiences an average annual temperature of 16.4 degrees Celsius and yearly precipitation of 3810 mm (ClimateData, 2021). This study was conducted during the month of April at the end of Panamá's dry season where Cerro Punta's average temperature is 16.8 degrees and the average accumulated precipitation is 209 mm (ClimateData, 2021). Cerro Punta is situated between the Parque Nacional Volcán Barú and Parque Internacional La Amistad (PILA), marking the surrounding environment with high levels of biodiversity and conservation significance (Jones, 2006). These two parks hold within them 6 (Volcán Barú) and 9 (PILA) of the twelve Holdridge life zones located in Panamá (Jones, 2006). As part of the larger Cordillera de Talamanca, a geographically isolated mountain chain shared by Costa Rica and Panamá, these life zones make up a global biodiversity hotspot with over 50 endemic species of birds (Liu et al., 2023).

At the same time, Cerro Punta finds itself among the agricultural lifeblood of the country. Much of its economy comes from fincas, or small farms, that commercially produce flowers and vegetables such as onions, carrots, peas, and potatoes (Shah, 2006). Thus, Cerro Punta hangs in the balance between maintaining rural livelihoods and protecting its vital natural ecosystems. The desire to yield large amounts of product to be sold nationwide invites the use of pesticides and agrochemicals. The use of these chemicals can compromise the health of avifauna by contaminating their food sources and can further disrupt avian populations by threatening their reproductive capabilities (Arya et al., 2019). The desire for higher production also drives farmers to expand their agricultural land higher up the mountains, bringing deforestation and habitat loss to the area's avifauna. Habitat loss is particularly threatening to those endemic species with higher vulnerability to ecosystem change. These economic incentives conflict with Cerro Punta's proximity to protected areas PILA and Parque Nacional Volcán Barú. The Western Highlands in which Cerro Punta is located is designated an Endemic Bird Area (EBA) by BirdLife International for being home to multiple restricted-range avian species (Angehr & Dean, 2010). This designation as an EBA and the location of areas devoted to the protection of natural ecosystems undisturbed by humans and the preservation of biodiversity are in direct contrast with the primary income of Cerro Punta residents.

The purpose of this study is to quantify the different contributions to avian diversity of agricultural land, forested land, and the border between the two. By understanding the unique ways in which avifauna utilize these distinct landscapes, recommendations can be made for management styles of farms or fincas in Cerro Punta for practices that promote conservation.

*Literature Review*

The rapid loss of species due to human impact has led scientists to believe that Earth has entered its sixth mass extinction event (Ceballos & Ehrlich, 2023). The great threat to the biodiversity of the planet that this mass extinction poses means a dramatic loss in ecosystem services provided by these species going extinct (Van Uhm, 2016). Each of Earth's organisms plays its own role within its ecosystem web. The interdependence of all of these organisms means that as more species go extinct, other species that depend on the services of the extinct species become threatened, worsening and accelerating the cycle of extinction (Ceballos et al., 2020). As extinctions accelerate and human activities that threaten species such as deforestation, poaching, and the introduction of invasive species remain ongoing, immediate action to prevent further loss of species is required.

In this current battle against mass extinction, maintaining connectivity between fragmented ecosystems presents itself as a possible route for conservation. Although species may periodically become extinct within certain fragments, it is the migration of species that can repopulate and prevent the extinction of entire populations (Perfecto et al., 2019). Maintaining connectivity across fragmented landscapes in the tropics is crucial in allowing migration to occur.

Birds are useful indicators of ecosystem biodiversity and health (Smits & Fernie, 2013). Their relatively high status on the food chain necessitates the presence of many other species to support them, reflecting their effectiveness as indicators of environmental change (Mekonen, 2017). Furthermore, birds provide important ecosystem services such as the dispersal of seeds and controlling insect populations which in turn can boost crop production (Whelan et al., 2015). Measuring avian diversity across different landscapes can give important insights into mechanisms for biodiversity conservation that promote connectivity.

Determining the different impacts on avian diversity by different vegetative landscapes is particularly relevant in the case of Cerro Punta due to its simultaneous proximity to protected areas and extensive land use for agriculture that creates a fragmented landscape. Cerro Punta's unique placement gives it the critical role of being a connector between a large nature reserve and surrounding areas. Because the matrix that surrounds these large reserves can be location-specific (for example suburbia, secondary forest, and cultivated fields will all have varying influences on fragment connectivity) research is necessary to produce sound management plans at the localized level (Laurence, 2008). Sasaki et al. (2020) found that the different land uses between Germany and Japan call for different conservation strategies specific to the landscape context of each country (Sasaki et al., 2020). Cerro Punta likewise needs conservation strategies developed from research specific to its own location and landscape.

Few studies have been conducted at the localized level in this region (Jones, 2014; Merdinger, 2015). Merdinger (2015) investigated the difference in avian diversity between areas of low, medium, and high anthropogenic disturbance on the Los Quetzales trail in Cerro Punta, and found that areas of high disturbance were significantly different from areas of low and intermediate disturbance. Jones (2014) studied the difference in avian diversity across three distinct agricultural landscapes in Guadalupe and found the avian diversity to be greatest at the forest edge, followed by the forest corridor, and lowest in the pasture. Following up on these findings ten years later will determine any changes to these trends that can influence further management recommendations.

In previous literature investigating the relationship between avian diversity and environmental gradients, landscape heterogeneity has been positively associated with avian diversity (Devictor & Jiguet, 2007). Šálek et al. (2021) compared the small-scale farms of Austria (similar to the agricultural practices of Cerro Punta) to the larger, more industrialized farms of the Czech Republic. They found bird species richness and abundance to be higher in the farmlands of Austria. Based on these findings they recommended the use of fragmented crop fields and increased field margins to be used as strategies for increasing avian diversity on farmlands. Dvořáková et al. (2023) build on these findings in their study that found forest plantations with homogenous tree composition to be negatively associated with bird species richness and diversity. The study by Sasaki et al. (2020) mentioned earlier similarly found that in agricultural landscapes of Germany and Japan, the number of bird species increased as the proportion of semi-natural habitats increased up to a maximum at which point the number of species decreased as the semi-natural habitat continued to increase. The trends in each of these studies suggest the need to conserve naturally forested areas around farmland, increasing the heterogeneity of these landscapes. Furthermore, reforestation efforts should center heterogeneity to ensure the forests that develop have complex structures capable of providing a wide range of niches.

More structurally complex habitats of lowland and secondary-growth forests have been shown to be the most important habitat for the widest range of bird species (Mendoza et al., 2014; Petit et al., 2003). Consistently higher species richness and abundance of birds were found in forest forms of tree cover (secondary forests, riparian forests, and forest fallows) in comparison with non-forest forms (live fences and both pastures with high and low tree cover) (Mendoza et al., 2014). Species of moderate to high vulnerability to disturbance were found to be unsupported in human-modified habitats such as sugar cane and Caribbean pine plantations, although shaded coffee plantations and riparian forest corridors were human-modified habitats that presented high conservation value for more vulnerable species (Petit et al., 2003). Rodewald & Yahner (2001) found that the type of disturbance (specifically between agricultural and silvicultural disturbances) holds more weight in influencing avian communities than the amount of disturbance. The trends of these studies suggest that avian diversity is most supported by natural forested habitats, but that not all human-modified landscapes are created equal in terms of supporting avian diversity. This is why studying the specific effects on avian diversity within a localized region is important. Being able to determine the differences between the forest, forest edge, and cultivated land within Guadalupe will develop site-specific conservation suggestions that might not be appropriate for other locations.

A number of studies have found contrasting results where higher species richness and abundance were found in anthropogenically disturbed areas compared to undisturbed areas, but a loss of unique functional groups was noted in the disturbed areas (Asefa et al., 2017; Coetzee & Chown, 2016). The intermediate disturbance hypothesis provides explanation that landscapes with moderate disturbance would hold higher species diversity (Wang et al., 2022). Human-modified land may provide this intermediate disturbance by increasing environmental heterogeneity.

However, intensive modification could go the reverse route and homogenize landscapes, decreasing diversity. Furthermore, loss of avian species with unique functionalities means a loss of ecosystem services that cannot be easily replaced by other species. Therefore, although it appears that many avian species can adapt to certain human-modified habitats that provide heterogeneous vegetation, the preservation of natural habitats that support unique functional groups of birds continues to be an essential part of conservation efforts.

While many studies investigate the difference between landscape types, few have focused their attention on the exact ecotone between the types. Terraube et al. (2016) demonstrated the importance of forest edges as bird habitats in longstanding human-made landscapes as they were found to support the breeding and feeding habits of the highest abundance and widest range of bird species. Although these forest edges have been shown to support generalist species, more sensitive species require developed forests with complex structures, further demonstrating the need for landscape heterogeneity (Petit et al., 2003, Terraube et al, 2016). This study will add to that body of research with a specific focus on Cerro Punta and the differences that may exist among their agricultural land, forested land, and ecotone.

## RESEARCH QUESTION

Is there a difference in avian diversity among agricultural land, forested land, and their ecotone in Guadalupe, Cerro Punta, Chiriquí?

## METHODS

### *Stationary Point Counts*

Avian diversity and abundance surveys were conducted using stationary point counts in three different sites (Ralph et al., 1995). The edge site followed the border of Finca Vafloreva's agricultural land with a 25-year-old reforested area at the top of the farm (Figure 1A) (D. Sanchez, personal communication, April 6, 2024). The cultivated site was located within the land cleared for agriculture on Finca Vafloreva and was separated by at least 50 meters from the edge site (Figure 1B). The forested site was located on a nearby hiking trail, Cabañas Los Quetzales, that followed the Río Chiriquí Viejo on the border of PILA (Figure 1C). At each of the sites, one transect was established with the locations of the point counts marked at each 100 meters using flagging tape (Figure 2). For the forested site and the cultivated site, the transects were each 800 meters long and included 8 point counts. However, the size of the forest edge on Finca Vafloreva was restricted to 600 meters and only included 6 point counts. Data were collected between 6:00 and 10:00 AM for morning sessions and between 2:30 and 5:30 PM for afternoon sessions. Due to the size restriction of the edge site, the method of data collection was intensified to include 2 repetitions of the transects during morning collections. This resulted in each transect being surveyed a total of 9 times, 6 in the morning and 3 in the afternoon.

To survey the transects using stationary point counts, 3 minutes were allotted for travel time between points and 2 minutes for allowing the birds to settle. Ten minutes were then used for recording data on the species and abundance at each point count using either audial or visual detections of birds. Binoculars and *The Birds of Panama: A Field Guide* by G. R. Angehr and R. Dean were used for visual identifications. The common and scientific names of the birds species in this study are according to *The Birds of Panama: A Field Guide* by G. R. Angehr and R. Dean as well. In the case that songs or calls could not be identified in the field, recordings were taken for later identification using xeno-canto.org and the Merlin Bird ID app (Xeno-canto, 2024; Van Horn, 2024). Only detections within 25 meters from the center of the point count were recorded in order to minimize the potential double-counting of individuals (Figure 2). Birds observed flying over the point counts were not included in the data collection.

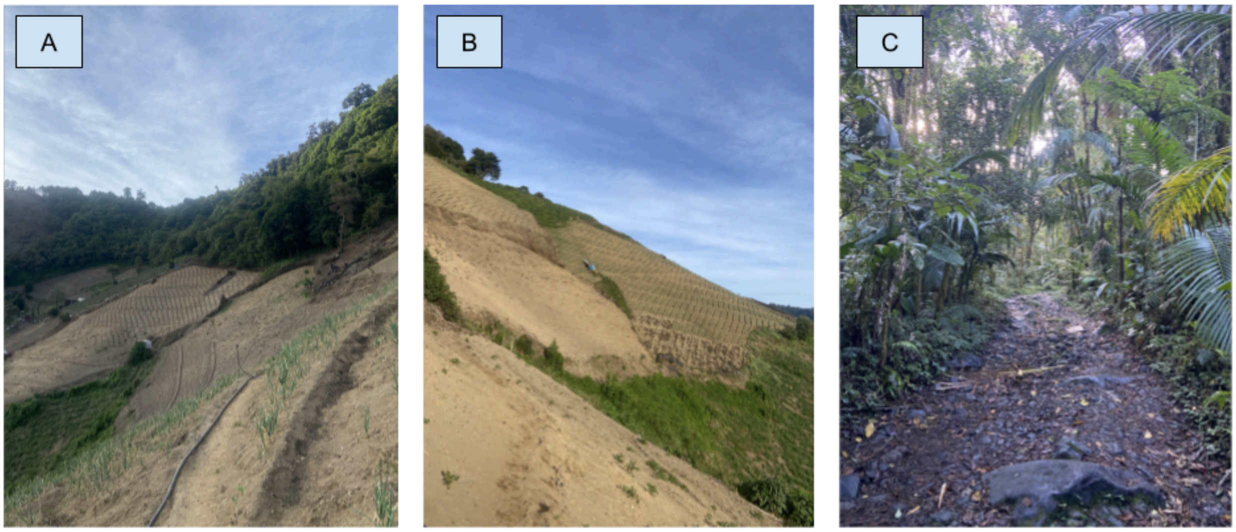


**Figure 1A-C.** Each of the observation sites, (A) edge site, (B) cultivated site, and (C) forested site.

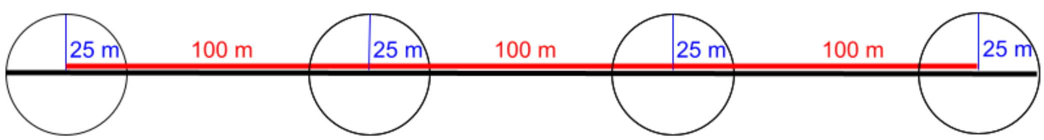


**Figure 2.** A map displaying the set up of point counts along a transect.

*Data Analysis*

Shannon-Wiener and Simpson's diversity indices were calculated using the relative abundances of the species recorded for each sampling period in order to produce mean diversity indices for each site. Single factor ANOVA tests were run comparing the Shannon-Wiener diversity index, Simpson's diversity index, and the overall avian abundance between each of the sites to determine any significant differences. In the event that the ANOVA tests found significant differences, post hoc t-tests using Bonferroni's correction were run to identify between which sites the differences exist. Sorenson's coefficient of community was used to determine the avian community similarity between each of the sites. Species were described by their IUCN conservation status as well as whether they were regional endemics or migrants (Angher & Dean 2010).

ETHICS

As a pre-requisite to the execution of this study, the informed consent of the owners of Finca Vafloreva–where the study took place–was given. This study, which did not involve the participation of any human subjects, was reviewed and approved by the Institutional Review Board (IRB). No physical interactions with any of the birds being studied were necessary as all detections were either visual or audial. Observations were made quietly to minimize any disturbance. Traveling to and from study sites was done along paths to minimize any disturbance to the soil, plants, or other organisms of the area. Likewise, transects were set up on previously established paths which further helped to minimize any disturbance to the surrounding environment. Any equipment or other materials that were brought into the field were returned by the end of the study so that no waste was left behind.

RESULTS

During stationary point counts, a total of 1,139 individuals were detected, including 52 distinct species. There were 39 species identified in the forested site, 34 in the edge site, and 27 in the cultivated site (Appendix Table 4). Out of those species, only 1, *Pharomachrus mocinno*, is considered nearly threatened with the rest being of least concern by the IUCN red list and one was only found within the forested site (Appendix Table 4). The overall most abundant family was Emberizidae which was also the most abundant family found in the edge and cultivated sites. The most abundant family in the forest site was Turdidae. The most abundant species found in each site was *Chlorospingus opthalmicus* (Common Chlorospingus) for the forest site and *Zonotrichia capensis* (Rufous-collared Sparrow) for both the edge and cultivated sites (Appendix Figure 4A-C). Fifteen species were described as regional endemics to the Western Highlands (Angehr & Dean, 2010). The number of regionally endemic species found in each site was 11 for the forest, 12 at the forest edge, and 6 within the cultivated site (Table 1). Only three species of migrants were identified, *Piranga rubra* (Summer Tanager), *Catharus ustulatus* (Swainson's Thrush), and *Wilsonia pusilla* (Wilson's Warbler). All three of these migrant species were found in the forest site while the edge site had both *Catharus ustulatus* and *Wilsonia pusilla* and the cultivated site only contained *Wilsonia pusilla* (Appendix Table 4).

**Table 1.** List of species endemic to the Western Highlands and the sites they were identified in.

| Scientific name (Common name) | Forest | Edge | Cultivated |
|---|---|---|---|
| *Chamaepetes unicolor* (Black Guan) | X | | |
| *Basileuterus melanogenys* (Black-cheeked Warbler) | X | X | |
| *Aulacorhynchus caeruleogularis* (Blue-throated Toucanet) | X | | X |
| *Myioborus torquatus* (Collared Redstart) | X | X | X |
| *Parula gutturalis* (Flame-throated Warbler) | | X | |
| *Troglodytes ochraceus* (Ochraceous Wren) | X | X | |
| *Semnornis frantzii* (Prong-billed Barbet) | X | X | |
| *Selasphorus scintilla* (Scintillant Hummingbird) | | X | X |
| *Scytalopus argentifrons* (Silvery-fronted Tapaculo) | X | X | X |

| Scientific name (Common name) | Forest | Edge | Cultivated |
|---|---|---|---|
| *Chlorospingus pileatus* (Sooty-capped Chlorospingus) | X | X | |
| *Tangara dowii* (Spangle-cheeked Tanager) | X | | |
| *Selasphorus flammula* (Volcano Hummingbird) | | X | X |
| *Lampornis castaneoventris* (White-throated Mountain Gem) | X | X | |
| *Pselliophorus tibialis* (Yellow-thighed Finch) | X | X | |
| *Vireo carmioli* (Yellow-winged Vireo) | | X | X |
| Total | 11 | 12 | 6 |

Single factor ANOVA testing revealed no significant differences in the abundances of the different observation sites (p-value = 0.20). ANOVA testing for both the Shannon-Wiener and Simpson's diversity indices revealed significant differences (Shannon-Wiener p-value = 0.000012, Simpson's p-value = 0.0000003). Bonferroni corrected post hoc t-tests revealed that for both types of diversity indices the forest and edge sites were significantly more diverse than the cultivated site but not significantly different from each other (Table 2).

**Table 2.** P-values from post hoc t-tests to determine which sites had significant differences between their average diversity indices.

| Site Comparison | Shannon-Wiener p-value | Simpson's p-value |
|---|---|---|
| Forest-Edge | 0.122153001 | 0.043731037 |
| Forest-Cultivated | 0.000000509 | 0.000000012 |
| Edge-Cultivated | 0.001440450 | 0.000393728 |

Green highlight designates significant p-values smaller than the Bonferroni corrected alpha of 0.0167.

The Sorenson's coefficient of community was highest for the comparison of the forest and edge sites with a value of 0.74, followed by the edge and cultivated site comparison with a value of 0.59, and finally, the lowest coefficient came from the forest and cultivated site comparison with a value of 0.48 (Table 3).

**Table 3.** Sorenson's coefficients of community for each site comparison.

| Site Comparison | Common Species | Sorenson's Coefficient |
|---|---|---|
| Forest-Edge | 27 | 0.74 |
| Forest-Cultivated | 16 | 0.48 |
| Edge-Cultivated | 18 | 0.59 |

## DISCUSSION

### *Diversity, abundance, and community similarity*

The scope of this study is limited to describing avian diversity and abundance trends within the town of Guadalupe, more specifically, the Finca Vafloreva and the Cabañas Los Quetzales trail. The distinction of landscape type between forest, forest edge, and cultivated land showed no statistically significant effect on avian abundance, therefore, failing to reject the null hypothesis. However, the difference in avian diversity (both Shannon-Wiener and Simpson indices) between the landscape types was statistically significant for comparisons between the forest and cultivated sites and the edge and cultivated sites. This is supported by previous literature showing that intensively modified land cleared for agriculture shows lower avian diversity due to its homogenized landscape (Jones, 2014; Devictor & Jiguet, 2007; Šálek et al., 2021; Dvořáková et al., 2023). Furthermore, the forest and forest edge sites of this study having significantly higher diversity than the cultivated site is supported by previous literature that shows more structurally complex habitats to support higher diversity. (Mendoza et al., 2014; Petit et al, 2003; Sasaki et al., 2020). Forest and forest edge having significantly higher diversity than cultivated land gives evidence for these landscapes holding more ecological niches to be filled by avian species due to their heterogeneity and higher structural complexity.

This study did not show a significant difference between the avian diversities of the forest and edge sites for either Shannon-Wiener or Simpson's diversity indices. This is in contrast to a previous study in Guadalupe that showed the forest edge to have statistically higher avian diversity than the forest corridor (Jones, 2014). Both of these studies have been restricted by small size, but the difference in findings and a ten-year difference between when each was conducted, could suggest a reduction in forest edge health between the research sites where each study occurred. Another contrasting result between these two studies was that the Sorenson's coefficient of community within this study found the forest and edge sites to have the highest similarity followed by the edge and cultivated sites and finally the forest and cultivated sites. In Jones' 2014 study, all three site comparisons were within 0.50-0.56. Jones' study finding more evenly distinct communities between the forest, edge, and cultivated sites than this study could further suggest a reduction in diversity between the research sites from this study and his. The least community similarity between this study's forest and cultivated sites fits the reasoning of these two sites being structurally the most distinct and geographically the farthest from one another. The forest and edge sites having the highest community similarity supports the fact that their diversity indices were not significantly different. These compunding results point to both forested land and the edges of cultivated lands that border forests being an important area for the conservation of avian species.


**Figure 3A-B.** (A) The forest islands and (B) trees along the paths of Finca Vafloreva.

*Conservation recommendations*

The results of this study indicate that between these three landscape types, forest and forest edge are the most important for potential species conservation. Not only were their diversity indices significantly higher than that of the cultivated land, but they also retained the highest numbers of endemic species (Table 1). The higher number of endemic species indicates that the forest and edge sites are able to provide habitats to species with more sensitive ecological ranges. This is further evidence of their unique structural complexity that lends to their conservation potential. Maximizing the amount of forest and forest edge present among the agricultural land in Cerro Punta will help to maintain the habitats of these avian species.

The findings of this study demonstrate the potential for forest edges to retain the biodiversity of fully forested habitats which is in accordance with previous literature (Jones, 2014; Mendoza et al., 2014; Terraube et al., 2016). This result is important for the farmers of Guadalupe who have an economic incentive to keep their cultivated land instead of allowing that land to be reforested, which might be the most ideal conservation tactic as secondary and riparian forests have shown to support the highest avian diversity (Mendoza et al., 2014; Petit et al, 2003). Conservation suggestions for farmers in Guadalupe would include maximizing forest edge interface with their farms and expanding fully forested land. Allowing for the regrowth of forests surrounding their farms that may also act as borders between fincas can increase the connectivity between these fragmented landscapes. Furthermore, the forest edges provide access to open areas preferred by many avian species that fully forested land does not provide (Sasaki et al., 2020, Terraube et al., 2016).

Finca Vafloreva can act as a preliminary model for this type of conservation as they have been reforesting areas in and around their farm for the past 25-35 years (D. Sanchez, personal communication, April 6, 2024). The regrowth has allowed for forests to repopulate the top of the mountain where their farm is located (the site of the forest edge transect) as well as in smaller forest islands around the farm (Figure 3A). While surveying the transect on the cultivated site, a vast majority of avian species other than *Zonotrichia capensis* (Rufous-collared Sparrow) and *Tiaris olivaceus* (Yellow-faced Grassquit) were observed in and near these forest islands that came within 25 meters of the cultivated site's transect as well as foraging on and calling from stand-alone trees that dotted the paths through the agricultural fields (Figure 3B). Following this example of Finca Vafloreva by implementing intermittent forest islands into cultivated land is a sound conservation tactic that allows birds foraging space on land that, if left only for crop cultivation, would be too homogenized to provide any ecosystem services to the majority of avian species (Ausprey et al., 2023). Planting trees along paths and throughout the agricultural land as Finca Vafloreva has begun to do would be a starting point for establishing these forest islands and provide connectivity for birds migrating through the landscape. The effect of this management style could prove similar to that of shaded coffee and cacao farms which have been shown to provide habitats for a wider range of avian species in comparison to their non-shaded counterparts (Greenberg et al., 1997; Petit & Petit, 2003; Van Bael et al., 2007; Variar et al., 2021).

*Sources of error*

The restricted size of the farm used for this study resulted in transects that were shorter than ideal, particularly that of the edge site. This led to smaller sample sizes that may have affected the analysis of the abundances between sites. The forest that the edge site bordered was not traversable which led to the forest transect being established outside of the farm on a nearby hiking trail. While two transects being located on the same finca and one transect being located outside of it broadens the scope of the study, it also leads to comparisons being made across unaccounted-for environmental conditions. The point count method utilized in this study did have the potential for pseudo-replication of individuals which could have affected the data. Due to the small time scale in which the study took place, it is possible that some species were misidentified as well as others may remain unidentified. This could result in an incomplete picture of diversity for the study sites. Another potential source of error could be the different levels of visibility in each of the sites. The cultivated land had higher visibility than the forest and forest edge due to a lack of trees to obscure visual detections of birds. These visibility differences could have led to skewed abundance and diversity metrics. Because of this lower visibility in the forest and edge sites, a bias existed towards audial detections and moreover, those songs and calls that were more easily identifiable, leading to another potential source of error in the diversity metrics for these sites. Similar studies conducted in the future would benefit from larger sample sizes in sites without the size restrictions of this study as well as a longer time scale that allows for more sampling hours and a larger data set with more statistical power.

## CONCLUSION

The research objectives of identifying any differences in diversity and abundance between three distinct landscape types in Guadalupe were met and statistically analyzed for significance. Abundance was found to have no significant difference between the three sites while both Shannon-Wiener and Simpson's diversity indices were statistically higher in the forest and forest edge than in the cultivated land. The findings of this study show that the disturbance caused by land used for agriculture leads to significantly lower avian diversity than that of forests and forest edges. These findings are substantially evidenced by the concordance of Shannon-Wiener and Simpson's indices being statistically higher in the forest and edge than the cultivated land as well as the Sorenson's coefficient of community showing forest and edge to have the highest similarity in community composition out of all three site comparisons. The hypothesis was partially supported in that the cultivated land had the lowest diversity, but the forest edge which was hypothesized to show the highest avian diversity was not significantly different from the forest site and had lower mean diversity indices than the forest. The forest edge was able to maintain a similar community composition and diversity to the forest corridor. Likewise, forests and forest edges held higher numbers of endemic species. These findings display the ability of forest edges to be used as part of the conservation efforts of farmers within Guadalupe. Further studies should expand their scope to more areas in the Chiriquí highlands. Recommendations for future studies include evaluating the differences in avian diversity between a farm with intermittent forest islands and a completely open farm without any tree coverage to quantify the proficiency of this proposed management plan.

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APPENDIX

**Table 4.** Complete list of species identified within point counts and the sites where they were found.

| | Scientific name (Common name) | Forest | Edge | Cultivated |
|---|---|---|---|---|
| | *Melanerpes formicivorous* (Acorn Woodpecker) | | | X |
| WH | *Chamaepetes unicolor* (Black Guan) | X | | |
| WH | *Basileuterus melanogenys* (Black-cheeked Warbler) | X | X | |
| | *Myadestes melanops* (Black-faced Solitaire) | X | X | |
| | *Volatinia jacarina* (Blue-black Grassquit) | X | X | X |
| | *Thraupis episcopus* (Blue-gray Tanager) | | X | X |
| WH | *Aulacorhynchus caeruleogularis* (Blue-throated Toucanet) | X | | X |
| | *Molothrus aeneus* (Bronzed Cowbird) | | | X |
| | *Arremon brunneinucha* (Chestnut-capped Brushfinch) | X | X | X |
| | *Turdus grayi* (Clay-colored Thrush) | X | X | X |
| WH | *Myioborus torquatus* (Collared Redstart) | X | X | X |
| | *Chlorospingus opthalmicus* (Common Chlorospingus) | X | X | X |
| | *Piranga bidentata* (Flame-colored Tanager) | X | X | X |
| WH | *Parula gutturalis* (Flame-throated Warbler) | | X | |
| | *Chlorophonia callophrys* (Golden-browed Chlorophonia) | X | X | |
| | *Henicorhina leucophrys* (Gray-breasted Wood-wren) | X | X | X |
| | *Quiscalus mexicanus* (Great-tailed Grackle) | X | | X |
| | *Phaethornis guy* (Green Hermit) | X | | |
| | *Colibri thalassinus* (Green Violet-ear) | X | | |
| | *Pezopetes capitalis* (Large-footed Finch) | X | | |
| | *Ptiliogonys caudatus* (Long-tailed Silky Flycatcher) | X | | X |
| | *Elaenia frantzii* (Mountain Elaenia) | X | X | X |
| | *Zenaida macroura* (Mourning Dove) | | | X |
| | *Turdus plebejus* (Mountain Thrush) | X | X | |
| WH | *Troglodytes ochraceus* (Ochraceous Wren) | X | X | |
| WH | *Semnornis frantzii* (Prong-billed Barbet) | X | X | |

| | Scientific name (Common name) | Forest | Edge | Cultivated |
|---|---|---|---|---|
| NT | *Pharomachrus mocinno* (Resplendant Quetzal) | X | | |
| | *Catharus aurantiirostris* (Ruddy-capped Nightingale-Thrush) | X | X | |
| | *Patagioenas subvinacea* (Ruddy Pigeon) | | | X |
| | *Cyclarhis gujanensis* (Rufous-browed Peppershrike) | X | X | X |
| | *Zonotrichia capensis* (Rufous-collared Sparrow) | | X | X |
| WH | *Selasphorus scintilla* (Scintillant Hummingbird) | | X | X |
| WH | *Scytalopus argentifrons* (Silvery-fronted Tapaculo) | X | X | X |
| | *Tangara icterocephala* (Silver-throated Tanager) | X | X | |
| | *Myioborus miniatus* (Slate-throated Redstart) | X | X | X |
| | *Amazilia edward* (Snowy-bellied Hummingbird) | | X | |
| WH | *Chlorospingus pileatus* (Sooty-capped Chlorospingus) | X | X | |
| WH | *Tangara dowii* (Spangle-cheeked Tanager) | X | | |
| | *Lepidocolaptes affinis* (Spot-crowned Woodcreeper) | X | X | |
| | *Phaethornis striigularis* (Stripe-throated Hermit) | X | | |
| M | *Piranga rubra* (Summer Tanager) | X | | |
| M | *Catharus ustulatus* (Swainson's Thrush) | X | X | |
| | *Mitrephanes phaeocercus* (Tufted Flycatcher) | X | X | |
| | *Campylopterus hemileucurus* (Violet Sabrewing) | X | | |
| WH | *Selasphorus flammula* (Volcano Hummingbird) | | X | X |
| | *Atlapetes albinucha* (White-naped Brushfinch) | | | X |
| WH | *Lampornis castaneoventris* (White-throated Mountain Gem) | X | X | |
| M | *Wilsonia pusilla* (Wilson's Warbler) | X | X | X |
| | *Spinus xanthogastrus* (Yellow-bellied Siskin) | | | X |
| | *Tiaris olivaceus* (Yellow-faced Grassquit) | X | X | X |
| WH | *Pselliophorus tibialis* (Yellow-thighed Finch) | X | X | |
| WH | *Viero carmioli* (Yellow-winged Vireo) | | X | X |
| | Total | 39 | 34 | 27 |

WH = Regional endemic species to the Western Highlands of Panama (Angehr & Dean, 2010)

NT = Near threatened IUCN conservation status

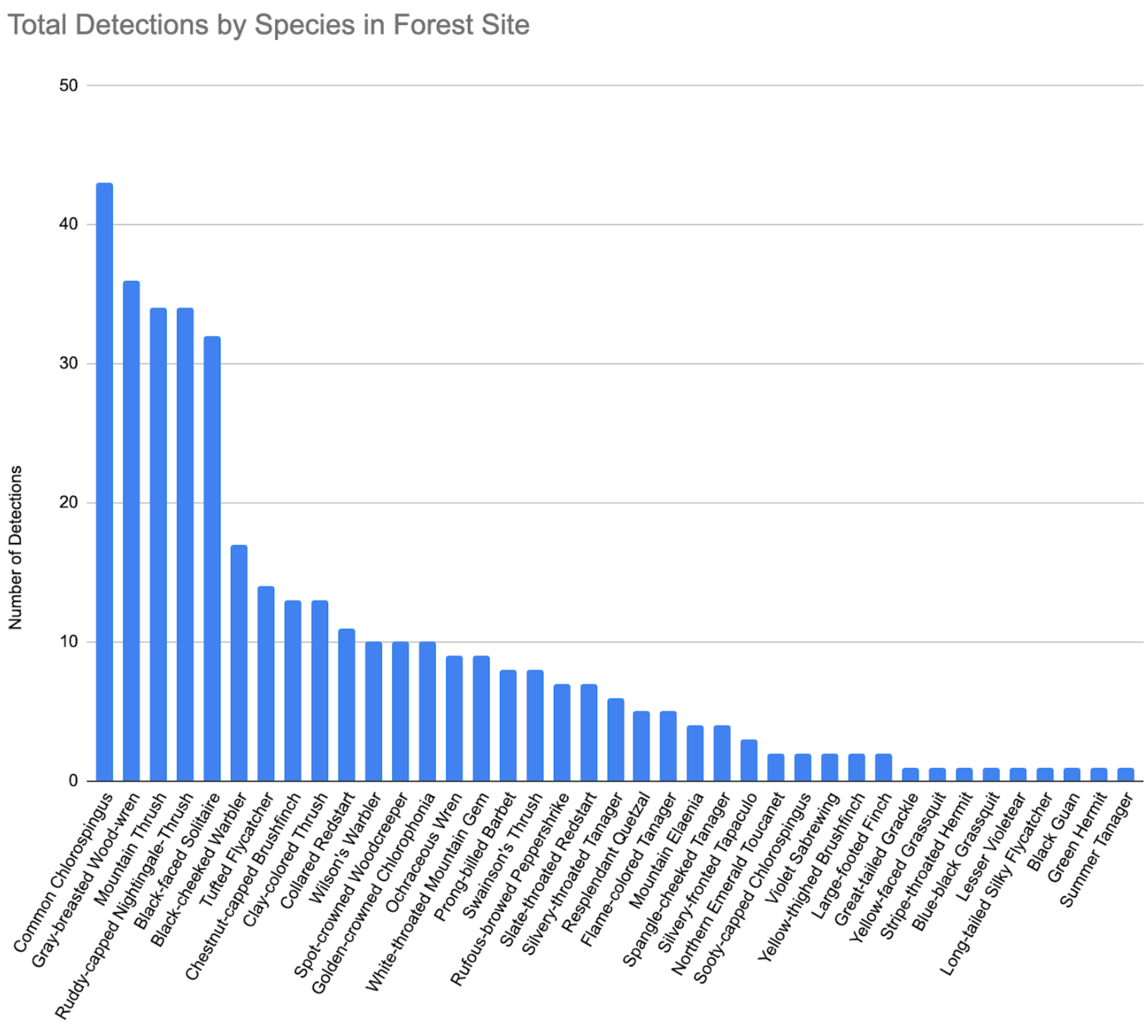
M = Migrant species (Angehr & Dean, 2010)

**Table 5.** Average abundance and diversity indices that were used in the ANOVA testing between all three observation sites.

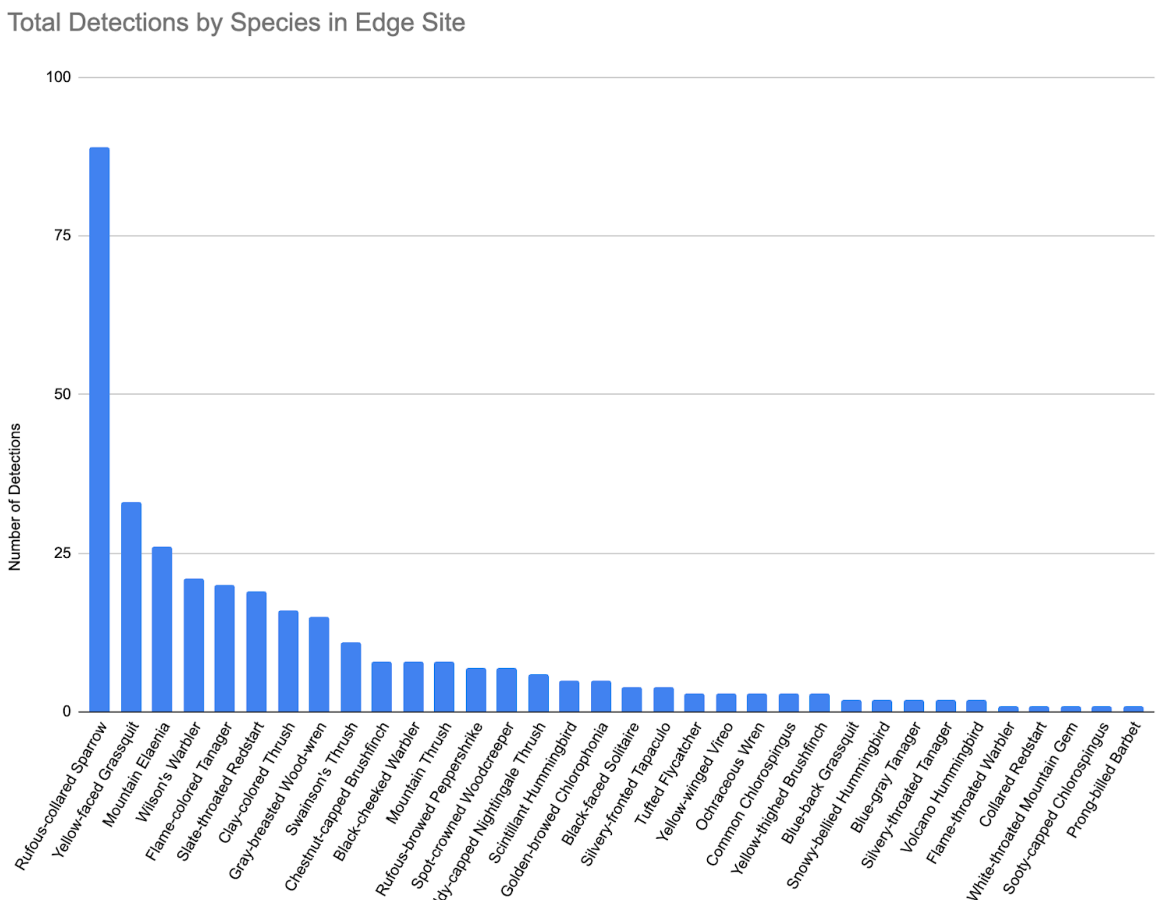
| Site | Average Abundance | Average Shannon-Wiener Diversity | Average Simpson's Diversity |
|---|---|---|---|
| Forest | 41.22 | 2.61 | 0.91 |
| Edge | 38.00 | 2.40 | 0.87 |
| Cultivated | 47.33 | 1.93 | 0.78 |

**Figure 4A-C.** Species detection distributions for each site, (A) forest, (B) edge, and (C) cultivated.

**A)**

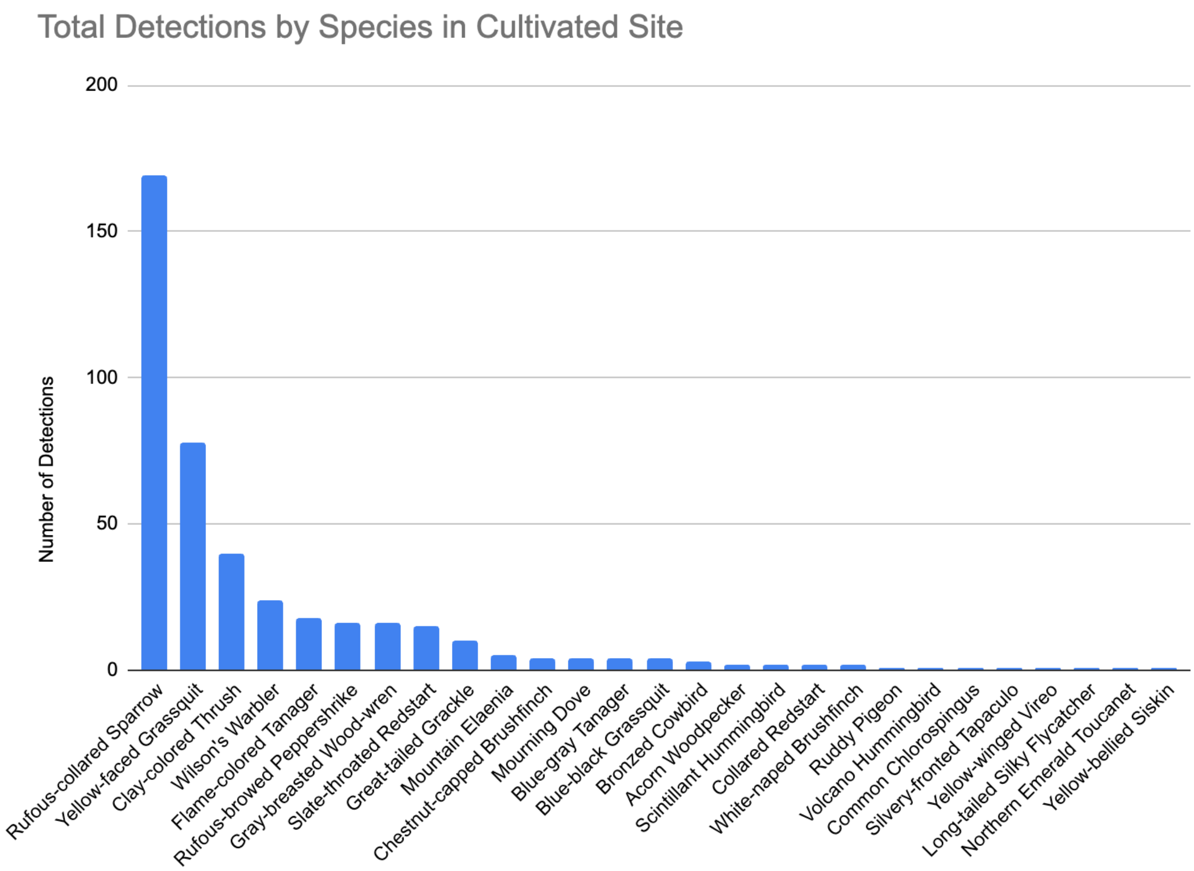


**B)**



Total Detections by Species in Edge Site
Number of Detections
100
75
50
25
0
Rufous-collared Sparrow
Yellow-faced Grassquit
Mountain Elaenia
Wilson's Warbler
Flame-colored Tanager
Slate-throated Redstart
Clay-colored Thrush
Gray-breasted Wood-wren
Swainson's Thrush
Chestnut-capped Brushfinch
Black-cheeked Warbler
Mountain Thrush
Rufous-browed Peppershrike
Spot-crowned Woodcreeper
Ruddy-capped Nightingale Thrush
Scintillant Hummingbird
Golden-browed Chlorophonia
Black-faced Solitaire
Silvery-fronted Tapaculo
Tufted Flycatcher
Yellow-winged Vireo
Ochraceous Wren
Common Chlorospingus
Yellow-thighed Brushfinch
Blue-back Grassquit
Snowy-bellied Hummingbird
Blue-gray Tanager
Silvery-throated Tanager
Volcano Hummingbird
Flame-throated Warbler
Collared Redstart
White-throated Mountain Gem
Sooty-capped Chlorospingus
Prong-billed Barbet

**C)**


Total Detections by Species in Cultivated Site
200
150
100
50
0
Number of Detections
Rufous-collared Sparrow
Yellow-faced Grassquit
Clay-colored Thrush
Wilson's Warbler
Flame-colored Tanager
Rufous-browed Peppershrike
Gray-breasted Wood-wren
Slate-throated Redstart
Great-tailed Grackle
Mountain Elaenia
Chestnut-capped Brushfinch
Mourning Dove
Blue-gray Tanager
Blue-black Grassquit
Bronzed Cowbird
Acorn Woodpecker
Scintillant Hummingbird
Collared Redstart
White-naped Brushfinch
Ruddy Pigeon
Volcano Hummingbird
Common Chlorospingus
Silvery-fronted Tapaculo
Yellow-winged Vireo
Long-tailed Silky Flycatcher
Northern Emerald Toucanet
Yellow-bellied Siskin