Relating Avian Diversity to the Environment Around the Rainforest Discovery Center

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Full Work Days: 20

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Introduction

It has become clear in the past decades that there is a strong need for frameworks that integrate social and ecological considerations, placing certain environmental limits on human activities (Steffen *et al.*, 2015). Habitat destruction is the main cause for species extinction (Tilman *et al.,* 1994), hence protected areas have become a necessary tool for conservation. Worldwide, protected areas cover over 12.7% of land surface area; looking at Panama more specifically, 20.89% of the country's total land area is protected (Geldmann *et al.*, 2013).

Soberania National Park in Panama is an area of ecological importance; the 55,000 acres of protected area were were established in 1980 and house 92% of Panama's forest-dwelling species (Robinson *et al.,* 2004). Soberania Park is a hotspot for bird diversity, with over 400 bird species identified by enthusiasts (eBirds, 2019). In addition to scientific studies, there have been considerable efforts in recent years to increase public awareness of the environmental issues in the neotropics. It is for this reason that non-governmental organizations such as the Avifauna Foundation have emerged in Panama. The NGO was founded in 2000, in the memory of Eugene Eisenmann, a world-renowned Panamanian ornithologist who dedicated himself to the conservation of Panama's bird species. In 2003, Avifauna was granted rights to land in Soberania National Park to construct a center for ecotourism and environmental education, now known as the Rainforest Discovery Center. By 2006, the site was opened for visitors, with access to trails for hiking, a visitor's center and an observation tower. The area became very popular for birding, while also continuing to be a place of learning for people of all ages, hosting group tours, activities and workshops for children. There is a significant amount of research that is conducted in Soberania, on topics ranging from forest ecology to endangered bird species, and most of these studies have been done for conservation purposes[LR2] .The *Avifauna Foundation* values scientific research to promote conservation in all its forms but places a special emphasis on research that relates to avian diversity, as this is the main concern of the organization.

Avian Conservation in Soberania National Park

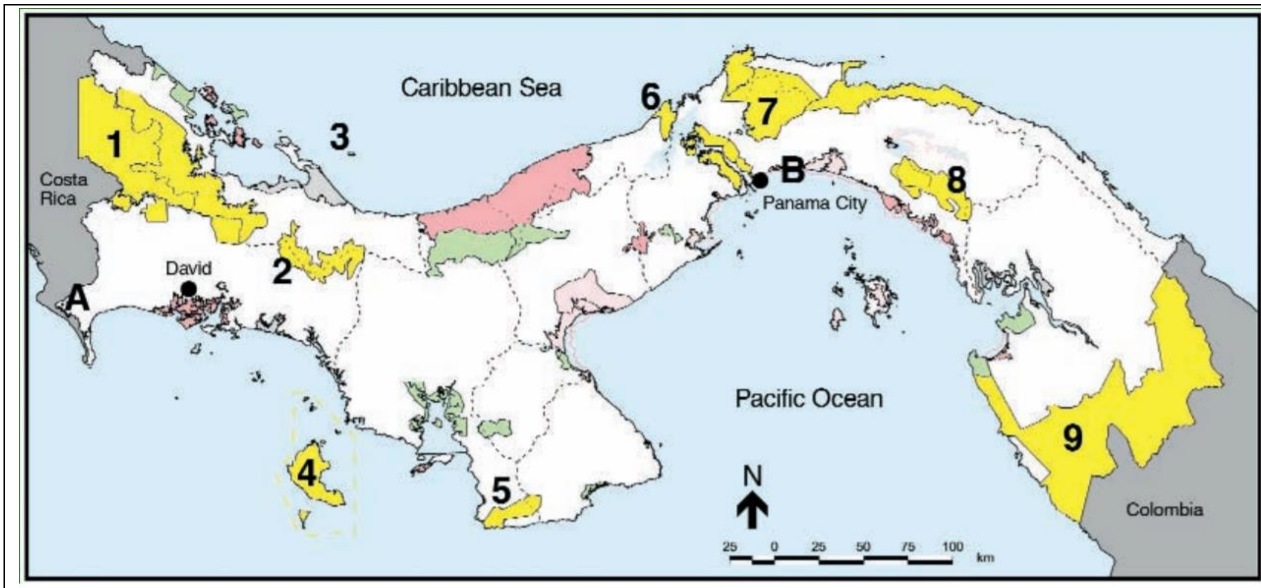


Figure 1: Panama's important bird areas identified by the Panama Audubon Society (yellow)
Montañez, D., and G. Angehr. 2007. Important Bird Areas of the Neotropics: Panama. Neotropical birding 2:13.

Panama is the meeting point for terrestrial diversity from North and South America. Consequently, Panama is a hotspot for diversity, the country houses an impressive 972 recorded bird species (Montanez *et al.*, 2007). In 2007, the Panama Audubon Society determined the most important areas for bird conservation in Panama, and by doing so introduced the concept of Important Bird Areas. The IBA program aims to identify which sites around the world must be preserved for the conservation of globally threatened, range-restricted or congregatory birds. The areas surrounding the Panama Canal, including the Soberania National Park, are characterized as an IBA. In addition to housing nationally threatened species, these sites are important because they act as a corridor between the Caribbean and the Pacific, allowing passage to migratory birds amongst other things (Montanez *et al.*, 2007).

Birds are amongst the most widely studied animals on Earth and can serve as key indicator species for ecosystem health (Sekercioglu *et al.*, 2012). With the current threat of climate change, assessing the condition of avian diversity may not only benefit their own conservation, but also broaden our understanding of how the environment is changing for other species as well. According to some models, tropical birds could be the most affected by increases in temperature. If current trends continue, by the year 2100, the surface of the planet will have warmed by 3.5°C. Models predict that this will result in the extinction of 600-900 land bird species, of which 89% are tropical species (Sekercioglu *et al.*, 2012). The threat is greater for tropical birds because they have lower basal metabolic rates due to their lack of exposure to pronounced temperature changes (Hails, 1983). If these predictions are correct, then the birds of central and southern America may be some of the first species to experience the consequences of climate change. Understanding the challenges they are facing would be key to devising effective conservation efforts.

From the Literature

Firstly, bird censuses are often conducted within Soberania National Park, most of them by citizen scientists, but none have been as complete as the one conducted in 1985 by Robert Ridgely and John Gwynne. To better understand the diversity inside the Park, these researchers, in collaboration with the Aububon Society, conducted a survey of the bird species present in the area around the Rainforest Discovery Center. Within 24 hours, they observed and identified a total of 239 avian species, all of which were reported in the second edition of their book A Guide to the Birds of Panama, published in 1989. The list can be found on the Rainforest Discovery Center's website, which includes all the species they observed and identified. Ridgely et Gwyne's study differed from most in the area because its methodology called for precision in the spatial localization of each observation. Though they did not stay in a fixed point to conduct their census, they took note of which site on the map they were nearest for each data point. This gives future researchers the opportunity to better analyse their results as it relates to interactions between avian and forest ecology. In fact, considering that the original assessment was conducted 34 years ago, a re-examination the avian species diversity of the park would be beneficial to capture the effects of a changing environment.

In the past, studies of avian diversity have focused on environments removed from human influence. For example, the previous study by Ridgely and Gwynne (1985) was conducted across 5 key sites within the park, but avoided areas with the most human activities, namely the entrance and the clearings just outside the centre's limits. More recent research, on the other hand, has been looking into the effects of Latin American urban features on biodiversity (Silva *et al.*, 2015). In a study conducted in 1990 by the University of Florida on the environmental conditions of Panamanian cut forests, it was found that the abrupt change in vegetation that results from clear-cutting can alter ecosystem dynamics at the forest edge. Clear-cutting can alter the abiotic environment by increasing wind velocity and reducing relative air humidity in the area. These changes can lead to biotic consequences by altering the vegetation structure of the forest at the edge and some distance within. It is important to understand how changes such as these impact avian wildlife and how this has affected the populations at Soberania.

Further studies have also assessed the ability of varying natural and non-natural habitats to support neotropical bird populations. As expected, most human-modified zones do not retain their ability to support at-risk wildlife and lose their conservation value, but certain areas with human activities, such as forest corridors and edges of cut forest, remain important to avian wildlife (Petit et Petit, 2003). This reinforces the need to assess the current bird species that use this type of environment in the Soberania National Park, as it will allow for more effective conservation efforts.

While the exact nature of the interaction between bird and their habitat remains largely misunderstood, there has been attempts to link the two in the past. There is significant literature that documents the seasonal fluctuations in flowering and fruiting plants in Neotropical environments (Croat, 1969). There have also been efforts to correlate plant seasonality with animal behaviour. In 1972, research was conducted on Barro Colorado Island by Dr. Charles Leck and his team to understand the feeding pressures being experienced throughout the year by fruit-and-nectar-eating birds. They found that the dry season was significantly richer in food sources, whereas the wet season had less flower availability, which the study suggested led to population emigration (Leck, 1972).

Bird species assemblages on the other hand, may be closely related to habitat complexity. Analyses have shown that bird species richness increases with plant species richness, but also with more rainfall, older forests and more complex topography (Rompré *et al.,* 2007). Some studies have tried to look at these link through time, in an attempt to understand what drives changes (or stability) in historical and contemporary bird diversity. In a study conducted in Australia (Hawkins *et al.,* 2005), spatial patterns of species richness were generated through time, and it was found that the distributions reflected water availability. As rainfall patterns changed over the years, so did avian distribution. Therefore, water may be a key factor to consider in future research in Panama as well.

Other factor-specific behaviours in birds have also been well documented in the literature, which is helpful to guide our understanding here in Panama. Temperature-specific behaviours, such asannual breeding cycles have the potential to be impacted very heavily by climate change (Carey, 2009). Reproduction of species usually occurs at a specific time in the year. Hummingbirds, for example, normally reproduce during the dry season so as to coincide with the peak flowering period of the area, an optimal time for raising young (Stiles, 1980). Breeding success depends in large part upon timing, and, as breeding constitutes the highest energy expenditure for many species (Carey, 1996), the costs are high when mistakes are made. The trouble is, many species use temperature as an indicator for their endogenous clock, which may no longer be reliable. On a wider scale, migration is also impacted by environmental changes. The departure and arrival of a species must coincide with food supplies for survival, which is now experiencing mismatches due to altered plant cycles (Carey, 2009).

Nature reserves only represent a small portion of the land, which makes the ecological value of the what is being protected all the more important (Petit & Petit, 2006). It is necessary to continue population and species censuses in Panama, to update our knowledge of the conservation status of certain birds, but we must also to look at dynamics within the environment. Located in a hotspot for bird biodiversity, the Rainforest Discovery Center is the ideal location to assess as many of these interactions in a short period of time.

Framework of Research

The overall research focused on understanding how the environment shapes bird diversity and distribution at the Rainforest Discovery Center. More specifically, we were interested in establishing the precise ecological factors that affect the present avian populations and if these interactions have led to population changes over time. This information was collected for conservation purposes, to inform us about the ecological importance of the different types of environments around the park. From the literature, it appears that clear links between bird populations and their environment, which could serve as key insight into understanding species behaviour and habitat choice, are lacking in most regions, including Panama's national parks.. We hope that the information we gather can serve as a foundation, upon which further analysis of the environmental composition of Soberania can build upon.

In order to establish the link between birds and their environment, we first had to examine the bird species richness found around the park. Then, we also had to examine the environmental factors surrounding the identified bird species, for this we looked amongst other things at plant diversity and composition, proximity to water and importance and impact of human activity. To establish the ecological importance of the different areas of the park for birds, we had to understand the change (or lack-there-of) avian populations had experienced through time. For this reason, the research conducted in 1985 could be used as a reference point. The main question being addressed by our research is thus the following:

i. Is there a significant change in bird abundance and species richness with changes in environmental factors of interest across sites in the Rainforest Discovery Center?

To further untangle the many factors involved in this first question, we will be addressing the following secondary question as well:

ii. Has there been a change in bird species richness across the Rainforest Discovery Center since 1985?

Methods

Research Design

Figure 2. Map of Panama Rainforest Discovery Center. Study sites are numbered (1-6) and indicated on the map.

Site 1: Entrance	**Site 3b:** Tower Bottom	**Site 5:** Calamito lake
Site 2: Visitors Center	**Site 3b:** Tower (top)	**Site 6:** Border between forest and clearing
Site 3a: Tower top	**Site 4:** Belvedere trail	

Our study was composed of surveys on bird abundance and species richness at 6 locations at the Panama Rainforest Discovery Center. The sites were strategically chosen to represented key points in the organization of the centre (entrance, visitor’s centre, observation tower). In our site criteria, we also looked for areas that encompassed unique vegetation or environmental factors such as undisturbed forest, proximity to water and deforestation.

Data Collection and Analysis

Data was collected at the PRDC between January and April. Throughout the sites, all bird surveys were conducted at a uniform time (6:30am – 7:30am). This ensured consistency in the results, as bird activity is highest at particular hours of the day, notably dawn and dusk (Robbins, 1981). All observations were made from a stationary point, around which a 10m radius was established. Any bird observed was recorded and given a time stamp, the birds position in the canopy, size and behavior were also noted. For birds that could not be identified immediately to the species level key physical characteristics were recorded; when possible photographs were also taken to facilitate identification. Using a bird identification guide, and with the help of the staff at Avifauna, all observed species were identified and recorded.

Data on forest composition at each of the 6 sites was also collected to complement the bird surveys. Using a meter wheel, a circumference with a 10m radius was established around each observation point at each of the sites. Within this circumference four (2m x 2m) plots were created at random.

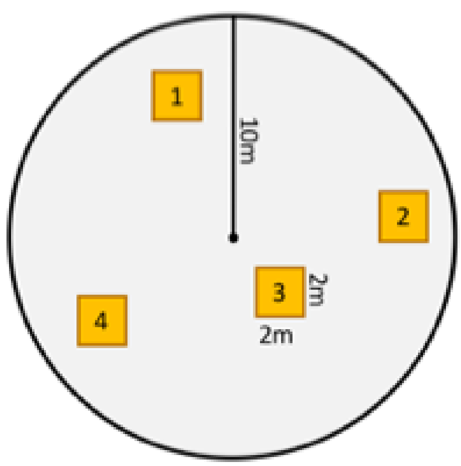


Figure 3. A 10m radius was established around each observation point. Four 2m by 2m plots were placed at randomized locations within the circumference.

Within each plot understory and canopy cover were estimated as a percentage. Canopy cover was approximated by standing in the center of each plot and looking directly upwards, the percentage of the sky that was obscured by leaves, branches and/or epiphytes was recorded. Metadata on understory composition and stratification was also documented. All trees within the plot with a diameter of 15cm or greater were identified using the DBH and numbered, the distance between each tree was calculated using the meter wheel. The data collected from the 4 plots was later used to estimate overall understory and canopy characteristics at each site.

Additionally, all trees within the entire circumference at each of the sites with a trunk diameter of 30cm or greater were identified and numbered as morpho-species (trees with similar characteristics were place under the same morpho-species). Characteristics of the bark, leaves and flowers (if present) were recorded through photographs and written data. Smaller trees and understory that were either flowering or fruiting were also documented through photos and recorded as morphospecies. With the guidance of Dr. Rolando Perez, each morphospecies was systematically identified and recorded, the results of which are presented in the following section. Once identified, tree species were categorized based on the number of individuals within the circumference.

1 individual	2-3 individuals	More than 3 individuals

Species with only one individual observed in the circumference were colored green, species with 2 to 3 individuals were colored yellow. Any species with more than 3 individuals present in one circumference were colored orange and labeled a dominant species in the area. Tables are presented in appendix 4.

Finally, we also determined the geographical positioning of each sampling site, in order to determine what was present in their surrounding environment. GPS coordinates of the sampling locations were taken using satellite maps. To determine the sites proximity to water, the GPS coordinates nearest water body were also determined. The distance between the 2 coordinates was then calculated.

Statistical Analysis of Data

Throughout 3 months of data collection at 6 different locations we compiled a database of information on the biotic and abiotic composition of each site. After sifting through the data, 6 quantifiable variables were identified: bird abundance, bird species richness, proximity to water, canopy cover, presence of fruiting tree species and presence of fruiting plant species. Correlation analyses were performed comparing avian species richness and abundance at each site with distance from water, number of fruiting tree species observed, number of fruiting tree and understory species observed, and overall canopy cover.

Table 1. Abundance and species richness at each site used for statistical analysis. The highest values in each column are colored blue; the lowest values are colored orange.

	Abundance	Species Richness
Site 1: Entrance	38	18
Site 2: Visitors Center	36	19
Site 3a: Tower (bottom)	14	16
Site 4: Belvedere Trail	34	26
Site 5: Calamito Lake	64	32
Site 6: Forest Border	198	27

The Pearson Correlation Coefficient was calculated using the formula:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Where (r) represents the correlation coefficient, (n) is the sample size and (x) and (y) are the variables being tested.

Table 2. Strong positive correlations (r > 0.7) are colored blue; strong negative correlations (r < -0.7) are colored orange.

(x,y)	Abundance	Species Richness
Distance from water	r = -0.3703	r = -0.7349
Canopy cover	r = -0.2630	r = -0.7262
# Fruiting tree species	r = +0.6381	r = +0.2738
# Total fruiting vegetation species	r = +0.7671	r = +0.0935

For all correlation coefficient (r) values a test of statistical significance was performed using a t-table and the formula:

$$\left| \frac{r}{\sqrt{\frac{1-r^2}{n-2}}} \right| > t_{1-\alpha/2}(n-2)$$

At significance level α = 0.05, none of the correlations were found to hold statistical significance; this can likely be attributed to the small sample size (n=6). Repeating this experiment with a larger sample size, using additional sites at the Panama Rainforest Discovery Center, might yield statistically significant results.

The Shannon-Wiener diversity index (H) was calculated for each site using the formula:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where (S) is the total number of species, (p_i) is the proportion (n_i/N) and (N) is the total number of individuals. Using the Shannon diversity index values obtained species evenness (E_h) was derived using the equation:

$$E_h = \frac{H}{H_{max}}$$

Where (H_{max}) is the natural logarithm of (S).

Table 3. The Shannon-Wiener diversity index and species evenness values at all 6 sites. High species evenness values ($E_h > 0.9$) are colored blue; low species evenness values ($E_h < 0.5$) are colored orange.

	Shannon-Wiener diversity index (H)	Species Evenness (E_h)
Site 1: Entrance	2.887	0.9482
Site 2: Visitors Center	2.811	0.8629
Site 3a: Tower (bottom)	2.736	0.9869
Site 4: Belvedere Trail	3.194	0.9802
Site 5: Calamito Lake	3.055	0.8815
Site 6: Forest Border	1.390	0.4218

Code of Ethics Statement

All methods carried out for the duration of this research project were done in accordance with the Code of Ethics of McGill University [see appendix 5].

Results

Table 4: Bird species identified at each site of the Rainforest Discovery Center in 2019 with a sampling period of 1 hour per site, and 7 hours in total, conducted over the months of March and April. The identification was done by direct observation of the bird or by sound when applicable.

2019								
	Entrance	Tower (Below)	Tower (Above)	Visitor's Center	Calamito Lake	Trails	Forest Border	Total
Total Abundance	38	36	14	26	34	64	198	**410**
Seen	36	34	5	21	24	59	192	
Heard	2	2	13	5	10	5	6	
Total Species Observed	18	16	15	19	32	26	27	**88***
Seen	16	17	4	12	18	29	21	
Heard	2	2	12	3	8	3	6	

**Species that were seen at more than one location were only counted once in the total*

Bird species richness across time

The sampling we conducted at the Rainforest Discovery Center within the year 2019 resulted in 88 species seen in total around the park (table 4), which can be found in the table presented in annexe 1. These observations were collected over 7 hours in total (1 hour per site, with an additional sampling at the top of the tower). In contrast, in 1985, the study conducted by Ridgely and Gwynne yielded a total of 239 species (table 5), observed over 24 hours (presented in annexe 2).

Table 5: Bird species identified at each site of the Rainforest Discovery Center in 1985 after a total sampling period of 24 hours (1 day).

1985							
Sites	Access Road	Obs. Tower	Visitor's Center	Calamito Lake	Trails	Forest Border	**Total**
Species Observed	101	128	87	88	141	No data	**239**

The sampling conducted 2019 was done in approximately the same locations as the previous study, except for the first site, which was the access road in 1985 and the entrance in 2019. The access road encompasses the entrance and represents an overall wider area. These sites are thus different but nonetheless geographically close and similar in human interference and proximity to water. The 2019 also included one additional site: the border of the forest situated right outside the park. For the purpose of comparison, by excluding this data we find 76 identified species in 2019, sampled in 6 hours. If we account for this difference in sampling time, we estimate the 1985 would have sampled approximately 60 species in 6 hours. However, it is important to note that this estimation cannot account for the time of day at which the sampling is done, and thus is not necessarily accurate. Bird activity is highest in the morning (Robbins, 1981), and there are very few species found at night. All of the sampling done in the 2019 study was conducted between 6:30 and 7:30 AM, whereas the 1985 study was conducted throughout the entire day. Therefore, we are certainly underestimating how many bird species Ridgely and Gwynne would have found in a 7-hour morning sampling 34 years ago.

If the estimation is accurate by more or less 15 species, then it can be said that overall bird species richness within the park has remained more or less constant over the past 34 years. This is different from global patterns, which have seen drops in population numbers and declines in population range sizes (Lundmark, 2006). This would indicate that avian conservation efforts have been successful in Soberania.

Looking at the species composition at each site for both studies, we notice that some species are present at multiple locations, while others can only be found in certain spots. When a large number of species only exist within a specific area, this increases its ecological importance within the region (Montanez *et al.*, 2007). For clarity, in this paper we will call species that are only found in one site ‘’unique species’’. In the 2019 edition of the study, 16 species were found nowhere other than at the lake, which was more than any other site. The forest border and the tower both had 12 unique species (5 above the tower and 7 below), the trail had 8, the entrance had 7, and the visitor’s center had the least, with only one. In the 1985 edition, the tower was the site with the most unique species, 46. The lake had the second most, with 29 unique species. The trails had 15, the access road had 5 and the Visitor’s Center had the least, 4.

The Visitor’s Center is consistently the site with the lowest number of unique species. Considering that this is also the site where you can find bird feeders, planted heliconia, and other flowers, it is quite possible that in their efforts to create an environment suitable for hummingbirds, the environment became less attractive to other species. Hummingbirds are notoriously territorial birds. Research has shown that this behaviour tends to be reinforced when floral abundance, and as a result population abundance, is high (Justino *et al.*, 2011). Food is consistently present at the visitor’s center in the bird feeders, and in high amounts, which likely promotes territoriality. Because the species found at the visitor’s center are, for the most part, also found elsewhere in the park, it can be said that this site has low ecological importance for bird biodiversity.

The site with the least amount of ‘’unique species’’ has remained constant over the two studies, but that is not the case for the one with the most. The tower counted many more than the other sites back in 1985, but not in 2019, when the lake had the most. We do not know the time of year at which the 1985 study was conducted, which means this may be a factor. If it was done at a time when migratory species are abundant, likely these would have been observed more readily from the tower, and nowhere else in the park. Apart from this, even in the 1985 study, the lake had a high number of species unique to its area, which tells us of its high ecological importance. The lake environment is very different from the other sites in terms of its plant diversity, its potential food sources and the access to water. We could therefore expect that some species would be adapted to this habitat and nowhere else.

Discussion of Statistical Results

While bird diversity is well documented at the Rainforest Discovery Center, little is known about the relationship between the vegetative composition of the forest and its avian inhabitants. There is also little information on the effects of abiotic factors, such as proximity to water and human disturbance on birds at the Rainforest Discovery Center. Correlation analyses were carried out comparing species richness and bird abundance with distance from water, canopy cover, and presence of fruiting plants and trees; the results are discussed in the following section. Results related to species richness and abundance per site can be found in table 4. Abundance of birds per site has also been mapped in figures 3 and 4.

Figure 3. Shows bird abundance at study sites 1-6. The size of the circle indicates abundance, where a larger circle indicates higher abundance.

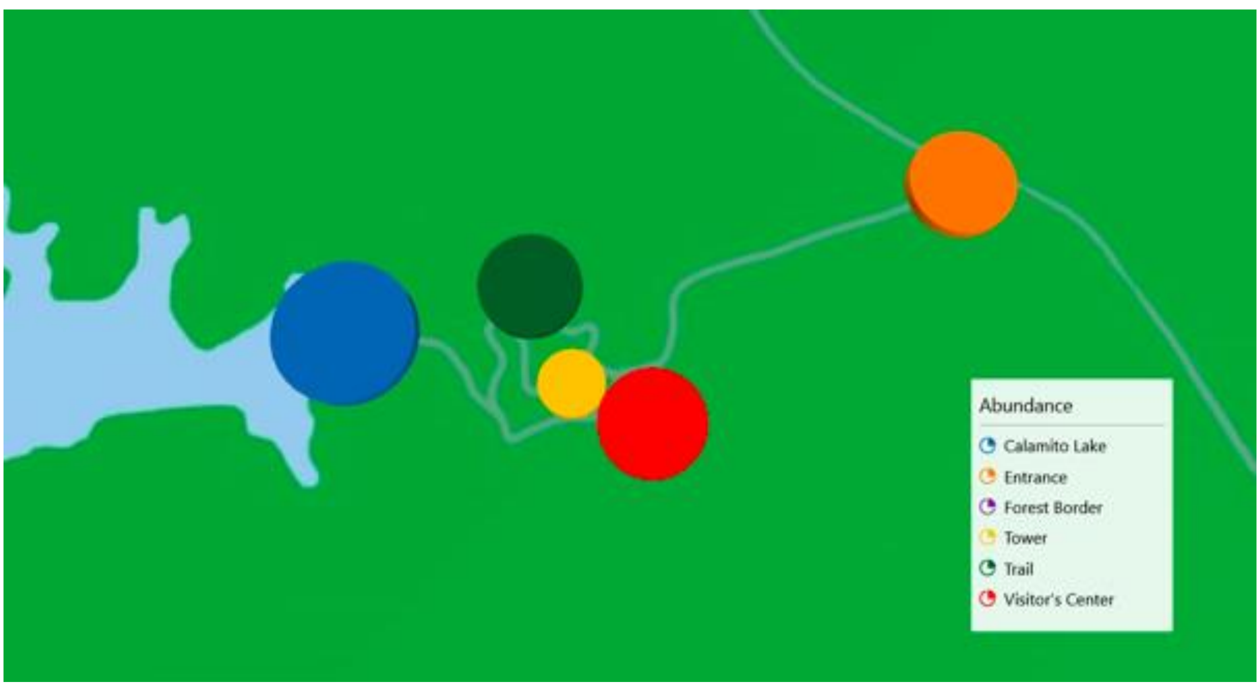
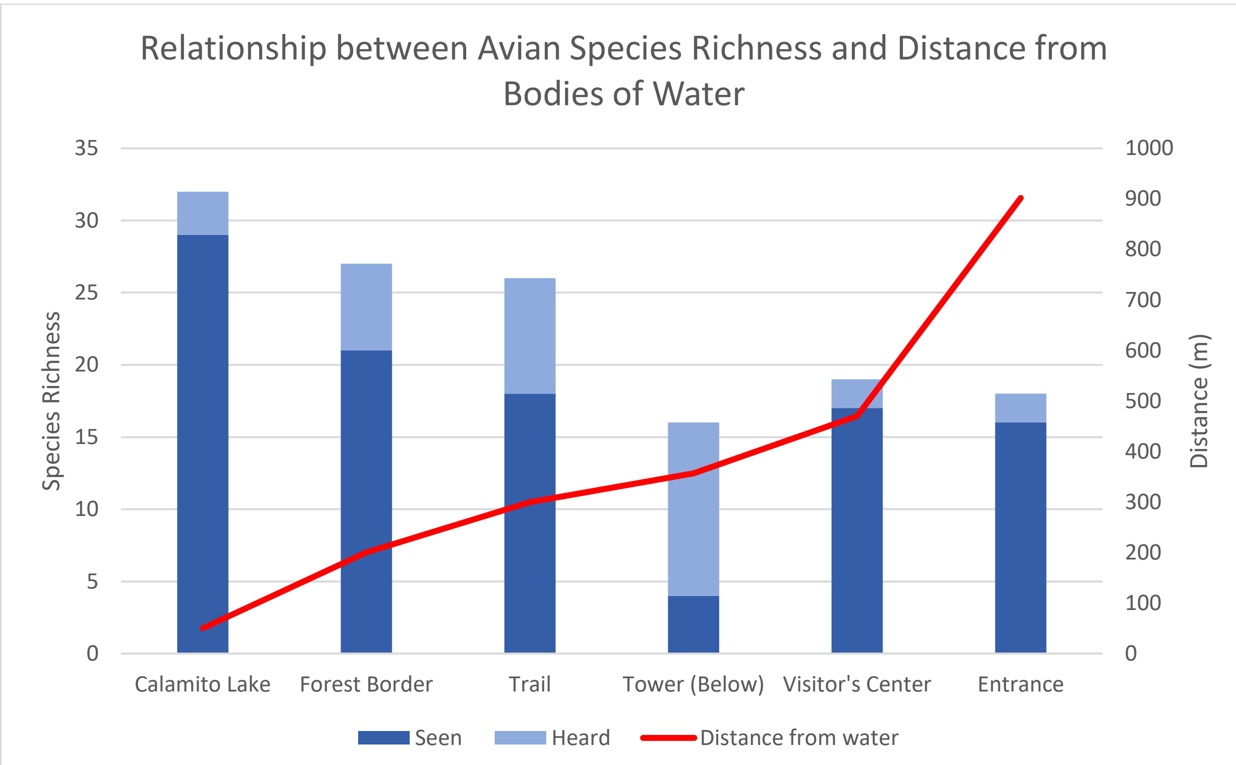


Figure 3a. A close up of bird abundance at sites within the grounds of the RDC 1-5. Site six (forest border) is excluded from this figure.

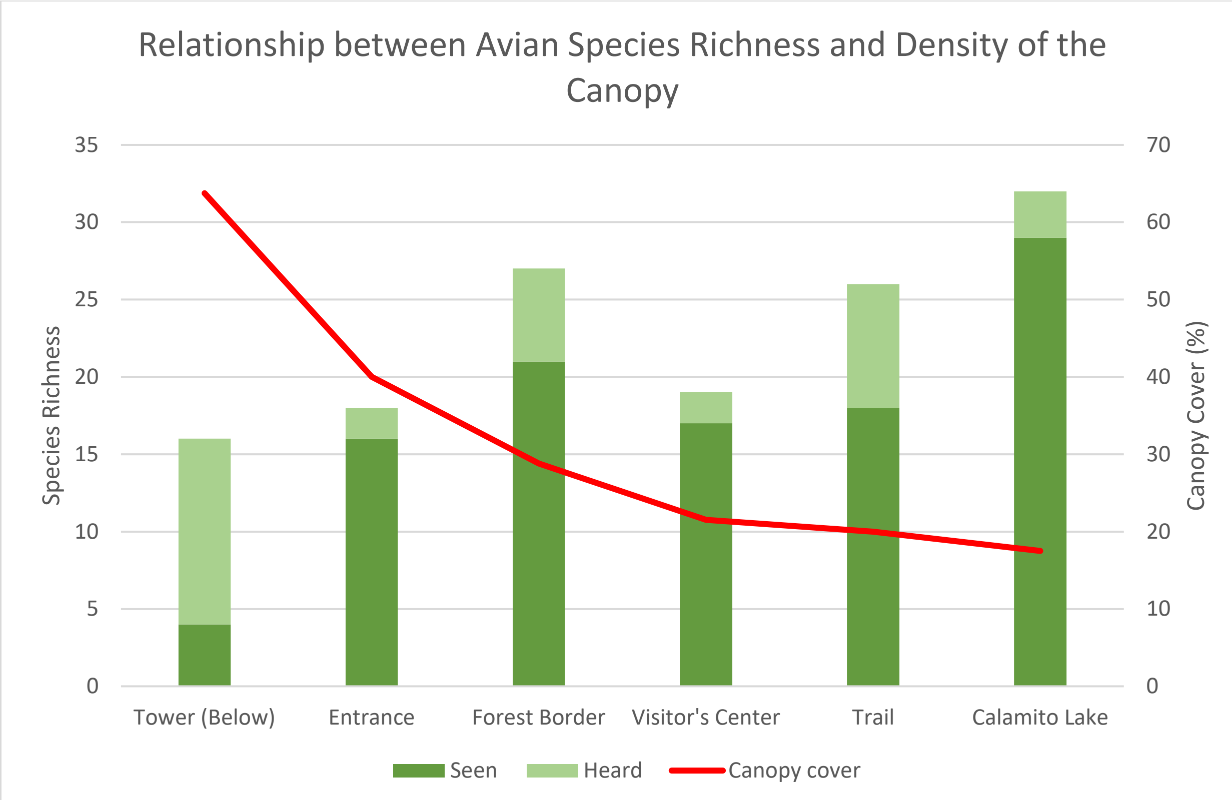
We found that species richness and distance from water had a strong negative correlation (r = -0.7349), while there was only a weak negative correlation between bird species abundance and distance from water. This indicates that avian species richness increased the closer a site was to a body of water, but the overall number of individuals observed was unaffected.



Graph 1. Species richness per site and its relationship with the site's distance from the nearest body of water, ranked from 50 to 900m from water.

One possible explanation for this is increased habitat diversification at locations near water. Sites like Calamito Lake (site 4) and the Forest Border (site 6), which had the highest avian species richness (graph 1), encompassed both marsh and tropical rainforest ecosystems. While sites with the lowest bird diversity, such as the Tower (site 3) and Entrance (site 1), had more homogeneous landscapes, comprised of old-growth tropical rainforest. The most abundant families at the Entrance were Thraupidae (Tanagers) and Thamnophilidae (Antbirds), which are primarily granivorous, frugivorous or insectivorous species (Nazaro et Blendinger 2017; Isler et al. 2014). Similarly, at the Tower the dominant family was Thamnophilidae. No piscivorous taxa were documented at either site. At the Lake and Forest Border Thraupidae and other Passeriformes were present in similar abundance to the other sites (appendix 1). However, new taxa, not observed at the other sites were also present at the Lake and Forest Border. Two Ringed Kingfishers (*M. torquata*), a primarily piscivorous species (Bitterman 2012), were observed at the Forest Border. At Calamito Lake Ardeidae (herons) and Anhingidae (snakebirds), carnivorous families that primarily feed on fish, crustaceans and aquatic vertebrates (Henry et Cumming 2016), were recorded. Families typically associated with wetlands, such as Rallidae (rails) and Jacanidae (jacanas) were also present at Calamito Lake (Henry et Cumming 2016). Thus, habitat diversification at sites closer to water, which promotes the coexistence of both aquatic and terrestrial bird species, is likely to contribute to higher avian species richness at these sites.

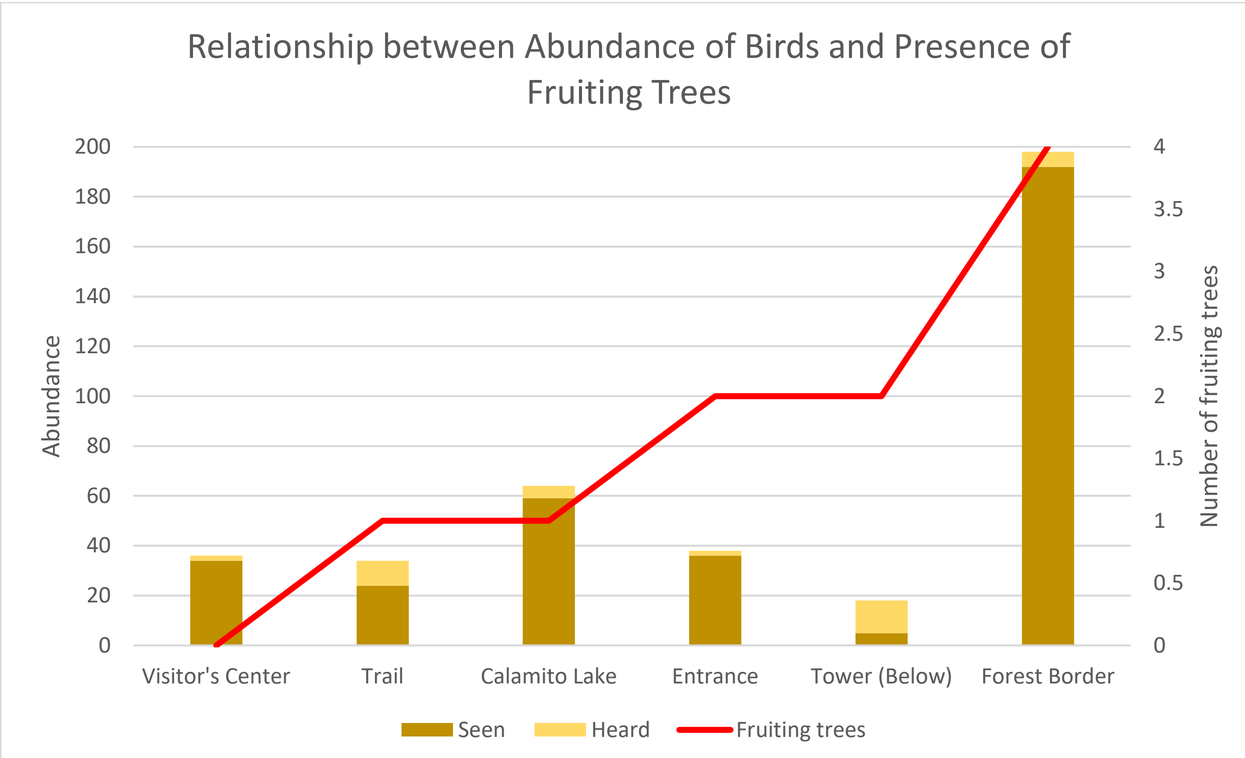
As seen in graph 2, a negative correlation (r = -0.7262) was observed between species richness and mean canopy cover of each site; as average canopy cover at each site increased avian species richness decreased.



Graph 2. Species richness per site and its relationship to the average percent canopy cover at the site.

The relationship between bird abundance and canopy cover was weak (r = -0.2630), indicating bird abundance at each site was independent of overall canopy cover. The Tower had the highest canopy cover, at almost 64%, but had the lowest avian abundance and diversity. Sites with the highest bird diversity, including the Lake, Gap and Trail had lower average canopy cover (17.5%, 40% and 20% respectively). Our findings contradict a study by Nadkarni (1994), which suggested that canopy contributes to avian diversity in tropical ecosystems. Fruiting canopy trees and plants are an essential food source, promoting diversity and abundance in frugivorous bird species. While the canopy itself provides shelter and materials for nest building (Nadkarni 1994). Canopy stratification creates a diverse landscape, which also promotes avian diversity (Pearson 1971). Avian families most frequently documented using canopy resources include Thraupidae (tanagers), Trochilidae (hummingbirds), Furnariidae (ovenbirds) and Tyrannidae (flycatchers) (Nadkarni 1994). In our study, Tyrannidae and Furnariidae were documented at sites with high canopy cover (Tower) and low canopy cover (Trail, Forest Border). Surprisingly, Thraupidae were observed at all sites except the canopy tower bottom. Tanagers were consistently one of the most diverse families, averaging around 3 species per site. The absence of tanagers at the Tower may have contributed to the low species diversity observed at this site. One limitation of our study is that it only considered overall canopy cover, and did not explore in detail the presence and density of epiphytes, vines and lianas at each site. Nadkarni (1994) defined "canopy" as "...the combination of all foliage, twigs, fine branches, epiphytes (plants growing upon other plants) as well as the interstices (air) in a forest [crown]." (Nadkarni 1994). Thus, canopy ecosystems are composed not only of tall emergent tree species, but also of the epiphytic species that reside within them. Arboreal epiphytes play essential roles in community canopy interactions. Rainfall stored in canopy epiphytes can serve as a water source for birds, and an arboreal nursery for certain species of insect larvae (Nadkarni 1994). Organic materials from epiphytes, including leaves, fruits and flowers are used for nest building in many bird species (Nadkarni 1994). Further research comparing epiphyte diversity and abundance at each site with avian species richness would need to be conducted to better understand the complex relationship between bird richness and forest canopy at the Panama Rainforest Discovery Center. It should be noted that the Lake and Gap sites also had the highest proximity to water (graph 1), which may also have influenced the observed avian diversity. Thus, repeating this experiment with sites of varying canopy cover at equidistance from a body of water might allow us to better understand the trends being observed.

There was a strong positive correlation ($r = 0.7671$) between bird abundance and number of fruiting tree species at each site, whereas there was only a very weak positive relationship (r = 0.0935) between bird diversity and presence of fruiting tree species. This indicates that more individuals were observed at sites with a greater presence of fruiting tree species, but species richness was unaffected.



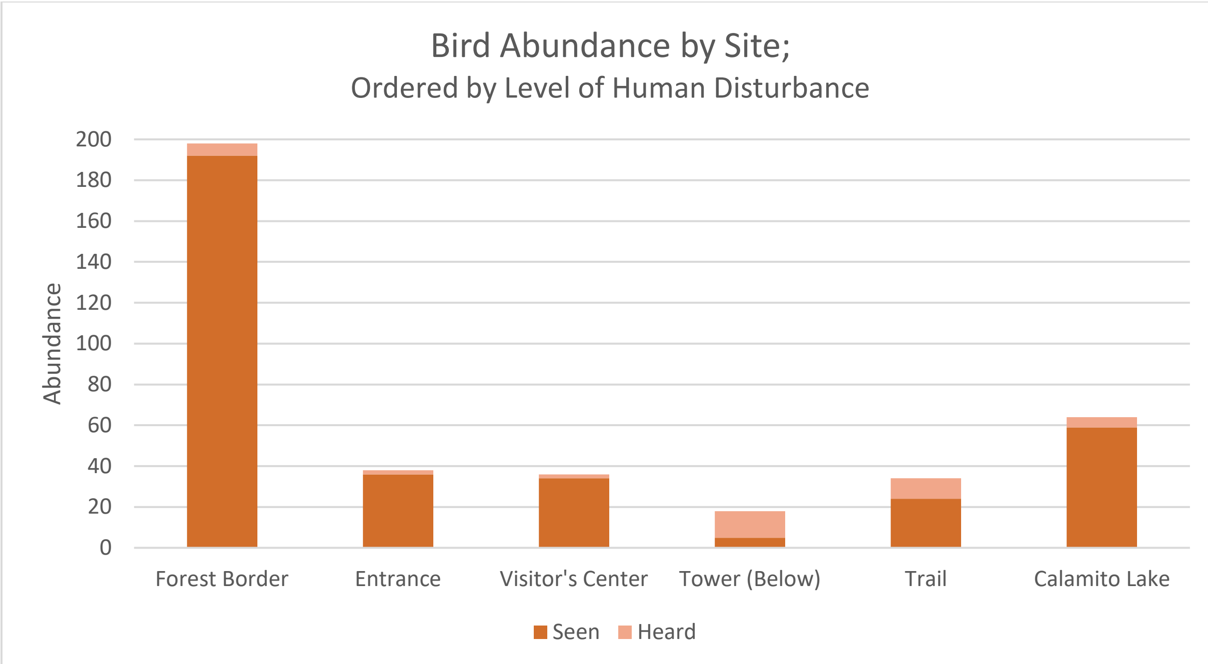
Graph 3. Abundance of birds observed per site and their relationship to the amount of fruiting trees found in the area.

There was also a strong positive relationship (r = 0.6381) between avian abundance and total number of fruiting plant species (including trees, lianas, vines and understory plants) at each site. A study on tropical forests in Australia found that there was higher avian abundance at sites with more fruiting plant species (Kanowski et al. 2005). Fleshy-fruited trees were of particular significance, as they are most commonly dispersed by birds (Kanowski et al. 2005). In our study at the Panama Rainforest Discovery center, sites with the highest bird abundance also had the highest presence of fleshy-fruited species. Currently fruiting tree species *F. insipida*, *M. calabura* and *M. argentea* were documented at the Forest Border, which had the highest overall bird abundance (graph 3). While sites with low bird abundance such as the Visitor's Center and the Belvedere Trail had either very few or no fruiting species. Two sites that did not follow this trend were Calamito Lake and the Tower (site 3a). The Lake had the second highest species abundance but no fruiting tree species; however this may be attributed to the sites proximity to water. A large proportion of the individuals recorded were piscivorous species and thus independent of fruiting tree presence (Henry et Cumming 2016). Although fruiting tree species *A. excelsum* and *F. insipida* were recorded at the Tower, the site had the lowest species abundance. It should be noted that both fruiting tree species were large emergent trees and that overall canopy cover was greater at the Tower than any other site (graph 2). Thus, visibility of birds present in the upper canopy was greatly reduced at this site. To circumvent this issue, an additional bird survey was conducted from the top of the Canopy Tower (site 3b). In one hour 26 individuals belonging to 15 species were recorded. While abundance at the tower top was still low relative to the other sites, it was significantly higher than the 14 individuals observed from the bottom of the tower.

The Shannon-Wiener diversity index incorporates both species richness and evenness. While the Lake site did not have a large species richness value its Shannon-Wiener index was high (3.055), this indicates there was significant species richness at the site. Of the 55 individuals, belonging to 32 species, observed at Calamito lake one species, the Smooth-Billed Ani, was seen 14 times (appendix 1); this likely contributed to the site's low species evenness value. The Entrance, Tower and Belvedere Trail all had very high species evenness (0.9482, 0.9869 and 0.9802 respectively). At the Visitors Center species evenness was slightly lower, at 0.8629. At the Visitors Center, we observed numerous species of fruiting flowers, including 2 species of heliconia and 1 species of passionflower. From interviews with staff at the RDC we determined that these flowering plants were not native to the site, but were planted to attract pollinating bird species, namely hummingbirds. Indeed, a strong link exists between hummingbirds (Trochilidae) and coevolved flowering plants such as heliconias (Dziedzioch et al. 2003). Of the 26 individuals seen at the Visitors Center 10 were hummingbirds (from 4 species). The abundance of flowering plants at the Visitors Center may explain the disproportionate number of hummingbirds seen at the site, and likely contributed to the site's low species evenness value. As mentioned previously, artificial hummingbird feeders, containing a sugar-water solution, were also installed at the Visitors Center. These feeders likely had a significant influence on the abundance of hummingbirds present at the site. Although the Forest Border had high species richness its overall Shannon-Wiener diversity index was low ($H = 1.390$) due to extremely poor species evenness ($E_h = 0.4218$) at the site. The strikingly low species evenness observed can probably be attributed to large flocks of migrating birds recorded during the survey. In total, 131 individuals of the same morphospecies were seen in one hour; this represents more than two-thirds of the 180 individuals observed during the Forest Border survey.

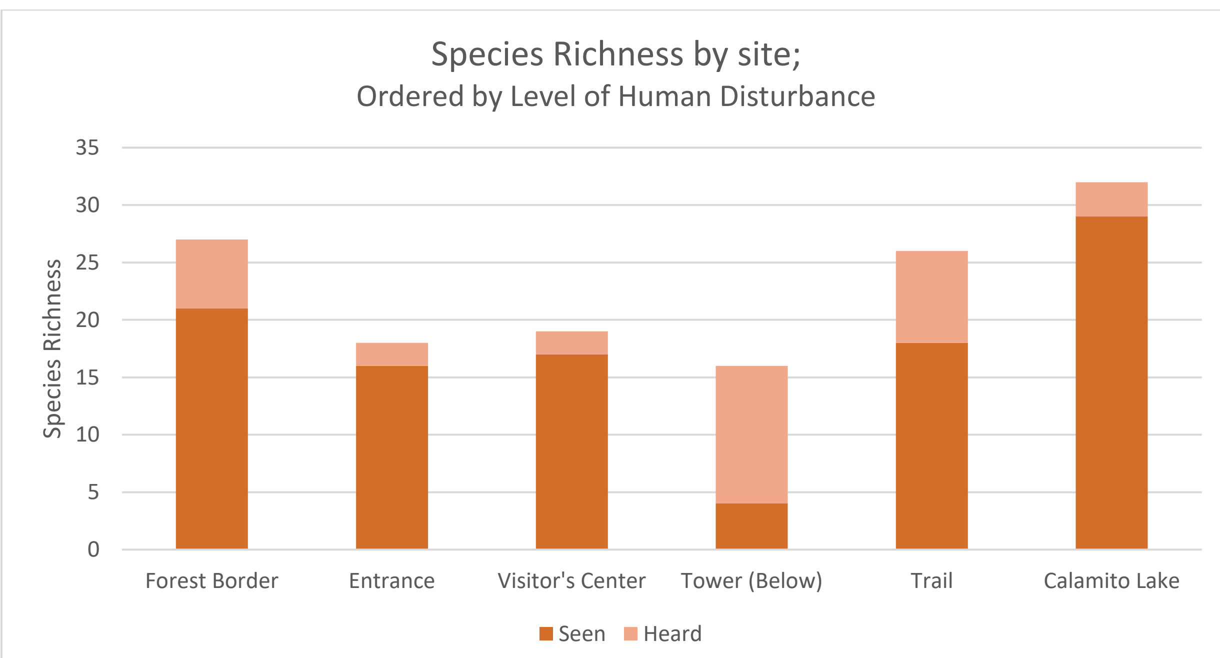
Discussion of Qualitative Data

Finally, our study examined the effect of human impact on bird diversity and abundance at the Rainforest Discovery Center. The degree of human impact at each site was not a quantifiable variable, thus it was not possible run correlation analyses. However, based on metadata and personal observations, it was possible to rank the sites from highest to lowest human disturbance.



Graph 5. Abundance at all sites, sites are ranked from highest to lowest human disturbance.

The Forest Border site was determined to have the highest degree of human impact, interestingly it also had the highest abundance.



Graph 6. Species richness at all sites, sites are ranked from highest to lowest human disturbance.

The least disturbed site, Calamito lake, had the highest species diversity. Interestingly, the Forest Border, which had the most significant human impact, had the second highest bird species diversity.

These results are difficult to interpret. What explains high avian diversity and abundance in sites with significant human disturbance? In fact, human impacted areas have been shown to support high bird diversity. A study by Gatesire et al. (2014) in Rwanda found that there was greater bird species richness in human impacted areas than in surrounding protected forests. The experiment took place in northern Rwanda, and compared avian species richness in various urban environments with a nearby protected area. They found that not only was species richness higher in urban areas, but there was also a high presence of endemic and migratory species, which hold high ecological importance in the area. However, while human impacted areas may support high avian species richness, a loss of phylogenetic diversity may still be occurring. A study by Frishkoff et al. (2014) in Costa Rica found that only 15% of bird species richness was lost in diversified agricultural systems compared to forest reserves. However, species in human impacted areas were more likely to be related to each other (Frishkoff et al. 2014). Certain clades are more likely to thrive in disturbed environments, particularly those already adapted to open environments, like shrubland or waterways (Frishkoff et al. 2014). While evolutionarily distinct species, with few extant relatives, are more likely to become locally extinct in human impacted areas (Frishkoff et al. 2014). Granivorous species and generalists are more likely to persist in agricultural areas (Frishkoff et al. 2014). Being small in size and having a large clutch size are also factors that increase survival in human disturbed environments (Frishkoff et al. 2014). The taxa most commonly observed in agricultural landscapes are Columbidae (pigeons), Thraupidae (tanagers) and Hirundinidae (swallows) (Frishkoff et al. 2014). While Trogonidae (trogons), Thamnophilidae (antbirds), Parulidae (ovenbirds) and Pipridae (manakins) are associated with forests (Frishkoff et al. 2014). Indeed, in our study more disturbance-affiliated species were observed at sites with high human impact. At the Forest Border 6 species of tanagers were recorded, compared to 3 species of tanager at Trail and 2 species at the Lake. A greater diversity of forest-affiliated species were also observed at more undisturbed sites, 2 species of trogon were observed at the Lake while only one species (*T. massena*) was seen at the Forest Border and Visitors Center. The only species of ovenbird (*P. noveboracensis*) was observed at the Lake, the least impacted site. The effect of human disturbance on ecosystem health is also reflected in the Shannon-Wiener diversity index and species evenness of the most disturbed site, the Forest Border. Although the Forest Border had high avian abundance and species richness, it had a very low diversity index (E_h = 0.4218). It should be noted that the Forest Border was also the only site where a large flock passerine birds (over 100 individuals total) was observed. While this observation may have been completely random, it's also possible the flock consisted of disturbance-associated species, and thus this abnormality could not be discounted. Based on the literature, and our own findings one trend is clear, although disturbed sites can support large populations, the overall diversity of these populations is reduced. Ultimately the protection of intact tropical forests, like those at the Rainforest Discovery Center, have an important role to play in preserving avian diversity and protecting vulnerable species.

Conclusion

The Panama Rainforest Discovery Center provides a unique environment to assess avian populations in the Soberania National Park. Located in the Canal Zone, one of the most significant areas for bird diversity in Panama, the RDC is home to over 400 species of birds (eBirds, 2019). The site encompass a number of unique ecosystems, including wetland and old-growth humid tropical forest. These pristine ecosystems provide excellent conditions for collecting data on forest-associated taxa. Signs of human disturbance are also present at the RDC; deforested areas and forest borders present unique environments to study the effect of human impact on avian abundance and diversity. Our study involved the completion surveys on avian abundance and richness at six unique locations at the RDC, and compared these surveys with the biotic and abiotic characteristics of each site. For a start, we found that bird species richness had likely remained stable since 1985. In addition, while none of our correlations analyses held statistical significance, we did obtain a number of strong correlation values. We found a strong negative correlation between bird diversity and distance from water, which is possibly linked to habitat diversification at sites closer to a body of water. There was a strong positive correlations between bird abundance and sites with a high presence of fruiting trees and plants. The presence of fruit likely encourages frugivorous bird abundance. Continued research, with a larger sample size (n), needs to be done at the Rainforest Discovery Center to determine if there are any statistically significant relationships between the biotic and abiotic characteristics of the parks diverse sites and the abundance and diversity of its avian inhabitants.

Species richness was high at both the most human impacted (site 6) and least impacted (site 5) locations. However, species evenness was significantly lower at the Lake (site 5). The lake also had the lowest Shannon-Wiener diversity index while less disturbed areas, like the Lake and Trail, had the highest diversity index. This indicates that although bird abundance and species richness appear to be unaffected by human disturbances at the Rainforest Discovery Center, the overall diversity index declines in significantly impacted areas. Furthermore, while impacted areas like the Forest Border support disturbance tolerant taxa, such as tanagers and swallows, forest-associated species and evolutionarily distinct taxa are more likely to become extirpated. In our surveys 2 species ranked by the IUCN as near threatened were observed at the RDC, in areas of low human impact.

Therefore, it is clear that areas protected by Soberania National park are indeed valuable for the conservation of more vulnerable species. However, it is important to understand that the act of designating protected areas is not sufficient to preserve biodiversity. The long-term effectiveness of forest protected areas is unclear and many forest-dwelling bird species are not year-long residents of the same region (Brown *et al.*, 2019). There is movement within populations, therefore, larger scale, regional population dynamics are important to consider. Moving forward, it will be necessary to place a greater emphasis on continuing to monitor the changes in environmental composition of protected areas, which is closely related to the health of bird populations.

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Annexe

Annexe 1: Complete list of bird species identified throughout the Rainforest Discovery Center grounds in 2019 with the location at which they were observed. The sampling sites are marked by letters; Entrance (E), Visitor's Center (V), Tower (To), Forest trail (Tr), Calamito Lake (L), Forest Border (B).

Order	Family	Genus	Species	Common name	Status	Location
Suliformes	Anhingidae	*Anhinga*	*anhinga*	Anhinga	LC	L
Accipitriformes	Accipitridae	*Spizaetus*	*melanoleucus*	Black and white hawk-eagle	LC	E
Accipitriformes	Cathartidae	*Coragyps*	*atratus*	Black Vulture	LC	To
Passeriformes	Tyrannidae	*Aphanotriccus*	*audax*	Black-beaked Flycatcher	LC	L
Passeriformes	Cotingidae	*Cotinga*	*nattererii*	Blue Cotinga		E
Passeriformes	Thraupidae	*Dacnis*	*cayana*	Blue Dacnis	LC	E - To - B
Apodiformes	Trochilidae	*Amazilia*	*amabilis*	Blue-Chested Hummingbird	LC	E - V - Tr
Passeriformes	Thraupidae	*Thraupis*	*episcopus*	Blue-Grey Tanager	LC	B
Psittaciformes	Psittacidae	*Pionus*	*menstruus*	Blue-headed Parrot	LC	E - Tr - L
Passeriformes	Tyrannidae	*Attila*	*spadiceus*	Bright-rumped Attila	LC	To
Passeriformes	Thraupidae	*Saltator*	*maximus*	Buff-throated Saltator	LC	B
Passeriformes	Thamnophilidae	*Epinecrophylla*	*fulviventris*	Checker-throated Antwren	LC	Tr
Passeriformes	Thamnophilidae	*Myrmeciza*	*exsul*	Chesnut -backed Antbird	LC	To
Piciformes	Ramphastidae	*Ramphastos*	*ambiguus swainsonii*	Chestnut-mandibeled Toucan		V - To
Passeriformes	Tityridae	*Pachyramphus*	*cinnamomeus*	Cinnamon Becard	LC	Tr
Piciformes	Picidae	*Celeus*	*loricatus*	Cinnamon Woodpecker	LC	To - Tr
Passeriformes	Turdidae	*Turdus*	*grayi*	Clay-colored Thrush	LC	B
Passeriformes	Furnariidae	*Xiphorhynchus*	*susurrans*	Cocoa Woodcreeper	LC	Tr
Piciformes	Ramphastidae	*Pteroglossus*	*torquatus*	Collared Aracari	LC	To
Accipitriformes	Accipitridae	*Geranospiza*	*caerulescens*	Crane Hawk	LC	Tr
Passeriformes	Thraupidae	*Ramphocelus*	*dimidiatus*	Crimson-backed Tanager	LC	V - Tr - L
Columbiformes	Columbidae			Dove sp.		Tr
Passeriformes	Thamnophilidae	*Cercomacroides*	*tyrannina*	Dusky Antbird	LC	To
Passeriformes	Tyrannidae	*Myiarchus*	*tuberculifer*	Dusty-Capped Flycatcher	LC	Tr
Passeriformes	Tyrannidae	*Contopus*	*virens*	Eastern Wood Pewee	LC	B
Trogoniformes	Trogonidae	*Trogon*	*caligatus*	Gartered Trogon		L

Passeriformes	Pipridae	*Manacus*	*vitellinus*	Golden-collared Manakin	LC	V - To - B
Passeriformes	Thraupidae	*Tangara*	*larvata*	Golden-hooded Tanager	LC	Tr - L
Pelecaniformes	Ardeidae	*Ardea*	*alba*	Great Egret	LC	L
Passeriformes	Tyrannidae	*Pitangus*	*sulphuratus*	Great Kiskadee	LC	Tr - L
Caprimulgiformes	Nyctibiidae	*Nyctibius*	*grandis*	Great Potoo	LC	B
Tinamiformes	Tinamidae	*Tinamus*	*major*	Great Tinamou	NT	E
Cuculiformes	Cuculidae	*Crotophaga*	*major*	Greater Ani	LC	L
Passeriformes	Icteridae	*Quiscalus*	*mexicanus*	Great-Tailed Grackle	LC	E
Passeriformes	Thraupidae	*Chlorophanes*	*spiza*	Green Honeycreeper	LC	To
Passeriformes	Vireonidae	*Vireolanius*	*pulchellus*	Green Shrike Vireo	LC	To - Tr - B
Piciformes	Ramphastidae	*Ramphastos*	*sulfuratus*	Keel-billed Toucan	LC	V - L - B
Passeriformes	Tyrannidae	*Philohydor*	*lictor*	Lesser Kiskadee	LC	L
Piciformes	Picidae	*Dryocopus*	*ineatus*	Lineated Woodpecker	LC	E - T
Tinamiformes	Tinamidae	*Crypturellus*	*soui*	Little Tinamou	LC	B
Apodiformes	Trochilidae	*Phaethornis*	*ongirostris*	Long-Billed Hermit	LC	V - L
Passeriformes	Tityridae	*Tityra*	*semifasciata*	Masked Tityra	LC	Tr - L
Psittaciformes	Psittacidae	*Amazona*	*farinosa*	Mealy Parrot	NT	L
Passeriformes	Parulidae	*Parkesia*	*noveboracensis*	Northern Waterthrush	LC	L
Psittaciformes	Psittacidae	*Brotogeris*	*jugularis*	Orange-chinned Parakeet	LC	To - Tr - B
Columbiformes	Columbidae	*Patagioenas*	*cayennensis*	Pale-vented Pigeon	LC	To - L
Passeriformes	Thraupidae	*Thraupis*	*palmarum*	Palm Tanager	LC	B
Passeriformes	Tyrannidae	*Legatus*	*leucophaius*	Piratic flycatcher	LC	E - L
Passeriformes	Furnariidae	*Xenops*	*minutus*	Plain Xenops	LC	To
Passeriformes	Furnariidae	*Dendrocincla*	*fuliginosa*	Plain-brown Woodcreeper	LC	V
Passeriformes	Thraupidae	*Tangara*	*inornata*	Plain-colored Tanager	LC	E - V - B
Gruiformes	Rallidae	*Porphyrio*	*martinicus*	Purple Gallinule	LC	L
Psittaciformes	Psittacidae	*Amazona*	*viridigenalis*	Red-Crowned Parrots	EN	To
Piciformes	Picidae	*Melanerpes*	*rubricapillus*	Red-Crowned Woodpecker	LC	Tr - B
Passeriformes	Vireonidae	*Vireo*	*olivaceus*	Red-Eyed Vireo	LC	Tr
Passeriformes	Thraupidae	*Cyanerpes*	*cyaneus*	Red-legged Honeycreeper	LC	To
Psittaciformes	Psittacidae	*Amazona*	*autumnalis*	Red-Lored Parrot	LC	E - V - To - Tr - L - B

Coraciiformes	Alcedinidae	*Megaceryle*	*torquata*	Ringed Kingfisher	LC	B
Passeriformes	Tityridae	*Terenotriccus*	*erythrurus*	Ruddy-tailed Flycatcher	LC	Tr
Apodiformes				Ruddy-tailed Hummingbird		B
Coraciiformes	Momotidae	*Baryphthengus*	*martii*	Rufous Motmot	LC	B
Pelecaniformes	Ardeidae	*Tigrisoma*	*lineatum*	Rufuscent Tiger Heron	LC	L
Columbiformes	Columbidae	*Patagioenas*	*squamosa*	Scaly Pigeon	LC	V - To - Tr - L
Passeriformes	Icteridae	*Cacicus*	*uropygialis*	Scarlet-rumped cacique	LC	E - V - L - B
Passeriformes	Thraupidae			Shining Honeycreeper	LC	To
Columbiformes	Columbidae	*Patagioenas*	*nigrirostris*	Short-billed Pigeon	LC	V - L
Trogoniformes	Trogonidae	*Trogon*	*massena*	Slaty-tailed Trogon	LC	V - To -L
Cuculiformes	Cuculidae	*Crotophaga*	*ani*	Smooth-billed Ani	LC	L
Accipitriformes	Accipitridae	*Rostrhamus*	*sociabilis*	Snail Kite	LC	L
Passeriformes	Tyrannidae	*Myiozetetes*	*similis*	Social Flycatcher	LC	Tr - L
Passeriformes	Thamnophilidae	*Hylophylax*	*naevioides*	Spotted Antbird	LC	To
Passeriformes	Tyrannidae			Street Flycatcher		Tr
Pelecaniformes	Ardeidae	*Butorides*	*striata*	Striated heron	LC	L
Passeriformes	Furnariidae	*Automolus*	*subulatus*	Striped Woodhaunter	LC	E
Trogoniformes	Trogonidae			Trogon sp.		B
Passeriformes	Tyrannidae	*Tyrannus*	*melancholicus*	Tropical Kingbird	LC	To - L - B
Accipitriformes	Cathartidae	*Cathartes*	*aura*	Turkey Vulture	LC	To - B
Apodiformes	Trochilidae	*Damophilia*	*julie*	Violet-bellied hummingbird	LC	E - V
Charadriiformes	Jacanidae	*Jacana*	*jacana*	Wattled Jacana	LC	L
Passeriformes	Thamnophilidae	*Thamnophilus*	*atrinucha*	Western Slaty-Antshrike	LC	E
Passeriformes	Thraupidae	*Tachyphonus*	*luctuosus*	White shouldered tanager	LC	E - Tr - B
Passeriformes	Thamnophilidae	*Myrmotherula*	*axillaris*	White-flanked Antwren		E
Apodiformes	Trochilidae	*Florisuga*	*mellivora*	White-Necked Jacobin	LC	V - Tr
Piciformes	Bucconidae	*Notharchus*	*hyperrhynchus*	White-necked Puffbird	LC	V - To
Gruiformes	Rallidae	*Laterallus*	*albigularis*	White-throated crake	LC	L
Columbiformes	Columbidae	*Leptotila*	*verreauxi*	White-tipped Dove	LC	To
Passeriformes	Furnariidae			Woodcreeper sp.		B
Passeriformes	Tyrannidae	*Tyrannulus*	*elatus*	Yellow-Crowned Tyranulet	LC	L

Annexe 2: Complete list of bird species identified throughout the Rainforest Discovery Center grounds in 2019 with the location at which they were observed.

	English Name **Ridgely and Gwynne / Panama Audubon Society**	Scientific Name **Ridgely and Gwynne / Panama Audubon Society**	Spanish Name	Status **C: Common U: Uncommon R: Rare**	Location **AR: Access Road OT: Observation Tower VC: Visitor's Center CL: Calamito Lake T: Trails**
	TINAMOUS	**TINAMIDAE**	**TINAMUES**		
1	Great Tinamou	*Tinamus major*	Tinamú Grande	C	AR-T
2	Little Tinamou	*Cryptorellus soui*	Tinamú Chico	C	AR-VC-T
	DUCKS, SWANS AND GEESE	**ANATIDAE**	**PATOS, GANSOS Y CISNES**		
3	Black-bellied Whistling Duck	*Dendrocygna autumnalis*	Pato Silbador Aliblanco	C	CL
4	Muscovy Duck	*Cairina moschata*	Pato Real	R	CL
5	Masked Duck	*Oxyura dominica*	Pato Enmascarado	R	CL
	CURASSOWS, GUANS AND CHACHALACAS	**CRACIDAE**	**PAVONES,PAVAS Y CHACHALACAS**		
6	Gray-headed Chachalaca	*Ortalis cinereiceps*	Chachalaca Cabecigris	C	OT-AR-T
7	Great Curassow	*Crax rubra*	Pavón Grande	R	AR-T
	PHEASANTS,GROUSE,TURKEYS AND QUAIL	**PHASIANIDAE**	**FAISANES, PAVOS Y CODORNICES**		
8	Marbled Wood-Quail	*Odontophorus gujanensis*	Codorniz Jaspeada	R	T
	GREBES	**PODICIPEDIDAES**	**ZAMBULLIDORES**		
9	Least Grebe	*Thachibaptus dominicus*	Zambullidor Menor	U	CL
10	Pied-billed Grebe	*Podilymbus podiceps*	Zambullidor Piquipinto	U	CL
	PELICANS	**PELICANIDAE**	**PELICANOS**		
11	Brown Pelican	*Pelecanus occidentalis*	Pelicano Pardo	C	CL-OT
	CORMORANTS	**PHALACROCARACIDAE**	**CORMORANES**		
12	Neotropic Cormorant	*Phalacrocorax olivaceus/ Phalacrocorax brasilianus*	Cormorán Neotropical	C	CL-OT
	DARTERS	**ANHINGIDAE**	**ANINGAS**		
13	Anhinga	*Anhinga anhinga*	Aninga	C	CL-OT
	FRIGATEBIRDS	**FREGATIDAE**	**FRAGATAS**		
14	Magnificent Frigatebird	*Fregata magnificens*	Fragata magnifica	C	CL-OT
	HERONS	**ARDEIDAE**	**GARZAS**		
15	Least Bittern	*Ixobrychus exilis*	Mirasol Menudo	C	CL
16	Rufescent Tiger-Heron	*Tigrisoma lineatum*	Garza Tigre Castaña	U	CL
17	Fasciated Tiger-Heron	*Trigrisoma fasciatum*	Garza Tigre Barreteada	R	CL
18	Bare-Throated TigerHeron	*Trigrisoma mexicanum*	Garza Tigre Cuellinuda	U	CL
19	Great Blue Heron	*Ardea herodias*	Garza azul Mayor	U	CL
20	Snowy Egret	*Egreta thula*	Garceta Nívea	U	CL
21	Little Blue Heron	*Egreta caerulea*	Garza azul chica	C	CL
22	Tricolored Heron	*Egretta Tricolor*	Garza Tricolor	R	CL
23	Cattle Egret	*Bubulcus ibis*	Garzeta Bueyera	U	CL

24	Green-backed Heron/ Green Heron	*Butorides virescens/ Butorides virescens*	Garza Dorsiverde/ Garza Verde	C	CL
25	Green-backed Heron/	*Butorides striatus*	Garza Listada	R	CL
	STORKS	**CICONIIDAE**	**CIGÜEÑAS**		
26	Wood Stork	*Mycteria americana*	Cigüeña americana	U	CL-OT
	VULTURES	**CATHARTIDAE**	**GALLINAZOS**		
27	Black Vulture	*Coragyps atratus*	Gallinazo negro	C	CL-OT
28	Turkey Vulture	*Cathartes aura*	Gallinazo Cabecirrojo	C	CL-OT
29	King Vulture	*Sarcoramphus papa*	Gallinazo Rey	R	OT
	HAWKS, EAGLES AND KITES	**ACCIPITRIDAE**	**GAVILANES, ÀGUILAS Y ELANIOS**		
30	Osprey	*Pandion haliaetus*	Águila Pescadora	C	OT-CL
31	Gray -headed Kite	*Leptodon cayanensis*	Elanio Cabecigris	U	OT-T-AR
32	Hook-billed Kite	*Chondrohierax uncinatus*	Elanio Piquiganchudo	R	OT
33	American Swallow-tailed Kite/ Swallow-tailed Kite	*Elanoides furficatus*	Elanio Tijereta	U	OT
34	Snail Kite	*Rostrhamus sociabilis*	Elanio Caracolero	C	OT-CL
35	Double-toothed Kite	*Harpagus bidentatus*	Elanio Bidentado	U	OT
36	Mississippi Kite	*Ictinia mississippiensis*	Elanio Migratorio	U	OT
37	Tiny Hawk	*Accipiter superciliosus*	Gavilán Enano	R	OT-VC
38	Plumbeous Hawk	*Leucopternis plumbea/ Leucopternis plumbeus*	Gavilán Plomizo	R	OT
39	Semiplumbeus Hawk	*Leucopternis semiplumbea/ Leucopternis semiplumbeus*	Gavilán Dorsiplomizo	U	OT-AR
40	White Hawk	*Leucopternis albicollis*	Gavilán Blanco	R	OT
41	Gray Hawk	*Asturina nitidus*	Gavilán Gris	R	OT
42	Common Black-Hawk	*Buteogallus anthracinus*	Gavilán Cangrejero	U	OT
43	Great Black-Hawk	*Buteogallus urubitinga*	Gavilán Negro Mayor	R	OT
44	Ornate Hawk-Eagle	*Spizaetus ornatus*	Aguilillo Adornado	R	OT
45	Broad-winged Hawk	*Buteo platypterus*	Gavilán Aludo	U	OT
46	Short-tailed Hawk	*Buteo brachyurus*	Gavilán Colicorto	R	OT
47	Swainson's Hawk	*Buteo swainsoni*	Gavilán de Swainson	R	OT
48	Harpy Eagle	*Arpia harpyja*	Águila Harpìa	R	OT-AR-T
49	Black Hawk-Eagle	*Spizaetus tyrannus*	Aguilillo Negro	U	OT
	FALCONS AND CARACARAS	**FALCONIDAE**	**HALCONES Y CARACARAS**		
50	Slaty-baked Forest-Falcon	*Micrastur mirandollei*	Halcón-Montés Dorsigris	R	OT
51	Collared Forest Falcon	*Micrastur semitorquatus*	Halcón Montes Collarejo	U	OT
52	Yellow-headed Caracara	*Milvago chimachima*	Caracara Cabeciamarilla	U	OT-AR
53	American Kestrel	*Falco sparverus*	Cernícalo americano	U	OT
54	Merlín	*Falco columbarius*	Merlín	R	OT
55	Bat Falcon	*Falco rufigularis*	Halcón cazamurciélago	U	OT-AR
56	Peregrine Falcon	*Falco peregrinus*	Halcón Peregrino	R	OT
	RAILS, GALLINULES AND COOTS	**RALLIDAE**	**RASCONES,POLLAS Y GALLARETAS**		
57	Gray-necked Wood-Rail	*Aramides cajanea*	Rascón Montés Cuelligris	U	AR-T
58	Purple Gallinule	*Porphyrula martinica/ Porphyrio martinica*	Gallareta Morada	C	CL
59	Common Moorhen	*Gallinula chloropus*	Gallareta Frentirroja	C	CL
	FINFOOTS	**HELIORNITHIDAE**	**AVES-SOLES**		

60	Sungrebe	*Heliornis fulica*	Zambullidor Sol	R	CL
	LIMPKIN	**ARAMIDAE**	**CARRAO**		
61	Limpkin	*Aramus guarauna*	Carrao	R	CL
	JACANAS	**JACANIDAE**	**JACANAS**		
62	Wattled Jacana	*Jacana jacana*	Jacana curunculada	C	CL
	PIGEONS AND DOVES	**COLUMBIDAE**	**PALOMAS Y TÒRTOLAS**		
63	Pale-vented Pigeon	*Columba cayennensis/Patagioenas cayennensis*	Paloma Colorada	U	OT-AR-T-CL
64	Scaly Pigeon	*Columba speciosa*	Paloma Escamosa	C	OT
65	Short-billed Pigeon	*Columba nigrirostris*	Paloma Piquicorta	U	VC-OT-AT
66	Ruddy Ground-Dove	*Columbina talpacoti*	Tortolita Rojiza	U	T
67	White-tipped Dove	*Leptotila verreauxi*	Paloma Rabiblanca	U	T-AR
68	Gray-chested Dove	*Leptotila cassini*	Paloma Pechigris	U	T-AR
69	Ruddy Quail-Dove	*Geotrygon montana*	Paloma Perdiz Rojiza	R	T
	PARROTS	**PSITTACIDAE**	**LOROS**		
70	Orange-chinned Parakeet	*Brotogeris jugularis*	Perico Barbinaranja	U	OT
71	Blue-headed Parrot	*Pionus menstruus*	Loro Cabeciazul	U	OT
72	Red Lored Amazon/ Redlored Parrot	*Amazona autumnalis*	Loro Frentirrojo	C	OT
73	Mealy Amazon/Mealy Parrot	*Amazona farinosa*	Loro Harinoso	U	OT
	CUCKOOS	**CUCULIDAE**	**CUCLILLOS**		
74	Yellow-billed Cuckoo	*Coccyzus melacoryphus*	Cuclillo Piquiamarillo	R	OT
75	Squirrel Cuckoo	*Piaya cayana*	Cuco Ardilla	C	OT-AR-VC-T-CL
76	Pheasant Cuckoo	*Dromococcyx phasianellus*	Cuclillo Faisán	R	T-AR
77	Rufous-vented Ground Cuckoo	*Neomophus geoffroyi*	Cuco Hormiguero Ventrirufo	R	VC-A-T
78	Greater Ani	*Crotophaga major*	Garrapatero Mayor	C	CL-T-AR
79	Smooth-billed Ani	*Crotophaga ani*	Garrapatero Piquiliso	R	CL
80	Groove-billed Ani	*Crotophaga sulcirostris*	Garrapatero Piquiestriado	R	CL
	TYPICAL OWLS	**STRIGIDAE**	**BUHOS TIPICOS**		
81	Black and White Owl	*Ciccaba nigrolineata*	Bujo blanquinegro	R	OT-T
82	Crested Owl	*Lophostrix cristata*	Búho Penachudo	U	T-AR
83	Mottled Owl	*Athene cunicularia*	Búho Moteado	T-AR	83
84	Striped Owl	*Asio clamatos*	Búho Listado	R	T-AR
85	Spectacled Owl	*Pulsatrix perspicillata*	Búho de Anteojos	U	OT-T-AR
	NIGHTJARS	**CAPRIMULGIDAE**	**TAPACAMINOS**		
86	Common Nighthawk	*Chordeiles minor*	Añapero Común	U	OT
87	Common Pauraque	*Nyctidromus albicollis*	Tapacaminos Común	C	AR-T
	POTOOS	**NYCTIBIIDAE**	**NICTIBIOS**		
88	Great Potoo	*Nyctibius grandis*	Nictibio Grande	R	AR
89	Common Potoo	*Nyctibius griseus*	Nictibio Común	R	AR
	SWIFTS	**APODIDAE**	**VENCEJOS**		
90	Chimney Swift	*Chaetura pelágica*	Vencejo de Chimenea	U	OT
91	Short-tailed Swift	*Chaetura brachyura*	Vencejo Colicorto	U	OT
92	Vau'x Swift	*Chaetura vauxi*	Vencejo de Vaux	U	OT

93	White-collared Swift	*Streptoprocne zonaris*	Vencejo Cuelliblanco	U	OT
	HUMMINGBIRDS	**TROCHILIDAE**	**COLIBRÌES**		
94	Long-tailed Hermit/ Long-billed Hermit	*Phaetornis superciliusus/Phaethornis longirostris*	Hermitaño Colilargo/ Hermitaño Piquilargo	C	VC-T
95	Little Hermit/StripeThroated Hermit	*Phaethornis longuemareus/Phaethornis striigularis*	Hermitaño Chico/Hermitaño Gorguirayado	C	VC-T
96	White-necked Jacobin	*Florisuga mellivora*	Jacobino Nuquiblanco	C	VC-T-OT
97	Black-trhoated Mango	*Anthracothorax nigricollis*	Mango Gorguinegro	C	VC-
98	Rufous Crested Coquette	*Lophornis delattrei*	Coqueta Crestirrufa	R	VC
99	Violet -crowned Woodnymph	*Thalurania colombica*	Ninfa Coroniazul	C	VC-T
100	Violet-bellied Hummingbird	*Damophila julie*	Colibrí Ventrivioleta	C	VC-T
101	Blue-chested Hummingbird	*Amazilia amabilis*	Amazilia Pechiazul	C	VC-T
102	Snowy bellied Hummingbird	*Amazilia edward*	Amazilia Ventrinivosa	U	VC
103	Rufous-Tailed Hummingbird	*Amazilia tzacatl*	Amazilia Colirrufa	C	VC-T
104	White vented Plumeleteer	*Chalybura buffonii*	Calzonario de Bufón	C	VC-T
105	Purple-crowned Fairy	*Heliothryx barroti*	Hada Coronipùrpurea	U	VC-OT
106	Scaly-breasted Hummingbird	*Phaeochroa cuvierii*	Colibrí Pechiescamado	R	VC-T
	TROGONS	**TROGONIDAE**	**TROGONES**		
107	White-tailed Trogon	*Trogon viridis*	Trogon Coliblanco	U	AR-T
108	Violaceous Trogon	*Trogon violaceus*	Trogon Violàceo	C	O-T-AR
109	Black-throated Trogon	*Trogon rufus*	Trogon Gorginegro		T-VC-AR
110	Black-tailed Trogon	*Trogon melanurus*	Trogon Colinegro	C	T-VC-AR
111	Slaty-tailed Trogon	*Trogon massena*	Trogon Colipizarra	C	T-VC-CL-AR
	MOTMOTS	**MOMOTIDAE**	**MOMOTOS**		
112	Blue- crowned Motmot	*Momotus momota*	Momoto Coroniazulado	U	AR-T-VC
113	Rufous Motmot	*Barypthengus martii*	Momoto Rufo	U	AR-T-VC
114	Broad-billed Motmot	*Electron platyrhynchum*	Momoto Piquiancho	C	AR-T-VC
	KINGFISHERS	**ALCEDINIDAE**	**MARTINES PESCADORES**		
115	Ringed Kingfisher	*Ceryle Torquata/ Megaceryle torquatus*	Martin Pescador Grande	C	CL
116	Green Kingfisher	*Chloroceryle americana*	Martin Pescador Verde	U	CL
117	American Pygmy Kingfisher	*Chloroceryle aenea*	Martin Pescador Pigmeo	U	CL
	PUFFBIRDS	**BUCONIDAE**	**BUCOS**		
118	White-necked Puffbird	*Notharchus macrorhynchos*	Buco Cuelliblanco	U	AR-T-OT-VC
119	Black-breasted Puffbird	*Notharchus pectoralis*	Buco Pechinegro	C	AR-T-OT-VC
120	White-whiskered Puffbird	*Melacoptila panamensis*	Buco Bigotiblanco	U	AR-VC-OT-T
	JACAMAR	**GALBULIDAE**	**JACAMARES**		
121	Great Jacamar	*Jacamerops aurea/Jacamerops aureus*	Jacamar Grande	R	AR-T-VC-CL
	BARBET AND TOUCANS	**RAMPHASTIDAE**	**BARBUDOS Y TUCANES**		
122	Collared Aracari	*Pteroglossus torquatus*	Tucancillo Collarejo	C	AR-T-VC-OT-CL
123	Keel-billedToucan	*Ramphastos sulfuratus*	Tucán Pico Iris	C	AR-T-VC-OT-CL

124	Chestnut-mandibled Toucan	*Ramphastos Swainsoni*	Tucán de Swainson	C	AR-T-VC-OT-CL
	WOODPECKERS	**PICIDAE**	**CARPINTEROS**		
125	Black-cheecked Woodpecker	*Melanerpes pucherani*	Carpintero carinegro	U	OT-T-AR
126	Red-crowned Woodpecker	*Melanerpes rubricapillus*	Carpintero Coronirrojo	U	OT-AR-T
127	Cinnamon Woodpcker	*Celeus loricatus*	Carpintero Canelo	C	OT-AR-T
128	Lineated Woodpecker	*Dryocopus lineatus*	Carpintero Lineado	C	OT-AR-T
129	Crimson-crested Woodpecker	*Campephilus melanoleucos*	Carpintero Crestirrojo	C	OT-T-AR
	OVENBIRD AND ALLIES	***FURNARIIDAE***	**HORNEROS Y ALIADOS**		
130	Buff-throated Foliagegleaner	*Automulus achrolaemus*	Rascahojas Gorguipalida	R	AR-T
131	Scaly-throated Leaftosser	*Sclerurus guatemalensis*	Tirahojas Gorguiescamoso	R	AR-T
	WOODCREEPER	**DENDROCOLAPTIDAE**	**TREPATRONCOS**		
132	Plain-brown Woodcreeper	*Dendrocincla fuliginosa*	Trepatroncos Pardo	C	AR-T
133	Wedge-billed Woodcreeper	*Glyphorynchus spirurus*	Trepatroncos Pico de Cuña	R	AR-T
134	Buff-throated Woodcreeper/Cocoa Woodcreeper	*Xiphorhynchus guttatus/Xiphorhynchus susurrans*	Trepatroncos Gorguianteado/ Trepatroncos Chocolate	C	AR-T
135	Barred Woodcreeper	*Dendrocolaptes certhia*	Trepatroncos Barreteado	U	AR-T
	ANTBIRDS	**THAMNOPHILIDAE**	**HORMIGUEROS**		
136	Fasciated Antshrike	*Cymbilaimus lineatus*	Batara Lineado	C	AR-T-CL-VC
	Slaty Antshrike/Western Slaty-Antshrike	*Thamnophylus punctatus/ Thamnophylus atrinucha*	Batara Pizarroso/Batara Pizarroso Occidental	C	AR-T-OT-VC-CL
137	Barred Antshrike	*Thamnophilus doliatus*	Batara Barreteado	U	AR
138	Checker-throated Antwren	*Myrmotherula fulviventris*	Hormiguerito Leonado	C	AR-T-VC-CL
139	White-flanked Antwren	*Myrmotherula axillaris*	Hormiguerito Flanquiblanco	C	AR-T
140	Western Slaty Antwren	*Myrmotherula schisticolor*	Hormiguerito Pizarroso	C	VC-TCL-AR
141	Dusky Antbird	*Cercomacra tyrannina*	Hormiguero Negruzco	C	VC-T-CL-AR
142	White-bellied Anbird	*Myrmeciza longipes*	Hormiguero Dorsicastaño	U	VC-T-CL-AR
143	Dot-winged Antbird	*Microrhopias quixensis*	Hormiguerito Alipunteado	C	VC-T-CL-AR
144	Chestnut-backed Antbird	*Myrmeciza exsul*	Hormiguero Ventriblanco	U	VC-T-CL-AR
145	Spotted Antbird	*Hylophylax naevioides*	Hormiguero collarejo	U	VC-T-CL-AR
146	Bicolored Antbird	*Gymnopithys leucaspys*	Hormiguero Bicolor	U	VC-T-CL-AR
147	Ocellated Antbird	*Phaenostictus mcleannani*	Hormiguero Ocelado	U	VC-T-CL-AR
	ANTTRUSHES AND ANTPITTAS	**FORMICARIIDAE**	**FORMICARIOS Y TOROROIS**		
148	Black-faced Antthrush	*Formicarius analis*	Formicario Carinegro	U	VC-T-CL-AR
149	Streak-chested Antpitta	*Hylopezus perspicillatus*	Tororoi Pechirayado	U	T
	TYRANTS FLYCATCHERS	**TYRANNIDAE**	**MOSQUEROS**		

150	Brown capped Tyrannulet	*Ornithion brunneicapillum/Ornithion brunneicapillus*	Tiranolete Gorripardo	U	VC-T-OT
151	Yellow-bellied Elaenia	*Elaenia flavogaster*	Elenia Penachuda	U	OT-T
152	Ochre-bellied Flycatcher	*Mionectes oleagineus*	Mosquerito ventriocraceo	U	VC-OT-T
153	Paltry Tyrannulet	*Zimmerius vilissimus*	Tyrannulet Cejigris	R	VC-OT-T
154	Southern Bentbill	*Oncostoma olivaceum*	Picotorcido Sureño	U	VC-AR-OT-T-CL
155	Common Tody-Flycatcher	*Todirostrum cinereum*	Espatulilla Común	U	VC-T-OT
156	Brownish Twistwing	*Cnipodectes subbrunneus*	Alitorcido Pardo	R	AR
157	Olivaceus Flatbill	*Rhynchocyclus olivaceus*	Picoplano Oliváceo	R	AR
158	Yellow-margined Flycatcher	*Tolmomyias assimilis*	Picoancho aliamarillo	U	VC-T-OT-CL-AR
159	Royal Flycatcher	*Onychorhinchus coronatus*	Mosquero Real	R	AR-T
160	Eastern Wood-Pewee	*Contopus virens*	Pibi Oriental	U	OT
161	Tropical Pewee	*Contopus cinereus*	Pibi Tropical	U	OT
162	Acadian Flycatcher	*Empidonax virescens*	Mosquerito Verdoso	U	OT
163	Bright-rumped Attila	Attila spadiceus	Atila Lomiamarilla	U	T
164	Rufous Mourner	*Rhytipterna holerythra*	Plañidera Rufa	U	T
165	Dusky-capped Flycatcher	*Myiarchus tuberculifer*	Copetón Crestioscuro	U	T
166	Panama Flycatcher	*Myiarchus panamensis*	Copetón Panameño	U	OT
167	Lesser Kiskadee	*Pitangus lictor*	Bienteveo Menor	C	CL
168	Great Kiskadee	*Pitangus sulphuratus*	Bienteveo Grande	U	OT
169	Boat-billed Flycatcher	*Megarynchus pitangua*	Mosquero Picudo	U	OT
170	Rusty-margined Flycatcher	*Myiozetetes cayanensis*	Mosquero Alicatańo	U	OT
171	Social Flycatcher	*Myiozetetes similis*	Mosquero Social	U	OT-VC-T
172	Streaked Flycatcher	*Myiodynastes maculatus*	Mosquero Rayado	U	OT-VC-T
173	Piratic Flycatcher	*Legatus leucophaius*	Mosquero Pirata	U	OT-VC-T
174	Tropical Kingbird	*Tyrannus melancholicus*	Tirano Tropical	U	OT
175	Easter Kingbird	*Tyrannus tyrannus*	Tirano Norteño	U	OT
176	Fork-tailed Flycatcher	*Tyrannus savana*	Tijereta Sabanera	U	OT
	TYRANT FLYCATCHER ALLIES	**INCERTAE SEDIS**	**ALIADOS DE MOSQUEROS**		
177	Speckled Mourner	*Laniocera rufescens*	Plañidera Moteada	R	AR-T
178	Cinnamon Becard	*Phachyramphus cinnamomeus*	Cabezón Canelo	C	VC-T-OT-CL-AR
179	White-winged Becard	*Phachyramphus polychopterus*	Cabezón Aliblanco	U	VC-T-OT
180	Masked Tityra	*Tityra semifasciata*	Titira Enmascarada	U	OT
181	Black-crowned Tityra	*Tityra enquisitor*	Tityra Coroninegra	R	OT
	COTINGAS	**COTINGIDAE**	**COTINGAS**		
182	Blue Cotinga	*Cotinga nattererii*	Cotinga Azul	C	OT
183	Purple-throated Fruitcrow	*Querula purpurata*	Querula Gorguimorada	C	OT-T-AR-VC-CL

	MANAKIN	**PIPRIDAE**	**SALTARINES**		
184	Golden -collared Manakin	*Manacus vitellinus*	Saltarín Cuellidorado	U	T
185	Blue-crowned Manakin	*Pipra coronata*	Saltarín Coroniceleste	U	T
186	Red-capped Manakin	*Pipra mentalis*	Saltarín Cabecirrojo	U	T
	VIREOS	**VIREONIDAE**	**VIREOS**		
187	Red-eyed Vireo	*Vireo Olivaceus*	Víreo Ojirrojo	U	OT
188	Lesser Greenlet	*Hylophilus decurtatus*	Verdillo Menor	C	VC-AR-CL-T-OT
189	Green Shrike Vireo	*Vireolanius pulcellus*	Vireón Esmeraldino	U	OT-VC-T-CL-AR
	JAYS AND CROS	**CORVIDAE**	**URRACAS Y CUERVOS**		
190	Black-chested Jay	*Cyanocorax affinis*	Urraca Pechinegra	U	OT-AR-T-CL-VC
	SWALLOWS	**HIRUNDINIDAE**	**GOLONDRINAS**		
191	Gray-Breasted Martin	*Progne chalybea*	Martin Pechigris	C	CL
192	Mangrove Swallow	*Tachycineta albilinea*	Golondrina Manglera	C	CL
193	Cliff Swallows	*Hirundo rustica*	Golondrina Tijereta	C	CL-OT
	DONACOBIUS	**INCERTAE SEDIS**	**DONACOBIO**		
194	Black-bellied Wren	*Thryothorus fasciatoventris*	Sotorrey Ventrinegro	U	VC-T
195	Bay Wren	*Thryothorus nigricapillus*	Sotorrey Castaño	U	VC-T
196	White-breasted WoodWren	*Henicorhina leucosticta*	Sotorrey Selvático Pechiblanco	U	VC-T
197	Song Wren	*Cyphorhinnus phaeocephalus*	Sotorrey Canoro	C	VC-T-CL-AR
	DIPPERS	**CINCLIDAE**	**CINCLOS**		
198	Long-billed Gnatwren	*Ramphocaenus melanurus*	Soterillo Piquilargo	C	AR-T-VC-T
199	Tropical Gnatcatcher	*Polioptila plumbea*	Perlita Tropical	U	VC-T-AR
	THRUSHES	**TURDIDAE**	**ZORZALES**		
200	Gray-cheeked Thrush	*Catharus minimus*	Zorzal Carigris	U	T
201	Swainson's Thrush	*Cathartus ustulatus*	Zorzal de Swainson	U	T
202	Wood Thrush	*Hylocichla mustelina*	Zorzal de Bosque	U	T
203	Gray Catbird	*Dumetella carolinensis*	Mimido Gris	U	T
204	Tropical Monkingbird	*Mimus gilvus*	Sinsonte Tropical	U	VC
	WOOD-WARBLERS	**PARULIDAE**	**REINITAS**		
205	Tennessee Warbler	*Vermivora peregrina*	Reinita Verdilla	U	T-OT
206	Yellow Warbler	*Dendroica petechia*	Reinita Amarilla	U	T -OT
207	Chestnut-sided Warbler	*Dendroica pensylvanica*	Reinita Flanquicastaña	U	T-OT
208	Blackburnian Warbler	*Dendroica fusca*	Reinita Gorguinaranja	U	T-OT
209	Bay-breasted Warbler	*Dendroica castanea*	Reinita Pechicastaña	U	T-OT
210	Black and White Warbler	*Mniotilta varia*	Reinita Trepadora	U	T-OT
211	Northern Waterthrush	*Seiurus noveboracensis*	Reinita Acuática Norteña	U	T
212	Canada Warbler	*Winsolnia canadensis*	Reinita Collareja	U	T-OT
	TANAGERS	**THRAUPIDAE**	**TANGARAS**		
213	White-shouldered Tanager	*Thachyphonus luctuosus*	Tangara Hombriblanca	C	T-OT-VC-CL-AR
214	Red-crowned Ant-Tanager	*Habia rubica*	Tangara Hormiguera Coronirroja	C	T-VC-CL-AR
214	Red-Throted Ant-Tanager	*Habia fuscicauda*	Tangara Hormiguera Goguirroja	C	T-VC-CL-AR
215	Summer Tanager	*Piranga rubra*	Tangara Veranera	R	T-OT-CL-AR
216	Scarlet Tanager	*Piranga olivacea*	Tangara Escarlata	R	T-OT-CL-AR

217	Crimson-backed Tanager	*Rhampocelus dimidiatus*	Tangara Dorsirroja	U	T-OT-VC-CL-AR
218	Palm Tanager	*Thraupis palmarum*	Tangara Palmera	C	OT-T-VC-AR
219	Plain -colored Tanager	*Tangara inornata*	Tangara Cenicienta	C	OT-T-VC-AR
220	Golden-hooded Tanager	*Tangara larvata*	Tangara Capuchidorada	C	AR-OT-VC-CL-T
221	Gray-headed Tanager	*Eucometis penicillata*	Tamgara Cabecigris	C	AR-OT-VC-CL-T
222	Blue Dacnis	*Dacnis cayana*	Dacnis Azul	C	AR-OT-VC-CL-T
223	Green Honeycreeper	*Chorophanes spiza*	Mielero Verde	C	AR-OT-VC-CL-T
224	Red-legged Honecreeper	*Cyanerpes cyaneus*	Mielero Patirrojo	C	AR-OT-VC-CL-T
	CARDINALS AND ALLIES	**CARDINALIDAE**	**CARDENALES Y ALIADOS**		
225	~~Streaked Saltator~~	~~*Saltator albicollis/Saltator striatipectus*~~	~~Saltador Listado~~	~~U~~	~~AR-OT-VC-CL-T~~
226	Buff-throated Saltator	*Saltator maximus*	Saltador Gorgianteado	U	AR-VC-CL-T
227	Slate-colored Grosbeak	*Pytilus grossus/Saltator grossus*	Picogrueso Piquirrojo	U	T-OT
228	Rose-breasted Grosbeak	*Pheucticus ludovicianus*	Picogrueso Pechirrosado	R	T-OT
229	Blue-black Grosbeak	*Cyanocompsa cyanoides*	Picogrueso Negriazulado	C	T-OT
	AMERICAN ORIOLES AND BLACKBIRD	**ICTERIDAE**	**BOLSEROS**		
230	Yellow-backed Oriole	*Icterus chrysaster*	Bolsero Dorsiamarillo	U	AR-VC-CL-T
231	Yellow-tailed Oriole	*Icterus mesomelas*	Bolsero coliamarillo	C	AR-OT-CL-T
232	Scarlet-rumped Cacique	*Cacicus uropygialis*	Cacique Lomiescarlata	C	AR-OT-VC-CL-T
233	Yellow-rumped Cacique	*Cacicus cela*	Cacique Lomiamarillo	U	AR-OT-VC-CL-T
234	Chestnut-headed Oropendola	*Psarocolius wagleri*	Oropéndola Cabecicastaña	U	AR-OT-VC-CL-T
235	Bronzed Cowbird	*Molotrhus aeneus*	Vaquero Ojirrojo	U	OT-VC
	GOLFINCHES AND ALLIES	**FRINGILLIDAE**	**JILGUEROS Y ALIADOS**		
236	Yellow-crowned Euphonia	*Euphonia luteicapilla*	Eufonia Coroniamarilla	U	AR-OT-VC-CL-T
237	Thick-billed Euphonia	*Euphonia laniirostris*	Eufonia Piquigruesa	U	AR-OT-VC-CL-T
238	Fulvus Vented Euphonia	*Euphonia fulvicrissa*	Eufonia Ventricanela	C	AR-OT-VC-CL-T
239	White-vented Euphonia	*Euphonia minuta*	Eufonia Ventriblanca	U	AR-OT-VC-CL-T

Annexe 3: Biophysical characteristics within each of the 4 sampled plots at each site. These characteristics were

		Slope	Soil	Understory	Canpy Cover (%)	Stratification (leaf cover)	Composition	# species: trs, plms, bmb, lns, undrstry	#tree(15cm) per 4m2	Average distance btwn trees
Entrance	S1Q1	20	Dry, coffee brown	20-es, 80-dll, scattered vascular plants, some seedlings	60	most foliage in upper canopy: some lianas (none over 15cm), mostly tree leaves	Tall canopy trees, no trunks over 30cm, no palms	3, 0, 0, 0, 3: 6	4	
	S1Q2	20	Dry, cracked	15-es, 15-logs+roots, 70-dll, 2sp short (1m) palms, small seedlings	35	mostly palm cover (med height), some canopy tree foliage, large (+15cm) lianas, foliage divided evenly between upper canopy and middle palm layers	Some canopy trees (3 over 30cm), outside quadrat 1 huge buttress canopy tree with bole around 0.7m diameter. 2 tall palm sp. One with spiky trunk	4, 0, 0, 0, 4: 8	4	
	S1Q3	30	Dry	10-es, 90-dll, floor littered with dried sticks and branches, small sapling growth (same msp.)	40%	virtually all foliage in upper canopy, few short understory trees, space between trees, layer of liana foliage under canopy	Mostly tall canopy trees, lianas, 1 short palm, 1 large termites nest (food source?)	4, 1, 0, 1, 2: 8	3	
	S1Q4	20	NA	100-dll, thick mat of leaves (approx. 5cm), few understory plants, fuzzy seed exocarp on ground	25%	no palms, short (2m) trees, lots of thin vines and lianas (apprx. 30 of coverage)60	Mostly small trees (under 30cm), no palms, not in plot: large tree that produces fuzzy seeds	5, 0, 0, 1, 2: 8	3	
	Avr.	22.5			40%			4, 0.25, 0, 0.5, 2.75: 7.5	3.5	
Visitor's Center	S2Q1	10	NA	10-es, 90-dll, scattered fallen logs, 1 short palm, sparse short vascular plant cover	20%	canopy around same height (20m)	Trees mostly under 15cm, 1 large tree (over 15cm), passion fruit flower	3, 0, 0, 0, 2: 5	5	

	S2Q2	20	Very dry	10-es, 80-dll, 10-r+l, little vascular cover	20%	vines contribute considerably to foliage	Mostly trees under 15cm, 2sp. Palm, 1sp. Fern, numerous beefsteak heliconia, small green berries w/ pink stem	2, 2, 0, 1, 2: 7	4	
	S2Q3	45	Dry, rocky, surrounded by gravel roads	20-es, 70-dll, 10-gravel, sparse vascular understory	30%	palms (2-3m), small canopy tree (5m), few vines + lianas	3sp. Palm (1 large), epiphytic fern, vines + lianas, 3 trees over 15cm	3, 3, 0, 3, 2: 11	4	
	S2Q4	10	dry	25-es, 75-dll. Some understory.	15%	50% middle tree 50% palm	1sp. Tree, 1 sp. Palm, 1sp heliconia, 2sp. understory	1, 1, 0, 0, 3: 5	2	1.3
	Avr.	21.25			21.25			2.25, 1.5, 0, 1, 2.25: 7	3.75	
Tower	S3Q1	60	med. dry	30-es, 60-dll, 10-fll. Scattered seedling growth.	60	High stratification: 25% emergent tree (_m) 10% palm 50% middle tree layer (_m) 15% epiphyte/liana	1 tree sp, 1 palm sp. 1 sp. Epiphytic fern, 1 sp. liana, 1 sp. sapling, 1 sp. understory	2, 1, 0, 2, 1: 6	2	1.01
Tower	S3Q2	20	med . dry	40-es, 60-dll. Little understory vegetation	70	High stratification: 30% emergent tree (_m) 10% liana 30% middle trees (20m) 30% palm (15m)	1sp. Emergent tree, 1sp. Large palm, 1 sp. Large liana.	1, 1, 0, 1, 1: 4	2	2.31
Tower	S3Q3	20	Thick humus mat (7cm)	75-dll, 25-fll. Abundant vascular understory.	65	40% emergent tree (_m) 20% epiphyte/ liana 20% middle trees (20m) 20% palm (15m)	2sp. palm , 1sp, fern, 2 sp. Understory. Huge buttress emergent trees surrounding plot.	0, 2, 0, 0, 3: 5	0	/
Tower	S3Q4	0	humus mat	10-es, 70-dll, 20-fll. Dense understory, mostly saplings.	60	50% emergent tree (_m) 40% epiphyte/ liana 5% palm (5m) 5% small trees	1sp. emergent tree, 2 sp. Sapling, 2sp. Palm, 1 sp. Liana, 2 sp. Epiphyte	3, 2, 0, 3, 1: 9	2	2.7
Tower	Avr.	25			63.75			1.5, 1.5, 0, 1.5, 1.5: 6	1.5	2.01m

Calamito Lake	S4Q1	20	Humid	10-gravel, 90-dll, sparse vascular vegetation (clumped together)	35%	50% in upper canopy trees (10m): mostly bamboo and palms 50% in lower canopy trees (3m): true trees	Mostly small trees in plot (under 15cm diameter), 1sp. Palm, 1sp. Bamboo, one sp. Sapling (3m), no lianas	2, 1, 1, 0, 2: 6		
	S4Q2	0	Moist, marshy, dark brown	30-es, 40-short grass, 15-moss/lichen, 15-lollipop	0%	NA	Marsh? No running water, dried up, nothing over 1/3m	0, 0, 0, 0, 3: 3		
	S4Q3	0	Soil very moist	50-grass+lollipop, 40-shrub, 10-palm	0%	NA	Mostly grass + lollipop, i sp. Shrub in a cluster, 1 sp. Palm, 1 sp. sapling	0, 1, 0, 0, 4: 5		
	S4Q4	10	dry	10-es, 80-dll, 10-fll, some vascular plants, small bamboo tree (1/2m)	35%	Gradual stratification: 30% upper canopy: tree outside quadrat (15m) 30% middle canopy trees (10m) 20% liana (8m) 20% lower palm layer	Lots of lianas, all intertwined, some quite thick Looks like there was a disturbance: dead tree	1, 0, 1, 2, 2: 6		
	Avg	15			17.5%			0.75, 0.5, 0.5, 0.5, 2.75: 5		
Forest Trail	S5Q1	10	Light brown, dry	20-es, 70-dll, 10-fll,lots of vascular understory plants, lots of bamboo, 1 short palm	15%	50% upper canopy trees (20m) 40% lianas (18m) 10% lower canopy (10m)	Gap, disturbance: fallen tree Middle canopy very empty Lots of understory vegetation	1, 1, 1, 1, 4: 7	3	
	S5Q2	40	Loamy, rocky	25-es, 70-dll, 5-other dry debris, some understory (sparse): short vascular plants	25%	Foliage all at same height (15m): 40% palm, 40% tree 10% lianas/vines 10% short tree (10m)	1sp. Palms, 1sp. Canopy tree (20m) with no leaves, 1 short tree (5m), covered in lianas/vines (with leaves)	2, 1, 0, 1, 2: 6	3	

	S5Q3	60	Light brown sandy loam	30-es, 60-dll, 10-dry sticks, very dense, lots of palms and saplings, no bamboo (1m)	10%	70% leafless branches (25m) 20% leafless lianas (25m) 10% vine leaves (5-10m)	One large leafless tree sp. (25m, +30cm diameter), one smaller tree sp., lots of large lianas, vines	2, 1, 1, 2, 3: 9	2	
	S5Q4	60	Light brown silt loam	10-es, 80-dll, 10-fll. Considerable vascular growth, spaced out, no clumps.	30%	10% mistletoe in upper canopy (12m) 10% lianas 70% trees and palms (10m) 10% lower palms (2m)	1 sp. Med tree, 1 sp. Tall palm, 1 sp. Short palm, 2 sp. Sapling, 1 sp. Liana, 1 sp. Fern, 3 sp. Vascular understory	3, 2, 0, 1, 4: 10	3	
		42.5			20			2, 1.25, 0.5, 1.25, 3.25: 8	2.75	
Forest Border	S6Q1	20	Dry, clay loam	60-es, 40-dll. Little small vascular plant growth.	40	30% upper canopy tree (25m), 20% middle canopy (15m), 20% (5m)	1sp. Small fruiting tree, 2sp. Sapling, 2sp. bush	3, 0, 0, 0, 2: 5	3	2.17
	S6Q2	0	moist	20-es, 70-dll, 10-fll. Few vascular understory plants. Lots of bamboo along edge.	15	95% two small trees (10m) 5% vines	1sp. Short tree, 1sp. Bamboo, 1sp. Vine, 2sp. Vascular understory.	1, 0, 1, 1, 2: 5	2	2.34
	S6Q3	10	wetish	5-es, 80-dll, 15-fll. Very dense understory. Lots of grass.	30	40% upper trees (10m) 30% palm (5m) 30% vines	2sp. Short tree, 1sp. Palm, 1sp. Vine, 1sp. Grass, 1sp. Fern, 1sp. Fruiting plant.	2, 1, 0, 1, 3: 7	3	1.79
	S6Q4	0	Dry, clay loam	40-es, 30-duff, 30-dll. Some understory plants, bamboo.	30	70% upper trees (8m) 20% vines 10% lower trees (5m)	1sp medium tree, 1sp. Sapling, 1sp. Palm, 1sp. Bamboo, 1sp. Vine, 1sp understory.	2, 1, 1, 1, 1: 6	3	2.00
	Avr.	7.5			28.75			2, 0.5, 0.5, 0.75, 2: 5.75	2.75	2.08m

Annexe 4: Tree species identified at each site.

Site 1: Entrance					
Msp. Understory	Msp. Tree	Family	Genus	Species	Additional Information
	1	Sterculiaceae	Guazuma	ulmifolia	
	2	Anacardiaceae	Spondias	mombin	Fruits are an important food source for fruitivorous birds (toucan)
	3	Fabaceae	Enterolobium	cyclocarpum	
	4	Melastomataceae	Miconia	argentea	Important food source for birds
	5	Euphorbiaceae	Sapium	glandulosum	
	6	Arecaceae	Atalea	rostrata	Currently fruiting, food source for monkeys, less for birds
1			Carludovica	palmata	Understory
2			Heliconia	sp.	Understory
3		Rubiaceae			Hot lips, understory.

Site 2: Vsitor Center					
Msp. Understory	Msp. Tree	Family	Genus	Species	Additional Information
	7	Malvaceae	Luechea	seemannii	
	8	Rutaceae	Zanthoxylum	panamense	
	9	Fabaceae	Dalbergia	retusa	Vulnerable
	10	Malvaceae	Ochroma	pyramidale	Fluffy seeds dispersed by wind (not consumed by birds), pollinated by bats
	11	Fabaceae	Albizia	adinocephala	
	12	Piperaceae	Piper	reticulatum	
1			Carludovica	palmata	Understory
3			Heliconia	mariae	Understory, flowering
	13		Cecropia	pelta	
2			Heliconia	sp.	Understory, flowering
4			Passiflora	sp.	Passionflower

Site3: Tower					
Msp. Understory	Msp. Tree	Family	Genus	Species	Additional Information
	14	Anacardiaceae	Anacardium	excelsum	Currently fruiting (small fruits)
	15	Combretaceae	Terminalia	amazonia	
	16	Moraceae	Ficus	insipida	Fig tree, fruiting
	17	Salicaceae	Tetrathylacium	johansenii	

Site 4: Lake					
Msp. Understory	Msp. Tree	Family	Genus	Species	Additional Information
	15	Combretaceae	Terminalia	amazonia	
	18	Poaceae	Cusuguea	sp.	Small bamboo, native to Panama
	19	Arecaceae	Astrocaryum	standleyanum	
	20	Fabaceae	Swartzia	simplex	Fruiting

Site 5: Trail					
Msp. Understory	Msp. Tree	Family	Genus	Species	Additional Information
	19	Arecaceae	Astrocaryum	standleyanum	
	11	Fabaceae	Albizia	adinocephala	Red bark
	2	Anacardiaceae	Spondias	mombin	Fruits are an important food source for fruitivorous birds (toucan)
	21	Malvaceae	Pseudobombax	septenatum	
	22		Burseria	simaruba	Peeling red bark
	13		Cecropia	pelta	

Site 6: Forest Border

Msp. Understory	Msp. Tree	Family	Genus	Species	Additional Information
	23	Rubiaceae	Pentagonia	macrophylla	
	24	Muntingiaceae	Muntingia	calabura	Fruiting, very important for birds.
	25	Fabaceae	Pseudosamanea	guachapele	
	26	Poaceae	Bambusa	vulgaris	Big yellow bamboo. Exotic, from Asia.
	6	Arecaceae	Atalea	rostrata	Currently fruiting, food source for monkeys, less for birds
	16	Moraceae	Ficus	insipida	Fig tree, fruiting
	27	Malvaceae	Pseudobombax	sp.	
	28	Malvaceae	Pachira	sessilis	
	13		Cecropia	pelta	
4			Passiflora	sp.	Passionflower
	4	Melastomataceae	Miconia	argentea	Important food source for birds
	18	Poaceae	Cusuguea	sp.	Small bamboo, native to Panama

Annexe 5: Certificate of completion of the Tri-Council Policy Statement by the researchers

PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Alexa Schubak

has completed the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans Course on Research Ethics (TCPS 2: CORE)

Date of Issue: **15 January, 2019**

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This document certifies that

Lily Ragsdale

has completed the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans Course on Research Ethics (TCPS 2: CORE)

Date of Issue: **20 January, 2019**