TRADITIONAL AGROFORESTRY SYSTEMS AS HABITAT FOR AVIAN SPECIES: ASSESSING THEIR ROLE IN CONSERVATION

by

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ABSTRACT

The objective of this study was to explore the role of traditional agroforestry systems in Ecuador, called *chakras*, in the conservation of avian species. Eleven examples of *chakra*, including plantations of yuca (*Manihot esculenta*), cocoa (*Theobroma cacao*), corn (*Zea mays*), coffee (*Coffea arabica*) and plantain (*Musa paradisiaca*), were studied near the traditional territory of the Kichwa Community of Verde Sumaco in Orellana province, Ecuador. A total of 11 surveys revealed 25 bird species belonging to 11 families across all the *chakras*, and 80 different plant species belonging to 36 families. The *chakras* were divided into two categories based on diversity of passerine birds: species-poor and species-rich. There were no tanager species recorded in species-poor *chakras*, while there were 20 tanager species recorded in species-rich *chakras*. Observations of hawks were linked significantly to the categories of species-rich and species-poor *chakras* (test of independence, $\chi^2 = 4.59$, $p = 0.02$). When hawks were present, a lower number of passerine species was observed. No significant correlation was found between bird species richness and plant species richness. However, a number of *chakras* had legacy trees that provided shelter and nesting, resting and foraging space for various bird species. This study can provide useful information for *chakra* owners interested in conservation of avian species in an era of natural wildlife habitat loss and degradation.

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INTRODUCTION AND OBJECTIVE

Deforestation in the Amazon has meant clearing and removing forested stands and converting them into farms, ranches, and urban areas. The rate of deforestation has increased throughout the Amazon, as a result, nearly 100 bird species are at risk of extinction (IUCN 2012). The removal or destruction of large areas of rainforest has caused adverse impacts on available food resources for a number of tropical birds. With fewer food resources available, bird populations will decline; however, traditional agroforestry systems have a high potential to contribute to mitigating the effects of deforestation (Torres et al. 2015).

Ecuador is considered one of the mega-diverse countries in the world, hosting around 1700 bird species, and is the eighth most biodiverse country in the world (Butler 2006). However, Ecuador also has the distinction of having had the highest deforestation rate and the worst environmental record in South America. Oil exploration, logging, and road building have had a disastrous impact on Ecuador's primary rainforests, which now cover less than 15% of the country's land mass (Butler 2006). Additionally, oil industries began land clearing in the 1960s and introduced human settlements into the rainforest, where settlement continued at a rapid pace during the country's land reform era from 1964 to 1973 (Torres et al. 2015). The process of agricultural colonization significantly changed the pattern of land use from primary forest to agricultural crops and livestock grasslands.

Amazonian communities in Ecuador use a traditional agroforestry system called *chakra*. The cultural meaning of the *chakra* system for the local population incorporates a sense of the need for conservation of the Amazon landscape (Torres et al. 2015). *Chakras* are a structurally complex system, in which trees or shrubs are grown around or among various types of crops, such as yuca (*Manihot esculenta*), cocoa (*Theobroma cacao*), corn (*Zea mays*), coffee (*Coffea arabica*) and plantain (*Musa paradisiaca*). The cultivation of *chakras* by Amazonian people dates to long before European arrival to South America, as evidenced by the number of tree species, mainly fruit-bearing, that were domesticated by Indigenous peoples (Porro et al. 2012). The cultivation of small plots within the rainforest is a traditional practice for the Kichwa populations to sustain their livelihoods. The agroforestry system allows Kichwa communities sustainable use of forests by combining cultivation of commercial products, controlled timber extraction, stable food production, and conservation of medicinal plants (Torres et al. 2015). Additionally, the *chakra* combines conservation of the region's biodiversity and production attributes by using an integrated resource management approach (Porro et al. 2012).

Biodiversity is essential for the health and resilience of tropical forests, and birds are a notable example. Birds provide a range of ecosystem services through their interaction with other species in the ecosystem, for example in keeping populations of plant-eating insects in check through predation and in dispersing the seeds of rainforest tree species (Bregman et al. 2016). Frugivorous birds have a mutualistic interaction between fleshy-fruited plants and seed dispersal – up to 90% of woody plant species of tropical and subtropical forests depend on fruit-eating birds for seed dispersal (Fleming et al. 1987, Kissling et al. 2009). Frugivorous birds also track fruit production that varies both spatially and temporally, and this activity should increase seed dispersal and provide positive feedbacks in plant recruitment (Lázaro et al. 2005).

Figure 1. Paradise Tanager perched on a fruit tree (Schulenberg 2019).

An example of a frugivorous passerine bird is the Paradise Tanager (*Tangara chilensis*), a multicolored Neotropical bird that is commonly found in Amazonian Colombia, Brazil, Venezuela, the Guianas, Bolivia, Peru, and Ecuador (Figure 1). It occurs at elevations of 100-1100 m (Restall et al. 2007). Paradise Tanagers are commonly sighted in tropical lowland evergreen forests and secondary forest (Parker et al. 1996, Schulenberg al. 2007). They are usually seen in the canopy from 25-50 m above the ground, but can sometimes be seen at forest edges in lower branches, or in clearings near fruiting trees (Isler and Isler 1987). In Peru, Paradise Tanagers were found in the upper branches of fruiting trees and never seen in areas without dull tree coverage (Terborgh 1967). In Eastern Ecuador, they have been observed in dispersed trees of both lowlands and foothills regions of the Amazon (Ridgely and Brown 1989).

The genus *Tangara* is the largest of the Neotropical birds. There are four recognized subspecies of Paradise Tanager: *chilensis, paradise, chlorocorys,* and *ceolicolor* (Restall et al. 2007). Both adult sexes have a similar appearance: the head is bright light green with a black eye-ring, while the nape, upper back, wings, upper tail and under tail, and central belly are all black; the lower back is bright red in color with a yellow or red rump, depending on subspecies. The chin and throat are dark blue along with the greater primary coverts, while the breast and flanks are a lighter blue. Depending upon subspecies, the upper wing coverts may be light ocean-blue or dark blue. Its apple-green cap, red and yellow rump, and blue abdomen are unique among tanagers. While a juvenile looks very similar to an adult, its lower rump and back are yellow or orange. As well, the lesser wing-coverts are black instead of sea-blue. The head is green speckled with black, the chin is turquoise, and the blue of breast and flanks are more turquoise in color with some speckling. In Bolivia, a study by Naoki (2003) found most foraging observations of the Paradise Tanager involved *Miconia* (53%) and *Cestrum* (28%) fruits. Isler and Isler (1987) summarized data from stomach contents and found vegetable matter for most individuals, including fruit pulp and seeds, but also arthropods such as fly larvae, short-horned grasshoppers, and spiders. As for most passerine birds, the Paradise Tanager is best described as omnivorous.

Loss and fragmentation of forests due to timber, crop, and livestock production or urbanization can cause declines in species richness of a wide variety of taxa (Yoshikawa et al. 2017). The replacement of natural forests with plantations is advancing at a global scale. According to Fuzessy et al. (2016), data between 1990 and 2015 show a decrease in the global forest cover from 31.9% to 30.9%. Clear-cutting is still a common practice in the Amazon forest and has created forest patches of secondary vegetation in different successional stages. The resulting landscape is associated with an "edge effect" that offers habitat that favours generalist species in the Amazon (Lawes et al. 2005). There is a need for conservation and restoration of native fauna in these fragmented forests, especially those species with special ecological functions, such as small mammals or passerine birds. López-Barrera et al. (2004) studied different edge types in agroforestry landscapes in Chiapas, Mexico and hypothesized that forest edges might influence regeneration of oak species, determining which are canopy dominants in the forest, by affecting the activities of small mammals. Not only did patch-clear-cutting affect regeneration within forest fragments by influencing the activities of small mammals, but also the nature of this effect depended on the characteristics of the forest edge created.

Chakras have a high conservation value in reducing the pressure on resources consumed for household use in and near protected areas, in extending the habitats of wildlife species, and in providing travel corridors and connectivity between fragmented forest patches (Yashmita-Ulman et al. 2016). The objective of this thesis is to describe how vegetation richness of *chakras* has effects on passerine bird species richness. The study was designed to include an inventory of bird and plant species in selected *chakras* in Verde Sumaco, Ecuador (Figure 2) to highlight their role and conservation value in terms of avian conservation in an era of habitat loss and degradation in the Amazon.

METHODS

The study was carried out in the traditional territory of the Kichwa Community of Verde Sumaco, in Orellana province, in the northeastern Ecuadorian Amazon region (Figure 3). The study *chakras* were selected based on their accessibility, using local trail systems and canoes from the centre of Verde Sumaco. The latitude and longitude at the centre of the study area are as follows: 0° 22′ 23.2″ S and 77° 15′ 25.2″ W.

Figure 1. Indigenous families use local river systems such as the Rio Pawshiyaku for transportation to chakras in Verde Sumaco, Ecuador (Kuchta 2018).

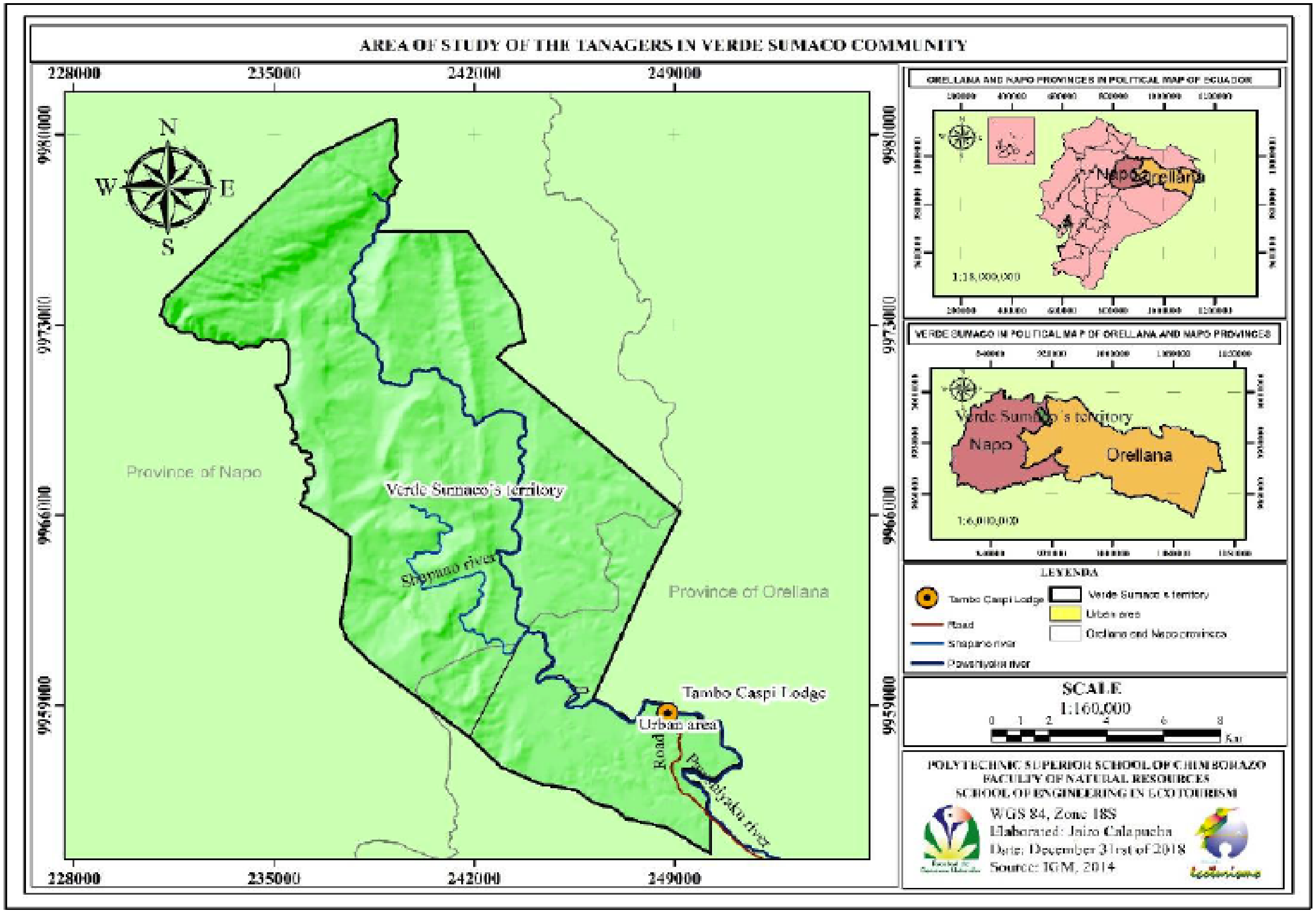

Figure 2. Overview of the study site in Verde Sumaco (Calapucha 2019).

Table 1. Field card for chakra vegetation inventory

CHAKRA 1
DATE: 18/12/2018
PLACE: SERGIO SHIGUANGO´S CHAKRA
MAIN CROP: YUCA

N°	FAMILY	SCIENTIFIC NAME	COMMON NAME	FREQUENCY	IMPORTANCE TO TANAGER	
					YES	NO
1	Arecaceae	*Oenocarpus batahua*	Ungurahua	++	X	
2	Arecaceae	*Iriartea deltoidea*	Pambil	+++++++	X	
3	Lecythidaceae	*Grias neuberthii*	Pitón	+		X
4	Poaceae	*Saccharum officinarum*	Caña	++		X
5	Euphorbiaceae	*Manihot esculenta*	Yuca	(+…)		X
6	Bromeliaceae	*Ananas comosus*	Piña	+		X
7	Poaceae	*Zea mays*	Maíz	+	X	
8	Solanaceae	*Solanun quitoensis*	Naranjilla	+		X
9	Musaceae	*Musa sapientum*	Plátano	++	X	
10	Arecaceae	*Phytelephas aequatorialis*	Tagua	+	X	
11	Bignoniaceae	*Crescentia cujete*	Pilche	+		X
12	Meliaceae	*Guarea kunthiana*	Manzano colorado	+	X	
13	Arecaceae	*Bactris gasipaes*	Palmito	+	X	

VEGETATION DIVERSITY ASSESSMENT

Vegetation was described using a transect method. Three surveyors walked transects, and with vegetation inventory cards recorded plant family names, scientific names, common names, frequencies, and suitability for tanager species based on fruit availability and structure (Table 1). Plant species in the *chakras* were identified by consulting local ecological knowledge, Ecuador plant identification guides and field photos. A list of plant species in each of the 11 *chakras* was the outcome (Appendix 1).

AVIAN DIVERSITY ASSESSMENT

Avifauna richness data was collected by walking line transects. The focus was directed at frugivorous avian birds. These species are residential to Amazon and generally do not exhibit long distance migration. Some species, such as in the *Pionus* genus, do conduct small seasonal migrations to obtain more resources, but still stay within the same vicinity of its original habitat throughout their lifetime. Line transects were used to survey the entirety of a *chakra* site, minimizing bias in the species found and identified. Depending on the size of the *chakra*, a maximum of 10 transects was implemented to cover approximately one hectare or larger. On sites that were smaller than one hectare, a minimum of 5 line transects were incorporated. Transect lines were spaced at 5-m intervals. Transects were walked at approximately 3 km/h, allowing time for species to be located and identified. Birds that were unidentifiable in the field due to low lighting or high distance were photographed using a Nikon Powershot sx50 and identified later. The *Birds of Ecuador: Field Guide* was used for identification. Avian species richness data was collected between 6:00-10:00 AM and 16:00-18:00 PM.

DATA ANALYSIS

Species Richness: The number of passerine bird species per *chakra* was identified as species richness. The more species observed in the *chakra*, the "richer" the sample. Species richness gives as much weight to those species that have very few individuals as to those that have many individuals (Walther and Morand 1998).

Species Range: The range was used to describe the difference between the lowest and highest number of species observed in the 11 *chakras*. The range was calculated by rearranging the data from least value to greatest value, then subtracting the smallest richness from the largest in each of two sets, to be labelled *species-poor chakras* and *species-rich chakras*.

Test of independence based on the chi-square distribution: The test was used to determine if there was a significant relationship between the presence of hawks and the number of passerine birds observed in the two *chakra* sets. The frequency of each category for one nominal variable was compared across the categories of the second nominal variable using a test of independence with a calculated χ^2_c value (Equation 1) compared to the probabilities associated with the Chi-squared distribution. In the equation, O_i is the observed number of species-poor and species-rich *chakras* with hawks and without hawks, and E_i is the expected number based on the total number of species-poor and species-rich *chakras* and the total number of *chakras* with hawks present. The test of independence required a null hypothesis (H_o) and an alternative hypothesis (H_a). The hypotheses were stated in such a way that they are mutually exclusive. That is, if one is true, the other must be false. The null hypothesis and alternative hypothesis is listed:

- Null Hypothesis (H_o): Passerine richness in *chakras* is independent of the number of hawk observations.

- Alternative Hypothesis (H_a): Passerine richness in *chakras* is statistically associated with number of hawk observations.

A significance level value of 0.05 was chosen to reject the null hypothesis. Microsoft Excel was used to calculate the test of independence based on the chi-square distribution.

$$\chi_c^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Equation 1. Chi-square formula to determine if there is a link between hawk presence and passerine bird richness

<u>Shannon Diversity Index:</u> The Shannon Diversity Index was used to characterize vegetation and passerine diversity in each *chakra*. The index, H′, accounts for both abundance and evenness of the species present (Equation 2). The value will always be positive and will increase with an increase in the number present for each species p_i, or with an increase in the evenness of number of all the species present, or both. H'_{max} is a measure of the maximum diversity for a given number of species. H'_{max} was calculated to determine a *chakra*'s diversity in comparison to the other *chakras*.

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

Equation 2. Shannon Diversity Index formula to determine abundance and evenness of the species present.

RESULTS

A total of 25 passerine species belonging to 11 families were recorded across all the surveyed *chakras*. The passerine species-rich *chakras* did not have a larger number of fruit-bearing plant species present compared to the species-poor *chakras*, while passerine species richness varied considerably along with passerine family diversity (Table 2). A total of 80 fruit-bearing plant species in 35 families were recorded across the 11 *chakras*.

There were no tanager species recorded in the species-poor *chakras*; however, there were 20 tanager species recorded in the species-rich *chakras* (Figure 4). The most common bird families were the Thraupidae (tanagers) and Icteridae, both having 20 individuals recorded; Icteridae were found in both categories of *chakra* (Figure 5). There were 11 birds of prey recorded in six of the chakras, six individuals recorded in four of the species-poor *chakras* (Table 3). The null hypothesis was rejected and hawks were linked significantly to the categories of species-rich and species-poor chakras with respect to observed passerines (test of independence, $\chi^2 = 4.59$, $p = 0.02$). Hawks were present in chakras with the lower number of passerine birds observed.

Table 2. Summary of the chakras according to passerine bird and vegetation inventory

	Passerine Species-rich	Passerine Species-poor
No. of *chakras*	5	6
Number of passerine species (range)	6-11	2-3
Average passerine family richness	10	3
Passerine family diversity (H-Value, Mean ± SEM)	0.97 ± 0.27	0.34 ± 0.37
Passerine family diversity (Index Value)	0.77	0.49
Average passerine species richness	24	5
Number of plant species (range)	9-29	7-27
Plant family richness	33	34
Plant family diversity (H-Value, Mean ± SEM)	2.04 ± 1.08	2.08 ± 0.99
Plant family diversity (Index Value)	0.80	0.83
Plant species richness	58	63

DISCUSSION

HABITAT STRUCTURE

Management of tree species richness (number of tree species in a given area), their vertical complexity, and the height of their canopies has proven important for bird conservation (Perfecto et al. 1996, Greenberg et al. 1997). Structurally complex *chakra* habitats serve as a substitute habitat for many bird species when natural rainforests are not available to them (Yashmita-Ulman et al. 2016).

Table 3. Birds of prey encountered in the chakras

Chakra number (Appendix 1)	Predator observed	Number of individuals	*Chakra* category	
			Species-rich	Species-poor
1	Yellow-headed Caracara	2	✓	
3	Slate-coloured Hawk	3	✓	
4	Roadside Hawk	1		✓
6	Slate-coloured Hawk	1		✓
7	Black Caracara	3		✓
8	Slate-coloured Hawk	1		✓

Table 4. Number of important plants to tanagers based on fruit availability and structure observed in (a) species-poor and (b) species-rich chakras, referencing the richness of passerine birds

(a) Species-poor *chakra* number (Appendix 1)	Number of plants observed
2	4
4	7
6	5
7	3
8	11
9	2
Arithmetic Mean	5

(a) Species-rich *chakra* number (Appendix 1)	Number of plants observed
1	7
3	9
5	6
10	4
11	8
Arithmetic Mean	7

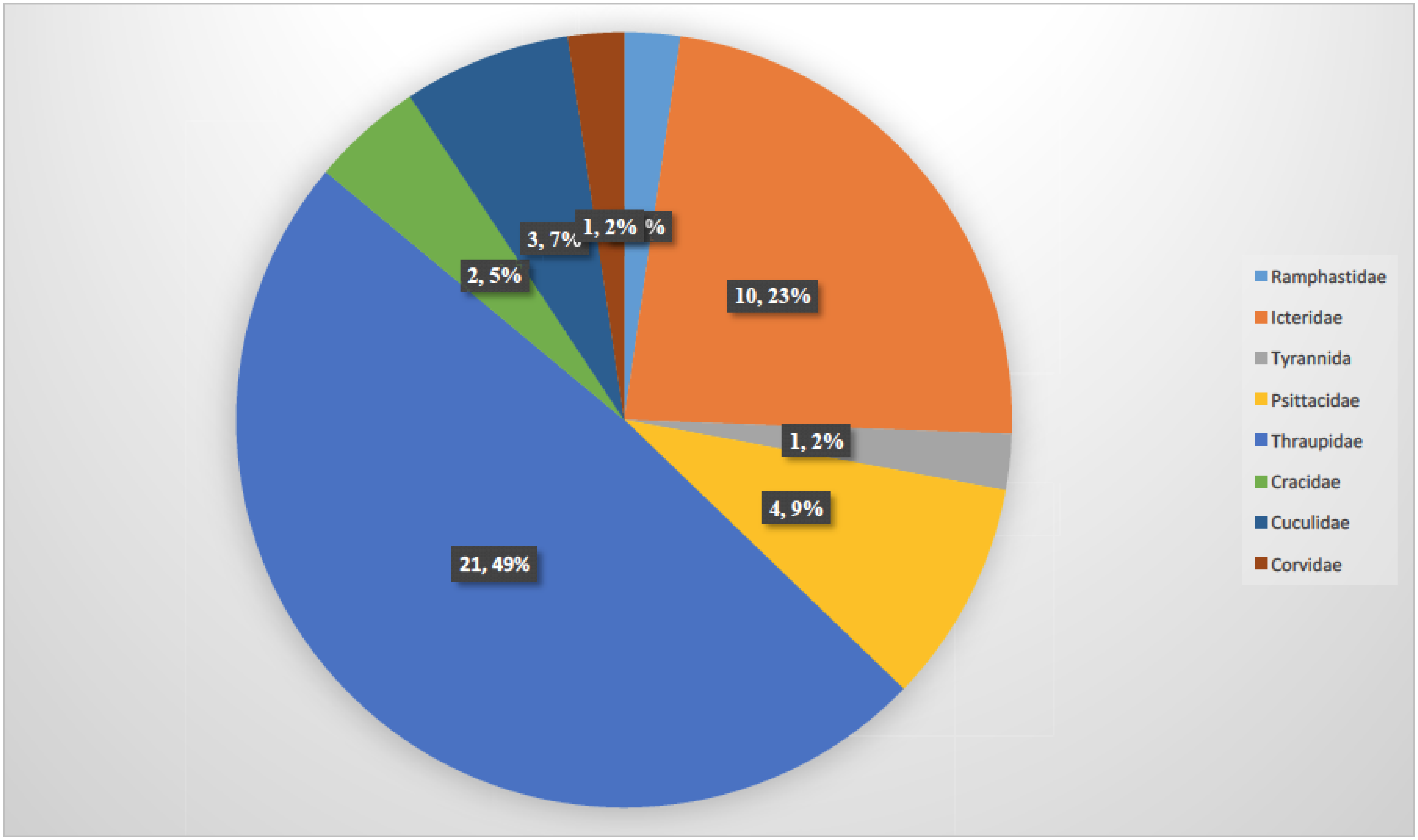

Figure 4. Observations of passerines by family (number of individuals, proportion of observations) in species-rich chakras

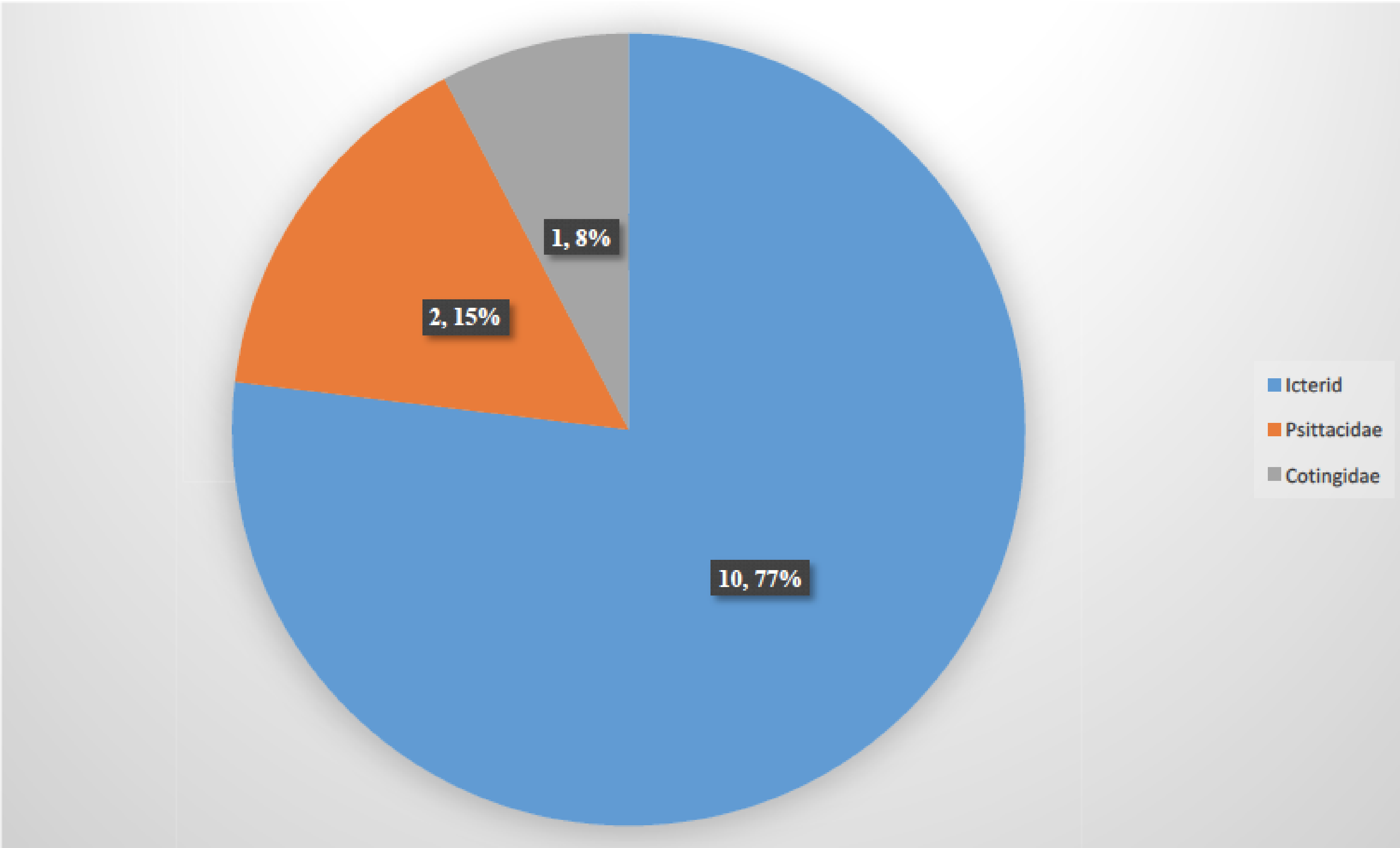

Figure 5. Observations of passerines by family (number of individuals, proportion of observations) in species-poor chakras

In the present study, bird species richness was not related to chakra vegetation species richness. In contrast, Harvey and Villalobos (2007) found bird species richness positively correlated with vegetation structure and composition. An abundance of bird species independent of tree diversity, like insectivorous, omnivorous, piscivorous, granivorous feeding guilds in the Verde Sumaco area may be one of the reasons for finding no relation between tree species richness and bird species richness (Yashmita-Ulman et al. 2016). According to Tanalgo et al. (2015), the insectivorous feeding guild was the most dominant feeing group in agroforests, which supports the findings of Blake and Loiselle (2001) who recorded greater number of insectivores in agroforests. Avian diversity studies in agricultural systems with similar vertical complexity to what was recorded show high bird species diversity in agroforestry systems across the globe; 86 species in Sri Lanka (Kottawa-Arachi and Gamage 2015), 88 species in Cachar Valley, Assam, and 59 species in southwestern China (Lin et al. 2012), all higher than the current study. In a similar study, Tanalgo et al. (2015) investigated the diversity of birds and their feeding guilds in different land-use types in south-central Mindano and found, among all of the habitat types, the highest bird species diversity was in agroforests.

LEGACY TREES

Bird species diversity may be closely linked to the distribution and abundance of legacy trees (Mazurek and Zielinski 2013). *Chakras* in Verde Sumaco include as legacy trees *Bactris gasipaees*, *Iraiatea deltoidea*, *Oenocarpus batahua*, *Mauritia flexuosa*, and *Phytelephas aequatorialis*, all represented by relatively old trees that were typically spared during the development and harvesting of *chakras*. As part of this study, I recorded an inventory of vertically complex tree species (legacy trees) and fruit-bearing species important for tanagers, and recorded a mean count of seven in species-rich *chakras* and five in species-poor *chakras* (Table 4). Therefore, this study also shows evidence that legacy trees could be positively affecting bird diversity (Figure 6). During the bird surveys, I occasionally observed passerines using legacy trees for perching, resting and foraging. Mazurek and Zielinski (2013) found the number of birds observed were significantly greater at legacy trees as measured by species richness, species diversity, and use by a number of different taxa; legacy trees appear to add significant habitat value to managed forests. According to Van Bael et al. (2007), the presence of large trees in a *chakra* is associated with important breeding areas and food resources for many bird species, and their presence may influence the high diversity of birds in the habitat.

Figure 6. Post-harvest distribution of legacy trees in one chakra in Verde Sumaco, Ecuador (Voysey 2019).

VERTICAL STRATIFICATION

Avian species richness in *chakras* might be related to structurally and floristically diverse canopies that compare well with other natural forest habitats (Greenberg et al. 1997). The study area in Verde Sumaco constituted of vertically complex trees such as the legacy trees listed above that formed the canopy layer, and a number of shrub-layer trees, including *Coffea* spp., *Manihot esculenta*, and *Thobroma caca*. The *chakra*'s multi-layered canopy structure could provide different opportunities for foraging, nesting and perching, according to the individual preferences among the passerines (Linberg et al. 1998)

FRUIT YIELDING TREES

Fruit yielding trees like *Annona cherimilia*, *Annona squamosal*, *Artocarpus altilis*, *Carica papaya*, *Carludovica palmate*, *Inga densiflora*, *Inga edulis*, *Guaba machitona*, *Guarea kunthiana*, *Musa acuminate*, *Musa sapientum*, *Persea americana, Pourouma cecropiifolia*, and *Pouteria camimito* were commonly found in the study area (Figure 7). Characteristics that have been given most attention in the conservation literature are properties of the fruits themselves. Avian preferences for fruits could be a degree of selectivity within a given fruit yielding species, for example, for large over small or ripe over unripe fruits. Further, the physical accessibility of fruiting resource may override preferences based on nutritional characteristics of the fruits (Moermond and Denslow 1983).

Figure 7. Man harvesting guava fruits in the chakra system in Verde Sumaco, Ecuador (Voysey 2019).

BIRDS OF PREY

Differences in passerine species richness in the *chakras* could be tied to the presence of predators. Birds of prey such as the Yellow-headed Caracara (*Milvago chimachima*), Slate-colored Hawk (*Buteogallus schistaceus*), Roadside Hawk (*Rupornis magnirostris*), and Black Caracara (*Daptrius ater*) were commonly found in the study area. The presence of hawks was responsible for the lower number of passerines observed. The abundance of hawks could have varied with their diet and prey preference, the availability of perches, and their prey distribution (Nicoll and Norris 2010). Janes (1985) found foraging behavior, particularly the dichotomy between perching and aerial foraging, is a crucial variable determining habitat preference for hawks, with open space next in significance in predicting their presence. Yellow-headed Caracaras use perching trees while they hunt for prey (Schulenberg 2018), thereby matching my observations. Yellow-headed Caracaras were occasionally seen perched within the *chakra* boundary on legacy trees. Additionally, *chakras* retain the legacy of hard edges next to forest, as I observed in many of the samples, the result of removing undesired vegetation within them that develops an open habitat (Lopez-Barrera et al. 2004). This kind of habitat assists hunting by Roadside Hawks and Slate-colored Hawks that occur in forest-edges and semi-open areas (Terraube et al. 2016).

VEGETATION DIVERSITY

In the present study, bird species richness was not predicted by vegetation richness. A similar avian study for agroforestry systems showed bird species richness had no positive correlation to tree species richness (Yashmita-Ulman et al. 2016). Vegetation diversity in agroforestry systems revealed high plant species diversity (107 species) in Lakhipur, Assam and Papumpare, Arunachal Pradesh (Zimik et al. 2012), even higher (142 species) in Goldaghat and Jorhat, Assam (Saikia et al. 2012), and somewhat lower (71 species) in Barak Valley, Assam (Devi and Das 2013), in each case higher than the tree species richness recorded in Verde Sumaco study (Figure 8). There were 58 plant species in the species-rich *chakras* and 63 plant species in the species-poor *chakras*. The vegetation species diversity likely reflects the objectives of most of the *chakra* owners, who plant species that provide commercial products for economic benefits (Torres et al. 2015). In other *chakras*, the owner's main objective may be to plant species for medicinal use and family food supplies, therein possibly increasing tree diversity.

Figure 8. Common chakra system with cocoa and yuca plants in Verde Sumaco, Ecuador (Voysey 2019)

SEASON, REGENERATION & CORRIDORS

Multiple factors could impact avian species richness, such as season, degree of *chakra* regeneration, and the presence of forest reserve corridors. Passerine species richness could have been impacted by age since the *chakra* was last harvested. In the present study, recently harvested *chakras* had fewer available fruiting resources for frugivorous avian species (Figure 9); in comparison, mature *chakras* had a greater abundance of fruiting resources. The availability of food resources is vital to the diversity of birds (Tanalgo et al. 2015). Bird diversity may also be affected by adjacent natural forests, which could serve as avian corridors. According to Waltert et al. (2005), *chakras* that are adjacent to primary forests sustain a high number of bird species compared to adjacent secondary forests. Corridors could increase inflow of species into *chakras*, which in in turn could increase or maintain avian species richness and diversity (Yashmita-Ulman et al. 2016).

Figure 9. Recently harvest chakra system in Verde Sumaco, Ecuador (Voysey 2019).

TANAGERS

The tanagers are an important group to forest restoration due to their efficient seed dispersal activity (Schulenberg 2019). There were nine tanager species recorded in the study area: the Bananaquit (*Coereba flaveola*), Blue-gray Tanager (*Thraupis episcopus*), Flame-crested Tanager (*Tachyphonus cristatus*), Fulvous-shrike Tanager (*Lanio fulvus*), Magpie Tanager (*Cissopis leveriana*; Figure 10), Palm Tanager (*Thraupis palmarum*), Paradise Tanager (*Tangara chilensis*), Silver-beaked Tanager (*Ramphocelus carbo*), and Swallow Tanager (*Tersina viridis*). Tanagers were only observed in the species-rich *chakras*. Therefore, the presence of any tanager as an indicator species may be associated with passerine species richness in general. However, tanager absence could also have been related to the presence of predators, more common in the species-poor *chakras*. Both the Slate-colored and Roadside hawks are known to forage on small prey such as tanagers (Schulenberg 2018). Of all of the bird species observed, the Blue-Gray Tanager and Palm Tanager were the most common. These two tanagers thrive at forest edges, along roads and rivers, and in plantations, corresponding to my observations of them in Verde Sumaco.

Figure 10. Magpie Tanagers (Schulenberg 2019)

CONCLUSION

The findings suggest that *chakras* can be taken as examples of sustainable production to mitigate the adverse impacts of deforestation, unsustainable logging practices, mining and urbanization. From the present study, it can be concluded that these traditional agroforestry systems serve a vital role in the conservation of avian species. The characteristics of the vegetation structure and the availability of food resources are vital to the diversity of birds in *chakras,* where food sources and legacy trees are largely available. *Chakras*, particularly the mature set, provided secure and alternative habitat for passerine species and other diverse ecosystem services that can only be maintained through the recognition of local knowledge (Caballero-Serrano et al. 2017). Indigenous communities have a rich traditional culture of protecting the environment and conserving the natural landscape, while sustaining their livelihoods. Traditional agroforestry practices and the present findings can guide policymakers and other stakeholders in their decisions on land development and land-use policies.

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APPENDIX

CHAKRA 1
DATE: 18/12/2018
PLACE: SERGIO SHIGUANGO´S CHAKRA
MAIN CROP: YUCA

Nº	FAMILY	SCIENTIFIC NAME	COMMON NAME	FREQUENCY	IMPORTANCE TO TANAGER	
					YES	NO
1	Arecaceae	*Oenocarpus batahua*	Ungurahua	++	X	
2	Arecaceae	*Iriartea deltoidea*	Pambil	+++++++	X	
3	Lecythidaceae	*Grias neuberthii*	Pitón	+		X
4	Poaceae	*Saccharum officinarum*	Caña	++		X
5	Euphorbiaceae	*Manihot esculenta*	Yuca	(+…)		X
6	Bromeliaceae	*Ananas comosus*	Piña	+		X
7	Poaceae	*Zea mays*	Maíz	+	X	
8	Solanaceae	*Solanun quitoensis*	Naranjilla	+		X
9	Musaceae	*Musa sapientum*	Plátano	++	X	
10	Arecaceae	*Phytelephas aequatorialis*	Tagua	+	X	
11	Bignoniaceae	*Crescentia cujete*	Pilche	+		X
12	Meliaceae	*Guarea kunthiana*	Manzano colorado	+	X	
13	Arecaceae	*Bactris gasipaes*	Palmito	+	X	

CHAKRA 2
DATE: 18/12/2018
PLACE: RICARDO GREFA´S CHAKRA
MAIN CROP: COCOA

Nº	FAMILY	SCIENTIFIC NAME	COMMON NAME	FREQUENCY	IMPORTANCE TO TANAGER	
					YES	NO
1	Arecaceae	*Oenocarpus batahua*	Ungurahua	+++	X	
2	Sapotaceae	*Pouteria caimito*	Avío	++	X	
3	Euphorbiaceae	*Manihot esculenta*	Yuca	(+…)		X
4	Musaceae	*Musa sapientum*	Plátano	++++++++	X	
5	Arecaceae	*Bactris gasipaes*	Palmito	+++++++++++ +++++++++++ ++	X	
6	Rutaceae	*Citrus nobilis*	Mandarina	+		X
7	Fabaceae	*Lonchocarpus utilis-nicoi*	Barbasco	+		X
8	Malvaceae	*Theobroma cacao*	Cacao	(+…)		X
9	Rubiaceae	*Coffea sp.*	Café	(+…)		X
10	Malvaceae	*Ochorama pyramidale*	Balsa	+		X
11	Urticaceae	*Cecropia peltada*	Guarumo	++		X
12	Fabaceae	*Brownea ucayalina*	Palo de cruz	++		X

CHAKRA 3
DATE: 19/12/2018
PLACE: BARTOLO SHIGUANGO´S CHAKRA
MAIN CROPS: COCOA

N°	FAMILY	SCIENTIFIC NAME	COMMON NAME	FREQUENCY	IMPORTANCE TO TANAGER	
					YES	NO
1	Malvaceae	*Theobroma cacao*	Cacao	(+…)		X
2	Arecaceae	*Mauritia flexuosa*	Morete	+++	X	
3	Arecaceae	*Bactris gasipaes*	Palmito	++++++++	X	
4	Musaceae	*Musa sapientum*	Plátano	+++++++++++++ +++	X	
5	Euphorbiaceae	*Manihot esculenta*	Yuca	(+…)		X
6	Fabaceae	*Inga edulis*	Guaba	+++	X	
7	Caricaceae	*Carica papaya*	Papaya	+++++	X	
8	Fabaceae	*Inga densiflora*	Guaba machitona	+++++	X	
9	Malvaceae	*Herrania nitida*	Cacao de monte	+		X
10	Poaceae	*Saccharum officinarum*	Caña	+++++		X
11	Sapindaceae	*Nephelium lappaceum*	Achotillo	++++++		X
12	Lecythidaceae	*Grias neuberthii*	Pitón	++		X
13	Lauraceae	*Laurus nobilis*	Laurel	+++		X
14	Caricaceae	*Carica cherimolia*	Chirimoya	+		X
15	Rutaceae	*Citrus medica*	Limón	+++		X
16	Marantaceae	*Calathea lutea*	Bijao	++		X
17	Cecropiaceae	*Pourouma cecropiifolia*	Uva	++++	X	
18	Sapotaceae	*Pouteria caimito*	Avío	+	X	
19	Malpighiaceae	*Banisteriopsis caapi*	Yagé	+		X
20	Fabaceae	*Lonchocarpus utilis-nicoi*	Barbasco	++		X
21	Malvaceae	*Theobroma bicolor*	Cacao blanco	+		X
22	Arecaceae	*Attalea butyracea*	Locata	+++		X
23	Monomiaceae	*Siparuna eriocalyx*	Malaria	+		X
24	Arecaceae	*Ceroxylon echinulatum*	Patigua	+	X	

CHAKRA 4
DATE: 19/12/2018
PLACE: CÉSAR CALAPUCHA´S CHAKRA
MAIN CROP: CORN

Nº	FAMILY	SCIENTIFIC NAME	COMMON NAME	FREQUENCY	IMPORTANCE TO TANAGER	
					YES	NO
1	Meliaceae	*Cedrela odorata*	Cedro	++		X
2	Musaceae	*Musa sapientum*	Plátano	++++++++++++	X	
3	Rutaceae	*Citrus medica*	Limón	+		X
4	Bignoniaceae	*Crescentia cujete*	Pilche	+		X
5	Bixaceae	*Bixa orellana*	Achiote	+		X
6	Arecaceae	*Attalea butyracea*	Locata	++++++++		X
7	Rubiaceae	*Calycophyllum spruceanum*	Capirona	++++++++++++		X
8	Fabaceae	*Myroxylon balsamum*	Bálsamo	++++++++		X
9	Arecaceae	*Bactris gasipaes*	Palmito	+++++++++++++++	X	
10	Solanaceae	*Capsicum annuum*	Ají	+		X
11	Sapotaceae	*Pouteria caimito*	Avío	+	X	
12	Rutaceae	*Citrus nobilis*	Mandarina	+		X
13	Malvaceae	*Theobroma bicolor*	Cacao blanco	++		X
14	Cyclanthaceae	*Carludovica palmata*	Paja toquilla	+++++++	X	
15	Poaceae	*Guadua angustifolia*	Guadua	(+…)		X
16	Lauraceae	*Persea americana*	Aguacate	++		X
17	Caricaceae	*Carica papaya*	Papaya	++	X	
18	Aquifoliaceae	*Ilex guayusa*	Guayusa	+		X
19	Poaceae	*Zea mays*	Maíz	(+…)		X
20	Fabaceae	*Inga edulis*	Guaba	+	X	
21	Urticaceae	*Stinging nettle*	Ortiga	(+…)		X
22	Musaceae	*Musa acuminata*	Guineo	(+…)	X	
23	Vochysiaceae	*Vochysia leguiana*	Tamburo	++		X

CHAKRA 5
DATE: 20/12/2018
PLACE: BOLÍVAR CALAPUCHA´S CHAKRA
MAIN CROP: COFFEE

Nº	FAMILY	SCIENTIFIC NAME	COMMON NAME	FREQUENCY	IMPORTANCE TO TANAGER	
					YES	NO
1	Poaceae	*Saccharum officinarum*	Caña de azúcar	++++++++++++		X
2	Fabaceae	*Lonchocarpus nicou*	Barbasco	++++++		X
3	Polygonaceae	*Triplaris cumingiana*	Arenillo	++++++++		X
4	Meliaceae	*Cedrela odorata*	Cedro	++		X
5	Euphorbiaceae	*Manihot esculenta*	Yuca	(+…)		X
6	Rubiaceae	*Coffea sp.*	Café	(+…)		X
7	Bromeliaceae	*Ananas comosus*	Piña	(+…)		X
8	Apocynaceae	*Lacmellea sp.*	Chicle	+		X
9	Malvaceae	*Gossypium herbaceum*	Algodón	+		X
10	Solanaceae	*Capsicum annuum*	Ají	+		X
11	Solanaceae	*Brunfelsia grandiflora*	Chiriguayusa	+		X
12	Anacardiaceae	*Anacardium occidentale*	Marañón	++		X
13	Arecaceea	*Cocos nucifera*	Coco	+++		X
14	Poaceae	*Triticum*	Trigo	(+…)		X
15	Fabaceae	*Inga edulis*	Guaba	+++	X	
16	Arecaceae	*Bactris gasipaes*	Chonta	++++	X	
17	Caricaceae	*Carica papaya*	Papaya	++++	X	
18	Poaceae	*Zea mays*	Maíz	(+…)		X
19	Musaceae	*Musa acuminata*	Guineo	(+…)	X	
20	Sapindaceae	*Nephelium lappaceum*	Achotillo	+		X
21	Solanaceae	*Solanum sessiliflorum*	Cocona	++		X

22	Musaceae	*Musa sapientum*	Plátano	+++++	X	
23	Poaceae	*Cymbopogon citratus*	Hierba luisa	+		X
24	Araceae	*Colocasia esculenta*	Papachina	+		X
25	Annonaceae	*Annona cherimilia*	Chirimoya	+	X	
26	Bixaceae	*Bixa orellana*	Achiote	+		X
27	Rutaceae	*Citrus sinensis*	Naranja	+		X
28	Fabaceae	*Arachis hypogaea*	Maní	+		X
29	Rosaceae	*Rubus ulmifolius*	Mora	+		X

CHAKRA 6
DATE: 20/12/2018
PLACE: SERGIO SHIGUANGO´S CHAKRA
MAIN CROP: CORN

N°	FAMILY	SCIENTIFIC NAME	COMMON NAME	FREQUENCY	IMPORTANCE TO TANAGER	
					YES	NO
1	Poaceae	*Zea mays*	Maíz	(+…)		X
2	Malvaceae	*Theobroma cacao*	Cacao	(+…)		X
3	Caricaceae	*Carica papaya*	Papaya	++++++	X	
4	Rubiaceae	*Calycophyllum spruceanum*	Capirona	+		X
5	Fabaceae	*Machaerium millei*	Cabo de hacha	+		X
6	Arecaceae	*Astrocaryum chambira*	Chambira	++		X
7	Arecaceae	*Astrocaryum murumuru*	Ramos	++		X
8	Arecaceae	*Bactris gasipaes*	Palmito	+	X	
9	Arecaceae	*Wettinia maynensis*	Palma canela	+		X
10	Arecaceae	*Iriartea deltoidea*	Pambil	++++++		X
11	Arecaceae	Ceroxylon echinulatum	Patigua	+		X

12	Lecythidaceae	*Grias neuberthii*	Pitón	+		X
13	Musaceae	*Musa acuminata*	Guineo	++++++	X	
14	Musaceae	*Musa sapientum*	Plátano	+++	X	
15	Solanaceae	*Solanum sessiliflorum*	Cocona	+		X
16	Convolvulaceae	*Impomea batatas*	Camote	+		X
17	Solanaceae	*Capsicum annuum*	Ají	+++++++		X
18	Lauraceae	*Persea americana*	Aguacate	+	X	
19	Poaceae	*Triticum*	Trigo	++		X
20	Fabaceae	*Arachis hypogea*	Maní	(+…)		X
21	Myrtaceae	*Eugenia stipitata*	Arazá	++		X
22	Euphorbiaceae	*Manihot esculenta*	Yuca	+++++++++++++		X

CHAKRA 7
DATE: 20/12/2018
PLACE: CAROLINA GREFA´S CHAKRA
MAIN CROP: YUCA

Nº	FAMILY	SCIENTIFIC NAME	COMMON NAME	FREQUENCY	IMPORTANCE TO TANAGER	
					YES	NO
1	Euphorbiaceae	*Manihot esculenta*	Yuca	(+…)		X
3	Musaceae	*Musa sapientum*	Plátano	++++++++++	X	
4	Malvaceae	*Theobroma bicolor*	Cacao blanco	++		X
5	Heliconiaceae	*Heliconia sp.*	Platanillo	(+…)		X
6	Fabaceae	*Inga sp.*	Guabilla	++++++++++++	X	
7	Arecaceae	*Oenocarpus batahua*	Ungurahua	+		X
8	Lauraceae	*Laurus nobilis*	Laurel	+		X
9	Solanaceae	*Solanum sessiliflorum*	Cocona	+		X

10	Fabaceae	*Brownea ucayalina*	Palo de cruz	+		X
11	Arecaceae	*Bactris gasipaes*	Palmito	+++++++++	X	
12	Rubiaceae	*Coffea sp.*	Café	++		X
13	Bromeliaceae	*Ananas comosus*	Piña	+++++++++++++		X
14	Myristicaceae	*Virola spp.*	Coco	+		X
15	Fabaceae	*Lonchocarpus nicou*	Barbasco	+		X

CHAKRA 8
DATE: 21/12/2018
PLACE: CARLOS (MAXI) GREFA´S CHAKRA
MAIN CROP: YUCA

N°	FAMILY	SCIENTIFIC NAME	COMMON NAME	FREQUENCY	IMPORTANCE TO TANAGER	
					YES	NO
1	Rubiaceae	*Coffea sp.*	Café	(+…)		X
2	Musaceae	*Musa sapientum*	Plátano	(+…)	X	
3	Mimosaceae	*Cedrelinga cateniformis*	Chuncho	++		X
4	Arecaceae	*Mauritia flexuosa*	Morete	+++	X	
5	Myrtaceae	*Psidium guajava*	Guayaba	++	X	
6	Areacaceae	*Bactris gasipaes*	Palmito	++++++++++++	X	
7	Sapotaceae	*Pouteria caimito*	Avío	++++	X	
8	Fabaceae	*Inga edulis*	Guaba	++	X	
9	Musaceae	*Musa acuminata*	Guineo	(+…)	X	
10	Euphorbiaceae	*Manihot esculenta*	Yuca	(+…)		X
11	Fabaceae	*Inga densiflora*	Guaba machitona	++	X	
12	Lauraceae	*Laurus nobilis*	Laurel	+++++		X
13	Cyclanthaceae	*Carludovica palmata*	Paja toquilla	++		X

14	Araceae	*Colocasia esculenta*	Papachina	+++++		X
15	Malvaceae	*Theobroma bicolor*	Cacao blanco	++		X
16	Cecropiaceae	*Pourouma cecropiifolia*	Uva	++	X	
17	Aquifoliaceae	*Ilex guayusa*	Guayusa	+		X
18	Moraceae	*Artocarpus altilis*	Frutipan	++		X
19	Lecythidaceae	*Grias neuberthii*	Pitón	+		X
20	Annonaceae	*Annona squamosa*	Anona	++	X	
21	Euphorbiaceae	*Croton lechleri*	Sangre de drago	+		X
22	Solanaceae	*Brunfelsia grandiflora*	Chiriguayusa	+		X
23	Rutaceae	*Citrus sinensis*	Naranja	+		X
24	Lauraceae	*Persea americana*	Aguacate	+	X	
25	Malvaceae	*Gossypium herbaceum*	Algodón	+		X
26	Malpighiaceae	*Banisteriopsis caapi*	Yagé	+		X
27	Sapindaceae	*Nephelium lappaceum*	Achotillo	+		X

CHAKRA 9
DATE: 21/12/2018
PLACE: CARLOS (MAXI) GREFA´S CHAKRA
MAIN CROPS: NO CROPS (IN THE FUTURE, CORN)

N°	FAMILY	SCIENTIFIC NAME	COMMON NAME	FREQUENCY	IMPORTANCE TO TANAGER	
					YES	NO
1	Heliconiaceae	*Heliconia sp.*	Platanillo	(+…)		X
2	Lauraceae	*Laurus nobilis*	Laurel	++++++		X
3	Sapotaceae	*Pouteria sapota*	Zapote	+		X

4	Caricacea	*Carica papaya*	Papaya	+	X	
5	Areacaceae	*Astrocaryum murumuru*	Ramos	+++		X
6	Moraceae	*Ficus eslastica*	Caucho	+		X
7	Musaceae	*Musa sapientum*	Plátano	+	X	

CHAKRA 10
DATE: 21/12/2018
PLACE: OTTO AGUINDA´S CHAKRA
MAIN CROPS: YUCA AND PLANTAIN

N°	FAMILY	SCIENTIFIC NAME	COMMON NAME	FREQUENCY	IMPORTANCE TO TANAGER	
					YES	NO
1	Heliconiaceae	*Heliconia sp.*	Platanillo	(+…)		X
2	Musaceae	*Musa sapientum*	Plátano	(+…)	X	
3	Caricacea	*Carica papaya*	Papaya	++++++	X	
4	Arecaceae	*Astrocaryum murumuru*	Ramos	+		X
5	Lauraceae	*Laurus nobilis*	Laurel	+++		X
6	Malvaceae	*Ochroma pyramidale*	Balsa	++		X
7	Euphorbiaceae	*Manihot esculenta*	Yuca	(+…)		X
8	Arecaceae	*Bactris gasipaes*	Palmito	+	X	
9	Musaceae	*Musa acuminata*	Guineo	(+…)	X	

CHAKRA 11
DATE: 21/12/2018
PLACE: OLGER CALAPUCHA´S CHAKRA
MAIN CROP: COCOA

Nº	FAMILY	SCIENTIFIC NAME	COMMON NAME	FREQUENCY	IMPORTANCE TO TANAGER	
					YES	NO
1	Malvaceae	*Thobroma cacao*	Cacao	(+…)		X
2	Caricacea	*Carica papaya*	Papaya	(+…)	X	
3	Euphorbiaceae	*Manihot esculenta*	Yuca	(+…)		X
4	Musaceae	*Musa sapientum*	Plátano	+++++++++++++	X	
5	Poaceae	*Saccharum officinarum*	Caña de azúcar	(+…)		X
6	Fabaceae	*Inga edulis*	Guaba	+++++++++++	X	
7	Lauraceae	*Laurus nobilis*	Laurel	++++++++++++++ +++++++++		X
8	Arecaceae	*Bactris gasipaes*	Palmito	++++++++++++++	X	
9	Arecaceae	*Mauritia flexuosa*	Morete	++		X
10	Meliaceae	*Cedrela odorata*	Cedro	+		X
11	Apocynaceae	*Lacmellea sp.*	Chicle	++		X
12	Myristicaceae	*Virola spp.*	Coco	++		X
13	Cecropiaceae	*Pourouma cecropiifolia*	Uva	+	X	
14	Rubiaceae	*Alibertia patinoi*	Borojó	+		X
15	Musaceae	*Musa acuminata*	Guineo	++++++++	X	
16	Fabaceae	*Lonchocarpus utilis-nicoi*	Barbasco	(+…)		X
17	Mimosaceae	*Cedrelinga cateniformis*	Chuncho	+		X
18	Sapotaceae	*Pouteria caimito*	Avío	+	X	
19	Lecythidaceae	*Grias neuberthii*	Pitón	+++		X
20	Moraceae	*Artocarpus altilis*	Frutipan	+	X	
21	Bromeliaceae	*Ananas comosus*	Piña	++		X
22	Polygonaceae	*Triplaris cumingiana*	Arenillo	+++		X