ISSN 2477-9458

BOLETÍN DEL CENTRO DE INVESTIGACIONES BIOLÓGICAS

Vol.54, N^0 1, Enero-Junio 2020

UNA REVISTA INTERNACIONAL DE BIOLOGÍA
PUBLICADA POR LA
UNIVERSIDAD DEL ZULIA, MARACAIBO,
VENEZUELA

Boletín del Centro de Investigaciones Biológicas
Vol. 54. Nº 1, Enero - Junio 2020, Pp. 1-25

Bird community composition on a cacao plantation in Venezuela.

Carlos Verea[1] and Cristina Sainz-Borgo[2]

[1]Universidad Central de Venezuela, Facultad de Ciencias, Instituto de Zoología y Ecología Tropical, Laboratorio de Biología y Conservación de Aves, Caracas, Venezuela.

[2]Universidad Simón Bolívar, Departamento de Biología de Organismos, Valle de Sartenejas, Caracas, Venezuela.

Corresponding author: cverea@gmail.com

Abstract

In order to know the bird diversity on a cacao *Theobroma cacao* plantation with high agricultural management, and its role as habitat for local birds and avifauna conservation, 36 mist-netting sessions (2,592 net-h) were carried out from January to December 2012. A total of 635 individuals from 59 species were captured. A high diversity index was obtained. Additionally, 26 species were visually and/or acoustically recorded, for a total richness of 85 species. The following conservation indicators were obtained from the overall avifauna: five endemic birds (species/subspecies), five migratory species (boreal, austral, and local travelers), and four waterbirds. Also, the families bioindicators of environmental quality were well represented. The insectivores were the richest feeding guild. These attributes confer certain value for bird conservation to the plantation studied. Nonetheless, a high fraction (86%) of these species were transient birds that eventually (1–3 captures/year) visited the plantation. These birds were benefited from the lack of a well-structured understory and many of them (29%) are catalogued as disturbed area birds. Thus, the plantation studied was only able to hold a low number of local birds and it was practically dominated by one nectar-dependent species: *Glaucis hirsutus* (32.1% of total captures). Due to this, Trochilidae was the main taxonomic group (51.3% of total captures), and also made the nectarivores-insectivores the main feeding guild (56.4% of total captures). These results suggest that our cacao plantation with a high level of management does not stand out as an appropriate ecosystem for local birds or bird conservation.

Key words: Agroecosystem; Agroforestry; Bird biodiversity; Conservation; Shade-grown crop.

Composición de la comunidad de aves en una plantación de cacao de Venezuela

Resumen

Con el objeto de conocer la diversidad aviar de una plantación de cacao *Theobroma cacao* con un alto manejo agrícola, así como su papel como hábitat para las aves locales y la conservación de la avifauna, 36 muestreos con redes de neblina (2.592 h-redes) se efectuaron desde enero hasta diciembre de 2012. Un total de 635 individuos de 59 especies fueron capturados, generando un alto índice de diversidad. Adicionalmente, 26 especies fueron registradas visual/auditivamente para una riqueza total de 85 especies. Los siguientes indicadores de conservación se registraron considerando la avifauna general: cinco aves endémicas (especies/subespecies), cinco migratorias (boreales, australes y viajeros locales) y cuatro aves acuáticas. Además, las familias indicadoras de la calidad ambiental estuvieron bien representadas. El gremio de los insectívoros resultó el más importante. Estos atributos le otorgan a la plantación estudiada cierto valor de conservación para las aves. A pesar de ello, una elevada fracción (86%) de estas especies fueron aves transitorias que eventualmente (1–3 capturas/año) visitaron la plantación. Estas aves fueron beneficiadas por la ausencia de un sotobosque bien estructurado, pero muchas (29%) eran aves típicas de áreas alteradas. De esta manera, la plantación estudiada fue solo capaz de albergar un bajo número de especies locales y fue prácticamente dominada por una especie dependiente de néctar: *Glaucis hirsutus* (32,1% de las capturas totales). Debido a ello, Trochilidae fue el grupo taxonómico más importante (51,3% de las capturas totales) y los nectarívoro-insectívoros el principal gremio alimentario (56,4% de las capturas totales). Estos resultados sugieren que la plantación estudiada con un alto manejo agronómico no resalta como un lugar apropiado para el mantenimiento de la avifauna local o la conservación de las aves.

Palabras clave: Agroecosistema; Agroforestería; Biodiversidad aviar; Conservación; Plantaciones de sombra.

Introduction

Due to the decline of biodiversity as a result of deforestation by agricultural activities, ornithological studies in agroecosystems have become essential. Modern agriculture involves extensive destruction of wooded areas, removing several habitat types including those used by birds for nesting, courtship, roosting, and foraging (Verea *et al*. 2009), resulting in fragmentation of the landscape. Species that survive the initial disturbance that comes with establishment of new agricultural areas must then survive secondary threats such as biocides (Newton 1998), which can affect bird vitality and survival (Freemark and Boutin 1995). As a result of the high environmental cost of agricultural activity, the current trend is to look for crops that provide a better option for bird conservation.

Recibido / Received: 23-01-2020 ~ **Aceptado / Accepted:** 25-05-2020

Cacao *Theobroma cacao* is one of the most important crop species in the world (de Schawe *et al*. 2018) and cacao agroforestry is considered a biodiversity-friendly farming practice by maintaining habitats for a high diversity of species, and plays a vital role in conserving bird diversity in tropical landscapes (Abrahamczyk *et al*. 2008, Rocha *et al*. 2019).

Studies in Neotropical and Asian regions have demonstrated that cacao agroforest systems with a complex vegetation structure can support a high number of bird species (Greenberg *et al*. 2000, Reitsma *et al*. 2001, Abrahamczyk *et al*. 2008), sometimes even higher than natural forested areas (Reitsma *et al*. 2001, Verea and Solórzano 2005, Faria *et al*. 2006). These plantations usually resemble an ecotone (Verea and Solórzano 2005, Faria *et al*. 2006), a place where the juxtaposition of transient birds from different nearby areas (Faria *et al*. 2006) enhance the local diversity. Thus, cacao plantations provide habitats and dispersal pathways (Faria *et al*. 2006) for birds, in addition to food places for a wide variety of feeding guilds (Greenberg *et al*. 2000, Verea and Solórzano 2005, Faria *et al*. 2006, Van Bael *et al*. 2007, Verea *et al*. 2009, among others) as well as opportunities for stop-over, roosting (Faria *et al*. 2006), nest construction (Faria *et al*. 2006, Van Bael *et al*. 2007), and courtship displays (Verea and Solórzano 2005).

They also assist in the conservation of the local birds (Faria *et al*. 2006), including endemic (Verea and Solórzano 2005, Abrahamczyk *et al*. 2008, Verea *et al*. 2009) and threatened species (Faria *et al*. 2006), aside of several migratory ones (Greenberg *et al*. 2000, Van Bael *et al*. 2007). Mainly planted below 1,000 m a. s. l. (Pancardo and Beristaín 2016), cacao likely represents the most important agroecosystem for boreal migratory birds once they reach northern South America (Verea and Solórzano 2005). Also, this plantation could form transects to protect many lowland species along its elevational gradient (Greenberg *et al*. 2000) since it mitigates the effects of deforestation and fragmentation (Greenberg *et al*. 2000, Faria *et al*. 2006). Besides the ecological attributes, birds that dwell in agroforestry systems, such as cacao, have also shown the ability to combat pests (Karp *et al*. 2013) reducing herbivore entities and thereby increasing the crop yields (Mass *et al*. 2013) to benefit farmers.

Although cacao was the first and most important exportable crop in the Venezuelan economy between the late 16th century and the early 19th century (Quintero and Cartay 2000), farmers began to abandon the plantations with the establishment of the oil economy (1920) and Venezuela quickly disappeared from the list of the world's main cacao producers (Quintero and Díaz 2004). Despite almost 400 years of cacao planting in Venezuela, little is still known about the role of these plantations as habitat for Venezuelan avifauna, increasing our need to evaluate the importance of the remaining cacao farms for the birds in the country. Our knowledge about birds that dwell and/or transit cacao plantations in Venezuela come from casual observations (Wetmore 1939, Schäfer and Phelps 1954, Phelps and Meyer de Schauensee 1994, Hilty 2003) and a few field studies (Parra 2004, Verea and Solórzano 2005, Verea *et al*. 2009, Molina and Bohórquez 2013), accounting for 147 bird species until now.

Most field studies were surveyed on rustic cacao farms –a mixture of cacao trees with other profit crops under the shadow of few remnant forest species– which certainly have shown the ability to harbor high bird diversity, especially when compared to tree-like monocultures (Verea *et al*. 2010, 2011; Montes and Solórzano 2012, Verea *et al*. 2013). However, modern cacao systems with a high farm management, devoid of well-structured understories and low shade covering, have not yet been evaluated. Considering that even simple plantations without well-developed forest structures have a certain value for bird conservation (Abrahamczyk *et al*. 2008), emerges the necessity to explore this kind of cacao systems in the country. This can help us develop a better understanding of cacao's potential for maintaining bird diversity in Venezuela and the Neotropical region.

In this study, we explored the avifauna of a cacao plantation located in the Barlovento area, a historical Venezuelan cacao zone. Our main goals are to inform about bird diversity and avian community structure on this plantation with a high farm management in a forested landscape; and determine its potential role for the maintenance of local birds and bird conservation.

Methods

Study area

This study was carried out inside the Padrón Experimental Station, Barlovento agricultural zone, Tapipa sector, Acevedo County, Miranda State (10°13'16.45"N–66°18'00.22"W, 38 m a. s. l.), an eight-hectare unit of experimental cacao production belonging to the "Instituto Nacional de Investigaciones Agrícolas (INIA)". The area, 36 km away from the coastline, corresponds to a tropical humid forest according to the Holdridge's life zones (1978). It experiences two climatic seasons: a dry season (November to April) and a rainy season (May to October), with an annual temperature average of 27°C, and annual precipitation of 1,440 mm (INIA 2016). There, cacao *Theobroma cacao* (Malvaceae) was mainly cultivated for research with a high farm management. Management practices included frequent mechanical trimming, which explains why the understory was virtually nonexistent (Fig. 1a, b).

Additionally, cacao trees were pruned twice a year, aside from the constant removal of epiphytes and mistletoes from their branches. Because the plantation was under an ecological pest control assay for Cocoa Beetle (*Steirastoma breve*), the area was a biocide-free zone. Cacao trees range from 4–6 m tall and were planted adjacent to irrigation canals. Irrigation was performed by periodic flooding, which resulted in the formation of several ponds (Fig. 1b), boosting the reproduction of mosquitoes (Diptera) and other animal life (e.g. snails, tadpoles). *Erythrina glauca* (Fabaceae), which blooms in March and experiences epiphyte (Araceae, Bromeliaceae) growth (Fig. 1d, e), provides all the shade to cacao plants, comprising a mean canopy cover of 50%. Shade trees were never pruned nor epiphytes and lianas removed, but a fraction (25–30%) of their leaves fall down in the dry season, allowing for a seasonal increase of sunlight on the plantation.

Most areas around the plantation correspond to a primary forest (Fig. 2), except for an old and small abandoned plantation southward. The plantation's edges were dominated by *Heliconia* (Heliconiaceae) shrubberies, along with other plants of Melastomataceae, Araceae, Piperaceae and Arecaceae, in addition to abandoned cacao plants mixed with *Musa* varieties (Musaceae) (Fig. 1c–1f).

There were no secondary forest patches between the cacao plantations and the adjacent forest. However, Poaceae (*Megathyrsus*) and Amaranthaceae (*Amaranthus*) weeds grew around the INIA facilities and alongside the access trails to the plantation.

Species richness, diversity and abundance

A set of 12 AVINET PQ-12 mist-nets (12 m length, 2.5 m high, and 30 mm mesh) were used to assess the bird diversity. They operated one day a week from 06:30 to 12:30 h, three times a month, from January to December 2012, yielding a total of 36 samples throughout the year (2,592 nets-h). Six mist-nets were placed in a linear arrangement (one next to the other) inside the plantation (core), and the remaining six (same arrangement) on a side of the plantation (edge) (Fig. 2). Both net groups were separated by 100 m, and they occupied the same places always. Once captured, each bird was carefully removed from the mist-net to record its identity and then released unharmed.

Species richness corresponds to the total number of captured species. Community richness level was determined as follow: poor, between 0–39 species; moderate, 40–69; high, 70–99; very high> 99 (Verea 2001). Similarity between core and edge samples was calculated using Sorensen's similarity index, which is expressed as: SI=[2C/(A+B)] x 100, where "C" represents the number of shared species between the core and edge samples; and "A" and "B" the total species count in the core and the edge samples each (Moreno 2001). Similarity levels were also determined. Values between 1–20 were considered very poorly similar; 21–40, poorly similar; 41–60, somewhat similar; 61–80, similar; and 81–99, very similar (Verea *et al*. 2000). A PERMANOVA analysis was applied between core/edge samples. The design considered a General Lineal Model based on Euclidean distance, where the month was a permanent factor, and sampled groups (core, edge) were a permanent factor orthogonal to the month. The analysis was performed with the program PRIMER v.6 (Clarke *et al*. 2014, Clarke and Gorley 2015).

Bird diversity was calculated using the Margalef index, which is expressed as: D=S-1/LnN, where "S" represents the total number of captured species, and "N" the total number of captured individuals (Moreno 2001). Values below 2.0 were considered as low diversity; 2.0–5.0, moderate; 5.1–10.0 high; and over 10.0, very high diversity (Verea *et al*. 2013). Bird abundance corresponds to the total number of captures. Species richness, diversity and community abundance values were compared with other similar mist-netted plantations of northern Venezuela (Verea and Solórzano 2005, Verea *et al*. 2009, 2010, 2011; Montes y Solórzano 2012).

Figure 1. Different views of the cacao plantation at Padrón Experimental Station, Barlovento agricultural area, Miranda state, northern Venezuela. a) cacao intensive exploitation system: cacao plants only, and no understory; b) typical ponds created after irrigation or heavy rains; c) the plantation border dominated by *Heliconia* (Heliconiaceae) shrubberies; d) epiphyte (Araceae) and various bromeliads on a shade tree; e) *Erythrina glauca* (Fabaceae) arise over the plantation; f) banana *Musa paradisiaca* planted mixed with cacao and other Musaceae varieties outside the plantation. Photos: C. Verea.

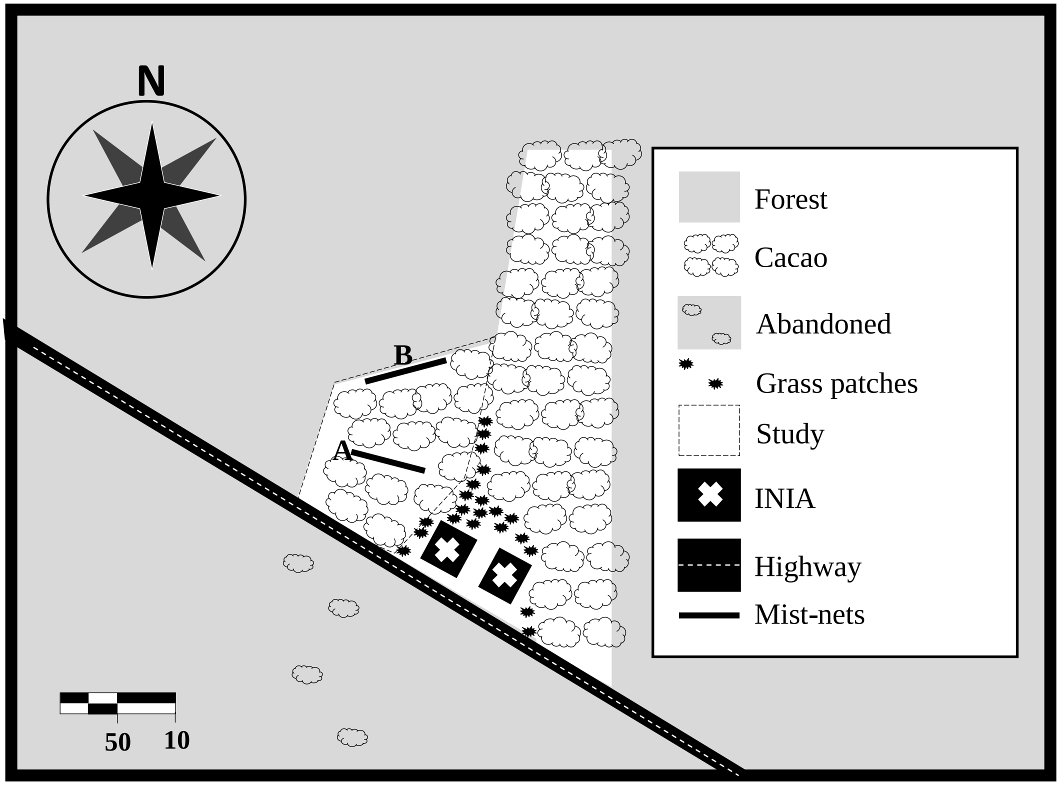


Figure 2. Schematic map of the study area at Padrón Experimental Station (INIA), Barlovento agricultural area, Tapipa sector, Miranda state, northern Venezuela. Grey parts show the forested area around the cacao plantation, except for an old abandoned plantation southward, and few patches of grass (weed) alongside trails and around INIA facilities. Mist nest places correspond to core (A) and edge (B).

Composition

The cacao community was examined based on bird composition in order to identify the plantation potential as habitat for local birds and bird conservation. Bird composition keys included common and rare species, as well as patrimonial, migratory, and disturbed habitat birds. Additionally, families and feeding guilds of conservation value were highlighted. Common and rare species were derived from their relative abundances (RA). Relative abundance was calculated by the expression: RA = [TCS/TCC] x 100, where "TCS" represents the total captures from each species; and "TCC" the total captures of the entire community. Thus, birds were grouped into common (RA ≥2%) and rare (RA <2%) species (Verea 2001). We considered patrimonial birds those birds with high conservation value, and included both species and subspecies endemic to Venezuela, as well as threatened species. The subspecies were identified as proposed by Restall *et al*. (2006).

Endemism (specific/subspecific) was determined according to Cracraft (1985), Phelps (1966), and Lentino (2003). Threatened species were assigned based on the Red List of the International Union of Nature Conservation (Birdlife International 2018). Migratory birds were those with intercontinental movements (boreal, austral) or seasonal movements within Venezuela (Hilty 2003, Lentino 2003). Disturbed habitat birds were identified based on Stotz *et al*. (1996), and Verea *et al*. (2009, 2010, 2013). Their relative abundance was employed as a measurement of environmental degradation according to Verea's *et al*. (2011): pristine, no records of disturbed habitat birds; little disturbed 1–5%; moderately disturbed, 6–20%; disturbed, 20–40%; highly disturbed, >40%.

Taxonomic family arrangement follows Remsen *et al.* (2020). Based on current taxonomy, families Cracidae, Picidae, Furnariidae, Thamnophilidae, Grallaridae, Rhynocryptidae, Formicariidae, and Troglodytidae are considered susceptible to disturbances (Sekercioglu 2002, Sekercioglu *et al*. 2002, Verea and Solórzano 2011, Brooks and Fuller 2006, Verea *et al*. 2013, Correa *et al*. 2014) since their species are the first to disappear after environmental changes and/or hunting pressure (Verea *et al*. 2011). Furthermore, their presence is considered a measurement of environmental quality, an efficient tool used in bird conservation studies (Verea *et al*. 2009), and are referred to as "families bioindicator of environmental quality".

Captured birds were assembled according to their main feeding guilds based on Cirqueira-Faustina and Graco-Machado (2006), Hilty (2003), and Verea *et al.* (2000, 2005, 2009). Birds feeding mostly on insects, and other arthropods, were considered insectivores (I); nectar and small arthropods, nectarivores-insectivores (NI); fruits (fleshy), frugivores (F); fruits and arthropods in similar proportion, frugivores-insectivores (FI); seeds, granivores (G); two or more of the mentioned guilds, omnivores (O). Also, the insectivore guild was considered the most important in terms of conservation, due to its susceptibility to habitat loss or fragmentation (Kattan *et al*. 1994, Sekercioglu 2002, Sekercioglu *et al.* 2002, Verea *et al*. 2013). Potential differences in feeding guilds composition between dry and rainy season were explored with a non-parametric U Mann-Whitney test. The analysis was performed with the program PAST V1.81 (Hammer *et al*. 2001).

Additional observations

In addition to the information provided by mist-netting, birds that visited the plantation, but were never actively captured, were also recorded. These records were made from visual (naked eye/Eagle Optics binoculars 10x40) and/or acoustic information. Since data was not taken systematically, it merely complements the information obtained from mist-netting, in order to improve the knowledge about the entire avifauna that makes use of our cacao plantation.

Results

Richness, abundance and diversity

A total of 59 species were captured (Table 1), ranking cacao richness as moderate. This richness level was lower compared to other plantations surveyed with an inferior sampling effort (Table 2). Nonetheless, the cacao plantation had a high diversity index (Table 2). From captured species, 44 were inside the plantation (core), and 40 at the edge. Both sampled groups (core, edge) were obtained similar (IS = 69) in species composition. Also, Permanova's analysis showed that there were no significant differences (p>0.05) in richness between the core and edge samples or in the richness between months.

In addition to mist-netted species, another 26 species were recorded visually and/or acoustically, increasing the cacao richness to 85 species. These species were (new records for cacao plantations in Venezuela*): *Ortalis ruficauda* (Cracidae); *Pilherodius pileatus**, *Bubulbus ibis** (Ardeidae); *Phimosus infuscatus** (Threskiornithidae); *Aramides cajaneus* (Rallidae); *Cathartes aura ruficollis**, *Coragyps atratus* (Cathartidae); *Rupornis magnirostris* (Accipitridae); *Milvago chimachima* (Falconidae); *Columbina talpacoti* (Columbidae); *Amazona amazonica*, *Forpus passerinus*, *Eupsittula pertinax venezuelae*, *Psittacara wagleri* (Psittacidae); *Galbula ruficauda* (Galbulidae); *Melanerpes rubricapillus* (Picidae); *Synallaxis albescens* (Furnariidae); *Tyrannus melancholicus** (Tyrannidae); *Chiroxiphia lanceolata* (Pipridae); *Pygochelidon cyanoleuca**, *Progne chalybaea**, *Stelgidopteryx ruficollis* (Hirundinidae); *Campylorhynchus nuchalis brevipennis** (Troglodytidae); *Turdus leucomelas* (Turdidae); *Setophaga pitiayumi* (Parulidae); and *Saltator coerulescens* (Cardinalidae). From the mist-netted data, 13 species also represented new records for cacao plantations in Venezuela (see Table 1).

A total of 635 individuals were captured, 428 (67.4%) inside the plantation, and 207 (32.6%) at the edge (Table 1). Most abundant species inside the cacao were *Glaucis hirsutus, Chionomesa fimbriata*, *Dendrocincla fuliginosa*, *Tolmomyias flaviventris*, *Turdus nudigenis*, and *Ramphocelus carbo*, while *G. hirsutus*, *C. fimbriata*, *Chrysuronia brevirostris*, *D. fuliginosa*, *C. flaveola* and *T. nudigenis* were at the edge (Table 1).

Composition

Only eight (14%) of the 59 mist-netted species were common. The remaining species (86%) were rare, mostly transients with isolated captures (Table 1). Patrimonial birds were represented by five endemic forms (species or subspecies): three captured (Table 1) and two visually/acoustically recorded: *E. pertinax venezuelae* and *C. nuchalis brevipennis*. We did not capture, nor otherwise detect, the presence of any threatened bird in the study area. Three migratory species were mist-netted (Table 1) and two others were visually recorded: *C. aura ruficollis* and *P. chalybea*. The last species corresponded to an austral migrant, while mist-netted *S. bouvronides* was a local traveler. Also, four waterbirds species were recorded inside the plantation (ponds): *P. pileatus*, *B. ibis, P. infuscatus* and *A. cajaneus*. Mist-netted disturbed habitat birds harbored 13 species (Table 1). Their proportion (22%) becomes the cacao plantation in a disturbed enviro-ment. In addition, 13 disturbed habitat birds were also observed (not captured): *B. ibis, C.*

aura, *C. atratus*, *R. magnirostris*, *M. chimachima*, *C. talpacoti*, *S. albescens*, *T. melancholicus*, *M. rubricapillus*, *P. cyanoleuca*, *P. chalybaea*, *S. ruficollis*, and *S. coerulescens*.

Table 1. List of the 59 mist-netted bird species with their captures number (core, edge) and feeding guilds, obtained from a cacao plantation studied from January to December 2012 at Padrón Experimental Station, Barlovento agricultural area, Tapipa sector, Miranda State, northern Venezuela.

Families and Species		**Captures**		
	Guild[1]	**Core**	**Edge**	**Total**[2]
Columbidae				
[e]*Claravis pretiosa*	G	0	1	1 (0.2)
Leptotila v. verreauxi	G	3	2	5 (0.8)
Leptotila rufaxilla pallidipectus	G	1	0	1 (0.2)
Trochilidae				
[a, e]*Chrysuronia brevirostris*	NI	25	11	36 (5.7)
[a,c]*Chionomesa fimbriata elengantissima*	NI	35	17	52 (8.2)
Chalybura buffonii aeneicauda	NI	1	0	1 (0.2)
Chlorestes n. notata	NI	1	3	4 (0.6)
Chlorostilbon mellisugus caribaeus	NI	0	1	1 (0.2)
[e]*Chrysolampis mosquitus*	NI	0	1	1 (0.2)
[e]*Colibri c. coruscans*	NI	1	0	1 (0.2)
[e]*Colibri thalassinus cyanotus*	NI	1	0	1 (0.2)
Phaethornis a. anthophilus	NI	4	2	6 (0.9)
Phaethornis striigularis ignobilis	NI	0	1	1 (0.2)
Phaethornis a. augusti	NI	2	0	2 (0,3)
Florisuga m. mellivora	NI	1	2	3 (0.5)
[a]*Glaucis h. hirsutus*	NI	123	81	204(32.1)
Picidae				
[e]*Colaptes r. rubiginosus*	I	1	0	1 (0.2)
Picumnus squamulatus roehli	I	4	0	4 (0.6)
Formicariidae				
[e]*Formicarius analis saturatus*	I	1	0	1 (0.2)
Furnariidae				
Lepidocolaptes souleyetii littoralis	I	6	1	7 (1.1)
[a]*Dendrocincla fuliginosa meruloides*	I	17	13	30 (4.7)
Phacellodomus rufifrons inornatus	I	2	0	2 (0.3)
[c]*Synallaxis albescens occipitalis*	I	1	0	1 (0.2)
Xenops minutus neglectus	I	0	1	1 (0.2)
Xiphorhynchus susurrans nanus	I	1	1	2 (0.3)

Boletín del Centro de Investigaciones Biológicas
Vol. 54. Nº 1, Enero - Junio 2020, Pp. 1-25

Cont. Tabla 1.

Families and Species	**Guild[1]**	**Captures** Core	Edge	**Total[2]**
Tyrannidae				
[e]*Legatus l. leucophaius*	FI	1	1	2 (0.3)
Leptopogon s. superciliaris	FI	2	0	2 (0.3)
[d,e,f]*Mionectes oleagineus abdominalis*	F	9	3	12(1.9)
[d,e]*Phylloscartes flaviventris*	I	1	0	1 (0.2)
[c]*Myiozetetes cayannensis rufipennis*	FI	1	0	1 (0.2)
[c]*Myiozetetes similis columbianus*	FI	10	2	12(1.9)
Myiopagis gaimardii bogotensis	FI	2	0	2 (0.3)
[c]*Pitangus sulphuratus rufipennis*	O	7	0	7 (1.1)
[a,c]*Tolmomyias flaviventris collingwoodi*	I	21	4	25(3.9)
Tolmomyias sulphurescens exortivus	I	5	4	9 (1.4)
[c,e]*Elaenia f. flavogaster*	FI	0	1	1 (0.2)
Pipridae				
Ceratopipra e. erythrocephala	F	7	0	7 (1.1)
Pipra filicauda subpallida	F	2	2	4 (0.6)
Tytiridae				
[e, f]*Pachyramphus polychopterus tristis*	FI	2	0	2 (0.3)
Vireonidae				
Hylophilus flavipes acuticaudata	FI	0	1	1 (0.2)
Pachysylvia aurantiiforns saturatus	I	1	0	1 (0.2)
Troglodytidae				
[c]*Troglodytes aedon albicans*	I	3	3	6 (0.9)
Turdidae				
[a, c]*Turdus n. nudigenis*	FI	46	15	61(9.6)
Turdus flavipes venezuelensis	FI	1	0	1 (0.2)
Turdus fumigatus aquilonalis	FI	3	0	3 (0.5)
Thraupidae				
[e]*Chlorophanes s. spiza*	F	0	1	1 (0.2)
[a,c]*Ramphocelus carbo venezuelensis*	FI	12	3	15(2.4)
[d]*Eucometis penicillata affinis*	I	3	3	6 (0.9)
[c,f]*Thraupis episcopus cana*	FI	1	2	3 (0.5)
[b]*Sporophila bouvronides*	G	1	0	1 (0.2)
Sporophila i. intermedia	G	8	1	9 (1.4)
Sporophila n. nigricollis	G	6	1	7 (1.1)

Cont. Tabla 1.

Families and Species	**Guild[1]**	**Captures** Core	Edge	**Total[2]**
Parulidae				
[a,c]*Coereba flaveola luteola*	NI	26	19	45 (7.1)
[b]*Parkesia noveboracensis*	I	8	1	9 (1.4)
[b]*Setophaga petechia aestiva*	I	1	1	2 (0.3)
Icteridae				
Cacicus c. cela	FI	1	0	1 (0.2)
Psarocolius d. decumanus	FI	4	0	4 (0.6)
[c]*Icterus n. nigrogularis*	FI	1	0	1 (0.2)
Fringillidae				
Euphonia laniirostris crassirostris	F	1	1	2 (0.3)

[1]Feeding guilds: F: frugivores; I: insectivores; FI: frugivores–insectivores; G: granivores; O: omnivores.

[2]Data in parenthesis correspond to Relative Abundance: RA = [TCS/TCC] x 100.

Composition: a, common species; b, migratory species; c, disturbed habitat bird; d, endemic (species or subspecies); e, new record for cacao plantations in Venezuela, based on Wetmore (1939), Schäfer and Phelps (1954), Phelps and Meyer de Schauensee (1994), Parra (2004), Verea and Solórzano (2005), and Verea *et al*. (2009); f, species previously known in cacao plantations from Neotropical region (Faria *et al*. 2006, Van Bael *et al*. 2007).

Table 2. Bird richness (number of species), abundance (number of captures), and diversity from a cacao plantation studied at Padrón Experimental Station (Barlovento) compared with other mist-netted plantations of northern Venezuela.

Plantation	**Effort (nets-h)**	**Number of species**	**Richness level[f]**	**Number of captures**	**Diversity[g]**	**Diversity level[h]**
Cacao (present study)	2,592	59	Moderate	635	9.6	High
Cacao *Theobroma cacao*[a]	600	54	Moderate	469	8.6	High
Cacao *Theobroma cacao*[b]	1,800	72	High	718	10.8	Very high
Orange *Citrus sinensis*[b]	1,800	75	High	684	11.3	Very high
Tangerine *Citrus reticulata*[c]	1,800	50	Moderate	200	9.2	High
Avocado *Persea americana*[d]	1,800	41	Moderate	608	6.2	High
Banana *Musa paradisiaca*[e]	1,800	23	Poor	313	3.8	Moderate

Sources: [a]Verea and Solórzano 2005, [b]Verea *et al*. 2009, [c]Montes y Solórzano 2012, [d]Verea *et al*. 2011, [e]Verea *et al*. 2010.

[f]Richness levels (Verea *et al*. 2000): 0–39 species: poor; 40–69: moderate; 70–99: high; >99 species: very high.

[g]Margalef diversity index: D = S–1/LnN.

[h]Diversity levels: < 2.0 low diversity; 2.0–5.0, moderate; 5.1–10.0 high; and over 10.0, very high diversity (Verea *et al*. 2013).

Boletín del Centro de Investigaciones Biológicas
Vol. 54. Nº 1, Enero - Junio 2020, Pp. 1-25

A total of 15 families were found in the mist-netted sample (Fig. 3). Of these, Trochilidae was the richest (13 species), and most abundant family (51.3% of total captures). Six families bioindicators of environmental quality were present: Cracidae (observed), Picidae, Furnariidae, Formicariidae, and Troglodytidae (mist-netted).

Mist-netted species accounted for six feeding guilds (Fig. 4). Although the insectivores were the richest guild (17 species), nectarivores-insectivores were the most abundant and harbored 56.4% of total captures (358 individuals). Percentual values of richness and abundance between the dry and rainy seasons were similar in all feeding guilds (Fig. 5). There was no significant variation in feeding guilds composition between both seasons according to U Mann-Whitney test (U = 14; p>0.05).

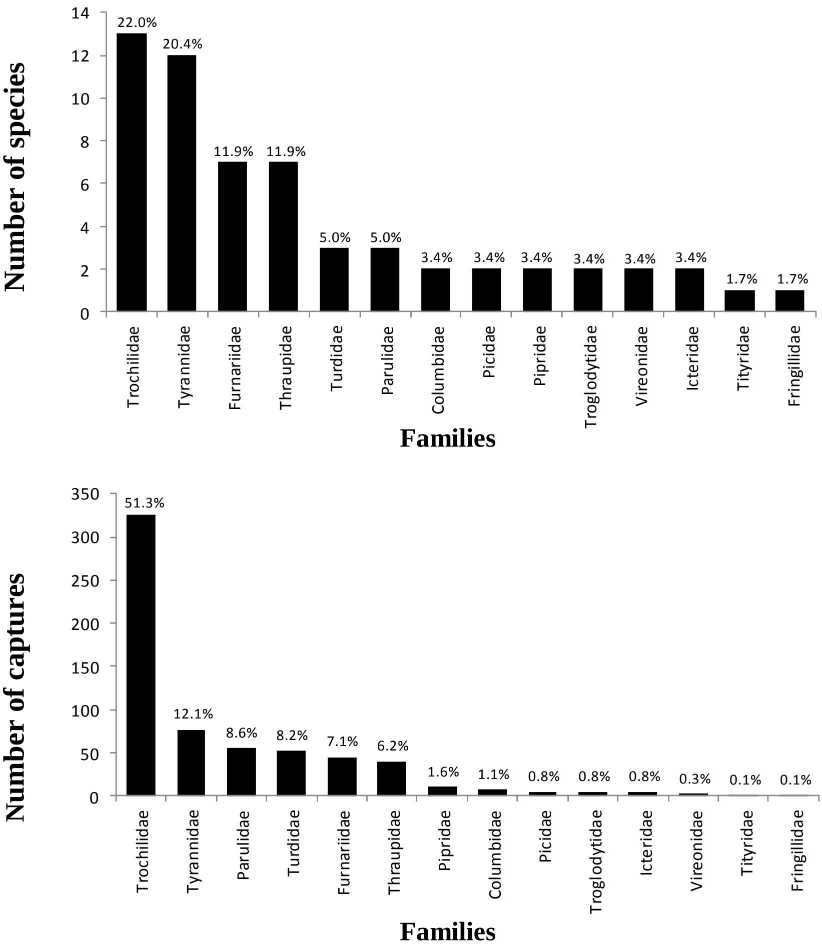


Figure 3. Family richness (above) and abundance (below) found in a cacao plantation studied at Padrón Experimental Station, Barlovento agricultural area, Tapipa sector, Miranda State, northern Venezuela. Data include mist-netted avifauna only

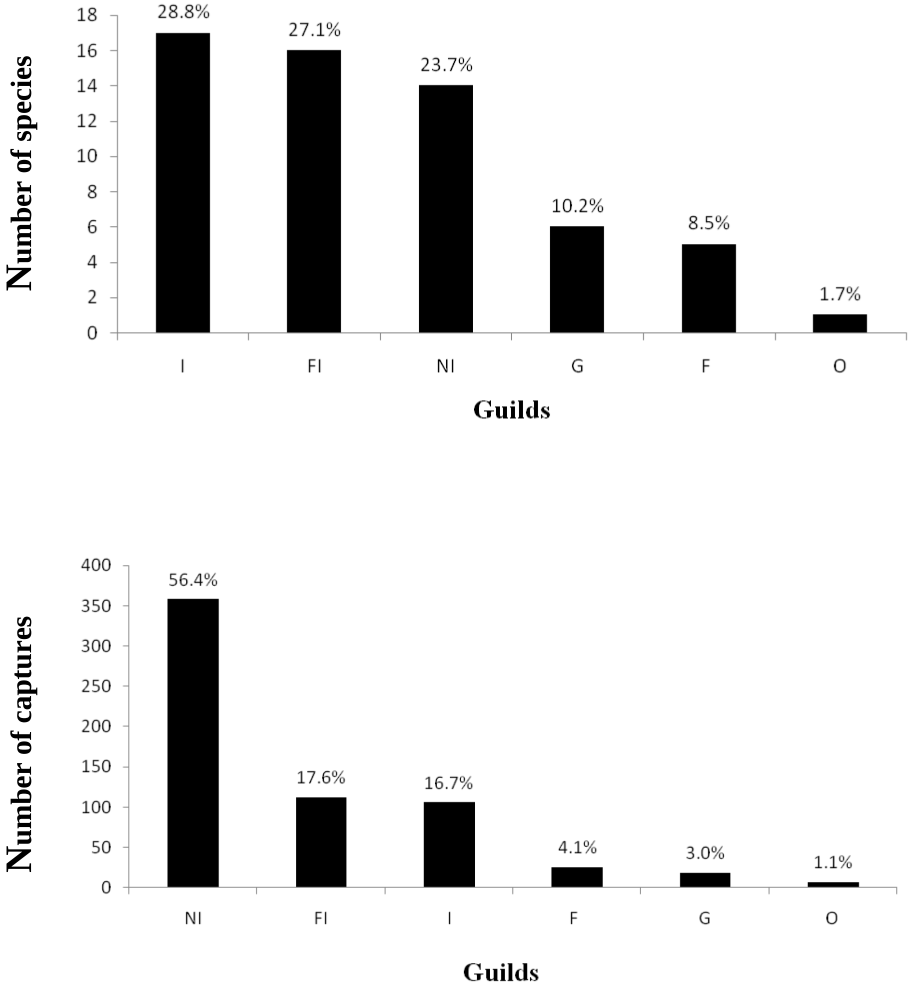
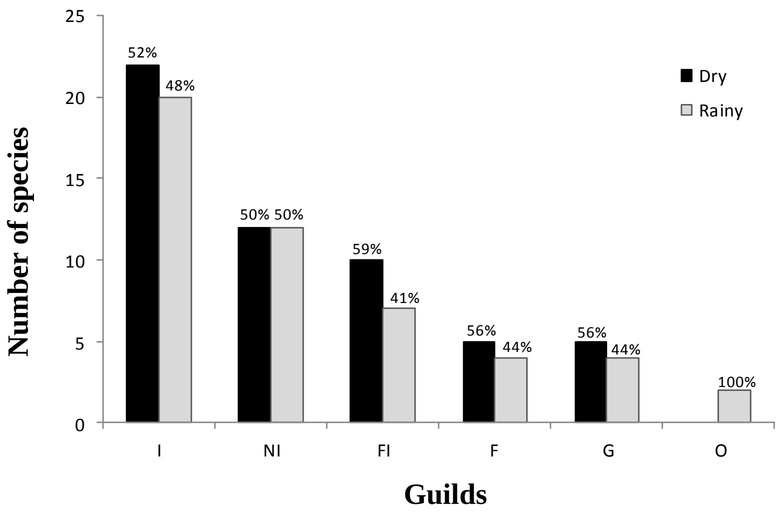


Figure 4. Feeding guilds richness (above) and abundance (below) found in a cacao plantation studied at Padrón Experimental Station, Barlovento agricultural area, Tapipa sector, Miranda State, northern Venezuela. Data include mist-netted avifauna only. Feeding guilds: NI, nectarivores-insectivores; F, frugivores; FI, frugivores-insectivores; I, insectivores; G, granivores; O, omnivores.



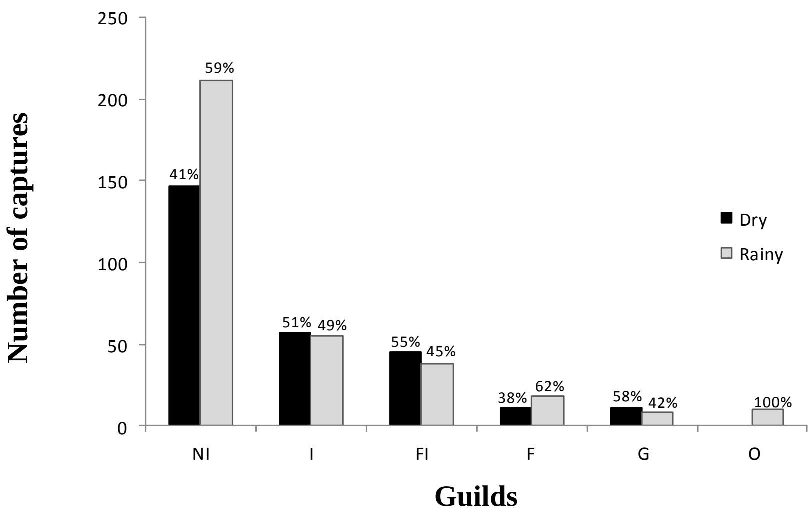


Figura 5. Percentual values of richness (above) and abundance (below) between the dry and rainy seasons of the feeding guilds recorded in the cacao plantation studied at Padrón Experimental Station, Barlovento agricultural area, Tapipa sector, Miranda State, northern Venezuela. Data include mist-netted avifauna only. There was no significant variation between dry and rainy seasons in feeding guilds composition according to U Mann-Whitney test (U= 14; P> 0.05). Feeding guilds: NI: nectarivores-insectivores; F, Frugivores; FI, frugivores-insectivores; I, insectivores; G, granivores; O, omnivores.

Discussion

Richness, abundance and diversity

Given the sampling effort (2,592 nets-h) for a small cacao unit in a forested area, we expected a high richness level. Nonetheless, our mist-netted sample resulted moderate and only exceeded the richness values reported in other sunny tree-like monocultures such as tangerine, avocado, and banana; and slightly that from a cacao plantation with a much lower effort (Table 2). Although similar richness values (57 species) are known for cacao agroecosystems of Indonesia (Clough *et al*. 2009), other Indonesian and Neotropical studies have reported 81–87 bird species (Greenberg *et al*. 2000, Van Bael *et al*. 2007, Abrahamczyk *et al*. 2008). But when we add the 26 species recorded visually/acoustically, our overall species richness increased to 85 species, a comparable number. This result was likely linked to the crop's ecotone-assembly (Verea and Solórzano 2005), a juxtaposition of transient birds from nearby areas (Faria *et al*. 2006) and canopy strata (Van Bael *et al*. 2007).

Certainly, a high number of rare species (86%) were found, and reveals a dynamic community, in which mist-nets (understory) continuously received birds from close environments. This dynamic was reflected in the similarity index value (IS = 69, similar) and the absence of significant differences between the core and edge samples. Most captured birds behave as transients, with isolated captures (see Table 1). The distance from the core plantation to the nearby forest (100 m) should have allowed these transients birds to visit the plantation, use it and return to the forest, or simply go through it to reach other environments. Similar behavior was also found by Abrahamczyk *et al*. (2008) in Indonesia. Distance to forest edge is a critical variable in explaining the composition of cacao bird communities (Reitsma *et al*. 2001, Clough *et al*. 2009).

Like richness, community abundance did not reciprocate the effort (Table 2). Since management practices are key factors in bird species richness and abundance losses associated to cacao plantations (Greenberg *et al*. 2000, Verea *et al*. 2009), systematic trimming in our study area did not allow for understory development and made the cacao's site an environment poor in resources. Thus, the plantation was only able to support a limited number of birds. Interestingly, the avian cacao community was dominated by *G. hirsutus* with 32.1% of total captures, a nectar-dependent bird. Although flowers were virtually absent in the understory, flowers from other strata (e. g. *Erythrina*, bromeliads) and edges (*Heliconia*) represent important resources for this species (Phelps and Meyer Schauensee 1994, Hilty 2003). In Brazil, Faria *et al*. (2006) found that *Erythrina* contribute to the increase of nectar-dependent birds in cacao farms. Likewise, flood irrigation favors the proliferation of mosquitoes, a cacao feature that especially attracts *G. hirsutus* to these plantations (Verea and Solórzano 2005, Verea *et al*. 2009). Mosquitoes and other tiny midges (e. g. Drosophilidae) recorded in cacao plantations (de Schawe *et al*. 2018), which were also present in our study area, have been found in the gizzards of *G. hirsutus* (C. Verea, unpubl. data).

While bird richness and abundance were not in the expected levels, the diversity index remained high (9.6). But a high diversity index is a common feature in most Venezuelan agricultural environments (Rico *et al*. 2011). Among these, cacao plantations have reached the highest diversity values (8.6–10.8) (Table 2). Thus, our result is within expectations.

Composition

Although our plantation, devoid of a well-structured understory, was capable of harboring an important avian richness, most species were transients with 1–3 captures/year (Table 1). This suggests a simple permeable matrix (Faria *et al*. 2006, Abrahamczyk *et al*. 2008) used by birds to visit the plantation in search of food or simply passing through cacao on the way to another habitat. Consequently, the site was only able to harbor a few common species. Among these, *G. hirsutus, C. fimbriata, D. fuliginosa, T. flaviventris, T. nudigenis* and *C. flaveola* are species consistently common in other cacao plantations of the Neotropical region (Verea and Solórzano 2005, Faria *et al*. 2006, Van Bael *et al*. 2007, Verea *et al*. 2009, Molina and Bohórquez 2013) and thereby could be considered cacao-dwelling birds, which explains their presence and abundance in the study area. These cacao-dwelling birds also harbored 65.6% of total captures (Table 1) and explain the high number of captures inside the plantation (67.4%) versus the edge (32.6%).

This permeable matrix also allowed the influx of open-field birds, such as seedeaters (*Sporophila*, *Columbina*) and swallows (*Progne*, *Pygochelidon*, *Stelgidopteryx*), several catalogued as disturbed habitat birds (Stotz *et al*. 1996, Verea *et al*. 2009, 2010, 2013). Thus, disturbed habitat birds harbored 29% of the overall community, the higher percentual value known compared to 22–23% of other rustic cacao plantations of Venezuela (Verea and Solórzano 2005, Verea *et al*. 2009). Indeed, disturbed habitat birds rise when disturbances to the environment increase (Dunn 2004), a fact present in our study area. Patrimonial birds included five endemic species (5.8%). This number seems to be low compared to 36% of endemic species recorded in cacao farms of Indonesia (Abrahamczyk *et al*. 2008). But a high number of endemic species is expected in plantations embedded in an environmental matrix with a high degree of endemism, such as Indonesia. Similar, Verea and Solórzano (2011) found 31 endemic birds (species/subspecies) in a highland pristine cloud forest, an area of high endemism. In the Neotropics, cacao plantations are lowland crops (0–1.000 m), areas with a low rate of endemism, a reason that explains our low number of endemic species. In fact, only *Eupsittula pertinax venezuelae, Mionectes oleagineus abdominalis, Basileuterus tristriatus bessereri* and *Eucometis penicillata affinis* are the endemic forms recorded from cacao plantations in Venezuela (Verea and Solórzano 2005, Verea *et al*. 2009). Thus, our cacao plantation gains a significant weight in bird conservation with the records of *Phylloscartes flaviventris* and *C. nuchalis brevipennis*. Our migratory birds number (five) might be considered standard in relation to other crops whose values range between 3–12 species (Verea and Solórzano 2005; Verea *et al*. 2009, 2010, 2011, 2013; Lentino *et al*. 2010, Rico *et al*. 2011). However, other shade plantations (coffee) have shown better potential for migratory birds in the region (Jones *et al*. 2002, Lentino *et al*. 2010). However, other shade plantations (coffee) have shown better potential for migratory birds in the region (Jones *et al*. 2002, Lentino *et al*. 2010). But coffee plantations have well-structured understories, a feature absent in our study area. Although our result also seems poor compared with the 28 migratory species reported in cacao farms of Mexico (Greenberg *et al*. 2000), that number is owing to the proximity of the Mexican crops to breeding grounds in the Nearctic regions. Terborgh and Faaborg (1980) report a diluent effect on migratory bird's richness when the distance between breeding and wintering grounds increase. This partly explains the low presence of migratory birds in our study area and other plantations of Venezuela. All migratory species captured have records in cacao plantations (Verea and Solórzano 2005, Verea *et al*. 2009).

An interesting group, unusual in shade plantations, but with a high conservation value as bioindicator of environmental quality (Figuerola and Green 2003), are the waterbirds. Waterbirds were well represented in our study. Previously, only *Ardea herodias, Aramides cajaneus*, *Chloroceryle americana* and *C. aenea* had records both in cacao (Schäfer and Phelps 1954, Verea and Solórzano 2005, Van Bael *et al*. 2007, Verea *et al*. 2009) and coffee plantations (Lentino *et al*. 2010). In cacao, they hunt for tadpoles in ponds that remain after irrigation or heavy rain. These aquatic microenvironments inside the plantation are important sources of not only of insects and tadpoles (Verea and Solórzano 2005; Verea *et al*. 2009) but also snails (Mollusca: Gasteropoda), which altogether attracted *P. pileatus*, *B. ibis, P. infuscatus* and *A. cajaneus* – all observed in our study area. Even a canopy bird (*Pitangus sulphuratus*) was recorded fishing tadpoles in the ponds.

Trochilidae dominated the bird richness. It also showed plenty difference in captures when compared with other families (Fig. 3), hence we can consider it the dominant taxonomic group in our plantation, a regular pattern observed in cacao plantations of Venezuela (Parra 2004, Verea and Solórzano 2005, Verea *et al.* 2009). Altogether, Trochilidae species comprised 51.3% of total captures, with *G. hirsutus* accounting for 32.1% by itself. As mentioned above, canopy and edge vegetation (flowers), as well as the tiny insects in our study area explain in part the overwhelming Trochilidae's abundance. In addition, the suppression of native understory cleared many areas inside the plantation, a scenario ideal for hummingbirds. dos Anjos *et al*. (1997) found that Trochilidae members are more common in open spaces. Also, Verea *et al*. (2000) noticed that open forests are used by these birds to hunt flying insects. But also, cacao plantations appear as important places to Trochilidae reproduction. From 23 bird species recorded by Van Bael *et al*. (2007) carrying nesting material in cacao farms of Panama, only four hummingbird species, including a *Glaucis* member, truly built nests on cacao trees. Thus, cacao plantations in the Neotropical region, including our study area, seem to be advantageous environments to this family.

The families bioindicator of environmental quality were well represented. Only Thamnophilidae, Grallaridae, and Rhynocryptidae were absent. However, Grallaridae and Rhynocryptidae comprise species that are spread in highlands (Phelps and Meyer Schauensee 1994, Hilty 2003), a r eason that explain their absence in our study area.

Boletín del Centro de Investigaciones Biológicas
Vol. 54. Nº 1, Enero - Junio 2020, Pp. 1-25

Thus, from the remaining six families that we expected to find (including the observed Cracidae), only Thamnophilidae was truly absent, a fact likely related to the absence of the suitable understory discussed above. While Thamnophilidae species definitely forage from the understory to the subcanopy (Ridgely and Tudor 1994), birds of this family are infrequent in Neotropical cacao plantations. Only *Drymophila squamata*, *Sakesphorus canadensis* and *Thamnophilus doliatus* have been recorded in this habitat (Verea and Solórzano 2005, Faria *et al*. 2006, Verea *et al*. 2009).

Among feeding guilds, insectivores, frugivores, and nectarivores-insectivores are the predominant guilds in cacao systems (Verea and Solórzano 2005, Verea *et al*. 2009, Rocha *et al*. 2019). In fact, the insectivores were the richest guild in our study area. Like mist-netted birds, avifauna recorded visually/acoustically were also predominantly insectivores. Previous cacao studies in the Neotropical area (Greenberg *et al*. 2000, Verea *et al*. 2009) show a similar arrangement. Although insectivore's guild led our avian community, its richness proportion (29%) was low compared with other cacao plantations in the region. Throughout the Neotropics, insectivores' richness represents 32–50% of cacao avian communities, including in Venezuela (Greenberg *et al*. 2000, Verea and Solórzano 2005, Verea *et al*. 2009). Since many insectivore species, particularly understory specialists, depend on the herbaceous and tangled vegetation of lower strata for successful foraging (Van Bael *et al*. 2007), constant trimming in our cacao plantation could explain, in part, the proportion reported. Thus, many typical lower strata insectivores, such as *Thryophilus*, *Sakesphorus*, *Thamnophilus*, and *Sittasomus*, were absent. However, this value could be lower. As suggested by Clough *et al*. (2009), the absence of a chemical pest control (insects) in our study area must favor the insect diversity and contributed with the insectivores' richness. Actually, army ant swarms, an insect group considered absent in cacao plantations (Van Bael *et al*. 2007), were recorded accompanied by their typical ant followers: *E. penicillata*, *D. fuliginosa*, *Xiphorhynchus susurrans* and *Lepidocolaptes souleyetii*.

Frugivores were poorly represented (Fig. 4). This could be explained by the fact that fruits, with the exception of some mistletoe berries from the canopy, were absent in our plantation. Edible fruits are necessary to support an important diversity of frugivore birds both in coffee and cacao plantations (Calvo and Blake 1998, Abrahamczyk *et al*. 2008). Different to ours, several cacao plantations lodge other profit trees intercropped with cacao plants (e. g. *Citrus*, *Musa*, *Persea*) for the direct economic benefits obtained by farmers (Bentley *et al*. 2004). These neighbor trees attract a large number of frugivores, a botanical structure that was absent in our study area. However, some strictly-frugivore birds (e. g. Pipridae), also present in our plantation, usually visit cacao plantations to perform courtship displays and mate (Verea and Solórzano 2005). On the other hand, nectarivores-insectivores were by far the most abundant guild. Given the close relationship between nectarivores-insectivores and Trochilids, details of this phenomenon were already mentioned above.

There was no significant variation in feeding guilds composition between both seasons. Although food resources between seasons can influence bird population dynamic and abundance, bird composition tends to remain stable (Poulin *et al*. 1994b). Indeed, feeding guilds' abundances were more affected than richness between both seasons (Fig. 5). And while arthropods abundance is lower during the dry season (Poulin *et al*. 1994a), variations in percentual values were more noticeable in frugivores and nectarivores than insectivores. Insectivores are a more sedentary species, and depend less on the seasonal food offer than frugivores and nectarivores. Similar community behavior was found by Poulin et al (1994b) in seasonal environments of northern Venezuela.

Despite the intensive management and disturbed nature of the cacao plantation studied, it harbored an important number of species and high diversity, including patrimonial, migratory, and waterbird species, even the families bioindicator of environmental quality were well represented. Although these attributes confer certain value for bird conservation to our plantation, a high fraction of these species were transient birds that eventually visited the plantation from nearby forest and open areas. These birds were benefited from the lack of a well-structured understory, but many of them (29%) are catalogued as disturbed area species.Thus, our plantation was only able to hold a low number of local birds and it was practically dominated by one nectar-dependent species: *G. hirsutus*. Due to this, Trochilidae was the main taxonomic group in our plantation, and also made the nectarivores-insectivores the main feeding guild.

Conclusion

Our results suggest that the small cacao plantation studied with a high level of management does not stand out as an appropriate place to support local birds' populations or avifauna conservation. Although this study only used one small sampling site, which makes it impossible to derive more general conclusions, it shows that not all cacao plantation is a biodiversity-friendly environment, not even embedded in a forested landscape. Our data also improves the knowledge about birds that dwell and/or transit cacao plantations in Venezuela and the Neotropical region with the addition of 21 novel resident species, three migratory travelers, and two endemic forms.

Recommendations

Some practices to improve the management of the cacao plantation at Tapipa or similar ones in benefit of the bird communities and farmers themselves should include: a) Reduction of excessive trimming to allow the development of the lower strata vegetation important to understory specialists (insectivores). These birds can also act as cacao's pest controllers; b) Planting profit-trees (e. g. *Persea*, *Psidium*, *Annona*; *Musa* and *Citrus* varieties) intercropped with cacao plants to attract frugivore birds. It generates additional incomes for farmers; c) Increase the number of shade trees to improve the canopy density and attract more birds to the plantation (frugivores-insectivores, nectarivores, omnivores). A shade cover around 60–65% is considered ideal for optimum cacao production levels; d) Important, farmers need to be educated to understand the benefits of birds to cacao plantations. They have the perception that birds only damage pods and spread parasitic plants. Otherwise, the above recommendations would hardly be carried out.

Acknowledgments

The authors thank Franklin Morillo and the Padrón Experimental Station's staff for the logistical support. For assistance in the field we thank Beatriz Herrera, Ignacio Buscema, and Rodolfo Jaffe. Emy Miyasawa, María Antonieta López and Luis Gonzalo Morales for their support and recommendations on the statistical analyses. Gabriela Verea Reimpell, Mónica Acosta Saldarriaga, Laura Alvarado and M. Andreína Pacheco for the comments on the manuscript. Three anonymous reviewers gave important suggestions to improve the manuscript. This work was partially supported by Fondo Nacional de Ciencia y Tecnología (Fonacit Project No. 2011001083).

Literatura Citada

ABRAHAMCZYK, S., M. KESSLER, D. D. PUTRA AND T. TSCHARNTKE. 2008. The value of differently managed cacao plantations for forest bird conservation in Sulawesi, Indonesia. Bird Conservation International. 18: 349–362.

BENTLEY, J. W., E. BOA AND J. STONEHOUSE. 2004. Neighbor trees: Shade, intercropping, and cacao in Ecuador. Human Ecology. 32: 241–270.

BIRDLIFE INTERNATIONAL. 2018. The IUCN Red List of Threatened Species. Available at http://www.iucnredlist.org. Accessed 10 September 2016.

BROOKS, D. M. AND R. A. FULLER. 2006. Biology and conservation of Cracids. Pp. 11–26, *in* D. M. Brooks (ed.), Conserving Cracids: the most threatened family of birds in the Americas. Miscellaneous Publications of Houston Museum of Natural Science (N° 6), Houston, Texas, USA.

CALVO, L. AND J. BLAKE. 1998. Bird diversity and abundance on two different shade coffee plantations in Guatemala. Bird Conservation International. 8: 297–308.

CIRQUEIRA-FAUSTINA, T. AND C. GRACO-MACHADO. 2006. Frugivoria por aves em uma area de campo rupestre na Chapada Diamantina, BA. Revista Brasileira de Ornitologia. 14: 137–143.

CLARKE, K. R., R. N. GORLEY, P. J. SOMERFIELD AND R. M. WARWICK. 2014. Change in marine communities: an approach to statistical analysis and interpretation (3th ed.). PRIMER-E Ltd, Plymouth, UK.

CLARKE, K. R. AND R. N. GORLEY. 2015. *PRIMER v7: User Manual/Tutorial*. PRIMER-E Ltd, Plymouth, UK.

CLOUGH Y., D. D. PUTRA, R. PITOPANG AND T. TSCHARNTKE. 2009. Local and landscape factor determine functional bird diversity in Indonesian cacao agroforestry. Biological Conservation. 142: 1032–1041.

CORREA, C., A. SOLÓRZANO AND C. VEREA. 2014. La avifauna del Jardín Botánico Universitario "Baltasar Trujillo", Facultad de Agronomía, Universidad Central de

Venezuela. Revista Venezolana de Ornitología. 3: 4–17.

Cracraft, J. 1985. Historical biogeography and patterns of differentiation within the South American avifaunas: areas of endemism. Ornithological Monographs. 36: 49–84.

de Schawe, C. C., M. Kessler, I. Hensen and T. Tscharntke. 2018. Abundance and diversity of flower visitors on wild and cultivated cacao (*Theobroma cacao* L.) in Bolivia. Agroforestry System. 92: 117–125.

dos Anjos, L., K. L. Schuchmann and R. Berndt. 1997. Avifaunal composition, species richness, and status in the Tibagi river basin, Parana state, southern Brazil. Ornitología Neotropical. 8: 145–174.

Dunn, R. R. 2004. Managing the tropical landscape: a comparison of the effects of logging and forest conversion to agriculture on ants, birds, and lepidoptera. Forest Ecology and Management. 191: 215–224.

Faria, D., R. R. Laps, J. Baumgarten and M. Cetra. 2006. Bat and bird assemblages from forests and shade cacao plantation in two contrasting landscapes in the Atlantic Forest of southern Bahia, Brazil. Biodiversity and Conservation. 15: 587–612.

Figuerola, J. and A. J. Green. 2003. Aves acuáticas como bioindicadores en los humedales. Pp. 47–60, *in* M. Paracuellos (ed.), Ecología, manejo y conservación de los humedales. Fundación Dialnet, Universidad de La Rioja, La Rioja, España.

Freemark, K. and C. Boutin. 1995. Impacts of agricultural herbicide use on terrestrial wildlife in temperate landscapes: a review with special reference to North America. Agriculture, Ecosystems and Environment. 52: 67–91.

Greenberg, R., P. Bichier and A. Cruz. 2000. Bird conservation value of cocoa plantations with diverse planted shade in Tabasco, Mexico. Animal Conservation. 3: 105–112.

Hammer, Ø., D. A. T. Harper and P. D. RYAN. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontología Electrónica. 4: 1– 9.

Hilty, S. L. 2003. Birds of Venezuela. Princenton Univ. Press, New Jersey, USA.

Holdridge, L. 1978. Ecología basada en zonas de vida. Instituto Interamericano de Ciencias Agrícolas, San José, Costa Rica.

INIA. 2016. Red Agrometeorologíca del INIA. Instituto Nacional de Investigaciones Agrícolas. Available at http:// www.inia.gob.ve/index.php/ institucional-inia/red-de-agrometeorologia-del-inia. Accessed 16 September 2009.

Jones, J., P. Ramoni-Perazzi, E. H. Carruthers and R. Robertson. 2002.

Species composition of bird communities in shade coffee plantations in the Venezuelan Andes. Ornitología Neotropical. 13: 397–412.

KARP, D. S., C. D. MENDENHALL, R. F. SANDÍ, N. CHAUMONT, P. R. EHRLICH, E. A. HADLY AND G. C. DAILY. 2013. Forest bolsters bird abundance, pest control and coffee yield. Ecology letters. 16: 1339–1347.

KATTAN, G. H., H. ALVAREZ-LÓPEZ AND M. GIRALDO. 1994. Forest fragmentation and bird extinction: San Antonio eighty years later. Conservation Biology. 8: 138–146.

LENTINO, M. 2003. Aves. Pp. 610–648, *in* M. Aguilera, A. Azócar and E. J. González (eds.), Biodiversidad en Venezuela. Editorial ExLibris, Caracas, Venezuela.

LENTINO, M., M. SALCEDO AND J. MÁRQUEZ. 2010. Aves de los cafetales de bosque del sector San Ramón, Ramal de Calderas, piedemonte andino. Pp. 51–60, *in* A. Rial, C. Lasso, J. Castaño and A. Bermúdez (eds.), Evaluación de la biodiversidad en los cafetales de bosque del Ramal de Calderas, piedemonte andino, Venezuela. Conservation International, Caracas, Venezuela.

MASS, B., Y. CLOUGH AND T. TSCHARNTKE. 2013. Bats and birds increase crop yield in tropical agroforestry landscapes. Ecology Letters. 16: 1480–1487.

MOLINA, I. AND K. BOHÓRQUEZ. 2013. Diversidad de aves: potencial indicador de sostenibilidad ecológica en agroecosistemas del sur del Lago de Maracaibo. Bol. Centro Invest. Biol. 47: 259–279.

MONTES, N. AND A. SOLÓRZANO. 2012. La comunidad de aves de un cultivo de mandarinas del norte de Venezuela. Revista Venezolana de Ornitología. 2: 4–15.

MORENO, C. E. 2001. Métodos para medir la biodiversidad. Manuales y Tesis SEA, Zaragoza, España.

NEWTON, I. 1998. Bird conservation problems resulting from agricultural intensification in Europe. Pp. 307–322, *in* J. M. Marzluff and R. Sallabanks (eds.), Avian conservation: research and management. Island Press, Washington D. C., USA.

PANCARDO, A. AND C. I. BERISTAÍN. 2016. Efecto del procesamiento del cacao (*Theobroma cacao* L.) en la capacidad antioxidante durante la obtención de licor y cocoa. Tesis de Maestría, Instituto de Ciencias Básicas, Univ. Veracruzana, Veracruz, México.

PARRA, L. 2004. Estructura de la comunidad de aves del sotobosque de un cultivo de cacao (*Theobroma cacao*) en el valle del Municipio Ocumare de la Costa de Oro, Edo. Aragua, norte de Venezuela. Tesis de Maestría, Instituto de Zoología Agrícola, Univ. Central de Venezuela, Maracay, Venezuela.

PHELPS, W. H., JR. 1966. Contribución al análisis de los elementos que componen la avifauna subtropical de las Cordilleras de la Costa Norte de Venezuela. Bol. de la Academia de Ciencias Físicas, Matemáticas y Naturales. 26: 14–34.

PHELPS, W. H., JR. AND R. MEYER DE SCHAUENSEE. 1994. Una guía de las aves de Venezuela. Editorial ExLibris, Caracas, Venezuela.

POULIN, B., G. LEFEBVRE AND R. MCNEIL. 1994a. Diets of land birds from northeastern Venezuela. Condor. 96: 354–367.

POULIN, B., G. LEFEBVRE AND R. MCNEIL. 1994b. Characteristics of feeding guilds y variation in diets of bird species of three adjacent tropical sites. Biotropica. 26: 187–197.

QUINTERO, M. L. AND R. CARTAY. 2000. El circuito del cacao en Venezuela, 1990–1999: caracterización y estrategias para mejorar la competitividad. Agroalimentaria. 11: 61–70.

QUINTERO, M. L. AND K. M. DÍAZ. 2004. El mercado mundial del cacao. Agroalimentaria. 9: 47–59.

REITSMA, R., J. D. PARRISH AND W. MCLARNEY. 2001. The role of cocoa plantations in maintaining forest avian diversity in southeastern Costa Rica. Agroforestry Systems. 53: 185–193.

REMSEN, J. V., JR., J. I. ARETA, E. BONACCORSO, S. CLARAMUNT, A. JARAMILLO, J. F. PACHECO, M. B. ROBBINS, F. G. STILES, D. F. STOTZ, AND K. J. ZIMMER. 2020. A classification of the bird species of South America. Available at http://www.museum.lsu.edu/~Remsen/SACCBaseline.html. Accessed 19 febrero 2020.

RESTALL, R., C. RODNER AND M. LENTINO. 2006. Birds of northern South America, Volume 2: an identification guide. Yale Univ. Press, New Haven, USA.

RICO, A., A. SOLÓRZANO AND C. VEREA. 2011. Avifauna asociada a un cultivo de arroz de los llanos centrales de Venezuela. Revista Venezolana de Ornitología. 1: 17–36.

RIDGELY, R. S. AND G. TUDOR. 1994. The Birds of South America: the Suboscines Passerines (Volumen 2). Univ. of Texas Press, Austin, USA.

ROCHA, J., R. R. LAPS, C. G. MACHADO AND S. CAMPIOLO. 2019. The conservation value of cacao agroforestry for bird functional diversity in tropical agricultural landscapes. Ecology and Evolution. 9: 7903–7913.

SCHÄFER, E. AND W. H. PHELPS. 1954. Las aves del Parque Nacional Henri Pittier (Rancho Grande) y sus funciones ecológicas. Bol. Soc. Venezolana de Ciencias Naturales. 83: 3–167.

SEKERCIOGLU, C. H. 2002. Forest fragmentation hits insectivorous birds hard. Directions in Science. 1: 62–64.

SEKERCIOGLU, C. H., P. R. EHRLICH, C. D. GRETCHEN, G. C. DAILY, D. AYGEN, D. GOEHRING AND R. F. SANDÍ. 2002. Disappearance of insectivorous birds from tropical forest fragments. Proceedings of the National Academy of Sciences of the United States of America, 99: 263–267.

STOTZ, D. F., J. W. FITZPATRICK, T. A. PARKER III AND D. K. MOSKOVITS. 1996. Neotropical birds: ecology and conservation. Chicago Univ. Press, Illinois, USA.

TERBORGH, J. W. AND J. R. FAABORG. 1980. Factor affecting the distribution and abundance of North American migrants in the eastern Caribbean region. Pp. 145–155, *in* A. Keast and E. S. Morton (eds), Migrant birds in the Neotropics: ecology, behavior, distribution and conservation. Smithsonian Institution Press, Washigton D. C., USA.

VAN BAEL, S., P. BICHIER, I. OCHOA AND R. GREENBERG. 2007. Bird diversity in cacao farms and forest fragments of western Panama. Biodiversity and Conservation. 16: 2245–2256.

VEREA, C. 2001. Variación en la composición de las comunidades de aves de cinco sotobosques de la vertiente norte del Parque Nacional Henri Pittier, Venezuela. Tesis de Maestría, Instituto de Zoología Agrícola, Univ. Central de Venezuela, Maracay, Venezuela.

VEREA, C. AND A. SOLÓRZANO. 2005. Avifauna asociada al sotobosque de una plantación de cacao al norte de Venezuela. Ornitología Neotropical. 16: 1–14.

VEREA, C. AND A. SOLÓRZANO. 2011. Avifauna asociada al sotobosque musgoso del Pico Guacamaya, Parque Nacional Henri Pittier, norte de Venezuela. Interciencia. 36: 324–330.

VEREA, C., A. FERNÁNDEZ-BADILLO AND A. SOLÓRZANO. 2000. Variación en la composición de las comunidades de aves de sotobosque de dos bosques en el norte de Venezuela. Ornitología Neotropical. 11: 65–79.

VEREA, C., M. A. ARAUJO, L. PARRA AND A. SOLÓRZANO. 2009. Estructura de la comunidad de aves de un monocultivo frutícola (naranjo) y su valor de conservación para la avifauna: estudio comparativo con un cultivo agroforestal (cacao). Memoria de la Fundación La Salle de Ciencias Naturales. 172: 51–67.

VEREA, C., F. ANTÓN AND A. SOLÓRZANO. 2010. La avifauna de una plantación de banano del norte de Venezuela. Bioagro. 22: 45–52.

VEREA, C., O. NAVAS AND A. SOLÓRZANO. 2011. La avifauna de un aguacatero del norte de Venezuela. Bol. Centro Invest. Biol. 45: 35–54.

VEREA, C., U. SERVA AND A. SOLÓRZANO. 2013. Avifauna asociada a un duraznero de la Colonia Tovar: estudio comparativo con un bosque nublado natural del Monumento Natural Pico Codazzi. Revista Venezolana de Ornitología. 3: 4–20.

WETMORE, A. 1939. Lista parcial de los pájaros del Parque Nacional de Venezuela. Bol. Soc. Venezolana de Ciencias Naturales. 5: 269–298

UNIVERSIDAD DEL ZULIA

BOLETÍN DEL CENTRO DE INVESTIGACIONES BIOLÓGICAS

Vol.54 Nº 1___________

Esta revista fue editada en formato digital y publicada en Junio de 2020, por el Fondo Editorial Serbiluz, Universidad del Zulia. Maracaibo-Venezuela

www.luz.edu.ve
www.serbi.luz.edu.ve
produccioncientifica.luz.edu.ve