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A Preliminary Assessment of the Species Richness of the Madamas Watershed: A Proposed National Park

E. S. Devenish[1], H. P. Nelson[2,3], F. Lucas[4] and E. Erdmann[3]
1. 13 Peacock Road, Oxford, UK
2. Asa Wright Nature Centre, Arima, Trinidad
3. Department of Wildlife Ecology, University of Wisconsin, Madison, USA
4. Department of Life Sciences, University of the West Indies, St. Augustine, Trinidad
E-mail: e_devenish@hotmail.com
hnelson@asawright.org

ABSTRACT
A preliminary species inventory and elevational transect was conducted in the Madamas Valley of Trinidad. A total of 50 tree species, 63 bird species, 24 bat species, 8 non-volant mammals, and 21 butterfly species were recorded from eight sample sites. This study recommends that a Protected Natural Area include the Madamas Valley.

Key words: Madamas, elevational gradient, species richness, endangered species.

INTRODUCTION

The Madamas Expedition was developed to fill a critical information gap on the ecology of the Madamas Watershed, the last road-less natural area on the island of Trinidad. Although identified as a candidate National Park by several authors (Thelen and Faizool 1980; CFCA 1998), the site remains unprotected and is threatened by proposals to develop roads through it.

The expedition sought to provide a baseline species inventory, which could be used for the management and conservation of this watershed. The study consisted of an elevational survey of faunal and floral species richness. This article presents the preliminary analysis of this study's findings.

RESEARCH AREA

Located in the north-eastern Northern Range, the Madamas Watershed covers approximately 18 km^2, with elevation rising from sea-level to approximately 610 m (Fig. 1 and 2). The topography is steep and the vegetation consists of closed-canopy tropical forest. The valley receives more than 2000 mm of rainfall annually (Wehekind 1955).

METHODOLOGY

The expedition was undertaken from May 17th to June 12th 2003. Eight sample sites were surveyed along a 502 m elevation transect (Fig. 3).

Modified Whittaker vegetation plots (20 m x 50 m) were established at each sample site (Barnett and Stohlgren 2003), and all woody stems greater than 10 cm diameter at breast height were sampled.

Bird species richness was assessed at each site using fixed-radius point counts and mist-netting (Gibbons *et al.* 1996). Between two and four mist-nets (either 6 or 18 m long, 2.5 m high) were used at any one time, placed across natural flyways. Ten minute point counts of a 20 m radius were carried out during hours of peak bird activity at each sample site.

Call-playback was used to detect the critically threatened endemic *Pipile pipile* and the locally rare *Grallaria guatimalensis*. This was done in the morning and evening for approximately an hour.

Infra-red cameras and sign surveys were used to assess non-volant mammal species richness (Silveira *et al.* 2003; Emmons 1997). Between two and eight wildlife cameras were placed at each study site. The locations of the cameras were determined after surveying for wildlife trails, tracks or scats.

Bat species richness was assessed at each study site using 6 m and 18 m ground-level mist-nets. (Bergallo *et al.* 2003; Estrada *et al.* 1993). Nets were opened at dusk and closed around midnight. Morphometrics of all volant mammals and avian species were recorded.

Opportunistic sampling using a non-fixed point count in natural clearings such as tree fall gaps and along river banks was employed to survey butterfly richness. Sampling was not carried out at all sites due to the absence of the group's butterfly specialist. We ignored the Hesperids for the purposes of this survey.

Species richness was estimated using the Chao2 estimator (Colwell and Coddington 1994). The Jaccard similarity index was used to determine the degree of similarity between plots. Spearman rank correlation was performed to examine the relationship between elevation and species richness.

Fig. 1. The Upper Madamas Watershed.

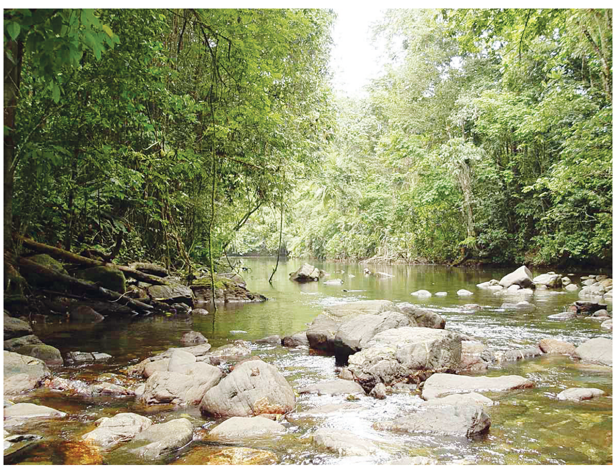

Fig. 2. The Lower Madamas River.

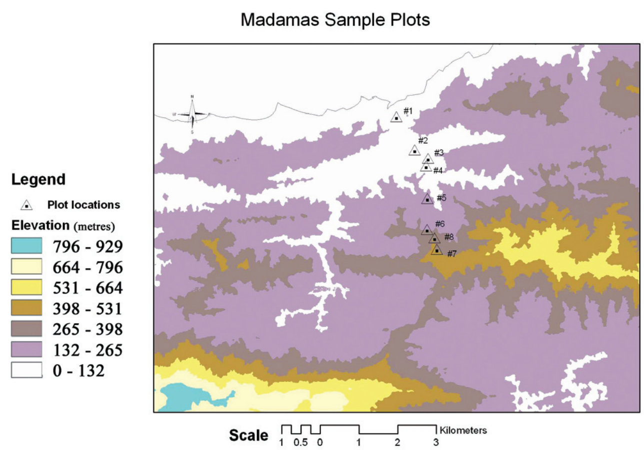

Fig. 3. Sample plot locations.

RESULTS

Vegetation Plots

Fifty woody plant species comprising of 437 individuals were recorded from all vegetation plots (see Appendix I). Figure 4 shows that the observed species richness is slightly lower than that predicted by the Chao2 estimator (64.41). *Licania* sp. were the most commonly recorded species.

The highest degree of similarity exists between sites four and five. No species were shared between sites five and eight with sites one, two and three, and site six with site two.

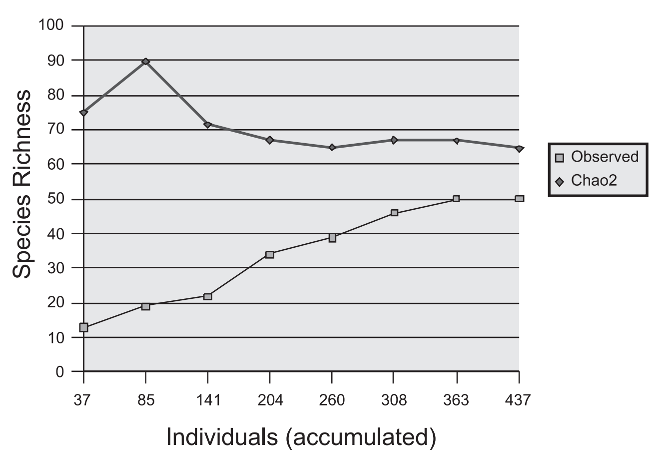

Fig. 4. Vegetation species accumulation curve.

Bird Survey

Sixty-three of the 123 breeding land bird species (51.2 %) recorded for Trinidad (ffrench 1991) were detected using mist-netting and point counts (Appendix I). A total of 109 individuals of 24 bird species were recorded from 131.10 net-hours from all sites (Fig. 5). The Chao2 estimator (35.31) indicates that the mist-netting sampled a large proportion of the predicted species richness.

The most commonly caught species was *Pipra erythrocephala*, accounting for 36.7% of total captures.

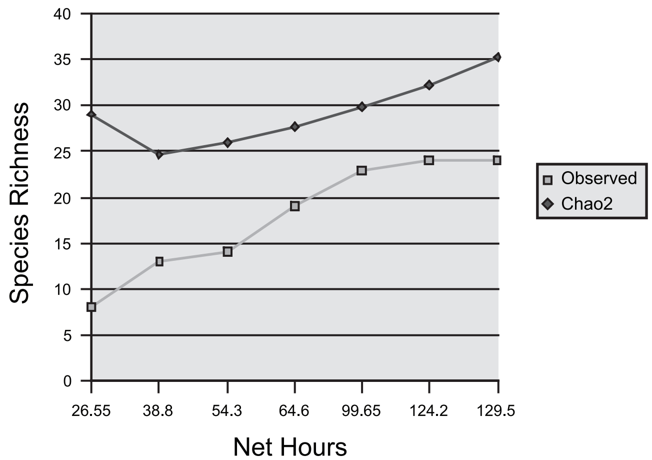

Fig. 5. Mist-netting species accumulation curve.

Sixty-one bird species were recorded using point counts (Fig. 6). Two bird species were added to the total species list by mist-netting (*Platyrinchus mystaceus* and *Mionectes oleaginea*). Observed species richness was lower than that predicted by the Chao2 estimator (130.08).

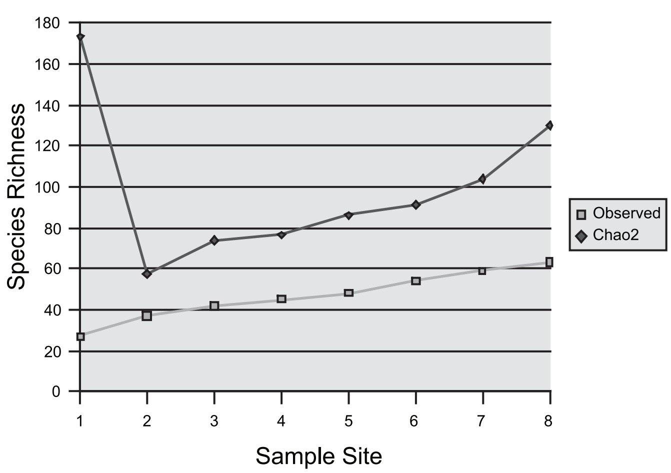

Fig. 6. Point count species accumulation curve.

When both the point count and mist-netting data were combined, the Jaccard similarity index showed that the highest degree of similarity exists between sites four and five, and the lowest degree between sites three and eight.

One confirmed *Pipile pipile* was detected using call-playback (site #6). Another possible *P. pipile* sighting was detected at site #2 where a single bird was briefly seen on the forest floor. No *G. guatimalensis* were observed during our study.

Non-volant Mammal Survey

No non-volant mammals were detected using automatic cameras, after 1332.23 camera-hours of effort.

Mammal-sign surveys detected eight of the thirteen medium-large mammals (above 2 kg) present on Trinidad (Table 1). Although the White-fronted Capuchin monkey, *Cebus albifrons*, was not observed during the survey, hunters in the valley advised the team of their presence.

Table 1. Large, non-volant mammals detected at each survey site.

Site	1	2	3	4	5	6	7	8
Lontra longicaudis †‡	+	+	+					
Agouti paca ‡	+							
Leopardis pardalis †‡	+							
Dasyprocta agouti ‡	+							
Coendou prehensilis §	+							
Mazama americana ‡		+	+					
Tayassu tajacu ‡*			+		+	+		
Alouatta seniculus *				+	+	+		

†Scats *Vocalisations ‡Tracks §Skull

Bat Survey

A total of 312 individuals from 23 species of bats were collected (Appendix I) after 240 net-hours of sampling effort (Fig. 7). We also observed an additional species, (*Lasiurus borealis*), which was not caught. The Chao2 diversity estimator predicts chiropteran species richness of 25.68. These data suggest that our sampling detected the majority of the bat species at the site. Similarity between sites was highest between four and seven and lowest between one and six. *Carollia perspicillata* was the most commonly caught bat, representing 23% of total captures. Phyllostomids accounted for 83% of captures.

Five trophic guilds were detected: aerial insectivores (four species), frugivores (10 species), gleaning animalvores (six species), nectarivores (two species) and omnivores (one species). Frugivores accounted for 79% of individuals captured.

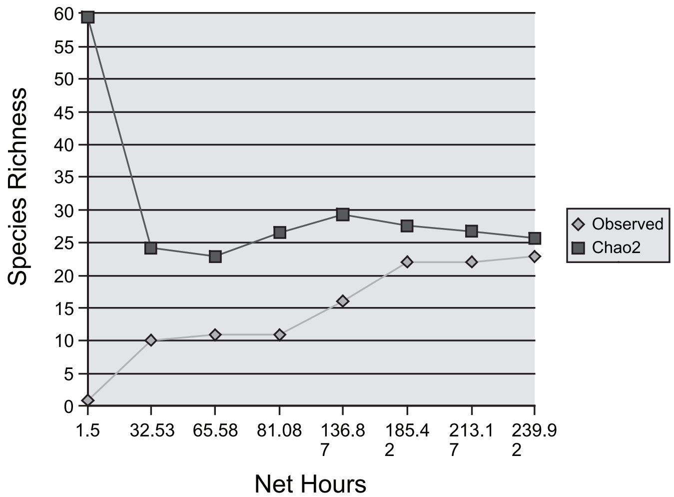

Fig. 7. Bat species accumulation curve.

Butterfly Survey

Twenty-one species of the 612 butterfly species recorded for Trinidad were collected in the Madamas Valley (Appendix I). The Chao2 estimator predicted a species richness of 37.33, indicating sampling was incomplete (Fig. 8). The Lycaenids, Riodinids and Satyrids are well represented in this sample.

Similarity was highest between sites five and six, while there was no similarity between site one with four and five, and between site two with four, five and six, and site four with five and six.

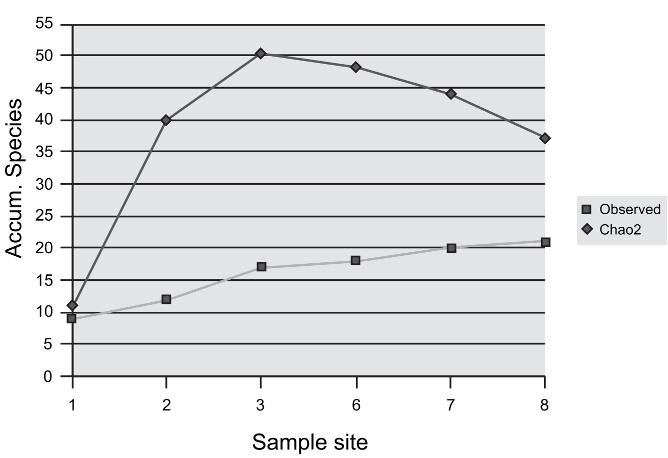

Fig. 8. Butterfly species accumulation curve.

DISCUSSION

Floral Diversity

While there have been no recent systematic published studies of the flora of this watershed, Beard's (1946) work suggests that *Licania* species should be expected to occur as a dominant in many of the forest plots we surveyed, and we did observe this pattern. However, our vegetation plots shared few species, suggesting great differences in stand-level community composition.

Our study did not find a significant relationship between elevation and woody vegetation species richness. This contrasts with previous studies of woody plant species diversity and altitude, which suggest an inverse relationship between these factors (e.g. Vazquez and Givnish 1998).

Richness patterns in the Madamas Valley may reflect a truncated form of those seen for longer elevational gradients, due to the valley's limited vertical displacement (600 m). On islands, high elevation forest types frequently occur at lower elevations in the form of the Massenerhebung effect when the elevation gradient is small (Lomolino 2001). Thus, in Trinidad, cloud forest is found at elevations less than 900 m, whereas in the Andes it occurs above 1400 m (Beard 1946).

Our study suggests that other additional factors further complicate the pattern of woody species richness, for the elevation interval we sampled. This is consistent with a model proposed by Nelson (2004) which suggests stand-level variability in Trinidad forests is driven by moisture availability.

Avian Diversity

Our findings are comparable with similar studies in Trinidad. Hayes and Samad (1998) recorded 66 species during point counts of a native broad-leaf forest. An elevational mist-netting study comparing two forested sites in the Arima Valley recorded 39 species from the higher elevation and 32 from the lower (Smith 2001). In southern Trinidad, 21 species were captured in virgin forest during a mist-netting study (White 2002). As in our study, *P. erythrocephala* was the most commonly caught species (White 2002). The high capture rate of *P. erythrocephala*, a forest interior species, is possibly due to clumped distribution or capture methods.

Bird species diversity typically decreases with elevation, or peaks at intermediate elevations (Graham 1990; Terbough 1977). Our data suggests no correlation between elevation and richness, although this observation may simply be a combination of noise in the data and small sample size. While we recognize that the area of each habitat sampled affects elevational-diversity patterns (Bachman *et al.* 2004; Rahbek 1997), we did not account for this effect in our study.

These data may also be biased due to the difficulty in detecting species typically under-represented in species richness surveys (Terbough 1977). Thus, mist-netting tends to under-represent canopy or large bird species. While the closed canopy and high crown heights precluded observation of secretive, canopy-dwelling species.

Often diversity patterns are not reflected in species richness changes alone. For example, trophic composition of bird communities can change across an elevation gradient and so affect species distribution (Terbough 1977; Graham 1990). Future investigation into avian guild structure, resource use and elevational breadth in the Madamas Valley may reveal patterns not apparent from our study.

Although the highest similarity between avian species richness corresponded to that of the vegetation, recent work on forest birds in Trinidad suggests that habitat preferences of these species may not be reflected in small scale, stand-level variations in tree species richness (Nelson 2004). Rather, this study suggests that bird species distribution and richness on Trinidad reflects broad spatial-scale changes in forest physiognomy.

The sighting of single individuals of *P. pipile* suggests that the density of this species may be low in the Madamas Valley. With *P. pipile* reported to be a gregarious species (Alexander 2002; ffrench 1991), we expected to observe more individuals. Our results are of concern as the Madamas Valley appears prime habitat for *P. pipile* and especially as cracids are potential keystone species as seed dispersers (Brooks and Fuller 2006).

The absence of *G. guatemalensis* was also of concern as the Madamas Valley again appears to be suitable habitat for this rare species.

Mammalian Diversity

Our survey data suggests that some of the rarest mammals on Trinidad, including *L. longicaudis, T. tajacu,* and *A. seniculus* were fairly abundant in the valley. Species composition in this survey is comparable with research carried out in the Trinity Hills Wildlife Sanctuary (Nelson 1996).

The importance of mammal species as keystone seed dispersers, predators and herbivores should not be underestimated. For example, *A. seniculus* was shown to be the primary seed disperser of 137 species in Brazil (Andresen 2002). Such large-bodied species require substantial areas of habitat to maintain genetically and demographically viable populations (Sunquist and Sunquist 2001). As a result, these species in the Madamas Valley may need to be managed as part of a larger eastern Northern Range meta-population.

The low encounter frequency of *L. pardalis* signs suggests that this species occurs at low densities in the valley. Ocelots are secretive and difficult to survey with sign surveys (Trolle and Kery 2003). However, our observations are consistent with a previous study, which suggested that ocelot densities are low in Trinidad due to hunting and habitat fragmentation (Nelson 1996).

Bat species richness is high in the Madamas Valley with over a third of the 63 bat species recorded for Trinidad being recorded. Our findings are similar to those of a study with comparable net-hours in the Victoria-Mayaro Reserve which captured 143 individuals of 22 species (Clarke and Downie 2001). *C. perspicillata* was similarly the most dominant species, but accounted for a higher percentage of captures (43%) than in our study. Clarke and Downie (2001) suggest density of favoured fruit species may account for their abundance.

Although none of the bats caught are globally threatened, several species caught in this study were defined as locally rare by Clarke *et al.* (2005). These are *Pteronotus parnellii, Micronycteris minuta, Phyllostomus hastatus* and *Chiroderma trinitatum.* In particular, cave-roosting bats such as *P. parnellii* are likely to have low densities due to the paucity of natural cave formations in Trinidad.

Previous research suggests that bat species richness declines monotonically with increasing elevation (Patterson *et al*. 1996; Sanchez-Cordero 2001; Graham 1990). Our data suggests a peak in bat species richness and feeding guild diversity at intermediate elevation. The patterns we observed may be due to i) insufficient sampling effort at each elevation; ii) independence between bat species richness and small elevation gradients (Patterson *et al*. 1996; Graham 1990); or iii) overlap of different forest communities along the transect. The presence of all five feeding guilds at 400-450 m elevation in this study suggests the presence of an ecological transition zone at this elevation. However, our vegetation sampling protocol was not designed to test this hypothesis. High levels of habitat heterogeneity are characteristic of ecotones, and greater levels of species and feeding guild diversity are expected here (White and Pickett 1985). Examination of the presence of the ecological transition zone suggested by our bat data could be the focus of a future study.

The high percentage of Phyllostomids in our study is typical of bat studies in the Neotropics, and could be due to a biased capture rate for this group (Bergallo 2003). Sampling techniques that account for patchiness, rarity, dietary specificity, and canopy use by bats are needed to better estimate richness and distribution of bats in Madamas.

Butterfly Diversity

Although this survey was incomplete, our results are not dissimilar to other work in Trinidad. Wood and Gillman (1998) in two undisturbed forest sites in the southeast recorded 37 and 22 species respectively. The low similarity between sites may reflect a high degree of microhabitat specialisation but requires further studies.

Forest butterflies are especially vulnerable to habitat change and fragmentation due to their specific microclimate requirements (Spitzer *et al*. 1997; Srygley and Chai 1990). This was illustrated for the Satyrids in south Trinidad, where fewer species of this family were observed in fragmented forests (Lucas *et al.* 2004).

The Satyrids in this study showed relatively high species richness and a large number of rare species. For example, we recorded *Antirrhaea philoctetes*, the 'Queen of the Night', which is considered the rarest Satyrid in Trinidad (Barcant 1970). The limited Lepidoptera species richness data collected in this study suggests that the Madamas Watershed has some of the rarest, edge sensitive butterflies on Trinidad. This highlights the area's value as a potential study site and conservation area for this group.

CONCLUSION

The Madamas Valley is one of the few areas in Trinidad maintaining a full complement of not only the native large-bodied mammalian and avian keystone species (such as *A. seniculus* and *L. pardalis*) but also some of the rarest vertebrates (*P. pipile*) and butterflies (*A. philoctetes*) on the island. Species richness measures among all taxonomic groups in this study suggest that our surveys detected a large proportion of the species present at this site. This together with the complex stand-level vegetation diversity observed among our plots suggests that the maintenance of the Madamas Watershed as an intact ecosystem should be a conservation priority. Our observations reveal that the area remains largely free from human disturbance, apart from low intensity hunting from nearby villages. These data imply that Madamas is among the most pristine areas on Trinidad, and an ideal site for the protection and study of tropical forest ecosystems on this island.

The incomplete survey of the elevation gradient and the lack of replicates at each elevation interval represent the most significant weaknesses in our study. We were unable to survey the highest elevations or repeat samples, due to funding constraints. As a result, the species richness trends we report may not be representative of the entire Madamas Valley.

We strongly recommend the establishment of a National Park or Environmentally Sensitive Area that includes the Madamas Valley.

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Appendix I. Species Lists for Madamas Valley

Tree Species

Family	Species	Local Name	Family	Species	Local Name
Flacourtiaceae	*Ryania speciosa*	Bois l'agli	**Myrtaceae**	*Eugenia confusa*	Wild coffee
Guttiferae	*Rheedia accuminata*	Wild primrose		*Eugenia lambertiana*	
	Symphonia globulifera	Yellow mangue		*Eugenia* sp.	
	Tovomita eggersii	Red mangue		*Marlierea ferruginea*	
Bombacaceae	*Pachira insignis*	Wild chataigne	**Lecythidaceae**	*Couroupita guianensis*	Cannon ball
	Sterculia caribae	Mahoe		*Eschweilera subglandulosa*	Guatecare
	Sterculia pruiens		**Melastomaceae**	*Miconia* sp.	
Burseraceae	*Protium sergoteanum*		**Rubiaceae**	*Warszewiczia coccinea*	Wild poinsettia
Meliaceae	*Carapa guanensis*	Crappo		*Psychotria capitata*	Café marron
Anacardiaceae	*Spondias monbin*	Hog plum	**Sapotaceae**	*Lucuma multiflora*	Penny piece
Leguminosae	*Swartzia* sp.			*Mimusops balata*	Balata
	Brownia latifolia	Mountain rose		*Mycropholis guyanensis*	Wild balata
	Calliandra guildingii			*Micropholis* sp.	
	Inga heterophylla			*Sapotacea* sp.	
	Inga sp.		**Ebenaceae**	*Diospyros ierensis*	Bois charbon
	Pithecellobium jupunba	Puni	**Boraginaceae**	*Cordia alliodora*	Cypre
Rosaceae	*Hirtella silicea*		**Bignoniaceae**	*Tabebuia stenocalex*	Wild calabash
	Hirtella triandra	Fruta paloma		*Tabebuia* sp.	
	Licania membranacea		**Myristicaceae**	*Virola surinamensis*	Wild nutmeg
	Licania heteromorpha		**Lauraceae**	*Aouiea densiflora*	Laurier mango
	Licania sp.			*Aniba panurensis*	Laurier cannelle
Rhizophoraceae	*Cassipourea guianensis*	Mountain coffee		*Ocotea eggersiana*	'Small leaf' Laurier mattack
Combretaceae	*Buchenavia capitata*	Yellow olivier	**Moraceae**	*Cholophore tinctoria*	Fustic
	Terminalia amazonia		**Palmaceae**	*Palmae* sp.	
	Terminalia sp.				

Bird Species

(Classification follows ffrench, 1991)

Tinamidae
Crypturellus soui, Little Tinamou

Accipitridae
Elanoides forficatus, Swallow-tailed Kite
Buteogallus urubitinga, Common Black-Hawk

Cracidae
Pipile pipile, Common Piping-Guan

Columbidae
Columba sp., Pigeon
Leptotila spp., Dove

Psittacidae
Touit batavica, Lilac-tailed Parrotlet
Pionus menstruus, Blue-headed Parrot
Amazona amazonica, Orange-winged Parrot

Strigidae
Pulsatrix perspicillata, Spectacled Owl
Glaucidium brasilianum, Ferruginous Pygmy-Owl

Caprimulgidae
Lurocalis semitorquatus, Short-tailed Nighthawk

Trochilidae
Glaucis hirsuta, Rufous-breasted Hermit
Phaethornis guy, Green Hermit
Phaethornis longuemareus, Little Hermit
Florisuga mellivora, White-necked Jacobin
Lophornis ornata, Tufted Coquette
Chlorestes notatus, Blue-chinned Sapphire
Chlorostilbon mellisugus, Blue-tailed Emerald
Amazilia chinopectus, White-chested Emerald
Amazilia tobaci, Copper-rumped Hummingbird

Trogonidae
Trogon viridis, White-tailed Trogon
Trogon violaceus, Violaceous Trogon
Trogon collaris, Collared Trogon

Alcedinidae
Chloroceryle americana, Green Kingfisher
Chloroceryle aenea, Pygmy Kingfisher

Momotidae
Momotus momota, Blue-crowned Motmot

Ramphastidae
Ramphastos vitellinus, Channel-billed Toucan

Picidae
Celeus elegans, Chestnut Woodpecker

Dendrocolaptidae
Dendrocincla fuliginosa, Plain-brown Woodcreeper
Xiphorhynchus guttatus, Buff-throated Woodcreeper

Furnariidae
Synallaxis albescens, Pale-breasted Spinetail
Sclerurus albigularis, Grey-throated Leaftosser

Thamnophilidae
Taraba major, Great Antshrike
Myrmotherula axillaris, White-flanked Antwren
Myrmeciza longipes, White-bellied Antbird

Formicaridae
Formicarius analis, Black-faced Antthrush

Cotingidae
Procnias averano, Bearded Bellbird

Pipridae
Pipra erythrocephala, Golden-headed Manakin
Manacus manacus, White-bearded Manakin

Tyrannidae
Attila spadiceus, Bright-rumped Atilla
Lathrotriccus euleri, Euler's Flycatcher
Platyrinchus mystaceus, White-throated Spadebill
Mionectes oleaginea, Ochre-bellied Flycatcher
Pachyramphus polychopterus, White-winged Becard
Tityra cayana, Black-tailed Tityra

Troglodytidae
Thryothorus rutilus, Rufous-breasted Wren

Turdidae
Turdus albicollis, White-necked Thrush

Sylviidae
Ramphocaenus melanurus, Long-billed Gnatwrenv

Vireonidae
Cyclarhis gujanensis, Rufous-browed Peppershrike
Hylophilus aurantiifrons, Golden-fronted Greenlet

Icteridae
Psarocolius decumanus, Crested Oropendola

Coerebidae
Coereba flaveola, Bananaquit

Thraupidae
Cyanerpes caeruleus, Purple Honeycreeper
Cyanerpes cyaneus, Red-legged Honeycreeper
Chlorophanes spiza, Green Honeycreeper
Dacnis cayana, Blue Dacnis
Euphonia trinitatis, Trinidad Euphonia
Euphonia violacea, Violaceous Euphonia
Thraupis palmarum, Palm Tanager
Tachyphonus luctuosus, White-shouldered Tanager

Bat Species

Emballonuridae

Rynchonycteris naso, Brazilian Long-nosed Bat

Mormoopidae

Pteronotus parnellii, Mustached Bat

Phyllostomidae

Micronycteris megalotis, Little Big-eared Bat
Micronycteris minuta, White-bellied Big-eared Bat
Micronycteris hirsute, Hairy Big-eared Bat
Micronycteris nicefori, White-lined Forest Bat
Tonatia bidens, Greater Round-eared Bat
Mimon crenulatum, Hairy-nosed Bat
Phyllostomus hastatus, Pale-faced Spear-nosed Bat
Glossophaga soricina, Common Long-tongued Bat
Anoura geoffroyi, Hairy-legged Long-tongued Bat
Carollia perspicillata, Linnaeus' Short-tailed Fruit Bat
Sturnira tildae, Yellow-shouldered Bat
Uroderma bilobatum, Yellow-eared Tent-making Bat
Platyrrhinus helleri, White-lined Fruit Bat
Chiroderma villosum, Greater Big-eyed Bat
Chiroderma trinitatum, Lesser Big-eyed Bat
Artibeus jamaicensis, Large Fruit Bat
Artibeus lituratus, Greater Fruit Bat
Artibeus cinerus, Pygmy Fruit Bat
Ametrida centurio, Little White-shouldered Bat
Centurio senex, Central American Wrinkle-faced Bat

Vespertilionidae

Myotis nigricans, Little Black Bat
Lasiurus borealis, Costa Rican Red Bat

Butterfly Species

Satyridae

Antirrhaea philoctetes, Queen of the Night
Euptychia junia, Iridescent Blue Night
Euptychia themis, Ringlet
Euptychia calpurnia, Large White Night
Euptychia renata, Ringlet
Euptychia brixiola, Blue Nymph
Euptychia hermes, Ringlet

Ithomiidae

Ithomia pellucida pellucida, Blue Transparent
Tithorea harmonia megara, Tiger

Heliconidae

Heliconius ethillus, Rare Tiger
Heliconius doris, Blue Doris

Morphidae

Morpho peleides peleides, Emperor

Papilionidae

Graphium pausanias, Pausanias

Pieridae

Dismorphia amphione astynomides, Tiger Pierid

Lycaenidae

Arawacus linus, White Lycid
Chalybs romulus, Small Green Hairstreak
Calycopis pion, Blue Metal Hairstreak

Riodinidae

Peplia lamis, Great Bronzed Handkerchief
Cremna thasus, Red-banded Zebra
Lemonias rhodope, Blue-tipped Sammond
Cariomothis erythromelas, Erythromelas