Status and Ecology of the Wattled Curassow (*Crax globulosa Spix, 1825*) in the low Caquetá River, Colombian Amazon.

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TABLE OF CONTENTS

ABSTRACT

The Cracidae is the most endangered bird family in the Neotropics and many species are facing declines due to habitat destruction and hunting. The Wattled Curassow (*Crax globulosa*) is classed as Endangered, and yet, it remains one of the least known and studied cracid species in the wild. This study attempted to investigate the status and ecology at three recently confirmed island populations in the lower Caquetá River, Colombia. The three islands were surveyed to estimate the population density and abundance. Forest structure variables recorded to provide information on habitat and to examine potential association with the occurrence and abundance of the study species. A total of 182 sightings of the Wattled Curassow were recorded and the mean flock size generally ranged from 2-3 individuals across islands. Density estimates ranged from 17.5-34.7 ind/km^2 across islands and 4.7-54.0 across transects. These densities suggest a total population of 41.65 (±11.25), 21.02 (±3.99) and 209.23 (±98.33) individuals on Amaure, Brazuelo and Mirití islands, respectively. Tree density ($P = <0.001$) and the distance of vegetation sampling points to internal water bodies ($P = <0.001$) were significantly different between islands. Differences between transects were much larger, with significant differences found in tree density ($P = <0.001$), DBH ($P = 0.049$), understorey density ($P = <0.001$), overstorey density ($P = 0.003$) and distance to water ($P = <0.001$). Abundance of Wattled Curassow was significantly correlated with distance from water and understorey density, suggesting a high preference for water and dense understorey. However, the habitat variables recorded were unable to explain the occurrence (presence or absence) of the Wattled Curassow at a local scale. The population densities derived are the highest for the Wattled Curassow found throughout its range, making the current population extremely important for conservation. Associations with water and a dense understorey appear to be consistent with other studies, but further work is clearly needed to fully unravel the factors influencing the presence or absence of this species to a particular site or region.

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1. INTRODUCTION

The Cracidae, is an avian family consisting of large, forest-dwelling, frugivorous birds (curassows, guans and chachalacas), which is endemic to the Neotropics (Brooks & Strahl 2000). The greatest diversity among present forms can be found in north-western South America (del Hoyo et al. 1994). At present, cracids are the most threatened avian family in the Neotropics (Brooks & Strahl 2000). BirdLife International lists 18 of the 50 species as Vulnerable, Endangered, Critically Endangered or Extinct in the Wild due to overhunting and unabated habitat destruction (Birdlife International 2009). Yet, details of their biology, distribution and conservation status remain poorly known (Strahl & Silva 1997, Brooks & Strahl 2000, Brooks 2006).

Among those, the Wattled Curassow (*Crax globulosa*) remains one of the least known cracid species in the wild despite a highly successful captive breeding program (Delacour & Amadon 2004). Endemic to the western Amazon basin, the Wattled Curassow occurs exclusively on river islands and in floodplain forests seasonally inundated by white-water rivers (hereafter *várzea* forests) in Brazil, Colombia, Ecuador, Perú and Bolivia (Brooks & Strahl 2000, Aranibar-Rojas 2006, BirdLife International 2009, Haugaasen and Peres 2008). Despite a wide geographic range, their distribution is extremely patchy across western Amazonia and individual sub-populations are generally limited to less than 250 individuals (Brooks and Strahl 2000, Aranibar-Rojas 2006). Like many of the species encompassing the Cracidae family, populations of the Wattled Curassow appear to be declining rapidly due to hunting and habitat destruction throughout its range (Santos 1998, Hennessey 1999, Bennett 2000). The situation may be aggravated considering that *várzea* forests are preferred areas for human settlement and agriculture in the region, and exploitation of timber resources also appear to be an important factor for the rapid destruction of their native habitats (Albernaz and Ayres 1999).

In Colombia, the Wattled Curassow is rare and “Critically Endangered” (Bennett & Franco-Meyer 2002). Historical records of occurrence include Isla Tres Troncos in the upper Caquetá River (Blake 1955), Isla Mirití in the lower Caquetá river (B. Bock and V. Páez in Bennett & Franco-Meyer 2002), around Chibiriquete and Araracuate at the Apaporis River (J. Estudillo López in Collar *et al.* 1994), and Isla Mocagua in the Amazon River (Bennett 2000). Until recently, the only well documented Colombian population of the Wattled Curassow was on Isla Mocagua (Bennett 2000), supporting a total of 61 individuals (Bennett 2003). Further surveys along the lower Caquetá River, however, confirmed a second important population on Isla Mirtí (Alrarcón-Nieto & Palacios 2005), with an estimated density of 30 ind/km^2 (Alarcón-Nieto & Palacios 2008). Additionally, two other sub-populations were also discovered on Isla El Brazuelo and Isla Amaure, with a density of 11 and 19 ind/km^2, respectively (Alrarcón-Nieto & Palacios 2008). The populations were therefore estimated to be 140, 35 and 20 individuals in Mirití, Amaure and Brazuelo islands.

A conservation program for the Wattled Curassow was developed for Isla Mocagua, greatly supported by local communities in the area (Bennett 2003). In the lower Caquetá River, however, Isla Mirití is considered an important bird area (IBA), but enjoys no legal protection (E. Palacios pers. comm.). A systematic investigation of the Wattled Currasow in this area should therefore be prioritised not only to improve the information about the population status and natural history of Wattled Curassows, but also to provide important base-line information upon which a management and conservation plan can be structured.

This study attempts to address the issues outlined above by investigating the current status and ecology of the Wattled Curassow in the lower Caquetá River of the Colombian Amazon. In particular, this study aimed to:

1) Estimate the population density and size on the three main islands where the species is known to occur

2) Provide basic information about their *várzea* forest habitats, including forest structure and composition

3) Investigate potential associations with habitat variables recorded on each island, using population abundance and occurrence as an indicator of habitat preferences.

2. METHODS

2.1 Study area

The study was conducted between September 2008 and March 2009, on three islands located at the lower Caquetá River in La Pedrera region of the Colombian Amazon (69º 35' 7.20" W 1º 19' 11.54" S) (Figure 1). The annual mean precipitation and temperature is 3648 mm and 25.7 ˚C, respectively (Duivevnvoorden 1995). While the temperature is relatively constant, the precipitation is highly seasonal with April through June as the wettest months, and November through December the driest (Duivevnvoorden 1995). Hence, the survey period of the current study coincided with the early dry, dry and early wet season of the region. The pronounced seasonal variation in precipitation produces marked fluctuations in the river water level (up to 14 m in amplitude; Ferreira 1997). The Caquetá River is the largest river in Colombia, covering up to 14% of the flooplains (Duivevnvoorden 1995). The river exhibits seasonal fluctuations (*sensu* Junk 1989) and as the only river with catchment areas in the Andes, is characterised by high sediment loads pulled from the Andes and deposited on the floodplains during the high-water season. During six months of the year, the river floods the lower of the plains, enriches the soils with nutrients and creates stressing environments that limits the growth of many plant species (Duivevnvoorden 1995).

Of the three islands surveyed, Mirtí (1º12'S, 69º 51' W) was the largest island with a surface area of approximately 7.2 km^2, located at the mouth of the Mirití-Paraná River. Mirití is mainly covered by primary *várzea* forests, with trees 25-35m tall. Secondary forests are found at the north-western part of the island due to previous and recent agricultural activities mostly situated on the bank of the Caquetá River. A few patches are still active, and these vary from 0.2 to 1.1 ha in size. The island also has an extensive swamp forest situated in the north-western part, characterised by permanently waterlogged forest patches. This type of area is locally known as *cananguchal* and it is primarily dominated by the palm tree *Mauritia fleuxuosa* L. Seven internal lakes are also found on Mirití Island, all connected to the Caquetá River to the north. These are hard to distinguish during the high-water season, as the lakes merge. During the low-water season, however, some of the narrowest sections of these lakes dry out, leaving a large number of small fish trapped and exposed. They serve as a food source for several bird species, including the Wattled Curassow (Alarcón-Nieto & Palacios 2008). Several temporal water pools are formed during the rainy season, limiting the access to the island.

El Brazuelo Iisland (1° 16 S, 69° 56' W), is situated at the mouth of the Brazuelo tributary and covers an area of 1.2 km^2. Small patches of secondary vegetation are found at the southwestern part of the island, due to previous agricultural activities. A single permanent lake is situated on the island, and remains unconnected to the Caqueta River. Other temporary water pools may form during the rainy season.

Amaure Island (1° 15' S, 69° 45' W) also covers an area of 1.2 km^2, with an internal lake subdivided into several channels across the island. The lake is connected to the Caquetá River at the south-eastern part of the island. Similarly, temporal water channels and pools are formed during the rainy season and subsequent rise in water level in the region.

There are currently no human settlements on any of the three islands. Nevertheless, there have been different degrees of anthropogenic impacts either in the form of banana and yucca plantations (which are still active on Mirití Island), poultry farming and logging. The latter was heavily practiced in the late 1990s (Nolberto Neira pers. com.). At present, fishing and hunting are the main activities on all three islands, conducted primarily by inhabitants of the neighbouring communities (Figure 1). Selective logging of trees for canoe construction is also frequent by local people. The Wattled Curassow has been the target of some hunting activities, but more as a complement to the hunting of other animals such as capybara (*Hydrochoeris hydrochaeris* L.) and Giant River turtle (*Podocnemis expansa* Schweigger).

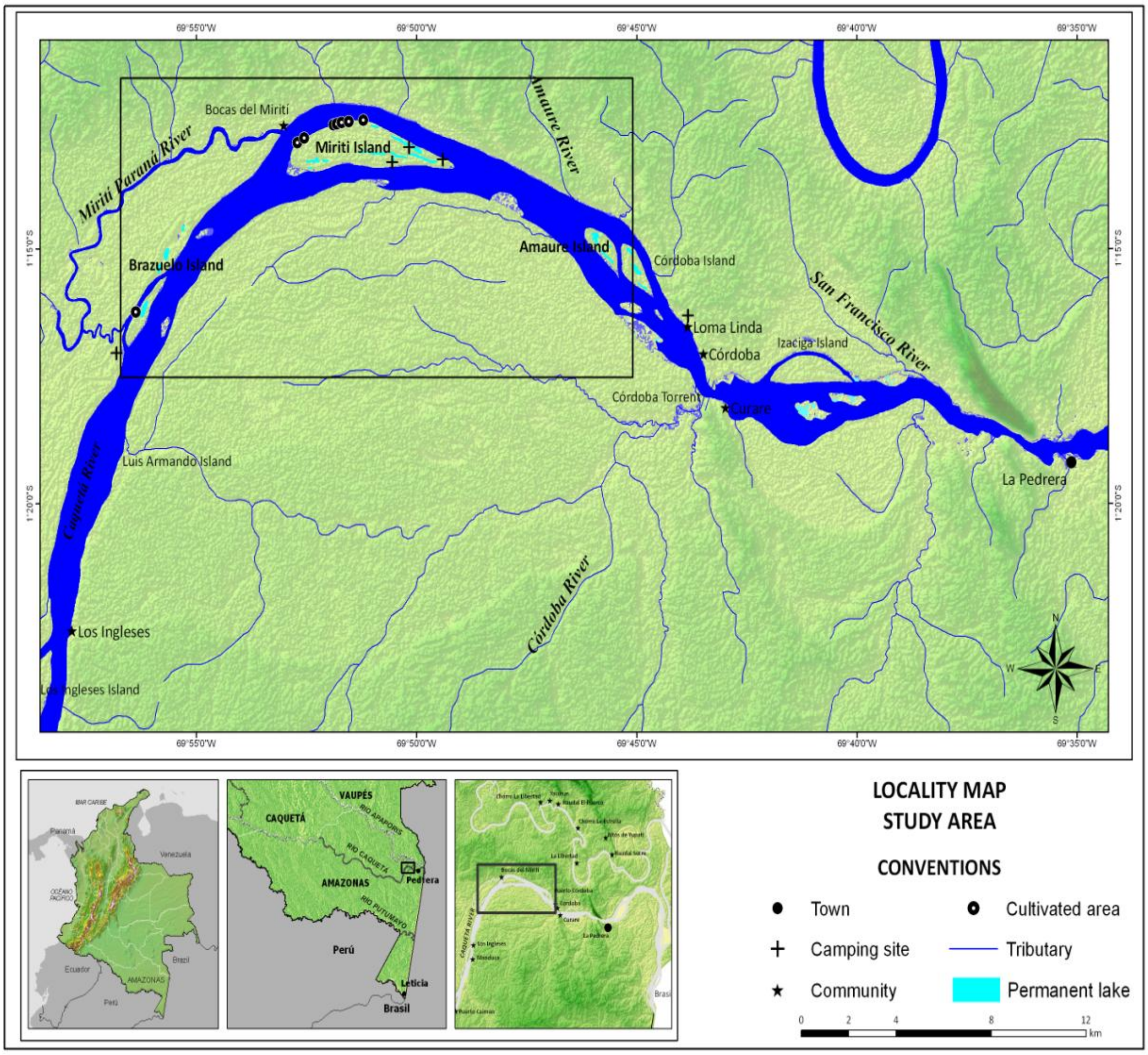

Figure 1 Study area at a local, regional and national scale. Islands surveyed are highlighed on map. Camping sites, cultivated areas and adjacent indigenous communities are included.

2.2 Study species

Previous observations suggest that the Wattled Curassow is a year-round resident of *várzea* forest. There have been reports of solitary individuals (either male or female) and groups of 3 to 6 or even up to 30 individuals (Santos 1998, Hennessey 1999, Bennett & Franco-Meyer 2002, Aranibar-Rojas 2006). The breeding system is still poorly known, although observations in Mocagua Island have reported reproductive periods almost throughout the year, peaking July-August and February-March (Bennett 2000, 2003; Delacour & Amadon 2004). The Foraging patterns may follow the flood pulse, with seeds and fruits being important food items during the high-water season and invertebrates such as insect larvae and crustaceans being important in the dry season (Bennett & Franco-Meyer 2002, Alarcón-Nieto & Palacios 2008).

The Wattled Curassow is considered to be elusive and found predominantly in areas devoid of human presence (Santos 1998). Compared to other curassows, the Wattled Curassow is thought to have more arboreal habits explained by complete lack of dry ground in their *vàrzea* forest habitat for much of the year (Bennett 2000). Further, the booming vocalization that is so characteristic of related cracids (Garcia & Brooks 1997) is also absent in this species. Instead, the Wattled Curassow produce a descending whistle, usually heard in high and dense tree crowns where they are usually difficult to see (Garcia & Brooks 1997, B. Whitney pers. comm.).

2.3 Line transect censuses

A total of five transects were placed in the study area: one transect on each of Amaure and Brazuelo islands, and three parallel transects on the largest island, Mirití (Table 1). Hereafter, transects will be referred to as T1, T2, T3, T4 and T5. The length of the transects varied according to the size and topography of the islands. All transect were marked with flagging tape every 50 m and parallel transect were placed at least 250 m apart to obtain independent samples. Surveys walks were carried out on sampling blocks of approximately 14 days each month, spending four days on each of the small islands and six days on the largest. In total, this study is based on a census effort of 359.95 km.

All sites were surveyed using a standardised line-transect census protocol based on Peres (1999). In brief, one-way census walks were performed starting at 6:30 in the morning with an approximate walking speed of 1-2km/h. Census walks were not conducted during rainy weather because this affected the detectability of the species. Parallel census walks on Mirití Island were conducted by three different observers. Investigators systematically alternated transect each day to avoid any confounding effects of observer bias. Upon a visual detection of Wattled Curassows, the time of day, perpendicular distance from the animal to the transect, sighting location along the transect, number of individuals, the perching height, tree species and the total height of the vegetation in which the bird was perched, direction of flight, feeding behaviour and other noticeable ecological information was recorded. Aural detections of the study species were also noted, but were not considered in the data analyses for this study.

Table 1 Census details of the islands surveyed with their respective transects number, length and effort. Only Mirití had three parallel transects

Survey site	Transect	Transect length (km)	No. of days surveyed	Sampling effort (km)
Brazuelo	1	3,05	19	57,95
Mirití	2	6,00	15	90,00
Mirití	3	6,00	16	96,00
Mirití	4	5,00	16	80,00
Amaure	5	2,00	18	36,00

2.4 Habitat characterisation

Vegetation variables were collected every 100 m along each transect. A modified point-quadrant method was used to assess floristic composition, in addition to the density and size distribution of trees. In brief, each point represented the centre of four cardinal directions (N, S, E, W) and the surrounding area was therefore divided into four 90° quadrants. Subsequently, the distance from the centre point to the nearest tree above 10 cm in circumference was measured in each quadrant. These trees were then tagged with individually-numbered aluminium tags, circumference measured at breast height (130 cm from ground) and crown cover estimated based on the ellipse formula C= D1 x D2 x 0.25π – where D1 is the largest crown (branch) diameter and D2 the perpendicular diameter to D1. To facilitate comparisons with other studies, circumference was converted to diameter at breast height (DBH) using the flowing formula: C/π – where C is the circumference. Specimens were then collected for later identification by a highly experienced herbarium technician at the Amazonian Institute for Scientific Research (SINCHI, Leticia).

Additionally, understorey and canopy density was measured at a distance of 20 m from each center point in every compass direction. Understorey density was measured by using a pole of 2 m long and 5 cm wide divided into 10 segments of 20 cm X 5 cm. The segments were painted altering orange and white colours to improve the visual differentiation of each segment. The difference between the number of segments covered by vegetation and the total number of segments on the pole was multiplied by 100 and expressed as the percentage of understory vegetation cover. Canopy openness was determined with the use of a convex spherical densitometer. Following Lemmon (1957), readings were taken directly above the centre point in each compass direction. The sum of the four measurements were then averaged and multiplied with 1.04 to obtain the canopy density from each vegetation point.

Internal water-bodies were delineated using a topographic map of the area. Measurements were performed the using ArcGIS 9.2 (ESRI) and Landsat TM 461 images (2001, 2007) and CBERS 2 (2009). Additional details registered during the fieldwork in the form of GPS waypoints were added to the map. Subsequently, the distance was measured from the centre of every vegetation point on each transect to the edge of the nearest water source.

2.5 Data analysis

Population density estimates of the Wattled Curassow on each island and transect were calculated using DISTANCE 6.0 software, following the Buckland *et al.* (2001) methodology for Distance Sampling. The data was firstly explored using all visual detection events. However, in some cases the detection data included outliers which distorted the model fits, and the perpendicular distance data were thus truncated by 5% to provide better model estimates. Models were then selected based on the model robustness, inspection of the detection curves, and the Akaike's Information Criterion (AIC) value. In this study, density estimates were derived from Half-Normal models with either cosine or polynomial adjustments which provided the best model fits for the data. Total population size was then calculated based on the density estimates provided by DISTANCE 6.0 and the total land area of each island, assuming an intact and homogenous habitat.

Bird abundance (number of individuals seen) was pooled for every 100 m section along each transect to coincide with points from which vegetation measurements were recorded. ArcGIS 9.2 (ESRI) and from Landsat TM 461 images (2001, 2007) and CBERS 2 (2009) were used to visualise patterns of abundance along the transects of each island (Figures 2-4).

The measures collected from field were tested for normality distribution using Anderson-Darling test (α-levels to 0.05). All habitat variables were non-normally distributed and a Kruskall-Wallis one-way analysis of variance test was used to examine habitat characteristics between islands and transects.

Regression analyses were performed to examine associations between bird abundance and occurrence, and the habitat variables recorded across the three islands. Habitat variables were transformed due to their non-normal distributions. Log_{10} transformations were carried out for tree density, DBH, basal area and crown cover. Arcsine square root was implemented on understorey and overstorey density percentage data and Log [x+1] for water distances due to the presence of zeros in our data. A Pearson Correlation matrix analysis was also performed to test whether correlations among the independent variables (habitat variables) were significant. The independent variables that were significantly correlated were used in different regression models.

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A binary, multiple logistic regression analysis was used to investigate the effect of habitat variables on the occurrence of the Wattled Curassow, because the dependent variable is categorical (presence = 1 and absence = 0). Multiple linear regression analyses were conducted to examine the effect of habitat components (independent variables) on Wattled Curassow abundance (dependent variable).

All statistical analyses were performed using MINITAB 15 (Kruskall-Wallis; Zar 1996) and SYSTAT 10 (regression models; Wilkinson 1998).

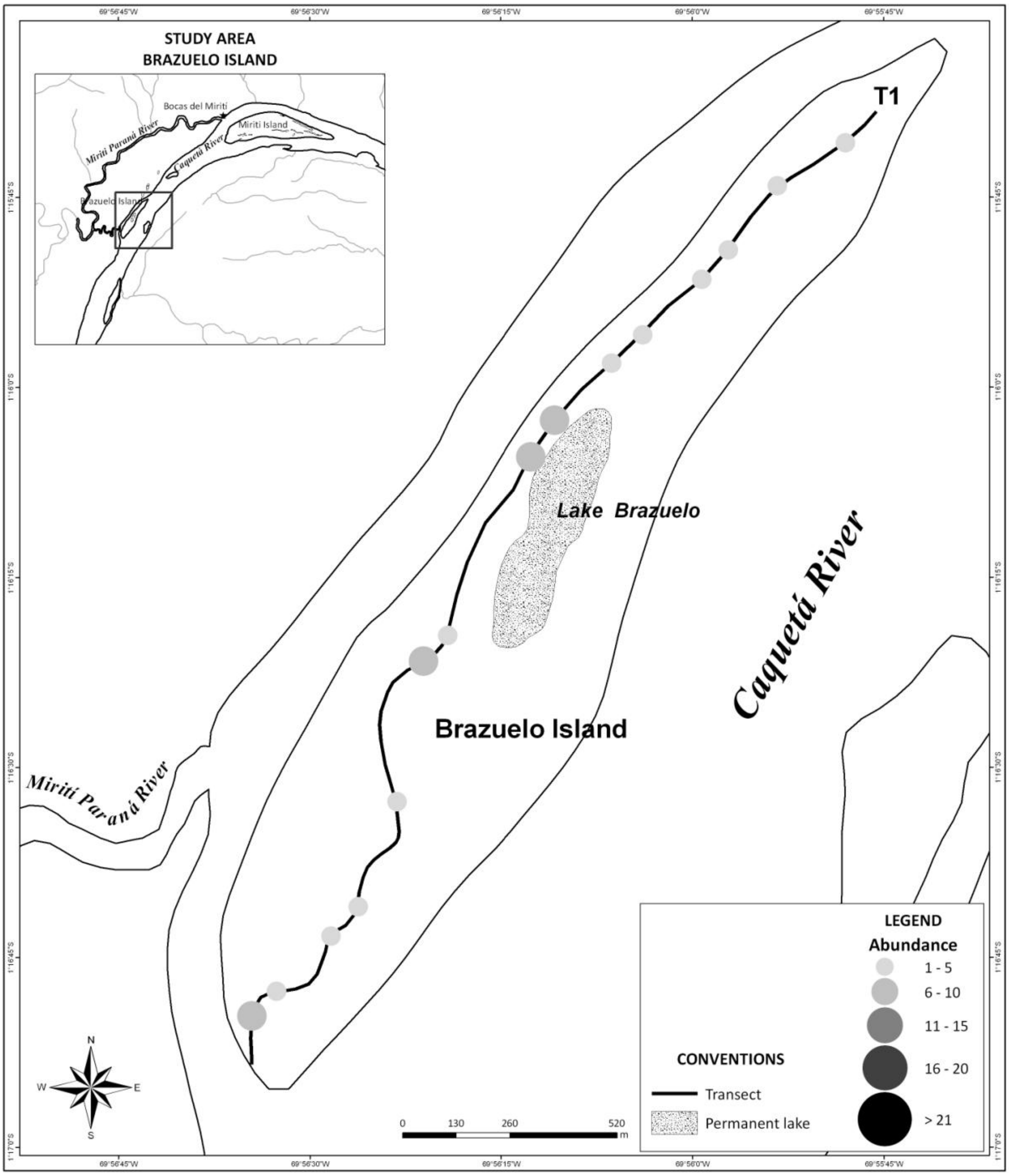

Figure 2 Abundance of Wattled Curassow after 19 days of survey (n= 56) along Transect 1 situated on Brazuelo Island.

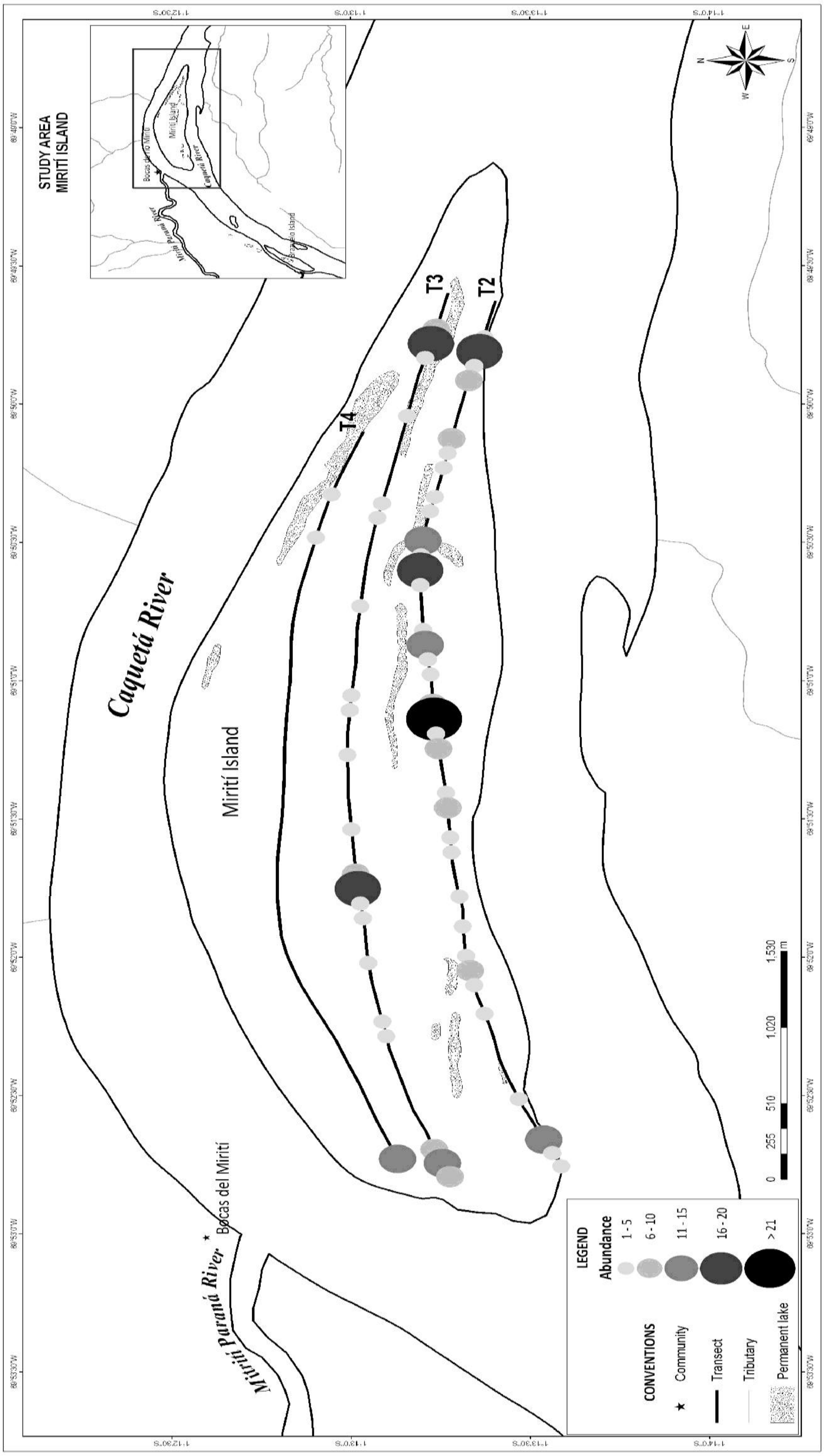

Figure 3 Abundance of Wattled Curassow after 16 days of survey (n= 378) along Transects 2-4 located on Mirití Island.

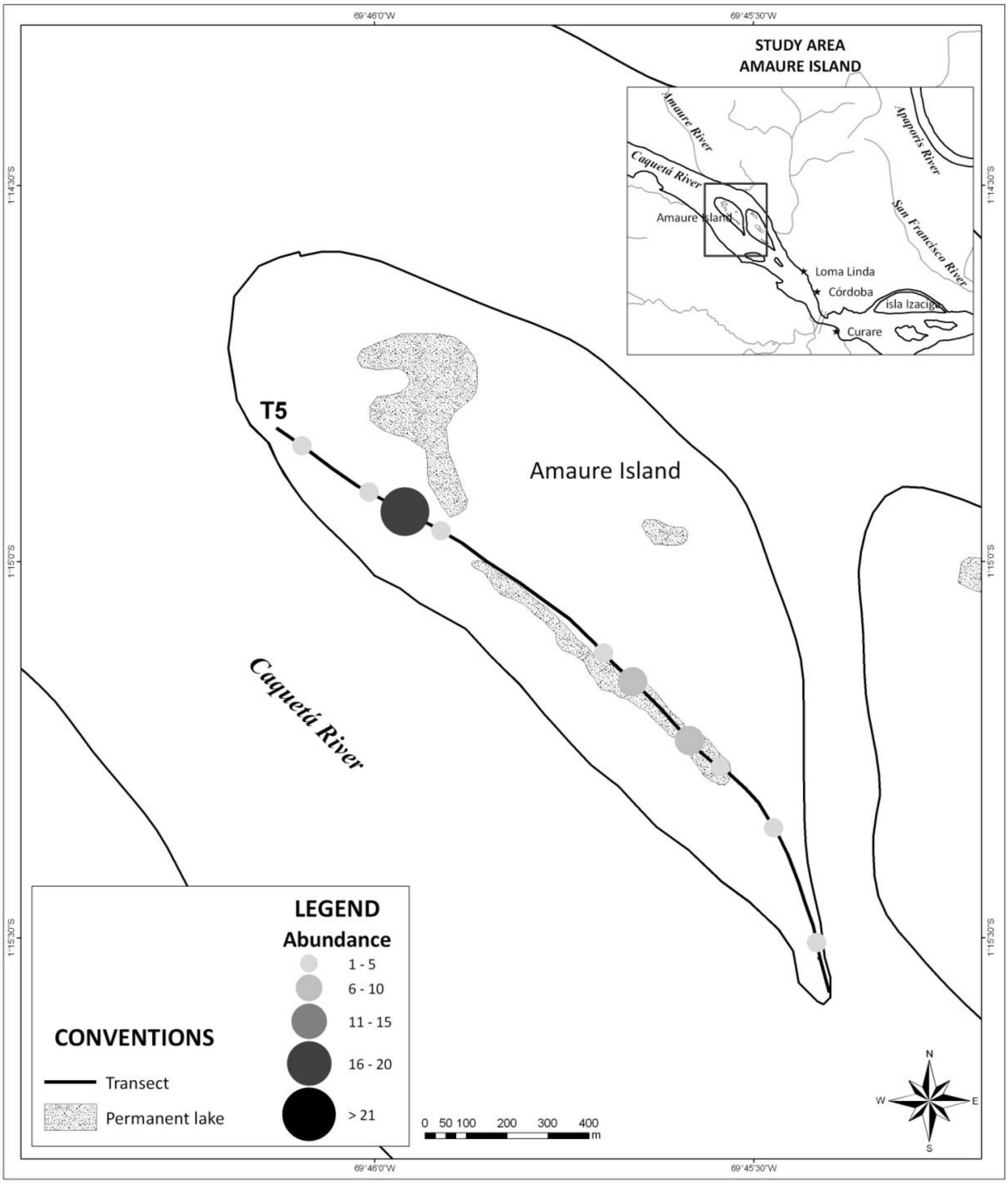

Figure 4 Abundance of Wattled Curassow after 18 days of survey (n= 54) along Transect 5 situated on Amaure Island

3. RESULTS

3.1 Aspects of encounters and Flock size

A total of 22, 26 and 134 observations of the *Crax globulos*a were recorded on Amaure, Brazuelo and Mirití islands, respectively. During survey walks, individuals were usually seen flying from the ground rather than from perched locations on higher vegetation. These encounters comprised 68% of the total number of observations. There was a slight seasonal variation in encounters, with observations being more frequent during December-January on Mirití and Brazuelo, whereas encounters were more frequent during November-December on Amaure Island. The mean flock size generally ranged from 2 to 3 individuals (Table 2). However, a number of encounters included groups with up to 5 individuals on Amaure and Brazuelo islands, and 9 individuals on Mirití Island.

3.2 Patterns of abundance

Density estimates for each island showed that the abundance of the Wattled Curassow was higher on Amure Island compared to the other survey sites (Table 2) being nearly twice as high as for Brazuelo. Encounter rates were more similar across islands, although slightly lower encounter rates were obtained on Brazuelo Island (Table 2).

The difference in density estimates were more pronounced when transects were compared, ranging from 4.7 to 54.0 individuals/km^2 (Table 2). The highest density and encounter rates were found on T2 and the lowest on T3 - both placed on Mirití Island. Based on these density estimates one would expect a total Wattled Curassow population size of 41.65 (±11.25), 21.02 (±3.99) and 209.23 (±98.33) individuals on Amaure, Brazuelo and Mirití, respectively.

Table 2 Density, encounter rate and group size of Wattled Curassow (*Crax globulosa*) along five transects on three islands surveyed.

Survey site	Transect No	Density (ind/km^2)	CV	Encounter rate (obs/km)	Effective band size (m)	Group size
Brazuelo	1	17.52	0,19	0.44	27.92	2.12
Mirití		29.06	0.47	0.50	19.5	2.49
	2	54.05	0.28	0.88	19.96	2,58
	3	26.08	0.17	0.49	18.74	2.47
	4	4.71	0.37	0.10	20.49	1.88
Amaure	5	34.71	0.27	0.50	23.45	2.61

3.3 Habitat structure and composition

Floristic composition

A total of 900 trees were examined in this study, from which 50 families and 141 genera were indentified. The number of individuals and genera found in different families across the three islands are presented in Appendix 1. Mirití exhibits the highest number of genera and families, followed by Brazuelo and then Amaure (Figure 5) – probably connected to differences in sample sizes between islands. Comparing islands, the most abundant families were Chrysobalanaceae (20.2%), Annonaceae (8.3%) and Lauraceae (7.1%) on Amaure, Moraceae (12.9%), Myristicaceae (10.5%) and Annonaceae (9.7%) on Brazuelo and Annonacea (11.4%), Moraceae (7.4%) and Chrysobalanaceae (6.2%) on Mirití.

The most diverse families were Euphorbiaceae with 11 genera, followed by Rubiaceae (8), Annonaceae (8), Arecaceae (6) and Fabaceae (6). Among the most abundant genera were *Hirtella* (Chrysobalanaceae), *Pourouma* (Cecropiaceae) and *Guarea* (Meliaceae).

Additional samples taken for the liana community adjacent identified individuals of the following genera: *Arrabideae* (Bignoniaceae), *Piptocarpha* (Asteraceae), *Coussapoa* (Cecropiaceae), *Doliocarpus* (Dilleniaceae), *Ficus* (Moraceae), *Cheiloclinium* (Hippocrateaceae), *Machaerium* (Fabaceae) and *Moutabea* (Polygalacaceae).

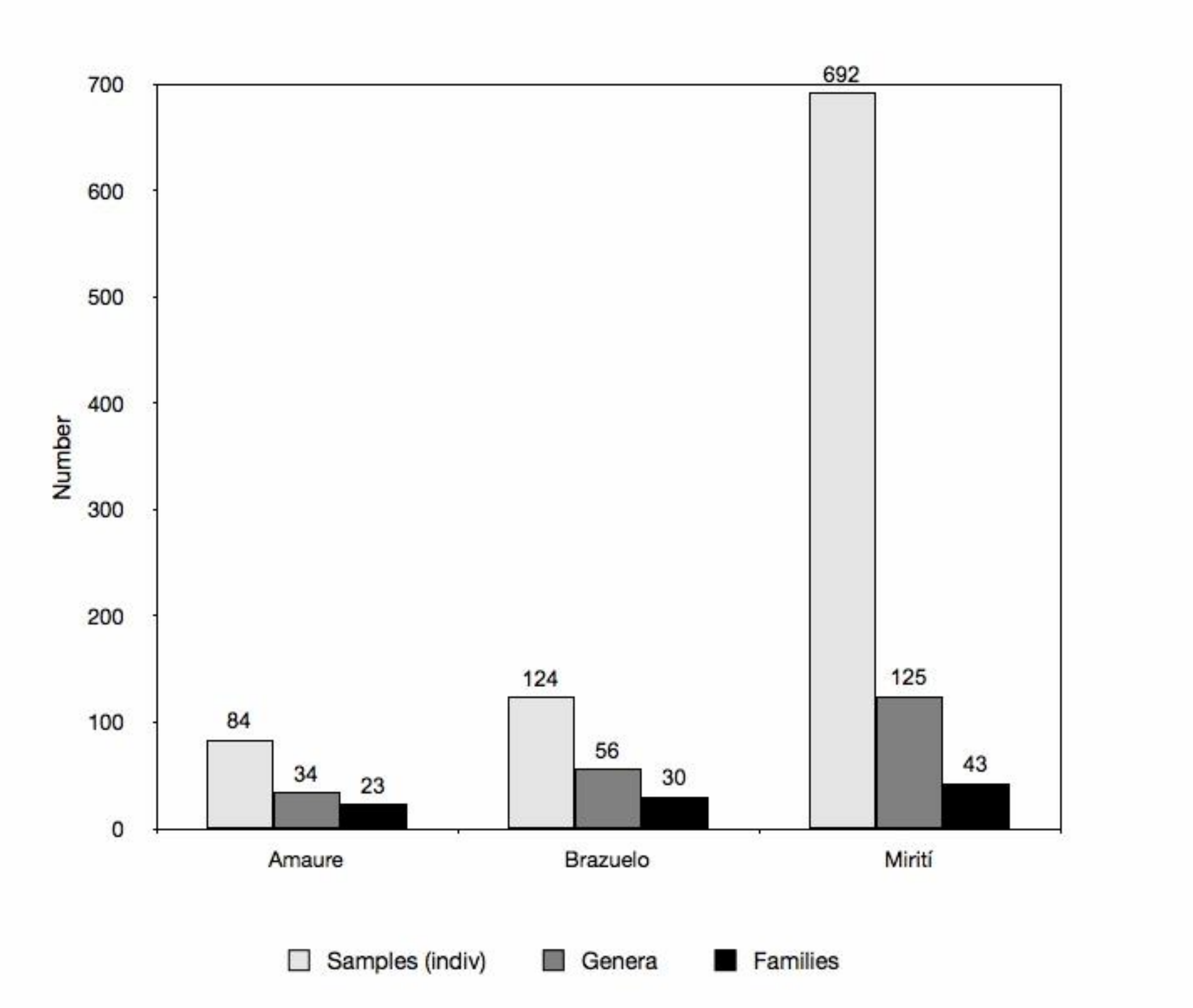

Figure 5 The number of individuals sampled, family and genera for Amaure, Brazuelo and Mirití

Vegetation structure

Vegetation variables were recorded from 21, 31 and 173 points on Amaure, Brazuelo and Mirití, respectively. The number of trees examined ranged from 84 on Amaure, 124 on Brazuelo and 692 on Mirití. Tree density differed significantly between islands (H = 32.52 DF = 4 P = <0.001). The overall tree distance on Mirití was lower (3.17 ± 1.13 m) compared to Amaure and Brazuelo (Table 3). The distance from each point (where vegetation variables were measured) to the nearest internal water body also differed significantly between islands (H = 17.77 DF = 2 P = <0.001); the longest distances were found on Brazuelo island and the shortest on Amaure Island (Table 3). Other variables were not significantly different among islands (Table 3). The DBH measures and the frequency for all islands are presented in Figure 6.

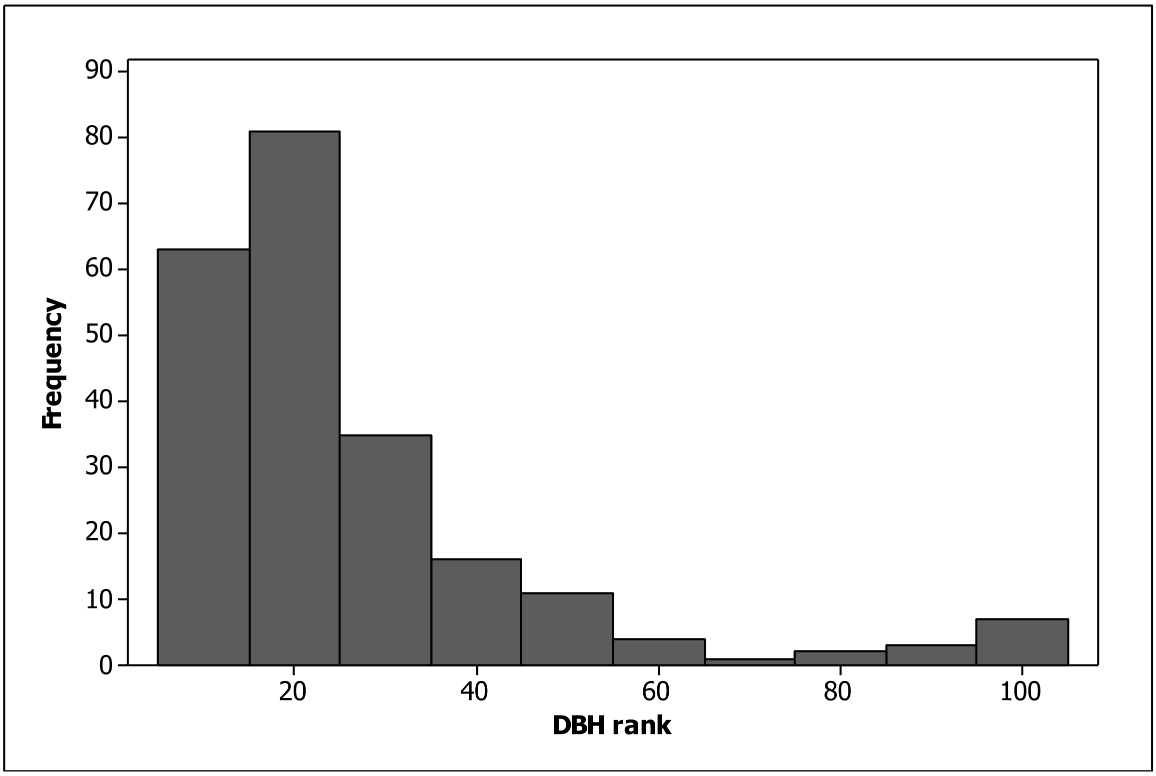

Figure 6 Pooled DBH distribution for Amaure, Brazuelo and Mirití islands (n= 225)

Tree distances and water distance were also significantly different when comparing between transects (H = 32.68 DF = 4 P = <0.001, H = 44.89 DF = 4 P = ≤0.001 respectively). The highest tree distance was found for Brazuelo (T1) and lowest for T4 located on Mirití Island (Table 3). T1 and T4 were also situated more distant from water sources compared to others. Understorey and overstorey density portrayed significant differences among transects (H= 40.82 DF = 4 P = <0.001, H = 16.07 DF = 4 P = 0.003, respectively). There were also significant differences within Mirití Island, as T3 portrayed the highest understorey density while T4 had the least dense understorey. DBH and basal area were also different among transects, but not significantly so for the latter (H = 9.52 DF = 4 P = 0.049, H = 8.85 DF = 4 P = 0.065).

Table 3 Mean (SD) for each vegetation variable across all transects surveyed in the lower Caquetá River, Colombia.

Habitat variables	Brazuelo		Mirití		Amaure	
	T1 (n=31)	T2 (n=61)	T3 (n=61)	T4 (n=51)	T5 (n=21)	*P*
Tree distance(m)	4.21 (1.32)	3.50 (1.38)	3.15 (0.96)	2.81 (0.85)	3.49 (1.00)	0.000*
DBH (cm)	30.37 (23.39)	25.17 (20.70)	30.33 (27.26)	19.43 (10.20)	27.04 (13.59)	0.049*
Crown cover (m^2)	9.30 (8.27)	8.98 (8.71)	9.14 (9.88)	7.00 (4.46)	10.40 (7.94)	0.205
Basal area (m^2)	0.25 (0.59)	0.17 (0.61)	0.26 (0.51)	0.06 (0.09)	0.13 (0.19)	0.067
Understory density (%)	54.92 (20.24)	62.44 (20.65)	60.32 (20.48)	41.23 (14.17)	45.54 (23.72)	0.000*
Overstory density (%)	92.06 (4.61)	91.37 (5.62)	91.37 (13.51)	93.68 (5.60)	89.82 (20.74)	0.003*
Distance to water (m)	356.4 (265.7)	207.12 (150.9)	139.36 (152.3)	412.83 (299.8)	119.5 (144.6)	0.000*

*Statistical significance of $P<0.05$ from Kruskal-Wallis analysis of variance

3.4 Bird and habitat associations

A total of 56 Wattled Curassow individuals were counted on Brazuelo Island during the study period and the bird was present at 15 (48.39%) vegetation points sampled on T1. On Mirití, a total of 378 individuals were counted and the species was present at 35 (57.38%), 24 (39.34%) and 14 (27.45%) sampling points of T2, T3 and T4, respectively. The Amaure Island count was 54, and individuals were present at 10 (47.61%) vegetation points sampled on T5 (Figures 2-4).

Pearson Correlation Matrix showed significant correlations between DBH, crown cover and basal area (P = < 0.05). To test the importance of each variable, three linear regression models were run, in which each of the three correlated variables were substituted. (Model 1 Abundance of Wattled Curassow= constant + tree distance + DBH + understorey + overstorey + water distance; Model 2 Abundance of Wattled Curassow= constant + tree distance+ crown cover + understorey + overstorey + water distance; Model 3 Abundance of Wattled Curassow= tree distance + basal area + understorey + overstorey + water distance). The significant correlations between DBH, crown cover and basal area had no influence on the outcome of the regression. Therefore, results from the complete model are presented here. The same procedure was repeated for the logistic regression with the same outcome. Multiple regression analysis showed no effect of tree density (R^2= 0.058, N= 223, T= 0.77, p= 0.442), DBH (R^2= 0.058, N= 223, T= -0.48, p= 0.629), crown cover (R^2= 0.062, N= 223 T= -1.153, p= 0.250), basal area (R^2= 0.058, N= 223, T= -0.589, p= 0.556) or overstorey density (R^2= 0.058, N= 223, T= 1.301, p= 0.195) on Wattled Curassow abundance. However, the abundance of the Wattled Curassow was positively correlated with understorey density (R^2= 0.058, N= 223, T= 2.742, p= 0.007), where higher understorey density resulted in increase bird abundance. Furthermore, abundance was negatively correlated with water distance, where there was a significant decrease in bird numbers with increased distance to water. (R^2= 0.058, N= 223, T= -2.397, p= 0.017).

Binary logistic regression on species occurrence resulted in no significant effect by any of the variables measured: tree distance (χ^2= 0.530, N= 223, T= 0.596, p= 0.230), DBH (χ^2= 0.530, N= 223, T= 1.074, p= 0.283), basal area (χ^2= 0.629, N= 223, T= 0.696, p= 0.486), crown cover (χ^2= 0.684, N= 223, T= -0.354, p= 0.723), understorey (χ^2= 0.530, N= 223, T= 1.096, p= 0.273), overstorey (χ^2= 0.530, N= 223, T= 0.597, p= 0.551) and water distance (χ^2= 0.530, N= 223, T= -0.790, p= 0.429).

Eliminating the outlier T4 from the analyses, multiple regression analyses showed no relationship between abundance and tree distance (R^2= 0.050, N= 172, T= 0.631, p= 0.529), DBH (R^2= 0.050, N= 172, T= -0.388, p= 0.698), crown cover (R^2= 0.057, N= 172, T= 0.239, p= 0.633), overstorey (R^2= 0.050, N= 172, T= 0.479, p= 0.633) or basal area (R^2= 0.050, N= 172, T= -0.475, p= 0.636). However, significant relationships were again found for understorey (R^2= 0.050, N= 172, T= 2.819, p= 0.005) and water distance (R^2= 0.050, N= 172, T= -2.867, p= 0.005).

Likewise, logistic regression on species occurrence again resulted no significant for all habitat variables when T4 was removed: tree distance (χ^2= 0.929, N= 172, T= 0.291, p= 0.927), DBH (χ^2= 0.929, N= 172, T= -0.314, p= 0.753), crown cover (χ^2= 0.929, N= 172, T= 0.445, p= 0.656), basal area (χ^2= 0.929, N= 172, T= 0.447, p= 0.634), understorey density (χ^2= 0.929, N= 172, T= 0.445, p= 0.656), overstorey density (χ^2= 0.929, N= 172, T= -0.333, p= 0.739), water distance (χ^2= 0.929, N= 172, T= 0.281, p= 0.863).

3.5 Biological and Ecological aspects of the Wattled Curassow

An additional 28 observations of the Wattled Curassow were recorded after the termination of census walks or during vegetation surveys. A total of 266 observations were thus registered in this study, including 40 aural records. Considering the general lack of information for the Wattled Curassows, a number of additional unquantified ecological observation made during this seven months field study are worthy of mention.

Three clear observations were obtained outside Brazuelo Island during the January census block. Two observations were made in the *várzea* forest close to the Mirití-Parana tributary on the other side of the river (69º 56' 26.72" W, 1º 16' 10.99" S; 69º 56' 39.58" W, 1º 16' 34.40" S) with 3 and 2 individuals registered in those events. The third observation was of a single individual and occurred on the sand islet formed during the low-water season at the shoreline of Brazuelo Island (69º 56' 28.90" W, 1º 16' 23.37" S).

As with the observations during census walks, most of the additional encounters were individuals seen on the ground. The species was mostly seen in groups throughout the study period, varying from 2-9 individuals. Nevertheless, a single sub-adult male was observed on Mitirí during December census walks. In addition, a female with two juveniles were recorded in mid-March during the final survey on Amaure Island (Figure 7). Furthermore, groups of more than 3 individuals seemed to form harems of one or two males with several females. Yet, this needs further confirmation due to observational difficulties relating to vegetation thickness making detailed observations difficult and the elusive behaviour of the species. On two occasions, the study species was observed in the presence of other bird species such as *Aburria pipile* and *Crypterullus undulatus* on Mirití Island.

Figure 7 Two Wattled Curassow chicks found during census surveys on Amaure Island

During the field study, groups of the Wattled Curassow were continuously found below or perched on *Coussapoa* spp. (Cecropiacea) or *Ficus* spp. (Moraceae), particularly between October and January (Figure 8-9). Although observations could not confirm that the Wattled Curassow was eating directly from the tree or liana, several half-eaten fruits were found on the ground on each occasion (Figures 8-9). Additionally, three observations of the study species were done at feeding sites of the Giant Otter (*Pteronura brasiliensis* Gmelin) at the edge of side-canals on Mirití Island. Pecked fish flesh and bones were found at these sites.

Figure 8 Fruits of *Ficus* sp. (Moraceae) found on the ground at sites where Wattled Curassow was observed on Transect 2 (Mirití) during surveys in the December block

Figure 9 Fruit of *Coussapoa* sp. (Cecropiaceae) found on the ground at sites where Wattled Currassow was observed on Transect 2 (Mirití) during surveys in the December block

4. DISCUSSION

4.1 Density estimates and Abundance

According to several authors (Silva & Strahl 1997, Brooks 2006), cracid species densities vary between 0.9 and 25.3 ind/km^2. Such densities greatly exceed population density estimates of *Crax globulosa* in most areas where the species has been surveyed, which vary between 0.56-3.4 ind/km^2 (Haugaasen & Peres 2008, Hill *et al*. 2008). The extremely high density estimates of the Wattled Curassow obtained in the current study were thus somewhat surprising. However, it was not totally unexpected since high density estimates were already reported from a previous study on the islands surveyed, with 29.2, 11.0 and 19.0 ind/km^2 reported on Amaure, Brazuelo and Mirití islands, respectively (Alarcon-Nieto & Palacios 2008). These numbers are slightly lower than those presented in this study (Table 2). Nevertheless, compared to the survey conducted two years previously (Alarcón-Nieto & Palacios 2005, 2008), the estimated population sizes for each island found in the current study suggests relative stable populations of the Wattled Curassow in the region. In fact, the results could even suggest that the populations in the study region are increasing. An encouraging explanation could be related to the efforts surrounding the previous study to expand the awareness about the Wattled Curassow in nearby communities. However, it could simply be an artifact of the great difference in survey efforts between the two studies, suggesting that numbers presented here are more robust.

4.2 Forest composition and structure

There is little information available on western Amazonian várzea forest. However, the family composition of the várzea forests presented here resembles those studied by Duivenvoorden (1994) along the middle Caqueta River. The five most dominant families (Annonaceae, Moraceae, Chrysobalanaceae, Myristicaceae, Sapotaceae) also correspond well with Balslev *et al*. (1987) who similarly found Moraceae and Myristicaceae to be important families at their site in Amazonian Ecuador. The super-family Leguminosae does not figure as this paper follows the Cronquist (1981) classification system by dividing the family into Caesalpiniaceae, Fabaceae and Mimosaceae. The composition in the current study nevertheless diverges somewhat from várzea forest inventories elsewhere in the región, such as the Piagaçu-Purus and Mamiraua extractive reserves in Brazil, where the Euphorbiaceae along with Lecythidaceae, Annonaceae and Fabaceae appear to dominate (Ayres 1993, Haugaasen 2004). However, caution must be taken while interpreting these results since 56 and 246 individuals remain undetermined to the level of family and genus, respectively. Additionally, trees smaller 10 cm DBH were included in the current study which may have confounded direct comparisons with work elsewhere.

The inverse-J shape curve of the three forest types is typical of other tropical forest sites (Campbell 1989, Ferreira & Prance 1998, Lima Filho *et al*. 2001). Similarly, the high proportion of trees below 30 cm DBH is within the range of those observed elsewhere. For example, Milliken (1998) and Boom (1986) reported proportions of 82 and 91% for Brazil and Bolivia, respectively. Canopy openness resembled that for *várzea* forest in the Purus river (Haugaasen & Peres 2006). Surprisingly, the mean DBH in the current study was higher (26.5 cm) than those reported in the Purus (Haugaasen & Peres 2006), despite the smaller DBH criteria set for tree measurements in the current work.

Only tree density and distance to internal water sources were different across islands. The increased distance between trees and slightly higher DBH values on Brazuelo could imply a more mature forest here, just as the higher tree density and lower mean DBH could suggest a more disturbed system on the other two islands. However, any local variation is probably diluted on the largest island (Mirití), as differences in forest structure were more conspicuous between transects. T4, for example, diverged the most in our results, with smaller tree sizes (DBH) and higher tree densities. This is supported by observations made during vegetation surveys which suggest that this transect was dominated by a higher number of seedlings and ferns, in addition to the *Mauritia flexuosa* swamp forest. This could imply a clayey soil type, characterized by poor drainage and higher acidity, with limited conditions for establishment and growth of many tree species (Cardenas 1997). This habitat patchiness could explain the poor animal diversity and the absence of the study species during field observations in these areas.

4.3 Habitat Associations

According to the abundance maps (Figure 2-4) the Wattled Curassow appeared to show a preference for the mid-southernmost areas of Mirití Island. The differences of forest structure between transects may have an important role for the distribution of the Wattled Curassow. . T2 and T3 were dominated by the presence of lakes had higher habitat heterogeneity compared to the northern part of the island. Furthermore, there was a clear absence of the study species in *Mauritia flexuosa* swamps found at T4. This suggests a low preference for such habitats by the study species.

According to Hennessey (cited in Delacour & Amadon 2004) and Santos (1998), the Wattled Curassow is usually seen in younger, low-stature, vine-tangled floodplain forests rather than more open, mature forest. Hill *et al*. (2008) observed that the species appear to be restricted to water-edge habitats. This study appears to confirm these observations. In the current study, the Wattled Curassow was found to occur at higher abundances in areas proximate to water-bodies and with high understorey density. The latter may simply be explained by the fact that vegetation surrounding water-bodies is denser, often covered by helophyte species or surrounded by secondary plant cover that could, for example, serve as protection for the Wattled Curassow against both terrestrial and aerial predators. Given that T4 appeared to be a severe outlier in the dataset, regression analyses were repeated with this transect excluded. However, similar results were obtained with distance to water and understorey remaining the important factors.

Habitat structure has been demonstrated to influence the abundance and occurrence of bird species (e.g. Terborgh 1985, Banks & Cintra 2008). Occurence and abundance is also determined by food availability, sites for reproduction and protection (e.g. Block & Brennan 1993) or other species characteristics such as social structure, life history strategies, ability of dispersion and interactions with other species (e.g. Rios *et al*. 2005).The habitat variables measured in this study were unable to explain the local occurrence of the Wattled Curassow on the three islands. The lack of correlation suggests a more complex depiction of the habitat use and selection of the species and clearly demands further investigation. For example, a number of seasonal internal water bodies (pools and channels) may have remained unaccounted due to the difficulties related to surveys in *várzea* environments. A particular focus of future research should therefore be a more detailed study of the spatial and seasonal fluctuations of flooding in order to assess the effects on and associations with the Wattled Curassow.

4.4 Ecological and biological aspects

Bennett (2000) and Alarcón-Nieto (2008) suggest that the populations of the Wattled Curassow in the Caqueta region seem to be concentrated and isolated to the várzea islands. However, the observations obtained of the species outside Brazuelo Island suggest wider movements at a local and perhaps regional scale. Occasional movements of the Wattled Curassow during low-water level seasons have been reported (Delacour & Amadon 2004), but further surveys are needed to confirm the presence of *Crax globulosa* in adjacent areas.

Group encounters suggest that the Wattled Curassow is a social species. The groups were relatively mixed, which is consistent with other observations (e.g. Bennett 2000, 2003; Hill *et al.* 2008). However, the results suggest that groups encompassed more females than males. The reproduction time at other study sites, such as Mocagua Island, suggests that reproduction occur throughout the year, but peak during July-August and January-February (Bennett 2000, 2003, Delacour & Amadon 2004). We observed two chicks in Amaure Island by mid-March – also suggesting a breeding time during January-February (Figure 5).

There is still a lack of detailed information on cracid diets in general. Diets of only a few species have been well documented. Many species feeds on fruit, some on leaves and insects, and a few species feed on vertebrates and seeds (Muños & Kattan 2007). Whether diets are specialised or generalised is still inconclusive for many. The observations obtained during this field study suggest a more generalised diet for the Wattled Curassow. This corroborates other observations of the study species (e.g. Bennett 2000, Alarcón-Nieto & Palacios 2005). The generalised diet may partially be explained by the seasonal fluctuations of resource availability caused by the highly seasonal environment they inhabit. Studies have shown the importance of alternative food items at times of fruit scarcity in cracids (Jiménez et al. 2001), and other animals and birds may simply migrate out of the *várzea* during the high-water season (e.g. Bodmer 1990, Haugaasen & Peres 2005a,b; 2007). Moreover, trees and liana species such as *Ficus* spp. (Moraceae) where the Wattled Curassow was continuously seen, have been determined as keystone species for large vertebrates during low-water seasons in Amazonian floodplain forests (Haugaasen & Peres 2007), as they are among the few tree species bearing fruits during this period. Observations done elsewhere show that the Wattled Curassow is associated to other tree species (Hill *et al*. 2008). More studies should therefore be centred on the dietary habits of the Wattled Curassow and also its association with seasonal fluctuations of flowers and fruits in the study region. This might provide a broader understanding of the occurrence and distribution of the species.

5. CONSERVATION IMPLICATIONS

Initiatives to develop a conservation and management program for the Wattled Curassow were planned by Conservation International (Colombia), emphasising the importance of the species and its precarious status to the communities living relatively close to the islands. However, this program has been facing setbacks which could have important implications for the conservation of the species in the future. Anthropogenic activities (cultivation, hunting and logging) are reestablishing and becoming more frequent (pers. obs.) due to a lack of clear guidelines and long term management (Angel Yukuna, Pedro Birto and Santo Domingo pers. com.). This is precarious since the estimated population size on Mocagua Island is 50 individuals (Bennett 2000), making the population of Wattled Curassow studied here by far the largest and most important population in Colombia, with more than 270 individuals inhabiting the region. In fact, this population is among the largest populations recorded for this species across its range (Hill *et al.* 2008). Coupled with their specialised habitat and fragmented populations, the vulnerability of the species alone should demand conservation action in the study region.

6. CONLUSION

The *várzea* forests surveyed in this study closely resemble those elsewhere in western Amazonia, and conspicuously portray characteristics of a seasonally flooded environment. The current study reports the highest densities of Wattled Curassow known throughout its range and that the island populations appear to be on the increase. Similarly, the results suggest that the Wattled Curassow population in the lower Caquetá River may be the most important population in Colombia, and therefore should be carefully considered for further conservation action. Habitat associations unravelled by the current study, showing a preference of *Crax globulosa* to *várzea* forests with a dense understorey proximate to *várzea* forest lakes, ponds and canals, appear to conform with observations by other investigators (Santos 1998, Hennessey 1999, Bennett 2000 and 2003, Hill *et al.* 2001, Delacour & Amadon 2004, T.Haugaasen, pers. comm.). However, despite the habitat associations perceived by this study and others, further studies are clearly needed to unravel the factors influencing the presence or absence of this species to a particular site or region. Such information may be crucial for the future conservation and management of the species.

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APPENDIX 1 List of families and genera across three islands surveyed in the lower Caquetá River, Colombia.

FAMILY	GENUS	AMAURE	BRAZUELO	MIRITÍ	Total
Annonaceae					
	Anaxagorea		4		**4**
	Annona			1	**1**
	Crematosperma	1		1	**2**
	Diclinanona			1	**1**
	Duguetia	2	1	3	**6**
	Guatteria	3	1	13	**17**
	Oxandra		5	10	**15**
	Unonopsis		1	18	**19**
	Undetermined	1		32	**33**
Apocynaceae					
	Aspidosperma			2	**2**
	Lacmellea			1	**1**
	Macoubea (cf duckei)		1		**1**
	Mucoa			1	**1**
Aquifoliaceae					
	Ilex			1	**1**
Arecaceae					
	Astrocaryum	3	1	7	**11**
	Bactris			2	**2**
	Euterpe			10	**10**
	Iriartella			1	**1**
	Oenocarpus			1	**1**
	Socratea		1	1	**2**
	Undetermined			7	**7**
Bombacaceae					
	Pseudobombax	3			**3**
	Quararibea			6	**6**
Boraginaceae					
	Cordia			5	**5**
Burseraceae					
	Protium		3	6	**9**
Caesalpiniaceae					
	Elizabetha			1	**1**
	Eperua		1	1	**2**
	Macrolobium	1		3	**4**
	Vouacapoua			1	**1**
	Undetermined			3	**3**
Cecropiaceae					
	Coussapoa			1	**1**
	Pourouma	1	5	15	**21**
	Cecropia	1	1	5	**7**
Chrysobalanaceae					
	Couepia	1	1	9	**11**

	Hirtella	13	7	14	**34**
	Licania	2	2	2	**6**
	Parinari	1	1	5	**7**
	Undetermined			13	**13**
Clusiaceae					
	Calophyllum	1	2	12	**15**
	Caraipa		1		**1**
	Chrysochlamys			1	**1**
	Marila			1	**1**
	Moronobea		1	1	**2**
	Undetermined			1	**1**
Combretaceae					
	Buchenavia			1	**1**
Connaraceae					
	Connarus		1	1	**2**
	Undetermined		1	20	**21**
Ebenaceae					
	Diospyros			1	**1**
Erythroxylaceae					
	Erythroxylum			3	**3**
Euphorbiaceae					
	Alchornea			1	**1**
	Alchorneopsis	1	2	2	**5**
	Amanoa	1	1	1	**3**
	Didymocistos	1			**1**
	Hevea			4	**4**
	Mabea		1	2	**3**
	Nealchornea			1	**1**
	Pera			2	**2**
	Sagotia			1	**1**
	Sandwithia			1	**1**
	Sapium	1		1	**2**
	Undetermined			4	**4**
Fabaceae					
	Andira			1	**1**
	Dussia		1	1	**2**
	Hymenolobium		1	3	**4**
	Ormosia		1	2	**3**
	Pterocarpus			4	**4**
	Swartzia			5	**5**
	Undetermined			4	**4**
Flacourtiaceae					
	Carpotroche			1	**1**
	Haseltia			1	**1**
	Lindackeria			1	**1**
	Ryania			7	**7**
	Xylosma			1	**1**
	Undetermined			1	**1**
Hippocrataceae					
	Cheiloclinum			1	**1**

Humiriaceae					
	Sacoglotis			1	**1**
Icacinaceae					
	Discophora			1	**1**
	Emmotum			1	**1**
	Metteniusa			1	**1**
Lauraceae					
	Aniba			5	**5**
	Endichleria		2	1	**3**
	Licaria	2		4	**6**
	Nectandra	1	2	2	**5**
	Ocotea		3	3	**6**
	Undetermined	3	2	11	**16**
Lecythidaceae					
	Couratari	1		2	**3**
	Eschweilera		2	9	**11**
	Grias			1	**1**
	Gustavia			2	**2**
	Undetermined			8	**8**
Melastomataceae					
	Loreya		1		**1**
	Maieta	1		1	**2**
	Miconia			2	**2**
	Undetermined			5	**5**
Meliaceae					
	Guarea		2	19	**21**
	Trichilia	1	1	5	**7**
Memecylaceae					
	Mouriri	1			**1**
	Undetermined	3			**3**
Mimosaceae					
	Abarema			1	**1**
	Inga	1	2	26	**29**
	Parkia			1	**1**
	Trichilia			1	**1**
	Zygia		2	7	**9**
	Undetermined			2	**2**
Monimiaceae					
	Mollinedia			1	**1**
	Siparuna			1	**1**
Moraceae					
	Brosimum		1	1	**2**
	Ficus	1	4	6	**11**
	Maquira			1	**1**
	Sorocea		4		**4**
	Undetermined	4	7	43	**54**
Myristicaceae					
	Compsoneura	1		11	**12**
	Iryanthera	1	8	5	**14**
	Ryania			1	**1**

	Virola		4	7	**11**
	Undetermined	2	1	8	**11**
Myrtaceae					
	Calyptranthes		1	1	**2**
	Eugenia	1		10	**11**
	Myrcia	1		4	**5**
	Myrciaria		2	3	**5**
	Undetermined	1	1		**2**
Nyctaginaceae					
	Neea	2	1	1	**4**
Olacaceae					
	Heisteria		2	9	**11**
	Minquartia			2	**2**
Polygalaceae					
	Securidaca	4			**4**
	Undetermined		1		**1**
Polygonaceae					
	Coccoloba		3	6	**9**
	Triplaris			9	**9**
Quiinaceae					
	Lacunaria			1	**1**
Rubiaceae					
	Bathysa			1	**1**
	Coussarea			2	**2**
	Faramea			7	**7**
	Genipa	2			**2**
	Hippotis			1	**1**
	Palicourea		1		**1**
	Psychotria			4	**4**
	Sommera			1	**1**
Rutaceae					
	Zanthoxylum			1	**1**
Sabiaceae					
	Meliosma	1			**1**
Sapindaceae					
	Allophylus		3		**3**
	Talisia		1	2	**3**
	Toulicia			1	**1**
	Undetermined			4	**4**
Sapindaceae					
	Undetermined			1	**1**
Sapotaceae					
	Chrysophyllum		1	2	**3**
	Ecclinusa			1	**1**
	Micropholis		1	1	**2**
	Pouteria		2	4	**6**
	Undetermined	3		29	**32**
Sterculiaceae					
	Guazuma		1		**1**
	Herrania			3	**3**

	Sterculia			5	**5**
Tiliaceae					
	Apeiba	2	3	5	**10**
Ulmaceae					
	Ampelocera		1	4	**5**
Violaceae					
	Amphirrhox			1	**1**
	Leonia			3	**3**
	Rinorea			3	**3**
Vochysiaceae					
	Erisma		2	3	**5**
	Vochysia			1	**1**
	Undetermined			1	**1**
Undetermined					
	Undetermined	6		50	**56**
Grand Total		**84**	**124**	**692**	**900**