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Habitat use and ecology of Wattled Curassows on islands in the lower Caquetá River, Colombia

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ABSTRACT. Despite being endangered, little is known about the natural history and habitat use of Wattled Curassows (*Crax globulosa*). From September 2008 to March 2009, we examined habitat associations of this species on three islands in the lower Caquetá River, Colombia. Observations of curassows were made during line-transect walks, and habitat variables were measured at points where curassows were and were not observed along those transects to assess potential habitat preferences. A total of 182 sightings yielded encounter rates ranging from 0.1 to 0.89 observations/km across transects. Curassows were more likely to be observed close to the river and to lakes on the islands. Additionally, the importance of the river increased as the distance to internal water sources increased. Other habitat characteristics, including tree density, tree diameter, understory density, and canopy cover, did not differ between areas where Wattled Curassows were and were not observed. Flock size ranged from 1 to 9 individuals; most solitary individuals were males and flocks (>2 individuals) generally consisted of more females than males. The association of Wattled Curassows with water sources during the low-water season may have conservation implications because it could increase their vulnerability to anthropogenic activities such as agricultural activities, fishing, and hunting. As a result, conservation of these curassows on islands in the lower Caquetá River will likely depend on local support.

RESUMEN. **Uso del hábitat y ecología de *Crax globulosa* en islas del bajo río Caquetá**
A pesar de estar en peligro, poco se conoce sobre la historia natural y el uso de hábitat de *Crax globulosa*. Desde Septiembre del 2008 a Marzo del 2009, examinamos asociación con el hábitat en esta especie en tres islas del bajo río Caquetá, Colombia. Observamos los paujiles durante caminatas en transectos en línea y medimos variables del hábitat, en puntos con y sin presencia de paujiles a lo largo de los transectos, para evaluar preferencias en el hábitat. Un total de 182 avistamientos produjeron tasas de encuentro entre 0.1 y 0.89 observaciones/km a lo largo de los transectos. La probabilidad de observar a los paujiles fue más alta cerca al río y lagos en las islas. Adicionalmente, la importancia del río incrementó con el aumento en la distancia a las fuentes de aguas del interior. Otras características de hábitat que incluyen densidad y diámetro de arboles, densidad del sotobosque y cobertura del dosel, no variaron entre áreas en donde *C. globulosa* fue o no observado. El tamaño de la bandada fluctuó entre 1 y 9 individuos; la mayoría de los individuos solitarios fueron machos y las bandadas (>2 individuos) generalmente tenían más hembras que machos. La asociación de *C. globulosa* con fuentes de agua durante la temporada de aguas bajas puede tener implicaciones para su conservación, debido a que puede incrementar su vulnerabilidad a actividades antropogénicas como agricultura, pesca y caza. Como resultado, la conservación de este paujil en las islas del bajo río Caquetá muy probablemente dependerá del apoyo local.

Key words: Amazonia, cracids, *Crax globulosa*, habitat preference, *Várzea*

Cracids (curassows, guans, and chachalacas) comprise a group of large, forest-dwelling frugivores and represent the most threatened avian family in the Neotropics (Brooks 2006, Brooks et al. 2006). Wattled Curassows (*Crax globulosa*) are endemic to the central-western Amazon basin where they occur exclusively on river islands and in floodplain forests seasonally inundated by white-water rivers (hereafter *Várzea* forests) in Brazil, Colombia, Ecuador, Peru, and Bolivia (Bennett 2000, Aranibar-Rojas 2006, Haugaasen and Peres 2008, BirdLife International 2011). Despite the wide geographic range, populations are discontinuous and individual subpopulations are generally limited to < 250 individuals (Aranibar-Rojas 2006). Like many cracids, populations of Wattled Curassows are

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declining due to hunting and habitat destruction throughout their range (Santos 1998, Hennessey 1999, Albernaz and Ayres 1999, Bennett 2000).

Previous observations suggest that Wattled Curassows are year-round residents of *Várzea* forest river islands and floodplains (Begazo 1997, Santos 1998, Bennett 2000, 2003, Alarcón-Nieto and Palacios 2008). They appear to have a patchy distribution in suitable areas of *Várzea* forest (Begazo 1997), mostly restricted to water-edge habitats during the dry season (Hill et al. 2008). Compared to other species of curassows, Wattled Curassows are thought to be more arboreal due to lack of *terra-firme* (upland, unflooded) forest in their *Várzea* habitat for much of the year (Santos 1998, Bennett 2003). Previous studies of habitat use by Wattled Curassows have largely been based on anecdotal observations and, as a result, their habitat requirements remain unclear.

In Colombia, Wattled Curassows are rare and critically endangered (Bennett and Franco-Maya 2002). Until recently, the only well-documented population in Colombia was on Mocagua Island (Bennett 2000). However, surveys along the lower Caquetá River confirmed populations on Mirití Island (Alrarcón-Nieto and Palacios 2005, 2008) and El Brazuelo and Amaure islands (Alarcón-Nieto and Palacios 2008). We examined the habitat preferences of Wattled Curassows on these three islands and, when possible, collected other information to help improve our limited knowledge of this species.

METHODS

Study area. Our study was conducted from September 2008 to March 2009 on three islands in the La Pedrera region of the lower Caquetá River, Colombia (Fig. 1), where precipitation is highly seasonal, with April to June the wettest months and November to December the driest (Duivenvoorden 1995). This seasonal rainfall produces great fluctuations in the water level of the river. Our survey period coincided with the early dry, dry, and early wet seasons when water levels of the Caquetá River are lowest.

Mirití Island (1° 12' S, 69° 51' W; 540 m from mainland) has a surface area of ~8.1 km^2 and is located at the mouth of the Mirití-Paraná River (Fig. 1). Mirití is mainly covered by primary *Várzea* forests, with trees 25–35 m tall. Secondary forests are found on the northwest part of the island due to previous agricultural activities, with a few patches (0.2–1.1 ha) still active. The northwest portion of the island has a swamp forest characterized by permanently waterlogged forest patches (locally known as *canangucha*l) dominated by *Mauritia flexuosa* palms. Seven lakes are present on Mirití Island, all connected to the Caquetá River.

El Brazuelo Island (1° 16' S, 69° 56' W; 125 m from mainland) is located at the mouth of the Brazuelo tributary (Fig. 1) and covers an area of 1.15 km^2. Small patches of secondary vegetation are found at the southwest part of the island due to previous agricultural activities. The island has one permanent lake that is not connected to the Caquetá River.

Amaure Island (1° 15' S, 69° 45' W; 760 m from mainland; Fig. 1) covers an area of 1.18 km^2 with an internal lake subdivided into several channels across the island. The lake is connected to the Caquetá River on the southeast part of the island.

At the time of our study, there were no human settlements on the three islands. However, there have been different degrees of anthropogenic impacts, including banana and yucca plantations (that are still active on Mirití Island), poultry farming, and logging. Fishing and hunting are currently the main activities on the islands. Curassows have been the target of some hunting activity, and some selective logging of trees for canoe construction also occurs on the islands.

Transect observations. We established five transects: one each on Brazuelo (T1) and Amaure (T5) islands, and three parallel transects on Mirití (T2-T4); hereafter, transects will be referred to as T1-T5 (Table 1). Transect length varied with the size and topography of the islands and each was marked with flagging every 50 m. Parallel transects on Miriti were ≥ 250 m apart to permit independence. We conducted surveys along transects each month throughout the study period, over four consecutive days on each of the small islands and six consecutive days on the largest island, with at least 14 d between each survey period. Our study was based on a total one-way survey effort of 359.95 km.

All transects were surveyed using a standardized line-transect census protocol for large vertebrates in tropical forests (e.g., Peres 1999, Peres and Cunha 2011). In brief, surveys were conducted during ~06:30–11:00, largely coinciding with the peak of vertebrate activity in tropical forests. Transects were walked by single observers at a speed of ~1–2 km/h, but were

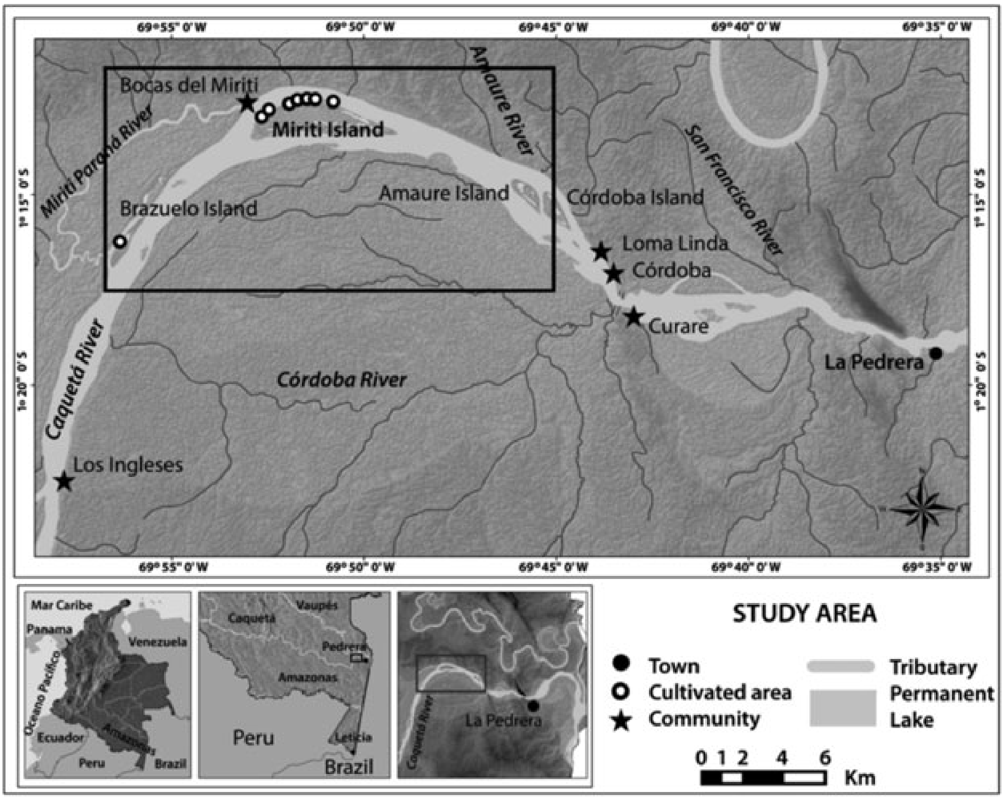

Fig. 1. Map of the study area with three focal islands located in the La Pedrera region of the lower Caquetá River, Colombia.

Table 1. Encounter rates and flock sizes of Wattled Curassows along five transects on three islands in the lower Caquetá River, Colombia.

Island	Transect	Transect length (km)	No. days surveyed	Sampling effort (km)	Encounter rate (observations/km)	Mean flock size ± SD	Maximum flock size
Brazuelo	1	3.05	19	57.95	0.47	2.1 ± 1.2	5
Mirití	2	6.00	15	90.0	0.89	2.6 ± 1.6	9
Mirití	3	6.00	16	96.0	0.47	2.5 ± 2.1	8
Mirití	4	5.00	16	80.0	0.10	1.9 ± 1.0	3
Amaure	5	2.00	18	36.0	0.61	2.5 ± 1.3	5

suspended during periods of rain because this affects detectability. Observers were rotated between transects to minimize potential observer-dependent biases. For all curassows detected, we noted the date, time, distance along transect, number of individuals, location (ground or perch), vegetation height, and, when possible, flight behavior, feeding behavior, and sex (determined through differences in plumage and beak morphology; Hilty and Brown 1986).

Habitat components. Habitat data were collected throughout the study period when censuses were not performed. At selected survey points, we measured the following habitat variables: distance to the closest tree (the shorter the distance, the higher the density of trees, i.e., distance is a proxy for tree density), diameter of the closest tree, percent understory density, percent canopy cover, and distances to the nearest internal water source and the river (Table 2).

Table 2. Mean characteristics ($\pm$ SD) of points where Wattled Curassows were present ($N = 83$) and not present ($N = 140$) on three islands in the lower Caquetá River, Colombia.

Variable	Present	Not present
Tree distance (density) (m)	3.52 ± 1.37	3.26 ± 1.04
DBH (cm)	25.66 ± 17.94	26.59 ± 22.82
Understory density (%)	55.7 ± 19.5	54.5 ± 21.4
Canopy cover (%)	92.2 ± 5.2	92.9 ± 5.8
Distance to internal water source (m)	221.9 ± 198.8	269.6 ± 265.1
Distance to river (m)	216.4 ± 152.4	340.3 ± 198.8

We selected these habitat variables because: 1) other investigators have suggested that the presence of water may influence habitat selection by Wattled Curassows (Bennett 2003, Hill et al. 2008), 2) greater understory density may provide better cover from terrestrial predators, 3) decreased canopy cover allows more light to penetrate the mid- and understory, potentially making curassows more visible for arboreal predators, and 4) the results of previous studies suggest that Wattled Curassows are more arboreal than their congeners (Santos 1998, Bennett 2000). These birds are large (2.5 kg; Dunning 2008) and may thus require larger trees for perching and nesting. In addition, larger trees may be crucial to the persistence of these curassows on the floodplains since smaller trees may have their canopies partially or fully submerged during the high-water season.

Habitat variables were collected every 100 m along each transect. A modified point-quadrant method was used to assess the distance to and size distribution of trees. Each point represented the center of four cardinal directions with the surrounding area divided into four 90° quadrants. The distance from the center point to the nearest tree $\geq$ 10 cm in circumference was measured in each quadrant. Circumference was measured at breast height (130 cm above ground) and was converted to diameter at breast height (DBH) using the following formula, C/π, where C is the circumference.

Understory density was measured 20 m from each center point in each cardinal direction using a pole 2-m long $\times$ 5-cm wide divided into 10 segments of 20 cm. Segments were painted with alternating orange and white stripes to improve visual differentiation of each segment. The difference between the number of segments partially or fully covered by vegetation and the total number of segments on the pole was multiplied by 100 to express percent understory vegetation cover. Canopy cover was determined using a convex spherical densitometer (Forestry Suppliers, Jackson, MS). Readings were taken directly above the center point in each cardinal direction, and the sum of the four measurements were averaged and multiplied by 1.04 to obtain percent canopy cover for each point (Lemmon 1957). Topographic maps of the area derived from Landsat TM 461 images (2001, 2007) and CBERS 2 (2009) were used to delineate internal water bodies and measure their distance to each transect using ArcGIS 9.2 (ESRI). Distance was measured from the center of every vegetation point on each transect to the edge of the nearest water source.

Statistical analyses. We tested for and quantified the effect of habitat variables on curassow presence using generalized linear mixed-effects models (GLMM). We used presence/absence of birds/100 m section of each transect (50 m along the transect on each side of a given habitat survey point) as the response variable (logistic regression). The most complex model that we considered included all six habitat variables.

Preliminary inspection of the data suggested a nonlinear relationship between distance to the river and the response. A quadratic transformation of distance from river resulted in the best fit. Based on our knowledge of the study system, we also considered two-way interactions between distance from the river and all other variables. Island and transect ID were included as nested random effects to control for lack of independence (e.g., due to spatial autocorrelation).

We performed model selection using AIC (Burnham and Anderson 2002). We had no reason to preclude any of the models nested under the most complex model as a candidate and therefore considered all. All analyses were carried out in R v. 2.13 (R-Development-Core-Team 2011) using the packages lme4 (for GLMM fitting; Bates et al. 2011), MuMIn (for model selection and inference, Barton 2012), and effects (for GLMM prediction; Fox 2003). ANOVAs were used to assess differences in flock sizes among islands. Values are presented as means $\pm$ 1 SD.

Table 3. Coefficients and test statistics from the GLMM fit to presence/absence data for Wattled Curassows on three islands in the lower Caquetá River, Colombia. Only fixed effects are shown. The magnitude of the coefficients (log-odds) involving distance to river is small due to the quadratic transformation.

Fixed effect	β	SE	*z* value	*P* value
Intercept	−3.43E-01	2.98E-01	−1.2	0.25
Distance to river $(m)^4$	8.25E-12	7.90E-12	1.1	0.30
Distance to internal water (m)	1.25E-03	8.70E-04	1.4	0.15
Distance to $river^4$: distance to internal water	−1.54E-13	5.75E-14	−2.7	0.007

RESULTS

Encounter rates, occurrence, and habitat preference. We recorded a total of 182 curassow sightings ($N = 22$, 27, and 133 on Amaure, Brazuelo, and Mirití islands, respectively). Encounter rates varied from 0.1 to 0.89 observations/km walked across the five transects (Table 1).

Curassows were observed along 15 of 31 (48.4%) 100-m sections on T1. On Mirití, curassows were observed along 35 of 61 (57.4%), 21 of 61 (34.4%), and three of 51 (5.9%) sections along T2, T3, and T4, respectively. On Brazuelo Island, curassows were observed along 10 of 21 (47.6%) sections of T5.

Additional encounters of curassows were made off the islands during January 2009. Two observations (one of two and another of three individuals) were made in *Várzea* forest near the Mirití-Parana tributary on the other side of the main river (1° 16' S, 69° 56' W). A third observation was of a single individual on a sand islet formed during the low-water season on the shoreline of Brazuelo Island (1° 16' S, 263 69° 56' W).

Habitat data were collected at 223 points along transects on the three islands and curassows were observed at 83 (37.2%) of these points (Table 2). Distance to river, distance to internal water sources, and the interaction between these two variables were retained in the top model that emerged during AIC-based model selection (Table 3). Although several other candidate models were within two AIC units of the top model, none of the variables retained in competing models showed either statistically significant coefficients ($P < 0.05$) or trends ($P < 0.01$).

The top GLMM predicted that the probability of curassow presence decreased with increasing distance from water in general, but with an interaction between the effects of distance from the river and distance from internal water sources (Table 3, Fig. 2). The negative effect of distance from river increased with greater distances from internal water sources; conversely, the distance to internal sources of water became less important as distance to the river decreased (Fig. 2). There was a pronounced decline in the probability of curassow presence > 250 m from the river (Fig. 2).

Most encounters of Wattled Curassows (124 of 182, 68%) were of individuals either on or flying from the ground rather than perched in trees ($N = 58$, 32%). Most perched curassows (84.5%) were observed in the midstory or canopy of trees at a mean height of 12 ± 7.0 m ($N = 58$) above ground. Mean height of perch trees ($N = 58$) was 18 ± 8.8 m.

Additional observations. Most flocks consisted of two or three birds (2.4 ± 1.6), with maximum flock sizes of nine at Mirití and five on Brazuelo and Amaure (Table 1). Flock sizes did not vary among islands ($F_{2,179} = 0.8$, $P = 0.45$, $N = 182$). Solitary individuals were observed on 67 occasions. Of 44 individuals that were sexed, 33 (75%) were males. Both sexes were present in 16 (80%) of 20 pairs observed where both individuals were sexed (total number of pairs = 42). Flocks were observed on 73 occasions. For flocks where the sex of all individuals was determined ($N = 26$), 88.5% ($N = 23$) included more females than males, with a mean of 2.4 ± 0.9 females and 1.5 ± 1.0 males.

Two ~3-week-old chicks were observed on Amaure Island on 18 March with an adult female nearby. At this age, chicks had a downy coat, fully functioning vision, and were able to move around the forest on foot (L. Maira, pers. obs.) and could fly, but were still dependent on parents to find food (D. Brooks, unpubl. data).

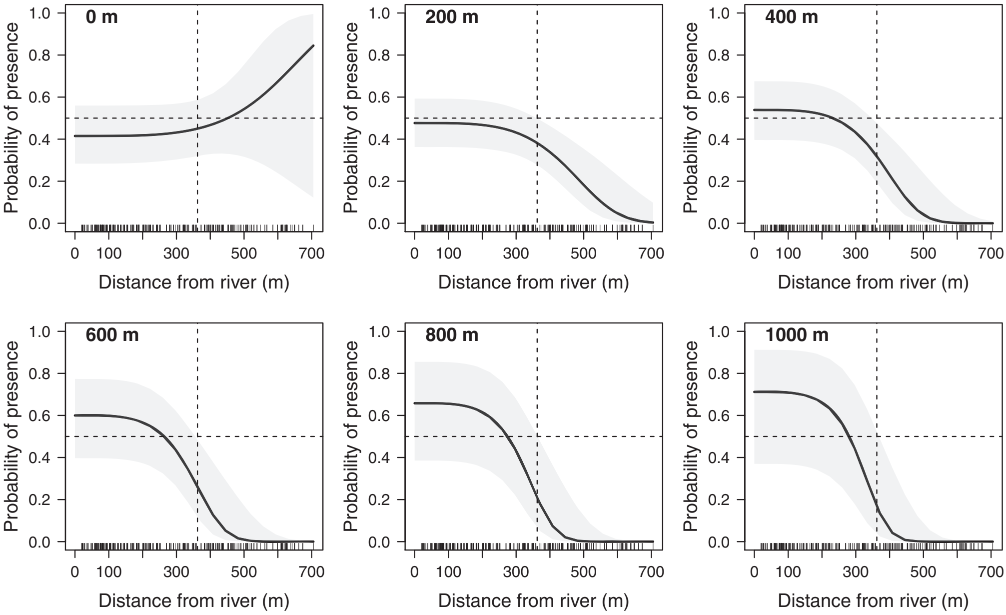

Fig. 2. Predictions (bold lines) from the generalized linear mixed effects model (logistic) with the probability of the presence of Wattled Curassows as the response and distance to river and distance to internal water sources as interacting predictor variables. Separate graphs are shown for six different distances to internal water sources (indicated in the top-left corner of each graph) to visualize the interaction between the predictors. Confidence intervals (95%) are represented by grey bands around the predictions, and dashed lines are provided as a visual reference to aid comparison of the curves.

From October 2008 to January 2009, curassow flocks were found below or perched in *Coussapoa* sp. (Cecropiaceae) or *Ficus* sp. (Moraceae) trees that were fruiting ($N = 19$). Fruits from other Cecropiaceae (*Pourouma* sp.) and Myristicaceae also appear to be in the diet of Wattled Curassows because they were observed in or under fruiting trees on nine occasions during our study. On Mirití Island, curassows were joined at feeding sites by other large game birds (Blue-throated Piping-guan, *Aburria cumanensis*, and Undulated Tinamou, *Crypturellus undulatus*) on two occasions (5 and 7 November 2008). On three occasions, curassows were observed on the banks of internal water-bodies on Mirití Island at Giant Otter (*Pteronura brasiliensis*) feeding middens consuming remains of fish flesh that otters had not eaten.

DISCUSSION

Habitat preference and occurrence. Our results suggest that Wattled Curassows prefer areas near water. The probability of finding curassows decreased dramatically > 250 m from the river; moreover, as the distance to other water sources increased, their association with the river became stronger and vice versa. Hill et al. (2008) also found that Wattled Curassows were located mainly along water-edge habitat in *Várzea* forests. This may have conservation implications because this association with water likely increases their vulnerability to anthropogenic activities that take place in such locations, including agricultural activities, fishing, and hunting.

The association of Wattled Curassows with water may reflect a dietary dependency on or seasonal availability of minnows, insect larvae, and crustaceans in small isolated pools or on recently exposed ground after waters recede (Bennett and Franco-Maya 2002, Alarcón-Nieto and Palacios 2008). Such prey represent a source of protein that could be important during the low-water season when fruit availability declines (Bennett 2000, 2003). Further study is needed to determine the reason(s) for the strong association of these curassows with water sources.

The large number of birds observed on the ground in our study appears to contradict prior suggestions that Wattled Curassows are more arboreal than other curassows (Santos 1998, Bennett 2000). However, our study was conducted during a period when dry ground was present. Because the islands become completely inundated during the wet season and this species occurs exclusively on river islands and floodplain forests, these birds are limited to arboreal strata during the high-water season.

Observations of curassows outside the three islands suggest that other unknown (sub-) populations may exist along the Caquetá River or that the species performs cross-river movements at a local scale. Although local movements by curassows during the low-water season have been reported previously (Delacour and Amadon 2004), we believe that such movements are unlikely due to the distance of the islands from the mainland (125–760 m). Nevertheless, additional surveys are clearly needed to confirm the presence of curassows in adjacent areas and to determine their local movements.

Additional ecological observations. Flocks of curassows in our study generally included individuals of both sexes. However, flocks in our study often contained more females than males, and most solitary individuals were males. Similarly, Bennett (2003) observed that most solitary individuals were male, and Hill et al. (2008) found more males than females in their study population, but did not report on flock composition. These findings suggest that Wattled Curassows are polygamous, as has also been noted for other congeners, e.g., Great Curassow (*C. rubra*; Zimmer 1997).

Most of our sightings were of solitary individuals or flocks consisting of two or three birds (maximum = 9). Other investigators have also reported many solitary Wattled Curassows and flocks typically ranging in size from three to six birds, with a maximum of 30 (Santos 1998, Hennessey 1999, Bennett and Franco-Maya 2002, Aranibar-Rojas 2006, Hill et al. 2008). Seasonal resource availability and proportions of various age-sex classes within the population likely contributes to fluctuations in flock size. However, historic accounts from the 1800's indicate flocks along the Beni River, Bolivia, could number about 100 birds (Cox and Cox 1997). Due to hunting, Wattled Curassows have either been extirpated or occur at low densities throughout large parts of their range and persecution continues in areas where they are still present (Aranibar-Rojas 2006). Hunting may therefore have influenced flock sizes on the islands in our study.

Based on our observation of two chicks on Amaure island in mid-March, Wattled Curassows probably begin nesting around February. Similarly, previous studies on Mocagua Island indicated a possible peak in reproductive activity in January and February (Bennett 2000, 2003, Delacour and Amadon 2004). Breeding during the low water season may be a strategy to avoid the annual floods.

Feeding associations between curassows and other large game birds observed in our study are interesting because there is little information about such associations of large birds. Nevertheless, Hill et al. (2008) observed mixed-species feeding associations between Wattled Curassows and Razor-billed Curassows in Bolivia, and Held (1997) reported mixed-flock associations involving three to five Black Curassows (*C. alector*) and Grey-winged Trumpeters (*Psophia crepitans*) in Suriname.

Conservation of Wattled Curassows in the lower Caquetá River. A formal monitoring program for the Wattled Curassow that empowers the community with management and decision-making is in place on Mocagua Island (Bennett 2003). In the lower Caquetá River, Mirití Island is considered an IBA (Important Bird Area; Franco et al. 2009), but has no legal protection. Due to the limited amount of *Várzea* habitat and their fragmented populations (Aranibar-Rojas 2006, BirdLife International 2011), Wattled Curassows are a vulnerable species in our study area. In addition, river islands, banks, and islets are owned by the Colombian State and are available for common use. Recent expansion of agricultural patches on Miriti Island suggests that anthropogenic activities are intensifying on the islands (L. Maira, pers. obs.) and could have detrimental impacts on the curassow population in the near future. Establishing a conservation awareness program will, therefore, probably be crucial for conserving Wattled Curassows in the lower Caquetá River. Conservation International Colombia has taken an initial step to emphasize the importance and precarious status of Wattled Curassows to communities near the islands (E. Palacios, pers. comm.), but, unlike Mocagua

Island, no community-driven program has yet been initiated.

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