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Biology of Tropical Birds

Life history of the Red-crowned Woodpecker (*Melanerpes rubricapillus*; family Picidae) in Colombia

Historia Natural del Carpintero de Corona Roja (*Melanerpes rubricapillus*; familia Picidae) en Colombia

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ABSTRACT. The Red-crowned Woodpecker, *Melanerpes rubricapillus* (family Picidae) is one of 24 species that makes up the genus. In Colombia, its distribution has increased in the last fifteen years, and the ecological aspects that are known about the species come from only a few specific nests. There are knowledge gaps for the species related to, among others, food preference, nestling development, and parental care. Between January 2019–March 2020, the natural history of *M. rubricapillus* was studied, with emphasis on reproduction, parental care, vocal communication, and body condition, in Cali, Colombia. Each nest was monitored from its discovery until fledging. Adult reproductive behavior was quantified in detail. The reproductive activity had a unimodal pattern with a maximum number of nests between January–March. Parental investment was the same for both sexes, both in the incubation period and in the chick rearing period. Incubation periods/hour were longer during the early stages of embryonic development and these (incubation periods/hour) increased with clutch size and rainfall intensity. Feeding rate increased with brood size and age of the chicks. The body condition index was correlated with the hematological profile-heterophils/lymphocytes, but the hematological profile-heterophils/lymphocytes were not related to the feeding rate of the adults. Compared to other studies, the findings were similar regarding fledging age and different relative to clutch size, incubation period, parental investment, and number of nestlings.

RESUMEN. El Carpintero de Corona Roja, *Melanerpes rubricapillus* (familia Picidae), es una de las 24 especies que conforman el género Melanerpes. En Colombia, su distribución ha aumentado en los últimos quince años, y los aspectos ecológicos conocidos sobre la especie provienen únicamente de algunos nidos específicos. Existen vacíos de conocimiento para la especie relacionados, entre otros, con la preferencia alimentaria, el desarrollo de los polluelos y el cuidado parental. Entre enero de 2019 y marzo de 2020, en Cali, Colombia, se estudió la historia natural de *M. rubricapillus*, con énfasis en la reproducción, el cuidado parental, la comunicación vocal y la condición corporal. Cada nido fue monitoreado desde su descubrimiento hasta el momento de la salida de los volantones. El comportamiento reproductivo de los adultos fue cuantificado en detalle. La actividad reproductiva tuvo un patrón unimodal con un número máximo de nidos entre enero y marzo. La inversión parental fue la misma para ambos sexos, tanto en el período de incubación como en el período de crianza de los polluelos. Los períodos de incubación/hora fueron más largos durante las etapas tempranas del desarrollo embrionario y estos períodos de incubación/hora aumentaron con el tamaño de la nidada y la intensidad de la lluvia. La tasa de alimentación aumentó con el tamaño de la nidada y la edad de los polluelos. El índice de condición corporal se correlacionó con el perfil hematológico-heterófilos/linfocitos, pero dicho perfil no se relacionó con la tasa de alimentación de los adultos. En comparación con otros estudios, los hallazgos fueron similares en cuanto a la edad de los volantones y diferentes en relación con el tamaño de la nidada, el período de incubación, la inversión parental y el número de polluelos.

Key Words: *body condition; clutch size; incubation; nest; parental investment; reproduction; vocalizations; woodpecker*

INTRODUCTION

Over the last 15 years, *Melanerpes rubricapillus,* a species of the family Picidae and the order Piciformes, has extended its geographical distribution around 200 km toward the south of the Colombian territory, extending as far as the departments of Cauca (Garcés-Restrepo et al. 2012) and Nariño (H. Álvarez-López, photographic records, *personal observation*) The male has a white and yellowish forehead, red crown and occiput, and black and white striped superior parts. The female differs from the male by having a buffy white crown and only a red occiput (Hilty and Brown 2001). *M. rubricapillus* presents four subspecies: *M. r. rubricapillus*, *M. r. subfusculus*, *M. r. seductus* and *M. r. paraguanae*, distributed in Costa Rica (Skutch 1969), Panamá (Wetmore 1968, Kilham 1972), Colombia (Hilty and Brown 2001), Venezuela, Tobago, Guayana, and Surinam (Goossen 1989, Winkler and Christine 2020), below 1900 MASL (Winkler et al. 2002).

M. rubricapillus inhabits secondary vegetation, forest clearings and dry scrub, cultivated areas, gardens, mangroves, and urban areas (Hilty and Brown 2001, Winkler and Christine 2020). The species feeds mainly on insects but also supplements its diet with larvae, spiders, fruits, and nectar from wild plants and from artificial feeders and drinkers (Winkler and Christine 2020). *M. rubricapillus* uses dry branches, standing dead trees or softwood, and large cacti in which to excavate their nests (Winkler et al. 2002, Sandoval 2009) at heights ranging from 0.76 m to 30 m (Winkler et al. 2002, Cruz-Bernate et al. 2019). The cavities have

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entrance dimensions as follows, 4.6 cm width by 4.55 cm height, depth 15 cm–34 cm, and chamber 8.9 cm (Cruz-Bernate et al. 2019, Skutch 1969).

Adult *M. rubricapillus* are monogamous and maintain a pair bond throughout the year (Hilty and Brown 2001, Winkler et al. 2002). Both sexes participate in excavation, incubation, and caring for nestlings (Skutch 1969). Clutch size is three to four eggs, and the incubation period is 10–15 days (Skutch 1969, Cruz-Bernate et al. 2019). The breeding period, or nestling rearing, varies from 28–33 days (Skutch 1969, Stiles and Skutch 1989, Garces-Restrepo et al. 2012, Cruz-Bernate et al. 2019). Accordingly, the commitment of the parents to the reproductive event is approximately 40 days. Vocalizations have been recorded on many occasions, and it is known that both males and females make very similar sounds to communicate with each other and with their nestlings (Hilty and Brown 2001, Winkler et al. 2002). Despite this, the vocalizations have not yet been measured or formally described, and we know that vocalizations during reproduction provide information that allows us to understand aspects of the bird's behavior, biology, evolution, and plasticity (Fernández-Gómez et al. 2023). For example, it is known that noise pollution generated by humans can affect communication between birds because it obscures their vocalizations and makes it more complicated to find a mate, locate fledglings, and warn of the danger of predators, among other effects (Leon 2019, Mendes et al. 2010).

Although both sexes participate in the different stages of nesting, the proportion of the contribution of each sex seems to oscillate (Skutch 1969, Cruz-Bernate et al. 2019). It is known that this variation in parental investment in birds may depend on factors such as environmental temperature, precipitation, and stage of embryonic development (Boerjan 2007, 2011, Jefferies et al. 2022) as well as individual factors such as age, sex, body condition, and state of health (Dubiec et al. 2005). Accordingly, individuals that occupy habitats of poorer quality (absence of resting and reproduction sites, nutritional stress, and exposure to microorganisms) can be directly affected in their health and body condition (fat reserves; Jiménez-Peñuela et al. 2019). Currently, there are methods to assess the condition of the individuals in the wild, such as blood body count (heterophiles/lymphocytes; Labocha and Hayes 2012, Masello et al. 2009, Wascher et al. 2017) and estimation of the scaled mass index (bone mass/structure ratio) from its morphometric measurements (Labocha and Hayes 2012, Peig and Green 2009). However, for many tropical species, such as *M. rubricapillus*, there is still a lack of basic information about their biology, much less on the condition of individuals.

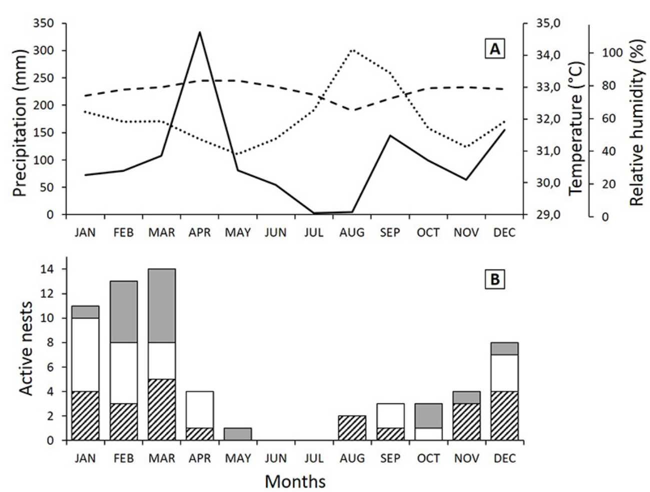
M. rubricapillus is distributed throughout Colombia, except in the Amazon and high Colombian Andes (Hilty and Brown 2001, Ayerbe-Quiñonez 2022). However, despite the species' wide distribution and its being relatively conspicuous in urban areas, the information documented thus far comes from only a few nests and sporadic records on its reproduction (Winkler et al. 2002, Hilty and Brown 2001, Garces-Restrepo et al. 2012, Cruz-Bernate et al. 2019). Details about feeding habits, nestling development, parental care, and morphometry, among others, are unknown. Consequently, the objective of this study was to describe some aspects of the natural history of the Red-crowned woodpecker *M. rubricapillus* with emphasis on its reproduction, parental care, vocal communication, and body condition. Furthermore, we examined their behavioral patterns according to environmental characteristics with intense precipitation used as a proxy for colder weather. This study documents, for the first time, ecological aspects of the species and demonstrates the use of urban trees as a nesting resource. Also, the information obtained from this research may serve as input for the design and implementation of management and conservation plans for other cavity nesting species.

METHODS

Study area

The investigation was carried out on the campus of Universidad del Valle (3°38′25.6″ N, 76°19′13.6″ W, 990 MASL), in the municipality of Santiago de Cali, within the department of Valle del Cauca, Colombia. The region is classified as tropical dry forest (Espinal 1968), with an average temperature and relative humidity of 32.02 °C and 74.38%, respectively. The annual average precipitation is 1184 mm (Instituto de Hidrología, Meteorología y Estudios Ambientales [IDEAM], 2019, personal communication; Fig. 1A). The campus has an approximate area of 100 ha, of which 9.5 ha are occupied by buildings, 44 ha by trees, 45.5 ha by meadows and pastures, and 1 ha by two lakes. Among the most common tree species are chiminangos (*Pithecellobium dulce*), samanes (*Samanea saman*), mangoes (*Mangifera indica*), African tulip (*Spathodea campanulata*), rubber trees (*Ficus elastica*), yellow guayacanes (*Tabebuia chrysantha*) and pink guayacanes (*T. rosea*; Ardila-Téllez and Cruz-Bernate 2014).

Fig. 1. (A) Average monthly precipitation, temperature, and relative humidity during 2019–2020 on the campus of Universidad del Valle, Cali, Colombia. Continuous line: precipitation (mm). Points: temperature (°C). Dashed line: relative humidity (%). (B) Accumulated monthly distribution of the reproductive activity of *Melanerpes rubricapillus* during the period from January 2019–March 2020. Bars-lines: nests under construction (excavation); white bars: nest with eggs; grey bars: nests with chicks.



Field work

Weekly rounds were conducted, lasting four hours, between January 2019–March 2020, in order to identify nesting sites. When reproductive activity was detected, the following were recorded: geographic coordinates, date, and state of progress of the nest. The latter was determined from the behavioral pattern of the adults and was classified into one of the following categories: (1) nest construction, (2) incubation (adults stay inside the cavity for long periods of time without delivering food), or (3) brood attention (transport of food in the beak to the nest).

In order to identify and monitor the adult owners of the nest, the individuals were captured with mist nets in the nesting territories. Each received a unique combination of four color rings in the region of the tibial tarsus. Morphometric measurements such as weight (digital scale ± 0.1 g, brand Scale, model 648), length, height and width of the beak, distance between nostrils, commissure, tarsus, wing, distance between primary and secondary feathers, rectrices, hallux, and total length (digital caliper ± 0.01 mm, brand Insize, model 1108-200) were recorded.

Reproduction and parental investment

Each nest was monitored from the time of discovery until the day the offspring fledged. In nests at an accessible height, the interior was inspected to establish the status of the eggs or nestlings. For this, we used a ladder (height 5.4 m) and an OEM cell phone endoscope (7 mm diameter, 640 x 480 resolution, 4 cm focal length) that allowed a serial photographic record. In inaccessible nests, the height was recorded with aluminum tubes of known length and one decameter. The length of the beak, wing, and tarsus of the nestlings were measured during their development inside the nest from image processing with the ImageJ software (Schneider et al., 2012). Each photograph included an object of known size, which served as a scale, located in the same plane as the body region to be measured.

Each nest was observed every two days, for 3.5 continuous hours, alternating between morning and afternoon. The observation days were conducted through: (1) direct observation at a distance of 15 m with Nikon 8 x 40 binoculars and a 20 x 60 telescope and (2) recording with a Sony video camera located 5 m away. The time that the parents dedicated to each of the activities during the reproductive event was determined, including nest construction (excavation), incubation days, feeding visits, inspection, and nest vigilance.

Items carried by adults during feeding visits and in accessible nests were recorded, and nestlings were measured and ringed. Nestlings and adults received an energy solution before returning them to the nest or being released, and the procedures were carried out in the shortest possible time to reduce stress. The reproductive success of the pairs was measured as the number of offspring that reached the age of fledging.

Vocal communication

Vocalizations of adults and nestlings were recorded for 4.26 h (in total) at a distance of 2–5 m for adults and 0.5 m for nestlings. A Tascam DR-44WL recorder and a Sennheiser ME 67 unidirectional microphone, in WAV format, 44100 Hz and 24 bits, were used to record the vocalizations. For the analysis of the acoustic structure, traditional and robust measurements suggested by the Bioacoustic Conservation Center, Cornell University (Charif et al. 2010) were used: peak, minimum, maximum frequency, bandwidth, duration, peak time (traditional) and 50% and 90% duration, center time, 50% and 90% bandwidth, center frequency, peak contour frequency, maximum contour frequency, and minimum contour frequency (robust). The spectrograms were visualized and analyzed with the Raven Pro Sound Analysis software, version 1.6.3 software (https://www.ravensoundsoftware.com/) with Hann window type, window size 634 samples, filter bandwidth 3dB 218 Hz, 50% overlap, hop size 317 samples, using Discrete Fourier Transform (DFT) of 1024 samples, grid spacing 93.8 Hz.

Body condition

The body condition of the individuals was estimated from: (1) the scaled mass index and (2) hematological profile. The scaled mass index (SMI) was calculated according to Peig and Green (2009), as follows:

$$IME=M_i(L_0/L_i)^{bSMA} \quad (1)$$

M_i is the weight of individual i, L_0 is the average bone length of all individuals, L_i is the bone length of individual i, bSMA is the standardized major axis regression (SMA regression).

To determine the hematological profile, two–three peripheral blood smears were made from four µl of blood sampled from the brachial vein. The smears were allowed to dry in the open air for two hours and were fixed in 70% alcohol for five minutes. They were stained with Giemsa stain for 50 minutes (Masello et al. 2009, Garamszegi et al. 2006), rinsed with distilled water, and allowed to dry. The blood cell count was performed in 100 visual fields with a binocular compound microscope with 100x magnification (Martínez et al. 2009, Luedtke et al. 2013). For cell identification, the identification guide for bird blood components (Briscoe 2015), the book Avian Haematology and Cytology (Campbell 1988), and the Atlas of Avian Hematology (Lucas and Jamroz 1961) were followed. Finally, the blood profile of the individuals was calculated using the heterophils and lymphocytes ratio (H/L ratio; Martínez Quintanilla et al. 2017).

Statistical analysis

Linear mixed models (LMM) and generalized linear mixed models (GLMM) were used to analyze whether reproductive behavior varied according to the ecological aspects. For the incubation stage, we examined whether the duration of the incubation period (dependent variable) was affected by the following independent variables: mean monthly precipitation (low: ≤ 80 mm vs intense: > 80 mm), clutch size (small: 1–2 eggs vs large: 3–4 eggs), degree of embryonic development (early: 1–8 days vs advanced: 9–15 days), and sex of the adult. We also determined whether significant differences existed between the sexes in the mean number of times that parents inspected the interior of the nest before entering it and the number of surveillance peeks (peeking from inside the nest). For the hatching stage, we examined whether the rate of feeding visits per hour (dependent variable) varied with the independent variables rainfall, brood size (small: 1 chick vs large: 2–3 chicks), chick age (early: 1–15 days vs advanced: 16–30 days), and sex of the adult. In all models, we included the nest and identity of the individuals as random factors, and the dependent variable was transformed to the square root to fulfill the assumptions of normality and heteroscedasticity. Several models were proposed (with and without interaction between the fixed effects); the one with the best adjustment was chosen with the criteria of maximum penalized likelihood (Akaike-AIC information criterion and Bayesian-BIC information criterion) and the likelihood ratio test (Agresti 2015). All analyses were conducted using the R 4.2.2 program (R Core Team 2022); models were made using the lme4 package (Bates et al. 2015).

RESULTS

A total of 22 nests distributed in the Universidad del Valle campus were discovered in various degrees of advancement in the reproductive cycle. Reproductive activity for the species was recorded in 10 of the 12 months of the year and had a unimodal pattern with a maximum number of nests between January–March and a minimum (absence of nests) between June–July (Fig. 1B). A total of 22 individuals were captured and ringed: 17 adults and 5 chicks.

Nesting

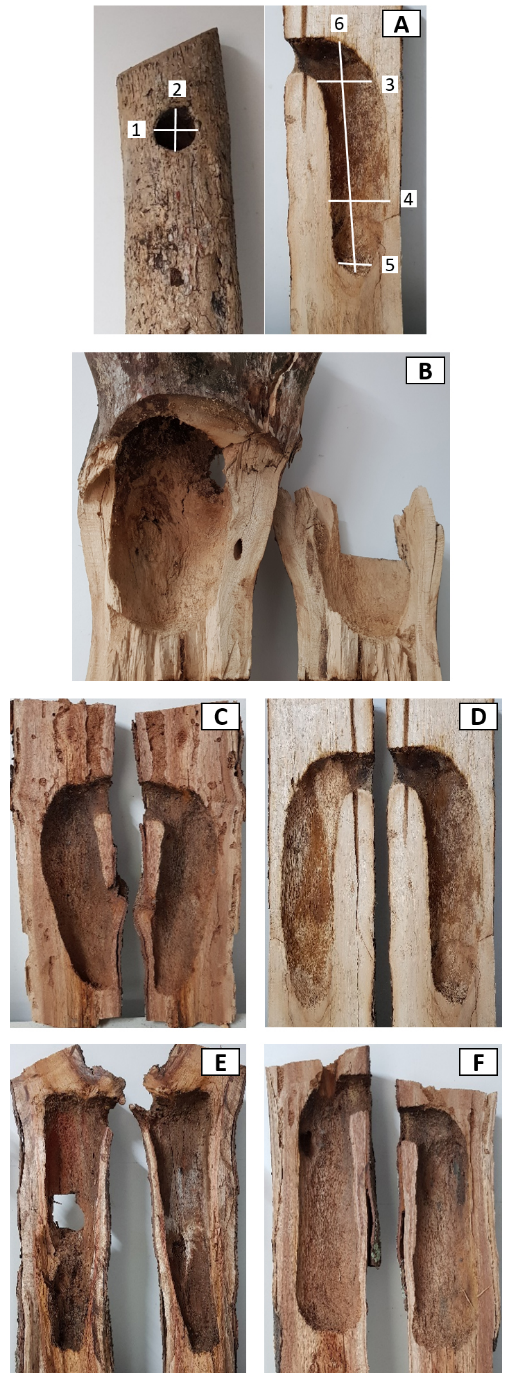
Nest building

M. rubricapillus burrowed in trunks or dry branches of *Pithecellobium dulce*, *Inga edulis*, *Ochroma pyramidale*, and also used a nest box. The average height of the nesting cavity was M = 4.63 ± 0.46 m (range: 0.76–7.82 m, n = 22). Both adults participated in the excavation of the cavity. The excavation periods (total 123 observations in three nests) had a mean duration of 10.14 ± 1.20 min (range: 0.17–48.92 min, total 56 observations) in males and M = 9.11 ± 0.77 min (range: 0.45–29.52 min, total 67 observations) in females. Sex was not found to affect the duration of excavation periods (LMM, $F[1, 2] = 0.839$, $P = 0.456$). The dedication of the six adults with respect to the total time observed (45.80 total hours of observation in three nests) was 22.82% in males and 23.56% in females.

In one nest, where it was possible to record the first day of laying, it was verified that excavation lasted 47 days and the adults made two cavities simultaneously; excavation ceased five days before egg laying commenced. Overall, the interior of the nest cavities showed a variety of designs, from oval to rectangular (Fig. 2). Entrance width measured M = 4.61 ± 0.57 cm (range 3.97–6.28 cm, n = 20) and entrance height, M = 4.78 ± 0.72 cm (range 4.02–7.37 cm, n = 20). Tunnels widths were M = 7.04 ± 1.64 cm (range 5.46–10.78 cm, n = 17). Regarding the chambers, widths in the middle zone were M = 8.15 ± 1 cm (range 6.63–10.25 cm, n = 17) and, in the base, M = 5.55 ± 0.86 cm (range 5.0–6.55 cm, n = 15). Cavity depths were M = 28.23 ± 4.89 cm (range 18.60–34.50 cm, n = 16).

Adults excavate holes in the same trunk not only to nest but also to rest during the day and spend the night; these are also used by offspring after fledging. On two occasions, individuals completely or partially opened an entrance in the side of an artificial nest box for this purpose. Another cavity used to spend the night was one excavated in a dry palm leaf that remained hanging. The use of the same tree for two consecutive reproductive cycles (different cavities) and even reuse of the same cavity were reported.

Fig. 2. Diversity of nest cavity size and shape of *Melanerpes rubricapillus* on the campus of the Universidad del Valle, Cali, Colombia. (A) 1. entry width; 2. input height; 3. tunnel width; 4. chamber width; 5. chamber base width, and 6. depth. (B) Rounded cavity. (C) Cavity with inclination of the bottom of the chamber. (D) Oval cavity. (E) Rectangular cavity. (F) Cavity, chamber narrower than its base.



Clutch and incubation

Clutch size ranged from one to four eggs (M = 2.55, SE = 0.28, n = 11). Of the 28 eggs found, nine were measured with the following results: length: M = 21.28 ± 0.40 mm (range: 20.13–24.07), width M = 16.51 ± 0.29 mm (range: 15.55–18.25) and weight M = 3.07 ± 0.27 g (range: 2.39–3.89, n = 6). Two clutches, with three eggs each, were recorded in a nest box installed in a royal palm (*Roystonea regia*).

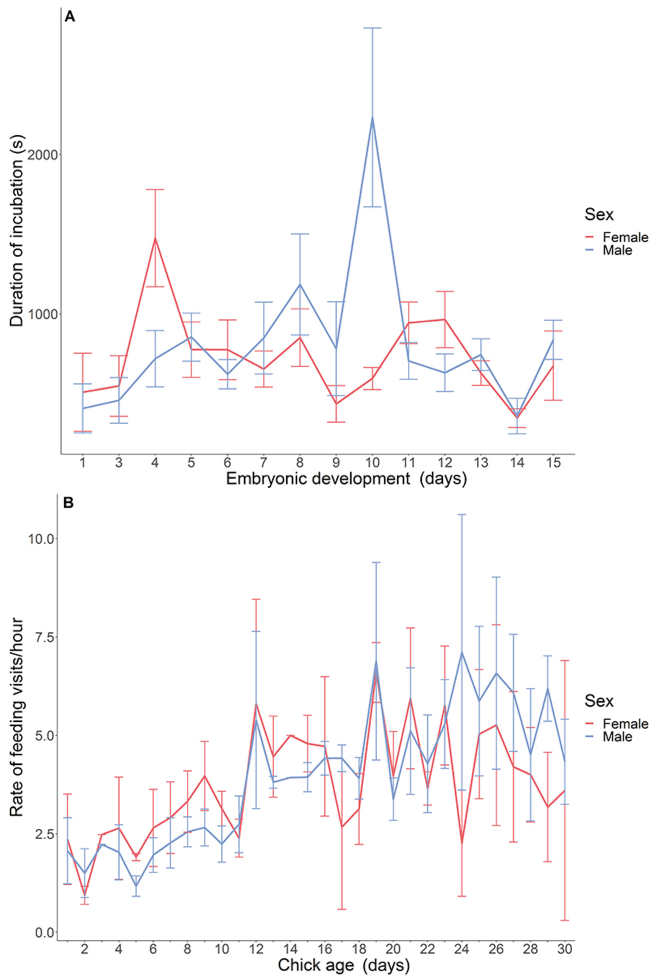
The duration of the incubation period was 15–16 days (n = 6 nests). Both adults participated in incubation; males completed an average of 1.49 ± 0.10 bouts/hour (65 observations) and females 1.55 ± 0.11 bouts/hour (65 observations). During each visit, the adults carried out actions such as external inspection of the entrance before entering the nest and surveillance (peeking from the inside). For males, external inspection/hour in six nests was 16.06 ± 2.67 times (range 1.01–156.52, total 100 inspections) and, for females, 31.88 ± 6.51 times (range 1.04–480, total 117 inspections), without a significant difference between the sexes (LMM, F[1,5] = 3.33, P = 0.13). For surveillance in eight nests, females had an average duration of 1.47 ± 0.10 min with a total of 724 surveillance observations, and males averaged 1.44 ± 0.10 min with a total 543 surveillance observations; there was not a significant difference by sex in the time dedicated to the surveillance period (LMM, F[1,7] = 0.00, P = 0.99). There was no significant difference between males and females in the number of surveillance events/hour (LMM, F [1,7] = 0.31, P = 0.59), where females carried out an average of 19.23 ± 1.98 events/hour (total 217 observations), and males averaged 23.70 ± 3.10 events/hour (total 198 observations).

The average duration of the incubation period was affected by the size of the clutch, embryonic development, and precipitation (Table 1). Adults spent more time incubating large clutches than small ones and, during early embryonic development, incubation periods are longer when there is greater precipitation and when they have large clutches (Appendix 1). The average duration of the incubation period was similar between sexes (Table 1; Fig. 3).

Table 1. Analysis of variance (ANOVA) of the linear mixed models (LMM) used in the analysis of the reproductive behavior of *Melanerpes rubricapillus*. (A) ANOVA of the LMM for incubation days. (B) ANOVA of the LMM for brooding. DF1= between groups degrees of freedom, DF2 = within groups degrees of freedom.

	DF1	DF2	F	P
(A) ANOVA incubation model				
Dependent variable: length of incubation day				
Precipitation	1	11	5.735	0.036
Embryonic development	1	487	0.052	0.820
Clutch size	1	11	9.825	0.010
Embryonic development * precipitation	1	487	8.116	0.005
Embryonic development * clutch size	1	487	10.443	0.001
(B) ANOVA brooding model				
Dependent variable: feeding visit rate/hour				
Precipitation	1	16	0.334	0.571
Chick's age	1	184	2.825	<0.001
Sex	1	16	0.170	0.686
Brood size	1	16	8.660	0.010

Fig. 3. (A) Duration mean of incubation bouts of adults throughout embryonic development of *Melanerpes rubricapillus*, Cali, Colombia. (B) Rate of feeding visits per hour of adults throughout of brooding of *Melanerpes rubricapillus*, Cali, Colombia. The whiskers correspond to the maximum and minimum standard error.



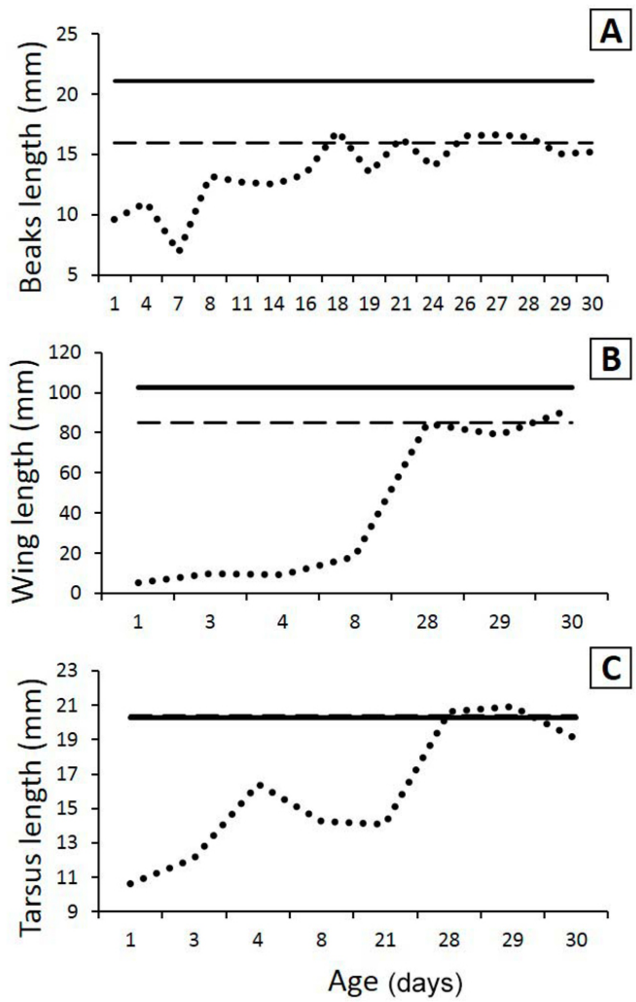
Brooding

Brood size was one–three chicks (M = 1.46 ± 0.18 chicks, n = 13 nests). Offspring hatched naked with eyes closed, with maxilla shorter than the mandible, and with egg tooth. By day nine, the maxilla already met the jaw and the young gradually started to open their eyes. By day 12, evidence of growth of the feather cannons was observed, and by day 13, sexual dimorphism was evident. At day 21, the nestlings were completely covered in feathers, except for the middle part of the crown. By the time they reached fledging age, females displayed a gray mottled crown, and the males had a dull red one (Fig. 4). Offspring completed their development in 30–31 days (n = 11 nestlings) and reached 93% of the body weight and 88% of the total length of the adults (Fig. 5; Appendix 2).

Fig. 4. Development of *Melanerpes rubricapillus* chicks inside the nest, Cali, Colombia. (A) Two days old. (B) Eight days old. (C) 12 days old. (D) 13 days old, sexually dimorphic on the crown. (E) 19 days old. (F) 21 days old. (G) 29 days old, appearance of a female chick one day before the exodus. (H) 30 days old, appearance of a male chick one day before fledging.

Both males and females attended to nests and nestlings, specifically with cleaning, covering, and feeding. The males remained inside the nest for 15.56% and females for 15.65% of the total time observed. Males made 4.56 ± 0.27 feeding visits/hour with an average duration of 0.88 ± 0.07 min (n = 1444 observations), and females made an average of 4.42 ± 0.25 feeding visits/hour (n = 102) for a duration of 0.77 ± 0.07 min (n = 1401 observations). The male covered the chicks throughout the night and remained from 18:00 until 05:30 the next day. Copulation was

Fig. 5. Growth rate of *Melanerpes rubricapillus* chicks during their stay in the nest. Dotted line: mean of the morphometric measurement. Solid line: average for adults. Dashed line: mean morphometric measurement in chicks close to exodus.



observed during the early brooding period with a duration of 8 ± 0.58 s (range: 7–9, n = 3) in a tree near the nest and at sunset (~16:00 h).

Based on 396 observations, both adults consumed and delivered the following food to the nestlings: adult insects, Coleoptera larvae, Lepidoptera larvae, and fruits of which cachito (*Tabernaemontana litoralis*), rubber benjamina (*Ficus benjamina*), mango (*Mangifera indica*), African palm (*Elaeis guineensis*), and mandarin (*Citrus reticulata*) were identified. They also brought lizards, which they beat against a hard surface before feeding them to the nestlings. Adults trapped spiders in the crevices of buildings and descended infrequently to the ground (n = 4; Appendix 3). When the eggs begin to hatch at 25.67 ± 0.56 days of age (range 24–28, n = 6 nestlings), the adults fed them from outside and entered the cavity only to remove the fecal sacs. On one occasion, a male fed a chick from a neighboring nest.

The rate of feeding visits per hour made by adults did not vary with sex (Fig. 3) or precipitation intensity but did vary with brood size and nestling age (Table 1). Adults had a significantly higher feeding rate in large clutches and with nestlings at an advanced stage of development (Appendix 4).

Reproductive success

For the six nests with exact records of the dates of laying and birth, 14 eggs were found and eight chicks were born, a hatching success rate of 57.14%. Of the 19 chicks from 13 nests, 15 reached the fledging state, a reproductive success rate of 78.9%. Nesting in the nest box was unsuccessful and the eggs disappeared after 16 days (first clutch) and 9 days (second clutch). *Milvago chimachima* was recorded as a nest predator, however other potential predators such as squirrels, snakes, and raptors specifically *Rupornis magnirostris*, *Falco sparverius*, and *F. femoralis*, exist in the area.

Vocal communication

The acoustic structure of the vocalizations of *M. rubricapillus* (adults and chicks; Appendix 5) is characterized by frequencies ranging from 0.001 ± 0.0004 kHz to 18.502 ± 0.707 kHz with a duration of 0.882 ± 0.07 s in chicks and frequencies ranging from 0.820 ± 0.096 kHz to 10.423 ± 0.423 kHz with a duration of 0.015 ± 0.0014 s to 2.216 ± 0.59 s in adults.

Six types of vocalizations were identified: (1) Contact ("Agrrr"), emitted softly and repeatedly when interacting with other individuals in the same tree (family group); (2) Call ("Grriiii"), loud vocalization by adults as a long-distance partner call (≥ 5 m); (3) Response ("Krraa"), issued after the call; (4) Alert ("Krir-krir-krir-krir..."), vocalization of alarm in the presence of another nearby individual of the same or a different species (max duration 4.28 s); (5) Interaction ("Wicc-wicc--wic-uic-uic-uicc"), infrequent vocalization emitted in family interactions when close to the nest; and (6) Request for food ("Grrr"), vocalization emitted by the nestlings inside the nest (Fig. 6).

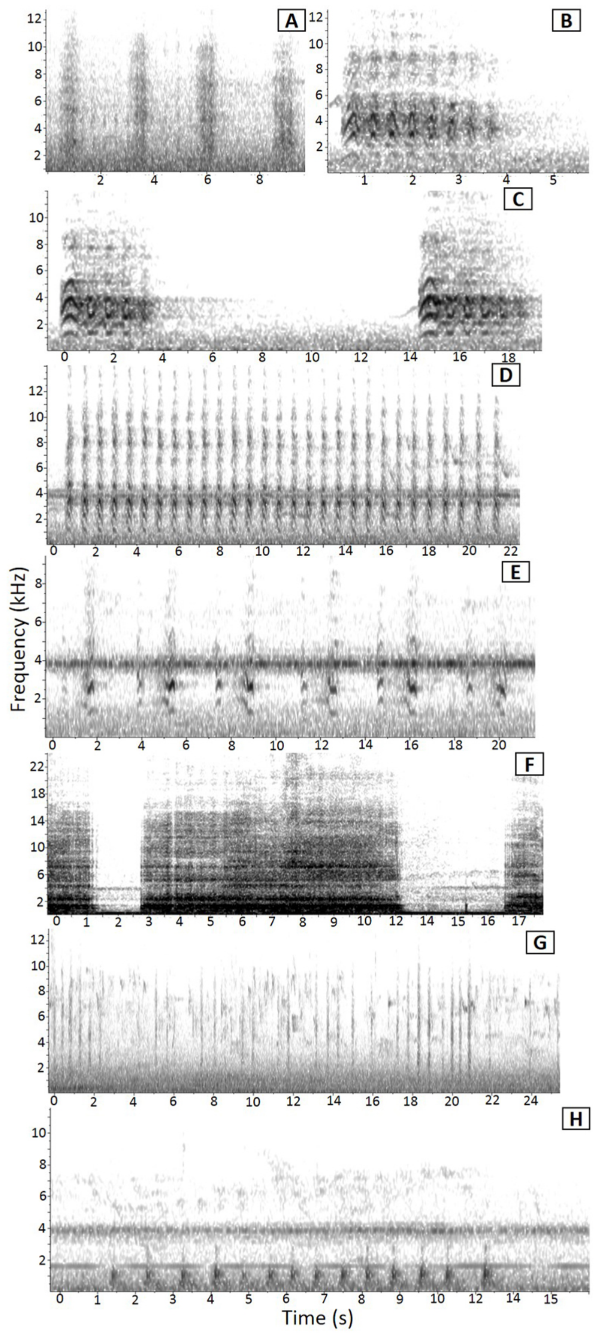
Body condition: scaled mass index and hematological profile

Compared with females, males' measurements were higher for weight, length and height of the beak, nostrils, and commissure (Appendix 2). Among adults, the scaled mass index was calculated and the bone measurement that most correlated with weight was the tarsus (Pearson r = 0.68, P = 0.005, n = 16). Among nestlings, the strongest association with weight was beak height (Pearson r = 0.96, P = 0.007, n = 5). Adults with better body condition had a mass index between 44.27–46.36 g; nestlings ranged between 41.19–42.41 g (Appendix 6).

Blood body counts were performed on ten individuals: eight adults (five males, three females) and two female chicks. On average, 68.75 ± 7.99 leukocytes and 26,000.88 ± 1623.63 erythrocytes were found in adults and 81.5 ± 10.5 leukocytes and 18,879 ± 516 erythrocytes in chicks. The proportions of heterophils and lymphocytes were very similar between adults and chicks. According to the morphological inspection, *Haemoproteus fringillae* was reported as a blood parasite in the species (Appendices 6 and 7).

The mass index was positively correlated with the H/L ratio (Pearson r = 0.77, P = 0.026, n = 8), where adults with the best body condition presented a H/L ratio close to one. No relationship was found between the rate of feeding visits and the body

Fig. 6. Sonogram of the vocalizations of *Melanerpes rubricapillus* in Cali, Colombia. (A) Contact "Agrrr." (B) Called "Grriiii." (C) Answer "Krraa." (D) Alert "Krir-krir-krir-krir…" (E) Interaction "Wicc-wicc—wic-uic-uic-uicc." (F) Request for feeding "Grrr" when they were still inside the nest and the adults came to feed. (G) Contact: adult male when it arrives to feed the fledgling female in a tree near the nest 25 days after the exodus. (H) Hammering carried out on one of the branches adjacent to the cavity that a male was building.



condition of the adults, nor between the rate of feeding visits and the size reached by the offspring upon reaching fledging age (Appendix 8).

DISCUSSION

This study reports the reproductive seasonality for *M. rubricapillus* in Colombia over a 10-month period (August–May) for the first time. This extends previous findings (Garces-Restrepo et al. 2012, Cruz-Bernate et al. 2019, Hilty and Brown 2001) to the months of September, October, and November. There was a maximum number of nests in February–March and an absence of reproduction in June–July. In other countries, such as Costa Rica, Panama, Venezuela, and Tobago, reproductive activity is found in June–July (intense rainfall season) but not in January or December (dry season or low rainfall; Winkler et al. 2002; Instituto Nacional de Meteorologóa e Hidrologóa [INAMEH] 2019 *personal communication*; Instituto Meteoroló Nationale, 1888, *personal communication*; Trinidad y Tobago Meteorological Service, Met. 1963, *personal communication*), whereas, in Colombia, June–July are dry and January–December have low and intense precipitation (IDEAM, 2019, *personal communication*). This suggests that *M. rubricapillus* prefers rainy seasons for reproduction.

Short (1979) mentioned that woodpeckers require individual cavities to rest, and these are changed by deterioration, which means that each of the territories has a variable number of cavities. In this study, it was observed that adults build several additional cavities in the same trunk or tree, which are used by the female and the offspring after the latter have fledged the nest. The dimensions of the entrance of these cavities were within the range reported for the species (Skutch 1969, Cruz-Bernate et al. 2019). *M. rubricapillus* used nest boxes, which shows some behavioral plasticity in terms of the selection of nesting resources. This is similar to *M. erythrocephalus*, which can occasionally use holes in buildings, nest boxes, and light poles (Winkler et al. 2002). One possible explanation is the competition with conspecifics or other secondary nesting species for the nesting resource (Hadow 1976, Short 1979). The availability of nesting substrates is a limiting factor and depends on habitat conditions (Tomasevic and Marzluff 2017). In urban areas, for example, the tendency to eliminate old trees and branches without leaves or stumps, for aesthetic reasons, has given way to homogeneous meadows and gardens that reduce the probability of finding nesting substrates. Furthermore, changing the poles used for urban lighting from wood to cement can cause damage to the bird populations that use this resource (Sandoval 2009). *M. rubricapillus* used nest boxes to roost and rest during the day; this behavior has also been reported in abandoned icterid nests (Goossen 1989).

The variation found in clutch size (one–four eggs) is greater than that reported by Cruz-Bernate et al. (2019) and Stiles and Skutch (1989); who only reported clutches of three or four eggs. Martin (1996, 2015) mentioned that clutch size can be influenced by predation because, by having a smaller number of nestlings, parents reduce the number of feeding visits and excessive visual signaling to predators about the location of the nest, which gives them an advantage in terms of reproductive success.

The observed incubation period was 15–16 days, higher than the time observed in Costa Rica with 10 days (Skutch 1969). During incubation and hatching, there were no differences between the sexes in parental investment, unlike what was reported by Cruz-Bernate et al. (2019), who found that the greatest investment was made by the female, and by Skutch (1969), who reported that, in Costa Rica, it was the male. This could be due to the sample size (Díaz 2009); the authors report this information with one and three nests respectively. In this research, information was obtained from 15 nests. In very small samples, only the variability of some pairs is reflected but not that of the population.

Parental investment in incubation was affected by precipitation, clutch size, and early embryonic development. It is known that adults invest more time in incubation when the clutch size is large as well as when the temperature drops because of high rainfall; this investment of time favors the maintenance of the optimal temperature of the embryo and the viability of its metabolic processes (Boerjan 2007, 2011, Jefferies et al. 2022). The early stage of embryonic development is a sensitive stage where the embryo initiates metabolic activities without yet having acquired a mature physiological system—achieved in the final stages of development—therefore, nestlings are reliant upon the care provided by their parents (transmission of heat and avoiding its loss; Boerjan 2007, 2011, Jefferies et al. 2022).

The finding of nests with three offspring constitutes the largest brood size for the species; previously a maximum of two chicks per nest had been documented (in Costa Rica; Skutch 1969). To date, the morphometric changes of chicks in the genus *Melanerpes* have not been documented, although they have been documented in *Dryobates pubescens*, which is a species similar in its morphometric measurements (Hadow 1976). The tarsus is the common measurement found in both species, and they present a similar growth rate, which indicates that they probably share biological rhythms of development. Furthermore, this confirms that the photogrammetric method used in this study can be used as a less invasive tool to report the development of the offspring of cavity nesting birds.

The nestling rearing period of 30–31 days was similar to that reported by Cruz-Bernate et al. (2019) and Skutch (1969) with 31–33 days in Costa Rica but higher than in Garces-Restrepo et al. (2012), with a 28-day report. The weight of the nestlings at the time of exodus relative to that of the adults was 93%, higher than in Cruz-Bernate et al. (2019), which was 80%. In Colombia, the reproductive success was 78% where its reproductive seasonality includes two rainy seasons. However, it is important to highlight that the maximum reproductive peak is prior to the period of greatest rainfall in the study area. It has been suggested that the first rains stimulate the initiation of the reproductive cycle, which begins with the excavation of nests and laying of eggs. Thereafter, as incubation and hatching progresses, the rains increase as does the availability of food for both the offspring and the adults (Brown and Sherry 2006, Flores and Ardón 2018).

Parental investment during brooding is affected by brood size and nestling age. As the chicks increase in age, both their movements and acoustic communication stimulate the adults to greater intensity in the search and provision of food (Weimerskirch et al. 2003, Royama 1966, Hadow 1976). This may be caused by metabolic requirements and energy expenditure as the offspring grow (Richards and Proszkowiec-Weglarz 2007, Royama 1966). It has been argued that adults increase their feeding rate in proportion to the size of the brood, so that the feeding rate per chick remains constant (Pettifor et al. 1966, as cited in Barba et al. 2009).

Vocal communication

Our study described the acoustic structure of vocal communication in *M. rubricapillus* for the first time. Kirkconnell (2000) named the vocalizations of *M. superciliaris* Call 1 (frequency range 2.5–2.8 kHz, duration 0.26 s) and Call 2 (frequency range 0.75–4.84 kHz, duration 1.05 s), with behaviors very similar to *M. rubricapillus* and vocalizations equivalent to what were referred here as Response (frequency range 0.83–5.62 kHz, duration 0.23 s) and Call (frequency range 1.45–7.07 kHz, duration 0.28 s). According to the behavioral context, *M. rubricapillus* presented a higher maximum frequency and shorter duration of the two vocalizations, whereas the minimum frequency was lower for Response and higher for Call.

Body condition and reproductive behavior

In relation to body condition, the two measurements (mass index and hematological profile) were positively correlated, and it was observed that the individuals with the best mass index presented hematological profiles close to one (H/L ratio). Heterophiles are associated with the immediate initial protection mechanism (innate response) that increases response to irregularities in diet, stress, trauma, and inflammation. Lymphocytes, of the acquired immune system, increase against bacteria, viruses, and ectoparasites (Masello et al. 2009). Gross and Siegel (1993) suggested that the characteristic values of the H/L ratio are around 0.2, 0.5, and 0.8 for low, optimal, and high degrees of stress, respectively, and considered the optimal level as the ideal to promote daily activities. Although the H/L value is known to vary with species and life history traits (Hau et al. 2010), the optimal level for the species is possibly close to one or was an immediate response to the capture event. It is suggested to carry out studies that evaluate how stressful factors influence leukocyte counts (Hau et al. 2010, Müller et al. 2011) in order to determine a reference for the species.

Investment in nestling feeding was not correlated with hematological conditions or adult mass index nor was there any relationship between the feeding rate of the adults and the size of the offspring at the time of exodus. However, it has been found that immune activity and body condition can, in some species, influence the behavioral patterns of individuals during their reproduction and thus affect their reproductive success (Hau et al. 2010, Müller et al. 2011). It is recommended to increase the sample size in order to have a better approximation of what happens in this species in the tropical dry forest.

This study has expanded information on the life history of *M. rubricapillus*, a species that has expanded its geographical distribution at an accelerated rate, establishes permanent territories for its reproduction, and has great adaptive plasticity. The species presents a unimodal reproductive seasonality with a maximum peak between the months of January–March, and both sexes participate equally in digging, incubation, and the rearing of offspring. It was found that paternal investment varies according to environmental and ecological characteristics (clutch size and nestling age), and communications based on six types of vocalizations are presented. Furthermore, the body condition of the reproductively active adults was characterized based on their morphometry and blood body count, and this was not found to be related to the degree of paternal investment nor to the maximum size reached by the offspring. It is an important species in the habitat by dispersing seeds and controlling populations of larvae and adult insects and, as a consequence of its reproduction, making nesting places available for other bird species. The latter makes it an indicator species of resources available in the habitat for cavity nesting because it uses available soft wood. This information provides particular requirements for the species, which allows pertinent decisions and measures to be taken in its environment regarding the management and conservation of populations. Furthermore, the plasticity in the use of nesting sites positions *M. rubricapillus* as a reference species when designing conservation plans for other cavity-nesting species.

Author Contributions:

YSSS: conceptualization, field and laboratory work, statistical analyses, writing-original draft and editing, visualization. LCB: conceptualization and study design, field work (supporting), statistical analyzes (supporting), writing-original draft and editing (supporting), funding acquisition (lead), supervision and project administration (lead). MCTLL: field and laboratory work (supporting), writing editing (supporting).

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Data Availability:

The data and code for this study are stored in the Open Science Framework (OSF), available at https://doi.org/10.17605/osf.io/zwm2a

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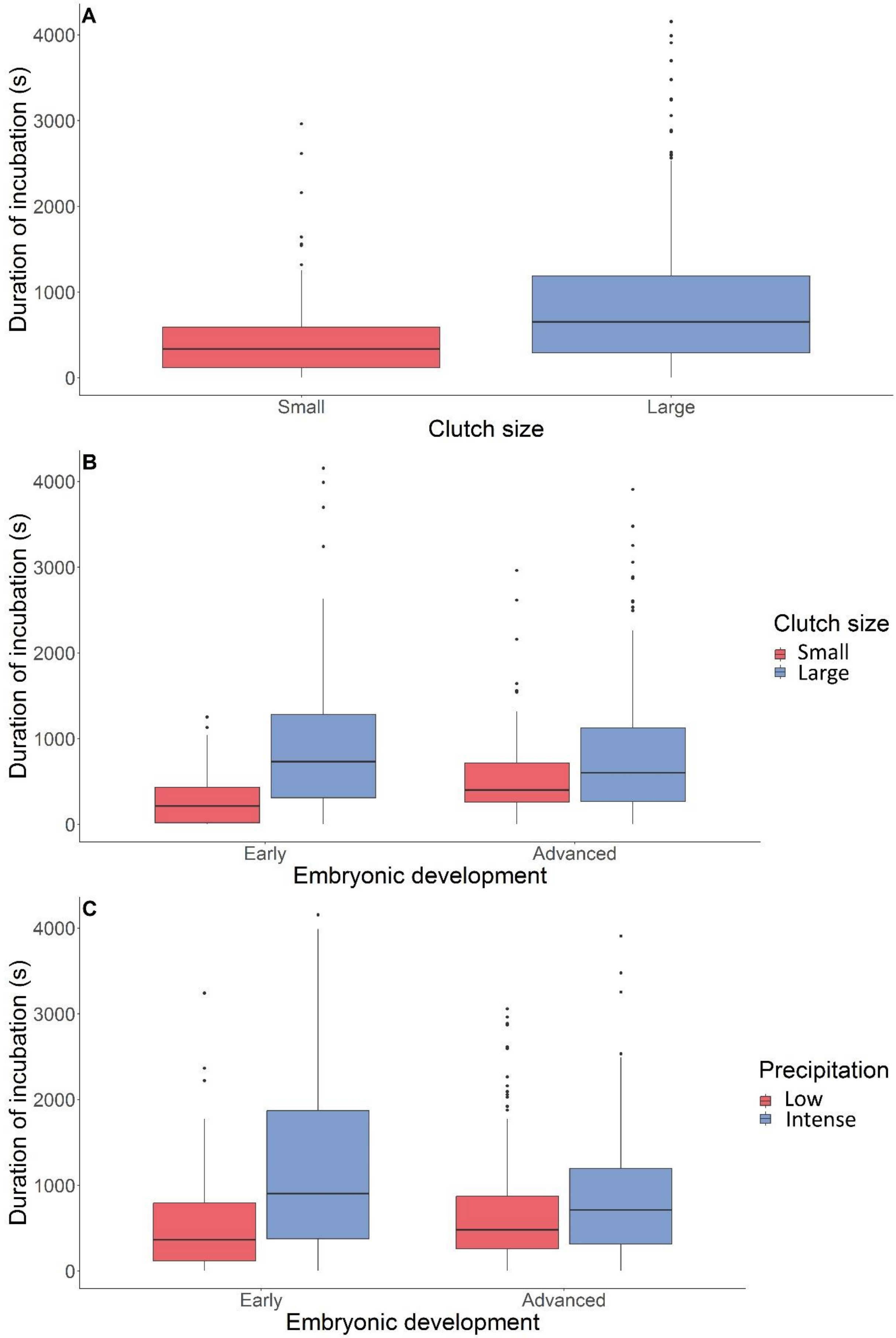
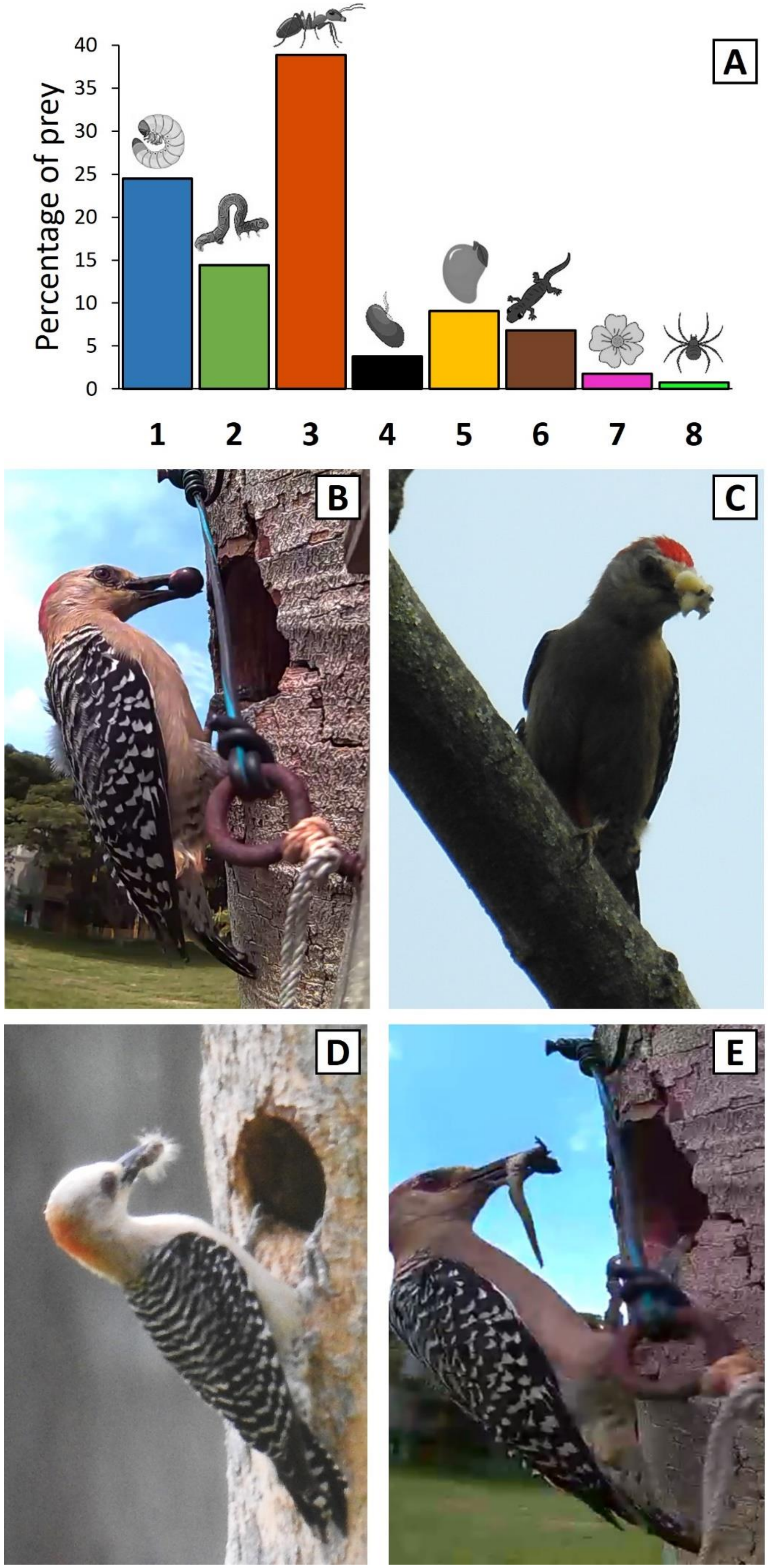


Appendix 1. Effect of clutch size, embryonic development and precipitation on the duration of incubation period of adults of *Melanerpes rubricapillus*, Cali, Colombia. A) Clutch size: small (one to two eggs), large (three to four eggs). B) Clutch size and embryonic development: early (one to eight days), advanced (9 to 15 days). C) Precipitation: low (≤80), intense (>80) and embryonic development.

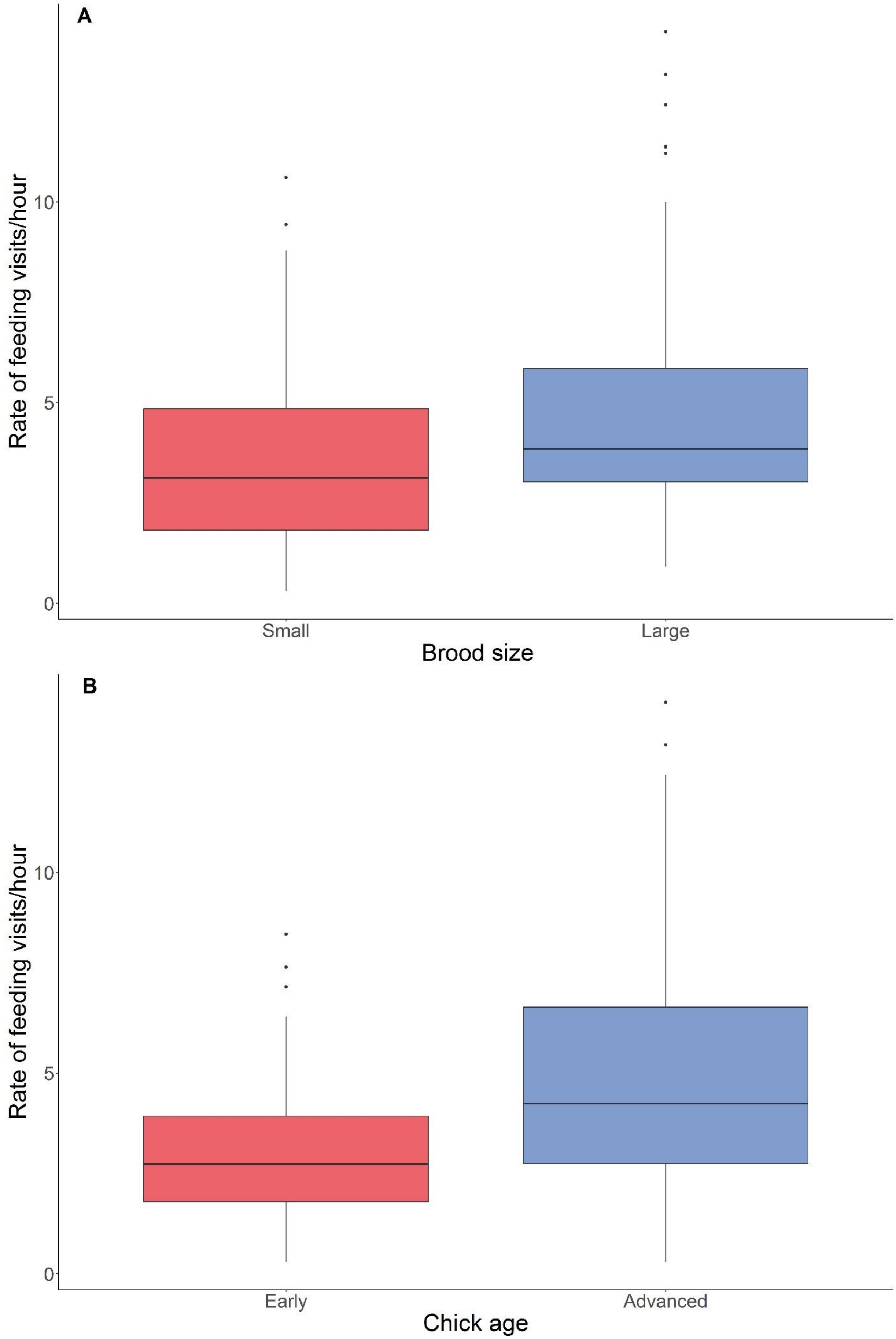
Appendix 2. Morphometric traits (mm) of individuals of *Melanerpes rubricapillus*, campus of the Universidad del Valle, Cali, Colombia. Dp-s: distance between primary and secondary feathers.

	Weight (g)	**Beaks length**	**Beaks height**	**Beaks width**	**Nostrils**	**Comissure**	**Wing**	**Dp-s**	**Tarsus**	**Halux**	**Rectrices**	**Total length**
						Adult females						
Half	43,77	19,98	6,38	6,78	3,10	10,21	101,59	17,15	19,83	5,47	47,59	169,38
SE	1,11	0,55	0,16	0,20	0,09	0,55	1,26	0,71	0,49	0,19	1,03	2,40
Median	43,74	19,65	6,38	6,9	3,13	10,10	101,9	17,36	19,43	5,25	48,33	171
SD	3,14	1,54	0,46	0,56	0,24	1,57	3,55	2,00	1,38	0,50	2,92	6,78
Minimum	38,59	18,35	5,58	5,92	2,67	8,36	96,28	13,98	18,02	5,06	42,44	158
Maximum	47,2	23,05	6,96	7,6	3,41	12,68	106	19,81	21,92	6,44	51	176
n	8	8	8	8	8	8	8	8	8	7	8	8
						Adult males						
Half	47,89	22,05	7,35	7,25	3,48	11,79	103,15	16,18	20,62	5,37	50,33	176,92
SE	0,67	0,44	0,15	0,34	0,09	0,31	1,12	0,77	0,40	0,43	1,14	3,70
Median	47,9	21,87	7,45	7,22	3,48	11,76	103,5	16,63	20,55	5,47	50,18	180
SD	1,77	1,33	0,44	1,03	0,26	0,88	3,36	2,17	1,19	1,29	3,42	9,06
Minimum	45,92	20,19	6,75	5,7	2,97	10,52	95	12,13	19,32	2,51	44,31	160
Maximum	50,28	24,93	7,97	9,42	3,98	12,99	106	19,37	22,52	6,92	56	186,5
n	7	9	9	9	9	8	9	8	9	9	9	6
Measurements differences												
Test†	***t***	***t***	***t***	***t***	***T***	***t***	***t***	***t***	***t***	***w***	***t***	***t***
Statistical	-3,07	-2,97	-4,47	-1,15	-3,07	-2,48	-0,93	0,94	-1,27	29	-1,77	-1,79
P-vauer	0,009	0,009	0,0004	0,27	0,008	0,026	0,37	0,37	0,22	0,84	0,098	0,099
						Chicks						
Half	42,32	15,92	6,03	5,77	2,65	10,80	84,83	10,28	20,37	5,42	41,07	151,86
SE	1,94	0,33	0,17	0,33	0,18	0,43	2,99	1,15	0,97	0,35	1,35	4,75
Median	44,31	16,22	6,05	5,72	2,73	10,23	87,87	9,4	19,76	5,77	42,12	157
SD	4,33	0,74	0,38	0,74	0,41	0,96	6,68	2,57	2,17	0,78	3,03	10,61
Mimimum	37,08	15,06	5,56	4,75	2,19	10,01	76,68	7,55	18,3	4,53	36,36	133,28
Maximum	46,1	16,75	6,44	6,7	3,22	11,96	92,22	14,22	23,85	6,22	44,47	159
n	5	5	5	5	5	5	5	5	5	5	5	5

† Mean difference test between adult individuals by sex: W = Wilcoxon t = t Student.



Appendix 3. A) Frequencies of food items used by adults during chick rearing in *Melanerpes rubricapillus*, Cali, Colombia: 1. Coleoptera larvae; 2. Larvae of Lepidoptera; 3. Adult insects; 4. Seeds; 5. Fruits; 6. Push-ups; 7. Flowers; 8. Spiders. B) Male with fruit of *Ficus benjamina*. C) Male with *Mangifera indica* fruit pulp. D) Female with Lepidoptera larva. E) Male with lizard.



Appendix 4. Effect of brood size and chick age on the rate of feeding visits per hour of adults of *Melanerpes rubricapillus*, Cali, Colombia. A) Effect of brood size: small (one chick), large (two to three chicks) on the rate of feeding visits per hour of adults. B) Effect of the age of the chicks: early (1-15 days of age), advanced (16-30 days of age) on the rate of feeding visits per hour made by *Melanerpes rubricapillus* adults.

Appendix 5. Acoustic measurements of vocalizations and each of the notes that compose them in *Melanerpes rubricapillus*, Cali, Colombia. Fmi=minimum frequency (kHz); Fma=maximum frequency (kHz); Fp=peak frequency (kHz); Tp= peak time (s); Ab=bandwidth (kHz); D=duration (s); D50=duration 50% (s); D90=duration 90% (s); Tc=central time(s); Ab50= bandwidth 50% (kHz); Ab90=bandwidth 90% (kHz); Fc=center frequency (kHz); HRc=maximum center frequency (kHz); Fcmi=minimum center frequency (kHz).

Vocalization type	Fmi	Fma	Fp	Tp	Ab	D	D50	D90	Tc	Ab50	Ab90	Fc	Fcma	Fcmi	
Interaction	1,1	3,7	2,7	1413,23	2,7	2,0	0,8	1,9	1413,2	0,9	2,1	2,7	3,7	1,1	
n = 2	0,1	0,0	0,1	571,3	0,1	0,05	0,22	0,036	571,33	0,0	0,0	0,0	0,0	0,0	‡
Note 1	2,2	3,1	2,7	1412,26	1,0	0,04	0,01	0,03	1412,3	0,3	0,6	2,7	3,0	2,5	
	0,0	0,1	0,1	571,09	0,1	0,001	0,00	0,003	571,1	0,0	0,1	0,1	0,0	0,0	‡
Note 2	2,4	3,6	3,0	1412,49	1,2	0,04	0,01	0,03	1412,5	0,4	0,9	3,1	3,5	2,7	
	0,2	0,0	0,1	571,10	0,3	0,005	0,003	0,003	571,1	0,1	0,1	0,1	0,1	0,0	‡
Note 3	2,2	3,2	2,8	1412,63	1,0	0,04	0,01	0,03	1412,6	0,2	0,5	2,8	3,1	2,6	
	0,0	0,1	0,1	571,10	0,1	0,0014	0,0	0,0	571,1	0,0	0,1	0,0	0,1	0,0	‡
Note 4	2,0	3,1	2,5	1412,92	1,1	0,04	0,01	0,02	1412,9	0,4	0,8	2,5	3,0	2,3	
	0,1	0,5	0,3	571,17	0,4	0,003	0,0	0,0017	571,2	0,2	0,2	0,3	0,5	0,3	‡
Note 5	2,0	3,5	2,8	1413,04	1,4	0,05	0,01	0,03	1413,0	0,3	0,6	2,8	3,3	2,4	
	0,1	0,2	0,1	571,15	0,1	0,0052	0,002	0,005	571,1	0,1	0,1	0,1	0,0	0,0	‡
Note 6	2,0	3,3	3,0	1413,27	1,3	0,05	0,01	0,03	1413,3	0,5	0,9	3,0	3,3	2,4	
	0,0	0,3	0,2	571,15	0,3	0,0017	0,002	0,0017	571,1	0,2	0,1	0,2	0,3	0,2	‡
Note 7	2,0	3,4	2,8	1413,40	1,4	0,06	0,01	0,03	1413,4	0,3	0,6	2,7	3,3	2,4	
	0,1	0,0	0,0	571,16	0,1	0,003	0,005	0,002	571,2	0,1	0,1	0,2	0,0	0,0	‡
Note 8	2,2	3,4	3,3	1413,64	1,2	0,04	0,01	0,02	1413,6	0,4	0,7	3,1	3,4	2,7	
	0,0	0,3	0,4	571,16	0,3	0,003	0,003	0,007	571,2	0,3	0,3	0,3	0,3	0,2	‡
Note 9	1,9	3,1	2,5	1413,77	1,1	0,06	0,01	0,03	1413,8	0,1	0,5	2,5	2,8	2,3	
	0,1	0,2	0,0	571,16	0,3	0,003	0,002	0,0017	571,2	0,0	0,1	0,0	0,1	0,0	‡
Note 10	2,0	3,2	2,7	1414,02	1,2	0,05	0,01	0,03	1414,0	0,4	0,8	2,7	3,2	2,6	
	0,0	0,2	0,1	571,15	0,2	0,003	0,0033	0,0017	571,1	0,2	0,2	0,0	0,2	0,0	‡
Note 11	1,8	2,8	2,4	1414,16	1,0	0,05	0,01	0,03	1414,2	0,2	0,5	2,4	2,7	2,1	
	0,2	0,0	0,0	571,14	0,2	2E-4	0,002	0,00	571,1	0,0	0,1	0,0	0,0	0,1	‡

Call	1,5	7,1	3,9	1417,86	5,6	0,28	0,12	0,23	1417,9	0,7	2,6	3,8	4,5	2,2	
n=47	0,1	0,3	0,1	153,07	0,3	0,006	0,0023	0,0041	153,1	0,1	0,1	0,0	0,1	0,1	‡
Note 1	2,8	4,5	3,8	1417,79	1,7	0,04	0,01	0,03	1417,8	0,5	1,1	3,8	4,2	3,2	
	0,0	0,0	0,1	153,07	0,0	0,0006	0,0006	0,0006	153,1	0,0	0,0	0,0	0,0	0,0	‡
Note 2	3,1	4,5	4,0	1417,83	1,4	0,03	0,009	0,02	1417,8	0,3	0,8	3,9	4,2	3,6	
	0,0	0,0	0,0	153,07	0,0	0,0012	0,0006	0,0010	153,1	0,0	0,0	0,0	0,0	0,0	‡
Note 3	3,1	4,5	4,0	1417,87	1,4	0,03	0,008	0,02	1417,9	0,4	0,9	4,0	4,2	3,6	
	0,0	0,0	0,0	153,07	0,0	0,0006	0,0004	0,0006	153,1	0,0	0,0	0,0	0,0	0,0	‡
Note 4	3,1	4,5	4,1	1417,91	1,4	0,03	0,008	0,02	1417,9	0,4	0,9	4,0	4,2	3,5	
	0,0	0,0	0,0	153,07	0,0	0,0004	0,0004	0,0006	153,1	0,0	0,0	0,0	0,0	0,0	‡
Note 5	3,1	4,5	4,0	1417,95	1,4	0,03	0,0083	0,02	1418,0	0,4	0,9	3,9	4,1	3,6	
	0,0	0,0	0,0	153,07	0,0	0,0007	0,0004	0,0007	153,1	0,0	0,0	0,0	0,0	0,0	‡
Note 6	3,2	4,4	3,9	1417,99	1,2	0,02	0,008	0,02	1418,0	0,3	0,7	3,9	4,1	3,6	
	0,0	0,0	0,0	153,07	0,0	0,0008	0,0005	0,0007	153,1	0,0	0,0	0,0	0,0	0,1	‡
Note 7, n=31	3,1	4,2	3,7	1257,27	1,2	0,02	0,0076	0,02	1257,3	0,3	0,8	3,7	3,9	3,5	
	0,1	0,1	0,1	169,71	0,0	0,0009	0,0005	0,0009	169,7	0,0	0,0	0,1	0,1	0,1	‡
Note 8, n=16	2,9	4,0	3,5	1286,29	1,1	0,02	0,006	0,02	1286,3	0,3	0,8	3,5	3,6	3,2	
	0,1	0,1	0,1	261,46	0,1	0,0009	0,0007	0,0007	261,5	0,0	0,0	0,1	0,1	0,1	‡
Note 9, n=2	2,8	3,7	3,3	1182,38	0,8	0,02	0,0033	0,01	1182,4	0,3	0,6	3,3	3,4	3,2	
	0,1	0,2	0,2	771,78	0,1	0,0014	0,00	0,0017	771,8	0,1	0,1	0,1	0,2	0,1	‡
Answer	0,8	5,6	3,8	2168,26	4,8	0,23	0,09	0,17	2168,3	1,1	2,6	3,4	4,0	1,7	
n=13	0,1	0,1	0,1	197,70	0,1	0,01	0,006	0,008	197,7	0,0	0,1	0,0	0,0	0,2	‡
Note 1	2,4	4,3	3,8	2168,26	1,9	0,22	0,09	0,17	2168,3	0,8	1,4	3,5	4,0	2,6	
	0,1	0,0	0,1	197,70	0,0	0,01	0,005	0,008	197,7	0,1	0,0	0,0	0,0	0,1	‡
Alert	1,1	10,4	4,0	688,78	9,3	1,89	0,88	1,62	688,7	1,3	5,2	3,0	6,7	1,2	
n=50	0,1	0,4	0,3	104,86	0,4	0,13	0,06	0,11	104,8	0,1	0,3	0,1	0,3	0,1	‡
Note 1, n=250	2,3	3,6	3,2	236,53	1,3	0,02	0,006	0,02	236,5	0,3	0,8	3,2	3,4	2,8	
	0,0	0,0	0,0	21,16	0,0	0,0003	0,0002	0,0002	21,2	0,0	0,0	0,0	0,0	0,0	‡
R† n=1533	1,2	9,9	2,9	837,45	8,7	0,02	0,007	0,02	837,4	1,0	4,3	3,0	3,5	2,2	
	0,0	0,1	0,0	20,21	0,1	0,0001	6,2E-5	9,3E-5	20,2	0,0	0,0	0,0	0,0	0,0	‡

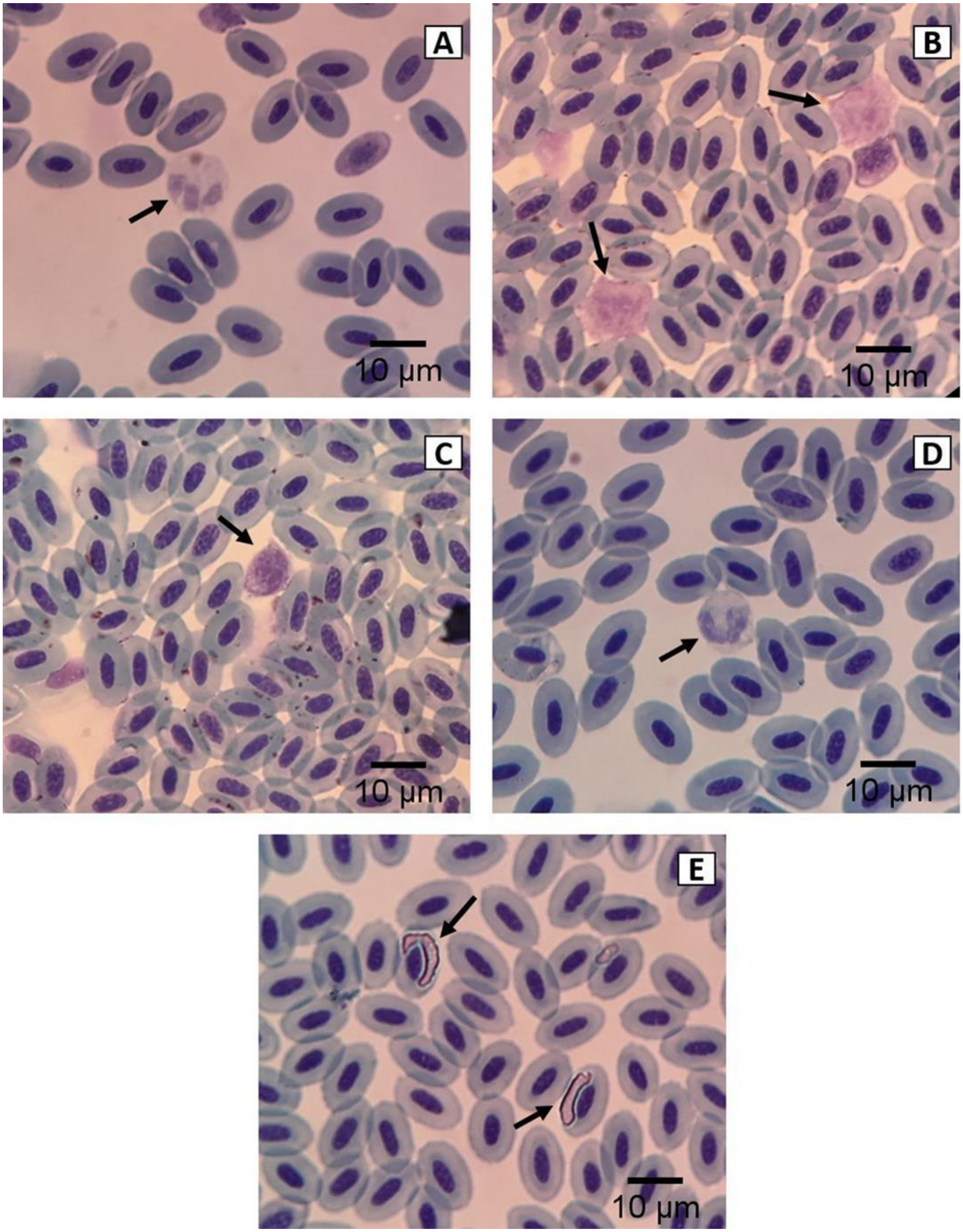
Contact	0,8	9,5	2,2	1485,56	8,7	2,22	1,14	2,03	1486,0	0,9	3,4	1,9	4,8	0,9	
n=4	0,1	0,7	0,6	146,80	0,6	0,59	0,38	0,55	147,1	0,3	1,1	0,5	0,9	0,1	‡
Note 1 n=30	1,0	7,7	1,9	1445,29	6,7	0,09	0,03	0,07	1445,3	1,5	3,5	2,1	3,2	1,2	
	0,0	0,5	0,2	48,41	0,5	0,004	0,002	0,003	48,4	0,1	0,3	0,1	0,2	0,0	‡
Food request (Chicks)	0,001	18,5	0,4	478,89	18,5	0,88	0,39	0,73	478,9	1,4	5,3	0,7	4,3	0,0	
n=78	0,001	0,7	0,1	41,21	0,7	0,07	0,03	0,06	41,2	0,1	0,2	0,1	0,2	0,0	‡

† Frequency of each of the notes of the alert vocalization including its harmonics.

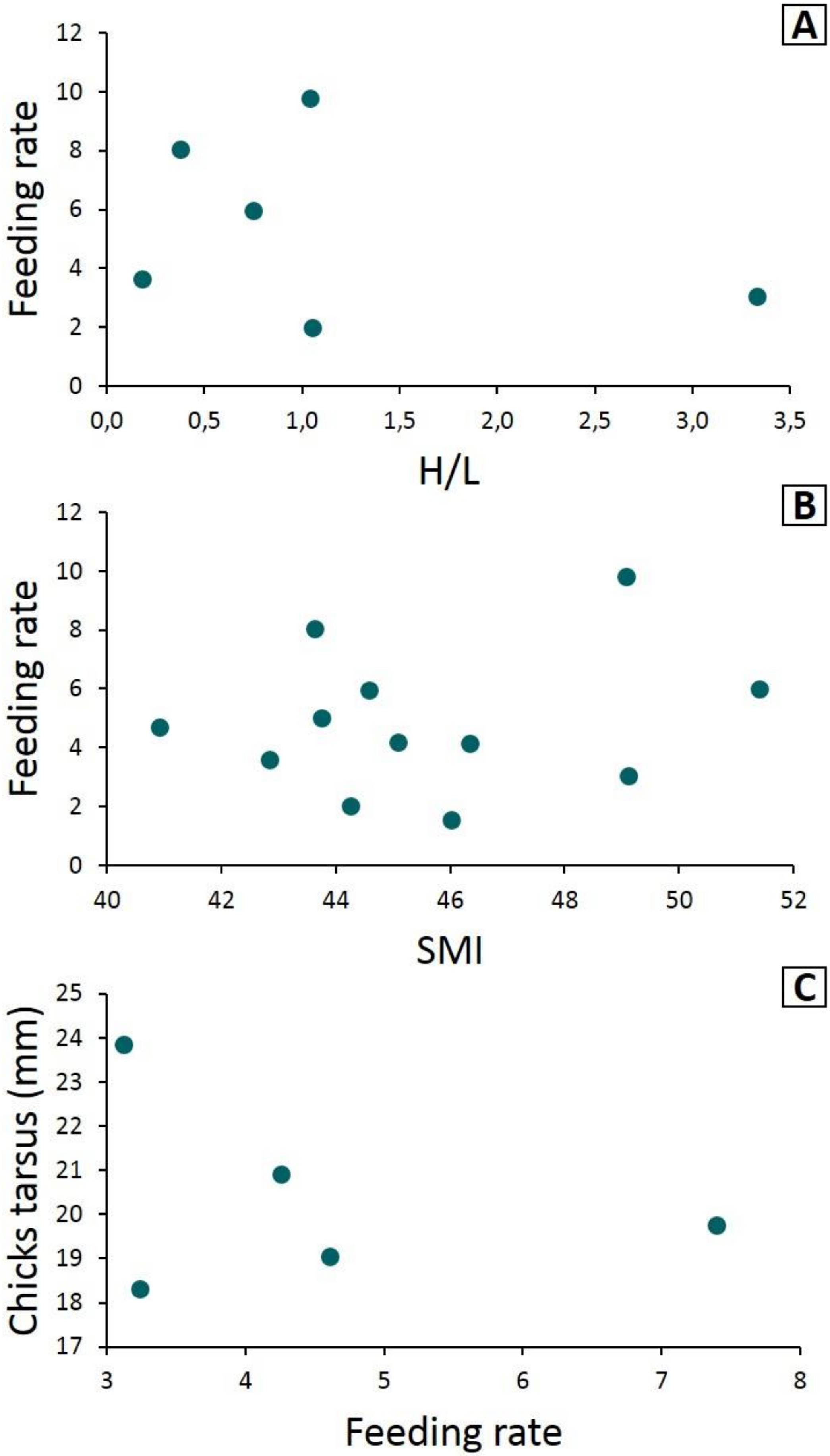
‡ Standard error.

Appendix 6. Scaled mass index, residuals, blood body count and hematological profile of individuals of *Melanerpes rubricapillus*, on the campus of the Universidad del Valle, Cali, Colombia. F = female; M = male.

Age condition	Sex	Smi	Residual	Heterophiles	Eosinophils	Basophils	Lymphocytes	Monocytes	Erytrocytes	Thrombocytes	H/L
Adult	F	42,9	-1,61	8	1	0	43	10	27114	66	0,19
Adult	F	43,6	-3,42	11	1	4	29	3	17244	59	0,38
Adult	M	44,6	0,04	15	6	1	20	10	25069	66	0,75
Adult	M	44,3	-0,34	19	4	2	18	42	29169	89	1,06
Adult	M	47,6	1,11	22	12	2	12	15	29532	64	1,83
Adult	M	49,1	3,44	23	1	1	22	5	24453	12	1,05
Adult	M	49,1	2,45	50	1	2	15	4	23350	68	3,33
Adult	F	45,4	-0,81	58	4	7	43	4	32076	188	1,35
Adult	M	40,9	-3,02	-	-	-	-	-	-	-	-
Adult	M	51,4	5,13	-	-	-	-	-	-	-	-
Adult	F	44,8	-0,41	-	-	-	-	-	-	-	-
Adult	F	46,0	-1,01	-	-	-	-	-	-	-	-
Adult	F	43,8	-4,07	-	-	-	-	-	-	-	-
Adult	F	46,4	-0,80	-	-	-	-	-	-	-	-
Adult	F	45,1	-0,08	-	-	-	-	-	-	-	-
Chick	F	41,4	-0,99	34	12	3	6	16	18363	90	5,67
Chick	F	42,2	0,11	44	3	1	42	2	19395	123	1,05
Chick	M	41,2	-0,91	-	-	-	-	-	-	-	-
Chick	F	42,4	-0,05	-	-	-	-	-	-	-	-
Chick	F	44,1	1,83	-	-	-	-	-	-	-	-



Appendix 7. Blood cells of *Melanerpes rubricapillus*; unlabeled erythrocytes, leukocytes and parasites marked with arrows: A) Heterophile. B) Lymphocyte. C) Monocyte. D) Eosinophilic. E) *Haemoproteus fringillae* blood parasite.



Appendix 8. Body condition of adults, parental investment and development achieved by chicks of *Melanerpes rubricapillus*. Hematological profile (H/L) (A) and mass index (SMI) (B) with feeding rate performed by adults. C) Feeding rate of parents and tarsus of chicks at the age of exodus.