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Article

Breeding biology of Hooded Gnateater *Conopophaga roberti* Hellmayr, 1905 (Aves: Conopophagidae)

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Abstract: The Hooded Gnateater *Conopophaga roberti* Hellmayr, 1905 is an insectivorous understory passeriform with discrete behavior, whose reproductive attributes are poorly-known. In the present study, we describe the reproductive biology of the species and the growth pattern of the nestlings, based on observations conducted in remnants of the Cerrado savanna in eastern Maranhão state, in Brazil. The nests were identified during active searches conducted between June, 2018 and March, 2021. A total of 22 nests were found over the course of three breeding seasons. The cup-shaped nests were supported by small branches and were constructed at a mean height of 40.6 ± 16.1 cm (N = 21) above the ground. The nests were 23.1 ± 3.9 cm in length and 14.1 ± 1.6 cm in width (N = 21). The eggs were beige in color, with irregular brown mottling only at the rounded end of the egg, which had a mean length of 21.3 ± 0.8 mm, width of 17.2 ± 0.8 mm, and mass of 3.1 ± 0.1 g (N = 23). Hatchlings are completely naked and weigh 3.1 ± 0.2 g (N = 7), and when they abandon the nest, they have yet to reach full adult size, with the total length being 65.4% of that of the adult, the wing, 65.4%, the head, 73.9%, the culmen, 74.2%, the body mass, 73.3%, and the tarsus, 89.0% that of the adult. The growth curves are sigmoidal and all the coefficients of determination are at least 0.96, with the body length having the highest value (R^2 = 0.98). During the breeding season, the adult pair emitted alarm calls constantly when observers were in the vicinity of the nest. On a number of occasions, members of the breeding pair were observed moving away from the nest as it was approached by observers, while engaging in broken-wing display. The nest architecture, the color of the eggs, and the behaviors presented by this gnateater were similar to those described for other *Conopophaga*. With this work we contributed to improve the knowledge on the breeding behavior of this poorly know group of understory insectivorous birds.
Keywords: *Cerrado; natural history; nesting success; Passeriformes; predation; reproduction.*

Biologia reprodutiva de *Conopophaga roberti* Hellmayr, 1905 (Aves: Conopophagidae)

Resumo: O chupa-dente-de-capuz *Conopophaga roberti* Hellmayr, 1905 é um passeriforme insetívoro de sub-bosque, de comportamento discreto e cujos atributos reprodutivos são pouco conhecidos. Aqui descrevemos a biologia reprodutiva da espécie e o padrão de desenvolvimento dos ninhegos, com base em observações realizadas em remanescentes de Cerrado no leste do Maranhão, Brasil. Os ninhos foram localizados por busca ativa entre junho de 2018 e março de 2021. Um total de 22 ninhos foram encontrados ao longo de três estações reprodutivas. Os ninhos, em forma de taça, foram sustentados por pequenos galhos e construídos a uma altura média de 40,6 ± 16,1 cm (N = 21) acima do solo. Mediram 23,1 ± 3,9 cm de comprimento por 14,1 ± 1,6 cm de largura. Os ovos são branco-amarelados e mediram 21,3 ± 0,8 mm por 17,2 ± 0,8 mm, com massa de 3,1 ± 0,1 g (N = 23). Ao eclodir, os ninhegos estão completamente nus e pesaram 3,1 ± 0,2 g (N = 7). Abandonam o ninho antes de atingirem o tamanho dos adultos, sendo o comprimento total equivalente a 65,4% do adulto, a asa 65,4%, a cabeça 73,9%, o cúlmen 74,2%, a massa corporal 73,3% e o tarso 89%. As curvas de crescimento apresentaram padrão sigmóide e todos os coeficientes de determinação foram maior ou igual a 0,96, sendo o comprimento do corpo o valor mais alto (R^2 = 0.98). Durante o período reprodutivo, o casal adulto emitia alertas constantemente quando os observadores se aproximavam dos ninhos. Em diversas ocasiões foi observado o comportamento de defesa de “asa quebrada” pelo casal reprodutor. A arquitetura do ninho, a cor dos ovos e os comportamentos

apresentados por *Conopophaga roberti* se assemelham aos descritos para outras espécies do gênero. Com este trabalho, melhoramos o conhecimento sobre a biologia reprodutiva deste grupo de aves insetívoras de sub-bosque pouco conhecido.

Palavras-chave: *Cerrado; história natural; Passeriformes; reprodução; sucesso reprodutivo.*

Introduction

The natural history of most birds, in particular their reproductive biology, is still poorly documented, and the breeding patterns of less than a third of the world's species have been described in detail (Xiao et al. 2017). However, this scenario has been changing gradually in recent years, with the constant publication of new data (*e.g.* Beier & Fontana 2019, Floriano et al. 2020, Lara et al. 2020, Studer & Crozariol 2020, Nunes et al. 2020, Martins et al. 2020, Cardona-Salazar et al. 2021, Larre et al. 2022).

Birds of the family Conopophagidae is endemic to the Neotropical region, being distributed between Costa Rica and southern Paraguay (Ohlson et al. 2013, Whitney 2020). Conopophagids are small birds with long tarsus, short tail and, in most species, an elongated post-ocular tuft usually white (Sick 1997). The family has two genera – *Conopophaga* and *Pittasoma* – and 11 species, of which nine (*aurita*, *melanops*, *lineata*, *cearae*, *roberti*, *peruviana*, *ardesiaca*, *castaneiceps*, and *melanogaster*) are members of the genus *Conopophaga* (Winkler et al. 2020).

Conopophaga is a clade of exclusively forest-dwelling species, which are typically solitary or form pairs with well-defined territories. Few data are available on the reproductive biology of the species of this genus, and the findings of a few case studies have been extrapolated to cover the remaining species (Whitney 2020). In some cases, the only information available on breeding patterns is a basic description of the nests and eggs (Peixoto 1932, Alves et al. 2002, Hillman & Hogan 2002, Sánchez & Aponte 2006, Leite et al. 2012), and even these characteristics are unknown in many species.

The Hooded Gnateater, *C. roberti*, is endemic to Brazil, where it is distributed in the states of Ceará, Piauí, Maranhão, and Pará (Whitney & Kirwan 2020), inhabiting densely vegetated and tangled portions of forest, often near the edge (Greeney 2020). The reproductive biology of the species is still poorly-known (Greeney 2018). Peixoto (1932) described two eggs collected by Emilie Snethlage in Pará, which were possibly obtained from the nest described subsequently by Snethlage (1935). In the present study, we describe the reproductive biology and growth patterns of the nestlings of *C. roberti.*

Material and Methods

1. Study Area

The present study was conducted in the Inhamum Environmental Protection Area (APA Inhamum; −4.891667, −43.414722) in the municipality of Caxias, eastern Maranhão, Brazil. The APA Inhamum has approximately 3,500 ha, and is located around two kilometers from the urban zone of the town of Caxias. The predominant vegetation is *sensu stricto* Cerrado (a savanna-like vegetation), with smaller patches of other habitats, such as Cerradão woodland, gallery forests, and stands of buriti palm (*Mauritia flexuosa*) along the margins of the local streams. The flora and fauna of the more humid environments in the vicinity of water bodies include many Amazonian elements, while the drier environments present many elements more typical of the Caatinga dry forest biome. The region's climate is "Aw" according Köppen-Geiger classification (Peel et al. 2007), with two well-defined seasons, a dry season, between June and November, and a rainy season, from December through May, with a mean annual precipitation of 1600 mm and a mean annual temperature of 27.8°C. The APA Inhamum is located in the middle basin of the Itapecuru River, and encompasses both perennial streams and some other intermittent watercourses.

2. Identification of territories and monitoring of the nests

During the first steps of the fieldwork, existing roads and trails were surveyed within the APA Inhamum to locate *C. roberti* territories. Once a territory was identified, the resident adults were captured using ornithological mist-nets. These individuals were weighed and measured (the length of the body, tarsus, culmen, wing, and head), and then banded with a numbered metallic ring provided by the Brazilian National Center for Bird Conservation (CEMAVE) and an additional set of unique, color-coded rings. The capture and handling of the birds was authorized by SISBIO (license 54623) and CEMAVE (protocol 3827).

As the period of the *C. roberti* breeding season is not well-known (Peixoto 1932), the territories identified in the APA Inhamum were monitored weekly between June 2018 and March 2021. Nest searches were based on the method proposed by Martin & Geupel (1993), which involves the careful inspection of all the vegetation within the territory and following individuals carrying nest-building materials or food items for nestlings. Attention was also paid to agonistic behaviors, such as constant vocalizations in response to the presence of observers in the vicinity of the nest.

Once found, the nests were monitored at intervals of one to four days for as long as they were active. The nests, eggs, and nestlings were measured using a metal ruler (1 mm scale) and caliper (accurate to 0.05 mm), and weighed with a portable digital balance (accurate to 0.01 g). The growth pattern of the nestlings was determined based on their body mass and the measurements of body length, and the tarsus, culmen, wing, and head. The nests were only measured when active, i.e., when they contained eggs or nestlings. The nest structure was classified according to the categories proposed by Simon & Pacheco (2005).

3. Analyses

The nests were classified as successful, abandoned or depredated, and the percentage of each category was calculated for the study period. The annual production of fledglings (APF) was calculated by the formula: APF = total number of fledglings/total number of clutches (Ricklefs & Bloom 1977). The apparent success corresponds to the number of successful nests/total number of nests, and is a parameter used primarily for comparisons with older studies, given that it does not take into account the phase of the nest when it was first identified, and thus provides an overestimate of the actual success (Johnson 1979, Jehle et al. 2004).

The growth curves of the nestlings were adjusted using a second degree polynomial regression. A polynomial equation was generated for each morphological parameter, and its coefficient of determination (R^2) was calculated. The comparison of the morphometric parameters of the nestlings was based on the data collected from 54 adults (35 males and 19 females) during the banding. The analyses were run in the R program (R Core Team 2019) using the ggplot2 (Wickham 2016), ggpmisc (Aphalo 2021), and dplyr (Wickham et al. 2020) packages.

Results

The surveys and monitoring of the nests were based on a total sampling effort of 340 hours in the field. A total of 22 active nests were identified over three breeding seasons (2018-2019, 2019-2020, and 2020-2021), all in Cerradão woodland understory. Overall, 40.9% of the nests were successful, 45.5% were preyed upon, and 13.6% were abandoned. The fledgling production rate was 0.7 fledglings/clutch for the study period as a whole, although it was 1.3 in 2018-2019 (N = 3), 0.3 in 2019-2020 (N = 7), and 0.5 in 2020-2021 (N = 12). The annual production of fledglings by *C. roberti* was 0.58 per adult female.

The earliest active nest was identified during the incubation phase in the first half of November, while the latest (with two nestlings that were lost to predators) was found in the first half of March. These findings indicated that the *C. roberti* breeding season lasts from November to March, which coincides with the rainy season in the study region.

Whenever observers approached a nest to within a distance of 10–15 m, the breeding pair emitted alarm calls continuously and insistently. This behavior was in fact the most reliable indicator of reproductive activity and ensured the identification of the majority (N = 12) of the nests. This defensive behavior was observed as soon as nest construction was initiated. On a number of occasions, members of the breeding pair were observed engaging in broken-wing display, in particular toward the end of the incubation and in the nestling stages.

The monitoring of color-banded adults permitted the confirmation of three events of a second attempt at reproduction in breeding pairs whose first nests had been depredated or abandoned. In one case, the breeding pair was observed building a second nest 83 days after the depredation of their original nest. In the second case, the pair was observed building a second nest 73 days after abandoning the first site, while in the third, the new nest was found in incubation phase 64 days after the depredation of the first clutch. The nests were never reused.

The nests were of the low cup/base type, and were built in a number of different substrates, including small branches and tangles of lianas, tufts of grass, and in the leaves of babaçu (*Attalea speciosa*) or tucum (*Bactris* sp.) palms or bromeliads (*Bromelia* sp.). All the nests were built in the understory at a mean height of 40.6 ± 16.1 cm (range = 15–75) above the ground. Five nests were collected and deposited in the Marcelo Bagno Ornithological Collection (COMB) of the University of Brasília, under catalog numbers N0730, N0731, N0732, N0733, and N0734.

Nest construction started with the establishment of a base formed by a pile of dry leaves and twigs, which measured 23.1 ± 3.9 cm × 14.2 ± 1.5 cm (N = 21) when complete. A smaller, cup-shaped structure is then built on top of the base using dry leaves and tree pericambium, arranged in a circular shape and lined with fine petioles, forming a chamber in which the eggs are deposited (Figure 1A). This structure has a mean depth of 40.6 ± 16.1 mm, internal diameter of 59.4 ± 7.2 mm, and external diameter of 79.1 ± 11.1 mm (N = 21). The construction process took eight days to complete (N = 1).

The eggs were beige and had irregular brown mottling on the more rounded extremity (Figure 1A). All the clutches contained two eggs (N = 17), which were laid at intervals of one or two days. Both members of the breeding pair incubated the eggs and cared for the nestlings.

When the nestlings hatch, they are completely naked, with dark brown skin and closed eyes (Figure 1B). The labial commissure is whitish and the inner surface of the bill is orange. When they hatch, the nestlings had a mean weight of 3.1 ± 0.2 g (N = 7) and one day before fledging, they weigh 16.2 ± 1.0 g (N = 4). On the second day of life, the pterylae were apparent, with darker tones in the alar, capital, dorsal, femoral, humeral, and ventral zones (Figure 1C). Dark gray feather sheaths are visible by the fourth day, when they appear in the

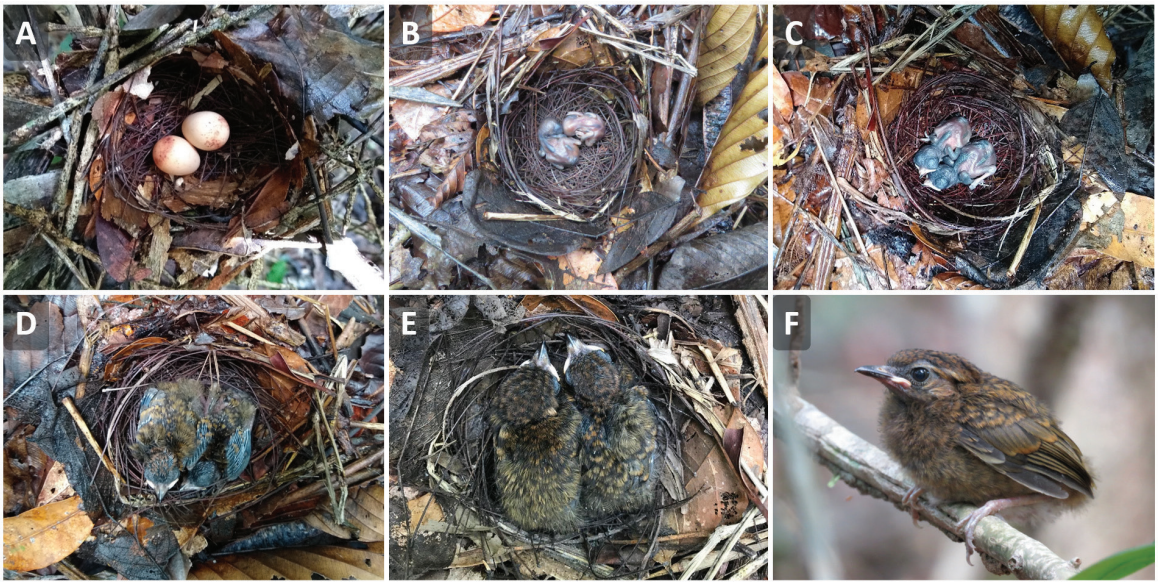

Figure 1. Eggs (A) and nestlings of Hooded Gnateater *Conopophaga roberti* at 1–2 (B), 2–3 (C), 7–8 (D), and 9–10 day after hatching (E), and after fledging (F), showing no clear sexual dimorphism.

alar, crural, capital, dorsal, femoral, humeral, and ventral pterylae, which is also when the eyes begin to open.

The bill begins to darken and the commissure acquires a more yellowish tone over the course of the development of the nestling. At around day eight, the body is partially covered with yellowish down, while the shafts of the remiges and the feathers on the head are clearly visible (Figure 1D). By the tenth day, the body is covered entirely with feathers and the remiges are well-developed (Figure 1E). At this stage, the nestlings are already able to produce vocalizations similar to those of the adults, but not as loud. Fledglings had poorly-developed tail, were still covered with down (Figure 1F). Two nestlings were monitored from the first day of life and fledged on days 13 and 14. No clear sexual dimorphism was observed in any of the fledglings (Figure 1F).

When they fledge, the fledglings have yet to reach full adult size (Figure 2), and their total length is 65.4% of that of the adult, while the wing is 65.4%, the head is 73.9%, the culmen is 74.2%, body mass is 73.3%, and the tarsus is 89.0% of the length of that of the adult. The growth curves are sigmoidal and all the coefficients of determination (R^2) are at least 0.96.

Few data are available on the reproductive biology of the species of the genus *Conopophaga* (Table 1). In most cases, the studies present no more than basic descriptions of the nests, eggs, and some associated behaviors. The best-studied species is the Black-cheeked Gnateater *C. melanops*.

Discussion

In general, the reproductive parameters of *C. roberti* are similar to those of other species of the genus *Conopophaga*. However, the predation nest rate of *C. roberti* (45,5%) were lower than that observed for *C. melanops* (64,9%), for example (Studer et al. 2019). Bodrati & Di Sallo (2020) also recorded only one successful nest from the five sites monitored in a study of Rufous Gnateater *C. lineata.* The nest

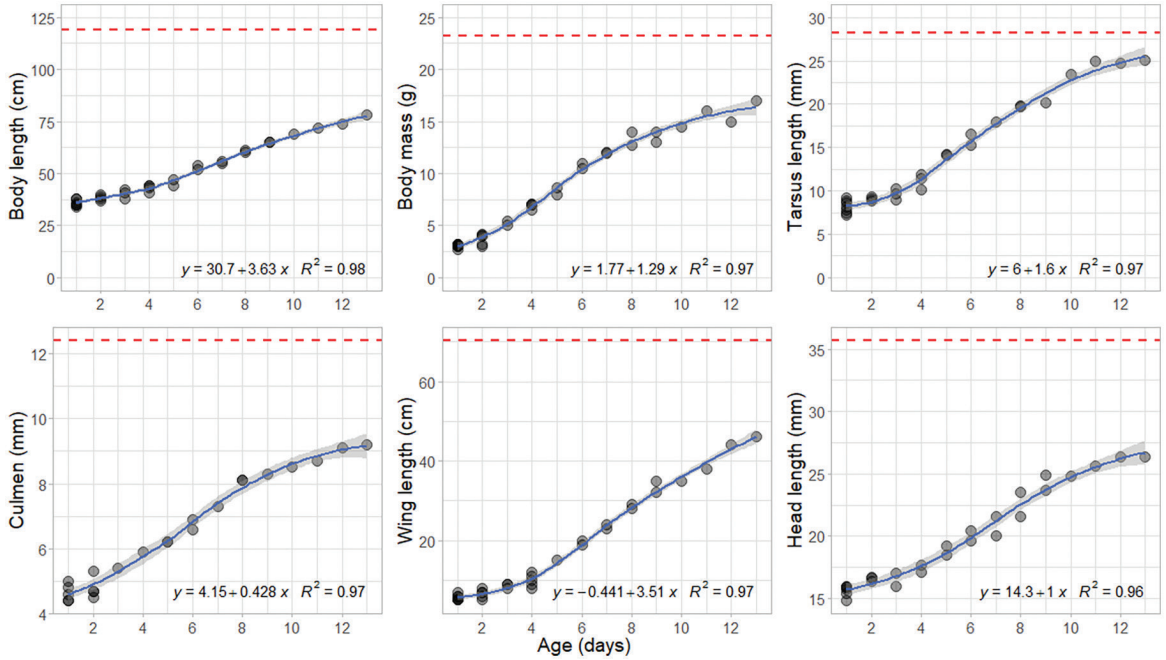

Figure 2. Growth curves of the Hooded Gnateater *Conopophaga roberti* nestlings fit using a second-degree polynomial regression. The dashed red lines represent the mean values for the adults (N = 54).

Table 1. Published data available on the reproductive biology of the species of the genus *Conopophaga*.

Species	Clutch	Incubation (days)	Nestling period (days)	Parental care	Source
melanogaster	–	–	–	–	–
melanops	2	12–18	13–18	Biparental	Straube (1989), Alves et al. (2002), Stenzel and Souza (2014), Studer et al. (2019)
aurita	1–2	–	–	Biparental	Leite et al. (2012), Greeney (2020)
peruviana	2	–	–	Biparental	(Hillman and Hogan 2002)
cearae	–	–	–	–	–
roberti	2	–	13–14	Biparental	Peixoto (1932), Greeney (2020)
lineata	1–3	–	13–14	Biparental	Marini et al. (2007), Lopes et al. (2013), Whitney et al. (2020), Bodrati and Sallo (2020)
castaneiceps	2	–	–	–	Steven and Hilty (1974)
ardesiaca	2	–	–	–	Sánchez and Aponte (2006)

success rate recorded here for *C. roberti* (40.9%) was nevertheless much higher than those found in *C. melanops* by Lima & Roper (2009), who registered a success rate of 22%, and Studer et al. (2019), who recorded a rate of 20%. Depredation and abandoning the nest are two of the principal factors that determine the low clutch success rates in most bird species from the Neotropical region (Marini et al. 2009, Nóbrega & Pinho 2010). In the present study period, in fact, all the nests were lost during one of the breeding seasons monitored, which had a major impact on the overall production of fledglings. The reproductive biology of most bird species is still poorly known, in terms of published data (Xiao et al. 2017), and this is especially true for forest-dwelling species, which hampered the systematic comparison of the data on the annual production of fledglings by *C. roberti* with other *Conopophaga* species or birds that are found in similar habitats. The only *Conopohaga* species with available data is *C. melanops*, with annual production of fledglings of 0.36 (Lima & Roper 2009), versus 0.58 of *C. roberti*.

The biparental behavior observed in *C. roberti* is typical of the genus, with both adults participating in territorial defense, nest-building, and infant caregiving. The broken wing display employed by *C. roberti* has also been observed in most other *Conopophaga* species, including *C. melanops* (Straube 1989), Ash-throated Gnateater *C. peruviana* (Hillman & Hogan 2002), *C. lineata* (Marini et al. 2007), and Chestnut-belted Gnateater *C. aurita* (Leite et al. 2012). This is a common behavior in many birds, and serves to distract the attention of a potential predator and lead it away from the nest and the nestlings (de Framond et al. 2022).

Many birds are known to engage in multiple attempts to reproduce following the loss of a first clutch (Rubio & Pinho 2008, Murcia et al. 2022). While it was not previously known whether this was also the case in *Conopophaga* (Winkler et al. 2020), the present study represents the first record of multiple breeding events in a species of this genus.

The general architecture of the nest of *C. roberti* is also similar to the patterns described for *C. aurita* (Leite et al. 2012), *C. melanops* (Alves et al. 2002), *C. lineata* (Marini et al. 2007), *C. peruviana* (Hillman & Hogan 2002), and Chestnut-crowned Gnateater *C. castaneiceps* (Hilty 1975). The dimensions and coloration of the *C. roberti* eggs observed in the present study were similar to the description of specimens collected in the Brazilian state of Pará by Emilie Snethlage, which measured 20 mm × 17 mm and were yellowish-white with a crown of reddish mottling around the upper pole (Peixoto 1932). The eggs of *C. roberti* are also similar to those of the congeners *C. lineata* (Willis et al. 1983), *C. melanops* (Straube 1989), and Slaty Gnateater *C. ardesiaca* (Sánchez & Aponte 2006).

The development of the *C. roberti* nestlings in the first days of life was similar to that presented (in photos) in *C. melanops* (Stenzel & Souza 2014), as was the period the nestlings: 14–15 days to *C. melanops* (Stenzel & Souza 2014); 13–14 to *C. lineata* (Bodrati & Di Sallo 2020); 13–14 days to *C. roberti* (present study). Stenzel & Souza (2014) observed that most of the *C. melanops* nestlings monitored in remnants of the Atlantic Forest in the Rio de Janeiro Botanical Garden remained in the nest for 15 days, although in one case, a fledgling abandoned the nest after 14 days. In other studies of *C. melanops*, the nestlings remained in the nest for between 13 and 18 days (Straube 1989, Alves et al. 2002, Studer et al. 2019). This variation in nestling period may be related to climatic and latitudinal factors within the ample geographic range of the species. However, the reproductive parameters of *C. roberti* may be less variable, given that the species occurs within the region of the transition among the Cerrado, Caatinga, and Amazonian biomes, which has well-defined climatic seasons.

The morphometric growth parameters of the nestlings analyzed in the present study are still unknown in other species of the family Conopophagidade. When the fledged abandoned the nest, the length of the tarsus was the parameter closest to that of the adult, which is consistent with the pattern observed in Yellow-olive Flycatcher *Tolmomyias sulphurescens* (Anciães et al. 2012).

When the *C. roberti* fledged, the feathers of their wings and tail are still poorly developed, which means that they are unable to undertake long-distance flights. When they fledged, the nestlings weighed 73.3% of the weight of the adults and did not go through a pre-fledgling peak in development, as observed in many bird species (*e.g.* Antas et al. 2010). In fact, some passeriform fledglings, such as those of *T. sulphurescens* (Anciães et al. 2012) and Cinnamon Flycatcher *Pyrrhomyias cinnamomeus* (Collins & Ryan 1995), are actually heavier than the adults when they abandon the nest, with the former reaching 107% of the weight of the adult, and the latter, 102%.

In most cases, the previous studies of the reproductive parameters of conopophagids have provided only basic descriptions of the nests, eggs, and some associated behaviors (Table 1), and even these data are lacking for *C. melanogaster* and Ceara Gnateater *C. cearae* (Greeney 2020, del Hoyo et al. 2020). In the specific case of *C. cearae*, the only evidence is a photograph (but no written description) of a nest containing two eggs, which was found on 17/03/2020, in the municipality of Guaramiranga, in the Brazilian state of Ceará (Vieira 2020). It is important to note that reliable data on the reproductive parameters of a species and the habitats in which it builds its nests represent an essential set of information for the development of effective strategies for the conservation and management of the species' natural habitats.

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Associate Editor

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Author Contributions

Surama Pereira: Substantial contribution in the concept and design of the study, data collection, data analysis and interpretation and manuscript preparation.

Bruna Stefane da Silva Santos: Substantial contribution to data collection, data analysis and critical revision, adding intelectual content.

Flávio Kulaif Ubaid: Substantial contribution in the concept and design of the study, data collection, data analysis and interpretation and manuscript preparation.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Ethics

We declare that the procedures used in this study have no conflict with the Brazilian Laws regarding the use of vertebrates in scientific research.

Data Availability

Besides the map, photographs and descriptions included here, other data was compiled from published literature, and appropriated cited along the manuscript.

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