ARTÍCULO/ARTICLE

Nesting biology of an Ecuadorian endemic hummingbird, the endangered Violet-throated Metaltail *Metallura baroni*

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Biología de anidación de un colibrí endémico del Ecuador, el amenazado Metalura Gorjivioleta *Metallura baroni*

Resumen

El colibrí Metalura Gorjivioleta *Metallura baroni* es una especie amenazada, endémica de los Andes del sur del Ecuador. La biología reproductiva de esta especie era casi desconocida. En este artículo describimos el nido, huevos y desarrollo de pichones de esta especie en base al seguimiento de nueve nidos encontrados en la vía Cuenca-Molleturo-Naranjal, en el Parque Nacional Cajas, durante 2019. Detectamos un periodo reproductivo entre marzo y mayo, que corresponden a la estación lluviosa. Los nidos fueron encontrados en taludes al borde de la vía, y fueron construidos con musgos, ramas pequeñas, raicillas, corteza de árboles de *Polylepis* sp. (Rosaceae) y fibras de *Puya* sp. (Bromeliaceae). En todos los nidos encontramos dos huevos ovales blancos. Los huevos y pichones fueron atendidos exclusivamente por la hembra. El tiempo desde la eclosión de los huevos hasta abandono del nido fue de 28–32 días. Anidar en el borde de la vía podría ser riesgoso debido a la probabilidad de atropellamiento por vehículos; por tanto, estudiar el éxito reproductivo de *M. baroni* en los nidos localizados en el borde de la vía es una prioridad de investigación para la especie. La información presentada en este artículo incrementa el conocimiento sobre la historia natural de *M. baroni*.

Palabras clave: Parque Nacional Cajas, trampa ecológica, colibrí, páramo, reproducción.

Abstract

Violet-throated Metaltail *Metallura baroni* is a threatened hummingbird species, endemic to the Andes of southern Ecuador. Details about the reproductive biology of this species are largely unknown. In this manuscript, we describe the nest, eggs, and nestlings' development based on nine nests found along with the Cuenca-Molleturo-Naranjal road, in Cajas National Park, in 2019. We document a breeding period from March to May, which corresponds to the rainy season. All nests were found in roadside embankments, and were constructed with mosses, small twigs, rootlets, *Polylepis* sp. (Rosaceae) bark, and *Puya* sp. (Bromeliaceae) fibers. In all nests, we found two white oval eggs that were exclusively attended by a female across the breeding period. Hatching to fledging period lasted 28–32 days. Nesting at roadsides can be particularly risky due to a high probability of collision with vehicles; thus, an assessment of the breeding success of *M. baroni* on nests located at roadsides is a research priority for this species. The information provided here increases the knowledge about the natural history of *M. baroni*.

Keywords: Cajas National Park, ecological trap, hummingbird, páramo, reproduction.

INTRODUCTION

Violet-throated Metaltail *Metallura baroni* is a hummingbird that belongs to the *Metallura aenocauda* clade (Graves, 1980; García-Moreno, 1999; Benham *et al*., 2015) in the monophyletic genus *Metallura*. It is endemic to the provinces of Cañar and Azuay, in the western Andes of southern Ecuador. *Metallura baroni* ranges from

3000 to 4000 m a.s.l. (Tinoco *et al*., 2009; Astudillo *et al*., 2015), occupying mainly shrubby páramo and *Polylepis* woodland, where it feeds on several short corolla flowers, including *Brachyotum* spp. (Melastomataceae), *Berberis* spp. (Berberidacae), and *Barnadesia arborea* (Asteraceae) (Tinoco *et al*., 2009). As a result of its small distribution range and fragmented populations that are declining in numbers over time, *M. baroni* is considered as Endangered, both at national (Freile *et al*., 2019) and global levels (BirdLife International, 2021).

Most of the ecological knowledge about *M. baroni* comes from studies focused on its distribution, general behavior and habitat use (Tinoco *et al*., 2009, Astudillo *et al*., 2014, 2015). However, its breeding biology remains largely unknown (Schuchmann, 1999; Tinoco *et al*., 2009). The only breeding information available to date comes in a brief report of a single, cup-shaped nest that contained a single egg, found in April in Cajas National Park, southern Ecuador (Schuchmann, 1999).

Many traits related to the breeding biology of bird species tend to show high levels of phylogenetic conservatism (Zyskowski & Prum, 1999; Fang *et al*., 2018); therefore, generalities about the breeding biology of *Metallura* species might inform about the reproduction of *M. baroni*. *Metallura* nests are usually located not high above the ground, mainly in rock ledges, caves, and embankments (Snow 1980; Schuchmann, 1999; Mamani-Cabana, 2020; Matta-Pereira *et al*., 2019; Soto-Patiño *et al*., 2021). Common nesting materials include mosses, lichens, small bird feathers, and mammal fur. As with other hummingbirds, females lay two eggs, and nest attendance is provided exclusively by the female (Schuchmann, 1999). However, it remains to be determined if those generalities apply to *M. baroni*.

Knowledge about the breeding biology of a species is key for learning about its natural history and it also can be useful for guiding scientifically sound conservation actions. In this manuscript, we provide detailed information about several aspects of the breeding biology of *M. baroni*, including characteristics of the nests, eggs, incubation time, and development of nestlings. This manuscript increases the knowledge about the basic biology of this endangered species, and the information presented can guide further research on the factors that influence the breeding success of the species.

METHODS

Study area
This study was conducted in Cajas National Park (CNP), Azuay province, southern Andes of Ecuador (-2.787222, -79.203055). This is a high-Andean national park with an elevation range from 3100–4450 m a.s.l. (Rodríguez-Girón *et al*., 2014). The temperature in the area has extreme daily fluctuations, commonly varying from 18 C° during day hours to -2 C° at night; the total annual precipitation ranges between 1000–1800 mm (Célleri *et al*., 2007), presenting a bimodal pattern with increasing rains from March to May, and from October to December (Campozano *et al*., 2016). The main vegetation type in CNP is páramo grasslands, with montane shrubs and montane forest occurring at lower elevations (below 3500 m a.s.l.). CNP is considered an important bird area for conservation (Freile & Santander, 2005; Astudillo *et al*., 2015), and it is part of the core area of Macizo del Cajas Biosphere Reserve (Rodríguez-Girón *et al*., 2014).

Data collection
We searched for nests of *M. baroni* along the borders of the Cuenca-Molleturo-Naranjal road, between Control Quinuas, 25.8 km from Cuenca (-2.784649, -79.193071; 3650 m a.s.l.) and Tres Cruces, 35.6 km from Cuenca (-2.777661, -79.240735; 4150 m a.s.l.). This is a paved road located in the north part of CNP, and connects two main cities in Ecuador, Cuenca and Guayaquil.

From January through February 2019, we visited the study area once every two weeks searching for nests, but when breeding activity was detected, we increased our sampling effort to visits every 3–6 days, until late May, when we did not find any new nests. On every visit, two observers walked along the two sides of the road, placing particular attention on embankments and rocky walls, as those are common places used by *Metallura* species to nest (Schuchmann, 1999; Mamani-Cabana, 2020; Soto-Patiño *et al*., 2021). The walks always started from Tres Cruces, at 8h00–10h00, and lasted c. 2–3 h. We are aware that roadsides might not be a high-quality habitat for *M. baroni* (Astudillo *et al*., 2014; Tinoco *et al*., 2019), but given the descriptive aims of this study, our observations are useful to provide basic ecological knowledge for the species.

The identity of nests was always confirmed by the observation of an adult *M. baroni* attending the nest. For each nest, we recorded the following variables: geographical coordinates with a handheld GPS, main habitat type around the nest, and nest shape type (*sensu* Simon & Pacheco, 2005). If the nest was located at less than 2 m in height above the ground, we took measurements of its external and internal diameter, height and depth of the internal chamber; all these measurements were taken with an analog caliper. We also noted the height above the ground of the nest using a measuring tape. For nests located above 2 m in height, we only estimated height above the ground in meters, and checked the status of the nest by using photos taken with a camera attached to an aluminum pole. One of the nests was collected after the breeding period to describe the materials used in its construction. Every nest found was visited at least once every 6 days to document the outcome of the breeding effort.

To obtain data about incubation time and nest attendance, we installed a time-lapse PlotWatcher Pro camera (Day 6 Outdoors) in one nest, once during the incubation period, for a total of 509 min, and once during the nestling period, at day 20 after hatching, for 233 min. The camera was set to take one picture every second. We could not install cameras in the other nests because most of them were exposed and located on the border of the road. We described the development of a pair of nestlings in one nest that was visually monitored by the observers from the hatchling day until nest abandonment by fledglings. We created a feather development table of the nestlings following Jongsomjit *et al.*, (2007).

RESULTS

Nest locations and season
We found a total of nine nests, all located between 3520–3990 m a.s.l. (Table 1). The first active nest was found on 4 March, while the last new active nest was found on 14 April. Eight nests were found in overhanging banks located at the border of the road (Fig. 1A), and one nest was found on the border of a small creek (less than 1 m wide), 5 m away from the road. In all cases, the surrounding habitat was páramo grasslands.

Table 1: General information about nine nests of Violet-throated Metaltail *Metallura baroni* found along the Cuenca-Molleturo-Naranjal road, Azuay province, Ecuador, in 2019.

Nest ID	Geographic Coordinates	Elevation (m a.s.l.)	Encounter date	Nesting stage in the encounter date	History of the nest
1	-2.800348, -79.29603	3525	4 March 2019	2 nestlings	1 egg depredated; 1 fledgling left the nest
2	-2.790281, -79.202500	3885	11 March 2019	2 eggs	2 eggs depredated
3	-2.787222, -79.203055	3820	16 March 2019	2 nestlings	2 fledglings left the nest
4	-2.789444, -79.201388	3875	22 March 2019	2 nestlings	Unknown
5	-2.787222, -79.206666	3925	22 March 2019	2 nestlings	2 nestlings died in the nest
6	-2.783888, -79.223333	3980	22 March 2019	2 eggs	2 eggs hatched, no further monitoring
7	-2.782777, -79.188611	3630	27 March 2019	2 nestlings	1 egg depredated; 1 fledgling left the nest
8	-2.788242, -79.205513	3925	4 April 2019	2 eggs	2 eggs depredated
9	-2.784166, -79.205555	3990	14 April 2019	2 nestlings	2 fledglings left the nest

Figure 1: A) Location of a Violet-throated Metaltail *Metallura baroni* nest (red circle) along an embankment in the Cuenca-Molleturo-Naranjal road, in a section that crosses Cajas National Park (Boris Tinoco). B) Placement of a *M. baroni* nest (red arrow) in the top of an embankment of the Cuenca-Molleturo-Naranjal road (Boris Tinoco).

Nest descriptions

The nests were found at 3.61 m above the ground, on average (N = 8; SD = 1.87 cm; range = 0.4–6.03 cm). The nests were attached to small rock ledges or were constructed within overhanging thin roots (Fig. 1B). The shape of all nests was open cup/late type. We took detail measurements of four nests, which presented the following mean sizes: external diameter 7.86 cm (SD = 0.87 cm; range = 7.36–9.25 cm), height 8.64 cm (range = 5.23–12.77 cm), internal diameter 4.13 cm (SD = 0.78 cm; range = 3.42–4.97 cm), depth of the internal chamber 3.28 cm (SD = 0,59 cm; range = 2.71–4.1 cm).

The outer layer of the one nest we disaggregated was made out of mosses, dry twigs, small rootlets, *Polylepis* (Rosaceae) bark, small dry leaves, spiderweb, animal fur, and small white flowers (Fig. 2A). The inner chamber was made of soft *Puya* sp. (Bromeliaceae) downy fibers and small feathers (Fig. 2B). Similar materials were observed in the other nests.

Figure 2: A) Shape and materials of a Violet-throated Metaltail *Metallura baroni* nest; an adult female incubating is present (Paúl Molina). B) Eggs (Boris Tinoco).

Eggs and nestlings
All the nests contained two white, oval eggs (Fig. 2B). Nestlings hatched with pink skin, yellow bill, and light cream neossoptiles in their dorsum (Fig. 3A). At day 10 since hatching, feather tracks started to emerge at the dorsal, wings, and head tracts, while their bills became darker towards the tip (Fig. 3B). By day 13 since hatching, some feathers started unsheathing and presented white tips, while some creamy feathers in their dorsum started to emerge (Fig. 3C). By day 16, larger feather pins were present in their heads and wings, showing a black base and whitish tips; moreover, creamy feathers had fully unsheathed in the dorsal tract (Fig. 3D). By day 22, feathers had fully unsheathed, and the nestlings were fully covered with feathers that were dark in the base and creamy at tip; flight feathers were dark green; the upper mandible was darker; a vaguely defined white postocular spot was present (Fig. 3E). By day 28, the fledglings were observed performing short flights outside the nest; they both conserved the neossoptiles in the dorsum, and the general color of the plumage resembled the dark green color of adults, although they did not present any iridescence on the throat; a well-defined postocular white spot was clearly visible at this age (Fig. 3F). In Table 2 we present a summary of the general feather development events according to our observation days.

We were able to determine the hatching day in two nests. The total nesting period, from hatching until fledglings abandoned the nests was 28 and 32 days, respectively.

Behavioral observations
Incubation and nesting attendance were exclusively performed by the female. During the incubation period, females visited the nest 2–6 times/h; in-nest bouts averaged 8.5 min (range: 1.1–13.7 min), while off-nest bouts averaged 4.9 min (range: 0.5–15.6 min). Females visited their nests to feed nestlings with a frequency of 4–5 visits/h, with an average visit length of 0.3 min (range: 0.1–1.2 min).

Nest success
We were able to monitor the outcome of seven nests. Two nests (28.5%) were successful and produce two fledglings, two nests (28.5%) were partially successful and produce one fledgling, and three nests (43%) lost their two nestlings. Two of these unsuccessful nests were preyed upon during the incubation period, as indicated by egg remains found in the nests, and one was abandoned during the nestling period, with two fledglings found dead in the nest (Table 1).

Table 2: Feather development table for nestlings of Violet-throated Metaltail *Metallura baroni* found along the Cuenca-Molleturo-Naranjal road, Azuay province, Ecuador, in 2019. Records come from one nest, and correspond to the observations of two nestlings. The day column refers to the day after hatchling. N, not visible; V, visible below the skin; P, pins above the skin; U, unsheathing; F, fully unsheathed. The two nestlings presented the same timing in their development.

Day	Head	Dorsum	Wings	Caudal track
1	N	N	N	N
10	V	P	P	P
13	P	U	U	U
16	U	U	U	U
22	F	F	F	F

DISCUSSION

This manuscript presents basic breeding information of the Ecuadorian endemic and threatened *M. baroni* in CNP, knowledge that can be used as a basis to expand on studies that explore the factors that determine breeding success in this species. A breeding period between November and April has been suggested for *M. baroni* (Schuchmann, 1999). Even though we did not find any nests in January and February, our observations fall within the time window suggested by Schuchmann (1999). The bird banding program carried out in montane

forest of CNP (Tinoco *et al.*, 2019) can also provide insights into the seasonality of the breeding season for *M. baroni*. This program samples birds in three climatic seasons of the year: rainy season (sampled in March–April), dry season (sampled in June–July), secondary rainy season (sampled in November) (Tinoco *et al.*, 2019). Of the 105 young *M. baroni* individuals captured in 2006–2018 in this banding program, only three were caught during the rainy season (B. Tinoco, unpubl. data). This result agrees with our observation that the nesting season of *M. baroni* coincides with the main rainy season (March–May). Nonetheless, an even sampling effort for nests across the year, and in different habitat types, is necessary to better determine the seasonality in the breeding period of *M. baroni*.

Regarding the general location of nests, nests architecture and nest materials, we can compare our findings with other description of *M. baroni* nests (Schuchmann, 1999), as well as to other *Metallura* species. Embankments, small cavities, and rocky walls are all common nest locations in *Metallura* hummingbirds (Snow, 1980, Matta-Pereira *et al.*, 2019, Mamani-Cabana, 2020). All the nine nests found were open cup-shaped, coinciding with the only other nest description for *M. baroni* (Schuchmann, 1999). Open cup nests have also been described for Tyrian Metaltail *M. tyrianthina* (Londoño *et al.*, 2014, Matta-Pereira *et al.*, 2019, Greeney & Juiña, 2020, Soto-Patiño, 2021) and Black Metaltail *M. phoebe* (Mamani-Cabana, 2020). We could not find previous information about nest dimension for *M. baroni*, but our measurements were similar to those reported for a *M. tyrianthina* nest in Colombia (Soto-Patiño, 2021), a *M. phoebe* nest in Peru (Mamani-Cabana, 2020), and a Coppery Metaltail *M. theresiae* nest in Peru (González, 2020).

The nesting materials found were similar to those used in nests of other *Metallura* species: mosses, twigs, roots, mammal fur, and spiderweb are all materials found in the external chamber of Neblina Metaltail *M. odomae* (Schuchmann, 1999), *M. phoebe* (Mamani-Cabana, 2020) and *M. tyrianthina* (Matta-Pereira, 2019; Greeney & Juiña, 2020, Soto-Patiño, 2021). Feathers are also reported in the inner chamber of *M. phoebe* (Mamani-Cabana 2020), *M. odomae* (Schuchmman, 1999), *M. theresiae* (González, 2020), and other high elevation hummingbirds, including Andean Hillstar *Oreotrochilus estella* (Carpenter, 1976) and Blue-throated Hillstar *O. cyanolaemus* (Molina *et al.*, 2021). Feathers as nesting material are likely being selected for birds in cold, high elevation environments due to their high insulation properties (Schöl & Hille, 2014). Overall, there is still much to learn about the nests of *Metallura* species, but there are many similarities among nests of all *Metallura* species, supporting the phylogenetic conservatisms in nest characters in birds (Fang *et al.*, 2018).

The cold temperatures prevalent at high elevations influence several life-history parameters associated with avian reproduction (Perfito *et al.*, 2014; Boyle *et al.*, 2015), including the duration of the nestling period (Bears *et al*, 2009; Bründl *et al.*, 2020). For instance, birds breeding at high elevations have longer nestling periods than those breeding in the lowlands (Badyaev, 1997; Altamirano *et al.*, 2015), a pattern probably related to a decrease in the energy available for reproduction in the high mountains (Boyle *et al.*, 2015). In correspondence, the nestling period of 28–32 days observed for *M. baroni* is longer than the nestling periods reported for lowland tropical hummingbirds (18–25 days; Fierro-Calderón & Martin, 2007). However, knowledge about the development time of nestlings is limited for tropical birds, and more studies about the reproduction of birds are needed to further understand how life histories can be shaped by environmental gradients.

We could not find studies on nesting success of tropical Andean hummingbirds to compare our observation of a 43% nest failure in *M. baroni* along a main road. However, nesting along roads may reduce nest survival because of road-related kills (Kuitunen *et al.*, 2003; Dietz *et al.*, 2013). Nesting on the side of the Cuenca-Molleturo-Naranjal road could expose adult females and fledglings alike to collisions with vehicles. Indeed, carcasses of *M. baroni* were reported in a bird road-kill study conducted in CNP (Aguilar *et al.*, 2019). The Cuenca-Molleturo-Naranjal road is likely acting as an ecological trap for birds in CNP (Astudillo *et al.*, 2014; Aguilar *et al.*, 2019), where birds are attracted to the sides of this road despite the high mortality risks that these areas represent (Astudillo *et al.*, 2014). The availability of novel nesting sites for *M. baroni* in the roadside embankments is likely attracting females to build nests along the Cuenca-Molleturo-Naranjal road, where nesting success could be affected. Measuring the effects of the road on *M. baroni* nesting success should be a research priority for the species, with important conservation management implications for CNP.

During this study, Blue-mantled Thornbill *Chalcostigma stanleyi* nested in the same roadside embankments used by *M. baroni*. On several occasions we even observed *M. baroni* females chasing away *C. stanleyi* from nesting areas. A limitation of nesting sites for high Andean birds can promote competitive interactions among

species (Carpenter, 1976), so this possibility should be further evaluated to learn more about interspecific interactions among birds in páramo habitats.

Future studies should expand knowledge about the breeding biology of *M. baroni*, since our results come from data gathered in a single páramo area along a main road. Populations of *M. baroni* are expected to keep declining in the future (BirdLife International, 2021), a problem that could be further aggravated by climate change in the high Andes (Laurance *et al*., 2011; Freeman *et al*., 2018). Therefore, sound conservation actions for this species should be guided by scientific knowledge about its natural history and its ecological needs.

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Figure 3: Nestlings' development in a Violet-throated Metaltail *Metallura baroni* nest. A) day 1 (identified by the presence of the remaining egg shale); B) day 10; C) day 13; D) day 16; E) day 22; F) Fledgling outside the nest (Paúl Molina).

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