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Breeding biology of the threatened Campo Miner *Geositta poeciloptera* (Aves: Scleruridae), a Neotropical grassland specialist

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ABSTRACT

The Campo Miner is a threatened grassland passerine endemic to the South American Cerrado, whose life history is almost unknown. In this paper, we studied during three breeding seasons (2014 to 2016) the breeding biology of a colour banded population of the species found in the Upper Rio Grande Grasslands, south-eastern Brazil. We found 98 nests, 81 of which became active and were monitored. The Campo Miner breeds in frequently burnt-and-grazed natural grasslands, successfully nesting in highly disturbed sites, such as dirt banks along roads and even in mine pits. The species is socially monogamous and both parents build the nest, which is a cavity/with-tunnel/simple/platform type. The nest chamber is lined with a platform made of grass fragments, charcoal, hairs, and mammal faeces. The most common clutch size is three eggs (n = 66), with some nests containing one (n = 1), two (n = 12) or four eggs (n = 2). The egg is white and pyriform and the incubation, performed by both parents, lasts 17.5 days. Mean nestling period is 15.5 days, with both parents feeding the young. Breeding season lasted for about 125 days (August to December) and multiple breeding attempts in a single season were common, with a maximum of three attempts recorded. All species of Scleruridae built their nests inside cavities dug in the soil with an access tunnel to it, where they lay a small clutch (usually 2–3 white eggs), but no other species in the family has been studied in detail to date. Further studies are required to understand why a species apparently tolerant to anthropogenic impacts such as *G. poeciloptera* can be so rare, patchily distributed and threatened throughout its range.

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Introduction

Recent ornithological studies revealed distinct life history patterns and reproductive strategies, allowing hypotheses about the evolution of behavioural ecology or increasing the efficacy of management and conservation strategies (Boyce 1992; Reed et al. 1998; Robinson et al. 2000; Auer et al. 2007; Marini et al. 2007). Unfortunately, life history patterns and reproductive strategies are poorly known for most Neotropical bird species (Stutchbury and Morton 2001; Bennet and Owens 2002; Xiao et al. 2017).

Although the last two decades have witnessed an enormous growth in number and quality of studies about the breeding biology of some common birds in the grasslands and savannahs of South America (e.g. Lopes and Marini 2005; Oliveira et al. 2010; Marini et al. 2012), we still have much to learn about those rare and threatened species. A good example of poorly studied species is the Campo Miner (*Geositta poeciloptera*, Scleruridae), an insectivorous and terrestrial passerine (Sick 1997; Remsen 2003; Ridgely and Tudor 2009) endemic to the Cerrado biogeographic province (Silva and Bates 2002). The species is uncommon and patchily distributed in the open grasslands of central-south Brazil, reaching eastern Bolivia and Paraguay (Remsen 2003; Ridgely and Tudor 2009). Given the high population decline suffered, caused by rampant destruction and fragmentation of its habitat, the Campo Miner is a globally Vulnerable species (BirdLife International 2017), considered Endangered in Brazil (MMA 2014). It is a cavity-nesting bird, whose breeding biology is known from anecdotal observations (Remsen 2003; Silva e Silva 2008).

In this paper, we provide the first comprehensive study of the breeding biology of the Campo Miner, aiming to: (1) estimate the breeding season of the species; (2) describe its nest and eggs; (3) investigate sex roles when breeding; and (4) estimate its life-history attributes.

Methods

Study area

We conducted fieldwork in the municipality of São João del-Rei, in a region known as the Upper Rio Grande Grasslands (URGG), southern state of Minas Gerais, Brazil (Figure 1). The URGG is a large (~1.2 million ha) mountainous region, with elevations of 900–1600 m, mostly covered by natural open grasslands, with semi-deciduous forests along creeks and lower areas (Azevedo 1962). The local climate is Cwb according to the Köppen Climate Classification System, which means a humid subtropical climate with dry winter and wet temperate summer, with ~1500 mm of mean annual precipitation and 14.3°C mean temperature during winter and 17°C during summer (Sá Júnior et al. 2012). Extensive cattle ranching and eucalyptus plantations are the main economic activities in the region (IBGE 2016). The grassland sites studied, although covered by native grasses, suffer from frequent fires, presenting a short and sparse grass cover.

Data collection

We observed colour-banded birds with binoculars from July 2014 to December 2016, recording their behaviour during nest building, incubation, nestling care, and nest

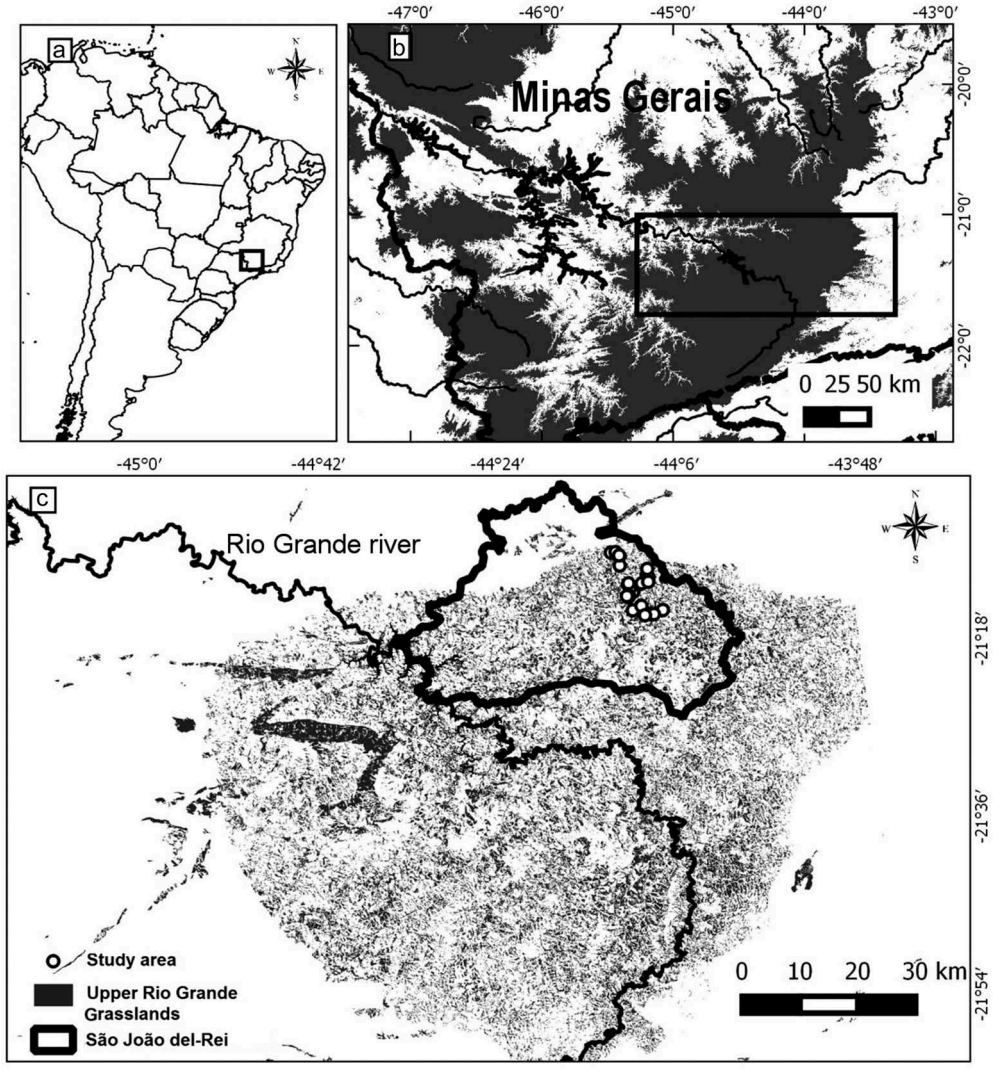

Figure 1. (a) Location of the study area. (b) Detail of the study area, depicting the Rio Grande. Grey areas are above 900 m asl. (c) Detail of the study area, depicting the limits of the municipality of São João del-Rei and the remaining patches of natural grasslands according to Carvalho and Scolforo (2008). Records of the Campo Miner for other municipalities were not depicted.

defence, among others. Whenever possible we refer to pictures illustrating typical behaviours of the species (http://en.wikiaves.com).

We looked for nests by: (1) searching for cavities in the ground; (2) searching in dirt banks along dirt roads; and (3) observing parental behaviour. We monitored nests with a borescope at intervals of one to three days. The length of the intervals (incubation and nestling periods) was estimated assuming that alterations in nest status occurred at the midpoint between the penultimate and final checks. Incubation period was considered as the time from laying of the last egg to hatching of the first egg. Nestling period was considered as the time from hatching of the first egg to fledging of the last young.

Length of the breeding season was considered as the time from building of the first nest until fledging of the last young. Eggs collected from abandoned or partially damaged nests (see below) were measured with a calliper (to the nearest 0.1 mm). A measuring tape (to the nearest 0.5 cm) was used to measure the depth of the nest cavity, the height and width of the entrance hole of the nest cavity, the distance from the entrance of the nest hole to the top of the bank where the nest is placed, and the distance from the entrance of the nest hole to the base of the bank where the nest is placed.

All linear measurements are presented as means ± standard deviation (SD). The relationship between the time spent on building activity (including digging and the platform construction) and the date of nest initiation was evaluated with a linear regression (Zar 1996) in R program (R Core Team 2016). It is expected that birds would build nests faster in the late breeding season than in the early breeding season due to time constraints.

Results

We captured and banded 95 birds, including four fledglings, 33 of which were resighted at least once. One resighted bird was soon depredated while incubating and four other birds disappeared soon after banding. Therefore, 28 birds were monitored for at least two months, with eight of them monitored during the three reproductive seasons (~18 months).

Sex identification

Sexes of the Campo Miner are alike, but it is possible to identify it with the aid of behavioural cues. Males show stronger territorial behaviour and are more vocal than females, often singing during hovering display flights. Females are shyer and seldom sing, usually during duets. Only once we observed a female exhibiting the hovering flight display. Field identification of the sex of 42 individuals was confirmed after collecting small blood samples that were sent to a private laboratory for molecular sexing.

Courtship behaviour

Male and female chase one another during courtship, with short flights near the ground. After that, the male perches on the ground in front of the female, and, with raised crown, throat, and breast feathers, tirelessly sings while flapping its wings. The male also performs low and brief hovering flight displays (about 1 m height) in front of the female, who stays perched on the ground. These displays are repeated several times, intercalated with brief perches, with the male barely touching the ground, until copulation occurs.

Nesting

We found 98 nests, 81 of which became active and were monitored. Nests studied in 2014 were found during its building (77.4%, $n = 41$), incubation (13.2%, $n = 7$) or nestling

(9.4%, n = 5) periods. During the 2015 and 2016 season, we did not record the nest building period. Nonetheless, we found nests during incubation (84%, n = 21) and nestling (16%, n = 4) for 2015, while in 2016 all nests (100%, n = 20) were found during incubation.

Length of the breeding season

The 2014 breeding season extended for 135 days, with the first active nest found under construction on 3 August, and the last active nest checked on 15 December, when its nestling fledged. During the 2014 breeding season, two nests with eggs remained active through January and the first week of February 2015, but given that these eggs failed to hatch and their incubation period was unusually large (31 and 55 days, respectively), we did not consider these two nests in the estimation of the length of the breeding season. The 2015 breeding season extended for 116 days, with the first active nest found on 18 August, and the last active nest checked on 11 December. During the 2016 breeding season, the first nest was found with eggs on 2 September, but fieldwork was interrupted on 28 November, before the end of the breeding season.

The largest number of active nests occurred during the last period of September until the mid-period of October (each month was divided in three 10-day periods) (Figure 2), and most nest initiations (estimated only in 2014 from nests found under construction) occurred during the second period of August.

Nest description

Nests of the Campo Miner are built inside a cavity dug in the soil with an access tunnel to it (Table 1, Figure 3), consisting of a tight platform made with soft material that

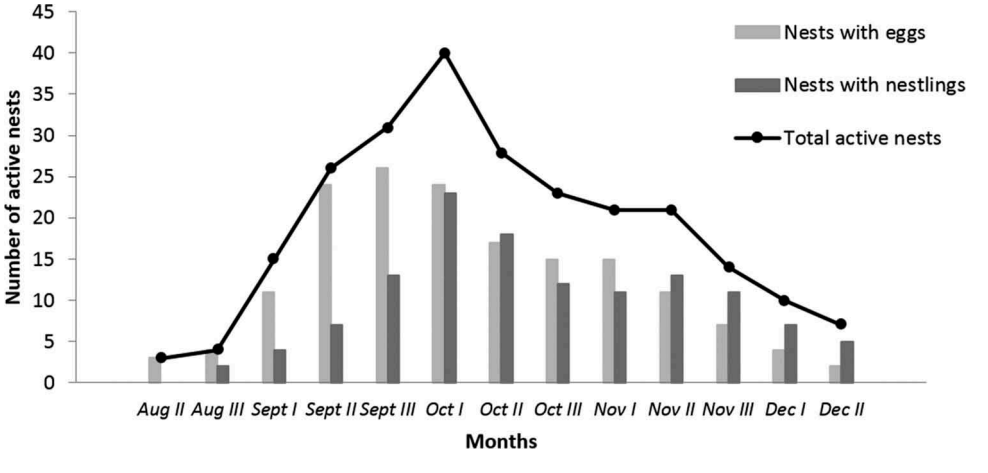

Figure 2. Number of active nests of the Campo Miner found during the 2014 to 2016 breeding seasons in São João del-Rei, south-eastern Brazil. Each month was subdivided in three periods of 10 days each (I, II and III) and each nest was counted only once during each stage: nest with eggs (day of laying of the first egg) and nest with nestlings (day of hatching of the first egg). Each nest was counted only once for tallying the number of active nests.

Table 1. Morphometric characters of 70 nests of the Campo Miner *Geositta poeciloptera* found in the Upper Rio Grande Grasslands, municipality of São João del-Rei, Minas Gerais, Brazil. All measurements are in cm.

Character	Mean (cm)	SD (cm)	Min (cm)	Max (cm)
Height of the entrance hole	8.57	2.52	4.5	18.0
Width of the entrance hole	8.69	1.81	6	14.0
Distance from the entrance hole to the top of the dirt bank	50.47	46.65	6	300
Distance from the entrance hole to the base of the dirt bank	72.87	33.87	25.0	198
Tunnel depth	42.52	9.4	29.5	73

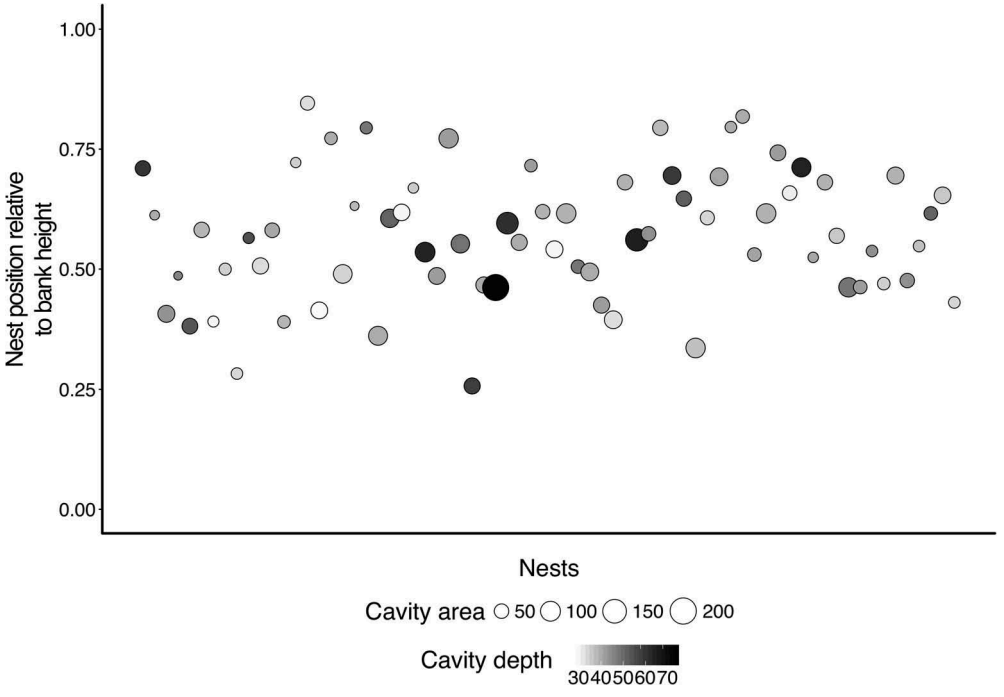

Figure 3. Relationship between cavity area, cavity depth, and relative position in the soil profile of 70 nest of the Campo Miner found during the 2014 to 2016 breeding seasons in the municipality of São João del-Rei, south-eastern Brazil.

cushions the eggs, fitting the nest type cavity/with-tunnel/simple/platform of Simon and Pacheco (2005) (Figure 4). Almost all nests were excavated in dirt banks (n = 89), with a few nests dug in the walls of armadillo's burrows (n = 2), in the walls of abandoned nests of the Campo Flicker (*Colaptes campestris,* n = 2) and the Burrowing Owl (*Athene cunicularia,* n = 1), in the wall of a hole dug in the ground to install a post fence (n = 1), or in a small abandoned mining pit (n = 1). Two additional nests were found in abnormally large cavities, possibly excavated by the Campo Flicker. Most nests found in dirt banks were built along road cuttings (61.5%, n = 56), with some nests built in ravines/gullies (30.7%, n = 28) or in eroded cattle trails (7.7%, n = 7). In all these cases, the dirt banks had no vegetation cover.

Both parents dig the nest and although we have not quantified the time spent by each sex on such activity, the male apparently dedicates more time to it. Soil is

Figure 4. (a) Entrance hole of a nest of the Campo Miner dug in a dirt bank along a dirt road; (b) the nest chamber (opened after being partially damaged by cattle activity); (c) materials used to line the nest, clockwise from left, mammal faeces, grass and other plant fragments, mammal hairs and charcoal fragments; (d) eggs. Photographs by TLSSM.

excavated with the bill, while the feet are used to remove the loose dirt from the cavity. The nest chamber is oval shaped and the access tunnel to it is curved. Both parents built the platform, which is made of grass fragments, charcoal, hairs, and mammal faeces (Figure 4). New material is continually added to the nest, even after egg hatching.

We observed large variation in the amount of time spent in nest building (including digging and the platform construction), ranging from three to 61 days, with a mean of 19.0 ± 15.8 days (n = 24). Generally, nests were built faster in the late breeding season than at the beginning (R^2 = 0.275, p = 0.005) (Figure 5).

Eggs and incubation

Eggs are pyriform and pure white (Figure 4), with mean length of 20.5 ± 0.7 mm (19.5–22.0 mm, n = 10) and mean width of 16.8 ± 0.5 mm (15.9–17.5 mm, n = 10). Usual clutch size is of three eggs (n = 66), with some nests containing one (n = 1), two (n = 12) or four eggs (n = 2). Eggs are laid on consecutive days or on each other day, with synchronous incubation and hatching. Parent birds seldom enter the nest when there is only one egg in it. After the second egg is laid, parent birds perform frequent visits to the nest, adding

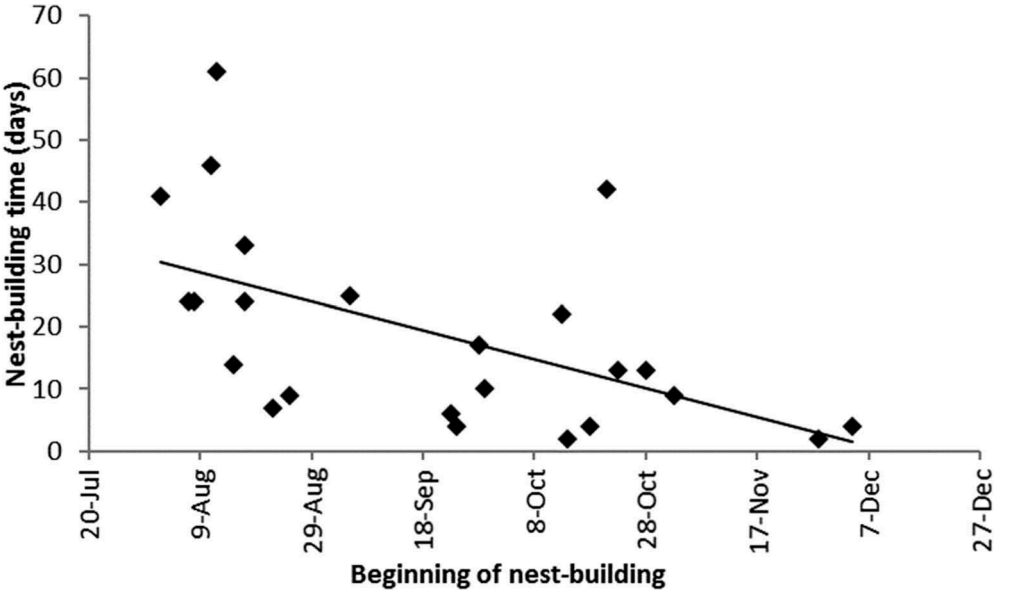

Figure 5. Relationship between the time spent on building activity (including digging and platform construction) and the date of nest initiation in 24 nests of the Campo Miner monitored in south-eastern Brazil during the 2014 breeding season.

fresh material to it, but usually spend less than 10 min inside the nest cavity. Both parents incubate, an activity that extends for 17.5 ± 1.9 days (ranging from 15–20 days, n = 37).

Nestlings and parental care

Mean nestling period was 15.5 ± 1.5 days (ranging from 15–19 days, n = 43). Both parents feed the nestlings, throwing away the faecal sacs. Nestlings are very vocal and start begging as soon as their parents approach the nest. Near-fledge nestlings usually wait for their parents in the entrance tunnel.

Newly hatched nestlings have pinkish skin and closed eyes, upper head and back covered with greyish downy feathers, pinkish bill with blackish tip and yellowish gape. The eyes open and the first pin feathers emerge in the wings and tail on the sixth day of life. Pin feathers emerge in the head on the eighth day. Nestlings are fully feathered by the 14th day.

Recently fledged birds can be identified by their short wings and tail, and by their short bill with enlarged yellowish gape. The juvenal plumage resembles the definitive basic plumage, but juvenile birds can be identified by their ochraceous superciliary line. Given that juvenile birds disperse before moulting to the first basic plumage, we were unable to determine for how long the juvenal plumage is retained. The first basic plumage is like the definitive basic plumage.

Young birds stay concealed amidst grass clumps in the first two days after fledging and, due to their cryptic plumage and behaviour, can hardly be seen. After the third day, the young became more active, walking on the ground while their parents search for

food, which is exclusively arthropods, such as grasshoppers, crickets, ants, and termites. Juveniles stay in their natal territory for about three weeks, dispersing afterwards. A young bird was observed in the natal territory 55 days after fledging and, although still exhibiting the juvenal plumage, was accompanied by another bird and exhibited the aerial hovering display in response to the playback.

Two nestlings (~12 days old) were parasitized by botfly larvae (*Philornis* sp., Muscidae), as directly verified in a cavity that was damaged by an ox that rubbed his horns against the dirt bank. Although this nest was damaged during incubation, the breeding pair continued to take care of it and, surprisingly, the two nestlings successfully fledged. Probably botfly larvae parasitism is more common than we recorded, because the images obtained by the borescope were not sharp enough to allow the visualization of the parasites.

Nests are defended by both parents, which aggressively walk on the ground while calling to distract potential predators. Males also relentlessly perform the hovering flight display, exhibiting the large rufous band across flight feathers, as well as the pinkish-chestnut underwing coverts, tipped whitish (e.g. WA1384753). Excited birds also raise crown, throat, and breast feathers, exhibiting their dark bases (e.g. WA144977).

Multiple breeding attempts

Multiple breeding attempts were not unusual, and at least 11 of the 55 pairs effectively monitored performed two or more breeding attempts during the same breeding season. One of these pairs performed a third breeding attempt, even after success in the two previous nests. We observed nest reuse on three occasions, even though the previous breeding attempts failed. Reused nests were meticulously cleaned, with all the material used in the construction of the platform being ejected. New material was added to the nest, but few bits of old material were brought back to it. On four occasions, the excavation of a new nest for a subsequent breeding attempt began soon after fledging, with the male being responsible for it, while the female took care of the young.

Social structure

The Campo Miner is a socially monogamous species and pair bonds persist year-round. New pair-bonds were usually formed only when a mate died or disappeared. On one occasion, a female paired with another male seven days after her former mate was depredated while incubating. This female made another breeding attempt, but her nest was depredated again. Few days later, this same female was observed in the territory of a third male, whose mate has also been depredated few days before, but soon returned to her territory, disappearing two days later. Unpaired birds were observed on only five occasions. We exceptionally observed small groups of up to seven birds, usually juveniles, at the end of the breeding season (e.g. WA2153692). These small groups freely crossed the borders of several territories while foraging, without signs of interspecific aggression.

We recorded mate abandonment during the breeding season on six occasions. One female left her mate soon after her three young fledged, moving to a neighbouring territory, where she kept on taking care of them. Soon after the young dispersed, the

female paired with the territory owner and made a second breeding attempt. Her former mate stayed unpaired in his territory during the rest of the breeding season.

Interspecific agonist interaction

Display flights are usually elicited when the Campo Miner detects potential predators, as well as in the presence of other cavity nesting birds that usually usurp their nests, such as the Tawny-headed Swallow (*Alopochelidon fucata*). Such displays, which sometimes resulted in vigorous chases (but seldom with physical interaction), were more commonly observed during nest building. Conversely, the aggressive Tawny-headed Swallow and, to a lesser degree, the Southern Rough-winged Swallow (*Stelgidopterix ruficollis*), directed attacks toward the Campo Miner throughout the year, sometimes in groups.

Discussion

All species of Miners nest inside cavities dug by the bird themselves or by other birds or mammals (Vaurie 1980; Narosky et al. 1983; Fraga and Narosky 1985; Remsen 2003; de la Peña 2013). Cavity nesting behaviour is also shared by all species of Leaftossers (*Sclerurus*) (Vaurie 1980; Remsen 2003), a genus which includes several species of forest dwelling passerines that, together with *Geositta*, are the only two genera of Scleruridae (Cheviron et al. 2005; Ohlson et al. 2013).

Silva e Silva (2005, 2008), who studied the breeding biology of the Campo Miner in Tapira, western Minas Gerais, recorded a breeding season similar to the one that we found, with the first active nest observed in the last days of July and the last nestlings fledging in December (Silva e Silva 2005). This same author reported that the nests were dug in dirt banks, armadillo burrows, or termite mounds. Willis (2004) reported a nest on an armadillo burrow found on 29 June in the state of São Paulo. Pinto (1936) observed several nests of the species along a ravine on October, in southern state of Goiás.

Material used for building the platform by the Campo Miner is similar to that used by other species of Miners, but differs by the use of mammalian faeces, a kind of material that, to the best of our knowledge, has never been reported to be used by any other Scleruridae (Remsen 2003; de la Peña 2013). Faeces used were from carnivorous mammals, as suggested by the large amount of hairs on them, and were always added to the nest after egg laying. We hypothesize that carnivorous faeces may hamper nest predation, because some animals may avoid places from which chemical cues suggest the presence of a predator (Kats and Dill 1998), as demonstrated by Schuetz (2005), who found that artificial nests containing faeces survived at higher rates than nests without faeces.

Small clutch size is typical of tropical passerines (Yom-Tov et al. 1994; Jetz et al. 2008), and clutches of two or three eggs have also been recorded for the Creamy-rumped Miner (*G. isabelina*), the Short-billed Miner (*G. antarctica*), the Rufous-banded Miner (*G. rufipennis*), and the Puna Miner (*G. punensis*) (Remsen 2003).

Long-term monogamy is also common in tropical passerines, contrasting with the more frequent mate switching observed in temperate regions (Morton et al. 2000; Fedy and Stutchbury 2004). Although the Campo Miner is socially monogamous and several pairs were recorded together even after the end of the breeding season, the relative

high number of mate switching events we recorded, as well as the causes for them, deserves further investigation.

Multiple breeding attempts in the same breeding season generally occur in response to the loss of previous nests (Fondell et al. 2006) and is a common strategy in species that suffer with high rates of nest predation (Claassen et al. 2014). For example, four or more breeding attempts in a single breeding season have been recorded for several species of passerines in the Cerrado (Lopes and Marini 2005; Aguilar and Marini 2007). The relatively low number of breeding attempts recorded here might not represent real numbers, because some breeding pairs abandoned their territories soon after fledging the first nestlings, hampering the investigation of such phenomena. Given that some birds only paired in the middle of the breeding season, another possible cause for a low number of breeding attempts might be late-pairing, because the number of possible breeding attempts is strongly tied to the date of first nesting attempt (Fondell et al. 2006; Claassen et al. 2014).

Males of the Campo Miner exhibit aerial displays in multiple contexts, including courtship behaviour, nest protection and territorial defence. Aerial displays are common among other congeneric species, being also frequent in some genera of terrestrial Furnariidae living in grasslands, such as *Cinclodes* (Remsen 2003). Such displays can, for example, reduce risks of injury during aggressive encounters (Grafe and Bitz 2004; Murphy 2008).

This is the first detailed study about the breeding biology of a species of Scleruridae, laying the foundation for new studies about the ecology of an entire Neotropical bird family. We demonstrated that the Campo Miner can inhabit frequently burn and grazed grasslands, successfully breeding in highly disturbed sites, nesting in dirt banks along roads and even in mine pits. We are now conducting further studies to understand why a species apparently tolerant to anthropogenic impact can be so rare, patchily distributed and threatened throughout its range.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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