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ECOLOGY AND BEHAVIOR

Effect of Shiny Cowbird (*Molothrus bonariensis*) brood parasitism on the reproductive success of the Rufous-collared Sparrow (*Zonotrichia capensis*) in Bogotá, Colombia

Efecto del parasitismo de cría de *Molothrus bonariensis* sobre el éxito reproductivo de *Zonotrichia capensis* en Bogotá, Colombia

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ABSTRACT

Obligate avian brood parasites lay their eggs in the nest of other bird species, or hosts, which negatively affects their reproductive success. Little information has been published about this strategy in the Neotropics, specifically in Colombia. In Bogotá, the Rufous-collared Sparrow (*Zonotrichia capensis*) population has decreased while the Shiny Cowbird (*Molothrus bonariensis*) population has increased. Brood parasitism is proposed as one of the causes of these demographic changes. To evaluate and quantify the effect of the Cowbird parasitism on the Sparrow reproductive success, I searched and monitored nests for twelve months in the city. I found 28 host nests, 48 % of which were parasitized, with an average of three Cowbird eggs per nest. I found evidence of negative effects on the reproductive success of the host, with parasite egg pecking and host nest desertion due to multiple parasitisms. Overall, my results showed that parasitized nests rarely succeed, and with nearly half of the nests being parasitized, a negative effect on the population is expected. Even though nest desertion does not produce parasitic chicks, intraspecific female competition and multiple parasitism may cause an oscillatory dynamic between the populations of both species. More studies including other hosts and long-term monitoring are needed to robustly assess the scenario of brood parasitism in this region of Colombia.

Keywords: avian brood parasitism, antiparasitic defenses, *Molothrus bonariensis*, nest desertion, *Zonotrichia capensis*

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RESUMEN

Los parásitos de cría obligados depositan todos sus huevos en nidos de otras especies, los hospederos, lo que afecta negativamente su éxito reproductivo. Poca información se ha publicado al respecto en el Neotrópico y, especialmente, en Colombia. Una investigación evidenció que en Bogotá la población del copetón o pinche (*Zonotrichia capensis*) disminuyó mientras la de un parásito de cría, el chamón (*Molothrus bonariensis*) aumentó. En este trabajo busqué evaluar y cuantificar el efecto del parasitismo del chamón sobre el éxito reproductivo del copetón. Para esto busqué y monitoreé nidos durante doce meses en una localidad dentro de Bogotá. Encontré 28 nidos, 48 % fueron parasitados con un promedio de al menos tres huevos. Obtuve evidencia de que el parasitismo tiene un efecto negativo sobre el éxito reproductivo del hospedero, cuyas causas principales fueron el abandono de nido por parasitismo múltiple y la picadura de huevos por parte del parásito. En general, los resultados demuestran que los nidos parasitados casi nunca son exitosos, por lo que se puede esperar un efecto negativo sobre la población. Sin embargo, el abandono de nido tampoco produce polluelos del parásito, por lo que la competencia intraespecífica entre hembras y el parasitismo múltiple podría causar una dinámica oscilatoria en la población de las dos especies. Futuros estudios deberían incluir otros hospederos y un enfoque de monitoreo a largo plazo para evaluar robustamente la situación del parasitismo en esta región del país.

Palabras clave: parasitismo de cría, defensas antiparasitarias, abandono de nido, *Molothrus bonariensis*, *Zonotrichia capensis*

INTRODUCTION

Obligate avian brood parasitism is a breeding strategy used by bird species that have lost their nest building and parental care abilities, wherein the female only lays her eggs in the nest of another bird species, the host, that will go on to rear the parasite's offspring (Friedmann 1929, Rothstein 1990, Zink 2000). By relying on host species, the parasite avoids the energetic investment of building a nest, defending it from predators, and raising the young (Zink 2000, Fiorini *et al.* 2019). Strategies to increase brood success, such as removal of host eggs and faster and earlier development of eggs and chicks have been adapted by many parasite species (Payne 1977, Hauber 2003). However, parasitism may carry adverse reproductive effects on the host species and their populations, especially on smaller hosts that face synergistic habitat fragmentation, degradation or other threats (Payne 1977, Rothstein *et al.* 2002). Much of these effects have been observed in Old World and North America bird host species, but little information is available about parasite-host relationships in the Neotropics (Fiorini *et al.* 2019).

The Shiny Cowbird (*Molothrus bonariensis* (J. F. Gmelin, 1789)) is the most widespread avian brood parasite in the Neotropics, parasitizing nearly 280 species across its entire distribution (Lowther c2024). Cowbirds are insectivores that prefer grasslands and open areas (Hilty and Brown 2001), at altitudes below approximately 2600 m above sea level (Valencia-Aguilar and Auqui-Calle 2024). Along its wide distribution the Shiny Cowbird more frequently parasitizes certain host species, such as the Rufous-collared Sparrow (*Zonotrichia capensis* P. L. S. Müller, 1776), (Lowther and Post 2020, Rising and Jaramillo 2020). There has been some research on their reproductive history in Argentina and Brazil (King 1973, Fraga 1978, Reboreda *et al.* 2003, Fernández and Duré 2007) but in Colombia almost no information has been published (Miller and Miller 1968).

In the sprawling metropolitan area of Bogotá, the general public, birders, and researchers have noted a reduction in *Z. capensis* abundance, which is even captured by Status & Trends demographic models of eBird (Fink *et al.* c2024). In a 26-year census study, Stiles *et al.* (2017) suggested a possible explanation for this: brood parasitism by *M. bonariensis*. This idea comes from their observations in the city, where they recorded increasing numbers of *Z. capensis* couples feeding parasitic fledglings; meanwhile, the *M. bonariensis* abundance increased in the same period (Stiles *et al.* 2017). Moreover, it has also been proposed that this growth may be explained by changes in land cover, as the Cowbird benefits from disturbances made by humans (Villaneda-Rey and Roselli 2011) and other bird species tend to decline with habitat degradation (Rothstein 2004, Stiles *et al.* 2017). To determine whether there is a negative effect on the reproductive success of the host, I quantified and analyzed the reproductive relationship between *M. bonariensis* and its host *Z. capensis* in Bogotá, Colombia. By searching and monitoring Sparrow nests for twelve months, I aimed to 1) determine the frequency and intensity of parasitism, and 2) evaluate the effect of parasitism on host nest success.

MATERIALS AND METHODS

Study area

Bogotá is located in the eastern Andes of Colombia at an altitude of 2650 m above sea level and has an annual total precipitation of 1000 mm (Angel *et al.* 2010). Despite being the most populated city in Colombia, Bogotá is surrounded by patches of Andean forest and has numerous green and wooded areas in an urbanized matrix. I monitored *Z. capensis* nests at three sampling locations within the Universidad Nacional de Colombia, in Bogotá (site 1: 4°38.51'N, 74°5.21'W; site 2: 4°38.13'N, 74°5.35'W; site 3: 4°38.44'N, 74°4.88'W). The locations share a domain of herbaceous vegetation, mainly kikuyo grass (*Cenchrus clandestinus* (Hochst. ex Chiov.) Morrone), with the presence of some arboreous and bushes elements both native (*Salix humboldtiana* Willd., *Inga nornata* Kunth, *Alnus acuminata* Kunth, *Ficus soatensis* Dugand) and introduced (*Tecoma stans* (L.) Juss. ex Kunth, *Pittosporum undulatum* Vent., *Cotoneaster pannosus* Franch., *Pinus radiata* D.Don) (Infante-Betancour *et al.* 2008).

Nest searching and monitoring

From February 2018 to January 2019 I actively search for *Z. capensis* nests in the field four hours per day (in the mornings), four days per week. The total sampling effort of the nest searching was approximately 768 hours of field time. Although I did not band individuals, I identified *Z. capensis* pairs by their fidelity to a territory (Miller and Miller 1968). I followed between 15-18 pairs distinguished by their territories. I used reproductive-related behaviors to find nests, such as nest material transport, search and delivery of food for the chicks, and flushing of adults from the vegetation.

After finding an active nest, I conducted visits every two days until the young fledged or the nest failed (predated or deserted). I consider a nest parasitized when it had at least one parasite egg or nestling. Once I found a nest I recorded the date and nest stage (building, laying, incubation or nestling) and in each visit I registered the number of host eggs or nestlings and the number of parasite eggs or nestlings. I consider a nest was deserted when the parents were not active at the nest (i.e., no presence at the nest or at the surrounding) and the eggs were cold on two consecutive visits. I recorded predation when the entire egg or nestling clutch was lost between visits. To avoid researcher-influenced parasitism or predation, I made short visits to the nests and tried not to leave evidence of my visits to the nest sites.

Data Analysis

Frequency and intensity of parasitism – I calculated the frequency of *M. bonariensis* parasitism on *Z. capensis* as the proportion of parasitized nests over the total number of nests, and the intensity as the number of parasitic eggs laid in a parasitized host nest. For both calculations one nest was excluded due to nest damage. For these calculations I only considered nests found during egg laying or incubation stages because during these stages brood parasitism could derive in nest failure and including nests in the fledgling stage could underestimate the parasitism frequency (Tuero *et al.* 2007). To obtain a unique value of the intensity of parasitism on the host nests, I averaged the number of parasite eggs laid in parasitized nests. The monthly distribution of nests was plotted with the R package ggplot2 (Wickham 2016).

Brood parasitism effect – To evaluate whether the fate of *Z. capensis* is predicted by *M. bonariensis* parasitism, I used a binomial generalized linear model (glm) of the package lme4 (Bates *et al.* 2015) in the R programming software version 4.4.1 (R Core Team 2025) only with nests with a known fate ($n = 22$ nests). The fixed variable was the condition of each nest (parasitized or non-parasitized), and the response variable was nest fate, success or failure, considering success as a nest producing host fledglings. I do not include site location in the model due to the invariance in vegetation characteristics at each nest site and also a binomial generalized model including this variable did not show statistical support (Location 2 $p = 0.960$; Location 3 $p = 0.994$). Although there were a few cases of renesting after predation or desertion, I consider each nest as an independent event and used a glm instead of a generalized linear mixed model (glmm). Finally, to communicate the results I used language of evidence as proposed by Muff *et al.* (2022) that allows for a more nuanced approach and to avoid an arbitrary p-value threshold.

RESULTS

I found 28 nests of *Z. capensis* of which nearly 40 % of which were found in July and August (n = 11; Fig. 1). Of these nests, six were found in the building stage, 16 in the incubation stage, and the remaining six were found in the nestling stage. I registered a total of 41 *Z. capensis* eggs, the most common clutch size was two (13 nests), and 22 host chicks were observed at different growth stages.

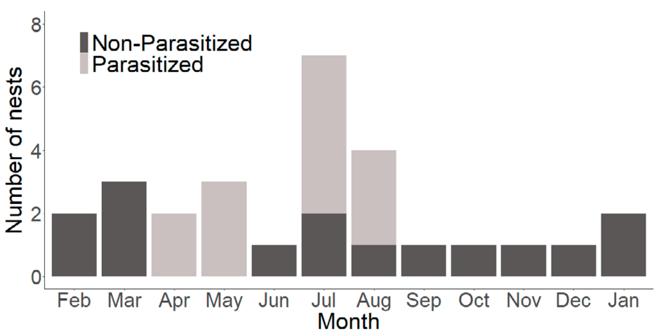

Figure 1. Monthly distribution of *Z. capensis* nests recorded from February 2018 to January 2019 in the study area of Bogotá, Colombia. Total number of nests = 28, non-parasitized nests = 15, and parasitized nests = 13.

Frequency and intensity of parasitism

The frequency of parasitism was 48 % (10 nests), considering only the nests found during the laying/incubation stage (n = 21 nests). Parasitism intensity was 3.3 ± 0.3 parasite eggs per parasitized nest (mean and SE, n = 31 eggs in 9 nests), with a range of 1 to 5 parasitic eggs per nest. There was also evidence of parent host egg ejection due to parasite pecking in six nests, one or two host eggs were pecked (4 and 2 cases respectively) and in two nests there were also eggs of the parasite pecked; all these nests were deserted. I also observed variation in *M. bonariensis* egg color; two eggs were completely white, unlike the common brown and white coloration (Fig 2).

Parasitism effect on the host nest success

Of 28 nests, seven were successful (host fledglings production), nine were deserted, two produced only parasitic chicks, and ten were predated or damaged by anthropic activities such as lawn mowing. I found moderate evidence for a negative effect of parasitism on nest success (estimate = -2.4849, SE = 1.211, z value = -2.052, p = 0.040). The probability of a non-parasitized nest being successful was 0.545 (6/11), while the probability for a parasitized nest being successful was 0.091 (1/11), and the effect of parasitism was an almost six-foldtime reduction in nest success probability (host fledgling production probability). Desertion was common in parasitized nests (7 of 13 nests), whereas predation was the mean cause of nest failures of non-parasitized nests (4 of 15 nests).

Figure 2. (a) Parasitized nests with two eggs of *Z. capensis* (top left, smaller and bluish eggs) and four eggs of *M. bonariensis*. (b) Parasitized nest of *Z. capensis* with no host eggs and two *M. bonariensis* eggs of different morphs: one egg of the more common spotted pattern (top egg) and one of the immaculate white morph (bottom egg). (c) Nestlings of *Z. capensis* (left) and *M. bonariensis* (right), despite the marked differences in size, *Z. capensis* nestlings were more developed with open eyes and broken pin feathers.

DISCUSSION

Avian brood parasitism strategy may cause a reduction in the breeding success of hosts and smaller host species could experience higher costs (Rothstein *et al.* 2002). In this study I found that *M. bonariensis* parasitized almost half of *Z. capensis* nests and the parasite laid on average more eggs than the host per nest. I also recovered statistical support for a negative effect of brood parasitism on the reproductive success of the host. This supports the hypothesis that *M. bonariensis* brood parasitism could be involved in the population decline of *Z. capensis* in Bogotá, but other environmental factors may also be involved (Rothstein 2004) as habitat loss due to expanding urbanization (Stiles *et al.* 2017). Learning about other possible hosts in the zone and how this process works in different areas will contribute to the knowledge of brood parasitism in the Neotropical region.

Frequency of parasitism was lower than the values reported in Argentina and Brazil (66 %, 73 %, and 54 %; King 1973, Fraga 1978, Fernández and Duré 2007). This difference could be explained by the stationary breeding season of hosts at these latitudes because the brood parasite may coordinate the egg laying period with the reproductive peak of the common hosts in the zone (Kattan 1997). Neotropical bird species can and often do breed at any time of the year but generally show some peaks in breeding activity associated with predictable annual precipitation cycles (Fig 1). Reproductive events outside these peaks could reduce parasitism frequency because the parasites might not be in reproductive condition. No parasitized nests were found between September and March (frequency of parasitism 0 %) even through *M. bonariensis* do not migrate and their abundance is constant during all months (Fink *et al.* c2024). However, it is unknown if *M. bonariensis* exploits other host species during this part of the year. On the other hand, I found parasitism intensity to be higher than reported in other published studies (2.1, 2, and 1.9 parasite eggs; King 1973, Fraga 1978, Fernández and Duré 2007). The elevated parasitism intensity I documented in this study could be explained by the "shotgun" strategy and multiple parasitism of parasitic females that lay multiple eggs even in nests already parasitized and in different host incubation stages (Kattan 1997) as well as the population growth of *M. bonariensis* in the region (Villaneda-Rey and Rosselli 2011, Stiles *et al.* 2017). Host nests thus may be a limiting resource for *M. bonariensis* females as a consequence of their increasing population and a reduced host population. Nevertheless more information about other host species such as *Troglodytes aedon* Vieillot, 1809 is needed.

In accordance with previous research, I found a negative effect of *M. bonariensis* parasitism on the reproductive success of *Z. capensis* (Hauber 2003, Reboreda *et al.* 2003, Tuero *et al.* 2007, De Mársico and Reboreda 2010, Atencio *et al.* 2022). Multiple *M. bonariensis* strategies and characteristics are responsible for the reduced host reproductive success, like pecking of host eggs, and lower incubation times. Parasite chicks also tend to hatch first and are larger thereby receiving more food than the host chicks in the same nest (Payne 1977, Hauber 2003, Bortolato *et* al. 2019, Fiorini *et al.* 2019). Some parasitized nests showed evidence of parasite egg pecking. I even found two active nests being incubated with no remaining host eggs (Fig 2). *M. bonariensis* does not frequently peck smaller host eggs because the parasite nestlings could be favored by the presence of nestlings (Fiorini *et al.* 2009), but the competence for host nests may induce parasite females to puncture both host and parasite eggs to increase parasite success probability. However, desertion was the principal cause of nest failure. Desertion may not be a host defense against brood parasitism because re-nesting does not avoid a second case of parasitism (Reboreda *et* al. 2013, Carro and Fernández 2013); however, it could be caused by the perturbation of the parasite or other cues, such as the reduction in host clutch size (Hosoi and Rothstein 2000, Guigueno and Sealy 2010, Geoghegan *et al.* 2025). Kattan (1997) found that almost all nests with more than two parasite eggs were deserted by the House Wren (*T.aedon*) adults; in contrast, nests that received only one parasite egg were not deserted. Thus, multiple or high intensity parasitism in the study area may cause hosts to desert their nests.

Generalizing these results to the entire host population of the Bogotá region, it is possible that nearly half of the *Z. capensis* will have a low probability of success resulting in reduced recruitment in the next generation and a commensurate reduction in population size. Nonetheless, factors such as host fledgling survival (it is suggested that only one fledgling survive; Miller and Miller 1968), the differential abundance of the host and the parasite in other zones, and overall predation and mortality likely also contribute to long-term population trends of *Z. capensis* (Ney-Nifle *et al.* 2005). Nevertheless, as the population dynamics of both species are likely connected and the parasite depends on different hosts, demographic changes of the most common host could generate effects on the parasite population, even if other hosts are available. Increasing competence for nests between parasitic females could lead to higher intensity of parasitism, which in turn leads to nest desertion and nest failure. Friedmann (1929) proposed an oscillatory behavior of a host and parasite populations, an aspect that could characterize the reproductive relations in the study area where *Z. capensis* is the most common host. Long-term monitoring of *Z. capensis* populations are needed to reveal aspects of their ecological dynamics and how these are affected by Cowbird parasitism but also other factors such as habitat degradation should be studied, to determine at the population level which process has the greatest impact on the species in the city.

In summary, nearly half of *Z. capensis* nests were parasitized with 3.3 +- 0.3 eggs of *M. bonariensis* eggs. The negative effect of brood parasitism on the host nest success was caused by nest desertion and egg pecking by the parasitic females. In addition, future studies could consider entire host communities and their behavioral responses to Cowbird parasitism to build robust models and predict the interactions between *M. bonariensis* and its hosts.

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