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RESEARCH ARTICLE

Multiple nesting attempts and long breeding seasons of *Mimus gilvus* (Aves: Mimidae) in southeastern Brazil

Rodrigo Morais[1], Luiz Carlos de Araújo[1], Gleidson Ramos da Silva[1], Charles Duca[2]

[1]*Programa de Pós-graduação em Ecologia de Ecossistemas, Universidade Vila Velha. Campus Boa Vista, 29102-920 Vila Velha, ES, Brazil.*
[2]*Laboratório de Ecologia de Populações e Conservação, Universidade Vila Velha. Campus Nossa Senhora da Penha, 29102-623 Vila Velha, ES, Brazil.*
Corresponding author: Charles Duca (cduca@uvv.br)

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ABSTRACT. This study describes aspects of the life history of the Tropical Mockingbird *Mimus gilvus* (Vieillot, 1808), including the breeding period, clutch size, nestlings and a list of plants used for nesting. Nests were monitored in an area of Restinga (sand-coastal plain) habitat in a protected area in southeastern Brazil. The data from 181 nests during five breeding seasons (2010-2014) showed that the Tropical Mockingbird has a long breeding season (26.1 ± 2.6 weeks) with up to two peaks of active nests from August to March. The breeding pairs made up to four nesting attempts in the same breeding season. The mean (± SD) clutch size was 2.4 ± 0.6 eggs (n = 169). The mean (± SD) incubation period was 14 ± 0.6 days, and the nestling remained in the nest for 14.5 ± 2.2 days. The nests were built on thirty plant species, and *Protium icicariba* (DC.) Marchand. was the plant species most commonly used for nesting. The breeding parameters of the Tropical Mockingbird are similar to those of other Mimidae species. The knowledge gained from this study makes the Tropical Mockingbird a good choice for future studies, particularly for testing ecological and evolutionary hypotheses regarding life history attributes, habitat selection and parental investment.

KEY WORDS. Breeding biology, clutch size, re-nesting, Restinga, Tropical Mockingbird.

INTRODUCTION

The natural history of organisms involves a balance between energy spent in survival and reproductive functions (Bennett and Owens 2002). Reproduction invariably entails risks and results in energy loss, which often affects the behavior and other selected attributes of the breeder (Ricklefs 2010). Although birds are a relatively well-known group, little is known about the breeding biology of tropical birds (Stutchbury and Morton 2008), particularly endemic species with restricted distribution in the Neotropical region (Mason 1985, Stutchbury and Morton 2001, Xiao et al. 2016). Studies about natural history try to ascertain the breeding parameters and are an important source of information about a species (Bartholomew 1986). However, the incubation and nestling period of less than 1/10 of passerine species are known (Pienaar et al. 2013).

Variations in nesting duration and clutch size were recorded for species in the highly seasonal Neotropical savanna (Duca and Marini 2011) and semi-arid ecosystems (Cavalcanti et al. 2016). These studies demonstrated that birds use rainfall as an environmental cue to adjust the timing of their breeding activities. However, little is known about the breeding flexibility of these species and their ability to adapt to changes in the precipitation patterns of a less variable ecosystem such as the Restinga (sand-coastal plain). In this paper, we addressed hypotheses related to differences in clutch size between breeding seasons and the influence of the weather on the nesting activity of a typical species from the Restinga, where precipitation is less variable than in the savanna and semi-arid ecosystems of the Neotropical region.

The Tropical Mockingbird *Mimus gilvus* (Vieillot, 1808) is distributed from northern Mexico to southern Brazil (Sick 1997). Despite its wide latitudinal geographic distribution, its occurrence in the northeastern and southeastern coast of Brazil is associated with the physiognomies in the sandy coastal plains (here after Restinga), which are threatened habitats restricted to a narrow strip near the coast (< 4 km of wide) (Sick 1997). The

Tropical Mockingbird is an omnivorous species with frugivorous habits in association with Restinga plants, being a valuable seed disperser there (Gomes et al. 2007). Little is known about the breeding biology of the Tropical Mockingbird in the wild, except that it lives in cooperative breeding groups (Morton et al. 2004, Botero et al. 2007).

The Tropical Mockingbird is currently considered endangered on the Red List of the states of Espírito Santo and Rio de Janeiro (Alves et al. 2000, Passamani and Mendes 2007), and the subspecies *Mimus gilvus antelius* Oberholser, 1919 is classified as "Near Threatened" to extinction in Brazil's Red List (Machado et al. 2005). The subspecies *M. gilvus antelius* occurs on the Brazilian coast from the northern portion of the state of Pará to south of Rio de Janeiro. It is considered endemic to the Atlantic Forest (Gonzaga et al. 2000), and some authors have advocated that this subspecies should be considered a distinct species (Cody 2005, Zanon et al. 2015). Due to its close association with coastal environments, the Tropical Mockingbird was once the most common bird in the Restinga (Sick 1997). However, the occurrence of the subspecies *M. gilvus antelius* overlaps with the most threatened Restinga area in Brazil (Rocha et al. 2007). The populations of the Tropical Mockingbird have been disappearing in the southern limit of its distribution in recent decades (Teixeira and Nacinovic 1992, Araujo and Maciel 1998, Argel-de-Oliveira and Pacheco 1998, Gonzaga et al. 2000), confirming its status as an Endangered species (Zanon et al. 2015). If the subspecies *M. gilvus antelius* is validated as a distinct species, when it is described it will already be a threatened species (Zanon et al. 2015).

This study aimed to characterize the breeding attributes of the Tropical Mockingbird, such as breeding period, clutch size, incubation and nestling periods, fledgling characteristics and the plants used for nest support.

MATERIAL AND METHODS

This study was conducted in the Setiba Environmental Protection Area (Área de Proteção Ambiental de Setiba, hereafter APA-Setiba), which includes the Paulo César Vinha State Park (hereafter PEPCV). The APA-Setiba has an area of 12,960 ha. Inside the APA-Setiba is the PEPCV, which consists of a sand-coastal plain of 1,500 ha, located in the municipality of Guarapari, state of Espírito Santo, southeastern Brazil (20°33' to 20°38'S; 40°23' to 40°26'W). The study area is within the Atlantic Forest biome, Restinga vegetation (i.e., sand-coastal plain; Pereira 2003). The study sites were considered priority areas for biodiversity conservation falling into the category of high biological importance (MMA 2000). According to the Köppen's classification system, the region has a monsoon climate (Am) (Alvares et al. 2013), with mean temperature of 23.3 °C and a mean annual rainfall of 1,307 mm^3 (Fabris and Cesar 1996).

The study was carried out in the phytophysiognomies of open shrubby/non-flooded vegetation and shrubland vegetation (Pereira 2003). This vegetation, consisting primarily of *Clusia hilariana* Schltdl. and *Protium icicariba* (DC.) Marchand., occurs on sandy soil arranged in thickets and sandbanks at sites where the water table is far from the surface (CEPEMAR 2007).

Data sampling was from August 2010 to March 2015 (five breeding seasons). Based on previous observations, we searched for nests mainly from August to March. We did not search for nests during other months, but the population was monitored weekly during the entire year, and no evidence of breeding activity was found.

Capture and banding of individuals were carried out using mist nets 12 m in length and 3 m in height. The captured birds were individually marked with metal bands provided by the National Center for Bird Research and Conservation/Chico Mendes Institute for Biodiversity Conservation (CEMAVE/ICMBIO, license #3138/7), and unique combinations of three plastic color-bands were used. Individuals captured in the breeding season had their incubation patches and/or cloacal protuberances analyzed to confirm their sex. As the cloacal protuberance is exclusive to males and we never observed banded males with incubation patches or incubating the eggs, we assumed that all individuals with incubation patches and/or recorded incubating eggs were females. Observations of individuals' activities were made with binoculars using the focal sampling method (Martin and Baetson 1993). The breeding period was based on the use of nests and the presence of active nests (with eggs or nestlings).

Nests were monitored at intervals of three to four days. Nests were checked every two days just prior to hatching and fledgling, to estimate time intervals more precisely. In each occasion, nests were checked and classified as empty, eggs, or nestlings. The following data were collected from the occupied nests: date of egg laying and hatching, date of departure of the fledglings from the nest, and the results of breeding (successful, depredated, and abandoned). Data about nestling development was collected by visually inspecting the nestlings, noting the skin and bill color, the presence of yellow gape, the eyes, and the stage of development and color of feathers. This monitoring provided information for estimating clutch size, incubation period and nestling period. We also collected data on the development of the nestlings such as hatching order, growth and plumage color. When a nest became inactive, the exact location was marked for the identification of the plant species in which the nest was built. A total of 89 nests were used for this analysis.

Only nests found before first egg was laid and which survived until at least one egg hatched were used to estimate the incubation period. Only successful nests with known hatching dates were used to estimate the nestling period. Successful nests were those in which at least one nestling fledged. Empty nests that had previously harbored fledglings for at least 15 days were considered successful. Empty nests found during the incubation period or that contained nestlings for less than 15 days, usually presenting traces of predation such as structural damage, traces of blood and/or feathers, were considered depredated. A nest was considered abandoned when the eggs remained in it for 18

days without visits from the breeding pair. This number of days exceeds the observed incubation period of the Tropical Mockingbird (see results). Also, nests with dead nestlings without any signs of aggression were considered abandoned.

Month rainfall was obtained from the closest weather station (approximately 25 km) to the study area (APA-Setiba). These data were then correlated with the number of active nests.

To assess the normality of the data, we used a Kolmogorov-Smirnov test, and the clutch size data did not have a normal distribution. Therefore, we used a Kruskal-Wallis test (*H* test) to assess differences in clutch size among the five breeding seasons. When the difference was significant, we compared the means using a Wilcoxon-Mann-Whitney test (*U* test) with independent samples to verify which pairs of breeding seasons were significantly different. We set the significance level at $\alpha = 0.05$ and performed statistical analyses using the statistical packages PAST (Hammer et al. 2001) and BioEstat (Ayres et al. 2007). The results are reported as the means ± standard deviation (SD).

RESULTS

A total of 43 breeding groups were monitored in the study area. Of these, 38 groups were composed of one pair, three groups of three individuals, one group of four individuals and one group of six individuals. Forty-one adults from 21 different groups were banded. In total, 181 nests were monitored: 32 between 2010 and 2011, 38 between 2011 and 2012, 40 between 2012 and 2013, 25 between 2013 and 2014 and 46 between 2014 and 2015.

Breeding season and nest building

The Tropical Mockingbirds bred from August to March (n = 181 nests, Fig. 1). The mean duration of the breeding season was 26.1 ± 2.6 weeks (Table 1). The peaks of breeding activity (most active nests) were in December 2010/2011, 2012/2013 and 2014/2015, and in January 2011/2012 and 2013/2014 (Fig. 1).

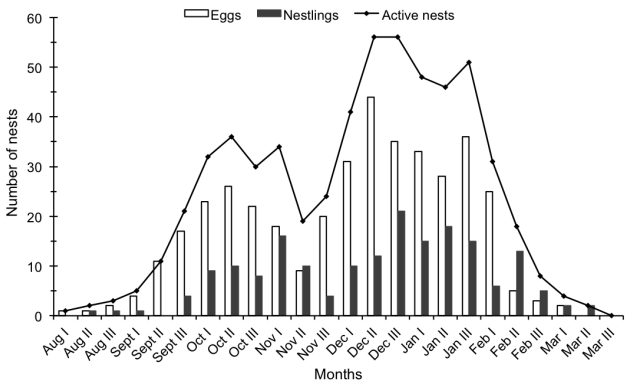

Figure 1. Number of active nests with eggs or nestlings of *Mimus gilvus* during the breeding seasons from 2010 to 2015 in a Restinga habitat (sand-coastal plain), southeastern Brazil. Roman numerals mean tens: I = 1-10 days; II = 11-20 days; III 21-30 (or 31) days.

In two seasons (2011/2012 and 2014/2015), we observed two peaks of breeding activity in the same season, the first being in mid-October and the second in mid-December (Fig. 1). The first active nests were found during the driest season of the five sampling years (Figs 1–2). However, most of the fledglings left their nests from October to January when the first peak of annual rainfall occurred (Figs 1–2).

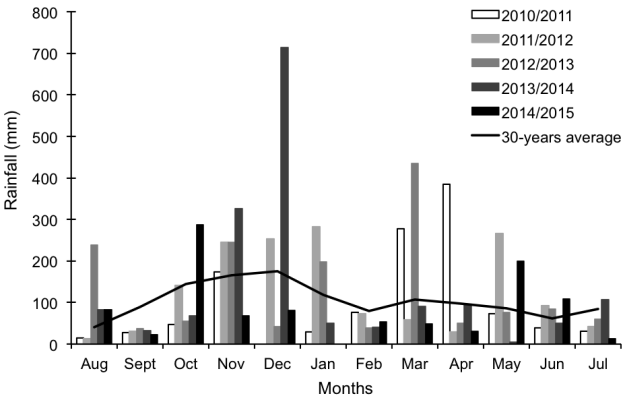

Figure 2. Average monthly rainfall in millimeters during the years 2010 to 2015 in the Municipality of Guarapari, southeastern Brazil.

Table 1. Period and duration of the breeding seasons of *Mimus gilvus* in a Restinga habitat (sand-coastal plain), southeastern Brazil.

Breeding season	First date of active nest	Last date of fledgling	Breeding season duration (weeks)
2010/2011	12/Sep/2010	11/Feb/2011	21.8
2011/2012	01/Aug/2011	19/Feb/2012	29.0
2112/2013	16/Sep/2012	21/Mar/2013	26.7
2013/2014	22/Aug/2013	24/Feb/2014	26.7
2014/2015	10/Aug/2014	08/Feb/2015	26.1

The breeding pairs made up to four nesting attempts in the same breeding season. The average number of nesting attempts was 2.6 ± 1.0 (n = 14), but we did not record couples that had success in one nesting attempt making another attempt in the same breeding season.

The average time spent on nest building was 6.7 ± 1.8 days (n = 15). The remaining nests were found in an advanced stage of construction. Both sexes were observed building nests (n = 19). New nests were built at each reproductive attempt without using material from previous nests. Nests were not repaired after egg laying.

Nest description

Tropical Mockingbird nests were cup-shaped and were placed on some branches. Nest exteriors were constructed with thicker sticks, and in the study area, *Eugenia cyclophylla* (Myrtaceae) and *Guapira* sp. (Nyctaginaceae) were commonly used. Nests

interiors were lined with a layer of thin plant materials such as grasses, roots, and fragments of *Cassytha filiformis* (Lauraceae).

The plant species most commonly used to support the nests were *Protium icicariba* (Burseraceae, n = 14; 15.7% of nests) and *Byrsonima sericea* (Malpighiaceae, n = 8; 9.0% of nests). Additional species were *Clusia hilariana* (Clusiaceae), *Jacquinia armiralys* (Theophrastaceae) and *Neomitranthes obtuse* (Myrtaceae), which were used for seven nests (Fig. 3).

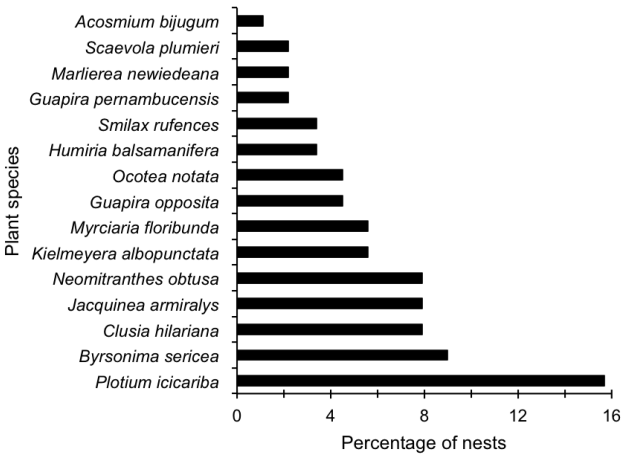

Figure 3. Plant species used for nest construction by *Mimus gilvus* in a Restinga habitat (sand-coastal plain), southeastern Brazil.

Clutch size

The mean clutch size was 2.4 ± 0.6 eggs (range: 1 to 3 eggs, n = 169) (Fig. 4). There was a significant difference in clutch size across breeding seasons ($H = 18.8$, df = 4, $p < 0.001$). However, the difference only occurred between the first and the last breeding seasons (2010/2011 and 2014/2015) ($U = 301$, $p < 0.001$) (Fig. 4).

Incubation and nestling period

Egg laying occurred on consecutive days with incubation beginning after the laying of the first egg, and the nestlings hatched asynchronously. The mean incubation period was 14 days ± 0.6 (range: 13–15 days; n = 19), and the mean nestling period was 14.5 ± 2.2 days (range: 12–18 days; n = 13). Only females participated in incubation. We recorded males playing a sentinel role during incubation by alerting the female when a potential predator approached the nest (n = 19). While caring for nestling, the couple took turns watching for potential predators and feeding the nestlings, and we did not record parental care behaviors from the other group members, contrasting with the idea there is cooperative breeding behavior in this species. Parental care continued up to 35 days after the fledglings left the nest (n = 22 couples).

Development of nestlings

At birth, the nestling presented grayish fuzz on the back and head, whereas the belly and wings were featherless (n = 77

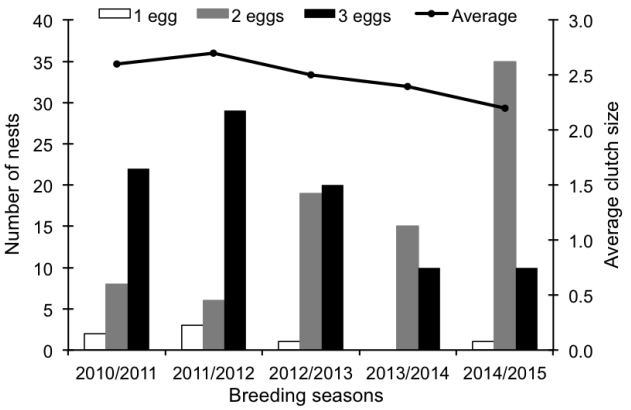

Figure 4. Number of nests and clutch size of *Mimus gilvus* from 2010 to 2015 in a Restinga habitat (sand-coastal plain), southeastern Brazil.

nestlings). The bare skin was pinkish and the beak a strongly yellow. A small calamus of feathers began to appear from the fifth day, first in the wings and with the head and body covered with feathers only in the final days of the nestling period. The nestlings were born with closed eyes, which became fully opened only at the end of the first week. When leaving the nest, the fledglings possessed plumage similar to the adults, except for black spots on the feathers of the breast and flanks, and rectrices that were half the size of the adult rectrices. The fledglings also showed the presence of a yellow gape, and the length of wings and tarsus was similar to adults.

DISCUSSION

Breeding Season and Nest Building. The breeding activities aligned with the rainy season in the study site. This species had a longer breeding season (6 to 7 months) than some Neotropical species from the Atlantic Forest (Aguilar et al. 2000, Duca and Marini 2004, Hoffmann and Rodrigues 2011). The breeding season of the Tropical Mockingbird was shorter than the breeding season of the subspecies *M. gilvus malnopterus* in Venezuela (Paredes et al. 2001). It is noteworthy that the breeding season of the congener *M. gilvus tobagensis*, also lasts six months (Hayes 2005). Variation in breeding season among populations is expected, especially in continental countries, since each region may have different climate types. For example, this variation in breeding period was recorded in the Nearctic region for the Northern Mockingbird (*Mimus polyglottos*) (Laskey 1962, Fischer 1981, Means and Goertz 1983), which is the closest species of *M. gilvus* (Arbosgast et al. 2006). The breeding season can also be influenced by other factors such as food availability, seasonal patterns of predation risk to the nest, and opportunities to renest. Birds can breed early or later each year (Wikelski et al. 2000, Langen and Berg 2016).

Long breeding seasons are expected for tropical species compared with species from temperate regions (Russell et al.

2004, Diniz et al. 2013, Langen and Berg 2016). A long breeding season and many nesting attempts per season may be an adaptive response to a high nest predation rate (Martin 1996, Roper 2005), but some species occasionally re-nest after fledgling a brood (Langen and Berg 2016). The breeding period of the Tropical Mockingbird began a few days before the onset of the rainy season in our study region, and the first fledglings left the nest at the beginning of this season. The relationship between rainfall and the nesting period has been shown by several studies of tropical species in most tropical biomes (Cruz and Andrews 1989, Aguilar and Marini 2007, Marini et al. 2012, Daros et al. 2018). The influence of the rainfall regimen on the breeding period of tropical species is secondarily related to the cascade effects that it triggers, for example, in the abundance of food (Boag and Grant 1984, Sick 1997, Langen and Berg 2016). The nesting period of the Chalk-browed Mockingbird, *Mimus saturninus* (Lichtenstein, 1823), extends from late August to December following the rainy season of central Brazil (Rodrigues et al. 2017).

The two peaks of active nests in the same breeding season observed in two breeding seasons for the Tropical Mockingbird (Fig. 1) are probably related to the re-nesting ability of this species. Biannual breeding cycles may be associated with two wet seasons in a year; these are particularly common in equatorial latitudes (Schondube et al. 2003). Two peaks of active nests within the same season can be a response to predation risk (Roper 2005), and both rainfall and prey availability may contribute (Diniz et al. 2013). It is possible that these two peaks of breeding activity of the Tropical Mockingbird also evolved coinciding with the rainfall pattern. However, it is different from the biannual breeding cycles near the equatorial latitudes because these two peaks of active nests occurred in the same breeding season. In Venezuela, the Tropical Mockingbirds are multi-brooded, and their peaks in breeding activity coincide with the rainy seasons (Paredes et al. 2001). This relationship between precipitation and breeding activities is widely discussed in the literature (e.g., Ricklefs and Bloom 1977, Stutchbury and Morton 2001) and is apparently more representative of semi-arid environments (Cavalcanti et al. 2016). Furthermore, the predation pressure may induce the Tropical Mockingbird to have many nesting attempts in the same breeding season. Studies about timing effects on breeding success and predation rates could elucidate which factor is most important to determine the pattern recorded in this study. It is noteworthy that the Tropical Mockingbird rarely attempted another nesting after success with the previous brood. This observation should be more fully investigated in future studies, but the predation pressure appears to be the main explanatory factor for several nesting attempts and the long breeding season of the Tropical Mockingbird.

Possibly, the long breeding season of Tropical Mockingbird is also associated with the stability of the environmental conditions in the region over the year, allowing the opportunity to renest many times in a single season. A breeding pair of Tropical Mockingbirds may make up to five nesting attempts in the same season (Hayes 2005). The Northern Mockingbirds also make several breeding attempts in a season with the number of attempts influenced by predation and the success of breeders (Laskey 1962). According to Roper (2005), sometimes only a high number of nesting attempts can ensure the seasonal breeding success in tropical regions. In contrast, the breeding phenology of tropical birds can also be related to other factors such as food availability and climate conditions after fledgling, the opportunity to re-nest, and timing of molt (Stutchbury and Morton 2001, Langen and Berg 2016).

The participation of both sexes of the Tropical Mockingbird in nest construction was also observed by Paredes et al. (2001). These authors showed that males select the nest site and are subsequently assisted by the female in nest building. Nest abandonment after construction may be related to the inability of inexperienced adults to perform tasks related to reproduction (Morbey and Ydenberg 2000). However, the energy cost of building a nest that will not be successful is high, and nest abandonment is costly for younger females. Therefore, the adaptive significance of the commitment of young or newly arrived females to the effective population may be the optimization of the number of offspring produced during their lifetime through learning from previous years (Curio 1983).

Plants Used to Support Nests. Tropical Mockingbirds nested on 30 plants species, and most nests were found on *P. icicariba* that has a relative frequency of 4.7% (CEPEMAR 2007) and low dominance in the study site (Ferreira et al. 2010). *Protium icicariba* is a shrub species that has favorable plant architecture and is the most commonly used plant for nesting by Mimidae species in open physiognomies (Argel-de-Oliveira 1994). The use of a common plant as support in the study area, such as *P. icicariba*, supports the potential prey hypothesis (Martin 1993). Nests located in the shrubs of species that are abundant are safer from predators due to the increased availability of potential sites for nest construction, thus reducing the efficiency of predators trying to locate them. The relative frequency of *P. icicariba* is the same for *Guapira pernambucensis* (Casar.) Lundell, but the latter harbored only two nests. Therefore, the preference of Tropical Mockingbird for *P. icicariba* over *G. pernambucensis* may be related to the possible protection that the first offers with respect to nest predation.

Clutch Size. The clutch size of the Tropical Mockingbirds in the study area was similar to another population in Venezuela (Paredes et al. 2001) for which a mean of 2.2 eggs (range, 2–3 eggs) was reported. For the tropical congener Chalk-browed Mockingbird, the mean clutch size was 2.9 eggs (Rodrigues et al. 2017). These low numbers of eggs are typical for tropical species (Stutchbury and Morton 2008). The high predation rate that occurs in the tropics favors smaller clutch sizes because adults invest in smaller numbers of eggs and many nesting attempts to ensure greater success in the breeding season (Slagsvold 1982). Regardless the regulatory mechanism of clutch size, the Tropical Mockingbird has a small clutch size and makes up to four nesting

attempts in the same breeding season, which is consistent with expectations for other tropical species.

Incubation and Nestling Periods. The 14 days of incubation of the Tropical Mockingbird in our study was similar to that of the other two subspecies, *M. gilvus melanopterus* (13 days; Paredes et al. 2001) and *M. gilvus tobagensis* (13 days; Hayes 2005), and to the Mimidae species Long-tailed Mockingbird (*Mimus longicaudatus*) (12 to 13 days; Marchant 1960), Chalk-browed Mockingbird (14.2 days; Rodrigues et al. 2017), and White-banded Mockingbird (*Mimus triurus*) (13 days; Mezquida and Marone 2001). According to Sick (1997), the mean incubation period of Atlantic Forest passerines is 15 days, close to what has been observed in the present study. However, slight variations may occur due to environmental conditions and food availability (Murphy 1986, Rotenberry and Wiens 1991).

The nestling period of the Tropical Mockingbird (14.5 days) is similar to that of other Mimidae species (Marchant 1960, Rodrigues et al. 2017). Short incubation and nestling periods can be related to the type of and vulnerability to nest predators (Alves and Cavalcanti 1990). These two factors reduce the exposure time to nest predators (Martin 1987). However, leaving the nest too soon without sufficient time to develop significant features for flight can also expose the fledglings to predation. Thus, each species may adopt a different strategy to increase their breeding success.

The roles of each sex in reproduction appear to follow a common pattern for Mimidae species, in which only females incubate the eggs and males defend the nests against predators. This behavior was also observed for Chalk-browed Mockingbirds (Rodrigues et al. 2017) and Northern Mockingbirds (Laskey 1962). Although evidence of facultative cooperative breeding behavior has been documented for the Tropical Mockingbird (Morton et al. 2004), we did not record behaviors that suggest cooperative breeding in our study.

Nestling Development. The nestlings of the Tropical Mockingbird are typical altricial birds that usually hatch featherless and with the eyes closed, completely dependent on the care of adults (Starck and Ricklefs 1998). The offspring resemble those of the Chalk-browed Mockingbird (Rodrigues et al. 2017) and Northern Mockingbird (Laskey 1962). The similar length of the wings and tarsus of fledglings relative to adults is explained by the need for movement on the ground during the first days out of the nest, thus helping them to escape from predators (Sick 1997).

In this study, we highlight that six to seven continuous months of breeding season with up to two peaks of active nests per season are uncommon for a non-equatorial neotropical bird species, even compared with Neotropical birds from Cerrado, Pantanal and other physiognomies of the Atlantic Forest. The knowledge gained from this study makes the Tropical Mockingbird a good choice for future studies, particularly for testing ecological and evolutionary hypotheses regarding life history attributes, habitat selection and parental investment.

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