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Cover: A male Helmeted Manakin (*Antilophia galeata*). Marçal & Lopes (in this issue) studied the breeding biology of this lekking species, in which only females took part of breeding duties, including nest building, incubation and nestling care. Photo author: Lindolfo Souto.

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ARTICLE

Breeding biology of the Helmeted Manakin *Antilophia galeata* in an ecotone between the Atlantic Forest and the Cerrado

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ABSTRACT: Manakins (Pipridae) are well-known by their promiscuous mating system. Nonetheless, scarce evidence suggests that the Helmeted Manakin *Antilophia galeata*, the only dichromatic manakin widely distributed in the South American Cerrado, is monogamic. We studied the breeding biology of the Helmeted Manakin in the state of Minas Gerais, southeastern Brazil. We found 17 nests, which are built in the forest undergrowth (usually below 3 m height). Nests are a cup attached by its top lip usually in the angle of a forked branch. The nest attachment zone is made mostly of spider silk. The structural zone is constructed with dry broad leaves, leaf petioles and horsehair fungus, which were bind together by a considerable amount of spider silk. The outer (decorative) zone is made with some hanging dry broad leaves, frequently forming a tail. Clutch size is always two (*n* = 12), and eggs are long oval, with a ground color in different shades of beige, marked with irregular spot, blotches and, sometimes, streaks ranging from light to dark brown. Mean eggs measurements were 23.9 × 16.3 mm (*n* = 14), weighting 3.3 g (*n* = 10). Eggs are laid once each day and hatching is synchronous. Females are the sole responsible for nest building (which usually took 10 days), incubation (18.5 days), and nestling care (18.3 days). The simple percentage of successful nests (*n* = 11) was 27% and predation was the main cause of nest failure. The breeding season extends from the second half of August to the first half of January. Renesting after loss of a first clutch is a common strategy and we recorded up to three nesting attempts for a single female. We present evidence that the Helmeted Manakin is promiscuous, as usual for a dichromatic manakin.

KEY-WORDS: Cerrado, Neotropics, nest, Pipridae, reproduction.

INTRODUCTION

There are huge knowledge gaps about the breeding biology of birds, especially of those species living in tropical forests (Heming *et al.* 2013, Xiao *et al.* 2017). It has been recently demonstrated that most Neotropical bird species have their breeding biology poorly-known (42.9%) or only partly-known (37.9%), what represents a major impediment to further development of life history theory (Xiao *et al.* 2017). In addition to the lack of information for some species, the scarce information derived from isolated and superficial observations are frequently biased or even wrong. This is worrying, because the naturalists are dying off (Noss 1996), especially those interested in descriptive natural history, probably because this kind of study is often published in low-impact journals (Beehler 2010, Tewksbury *et al.* 2014).

A good example of a poorly known tropical forest bird is the Helmeted Manakin *Antilophia galeata*, a species for which less than a dozen nests have been reported in the literature, most of them superficially described and none properly monitored. Consequently, basic life history parameters for the species, such as incubation and nestling periods, or even sex roles in parental care, are unknown (Marini 1992, Marini *et al.* 1997, Snow 2004). The range of the Helmeted Manakin is mostly restricted to the Cerrado, one of the largest and most biodiverse biogeographic provinces in the Neotropics, mostly covered by savannas (Silva & Bates 2002), a kind of habitat not suitable for manakins, which are, as a rule, forest species (Kirwan & Green 2011). The Helmeted Manakin is fairly common in the gallery forests and patches of semideciduous forests in the Cerrado (Marini & Cavalcanti 1996, Kirwan & Green 2011).

The genus *Antilophia* includes two species, the Helmeted Manakin and the recently described Araripe Manakin *A. bokermanni* (Kirwan & Green 2011). The genus is sister to *Chiroxiphia* (Ohlson *et al.* 2013), maybe congeneric with it (Silva *et al.* 2018), and there are several reports of hybridization between them (Rezende *et al.* 2013, Alves *et al.* 2016). The Helmeted Manakin is a highly dimorphic species, with males predominantly black with a distinctive red crest, nape, and mantle; females, as well as young males, are mostly olive green (Ridgely & Tudor 2009). *Antilophia* is considered the only genus of dichromatic manakins with a non-promiscuous mating system (Marini 1992, Marini & Cavalcanti 1992, Kirwan & Green 2011). This is a noteworthy and odd behavior for a genus included in an essentially promiscuous family in which males exhibit extraordinary courtship displays in arenas (Snow 2004, Kirwan & Green 2011). Nevertheless, our field observations revealed that the purported monogamy of the species does not hold true, being a result of scarce and hard to interpret information about the breeding biology of the species. Here we describe in detail the breeding biology of the Helmeted Manakin, also presenting a compilation of previous studies and unpublished data obtained from citizen science networks. With this study we aim to contribute to the understanding of the evolution of life history traits within the Pipridae.

METHODS

Study area

We conducted this study in the Universidade Federal de Viçosa - Campus Florestal, municipality of Florestal, state of Minas Gerais, southeastern Brazil. Florestal lies in the transition zone between two important Neotropical biogeographic provinces, the Atlantic Forest and the Cerrado (IBGE 2004), both considered global hotspots of biodiversity (Myers *et al.* 2000).

We conducted most of the fieldwork in a ~180 ha forest fragment (centered at 19°52'02''S; 44°25'51''W, 800 m a.s.l.) in the very margins of a ~13 ha artificial pond ("Represa do Pivô"). There is not perennial creek inside the forest fragments. The forest is semideciduous and secondary, in an intermediate stage of ecological succession (Vieira 2016), with an age of ~40 years according to old employees of the university. Mean canopy height is ~10–12 m height, with some trees reaching 15 m or more. We also included in this paper data from opportunistic observations obtained by colleagues in a nearby ~65 ha forest fragment with similar age and structure ("Mata dos Equídeos", centered at 19°53'22''S; 44°24'34''W, 800 m a.s.l.).

Local climate is subtropical with a mild dry winter and a wet hot summer (*Cwa* according to the Köppen classification system), with a mean annual temperature of 19.9°C (Lopes & Marçal 2016). Mean annual precipitation is 1447 mm, with a wet season from October to March and a well-marked dry season from April to September (Lopes & Marçal 2016).

Capturing, banding, and sexing

Birds were mist-netted (nets measuring 12 × 3 m, netting effort of ~250.000 h.m^2) from March to September 2016 and received a numbered metallic band from the Brazilian National Center for Bird Conservation and Research (CEMAVE) and a unique combination of three color bands. Given that young males and females are hardly told apart by plumage, we collected a blood sample from greenish birds after puncturing the brachial vein and send it to a private laboratory for molecular sexing (http://www.unigen.com.br).

Nest searching and monitoring

We followed banded birds with the aid of 8 × 42 binoculars from March to December 2016, while studying the territorial (data not show) and breeding behavior of the species. Opportunistic observations by colleagues were obtained from September to December 2017. During fieldwork, we searched for evidence of breeding activity, such as the transportation of nesting material or food for nestlings that could reveal nest location (Martin & Geupel 1993). Once found, we briefly monitored nests at two days interval, taking notes on its content (*e.g.*, number of eggs and/or nestlings, stage of development). We spent at least 20 h observing nest construction (n = 7 nests) and 10 h observing nestling care (n = 4).

We classified the nest type following the proposal of Simon & Pacheco (2005) and described it after the proposal of Hansell (2000) for standardizing nest description, taking the following measurements (mm) with a caliper: nest depth, nest diameter, cup depth, cup diameter, and support diameter; the height of the nest in relation to the ground (cm) was measured with a measuring tape. We measured (mm) and weighed (g) the eggs, respectively, with a caliper and a spring scale, and described their shape after Birkhead (2016). Once found, we examined the eggs in the field to determine their approximate incubation stage using the flashlight of a smartphone as a candler (Lokemoen & Koford 1996).

Literature and citizen science review

We complemented our field observations with data gathered from the literature and from two of the most important citizen science projects that deal with Neotropical birds, the Internet Bird Collection (http://www.hbw.com/ibc) and the Wikiaves (http://www.wikiaves.com). All online searches were conducted in April 2018.

RESULTS

We captured and banded 38 birds (nine females, 24 definitive plumaged males and five greenish birds that could not be sexed). We found 17 nests (six of them opportunistically found during the 2017 breeding season), 12 of which were monitored. These nests belonged to at least seven distinct females. Eight of the 12 nests monitored were found during its construction and four after the first egg was laid. Five nests were found already built, but they were probably already inactive, because they were abandoned, depredated, or their nestlings fledged before we found them. We identified these nests as belonging to the Helmeted Manakin, which build characteristic nests, based on their similar shape, measurements, and construction material (see below).

During the 2016 breeding season, we found the first nest under construction on 27 September, and the last active nest was observed on 23 December, when its single nestling successfully fledged. During the 2017 breeding season, when observations were opportunistic, we found the first active nest with two eggs on 25 August, and the last active nest was observed on 03 November, when it contained two dead nestlings being eaten by ants. Given the low number of nests found, we can only estimate the length of the breeding season by indirect evidence. A juvenile observed being reared by its mother out of the nest on 06 October 2016 (the entire nesting cycle, from the onset of its construction to fledging, is ~45–50 days) indicates that the breeding season starts as early as mid-August. A copulation observed on 28 November indicates that the breeding season extends through mid-January. Therefore, the breeding season of the Helmeted Manakin in the study area extends for about five months, from the second half of August to the first half of January, coinciding with the end of the dry season and the first half of the wet season.

All nests found were in the undergrowth of the forest fragments and were attached to branches of trees or shrubs, ranging from 1.15–5.64 m (*n* = 17) above the ground (Table 1). Only one nest was close to a water body (15 m from the margin of the pond), whilst all other nests were at least 25 m away from water. The six nests found during the 2017 breeding season were at least 150 m from the nearby water body, which was isolated from the forest fragment by a stretch of artificial pasture.

Females are the sole responsible for nest construction (Fig. 1), an activity that usually took nine days, ranging from eight to ten days (*n* = 8). We observed nest building

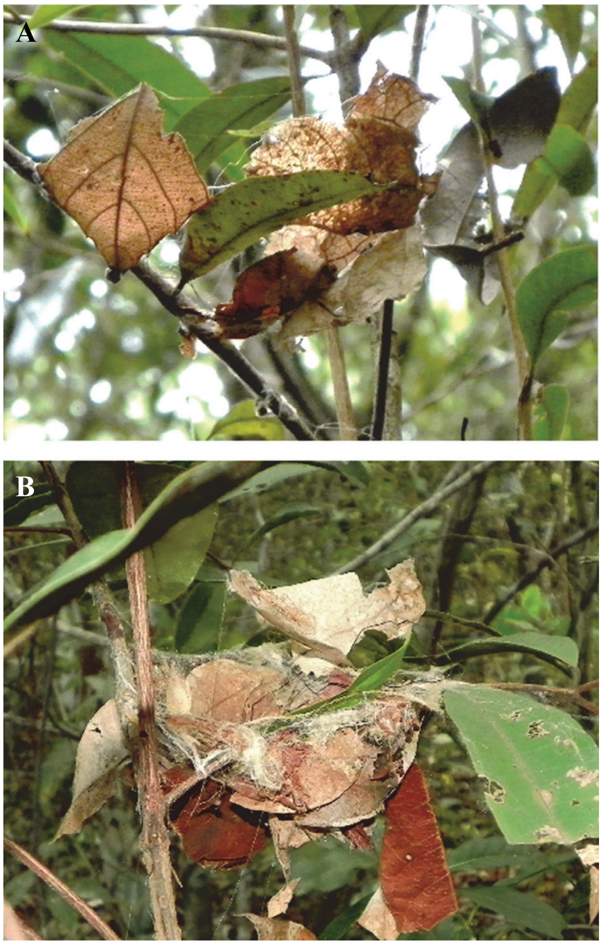

Figure 1. Nest of the Helmeted Manakin *Antilophia galeata* on the first day of construction, evidencing the large amount of spider silk used to attach the nest to the support plant (**A**). Note that the first dry broad leaves have already been deposited and that some green broad leaves, still attached to the branch, were being incorporated into the nest. Another nest of the Helmeted Manakin, almost completely built (**B**). Photo author: B.F. Marçal.

Table 1. Measurements of some nests of the Helmeted Manakin *Antilophia galeata* found in the municipality of Florestal, Minas Gerais, Brazil. All measurements follow Hansell (2000).

Variable	Mean	Standard deviation	Minimum	Maximum	*n*
Height above ground (m)	2.3	1.18	1.15	5.64	15
Support diameter (mm)	5.5	1.6	3.5	7.8	7
Nest depth (mm)	41.5	9.1	27.7	55.0	9
Cup depth (mm)	28.5	4.8	19.7	35.3	9
Nest diameter (mm)	66.1	7.7	53.4	75.2	9
Cup diameter (mm)	49.8	4.7	44.1	57.9	9

throughout the day, but this activity was seldom recorded during the first hours after dawn, when birds spent most of the time foraging.

The nest, according to the standard classification of Simon & Pacheco (2005), is a low cup/fork. The nest is best described as a cup attached by its top lip in the angle of a forked branch (Fig. 2), according to the Hansell (2000) standard system. Two nests were built between two parallel branches that were functionally equivalent to a forked branch (Fig. 1). Nest measurements are presented in Table 1. Plants used as support were: *Calyptranthes* sp. (Myrtaceae, *n* = 3), *Syzygium* sp. (Myrtaceae, *n* = 2), *Amaioua* sp. (Rubiaceae, *n* = 2), and Rubiaceae sp. (*n* = 4). It was not possible to identify the support plant of the other six nests.

Nests (Figs. 2 & 3) show three well-delimited zones: attachment, structural, and decorative. The nest was attached to the fork mostly with spider silk. The structural zone is constructed with dry broad leaves, leaf petioles, and horsehair fungus (*Marasmius*), which are bind together by a considerable amount of spider silk (scored as two in a three-point scale, as suggested by Hansell 2000). Sometimes, green broad leaves, still attached to the branch, are also incorporated into the structural zone (Fig. 1). The inner layer of the structural zone, *i.e.*, that which is in contact with the eggs, is built with thin leaf petioles and unidentified vegetable fibers. The decorative (outer) zone is made of some few hanging dry broad leaves, frequently forming a tail (Fig. 2).

Spider silk was collected within a radius of ~100 m from the construction site, as suggested by the several observations of females collecting material for nest construction. At each visit in which she brings material, the female sits in the unfinished nest and, with the wings held close to the body, she makes circular movements in the nest, shaping it with her legs while compressing the nest material with her breast and flanks. The female then perches on the edge of the nest and arranges the leaves and petioles with its beak, sits again in the nest and compresses and shapes the newly added material

Figure 2. Female Helmeted Manakin *Antilophia galeata* incubating its eggs (**A**). Note that the crest, nape and back of this bird is slightly washed with red, what suggests that it is an old female, as previously reported for the species (Marini 1989) and members of *Chiroxiphia* (Kirwan & Green 2011). Side view of another nest, showing a long tail made of dry leaves, leaf petioles, and horsehair fungus hanging on its outer walls and lower part (**B**). Photo author: B.F. Marçal.

Figure 3. The nest of the Helmeted Manakin *Antilophia galeata* with an egg and a freshly hatched nestling. Nests of this species are a cup attached by its top lip in the angle of a forked branch (**A**). Nest constructed between two nearby parallel branches, evidencing the presence of leaf petioles and some unidentified vegetable fibers in the inner layer of the structural zone (**B**). Photo author: D.F. Ferreira (**A**) & B.F. Marçal (**B**).

against the walls of the nest. During this process some dry broad leaves and horsehair fungus fall apart from the nest, hanging from the lower part of the nest. These leaves are not removed, but fixed loosely with additional spider silk, thus forming the nest tail.

Clutch size was always two eggs (*n* = 12), which are long oval, with ground color in different shades of beige, and marked with a highly variable patterning of spots, blotches and, frequently, streaks ranging from light to dark brown (Figs. 3 & 4). Egg patterning can be concentrated around the larger pole or homogeneously distributed throughout the egg surface. Eggs measured 23.9 ± 0.6 mm (23.2–25.4 mm, *n* = 14) × 16.3 ± 0.3 mm (15.8–16.9 mm, *n* = 14) and weighted 3.3 ± 0.2 g (3.0–3.6 g, *n* = 10). The first egg is laid on the first or second day after nest building is complete, with the second egg laid on the following day (*n* = 9). Incubation is performed by the female alone, during a mean incubation period of 18.5 days (18–19, *n* = 7). The onset of incubation is delayed until all eggs are laid, resulting in synchronous hatching.

Only the female brood and feed the nestlings. The nest is constantly kept clean, with females ingesting the regurgitated seeds and fecal sacs (video at http://hbw.com/ibc/1365115), which are usually regurgitated far away from the nest. Nestlings older than 10 days usually regurgitate seeds straight on the ground, what results in the accumulation of a large amount of seeds just below the nest (Fig. 5). Juvenile fledge after 18.3 ± 1.15 days (17–19, *n* = 3), but the female still feed them out of the nest for at least 10 days.

Renesting after loss of a first clutch is common, and at least three breeding attempts in a single breeding season have been recorded, as indicated by indirect evidence. One of the banded females monitored was seen carrying material to construct its nest at the last days of September 2016, with eggs hatching on 23 October. We waited four days after hatching to band the nestlings, but, unexpectedly, the female held them by the tarsus with its beak and removed them from the nest, one by one, carrying them to a distant place, where they were abandoned and died (video at http://hbw.com/ibc/1384202). After this event we decided not to handle the nestlings anymore. Two days after the occurrence, the female began issuing short calls with one or two notes (http://www.wikiaves.com/2574665 and http://www.wikiaves.com/2574636), which caused the appearance of four males, probably seeking a mate, but no copulation was observed. We found on 09 November the second nest of the same female, already with two eggs, only 13 days after the previous clutch become inactive. This nest was depredated 16 days after we found it, on 25 November. This female was only sighted again on 28 November, again accompanied by four males, while issuing the same short calls described earlier. On the same day this female copulated with a definitive plumaged male that was engaged in the chasing displays discussed below, what indicates a third attempt of reproduction, even thought we did not find this third nest. This was the only copula we observed,

Of the 11 nests monitored (excluding the one lost due to observer interference), one was abandoned during construction stage, five were depredated during incubation, two were depredated with nestlings, and only three were successful (27% apparent success). One of the successful nests produced two juveniles, while the other two nests produced only one juvenile, because one egg in each disappeared during incubation stage. Three of the five nests that we found already built probably harbored nestlings in an advanced stage of development, as attested by the large number of regurgitated seeds below them.

Our bibliographic review revealed 10 nests of the species previously reported in the literature, two of them

Figure 4. Two eggs of the Helmeted Manakin *Antilophia galeata* belonging to the same clutch. Note the marked chromatic differences between them. Photo author: L.J. Ferreira.

Figure 5. Regurgitated seeds accumulated under a nest of the Helmeted Manakin *Antilophia galeata*. Some of the more than 100 seeds found were highlighted by a white circle. Photo author: B.F. Marçal.

consisting only of a color photograph, unaccompanied by any additional information. We also found 11 breeding records of the species in the citizen science networks consulted (Table 2).

DISCUSSION

The breeding season of the Helmeted Manakin in the study area extends from mid-August to mid-January, coinciding with the period observed or inferred from indirect evidences throughout its range (Table 2). This suggests that the time of breeding in the species varies little along its wide geographical distribution, what is probably related to the relative similarity of climate throughout the Cerrado, especially in relation to the timing of the wet season (Nimer 1989, Alvares *et al.* 2013).

The breeding season of members of *Antilophia* and *Chiroxiphia* begin at the end of the dry season and extends through the first half of the wet season, irrespective of the region and habitat occupied. The breeding season of the Blue Manakin *Chiroxiphia caudata* in a primary submontane rain forest in the Brazilian Atlantic Forest lasted about five months, extending from October to February (Zima *et al.* 2017). Similarly, the breeding season of the Long-tailed Manakin *Chiroxiphia linearis* in

Table 2. A compilation of breeding records of the Helmeted Manakin *Antilophia galeata* obtained from the literature* or from the following citizen science websites Wikiaves (WA) and Internet Bird Collection (IBC). Except when indicated, all records are from Brazil.

Date	Place of record	Type of record	Source
-	Brasília, Distrito Federal	Abandoned nest.	Sick (1958)
-	Minas Gerais	Nest with eggs.	Snow (2004)
-	"central Brazil"	Nest with two eggs.	Buzzetti & Silva (2005)
04 Sep	Vargem Grande do Sul, São Paulo	Nest with incubating female.	WA 1073140
07 Sep	Uberlândia, Minas Gerais	Nest with two eggs.	Marini *et al.* (1997)
26 Sep	Serranía de Huanchaca, Santa Cruz, Bolivia	Female with egg in oviduct.	Bates *et al.* (1992)
26 Sep	Uberlândia, Minas Gerais	Nest with two nestlings.	Marini *et al.* (1997)
Oct	São Paulo	Nest with two eggs.	von Ihering (1900)
Oct	Brasília, Distrito Federal	Female with egg in oviduct.	Marini (1992)
Oct	Brasília, Distrito Federal	Nest with two eggs.	Marini (1992)
13 Oct	Brasília, Distrito Federal	Nest with two eggs.	Marini (1992)
09 Oct	Brasília, Distrito Federal	Nest with two nestlings.	Marini (1992)
10 Oct	Brasília, Distrito Federal	Nest with two eggs.	WA 1224919
11 Oct	Florestal, Minas Gerais	Nest with two eggs.	WA 2887907
13 Oct	Chapada dos Guimarães, Mato Grosso	Nest with two eggs.	Allen *et al.* (1893)**
Nov	Brasília, Distrito Federal	Female with egg in oviduct.	Marini (1992)
02 Nov	Carmópolis de Minas, Minas Gerais	Female carrying nest material.	WA 2767569
12 Nov	Uberlândia, Minas Gerais	Nest with two eggs.	Marini *et al.* (1997)
14 Nov	Brotas, São Paulo	Nest with incubating female.	WA 508697
19 Nov	Paracatu, Minas Gerais	Nest with incubating female.	WA 1524895
03 Dec	Brasília, Distrito Federal	Nest with incubating female.	WA 513118
08 Dec	Pará de Minas, Minas Gerais	Nest with two fledglings.	WA 646945
10 Dec	São Roque de Minas, Minas Gerais	Nest with incubating female.	WA 2428180
12 Dec	Batatais, São Paulo	Nest with two eggs.	von Ihering (1902)***
21 Dec	Chapada Diamantina, Bahia	Nest with one nestling.	IBC 1196099
25 Dec	Alto Paraíso de Goiás, Goiás	Nest with incubating female.	WA 1588195

*Marini (1992) reports that females collected and/or mist-netted in Brasília by him exhibited brood patch from September to December; males with enlarged testes were collected from July to December.

** The eggs of this clutch are deposited at the American Museum of Natural History, New York, USA (AMNH 14439, M.Â.M., pers. comm.).

*** This nest is deposited at Museu de Zoologia da Universidade de São Paulo, São Paulo, Brazil (MZUSP 900) and one of the eggs is probably an egg deposited at the Museum für Naturkunde, Berlin, Germany (ZMB 1433, M.Â.M., pers. comm.).

a riparian woodland within a disturbed tropical dry forest in Costa Rica also lasted for about five months, extending from March to July (Foster 1976). Therefore, the length of the breeding season is remarkably similar for the Helmeted Manakin and the two species of *Chiroxiphia* that occupy quite distinct habitats.

Nest placement and its morphology, as well as life history parameters, are quite uniform between members of *Antilophia* and *Chiroxiphia*. The Helmeted Manakin nests in the undergrowth, usually below 3 m, using both shrub and trees as support, even though some nests can be built as high as 10 m (Marini 1992). Linhares *et al.* (2010) found similar result for the 28 nests of the Araripe Manakin *A. bokermanni*, with 93% of them constructed below 2 m. The Blue Manakin and the Long-tailed Manakin also construct their nests in the forest undergrowth, usually below 3 m, although they also show substantial variation in nesting height (Foster 1976, Zima *et al.* 2017). Nests of all species in these two genera are a cup attached by its top lip in the angle of a forked branch, often including a tail of loose dry broad leaves (Kirwan & Green 2011). Other similarities in breeding parameters between *Antilophia* and *Chiroxiphia* are: clutch size of two eggs, incubation performed exclusively by females during a period of ~18 days, nests kept clean, and nestlings brooded and feed exclusively by females for a period of ~16 days (Foster 1976, Coelho & Silva 1998, Silva 2004, Linhares *et al.* 2010, Zima *et al.* 2017).

Low reproductive success such as that recorded for the Helmeted Manakin (27%) was also recorded for other passerine birds in our study area. For example, the simple percentage of successful nests for the syntopic Pale-bellied Tyrant-manakin *Neopelma pallescens* (Pipridae) was as low as 15.4% (*n* = 13; Ferreira & Lopes 2018). Slightly higher percentage of successful nests was recorded for the forest edge Gray-headed Tody-Flycatcher *Todirostrum poliocephalum* (Rhynchocyclidae) (30.8%, *n* = 13; Ferreira *et al.* 2019) and for the open area Lined Seedeater *Sporophila lineola* (Thraupidae) (36.5%, *n* = 74; Ferreira & Lopes 2017).

Members of *Antilophia* and *Chiroxiphia*, although closely related, present quite distinct courtship displays. Males of *Chiroxiphia* usually congregate in fixed arenas where they exhibit complex courtship displays to impress females (Kirwan & Green 2011). The Helmeted Manakin has no fixed territory during the breeding season, but rather, range widely along its home range, seeking sexually receptive females. Multiple males them congregate near a receptive female and exhibit an unspectacular chasing courtship display (Marçal 2017). These chasing displays have already been described by previous authors for the Helmeted Manakin (Sick 1967, 1997, Marini & Cavalcanti 1992) and the Araripe Manakin (Silva & Rêgo 2004), but they have never been properly interpreted as such.

Data summarized here indicates that the Helmeted Manakin is not a monogamic species as previously suggested (Marini 1992, Marini & Cavalcanti 1992, Kirwan & Green 2011), but a promiscuous one, with males potentially copulating with any receptive female, but without providing any paternal care. Doubts about the true mating system of the Helmeted Manakin were expressed by Marini & Cavalcanti (1992), who stated that the species was "possibly monogamous", but that "several possible problems with this interpretation" existed.

The hypothesis of promiscuity presented here can only be unequivocally confirmed with an investigation of genetic paternity of nestling associated with closer observations of copulations in the field. The study of DuVal & Kempenaers (2008), for example, demonstrated that in the Long-tailed Manakin nestlings were overwhelmingly sired by alpha males.

The fact that most of the nests found in our study area were far from water shows that breeding in the Helmeted Manakin is not restricted to the riparian forests of the Cerrado, and that it can reproduce in areas with no water body at all. Several studies found the species inhabiting small forest fragments in degraded environments, revealing the plasticity and versatility of the species in relation to its habitat use (Andrade & Marini 2002, Ferreira & Cavalcanti 2005, Manica *et al.* 2010). The data summarized here, although obtained during a short-term study, provided evidence of a promiscuous breeding system and a high capacity of adaptation to different habitats by the Helmeted Manakin, which is threatened by climate changes (Anciães & Peterson 2006, Marini *et al.* 2009).

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ARTICLE

Diet of the Bobolink (*Dolichonyx oryzivorus*) in rice fields on its wintering grounds in Argentina

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ABSTRACT: Winter diet of Bobolinks (*Dolichonyx oryzivorus*), a bird considered a pest of rice fields, is known to consist primarily of seeds. However, it is not yet possible to establish the extent to which non-rice plants and animal components contribute to its diet. To contribute to these issues, we studied the diet of the Bobolink found in rice fields on its wintering grounds in Santa Fe, Argentina, to provide information on (*i*) the composition of the diet and (*ii*) the relative importance of plant and animal components in the diet and of the different prey categories. We captured Bobolinks with mist nets and obtained samples of stomach contents by warm water and emetic-based regurgitation to determine the composition of the diet ($n = 46$ samples) and the importance of the different prey ($n = 25$ samples), mainly during March, just prior to northbound migration. We confirmed that the Bobolink's diet in this region during this period is predominantly herbivorous (97%) and rice-based (55%), although it also consumes a large number of seeds of non-cultivated plants that represented 42% of the diet. Invertebrates, although of less importance than plant components (3%), had been consumed by 97% of captured individuals. Our results document the importance of non-cultivated plants and animal prey in the diet of Bobolinks in addition to rice.

KEY-WORDS: agroecosystems, birds, emetic, foraging, pests.

INTRODUCTION

Bobolink (*Dolichonyx oryzivorus*), an obligate-grassland species, has one of the longest annual migrations of any New World passerine (≈ 20,000 km round trip), with breeding and wintering grounds located in North America and South America, respectively (Renfrew *et al.* 2015). Reports of population declines on the breeding grounds (Sauer *et al.* 2004) highlighted the need for studies on the natural history and ecology of the species, in order to identify threats to the development of conservation strategies, mainly on the wintering grounds where studies have been more limited (Renfrew *et al.* 2015).

Knowledge of Bobolink ecology on its wintering grounds has increased significantly in the last decade (López-Lanús *et al.* 2007, Renfrew & Saavedra 2007). Additional research needed to guide conservation of Bobolinks includes investigating its trophic ecology on wintering grounds (Renfrew & Saavedra 2007, Blanco & López-Lanús 2008), because the Bobolink is considered a pest of rice fields (López-Lanús *et al.* 2007, Renfrew & Saavedra 2007), although the extent to which the species relies on rice during austral summer remains largely unknown (Renfrew *et al.* 2017). Although the diet of Bobolink on its wintering grounds is known to consist primarily of plant material (Renfrew & Saavedra 2007), no empirical studies have established the importance of rice and animal parts (invertebrates) in relation to other items in the diet. Recently, Renfrew *et al.* (2017) used stable isotopes to demonstrate that Bobolinks rely on rice for approximately one-third of their diet and that importance of rice in the diet is higher in rice fields than in natural grasslands within their wintering grounds.

Beyond these contributions, however, yet there is no quantitative information on the diet of the Bobolink on different parts of its wintering grounds, information necessary for a more precise quantification of damages and benefits that the species contributed to rice-field agroecosystems, based on the relative importance of rice, non-cultivated plants and invertebrates in the Bobolink diet. Here, we studied the diet of Bobolinks found on rice fields in Santa Fe, Argentina, an area where a large concentration > 100,000 individuals has been documented during several seasons (López-Lanús *et al.* 2007, López-

Lanús & Marino 2010). Our objectives were to provide information on (*i*) the diet of the species and (*ii*) the relative importance of plant and animal components of the diet and of the different prey categories.

METHODS

Study area

The study area included the rice zone located in the eastern part of Santa Fe province, Argentina (Fig. 1). This zone covers a north-south band, approximately 10–20 km wide, west of the San Javier River, part of the Paraná River system, from approximately Romang (29°29'S; 59°45'W) in the north to Cayasta (31°11'S; 60°9'W) in the south. This area is characterized by xerophilous forests of the Espinal ecoregion at higher elevations, and by marshes and flooded grasslands in lower elevations (López-Lanús & Marino 2010).

Bird captures and samples of stomach contents

We captured Bobolinks (*n* = 70 individuals) with mist nets to obtain samples of stomach contents in three rice fields from 14 January to 12 March 2016 (Fig. 1). We placed one to three mist nets in foraging sites and near day roosts. We opened the mist nets only after we had observed foraging behavior of flocks for at least 2 h to obtain captures after individuals have foraged to increase the regurgitation rate (Durães & Marini 2003).

We assessed the diet with a combination of techniques. First, we used warm water to force regurgitation because this technique is considered less harmful to the bird than emetic-based regurgitation, although also less effective (Major 1990, Poulin *et al.* 1994). Warm water was administered orally into the beak and down the esophagus by means of a 1 cm^3 syringe connected to a 1.5 mm diameter silicone tube that had been moistened in saline solution or vaseline. We inverted the bird over a plastic cup so that, as fluid was forced into its stomach, the excess fluid plus the stomach contents flowed into the cup (Hess 1997). We obtained 13 samples using this technique. Individuals that did not regurgitate on the first attempt were released to minimize stress. Preliminary inspection in the laboratory revealed few food items, represented by highly disaggregated seeds and arthropods. Given the low effectiveness of this method because very little food was regurgitated, we chose to use an emetic (potassium antimony tartrate) to obtain additional samples of stomach contents. Following Poulin *et al.* (1994), we gave birds 0.8 cm^3 of a 1.5% solution of antimony potassium

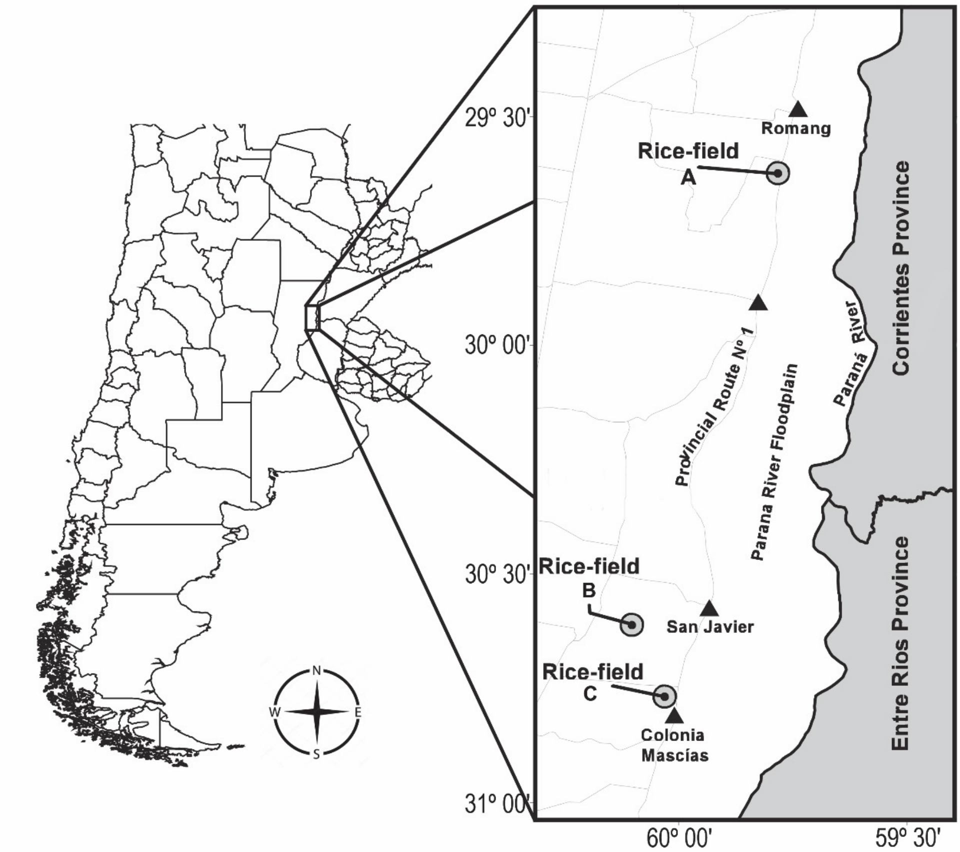

Figure 1. Location of the three rice fields (**A**, **B** and **C**) where Bobolinks (*Dolichonyx oryzivorus*) were captured in mist nets and sampled for gut contents.

tartrate per 100 g of body mass. After the solution was given orally through a 1.5-mm diameter flexible plastic tube attached to a l cm^3 syringe, we placed the bird in a small box lined with absorbent paper for 15 to 20 min to allow them to regurgitate and also to recover after regurgitation (Poulin *et al.* 1994, Johnson *et al.* 2002, Carlisle & Holberton 2006). We obtained 23 samples using this technique after which we discontinued its use because mortality rate was high (33%, *n* = 10 individuals). Two additional samples were from the stomach contents analysis of two individuals that did not regurgitate and died. Dead individuals were collected and deposited in the collection of the National Institute of Limnology (INALI: CONICET-UNL). Subsequently, we resumed using the saline solution regurgitation method obtaining eight more samples, and all of these birds were released successfully after samples were obtained. All gut contents were preserved in 70% ethanol.

Analysis of digestive tract contents

We examined contents of digestive tracts under a Nikon® stereoscope binocular. We counted, measured and classified prey categories to the lowest possible taxonomic level. We considered all samples, regardless of the collection technique to inventory the total number of prey items found in the diet of Bobolink (*n* = 46 samples). These samples were obtained from 14 January to 12 March 2016. However, to assess relative importance of prey categories, we did not use samples obtained by water-based forced regurgitation because this technique likely under sampled vegetal fraction of stomach contents (26.4 *vs.* 2.6 plants by sample in emetic- and water-based forced regurgitation samples, respectively) affecting the comparison with the animal fraction, which was affected, but to a lesser extent, by the technique (1.4 *vs.* 0.5 animal prey by sample in emetic- and water-based forced regurgitation samples, respectively). Thus, we calculated the number and frequency of prey types only from 25 samples to assess relative importance of prey categories, 15 represented only by emetic samples, two only by digestive tract dissection, and eight represented by both emetic and digestive tract samples. In this way, the samples considered in this analysis were obtained only at the beginning of March (between 08–11 March 2016). Given that we could only identify mature seeds in the digestive tract, the importance of rice in the diet was underestimated because we could not quantify immature liquid or "milky" stages of rice. However, because estimation of relative importance of rice was based on samples obtained in the final stage of rice production during March, it is unlikely that the immature liquid or "milk" stage of rice represented a high proportion of the rice consumed at this stage of the crop. We quantified the abundance (N%), frequency of occurrence (F%), volume (V%) and index of relative importance (IRI%) of each category of prey to determine the contribution of each category to the diet of the species. We calculated the biovolume of ingested categories by approximation to regular geometric shapes. The volume of fractionated and disarticulated prey was estimated by comparison with reference prey. However, this was implemented mostly for animal prey since seeds were found intact in most cases. Index of relative importance of prey (Pinkas *et al.* 1970) was used to determine the importance of each prey category in the diet.

RESULTS

General composition of the diet

We recorded 1597 items from all samples (*n* = 46 samples), corresponding to 17 food item categories (Table 1). Of the total items, 1521 (95%) were from plants, represented by 6 families and 10 plant species (in the case of rice, *Oryza sativa*, two varieties were recorded and treated separately: Rice and Red Rice, cultivated and weed, respectively) and 76 items (5%) were from invertebrates, represented by 6 orders (Table 1). Plant items were mainly Cyperaceae (48%) and Poaceae (43%). The high degree of digestion did not allow finer taxonomic resolution of invertebrate samples, with the exception of nymphs of Hemiptera assigned to the family Pyrrhocoridae and a Hemipteran assigned to the family Lygaeidae.

Relative importance of prey categories

Among the 25 individuals represented by complete (or mostly complete) stomach contents, plants represented almost the entire diet (IRI% = 97%), while animals were a minor component (IRI% = 3%), reflecting the greater number and volume of seeds in the diet (Table 1). However, although only 4% of the total number of prey items was invertebrates, 92% of the samples had at least one item from this category, indicating that most Bobolink individuals consumed at least some animal prey. The highest number and frequency of invertebrate in the diet corresponded to the orders Hemiptera and Coleoptera (Table 1).

Rice was the most important component of the diet because it was the most frequent prey category (F% = 73%) and represented the largest volume (V% = 59%) of items in the diet (Table 1). The most abundant component of the diet was a species of the family Cyperaceae (N% = 48% *vs.* N% = 15% for rice) that, although it also had a high frequency among samples (F% = 58%), had a minor relative importance in the diet than rice due to the

Table 1. Total number (*n* = 46 samples) and importance (*n* = 25 samples) of the prey categories found in diet samples of Bobolinks (*Dolichonyx oryzivorus*) on its wintering grounds in Argentina. Prey categories within the plant and animal fractions are arranged in decreasing order according to the number of categories of prey recorded. Values in bold indicate the totals for the plant and animal fractions. The script indicates that the item was not found in this group of samples. Total number of prey categories is based on all samples. Abbreviations: percentages of number (N%), frequency (F%), volume (V%) and index of relative importance (IRI%); NI: not identified.

Prey category	**Total number (n)**	**Importance**			
		N%	**F%**	**V%**	**IRI%**
Plant fraction	**1521**	**96**	**96**	**95**	**97**
Echinochloa sp.	235	15	15	6	3
Oryza sativa (Rice)	232	15	73	59	55
Paspalum sp.	96	6	35	3	3
Oryza sativa (Red Rice)	94	5	15	20	4
Cyperaceae NI	733	48	58	4	30
Polygonaceae	63	4	42	1	2
Solanum sp.	30	2	8	0	0
Conyza bonariensis	20	1	31	0	0
Amaranthus sp.	8	0	8	0	0
Sp. NI (Asteraceae?)	5	0	12	0	0
Sp. NI	5	0	4	0	0
Animal fraction	**76**	**4**	**92**	**5**	**3**
Coleoptera	25	1	42	3	1
Hemiptera	18	1	23	1	1
Diptera	4	0	12	0	0
Hymenoptera	3	0	4	0	0
Psocoptera	2	0	8	0	0
Araneae	1	-	-	-	-
Undetermined	23	1	50	0	0

smaller size and volume of the seeds (Table 1). Overall, seeds and fruits of non-rice species were more abundant and frequent than rice among the individuals analyzed, but rice accounted for a greater volume of the diet due to the larger size of the grains (Table 1, Fig. 2).

DISCUSSION

Bobolinks are persecuted by rice producers in their wintering grounds because they are considered pests of rice crops (López-Lanús *et al.* 2007, Renfrew & Saavedra 2007). However, knowledge of its trophic ecology on the wintering grounds is limited because, although Renfrew *et al.* (2017) estimated the importance of rice, no previous study has assessed quantitatively the importance of non-cultivated plants and animal prey in their diet. In this study, in agreement with previous studies of the species (*e.g.*, Martin & Gavin 1995, Renfrew & Saavedra 2007), we confirmed that Bobolinks have a diet that is

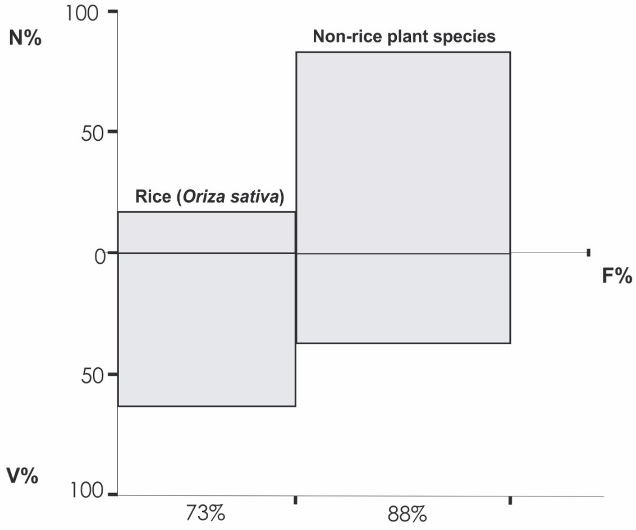

Figure 2. Relative importance index (IRI%) of rice (*Oryza sativa*) *vs.* other plant species in the Bobolink (*Dolichonyx oryzivorus*) diet in Santa Fe, Argentina. Abbreviations: percentages of number (N%), volume (V%) and frequency (F%).

predominantly herbivorous and rice-based during March, just prior to northbound migration (*i.e.*, emetic-based samples, on which the calculations of relative importance of the prey were based, were obtained at the beginning of this month) in areas of intensive rice production. However, our results also indicate that Bobolinks consume more seeds of non-cultivated plants. Invertebrates, although of minor importance in relation to plants, were present in the diet of most individuals, possibly as a result of occasional intake of invertebrates found while birds were searching for seeds (*e.g.*, arthropods associated with seeds of plants).

General composition of the diet

Grains of mature Rice (*O. sativa*) represented an important fraction of the diet in this study, which is in agreement with previous studies that have examined diet composition of Bobolinks in rice fields within their wintering area (*e.g.*, López-Lanús *et al.* 2007, Renfrew & Saavedra 2007, Blanco & López-Lanús 2008). Rice was more important in the diet because it was abundant, frequent, and comprised the greatest volume of the plant component in the diet. The observed relative importance of rice in the Bobolink diet (55%) was lower than that reported by Renfrew *et al.* (2017), who found that the relative proportion of rice was approximately 69% in a rice-producing region in Bolivia. Our results about the relative importance of the rice correspond only to the days before harvest, *i.e.* we only used samples obtained by emetics and stomach analysis obtained between 08–11 March 2016 to determine the relative importance of the different prey, when the rice is already in a mature and hard stage. Under these conditions, Bobolinks could include a greater proportion of other plants in their diet because rice is no longer found in the milky and soft stages preferred by the species in the studied rice fields.

Echinochloa sp. and a Cyperaceae species were among the most abundant food items. However, because these seeds and fruits are small, these were lower in volume of diet and relative importance than rice. Seeds of *Echinochloa* sp. probably corresponded to *E. colona*, a naturalized grass introduced from Europe (Pensiero & Gutiérrez 2005) that previously was reported by López-Lanús *et al.* (2008) as part of the diet of Bobolinks in the same area. *Cyperus* sp. is among the probable Cyperaceae genera corresponding to the species found in the rice field A, because this also has been reported as part of the diet of Bobolink in the area (López-Lanús *et al.* 2008). The same study also mentioned that Bobolinks feed on *Conyza bonariensis*, a grass species that was also found during the present study, mainly in samples from field A, where grasslands composed of this plant were observed. Other plant species present in the area that have been mentioned as part of the Bobolink diet (*e.g.*, *Echinochloa crus-galli*, *Echinochloa polystachya*, *Sorghum halepense*, *Hymenachne amplexicaulis*) were not found in samples during our study.

Remaining plant items corresponded to native or naturalized non-cultivated herbs and mostly coincided with those documented in previous studies. However, fruits of Polygonaceae and seeds of *Solanum* sp. (Solanaceae) and *Amaranthus* sp. (Amaranthaceae), although of little importance, had not previously been mentioned as part of the Bobolink diet in the area. Presence of Polygonaceae species has been reported in the Bobolink diet from breeding and stopover sites in the United States (Beal 1900, Meanley & Neff 1953). Presence of *Solanum* sp. seeds suggests that unless Bobolinks extract the seeds without ingesting the fruit, Bobolinks could also consume fleshy fruits such as those of these plant species. Solanaceae species have not been mentioned as part of the Bobolink diet in any previous study and, thus, this could simply correspond to an occasional intake, although it was found in samples from two individuals in rice field B.

Results of the current study also have expanded our knowledge of invertebrates consumed by Bobolinks. For example, although Hemiptera have been mentioned as present in the diet of the Bobolinks in the wintering area (López-Lanús & Marino 2010), the present study provides the first documentation of Hemiptera in diet samples; eight Hemiptera nymphs were found in the sample from a single individual Bobolink. Similarly, although some of the recorded invertebrate prey have been documented in samples from breeding and stopover sites *(e.g.*, Coleoptera, Hemiptera, Hymenoptera and Araneae; Beal 1900, Meanley & Neff 1953), documentation of invertebrate prey in the diet of Bobolinks on their wintering grounds was previously limited to caterpillars (Lepidoptera; Renfrew & Saavedra 2007, López-Lanús *et al.* 2008).

Considerations on the techniques used to study Bobolink diet

Our study showed that water-based forced regurgitation is a technique much less effective than emetic-based technique to study the Bobolink's diet. However, use of emetic implied a relatively high mortality rate that limited the number of samples obtained. This contrasts with studies that have shown that mortality caused by emetics is relatively low in icterids (Poulin *et al.* 1994, Poulin & Lefebvre 1995). However, responsiveness to emetics is highly species-specific (Durães & Marini 2003). Although the manipulation of birds mainly during the oral administration into the beak and down the esophagus by means of a syringe connected to a silicone tube can cause damage to the birds if not implemented correctly, all the birds that received the same treatment, but with warm water were not damaged and were successfully released. This indicates that the mortality was directly related to the emetic and not to the manipulation. Emetic solution was prepared in laboratory by a professional chemist to assure a correct preparation. Characteristics that differentiate the Bobolink from other icterids like the high energetic cost of migration and the use of agrochemicals in rice fields where they feed could be related to this sensitivity to the emetic. These aspects could be evaluated by studying the health conditions of these populations. Beyond this, we do not recommend the use of emetics for the study of the diet of Bobolink. Alternatively, the use of water-based forced regurgitation can be used to establish qualitative lists of ingested prey, and not of their relative importance, because of the little food regurgitated by this technique in relation to the use of emetic. Other techniques such as the use of stable isotopes and the genetic analysis of feces could improve our knowledge of the Bobolink diet on its wintering grounds.

Conservation implications

Our results show that Bobolinks consume a great quantity of seeds and grains of non-cultivated plant species. These results are remarkable because we captured Bobolinks within rice fields where the rice crop is the predominant land-cover. Thus, these results agreed with the idea that damage to rice crops could be lower in fields that maintain the presence of non-cultivated patches and roadsides with the presence of naturally occurring grass, which provide an alternative food source to the Bobolink.

Our results also showed that Bobolinks could contribute to the control of pest insects in rice fields. Although the insect component of the diet was of relatively minor importance, the documentation and confirmation of the presence of invertebrates in the Bobolink diet suggest that Bobolinks can potentially have a beneficial role in agroecosystems based on their contribution to the regulation of populations of these insects. This function can be important considering that the number of Bobolinks counted in the region has exceeded 100,000 individuals (López-Lanús *et al.* 2007, López-Lanús & Marino 2010). Insects consumed by Bobolinks included members of the orders Hemiptera and Coleoptera, both of which include species that can damage rice crops (Kruger & Burdyn 2015). The opportunistic behavior shown by the Bobolink to capture their animal prey can be important when these groups of insects become abundant.

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ARTICLE

Wildlife and damage to agriculture: an ethnobiological approach with rural producers in southeastern Brazil

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ABSTRACT: Some wild animal species quickly adapt to anthropogenic environments, producing unusually large populations, causing human-wildlife conflicts. The objective of this study is to understand the way the farmers perceive the fauna and the information they possess regarding the damages those animals inflict on their crops in southeastern Brazil. We collected data by presenting 200 questionnaires and conducting 22 semi-structured interviews with the rural producers in a region characterized by an agrarian matrix intermixed with small forest patches. Nearly every rural producer (99%) who answered the questionnaire (*n* = 107) had suffered wild animal-triggered economic losses, especially by the White-eyed Parakeet *Psittacara leucophthalmus* (51%), which attacked maize and fruit crops. A substantial portion of these farmers (38%) has employed some control method, including acoustic techniques (42.5%), like fireworks, and visual techniques (41%), like scarecrows. The farmers concurred that effective control methods are necessary for the White-eyed Parakeet, as current techniques proved inadequate. The understanding that the rural producers possess about the problem will facilitate designing new control strategies to manage this pest species. However, to ensure its success, a suitable management plan must be formulated to guarantee that the local rural occupations are maintained, incorporating human dimensions into wildlife management.

KEY-WORDS: crops damage, ethnozoology, human-wildlife conflict, problem species, Psittacidae.

INTRODUCTION

Vast sections of almost all the world ecosystems have been converted into landscapes predominantly for human exploitation, particularly farming (Greenberg *et al.* 1997, Daily *et al.* 2001), thus negatively affecting most wild species and their populations (McLaughlin & Mineau 1995, Verhulst *et al.* 2004). However, the extension of agricultural locations may also result in the population explosion of some species, partly due to the associated rise in the food, as well as resting and reproduction sites becoming more available (Singleton *et al.* 1999, Koopman & Pitt 2007).

Any animal species in an agricultural ecosystem which shows disproportionate and unrestrained population explosion frequently poses a problem for man (Fall & Jackson 2002). Such human-wildlife conflicts mostly originate from the economic losses these species inflict on the rural owners (Tracey *et al.* 2007), inducing a change in their perception of the wildlife (Messmer 2009). Thus, wild fauna, normally accepted as being economically, recreationally, and aesthetically useful, are hence considered undesirable and problematic (USDA 1997, Conover 2001, Ormerod 2002).

Any living organism having a population density that directly or indirectly impinges on society, injuring its health and constructions, or influencing plantations of food crops and raw materials, thus necessitating control methods, is defined as a pest species (Sinclair *et al.* 2006). Control management techniques to tackle these pest species attempt to diminish the damage they cause, either by blocking or decreasing the accessibility of the species to food sources or reducing its population growth (Moreira & Piovezan 2005, Sinclair *et al.* 2006).

A global war is on between wildlife and agriculture with serious economic backlashes (de Grazio 1978). Each problem is unique to the social and cultural contexts of the part of the world where it happens, in terms of the species involved and the types of region they inhabit (Beasley & Rhodes-Jr. 2008, Rao 2010). Therefore, workable, and long-term control methods are required to minimize the damage to agriculture caused by wildlife (Messmer 2009). To successfully manage the control of the human-wildlife conflict a correct understanding of the affected and unaffected actors in society is required (Conover 2001), as well as the knowledge of the positive and negative sides of the various management alternatives, keeping the focus of wildlife conservation intact (Brook 2009). In this context, an ethnobiological approach is highly desirable, because it has the "potential to integrate local and global knowledge, connect cultures and academic approaches, and to relate biological and social aspects of the human experience to the environment" (Albuquerque & Alves 2016).

Brazil ranks high among the leading food producers and exporters worldwide (OECD-FAO 2015); however, despite facing serious conflict between wildlife and agriculture, very little study has been done (Moreira & Piovezan 2005), with the result that management strategies for problem species of birds are few or absent. Therefore, farmers frequently implement rather inadequate self-developed practices, a few of which do more damage to the environment. Given that human-wildlife conflict is a growing issue in Brazil (Marchini & Crawshaw-Jr. 2015), the objective of this study is to understand the way the farmers perceive the fauna and the information they possess regarding the damages those animals inflict on their crops in southeastern Brazil.

METHODS

Study area

We conducted this study in 12 municipalities in the southeast of the state of Minas Gerais, Brazil, in a region known as Campo das Vertentes (between 21°00'S–21°40'S; 43°20'W–45°20'W) (Fig. 1). The original vegetation of the region, which is in the transition between the Cerrado and the Atlantic Forest, was a mosaic composed by montane semideciduous forests, open savannas, and pure grasslands (Azevedo 1962, Gavilanes *et al.* 1995, Oliveira-Filho & Fluminhan-Filho 1999, IBGE 2012). The climate of the region, which is mostly between 1000 and 1200 m altitude, is humid temperate, with hot wet summers and cold dry winters (*Cwb*-Köppen's climate classification system) (Alvares *et al.* 2013), with average annual temperatures varying locally between 17.4°C and 20.5°C, and annual average precipitation varying between 1200 and 1600 mm (Naime *et al.* 2006).

Currently, the landscape of the Campo das Vertentes is highly modified and fragmented, with a mosaic of

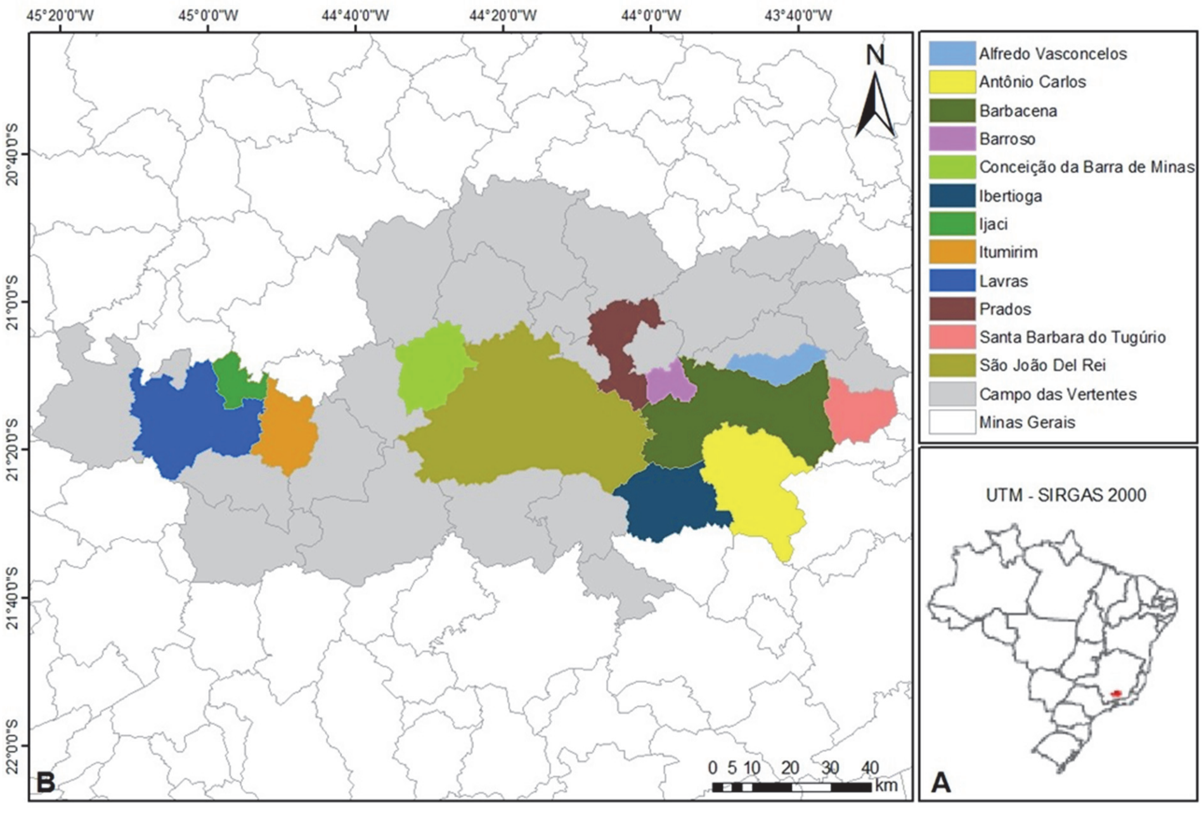

Figure 1. Location of the study area in the Campo das Vertentes region (**A**), the municipalities involved in the research are highlighted in color (**B**).

small forest fragments, agricultural areas, *Eucalyptus* plantations, and artificial pastures for livestock raising (Lopes *et al.* 2010, A.L.C.C. pers. obs.). According to an unpublished report of EMATER-MG ("*Safra Agrícola* 2014"), local agriculture is characterized by plantations of fruit, maize, sorghum, soybean, beans, coffee, and vegetables, with most farmers being small and medium-sized rural owners.

Data collection

Between July and September 2014, we collected data via questionnaires and semi-structured interviews. We distributed a total of 200 questionnaires, among which 120 were administered in collaboration with EMATER-MG, which sent out 10 questionnaires to each of their 12 local offices in the cities of Alfredo Vasconcelos, Antônio Carlos, Barbacena, Barroso, Conceição da Barra de Minas, Ibertioga, Ijaci, Itumirim, Lavras, Prados, Santa Bárbara do Tugúrio, and São João del-Rei (Fig. 1). We administered the remaining 80 questionnaires during meetings with farmers from the Rural Union of Barbacena ("*Sindicato Rural de Barbacena*") and the National Program of Access to Technical Education and Employment (PRONATEC), both held in Barbacena. The semi-structured questionnaire included 13 objective questions (answerable briefly or with yes/no) dealing with the relationship between wildlife and its agricultural impact (Ditt *et al.* 2009).

Using the semi-structured questionnaires, we conducted face-to-face interviews with 22 fruit growers, maize and sorghum from Barbacena. The main issues in the interviews addressed the level of damage, control techniques, species behavior and population variations that the farmers experienced with their respective pest species on the agricultural crops. To verify the pest species cited by the farmers, we presented illustrations and a list of likely problem species that could occur in the region.

Besides questionnaires and interviews, we also accessed the rural producers' perceptions during a meeting conducted in March 2014 at the Rural Union of Barbacena. They discussed the conflict between the fauna and agriculture and the pest management control methods prevalent in Brazil and the alternative methods available in the rest of the world. This meeting facilitated profitable dialogue among the rural producers and an exchange of experiences.

RESULTS

Questionnaires

There was a 53.5% (107 of 200) response rate to the questionnaire from the 12 local EMATER-MG offices: Alfredo Vasconcelos (*n* = 9), Antônio Carlos (*n* = 10), Barbacena (*n* = 5), Barroso (*n* = 5), Conceição da Barra de Minas (*n* = 7), Ibertioga (*n* = 10), Ijaci (*n* = 10), Itumirim (*n* = 10), Lavras (*n* = 10), Prados (*n* = 4), Santa Bárbara do Tugúrio (*n* = 1), and São João del-Rei (*n* = 5). We obtained 21 questionnaires from the meetings with the farmers at the Rural Union of Barbacena and the meeting with the PRONATEC farmers.

The farmers mentioned the most frequently cultivated agricultural products in the region and their respective areas in hectares (ha) as maize (52% of the producers; grown on 0.5 to 55 ha), fruits (22.4%; on 5 to 130 ha); vegetables (12.8%; on 1 to 3 ha), beans (9.6%; on 0.5 to 20 ha), sorghum (2%; on 0.5 to 5 ha), rice (0.6%; on 0.5 ha), and sugarcane (0.6%; on 3 ha). The cultivated areas within a farm were thus usually small, below 10 ha. With only one exception, all farmers had experienced economic losses induced by wild animals.

Among the 16 animals identified as the cause of economic losses (Table 1), the White-eyed Parakeet *Psittacara leucophthalmus* was the most problematic as mentioned in the questionnaires by 51% of the producers, principally on maize (36.4%) and fruits (13.5%) (Fig. 2 & 3). All producers mentioned a significant increase in the local population of this species over the recent years. Capybara (*Hydrochoerus hydrochaeris*) was the second most

Figure 2. Damage caused by White-eyed Parakeets *Psittacara leucophthalmus* (**a**), in maize (**b**) and guava (**c**) crops in southeastern Brazil. Photo author: Ana Laura C. Carvalho.

Table 1. Damage-causing vertebrate pests on agricultural crops in the southeastern Minas Gerais, Brazil.

Taxon	English name	Scientific name
BIRDS		
Galliformes	Dusky-legged Guan	*Penelope obscura*
Gruiformes	Slaty-breasted Wood-Rail	*Aramides saracura*
Columbiformes	Pigeon	*Patagioenas* spp.
Piciformes	Toco Toucan	*Ramphastos toco*
Cariamiformes	Red-legged Seriema	*Cariama cristata*
Psittaciformes	White-eyed Parakeet	*Psittacara leucophthalmus*
Passeriformes	Curl-crested Jay	*Cyanocorax cristatellus*
Passeriformes	Chopi Blackbird	*Gnorimopsar chopi*
Passeriformes	Tanager	*Thraupis* spp.
MAMMALS		
Rodentia	Capybara	*Hydrochoerus hydrochaeris*
Artiodactyla	Wild Boar[a]	*Sus scrofa*
Carnivora	South American Coati	*Nasua nasua*
Cingulata	Armadillo	*Dasypodidae* spp.
Didelphimorphia	Opossum	*Didelphis* sp.
Primates	Howley Monkey	*Allouatta* sp.

[a] The Wild Boar is an exotic species in Brazil, and in the region, it probably refers to a cross between the Domesticated Pig (*Sus scrofa domesticus*) and the Wild Boar (*Sus scrofa scrofa*).

cited species (11% of the producers), causing problems mostly on maize crops (9%), while the Dusky-legged Guan (*Penelope obscura*) was the third most mentioned species (10% of the producers), chiefly on bean (4%) and vegetables (3.6%) (Fig. 3).

A significant degree of financial loss was attributed to wild animals by 72% of the rural producers. The problematic species included those that inflicted economic losses (81%), which could not be controlled by the currently used management techniques (13%), and those with huge populations that attacked the food crops (6%). All the producers unanimously bemoaned the lack of government support in preventing the financial losses these wild animals caused.

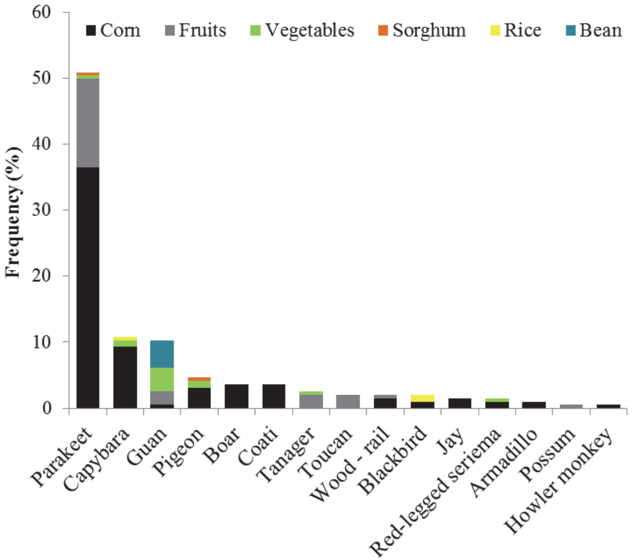

Figure 3. Frequency of the cited damage-causing vertebrates on agricultural crops in southeastern Brazil.

Most of the rural producers (57%) stated in the questionnaire that September to December was the period when the animals most attacked plantations. Crop damage, however, continued the whole year through.

From the questionnaires, it was evident that 38% of the rural producers who experienced financial losses caused by the wild fauna used some control measures. The commonest techniques used by 42.5% of the producers were of the acoustic type (*e.g.*, fireworks, gas cannon, and other devices producing a variety of sounds), but with marginal success, whereas 41% of the producers employed the visual types (*e.g.*, scarecrows, reflectors, and lookouts on foot and on motorcycle) (Fig. 4).

The control methods employed by the rural producers were generally regarded as ineffective, with only 12% registering any decrease in the degree of damage and 88% denying any positive outcomes. Reportedly, the White-eyed Parakeet quickly got used to the acoustic (fireworks) and visual control methods (scarecrows, reflectors) (Fig. 5A–D). Measures such as human or motorcycle riding lookout should be continuously applied in these areas to gain some success (Fig. 5E–G).

However, they reported that such methods only changed the location of the problem, as the animals moved on to neighboring plantations for food. Total isolation of the White-eyed Parakeet-affected plantations, by covering them with protective (drape over) netting, was regarded as economically unfeasible (Fig. 5H & I).

While most rural producers (69%) strenuously denied any hunting on their property, 19% acknowledged it was prevalent and 12% did not comment about this management technique. Among those who admitted to hunt, birds (9.5%) and mammals (90.5%) were sought as food (67%), sport and leisure (19%), and as pest extermination (14%). A little below half the rural producers (44%) acknowledged they would hunt wild animals legally and with control, while 56% stated they would not indulge in hunting. The reasons proffered for avoiding hunting included not being habituated to hunt, disliking the concept, lacking the courage to kill an animal, lacking time and resources, or even because several animals had become extinct.

All the rural producers unanimously agreed among the many suggestions offered that pest species required management, such as controlled hunting (48.5%) and interventions to reduce their populations (26%) (Fig. 6).

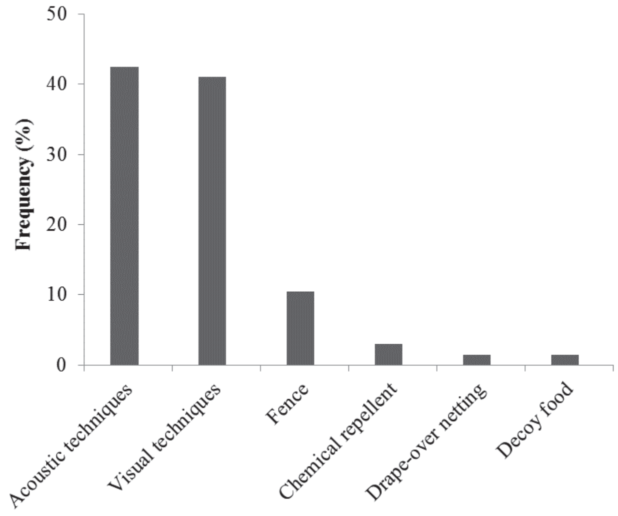

Figure 4. Frequency of implementing various types of control measures by the rural producers in southeastern Brazil.

Interviews

All the farmers interviewed indicated that the White-eyed Parakeet was the chief pest species in the region. The main damages caused by the species and its impacts are mentioned below:

As it is no longer economically feasible to cultivate

Figure 5. Control methods utilized by the rural producers in southeastern Brazil. Scarecrows (**A–C**); reflectors (**D**); lookout on foot (**E** & **F**); lookout on motorcycle (**G**), protective netting (**H** & **I**). Photo author: Ana Laura C. Carvalho.

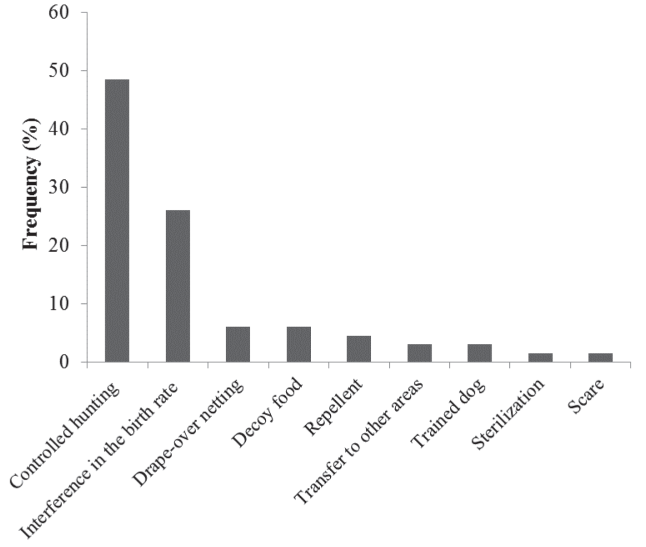

Figure 6. Popular methods advocated by farmers as potential control methods for wildlife posing problems species posing problems to crops in southeastern Brazil.

fruits and maize in the region because of the large extent of financial loss caused by White-eyed Parakeet attacks, many rural producers have ceased to do so;

Electrical wiring and house tiles are frequently damaged;

The White-eyed Parakeet population has exploded over the last few years when compared to its numbers 15 years ago, at which time the economic damage inflicted was minimal;

The White-eyed Parakeet population thrives through the whole year in the region because food is readily available (crop cycle of fruits, maize and sorghum);

White-eyed Parakeet prefer grains and seeds (maize and the weed *Jaegeria hirta,* Asteraceae), over fruits, and feed mainly on apple, peach, and guava;

During the fruit harvest, the White-eyed Parakeet stay in the orchards throughout the entire day, aggregating in communal roosts to overnight close to the food supply;

Although the White-eyed Parakeet come to the orchards in small flocks of up to 50 individuals, they gradually grow into large groups up to 300 individuals;

Once they eat the first fruit, White-eyed Parakeets always return to the place. Frightening them most often is not the solution, as they quickly return after landing in other parts of the orchard and damaging the fruits there;

Nests are built inside cavities excavated in dirt banks and ravines of inside house roofs, with hatching occurring from December to March, producing up to four youngs per clutch;

When a new method is employed to scare the White-eyed Parakeet from the orchards, they refrain do not immediately return to the area, perching in the trees nearby until they realize that the scaring technique poses no real threat;

The short-term control methods (visual and acoustic) tested were found to have poor effect, as the White-eyed Parakeet are intelligent and quickly get accustomed to them;

While protective netting works more efficiently than the short-term measures, the cost-benefit balance must be considered;

Cultivation of maize varieties with harder kernels could minimize the White-eyed Parakeet attacks;

When maize was planted near the Guava cultivations, White-eyed Parakeet induced damage to the Guavas decreased;

Agronomic crop management techniques (pruning and dormancy control) may reduce economic losses, because it may help circumvent the period of the most intense White-eyed Parakeet attacks;

The White-eyed Parakeet population requires more efficient control measures, as the ones presently in use have been proven to be ineffective in solving the issue.

DISCUSSION

Economic losses in agricultural crops due to wild animals is a global issue, involving implications for species preservation, agricultural sustainability, and socioeconomic problems (Nyhus *et al.* 2000). Several species of Psittaciformes, such as the White-eyed Parakeet, are the main consumers of grains and fruits in most agricultural pockets across the world (Long 1985, Bucher 1992, Galetti 1993, Santos-Neto & Gomes 2007, Tracey *et al.* 2007, Ahmad *et al.* 2012). Minas Gerais state, for example, experienced significant economic losses from the White-eyed Parakeet in sorghum (Jacinto *et al.* 2007), maize, and guava crops (Mateus 2013).

Besides destroying crops, the White-eyed Parakeet have also reportedly damaged electrical wiring and roofs of civilian buildings in the western parts of Minas Gerais (Saiki *et al.* 2009). In Australia, the Rose-breasted Cockatoo *Eolophus roseicapilla* causes great damages in urban regions, destroying electric wires, wooden frames, and communication antennae (Tracey *et al.* 2007).

Bird pests have been recorded to inflict greater agricultural damage in the dry seasons, when food resources in nature are scarce and irrigated crops offer abundant food and water supplies (de Grazio 1978). Although in the current study the White-eyed Parakeet attacks were reported in the orchards mostly between the end of the dry season and the commencement of the rainy season, it is not easy to propose any relationship considering this, as this period is also the peak harvest time for the commercial fruits. The White-eyed Parakeet foraging behavior, as reported by the local farmers, bears similarity to that reported for other species of

Psittaciformes in Australia, which repeatedly return to the feeding sites if the food supply is available, and set up their communal roosts close to the agricultural crops (Tracey *et al.* 2007).

The control measures implemented by the farmers were ineffective and frequently economically unfeasible. Common methods used to scare birds (visual and acoustic) are usually poorly efficient, as birds quickly accustom themselves to them (Booth 1994, Tracey *et al.* 2007, Cook *et al.* 2008). When preventive control methods are applied (*e.g.*, just prior to fruit formation), they may possibly exert a greater effect (Booth 1994).

A few rural producers (1.5%) employed protective netting as an effective control measure. Although it has been proven to be effective in minimizing bird damage over the short-, medium- and long-terms (Fisher 1992, Canavelli 2010), it continues to be less implemented because it is not easy to handle (Pritts 2001, Bishop *et al.* 2003, Simon 2008), as well as due to its high cost (Curtis *et al.* 1994, Somers & Morris 2002).

Some farmers (3%) mentioned utilizing chemical repellents as a control method, although none indicated the nature of these products. Brazil, to the best of our knowledge, has not regulated the use of any secondary chemical (toxic) repellant and no testing has been conducted by any scientific study on primary (non-toxic) chemical repellents as a control method for bird pests. In the US, some studies are available on the use of primary chemical repellents as a type of bird-pest control, but a varying degree of success have been reported with their use (Avery 2002, Avery & Cummings 2003).

Agronomic practices of pruning management and dormancy control implemented by some farmers during this study have been recommended by other authors as well, as they can reduce bird damage and raise yields (Canavelli 2009 & 2010, Linz *et al.* 2011). Cultivating alternative food sources like maize, in proximity to a vulnerable crop, is also an effective method of decreasing short-term bird damage. However, it must also be understood that these alternative crops are costly and may not be able to satisfy all the birds in the population, especially in the medium- long-term, resulting in even greater damage to the target crops (Bishop *et al.* 2003).

We collected contradicting reports from the rural producers on the perception of hunting; this was because despite a great majority a great majority of them stating that hunting was absent in their communities (69%) and/or that they would refrain from practicing it (56%), many producers (74.5%) suggested hunting and birth interference as population control measures. Hunting wildlife is legally prohibited in Brazil (Federal Law No. 5197, from 1967) and considered an environmental crime (Federal Law No. 9605, from 1998). Therefore, it is expected that rural producers are wary of discussing this subject and, in the rural communities visited during this study, only a few confirmed hunting, even if the problem was a recurrent one (Pinto *et al.* 2012).

However, hunting pest species in Brazil can be allowed under special circumstances without it being considered a crime. Article 37 of the Brazilian Environmental Crimes Law states, "it is not a crime to slaughter an animal when it is carried out: because it is harmful, as long as it is characterized by the competent agency" (Brazil 1998). Thus, the Monk Parakeet *Myiopsitta monachus* featured among the species authorized for slaughter in Rio Grande do Sul (IBAMA 2004a). The introduction and explosion of the wild populations of the European Wild Boar in several Brazilian municipalities has recently instigated successive normative instructions to hunt down these animals (IBAMA 2004b).

The sustainable exploitation of wild animals in the Sustainable Development Reserves in Brazil was foreseen by the National System of Conservation Units (Decree No. 4340, 22 August 2002). For instance, hunting chelonians, mammals, and birds, which have been the protein supply for traditional communities, regularly occurs in the Amanã Sustainable Development Reserve, central Amazon (Valsecchi & Amaral 2009). IBAMA (2005) authorized a regulated trial period of commercial management of the Yacare Caiman *Caiman yacare* in the Pantanal wetlands, in which a section of the production cycle takes place in the wild. Such initiatives imply that Brazil may try new temporary and experimental wildlife management regulations.

According to the local producers, population control of the White-eyed Parakeet in the Campo das Vertentes region needs more effective methods than those presently utilized, as the problem continues unsolved. This is because any pest population which is stable in an undesirable size, and inflicting economic losses on the farmer or his property, must have its population reduced and maintained by management activities (Caughley & Sinclair 1994).

Controlling a population by using lethal methods is legally restricted, toilsome, and questionable both ethically and socially, and frequently, it is inefficient in minimizing bird damage (Tracey *et al.* 2007). For instance, the usefulness of the method may be directly influenced by compensatory responses in the reproduction and survival rates of the pest species (Feare 1991). A few authors propose that in cases of small isolated populations and where immigration can be prevented, reducing populations may be possible (Dolbeer 1998, Feare 1991). However, no published study is available that demonstrates that either short- or long-term lethal control of birds can minimize crop damage (Tracey *et al.* 2007). For those pest birds having high reproductive rates, control measures implemented during the reproductive cycle (*e.g.*, destruction of eggs and nests) may prove more successful than any control exerted during maturity (Paton *et al.* 2005). With respect to the bird breeding inhibitor (Diazacon), a few studies conducted on the Monk Parakeets revealed hopeful outcomes (Avery *et al.* 2006).

Implementing management measures in agriculture poses a challenge, as no single control technique is available which can produce prompt and economically effective outcomes (Canavelli 2009). Frequently, several simultaneous or sequential control methods need to be utilized to get the most effective results in minimizing the losses inflicted by the wild birds. It is important though to implement the techniques selected on a suitable spatial scale and, particularly, in foreseeing the damages (Dolbeer 1990 & 1998, Bruggers *et al.* 1998, USDA 2010). Monitoring and assessment of the results is fundamental to success, as only then can the most effective strategies be identified, as well as the ways they can be modified to suit the program for the next year (Canavelli 2010).

Finally, while man-wildlife conflicts are being addressed, wildlife managers should consider the needs of all the participants directly affected, as well as be conscious of the range of environmental, socio-cultural, and economic factors involved. Therefore, it is necessary to be sensitive to various perspectives and values and strike an accurate balance between the needs of humans and wildlife (USDA 1997).

We conclude that the conflicts revealed by the rural producers in southeastern Brazil with the pest species identified are due to the financial losses they inflict by damaging the crops of fruits and grains. Farmers are helpless and unable to effectively deal with the problem, as the control techniques used by them are either unviable or inadequate. The knowledge and perception of the rural producers in the region are evidently significant in drawing up and designing implementable management and control measures of the pest species. The ethnobiological study conduct here was a first step to understand the problem. However, more detailed studies on the biology of pest species and the intrinsic features of each crop are required to enable drawing up an elaborate management plan on wildlife control based on three principal aspects: man, animal and habitat. This will be the only possible way of ensuring that rural activities, and wildlife, can be sustained.

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ARTICLE

Recurrent seasonal occurrence of the Lineated Woodpecker (*Dryocopus lineatus*) in a riparian fragment of the Atlantic Forest, northeastern Brazil

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ABSTRACT: Riparian forests play important roles as ecological corridors and refuge habitat for many bird populations in fragmented landscapes. This report describes the seasonal occurrence of the Lineated Woodpecker (*Dryocopus lineatus*) in a small riparian fragment of Atlantic Forest, northeastern Brazil. A female was recorded by its visual and acoustical signals from September to October 2014. Similar occurrences were observed in the same months over three consecutive years. Two major hypotheses regarding the woodpecker seasonal occurrence are discussed here: *i*) the use of the riparian fragment for breeding, evidenced by tree-cavity nests; and *ii*) fleeing of the bird from its natal habitat due to fire in adjacent sugarcane fields, which commonly are burned in these two months. Such recurrent events suggest that *D. lineatus* uses the riparian fragment as refuge habitat, highlighting the importance of these environments for bird populations that inhabit fragmented landscapes of the Brazilian Atlantic Forest.

KEY-WORDS: breeding, cavity-nesting birds, Picidae, refuge habitat, sugarcane burning.

INTRODUCTION

Riparian forests are interface zones between terrestrial and aquatic systems characterized by high nutrients cycling and flood-influenced seasonal resources (Naiman & Décamps 1997). Birds use these environments as ecological corridors for crossing habitats and as refuge for feeding and breeding (Knopf & Samson 1994). In Brazil, the riparian forests are essential for maintenance of bird fauna in fragmented environments (Anjos *et al.* 2007), hosting increased species richness in rivers with larger riparian margin width (Ramos & Anjos 2014).

The Brazilian Atlantic Forest is recognized as one of the major biodiversity hotspots around the world (Myers *et al.* 2000). Historically, the domain has largely been reduced to fragmented landscapes as a result from human-disturbances, with only 11.7% of its original coverage remaining (Ribeiro *et al.* 2009). Despite highly fragmented, the northeastern region of the Atlantic Forest (known as Pernambuco Endemism Center) shelters a rich and endemic avifauna (Silva *et al.* 2004) within forest patches often surrounded by sugarcane fields. Therefore, riparian fragments may display higher, deeper and more complex ecological interactions with bird populations inhabiting the Pernambuco Endemism Center than other areas.

Woodpeckers (Picidae) are forest-dependent birds, in which the species richness is closely associated with tree cover (Ilsøe *et al.* 2017), being widely used as bioindicators of changes in forest structure (Mikusiński 2006, Vergara-Tabares *et al.* 2018). The Picidae is a speciose group across South America with *c.* 83 species (Erize *et al.* 2006) that display key ecological roles as builders of tree-cavities (excavators), which are used as nests for many species (Cockle *et al.* 2011, Gorman 2014). The Lineated Woodpecker *Dryocopus lineatus* (Linnaeus, 1766) is a tropical widespread species, ranging from Mexico to northeastern Argentina (Malekan 2011, Gorman 2014). In South America, it occurs in Argentina, Bolivia, Paraguay and throughout Brazil (Sick 1997), from the core to edges of the forest fragments (Stotz *et al.* 1996). Its acoustical signals are easily identifiable, especially when drilling soft-woods (drumming) for feeding on small insects, such as ants and beetles (Malekan 2011).

This report describes the recurrent seasonal occurrence of *D. lineatus* in an Atlantic Forest riparian fragment, northeastern Brazil. Because similar events occurred along years (2015, 2016 and 2017), always between September and October months, we suggest that the woodpecker uses the riparian fragment to refuge for breeding or escaping from the burning of sugarcane fields around its natal habitat.

METHODS

A female of *D. lineatus* was photographed (Fig. 1) on 23 September 2014 at ~07:50 h in a small riparian fragment of Atlantic Forest of the Pernambuco Endemism Center at the Santa Rita municipality, Paraíba state, northeastern Brazil. Its sex was determined by the presence of a black spot on the anterior region of the head and by the absence of a red stripe on the cheek (Erize *et al.* 2006). It remained ~5 min on a branch of a *Cecropia palmata* tree, foraging on small insects (ants). For this record, researchers (R.M. and G.M.P.) were at the exact point (7°10'16.2''S; 35°00'12.9''W), where local residents had previously reported sighting the bird. A playback sound with the laughing call of the species (download freely from WikiAves) was used for attracting the woodpecker, as a response to the territorial behavior (Gorman 2014). The site is a farm with 74 ha (*c.* 70% of forest cover) surrounded by sugarcane fields and pineapple plantations. The vegetation is typical of secondary stage composed by a high abundance of Arecaceae, Cecropiaceae and senescent trees. Tibiri River crosses the forest fragment entirely (Fig. 2A) forming microhabitats similar to floodplains and wetlands in some areas.

Figure 1. Female *Dryocopus lineatus* on a branch of *Cecropia palmata* in the riparian fragment of Atlantic Forest, Santa Rita (Paraíba state), northeastern Brazil. Photo author: Georgiana Pimentel.

RESULTS

Visual and acoustical signals of the bird were recorded until October 2014 and ~6 tree-cavity nests (Fig. 2B) were accounted in the area. The most common sounds were territorial calling and drumming. Sighting of the woodpeckers were reported by local residents on each consecutive year (2015, 2016 and 2017) after the initial record in 2014, including a low-resolution video provided by one of them in 2016 (supplementary material). They also reported that the detections of the bird started in September and lasted until October, with often more than one individual observed at the same time. The authors validated the information provided by residents by showing photos of the bird (*i.e.* species identification) and inquiring about the record (*e.g.*, microhabitat,

Figure 2. Tibiri River within the forest fragment in which *Dryocopus lineatus* was recorded (**A**). Tree-cavity nest of woodpecker on a dead tree (snag; **B**). Photo author: Rafael Menezes.

sounds, size). It is worth mentioning that only piculet species (Picuminae, Picidae) occur in the area, with the absence of larger woodpeckers that could be confused with *D. lineatus* [*e.g.*, Crimson-Crested Woodpecker *Campephilus melanoleucos* (Gmelin, 1788)]. The same local ancient residents claimed that the occurrence of woodpeckers is very recent in this area, because they were never seen or heard them before 2014.

DISCUSSION

The recent appearance of woodpecker can be related to well-preserved traits of the riparian fragment, as supported by occurrence of other birds [*e.g.*, *Aramides cajaneus* (Statius-Muller, 1776), *Porphyrio martinicus* (Linnaeus, 1766)] and mammals [*e.g.*, *Lontra longicaudis* (Olfers, 1818), *Dasyprocta* spp.) indicators of healthy environments. The high habitat heterogeneity in riparian fragment (*e.g.*, dead tree areas, Cecropiaceae soft-wood zones, and floodplains) may also be an ecological driver for the species presence. In corroboration, recent studies have shown that *Dryocopus martius* (Linnaeus, 1758) uses a wide variety of forest environments in the Italian Alps (Bocca *et al.* 2007), *D. lineatus* prefers dead tree areas (snags) in Santa Fe de Antioquia/Colombia (Granada-Ríos & Mancera-Rodríguez 2015) and *D. pileatus* (Linnaeus, 1758) has the home range limited by the snags abundance in lowland forest of the United States (Tomasevick & Marzluff 2018). Although the riparian fragment is relatively small, the high preservation degree coupled with habitat heterogeneity, especially dead tree areas, may have promoted the immigration of the woodpecker.

Two major hypotheses are addressed here for the woodpecker seasonal occurrence. First, *D. lineatus* used the riparian fragment as breeding refuge, as individuals were observed using the tree-cavity nests in 2014 (R.M., pers. obs.). The use of nests was also reported by local residents on each year (2015, 2016 and 2017) between September and October months. Different breeding periods have been documented for *D. lineatus* around the world, including March–April in Panama, April–May in Belize (Caribbean) and February–April in Trinidad and Suriname (Malekan 2011). These records reveal a short-time breeding (2–3 months), which sustain the hypothesis of breeding-related seasonal occurrence. Nevertheless, comprehensive information on biology and ecology of this species is scarce in Brazil, especially on breeding, nesting and roosting.

Secondly, the woodpecker dispersed to the riparian fragment driven by pre-harvesting sugarcane burning around its natal habitat. The region harbors large sugarcane fields and the burning practice commonly occurs over September and October. Natal habitats of woodpeckers are probably large forest remnants of legal reserve (*i.e.* 20% of preserved native forest within a property) belonging to sugarcane companies, which are located closer to the riparian fragment. In this sense, the bird fled from its natal habitat to the riparian fragment in order *i*) to avoid fire-caused injuries (Lyon & Marzluff 1985); or *ii*) to increase the forage on small invertebrates that escape to the forest patches nearby the fire-disturbed area (Vasconcelos *et al.* 2009). Fire effects on birds are species-specific and the harms increase with high-severity burning (Barlow *et al.* 2002, 2006).

The landscape connectivity facilitates the bird movement among nearby forest fragments (Uezu *et al.* 2005), and this has been recorded for large-bodied woodpeckers, such as *D. martius* (Gil-Tena *et al.* 2013) and *Campephilus magellanicus* (King, 1828) (Vergara *et al.* 2019). Recent studies have documented that woodpeckers disperse to neighboring patches mainly for foraging activities, with the movement decision influenced by the habitat quality (Vergara *et al.* 2015, 2019). It is likely that *D. lineatus* used the riparian vegetation as an ecological corridor for crossing from its natal habitat to the patch site. Indeed, riparian corridors have been shown effective for movement among habitats for forest specialist birds (Gillies & Clair 2008). However, there is no study that reports seasonal movement behavior or dispersal ability for the species up to date, which raises the need of monitoring studies to understand patterns of use of forest patches by these birds.

The seasonal occurrence of *D. lineatus* in the riparian fragment suggests its use as refuge habitat, but the available information is insufficient for an unbiased definition regarding the two hypotheses on the ecological drivers operating at the population level. Further observations on breeding habits and the use of mark recapture techniques are required. Such recurrent events highlight the importance of river-edge environments for forest-dependent birds that inhabit fragmented landscapes of the Brazilian Atlantic Forest.

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ARTICLE

Diet of Ornate Hawk-Eagle (*Spizaetus ornatus*)

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ABSTRACT: The Ornate Hawk-Eagle (*Spizaetus ornatus*) is a top predator and inhabits mainly preserved forests. It occurs from Mexico to Argentina and throughout Brazil, where it is threatened by extinction. It hunts birds, mammals and reptiles, picking up both on the ground and on the branches in the forest. Here we report data on a pair and one young individual of this species registered in the southeast of Minas Gerais state, eastern portion of the Espinhaço Range, Brazil. In addition, a literature review on the diet of the species was carried out aiming gather data on food habits. The nesting territory, as well as the nest was discovered in semi-deciduous seasonal forest area. We recorded predation of a Lesser Yellow-headed Vulture (*Cathartes burrovianus*) by the young. After two days of observation, the nest was overthrown, what allowed its screening for other food items discovered after analysis of some feathers and bones. Detailed records of predation of *S. ornatus* were non-existent or inaccurate. Taking together our own field observation and the literature review, we found 121 taxa consumed by *S. ornatus*. A total of 78 bird species were reported, mainly Galliformes, followed by medium-sized mammals (38 species), well represented by Rodentia and Primates.

KEY-WORDS: birds of prey, diet, nesting, predation, review.

INTRODUCTION

The Ornate Hawk-Eagle *Spizaetus ornatus* is a large and imposing bird of prey from the family Acciptridae. The species' size ranges from 56 to 68.5 cm in length (Howell & Webb 1995) and 820 to 1272 g in body mass (Dunning-Jr. 2008). Ornate Hawk-Eagle occurs in rainforest, wetlands, riparian forests, seasonally deciduous and semi-deciduous forests, up to elevations of ~1800 m a.s.l. (Íñigo *et al*. 1987, del Hoyo *et al*. 1994, Ferguson-Lees & Christie 2001). Ornate Hawk-Eagle has a wide distribution, from Mexico to the northern of Argentina and Paraguay, including all Brazil (Ferguson-Lees & Christie 2001), but it is considered rare throughout its range, mainly in southern populations such as in northern Argentina and south-southeastern Brazil (Márquez *et al*. 2000).

Observations of birds of prey, like the large Ornate Hawk-Eagle, are difficult to get because of the low densities, shy behavior and closed forest preferences (Bibby *et al*. 1992). For these reasons, basic information of its life history is still poorly known (Robinson 1994, Naveda-Rodríguez 2004).

Despite Ornate Hawk-Eagle is often found in forest fragment edges and even in open degraded areas (Ferguson-Lees & Christie 2001) it needs preserved habitats for breeding (Lyon & Kuhnigk 1985). The combination of habitat loss and low breeding rate has been threatening of extinction this species, with the populations decreasing throughout its occurrence area (Márquez *et al*. 2000). It is not a surprise that Ornate Hawk-Eagle is globally "Near Threatened" (BirdLife International 2016), and has been listed as threatened in several locations, such as Paraguay (del Castillo & Clay 2005). In Brazil, *S. ornatus* is "Critically Endangered" in the states of Rio Grande do Sul (Rio Grande do Sul 2014), São Paulo (Silveira *et al*. 2009), Espírito Santo (Simon *et al*. 2007) and Santa Catarina (CONSEMA 2011), and "Endangered" in Paraná (Mikich & Bérnils 2004), Rio de Janeiro (Alves *et al*. 2000) and Minas Gerais (Copam 2010).

The overall negative impacts of habitat changes in the distribution and in the reproduction of the species also affect feeding behavior. It is known that Ornate Hawk-Eagle hunts its prey in roosts on dense vegetation, including the edge and the interior of forests patches (Robinson 1994). Ornate Hawk-Eagle has fast flying attack to reach and capture the prey both in trees and on the ground (Trail 1987, Ferguson-Lees & Christie 2001). Prey include bird flocks such as egrets in nesting colonies (Hilty 2003), birds that feed in flocks (Kilham 1978, Robinson 1994), groups of birds in reproductive display such as Guianan Cock-of-the-Rock (*Rupicola rupicola*), and also mammals such as monkey groups (Hilty 2003). The literature shows that most of the food items of *S.*

ornatus consists of medium-sized mammals and large birds, which are frequently missing in forest due to the defaunation caused by human-induced fragmentation (Kurten 2013); and less frequently, reptiles (Klein *et al.* 1988). However, the published data is scarce and there are few studies with more detailed data (*e.g.*, Lyon & Kuhnigk 1985 and Madrid *et al.* 1992 in Guatemala, Klein *et al.* 1988 in Brazil, Clinton-Eitniear *et al.* 1991 in Belize, and Robinson 1994 in Peru). Understanding the diet of *S. ornatus* allow us to better planning actions for Ornate Hawk-Eagle conservation.

This study shows a new predation record by a young *S. ornatus* observed at the field. In addition, a data set was collected from the nest of Ornate Hawk-Eagle. Finally, we reviewed dietary records from published articles and unpublished data shared between researchers about Ornate Hawk-Eagle.

METHODS

Field observations

Observations and recordings were carried out in the Conceição do Mato Dentro, southeast Minas Gerais state, Brazil. The area is inserted in an ecotone between areas of Atlantic Forest and Cerrado Domains, located in the eastern portion of the Espinhaço Range (18°54.584'S; 43°25.596'W). The Atlantic Forest and the Cerrado are considered hotspots of biodiversity (Mittermeier *et al.* 2004), reflected in bird diversity, which have the highest number of threatened (54 species in the Atlantic Forest and 14 in the Cerrado) (Marini & Garcia 2005) and endemic species in Brazil (223 species in the Atlantic Forest and 29 in the Cerrado region) (Silva 1997).

Observations were carried out in semi-deciduous riparian forest areas and rocky outcrops at 816 m altitude. Because of the recent fragmentation, the area is a mosaic between forest fragments and open areas. In 07 April 2016, we observed a young *S. ornatus* resting on the ground in an open area, near the forest remnant. Two days later, an individual with adult plumage was found flying in thermals. Since then, those individuals were monitored to identify prey captured by the species. Through observations and monitoring the young *S. ornatus*, we discovered, at the same month, the nest between thick forks of Jatobá tree (*Hymenaea courbaril*) approximately 25 m height and about 300 m from the predation site.

On 01 June 2016 the tree nest was cut down (properly authorized by the competent organs), and we collected the nest with its content. At this moment the young had already abandoned the nest and its withdrawal could be done without causing direct damage to the birds. All biological material contained in the nest (bones and feathers) was screened and identified with the help of specialists from the Natural History Museum of the Catholic University of Minas Gerais.

Literature review

To review the available information of the diet of Ornate Hawk-Eagle, we consulted scientific articles (searched in Web of Science, Scirus, JSTOR and Scielo), unpublished information, and photographs from citizen science webpages (*e.g.*, http://www.wikiaves.com.br/, http://ibc.lynxeds.com/, http://www.ebird.org). In these cases, authors were contacted to confirm information.

RESULTS

Field observation

On 07 April 2016, a young of *S. ornatus* was observed among the branches of a cut tree on the floor feeding an adult Lesser Yellow-headed Vulture (*Cathartes burrovianus*) (Fig. 1). On the next day the same bird was observed again feeding on the carcass in the same place, consuming all flesh and bones, leaving feathers.

In the following days, new predation records were observed. The same young was observed feeding on the rest of a mammal and at least two small birds at the same location of the previous record. However, it was not possible to identify species. In these latter cases the bird was feeding in the forest edge, between canopy branches.

The nest material collected revealed a higher consumption of birds. Five species of birds were identified by feather remains (*Penelope* sp., *Trogon surrucura*, *Patagioenas picazuro*, *Hydropsalis albicollis*, *Piaya cayana* and Strigidae). In addition, two jaws and one pelvic

Figure 1. Ornate Hawk-Eagle (*Spizaetus ornatus*) eating a Lesser Yellow-headed Vulture (*Cathartes burrovianus*) in 07 April 2016, in Conceição do Mato Dentro, southeast of Minas Gerais, Brazil. Photo author: Michele A. Ferreira.

bone were identified, both attributed to two individuals, one adult and one juvenile of Paraguayan Hairy Dwarf Porcupine (*Coendou spinosus*).

Literature review

We gathered 23 papers, ten books, five records of unpublished information and photographs from citizen science and one conference abstract with some information on the species' diet. Most data were from observations of carcasses taken from nest, while other provided information about attacks and attempted predation events.

Taking together our own field observation and the literature review, we found 121 taxa consumed by *S. ornatus* (Table 1). The largest number of species (78 species) was birds, mainly Galliformes, followed by medium-sized mammals (38 species), well represented by Rodentia and Primates. Among the Squamata, there are few records of predation on *Iguana iguana* and some unidentified snakes and lizards.

DISCUSSION

Field observations

The young *S. ornatus* seems to feed on a dead individual, since no traces of predation were observed. Jones & Dorward (2014) recorded the "interaction" between *S. ornatus* and a bovine femur and suggested that the species may present scavenging behavior. However, since the young bird was observed again feeding on the carcass in the consecutive days, it is possible that the vulture was captured before the first record. This would explain the absence of traces of recent predation regarding that return-hunting behavior is rare among birds of prey (*e.g.*, Springer *et al*. 2011, Whitacre *et al*. 2012).

Detailed records of predation of *S. ornatus* are non-existent or inaccurate. Stiles & Skutch (1989) have already mentioned that the species "captures birds up size of guans or vulture", and Sigrist (2006) mention that they "catch macaws, parrots, vultures, *Coragyps atratus*". However, those authors did not provided details, probably referring

Table 1. Food items consumed by *Spizaetus ornatus* based in a literature review and based in the nest material from Minas Gerais, Brazil (current study).

Class/Order	Family	Species	Common name	Reference
Aves				
Tinamiformes	Tinamidae	*Crypturellus boucardi*	Slaty-breasted Tinamou	Whitacre *et al.* 2012
		Crypturellus cinnamomeus	Eastern Thicket Tinamou	Whitacre *et al.* 2012
		Crypturellus obsoletus	Brown Tinamou	Joenck *et al.* 2011
		Crypturellus parvirostris	Small-billed Tinamou	Greco *et al.* 2004
		Crypturellus soui	Little Tinamou	Flatten *et al.* 1989, Whitacre *et al.* 2012
		Crypturellus sp. (*variegatus* or *soui)*	Tinamou	Klein *et al.* 1988
		Crypturellus sp.	Tinamou	Madrid *et al.* 1991, 1992
		Tinamus major	Great Tinamou	Flatten *et al.* 1989, Madrid *et al.* 1991, 1992, Whitacre *et al.* 2012
		Tinamus sp. (*major* or *guttatus)*	Tinamou	Klein *et al.* 1988
		unidentified Tinamou	Tinamou	Lyon & Kuhnigk 1985
Anseriformes	Anatidae	*Amazonetta brasiliensis*	Brazilian Teal	Greco *et al.* 2004
Galliformes	Cracidae	*Crax rubra*	Great Curassow	Russell 1964, Flatten *et al.* 1989, Madrid *et al.* 1992, Phillips & Hatten 2013, Whitacre *et al.* 2012
		Oreophasis derbianus	Horned Guan	Gómez-de-Silva 2006
		Ortalis garrula	Chestnut-winged Chachalaca	Olrog 1985
		Ortalis guttata	Speckled Chachalaca	Sigrist 2006
		Ortalis motmot	Little Chachalaca	Klein *et al.* 1988
		Ortalis ruficauda	Rufous-vented Chachalaca	Friedmann & Smith-Jr. 1955
		Ortalis vetula	Plain Chachalaca	Lyon & Kuhnigk 1985, Flatten *et al.* 1989, Madrid *et al.* 1991, 1992, Whitacre *et al.* 2012
		Penelope obscura	Dusky-legged Guan	Joenck *et al.* 2011

Class/Order	**Family**	**Species**	**Common name**	**Reference**
		Penelope purpurascens	Crested Guan	Kilham 1978, Lyon & Kuhnigk 1985, Madrid *et al.* 1992, Abadia & Navarro 2011, Whitacre *et al.* 2012
		Penelope sp. (cf. *jacuacu*)	Guan	Klein *et al.* 1988
		Penelope sp. (cf. *marail*)	Guan	Klein *et al.* 1988
		Penelope superciliaris	Rusty-margined Guan	Greco *et al.* 2004, Lucheti 2015
		Penelope sp. (cf. *superciliaris* or *obscura*)	Guan	This study.
	Odontophoridae	*Odontophorus capueira*	Spot-winged Wood-quail	Joenck *et al.* 2011
		Odontophorus guttatus	Spotted Wood-quail	Whitacre *et al.* 2012
	Phasianidae	*Gallus gallus*	Domestic chicken	Friedmann & Smith-Jr. 1955, Ffrench 1991, Robinson 1994
		Meleagris ocellata	Ocellated Turkey	Madrid *et al.* 1991, 1992, Phillips & Hatten 2013, Whitacre *et al.* 2012
Suliformes	Anhingidae	*Anhinga anhinga*	Anhinga	Greco *et al.* 2004
Pelecaniformes	Ardeidae	*Ardea alba*	Great White Egret	Teixeira 2015
		Butorides striata	Green-backed Heron	Aldes Lamounier, pers. comm.
Cathartiformes	Cathartidae	*Coragyps atratus*	American Black Vulture	Dickey & van Rossem 1938
Gruiformes	Psophiidae	*Psophia leucoptera*	White-winged Trumpeter	Robinson 1994
	Rallidae	*Aramides cajaneus*	Grey-necked Wood-rail	Robinson 1994, Whitacre *et al.* 2012
		Gallinula chloropus	Common Moorhen	Greco *et al.* 2004
		Pardirallus nigricans	Blackish Rail	Greco *et al.* 2004
		Porphyrio martinicus	Purple Gallinule	Robinson 1994
Columbiformes	Columbidae	*Columba* sp.	Pigeons	Flatten *et al.* 1989, Madrid *et al.* 1991, 1992
		Columbidae (*Columba, Leptotila,* or *Geotrygon*)	Pigeons and Doves	Whitacre *et al.* 2012
		Geotrygon montana	Ruddy Quail-Dove	Whitacre *et al.* 2012
		Leptotila plumbeiceps	Grey-headed Dove	Lyon & Kuhnigk 1985
		Leptotila rufaxilla	Grey-fronted Dove	Joenck *et al.* 2011
		Leptotila verreauxi	White-tipped Dove	Greco *et al.* 2004
		Patagioenas picazuro	Picazuro Pigeon	Greco *et al.* 2004, this study
		Patagioenas speciosa	Scaled Pigeon	Whitacre *et al.* 2012
Opisthocomiformes	Opisthocomidae	*Opisthocomus hoazin*	Hoatzin	Dornas & Pinheiro 2007, Robinson 1994
Cuculiformes	Cuculidae	*Piaya cayana*	Common Squirrel-Cuckoo	Joenck *et al.* 2011, this study
Strigiformes	Strigidae	*Megascops guatemalae*	Guatemalan Screech-Owl	Madrid *et al.* 1992, Whitacre *et al.* 2012
Caprimulgiformes	Caprimulgidae	*Hydropsalis albicollis*	Pauraque	This study.
Trogoniformes	Trogonidae	*Trogon surrucura*	Surucua Trogon	This study.
Coraciiformes	Alcedinidae	*Megaceryle torquata*	Ringed Kingfisher	Wetmore 1965
Piciformes	Ramphastidae	*Aulacorhynchus prasinus*	Emerald Toucanet	Abadia & Navarro 2011, Whitacre *et al.* 2012, Monroy-Ojeda *et al.* 2014
		Pteroglossus castanotis	Chestnut-eared Araçari	Leonardo Lopes pers. comm.
		Pteroglossus torquatus	Collared Araçari	Madrid *et al.* 1991, Phillips & Hatten 2013, Whitacre *et al.* 2012
		Ramphastos cuvieri	Cuvier's Toucan	Giudice 2007
		Ramphastos sulfuratus	Keel-billed Toucan	Flatten *et al.* 1989, Madrid *et al.* 1991, 1992, Phillips & Hatten 2013, Whitacre *et al.* 2012
		Ramphastos vitellinus	Channel-billed Toucan	Klein *et al.* 1988

Class/Order	**Family**	**Species**	**Common name**	**Reference**
	Picidae	*Campephilus guatemalensis*	Pale-billed Woodpecker	Whitacre *et al.* 2012
		Melanerpes sp.	Woodpecker	Madrid *et al.* 1991
Psittaciformes	Psittacidae	*Amazona autumnalis*	Red-lored Amazon	Whitacre *et al.* 2012
		Amazona farinosa	Southern Mealy Amazon	Whitacre *et al.* 2012
		Amazona sp. (cf. *albifrons*)	Probably White-fronted Amazon	Whitacre *et al.* 2012
		Ara macao	Scarlet Macaw	Klein *et al.* 1988
		Ara sp.	Macaw	Robinson 1994
		Ara sp. (cf. *Orthopsittaca manilatus*)	Red-bellied Macaw	Klein *et al.* 1988
		Aratinga sp.	Parakeet	Robinson 1994
		Brotogeris sp.	Parakeet	Robinson 1994
		Pionus sp.	Parrot	Naveda-Rodríguez 2004
		Psittacidae (*Pionus* or *Pionopsitta*)	Parrot	Whitacre *et al.* 2012
Passeriformes	Bombycillidae	*Ptilogonys caudatus*	Long-tailed Silky-Flycatcher	Acosta-Chaves *et al.* 2012
	Cotingidae	*Rupicola rupicola*	Guianan Cock-of-the-Rock	Trail 1987
	Tyrannidae	*Tyrannus melancholicus*	Tropical Kingbird	Souza 2013
	Corvidae	*Cyanocorax cyanopogon*	White-naped Jay	Luiz Trinchão pers. comm.
		Psilorhinus morio	Brown Jay	Whitacre *et al.* 2012, Flatten *et al.* 1989, Madrid *et al.* 1992
	Icteridae	*Cacicus cela*	Yellow-rumped Cacique	Robinson 1994
		Dives dives	Melodious Blackbird	Whitacre *et al.* 2012
	Icteridae	*Psarocolius montezuma*	Montezuma Oropendola	Whitacre *et al.* 2012
	Undetermined	*Probably Quiscalus mexicanus* or *Crotophaga sulcirostris*	Great-tailed Grackle or Groove-billed Ani	Whitacre *et al.* 2012
Mammalia				
Carnivora	Procyonidae	*Nasua narica*	White-nosed Coati	Madrid *et al.* 1991, 1992, Abadia & Navarro 2011, Whitacre *et al.* 2012
Chiroptera	Phyllostomidae	*Artibeus jamaicensis*	Jamaican Fruit-eating Bat	Whitacre *et al.* 2012
		Artibeus sp.	Fruit-eating Bat	Whitacre *et al.* 2012
		Unidentified Bats	Bat	Lyon & Kuhnigk 1985
	undetermined	Unidentified Bats	Bat	Madrid *et al.* 1991
		Unidentified Bats	Bat	Lyon & Kuhnigk 1985, Madrid *et al.* 1992
Didelphimorphia	Didelphidae	*Caluromys derbianus*	Central American Woolly Opossum	Madrid *et al.* 1992
		Didelphis marsupialis	Common Opossum	Klein *et al.* 1988
		Didelphis sp.	Opossum	Abadia & Navarro 2011
		Marmosa mexicana	Mexican Mouse Opossum	Whitacre *et al.* 2012
		Metachirus nudicaudatus	Brown Four-eyed Opossum	Klein *et al.* 1988
		Philander frenatus	Southeastern Four-eyed Opossum	Greco *et al.* 2004
Lagomorpha	Leporidae	*Sylvilagus brasiliensis*	Tapeti	Greco *et al.* 2004
Pilosa	Cyclopedidae	*Cyclopes didactylus*	Silky Anteater	Giudice 2007
	Myrmecophagidae	*Tamandua mexicana*	Northern Tamandua	Abadia & Navarro 2011

Class/Order	**Family**	**Species**	**Common name**	**Reference**
Primates	Callitrichidae	*Callithrix penicillata*	Black-pencilled Marmoset	Greco *et al.* 2004, Luiz Trinchão pers. comm.
		Saguinus fuscicollis	Saddleback Tamarin	Robinson 1994, Heymann 1990
		Saguinus imperator	Emperor Tamarin	Terborgh 1983
		Saguinus martinsi	Martin's Ochraceous Bare-face Tamarin	Cirino 2015
		Saguinus mystax	Moustached Tamarin	Heymann 1990
	Cebidae	*Saimiri boliviensis*	Bolivian/Peruvian Squirrel Monkey	Boinski *et al.* 2003
		Saimiri oerstedii	Black-crowned Central American Squirrel Monkey	Boinski *et al.* 2003
		Saimiri sciureus	Common Squirrel Monkey	Boinski *et al.* 2003, Lopes *et al.* 2015
		Saimiri sp.	Squirrel Monkey	Robinson 1994
Rodentia	Cricetidae	*Sigmodon* sp.	Cotton Rat	Naveda-Rodríguez 2004
	Dasyproctidae	*Dasyprocta azarae*	Azara's Agouti	Joenck *et al.* 2011, Meller 2015
		Dasyprocta leporina	Red-rumped Agouti	Naveda-Rodríguez 2004
		Dasyprocta punctata	Central American Agouti	Whitacre *et al.* 2012
		Dasyproctidae (*Myoprocta* or *Dasyprocta*)	Agouti	Klein *et al.* 1988
		Myoprocta sp.	Acouchi	Klein *et al.* 1988
	Echimyidae	*Proechimys sp.*	Spiny Rat	Robinson 1994
	Erethizontidae	*Coendou mexicanus*	Mexican Hairy Dwarf Porcupine	Whitacre *et al.* 2012
		Coendou sp.	Porcupine	Klein *et al.* 1988
		Coendou spinosus	Porcupine	This study.
	Sciuridae	*Sciurus granatensis*	Red-tailed Squirrel	Naveda-Rodríguez 2004
		Sciurus sp.	Squirrel	Madrid *et al.* 1991, 1992
		Sciurus yucatanensis	Yucatan Squirrel	Phillips & Hatten 2013, Whitacre *et al.* 2012, Flatten *et al.* 1989
	Muridae	Unidentified rat	Rat	Flatten *et al.* 1989
Reptilia				
Squamata	Colubridae	Colubridae	Unidentified snake	Robinson 1994
	Iguanidae	*Iguana iguana*	Common Green Iguana	Clinton-Eitniear *et al.* 1991, Luiz Trinchão pers. comm. Sidnei Dantas pers. comm.
	Teiidae	Unidentified lizard	Lizard	Klein *et al.* 1988
	undetermined	Unidentified lizard	Lizard	Klein *et al.* 1988
		Unidentified snake	Snake	Klein *et al.* 1988

to Dickey & van Rossem (1938), who, after dissecting the stomach of an adult *S. ornatus*, found rests of a monkey and fresh meat. Studying the area, the authors found a primate carcass near a Black-Vulture (*Coragyps atratus*) with back parts eaten. The authors then inferred that the vulture was killed by the eagle and partially eaten while feeding on the carcass of the monkey already killed a few days ago.

Among the collected material from the nest, only *Penelope* was found, species as large as the New World vultures (Dunning-Jr. 2008). The lack of other large bird species could be because *S. ornatus* does not carry large prey, eating them directly on the ground (Whitacre *et al.* 2012). Thus, to the best of our knowledge, vulture could be considerate an unusual prey of the Ornate Hawk-Eagle and eating the carcass suggests food habitat changes.

Literature review and collected nest information

Ornate Hawk-Eagle is considered an opportunistic predator, capturing prey according to availability in the environment (Clinton-Eitniear *et al.* 1991). However, in Guatemala, even in areas where large lizards are abundant, during seven years of study, there were no cases of predation of these species, indicating that *S. ornatus* is more specialist than thought (Whitacre *et al.* 2012).

In Manaus, Brazil, the consumption of 45 different prey was observed, of which 63.3% were identified as birds, 32.7% were mammals and only 4.1% were reptiles (Klein *et al.* 1988). Madrid *et al.* (1992) observed 83 prey in six nests, 38.5% mammals and 38.5% birds. In Guatemala, among 52 prey observed 40.4% were birds, 46.1% were mammals and 13.5% were not identified (Flatten *et al.* 1989). The same authors observed a different proportion of prey items in the diet of Ornate Hawk-Eagle years later: of the 325 items identified, 56.3% were birds (69.8% of the biomass) and 43.7% were mammals (30.2% of the biomass) (Whitacre *et al.* 2012). Among the items consumed, a predominance of large birds and medium-sized mammals was observed. Among birds, the most captured species was Cracidae (genus *Ortalis* and *Penelope*), Tinamidae and Ramphastidae (*Ramphastos*); among mammals, the medium rodents (*Sciurus* and *Dasyprocta*) predominated (Klein *et al.* 1988, Whitacre *et al.* 2012).

The preference by large birds and medium-sized mammals needs more attention. Deforestation could have indirect effects on Ornate Hawk-Eagle food diet, like the feeding on domestic animals such as chickens (Friedmann & Smith-Jr. 1955, Ffrench 1991, Robinson 1994).

It should be noted, however, that most reports on predation were from carcasses found in the nest. Thus, large prey consumed in the soil or small animals are possibly underestimated. According to Bednarz (1988), diet records based in nest material are biased towards larger prey items because smaller items are more likely to be distorted or fragmented beyond recognition, and are more difficult to find than larger bones.

The knowledge about the ecological behavior of this species is still scarce. In recent years the Ornate Hawk-Eagle populations have been declining in several places throughout its distribution (BirdLife International 2016). Among the species of *Spizaetus* genus, *S. ornatus* is one of the most affected by habitat losses and hunting leading to local extinctions (Canuto 2008). For Ornate Hawk-Eagle, conservation efforts should take into account food items used by birds. As demonstrated in the present survey, detailed records are non-existent or inaccurate and careful must be taken when using this information.

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ARTICLE

The lack of males due to illegal trapping is causing polygyny in the globally endangered Yellow Cardinal *Gubernatrix cristata*

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ABSTRACT: We present breeding data from the southernmost populations of the globally "Endangered" Yellow Cardinal *Gubernatrix cristata* in Argentina, confirming the presence of current breeding populations in the region. We monitored a family group in a nesting territory composed of one male and three females throughout the breeding season 2017–2018. We found a low nest success and productivity, probably associated with the lower contribution of the male, since it was attending three reproductive females simultaneously. We attribute this uncommon case of polygyny to the lack of males in the area caused by the high intensity of male trapping for illegal trade.

KEY-WORDS: breeding biology, cage birds, Monte ecoregion, Neotropical birds, threatened species.

INTRODUCTION

The Yellow Cardinal *Gubernatrix cristata* is a Neotropical threatened passerine from the southern cone of South America (Ridgely & Tudor 2009). It is a territorial and socially monogamous species, where mated pairs usually stay together for more than one breeding season (Domínguez *et al.* 2015a, Beier *et al.* 2017). In the past, this species was widely distributed in thorny deciduous shrubland forests of central Argentina, most of Uruguay and part of southern Brazil (Jaramillo 2019). Due to their colour and song, they have been captured for illegal trade in wildlife (mainly the males) and, along with habitat loss, were the main causes of the great population decline and fragmentation for this species (Domínguez *et al.* 2017), now considered as globally "Endangered" and regionally "Threatened" (estimated total population: 1500–3000 individuals; BirdLife International 2018).

Social polygyny, where one male mates with more than one female while each female mates with only one male, is thought to be the fundamental mating system of animals (Bennett & Owens 2002). Under certain circumstances, polygyny among birds may occur when males hold valuable resources, such as high-quality territories, and then females tend to choose superior males (Orians 1969). But most birds, however, are monogamous because apparently both parents must help to rear the young if the adults are to have much chance of leaving any genes to posterity (Bennett & Owens 2002). In this contribution we present novel information about an uncommon case of polygyny in this socially monogamous cardinal. In addition, we present breeding data from a family group composed of one male and three females throughout the entire breeding season 2017–2018.

METHODS

The study was conducted in a private farm located northeast of General Conesa, eastern Río Negro province, Argentina (39°55'12.32''S; 64°16'29.14''W; Fig. 1). From the National Road 251 (distant 12 km straight line), the access to the study site does not present any restrictions, which is why the area has been used for illegal trapping in recent decades. At present, although the access is still free, the farm-owners chase away the trappers preventing captures in this area. The study area is representative of the Monte ecoregion (Brown *et al.* 2006), with large areas of native xerophytic vegetation altered by extensive and low-density cattle grazing. This region is characterized by warm summers (maximum temperature: 42.3°C) and cold winters (minimum temperature: -13.5°C), with most precipitations occurring between November–March. The National Meteorological Survey of Argentina from 1985 to 2015 reports mean annual rainfall as 259 mm and mean annual temperature as 15°C.

Following the comment of a local birdwatcher during September 2017 (prior to the start of the breeding season), we detected a family group composed of one male and three females of the threatened cardinal. We then carried out observations in that breeding area during the entire breeding season, from October 2017 to January 2018. The nests were found by systematically searching in potential nest sites and observing the behaviour of territorial breeders. We georeferenced each nest location (Garmin GPS) and we visited nests every 10–15 days during the nesting cycle. We monitored the nests until nestlings fledged or the nest failed. Close to the fledging date, we inspected nests from a distance of 2–4 m to minimize the risk of premature fledging. At each visit, we avoid manipulating the nest content (eggs or nestlings) to avoid disturbances that influence reproductive success.

We considered a nest successful when at least one nestling left the nest. We considered a nest predated if clutch disappeared between two consecutive visits or when the chicks disappeared from their nests before they were old enough to fledge and no parental activity was detected near the nest (see Segura & Reboreda 2012). None of the monitored nests was abandoned. As individuals were unmarked, we identified each breeder by field observations of unique marks on plumage (mainly in females) and also on the dates of start and end of each breeding attempt. Productivity was calculated as the mean number of fledglings by successful nests. We calculated the apparent nest success as the ratio between the number of successful nests and all monitored nests (Segura *et al.* 2015). We delimited the breeding territory as the maximum area that the male defended, where it nested and where the family group was observed feeding (see Beier *et al.* 2017). To locate the territory and nests in a map, we used an image from Google Earth (02 January 2018).

RESULTS

During the entire breeding season, we found a nesting territory with three females and only one male. During visits, while we were moving from one nest to another, the lonely male accompanied us and defended each of the nests from where one of the three females flushed. We found a total of eight nests (two for one female, two for another and four for another). One nest was found under

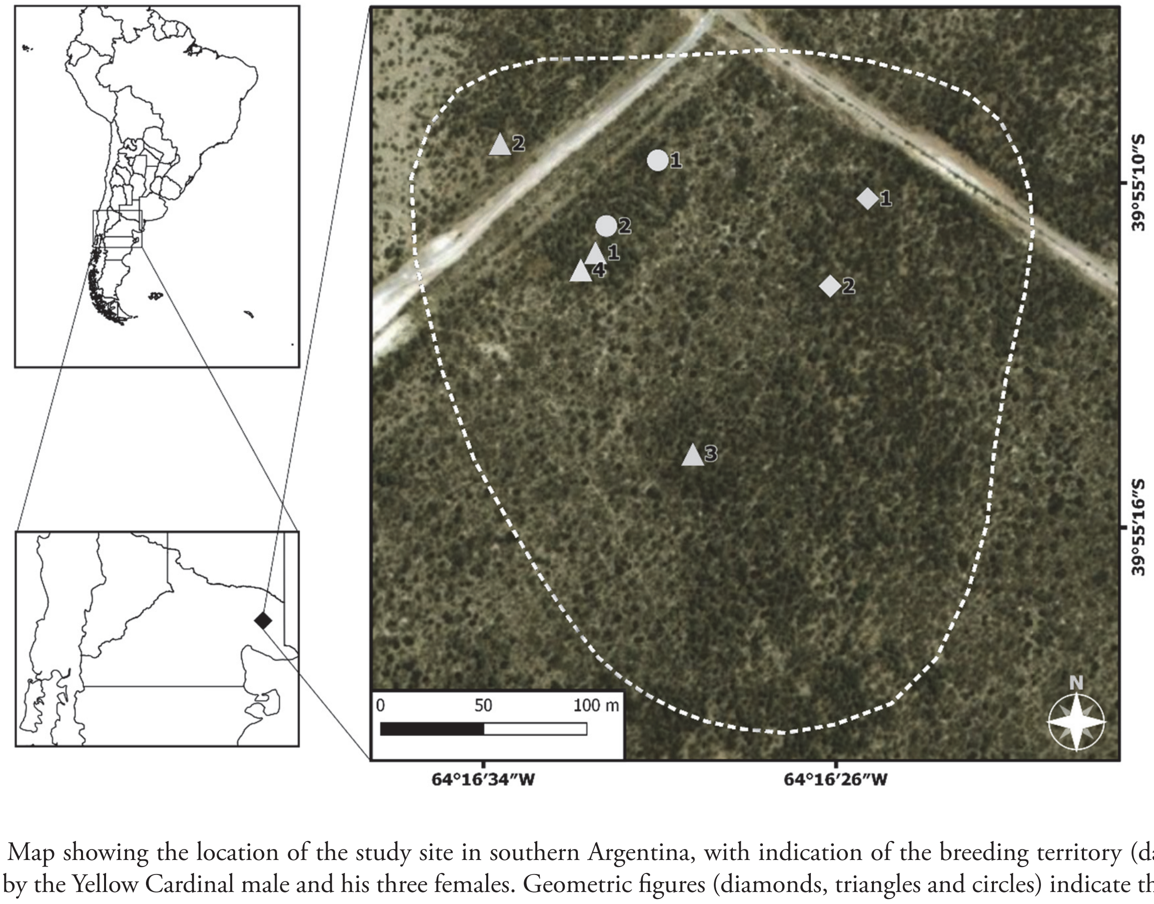

Figure 1. Map showing the location of the study site in southern Argentina, with indication of the breeding territory (dashed line) defended by the Yellow Cardinal male and his three females. Geometric figures (diamonds, triangles and circles) indicate the different females, while numbers indicate the order of each female breeding attempt throughout the breeding season 2017–2018.

construction and the remaining ones during incubation. By backdating from hatching dates, the first evidence of nest initiation was on 02 October (considering 13 days of incubation; Domínguez *et al.* 2015a, Beier & Fontana 2019) and the latest evidence of nest activity was a predated nest on 19 January, thus giving a breeding season length of 108 days. Breeding territory size was ~9 ha (Fig. 1), including movements of the entire family group.

The nest was a semi-spherical cup of ~15 cm external diameter with an external layer of twigs with thorns, and an internal layer of finer branches, horse hair, compacted grass material grass and seeds (Fig. 2). All nests were built in Chañar Tree (*Geoffroea decorticans*) and were located in main branches close to the center of the tree crown, never in the periphery. Mean clutch size was 3.12 ± 0.12 eggs (range = 3–4, *n* = 8 nests). Eggs were ovoid, bluish-green background colour with black spots more concentrated on the wider end of the egg. Mean number of hatchlings per nest was 2.75 ± 0.25 (range = 2–3, *n* = 4 nests) and nest productivity was one fledgling per successful nest (*n* = 2 nests). We did not detect partial egg loss, but partial brood losses were detected in the two nests that reached the fledging stage (in one nest the reduction was from three chicks to one, and in the other from two to one). Of the eight monitored nests, two (25%) were successful and six (75%) were predated (four during incubation and two during the nestling stage). We did not observe nest helpers, nor Shiny Cowbird (*Molothrus bonariensis*) brood parasitism, as well as any agonistic interactions with other conspecifics in the area.

DISCUSSION

We present relevant breeding data from Argentinean populations of the Yellow Cardinal, confirming the presence of current breeding populations in the southern limit distribution for this globally "Endangered" species. This contribution adds to the few existing breeding studies on the species (Domínguez *et al.* 2015a & b, de la Peña 2016, Beier *et al.* 2017, Beier & Fontana 2019), finding a new problem for the species caused by the low proportion of males (see Pessino & Tittarelli 2006) that may force them to incur a polygynous system in which they have less reproductive success. These results mean that greater control by government authorities to prevent illegal trapping is essential and must be implemented soon.

Figure 2. Yellow Cardinal nest with three nestlings observed on 11 November 2017 in a private farm located northeast of General Conesa, eastern Río Negro province, Argentina. Photo author: M. Perelló.

For these latitudes, the only nesting record for the species dates from 1995 (compiled by de la Peña 2016), where an active nest with three eggs in November was report. Unlike what has been recently published for the species (Beier *et al.* 2017, Beier & Fontana 2019), we did not observe breeding attempts with helpers contributing on the nest defence or the nestling/fledgling provisioning. Similarly, although Shiny Cowbirds are common in the area (L. Segura, pers. obs.), we did not observe brood parasitism in nests (Domínguez *et al.* 2015a, Beier & Fontana 2019). We found that 25% of the nests were successful, which is similar to that found by Beier & Fontana (2019), but less than the ~40% found by Domínguez *et al.* (2015a) or ~50% by Beier *et al.* (2017) for the northern populations of the species. Nest productivity found (only one fledgling per successful nest) was also lower than the 1.6 fledglings per successful nest reported by Domínguez *et al.* (2015a), Beier *et al.* (2017) and Beier & Fontana (2019). In the same sense, partial brood loss detected was higher than reported by Domínguez *et al.* (2015a). As we did not manipulate nestlings, we are unable to determine if brood reduction was caused by starvation. Both the low apparent nest success as well as the low nest productivity (Domínguez *et al.* 2015a, Beier *et al.* 2017, Beier & Fontana 2019) could be associated with the lower contribution of the male in this socially monogamous species (*i.e.*, by reducing the nest defence or the food delivery to the nestlings; Bennett & Owens 2002) since it was attending three active reproductive females simultaneously.

As regards the case of polygyny we are reporting, we are confident that the origin of this uncommon behaviour (considering that the species is typically socially monogamous) is the lack of males in the area, caused directly by the high intensity of male trapping for illegal trade (Collar *et al.* 1992, Pessino & Tittarelli 2006, Bertonatti 2017, SAyDS 2017). Based on farm-owners' comments and local birdwatchers' sightings records (COA Valle de Conesa, unpub. data), captures for illegal trade in the area was severe in the last decades. Then, when females outnumber males, at least shortly in a given breeding area, it is expected that certain breeding anomalies begin to appear (Engen *et al.* 2003). In addition to our case of polygyny, another phenomenon for southern populations of the cardinal is the presence of hybrids between females Yellow Cardinal and males of the Common Diuca-Finch *Diuca diuca* (BirdLife International 2018), which has been also associated to the lack of males in the breeding areas (Bertonatti & López-Guerra 1997). In addition to our finding, there are some recent records in the area from online databases, such as eBird (https://ebird.org/), or the "*Censo Nacional de Cardenal Amarillo*" (https://www.avesargentinas.org.ar)" that evidence that the species is still present in the area and that conservation actions must be taken immediately. As the southern populations of the cardinal are genetically isolated (Domínguez *et al.* 2017) and have very few natural protected areas (Brown *et al.* 2006) that ensure adequate nesting habitat for the species, we strongly recommend that government authorities take urgent measures to ensure the conservation of these breeding populations.

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ARTICLE

Breeding biology of the endangered Yellow Cardinal *Gubernatrix cristata* in Brazil

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ABSTRACT: The Yellow Cardinal, *Gubernatrix cristata*, has a small geographic range in Brazil, Uruguay, and Argentina. We studied the natural history of the only known Brazilian population of this "Endangered" species (~50 individuals), which is socially monogamous and may breed cooperatively. During two breeding seasons (October to February 2013–2015), we monitored nests and described the main breeding traits. The breeding season started from the first week of October, with a peak of active nests in mid-November and lasted until mid-February. We found 32 nests, of which 30 were monitored. Female built the open-cup nests in six days (*n* = 1). All nests were built on *Prosopis* trees, on average at 2.4 m from the ground. Modal clutch size was three eggs (*n* = 19), and female incubated for 13 days on average (*n* = 7). Hatching rate was 76% and nestlings fledged after 16 days (*n* = 6). Nestling survival rate was 67% with mean productivity of 1.6 fledglings/successful nest. Shiny Cowbird, *Molothrus bonariensis*, parasitized nests of the Yellow Cardinal, with a frequency of 67% and intensity of 1.9 egg per parasitized nest (1–4 eggs; *n* = 13). Parasitism in nestlings by botfly larvae (*Philornis* sp.) occurred in 33% of nests with nestlings. Nest predation was the main cause of nest losses (73%) and we recorded a Geoffroy's Cat, *Leopardus geoffroyi*, preying on a nest with eggs. The probability of success using the Program MARK was 13%. Fledgling survival rate during the first month outside the nest was 62% (8/13 fledglings). We found a longer breeding season, occurrence of second broods, and higher rates but fewer nest losses due to brood parasitism in comparison to the Argentinian population. We highlight the importance of natural history studies for the conservation of different populations of the same species.

KEY-WORDS: brood parasitism, *Molothrus bonariensis*, nest predation, nesting success.

INTRODUCTION

The Yellow Cardinal, *Gubernatrix cristata*, is a passerine that was more abundant in the past and now have a very fragmented distribution through northeast Argentina, Uruguay and southern Brazil (Ridgely & Tudor 2009). Records in Brazil were few and it was even thought that the species was possibly extinct in the country (BirdLife International 2018, Jaramillo 2019). Historical records are concentrated in southern and western Rio Grande do Sul state (Bencke *et al.* 2003). Nowadays, there is at least one established resident population in the Rio Grande do Sul with less than 50 individuals (Martins-Ferreira *et al.* 2013, Beier *et al.* 2017). Bird trapping and habitat loss led to a drastic population decline of the Yellow Cardinal in all its range (Dias 2008, Ridgely & Tudor 2009, Azpiroz *et al.* 2012, Martins-Ferreira *et al.* 2013).

Studies of breeding biology and life-history comparisons between populations enable early identification of threats, even before any evident population decline occur (Martin & Geupel 1993). Despite the decreasing trend of populations advised for the Yellow Cardinal (BirdLife International 2018), until recently its natural history was poorly known. Previous information about its breeding biology was limited to a few old nesting records (Castellanos 1932, Höy 1969), a nest description (de la Peña 1981), and the breeding status of collected specimens (Belton 1994). Domínguez *et al.* (2015) published the first study of the breeding biology of a Yellow Cardinal population in Corrientes province, Argentina. Some potential threats to breeding cardinals are nest predation, brood parasitism, botfly parasitism (Domínguez *et al.* 2015), hybridization (Bertonatti & López-Guerra 1997), and endogamy (Beier *et al.* 2017).

Shiny Cowbird, *Molothrus bonariensis* (hereafter, cowbirds), is a generalist brood parasite and its eggs were found in nests of 270 bird species (Lowther 2018), including Yellow Cardinal (Domínguez *et al.* 2015). The main impact of cowbirds that parasitize hosts with similar or larger body masses is the egg puncturing, which increases the probability of nest abandonment (Massoni & Reboreda 2002, Reboreda *et al.* 2003, Domínguez *et al.* 2015). Also, botfly larvae, *Philornis* sp. (Diptera), may infest nestlings of the Yellow Cardinal (Domínguez *et al.* 2015). Botflies put their eggs on nests of several bird species and their larvae infest the nestlings, feeding mainly on blood cells for four to eight days until they drop out to pupate (Dudaniec & Kleindorfer 2006). Depending on the infestation intensity, *i.e.* the number of larvae infesting a nestling, it may have negative effects on nestling survival and increase nest abandonment after all nestlings died (Dudaniec & Kleindorfer 2006, Rabuffetti & Reboreda 2007).

We studied the breeding biology of the only known population of the Yellow Cardinal in Brazil. The main breeding traits such as breeding season, nest, eggs, clutch size, incubation, nestlings, brood parasitism, and nest survival were described.

METHODS

Study area

We conducted this study in the municipality of Barra do Quaraí, state of Rio Grande do Sul, Brazil. Three study areas were in the Espinilho State Park (ESP), and one at São Marcos Ranch (SMR), adjacent to the ESP. The climate is classified as humid subtropical with hot summer (Cfa) in Köppen's climate classification, with 1300 mm accumulated annual rainfall and 19°C mean annual temperature (Alvares *et al.* 2013; maximum 46°C was taken by a camera trap in December 2013). The vegetation is characterized by an area of insertion of Espinal Province (Cabrera & Willink 1973), which consists of grasslands with scattered thorny trees and shrubs, dominated by *Prosopis affinis* and *Vachellia caven* (Fabaceae). This is one of the last and the largest reminiscent of this vegetation in Brazil (Marchiori & Alves 2011). Three areas were grazed by cattle (Fig. 1).

We studied the breeding biology of the Yellow Cardinal from October through February (2013–2015), since nesting activity has not been recorded before October in a previous pilot study. Our dataset is the same used by Beier *et al.* (2017). We searched for adults at the beginning of each breeding season. Adults found were captured using mist nets and marked with a numbered aluminum ring (standard CEMAVE/ICMBio, the Brazilian Banding Agency) and a unique combination of colored plastic rings. We banded nestlings at 10 days of age or captured soon after fledging.

Nest search

We searched for nests only in areas with savanna vegetation mainly observing the mating pair, following the female and/or any individual carrying materials for nest building or feeding the nestlings. Each nest found was georeferenced and monitored every two or three days (rarely four or five days), when we recorded the nest status (active and inactive) and contents (number of eggs and/or nestlings), from the day that nest was found until it became inactive. When it was not possible to infer the exact day that a nest event occurred (laying, start of

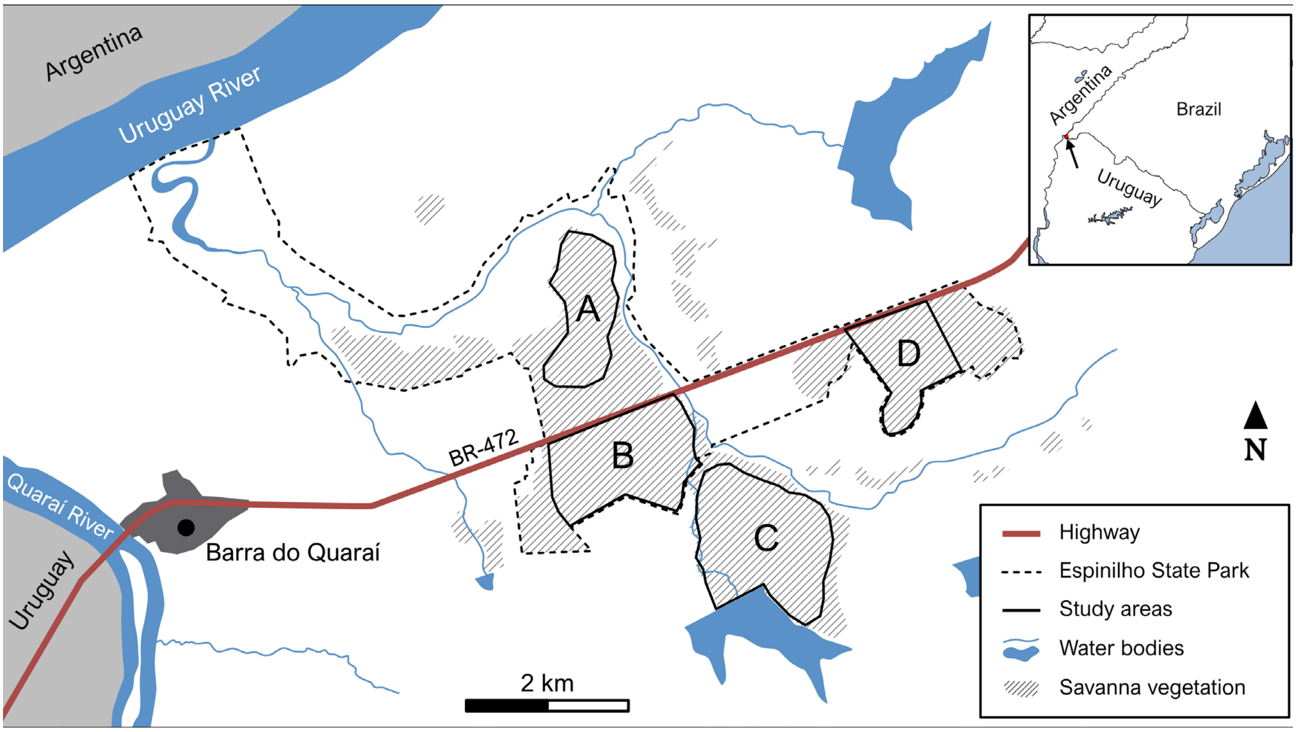

Figure 1. Espinilho State Park with the localization of the four study sites in Barra do Quaraí, Rio Grande do Sul state, at the frontier of Brazil, Argentina, and Uruguay. Study sites B, C, and D were cattle grazed.

incubation, hatching, fledging or nest loss), we considered that it occurred halfway between nest observations.

Breeding season

We considered the breeding season length as the period of days between the beginning of the first nest construction and the day the last nest ended, for both breeding seasons together. To estimate the start of the first nest construction in the breeding season, we used the mean duration for each nest period (construction, laying, incubation, and nestling). We estimated nest building initiation date of the first nest based on the mean duration of nesting stages and plumage development of fledglings, for a mating pair found with two fledglings in November 2014. Last day of breeding period was estimated using the approximated date when the last active nest became inactive.

Description of nests and eggs

We described nest format and support type (as recommended by Simon & Pacheco 2005), supporting plant species, and materials of which it was composed. The nest construction period was considered from the placing of first materials on nest site until the first egg laying. Nests and eggs were measured only after they were abandoned, or when the egg failed to hatch, to avoid possible negative effects of nest manipulation. Nests were measured using a ruler (1.0 mm precision) and nest height was measured using a retractable ruler (1.0 cm precision). Egg measurements were taken using a caliper (0.05 mm) and weighed using a digital scale (0.01 g).

Clutch size, incubation, and nestlings

Clutch size was noted at all nests, excluding those with evidence of partial losses during egg laying. The clutch was considered completed after two consecutive visits without an increase in the number of eggs, and only from nests found during building, laying, or up to four days after incubation started (Lopes & Marini 2005). Incubation period starts after laying of the penultimate to the last egg until hatching, according to our observations and literature (Domínguez *et al.* 2015). Hatching rate was calculated as the ratio between the number of hatchlings and the number of eggs at hatching (Di Giacomo *et al.* 2011). Nestling stage starts at hatching and ends when the first nestling leaves the nest, and we used only nests found with eggs and became successful to estimate its duration. Nest productivity was the number of fledglings per successful nest and per female. Nestling survival was calculated as the ratio between the number of fledglings and hatchlings, considering only nests found during construction, egg laying or incubation (Di Giacomo *et al.* 2011). We calculated fledgling survival as the ratio between the number of young that survived 30 days after fledging (young cardinals disperse after >10 months; Beier *et al.* 2017) and the total number of fledglings. We assumed that fledgling died or was predated when it was not seen with its parents after three consecutive visits (six to nine days), which we considered enough time for the chick be able to follow its parents and to be more easily detected.

Renesting

We calculated the mean time interval and distance between nesting attempts of the same female on each breeding season. Although only seven females were marked, we assumed that nesting attempts in the same territory were from the same female, especially when there was no evidence of divorce or female death (*i.e.*, male alone for several days and performing courtship displays). At least one individual of the mating pair was marked in all nests (13 nests only the male, four nests only the female, and 13 nests both individuals marked).

Parasitism

Brood parasitism frequency was the proportion of nests with at least one cowbird egg from the total of nests that completed laying. For calculating brood parasitism intensity, we used the mean number of cowbird eggs per parasitized nests, considering only nests without partial clutch losses. Prevalence of botfly parasitism was calculated as the ratio between the number of parasitized nests and the number of nests where nestlings were at least 5 days old.

Nest survival

We considered the nest as predated when eggs or nestlings too young to fledge vanished, including nests with eggshells. Nests were considered as abandoned if their contents remained with no sign of parental care. Other potential causes of nest losses were nestling death and brood parasite success. We installed camera-traps (Bushnell Trophy Cam HD) at eight nests to identify nest predators, during incubation and nestling periods, 5–10 m far from the nests, and recorded a total of 12.5 h of video. A nest was considered successful when at least one nestling of Yellow Cardinal fledged. We calculated the nest survival using three different methods: (a) the apparent success, as the ratio between the number of successful nests and the total number of monitored nests (Marini *et al.* 2010); (b) the Mayfield nesting success, estimating the Daily Survival Rates (DSR) and the probability of success (DSR^t) for each nest period (DSR^{ti} and DSR^{tn}, where, ti

= number of days between laying and hatching = 14 days, tn = number of days between hatching and fledging = 17 days; Mayfield 1975), with modifications suggested by Hensler & Nichols (1981) to calculate the standard deviation (SD) of the DSR for each period; and (c) the Program MARK, running the null model to calculate the DSR and DSR^t (t = number of days between laying and fledging = 31 days; White & Burnham 1999). Only nests with known fate were used to estimate nest survival. Nest survival was not associated with nesting attempt order, so we considered successive nesting attempts of the same female/pair as independent events (six successful nests of 12 among first, two of six among second, and zero of two among third nesting attempts; chi-squared test: $\chi^2(2) = 1.36$, $P = 0.51$; Di Giacomo *et al.* 2011).

Statistical analysis

To assess differences on mean time interval and distance between successful and unsuccessful nesting attempts we used non-parametric Mann-Whitney *U*-test (or Wilcoxon rank sum test). We also used *Z*-test to assess differences of DSR and DSR^t between incubation and nestling stages and parasitized and unparasitized nests. We used R software (R Core Team 2015) to run the statistical tests. Values are presented as mean ± SD and considered statistically significant when $P < 0.05$.

RESULTS

Nest search and breeding season

We found 32 nests, 14 in 2013–2014 of nine breeding pairs and 18 in 2014–2015 belonging to 12 pairs. Two nests found during construction were apparently abandoned (never seen with eggs). Of the 30 remaining nests, six were found during nest-building, eight during egg laying, 13 during incubation, and three nests with nestlings. Both individuals of the pair were marked in 13 nests, only the male was marked in 13 nests and in four nests only the female was marked. We estimated that the beginning of nesting season was 03 October and the last nest became inactive on 12 February, totalizing 131 days. The peak of active nests was in late November (Fig. 2).

Description of nests and eggs

Nest building was performed by females but closely followed by males. The nest is a high cup/fork, with an external layer of twigs (*Prosopis* spp.) and an inner layer of thinner sticks, grass, and other plants, lined with filamentous plants and horse/cattle hair. The nest was built in six days ($n = 1$), considering the period from the first twigs until laying of the first egg. Mean nest height was 2.43 ± 0.67 m (1.07–4.43 m, $n = 30$). Nests were built mostly in *Prosopis affinis* trees (97%), and one nest was built in *P. nigra*. Eggs were ovoid with a light bluish-green background color and black spots (sometimes it could have a few streaks) distributed over the entire surface or concentrated at the blunt pole (Figs. 3A & C). Mean egg mass was 3.84 ± 0.15 g and measured 24.7 ± 1.1 mm in length and 17.7 ± 0.6 mm in width (seven eggs at different ages from three nests).

Clutch size, incubation, nestlings and fledglings

Mean clutch size was 2.95 ± 0.52 eggs (2–4 eggs; mode = 3 eggs; $n = 19$), laying one egg/day. The incubation was initiated on the penultimate egg laid, lasted 12.9 ± 0.9 days (12–14 days; $n = 7$) and only the female incubated the eggs. Hatching rate was 0.76 ± 0.25 ($n = 14$ nests) and there was no difference between unparasitized and parasitized nests (unparasitized: 0.80 ± 0.16, $n = 6$; parasitized: 0.73 ± 0.31, $n = 8$; $U = 23$, $P = 0.95$). Hatchlings (Fig. 3B) were orange skinned, with light grey down feathers on the head and back, red-carmine mouth, yellowish gape, and opened their eyes around seven days old. The nestlings (Fig. 3D) remained in the nest for 16.0 ± 1.3 days (15–18 days; $n = 6$). Nestling survival rate of successful nests was 0.67 ± 0.28 ($n = 6$). Mean productivity was 1.6 ± 0.7 (1–3) fledglings per successful nests ($n = 8$) and 2.6 ± 1.8 (1–5) fledglings per female ($n = 5$). Fledglings had bare nape and belly, with remaining grey down feathers on the crown; greyish and streaked breast, yellowish margins in wing feathers; flight and tail feathers not fully developed; yellowish gape. Fledglings at the age of 35–40 days from hatching were muddy forms of the adult female (Figs. 3E & F). The fledgling survival rate was 62% (8/13 fledglings).

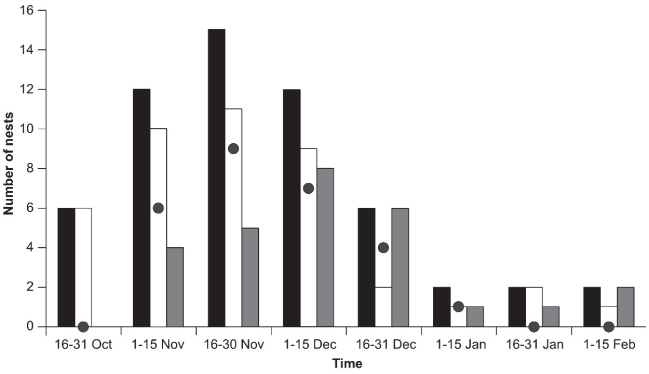

Figure 2. Number of estimated nests of Yellow Cardinal by nesting stage (laying/incubation: white bars; nestling stage: grey bars), total active nests (black bars), and nests parasitized by cowbirds (dots) by two-week intervals during two breeding seasons (2013–2015) in Barra do Quaraí, Rio Grande do Sul state, Brazil. Data from both breeding seasons were combined.

Figure 3. Nest and eggs of Yellow Cardinal in the municipality of Barra do Quaraí, Rio Grande do Sul state, Brazil (**A**). Nestling in the day of hatching with host egg (top) and brood parasite egg (left of nestling) (**B**). Destroyed clutch with one egg of Yellow Cardinal and four eggs of Shiny Cowbird, including the white egg (**C**). Yellow Cardinal nestling (right) and Shiny Cowbird nestling (left) from the same successful nest (**D**). Yellow Cardinal a few hours after fledged (**E**). Yellow Cardinal of about 25 days after fledged (**F**). Photo author: Christian Beier.

Renesting

We observed up to three nesting attempts performed by the same female (two females). From all nesting attempts, 40% was renesting, 35.7% (5 of 14) in 2013–2014 and 43.8% (7 of 16) in 2014–2015 breeding seasons, eight pairs did one renesting attempt and two pairs did two renesting attempts. We observed renesting after a successful attempt ($n = 2$) in two breeding pairs with helpers. Other two renesting occurred after successful attempts, but the fledglings of the previous nests did not survive the first month after fledging, then we did not consider them as second broods. Mean interval between renesting attempts was 15.6 ± 10.1 days (6–36 days, $n = 11$), and the interval was significantly longer after successful ($n = 4$) than after unsuccessful ($n = 7$) attempts (25.2 ± 10.3 days *vs.* 10.1 ± 4.3 days; $U = 1.5$, $P = 0.02$). Mean distance between renesting attempts was 220.75 ± 86.36 m (99–330 m, $n = 12$), and there was no difference between successful ($n = 4$) and unsuccessful ($n = 8$) attempts (174.75 ± 74.58 m *vs.* 243.75 ± 86.74 m; $U = 7$, $P = 0.15$).

Brood parasitism

The frequency of brood parasitism was 67% (20/30). The intensity of parasitism was 1.9 ± 1.3 eggs per parasitized nest (1–4 eggs, $n = 13$). Three cowbird eggs measured 25.1 ± 0.6 mm in length, 20.4 ± 0.1 mm in width and weighed 5.23 ± 0.12 g. Parasite eggs were white or creamy, completely covered with brown spots, except for one egg that was white with a single brown spot (Figs. 3B & C). Cowbird eggs were never rejected. We found punctured host eggs in 15% (3/20) of parasitized nests, and then the owners abandoned the nest. Punctured eggs were often consumed by ants. In four parasitized nests (20%, 4/20) cardinals were successful (unparasitized successful nests: 40%, 4/10). Even on nests where cowbirds hatched (*n* = 8), in three (37.5%), the cardinals were successful and in only one (12.5%) the two cowbirds fledged (without cardinal fledglings). In three cases, the cowbird nestling hatched about three or four days after cardinals, and was seen in only one nest revision, then disappeared. In one nest we found the corpse of the cowbird nestling at the bottom of the nest after the cardinals fledged.

Botfly parasitism

Prevalence of botfly parasitism was 33% of nests (6/18). In one nest, nestlings were only cowbirds and they were predated. The earliest nest with botflies was recorded on 07 November and the latest on 18 December. Four botfly-parasitized nests (80%, *n* = 5) were successful and one nest was lost with the nestling death, for which we were not able to determine the cause. The intensity of botfly parasitism was in average 12.7 ± 5.5 larvae/nestling (*n* = 3). We found one nestling with 19 botfly larvae, it fledged but disappeared soon after.

Nest survival

Only eight nests (26.7%, *n* = 30) were successful, four (28.6%, *n* = 14) in 2013–2014 and four (25.0%, *n* = 16) in the 2014–2015 breeding seasons. The main cause of nest loss was predation (73%), followed by egg puncture (14%), nestling death (9%) and nest parasite success (4%) (*n* = 22). One Geoffroy's Cat (*Leopardus geoffroyi*) was recorded by the camera trap preying on a nest with eggs. The nest was about 1.8 m above ground, in a fork of the tree trunk. We did not record any other predation attempt or identified other predators.

The DSR was 0.938 ± 0.018 during incubation and 0.948 ± 0.016 during the nestling stage. The DSR^{r} during incubation was 0.431 ± 0.105 (*n* = 193 nest-days, 12 nest losses) and during the nestling stage was 0.425 ± 0.117 (*n* = 193 nest-days, 10 nest losses). The Mayfield Nesting Success was 18.3% (23.65% in 2013–2014 and 12.32% in 2014–2015). There was no difference between 2013–2014 and 2014–2015 breeding seasons in DSR for incubation (0.956 ± 0.020 *vs.* 0.912 ± 0.033; *Z* = 1.12, *P* = 0.26) and nestling stages (0.945 ± 0.025 *vs.* 0.951 ± 0.022; *Z* = 0.18, *P* = 0.86) or in DSR^{r} for incubation (0.568 ± 0.146, *n* = 113 nest-days, 5 nest losses *vs.* 0.285 ± 0.138, *n* = 80 nest-days, 7 nest losses; *Z* = 1.41, *P* = 0.16) and nestling stages (0.416 ± 0.167, *n* = 91 nest-days, 5 nest losses *vs.* 0.432 ± 0.166, *n* = 102 nest-days, 5 nest losses; *Z* = 0.07, *P* = 0.95).

Mayfield Nesting Success for the Yellow Cardinal was 24% for unparasitized and 15% for parasitized nests. There was no difference between the DSR^{r} of unparasitized and parasitized nests during incubation (0.492 ± 0.178, *n* = 76 nest-days, 4 nest losses *vs.* 0.395 ± 0.132, *n* = 117 nest-days, 8 nest losses; *Z* = 0.44, *P* = 0.66) and nestling stage (0.485 ± 0.179, *n* = 91 nest-days, 4 nest losses *vs.* 0.391 ± 0.154, *n* = 106 nest-days, 6 nest losses; *Z* = 0.40, *P* = 0.69). For *Philornis* parasitism, the DSR^{r} during the nestling stage was 0.279 ± 0.129 (*n* = 105 nest-days, 8 nest losses) for unparasitized and 0.691 ± 0.183 (*n* = 88 nest-days, 2 nest losses) for parasitized nests, and there was no significant difference between them (*Z* = 1.84, *P* = 0.07). We found a DSR of 0.937 ± 0.013 (SE) and a DSR^{r} of 0.134, using Program MARK.

DISCUSSION

The natural history of the Yellow Cardinal was poorly known until recently when a study was conducted in Argentina (Domínguez *et al.* 2015), relatively close to our study site (at two sites, about 130 and 180 km northwest, respectively). Despite the geographic proximity, we found some differences: a longer breeding season, occurrence of second broods, and higher frequency and intensity but fewer nest losses due to brood parasitism. Domínguez *et al.* (2015) conducted their study prior (2011–2012) to ours (2013–2015), so we cannot determine whether the differences found were related to temporal or spatial factors. Additionally, we have already reported cooperative breeding in the Brazilian population (Beier *et al.* 2017), which was not reported in other populations (Domínguez *et al.* 2015, Segura *et al.* 2019).

We found higher frequency (67%) and intensity (~2 eggs/parasitized nest) of brood parasitism by cowbirds than in Argentina (33%, 1 egg/parasitized nest; Domínguez *et al.* 2015). Despite that, only 18% of nest losses were due to cowbird parasitism in our study. While in Argentina nest abandonment due to egg puncturing by female cowbirds (54% of parasitized nests) represents a threat of concern (Domínguez *et al.* 2015), in our study, it seems to have lesser importance (15% of parasitized nests). Shiny Cowbird has an incubation period of 11–12 days (Fraga 2011), very similar to the Yellow Cardinal (13 days), and cowbird nestlings disappeared from nests where cardinals hatched first. Cowbirds hatchlings may not get enough food competing with cardinal nestlings three or four days older, or the host parents rejected the parasite, for which we do not have other evidence. Brown-headed Cowbird, *Molothrus ater*, nestlings are more successful in nests of hosts with similar or intermediate body size

(Kilner 2003), which is the case for Yellow Cardinal (47 g; Beier *et al.* 2017) and Shiny Cowbirds (45–51 g; Fraga 2011), but we did not find nests where both, host and parasite, were successful.

Prevalence of botfly parasitism was greater in Brazil (33%) than in Argentina (22%), occurred during a longer period (~40 days *vs.* 14 days), and apparent success was higher on infested nests (80%, *n* = 5 *vs.* 50%, *n* = 4; Domínguez *et al.* 2015). Domínguez *et al.* (2015) found no significant difference in chick survival between parasitized (25%) and unparasitized nests (78%). In our study, some fledglings disappeared a few days after they fledged, which we assumed that they died, based on their developmental stage. Ectoparasites may delay the development of the nestling, and even when they do not affect the nestling success, they could decrease the post-fledging survival (Streby *et al.* 2009).

The breeding season was around 45 days longer in Brazil than in Argentina (Domínguez *et al.* 2015). A longer breeding season could mean more nesting attempts (Ricklefs & Bloom 1977) and may be a strategy to compensate high rates of nest predation (Slagsvold 1984, Martin 1996, 2014, Di Giacomo *et al.* 2011), which in our study accounted for 73% of nest losses. Unless it is too late in the season, females will always renest after nest predation and the number of nesting attempts will be determined by the number of days lost in the breeding season for each nest lost (Schmidt & Whelan 1999). We observed more renesting attempts (40% of all nesting attempts) and longer mean interval between attempts (16 days), but less attempts per pair during a breeding season (up to three attempts) than in Argentina (30%, 12 days, and up to four attempts per pair; Domínguez *et al.* 2015).

The Yellow Cardinal have biparental care, and some nests (*n* = 7) were also attended by helpers, which contributed to brood provisioning and territorial defense (Beier *et al.* 2017). Cooperative breeding in this population may be a response to high rates of nest predation and brood parasitism, and/or habitat saturation (*e.g.*, Manica & Marini 2012, Beier *et al.* 2017). Only mating pairs with nest helpers had second broods, probably due to the extra food and vigilance provided by them. Cooperative breeding may also allow reducing female investment on egg yolk (Russell *et al.* 2007, Paquet *et al.* 2013), for which we do not have information for the Yellow Cardinal.

In a pilot study in 2012, we found two nests (*n* = 8) on cactus *Cereus hildmannianus* (C.B., M.S. Pereira & M.S. Borba pers. obs.), but all nests of the present study were found on *Prosopis* trees. Domínguez *et al.* (2015) also found more nests on *Prosopis affinis* (76%), followed by 15% on *Vachellia caven*. Although *V. caven* occurs in our study area, we did not find any nest on that tree species. The preference to nest on a supporting plant species may be related to nest concealment (Martin & Roper 1988, Martin 1993) or to the most common potential nest site, reducing predation probability (Martin 1993, Liebezeit & George 2002).

The Yellow Cardinal and other threatened bird species are also associated with short grass, which is maintained mostly by cattle grazing in our study area (Pereira 2015). The removal of cattle may lead to the development of taller grass and shrub encroachment, and consequently, ground feeding birds could be evicted from this area. Conservation schemes must consider vegetation management to prevent potential impacts on populations of ground-foraging birds.

The natural history of many bird species is still poorly known, if not completely unknown, especially in the Neotropics (Stutchbury & Morton 2001, Xiao *et al.* 2017). Various of these species are threatened and the knowledge on their natural histories is of the utmost importance to their conservation. Even across distinct populations of a species, there are remarkable differences, such that each of these populations should be considered as a single unit for the conservation of genetic, ecological and cultural variability, as it is for the Yellow Cardinal (Domínguez *et al.* 2016, 2017). Our study highlights the importance of autecology studies in different populations of a single species, to allow a better understanding of variations in spatial-temporal patterns and processes and their implications for species and ecosystems conservation.

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SHORT-COMMUNICATION

Aggregations of Southern Caracaras (*Caracara plancus*) in soybean plantations in central Cerrado, Brazil

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ABSTRACT: This study reports on large aggregations of Southern Caracaras (*Caracara plancus*) in soybean plantations in the surroundings of *Parque Nacional das Emas*, southwestern Brazil. Observations were done during harvesting activities in February 2009. Aggregations were found by driving a vehicle through roads that crossed or bordered soybean plantations located at less than 4 km from this park. For each aggregation detected, individuals found around harvesting machines were counted. The abundance of Southern Caracaras of each aggregation ranged between 76 and 104 individuals ($n = 8$). Despite the attraction of high numbers of caracaras to proximities of machines, most of them appear to do not obtain much food resources during harvesting of soybean fields. Caracaras were seen capturing small mammals, lizards, birds and large insects. This association between *C. plancus* and harvesting activities can be considered as opportunist behavior in response to rapid modification of grain-production landscapes in the Cerrado.

KEY-WORDS: agribusiness, bird, Falconidae, feeding ecology, grassland, savanna.

In the Cerrado, the savanna ecosystem that dominates central Brazil, landscapes were originally dominated by open vegetation such as grasslands and woodlands (Oliveira & Marquis 2002). However, extensive areas of these matrix types have been converted to agricultural land during the last three decades (Klink & Machado 2005). As consequence, numerous landscapes are now covered mainly by exotic vegetation such as soybean plantations (Klink & Moreira 2002). Despite this dramatic modification of landscapes, the use of soybean plantations by native wildlife remains poorly investigated in the Cerrado.

Some bird species, such as the Southern Caracara (*Caracara plancus*) can be occasionally found in soybean fields (pers. obs.). This raptor species is associated to open vegetation and human-modified landscapes in the Neotropical region (Ferguson-Lees & Christie 2001, Erize *et al.* 2006, Sazima 2007). It is usually found in landscape elements such as grasslands, savannas, pastures, agricultural fields, roads and urban areas (del Hoyo *et al.* 1994, Sick 1997, Narosky & Yzurieta 2006). Its omnivorous diet includes a wide range of alive and dead animals, plants and human-made food (Wallace & Temple 1987, Ferguson-Lees & Christie 2001, Travaini *et al.* 2001, Galetti & Guimarães-Jr. 2004, Vargas *et al.* 2007). In the Cerrado, lone birds or pairs of this species often feed on the ground of open areas (Antas & Cavalcanti 1988), including the consumption of rodents, lizards, beetles and grasshoppers in harvested soybean plantations (pers. obs.). This study aimed to report on large aggregations of the Southern Caracara in soybean plantations during harvesting operations in a central Brazilian Cerrado.

Observations were done in the surroundings of *Parque Nacional das Emas* (17°49'S–18°28'S; 52°39'W–53°10'W), a 1330 km² nature reserve located in Goiás state, central Cerrado, southwestern Brazil. Elevations range between 720 and 900 m a.s.l., and most of the original landscape consists of flat tableland covered by grasslands and open woodlands (França *et al.* 2007). Climate is marked by two well defined periods, wet and dry seasons. Most of the annual precipitation falls between October and March. Annual rainfall ranges between 1200 and 2000 mm (Assad 1994). The park is mostly surrounded by agricultural land, such as soybean, cotton and corn plantations. Soybean plantations usually occur between early November and late February and a single stand might cover several km² (pers. obs.).

Cultivation and harvesting of soybean fields in the study area are made mechanically. Large machines (*colheitadeiras*) usually harvest plantations in mid or late February. To harvest a given stand, these machines are usually driven straight for about 600–2000 m and then moved in opposite way, to pass over juxtaposed areas of plantations still not harvested. Thus, bands of clear cuts (harvested areas) of about 10 m in width are created in sequence.

Observations were done during afternoons between

17 and 22 February 2009, when most soybean plantations in this Cerrado region were being harvested. To search for caracara aggregations associated with harvesting activities, I drove a vehicle through roads that crossed or bordered soybean plantations located at less than 4 km from the park. When harvesting machines surrounded by numerous caracaras were detected, I left the vehicle and approached them by walking. Caracaras located around the harvesting machines were counted. Usually, I spent about 10 min for each aggregation and I could get at less than 200 m from most of the individuals, which were easily seen from this distance (Fig. 1).

Eight large aggregations of *C. plancus* associated with machines harvesting soybean fields were recorded. The numbers of individuals detected in each aggregation were: 96, 104, 76, 85, 94, 88, 79 and 82. Studies in the Cerrado and elsewhere reported that *C. plancus* usually forages solitary or in pairs, while groups of three to nine birds have been recorded sporadically (Whitacre *et al.* 1982, Antas & Cavacanti 1988, Yosef & Yosef 1992, del Hoyo *et al.* 1994, Sick 1997, Goldstein & Hibbitts 2004). These numbers are comparable to those found by myself in young soybean plantations in the study area during late 2006 and 2008. In relation to the aggregations reported in this study, most caracaras foraged lonely or in pairs, and not cooperatively as reported by Jones (1999) for the Mountain Caracara (*Phalcoboenus megalopterus*) in Peru. Additionally, in his review of the feeding habits of *C. plancus*, Sazima (2007) also reported that this species follows ploughs in South America. As social learning of foraging in birds might occur by the observation of conspecifics at feedings sites (see review in Slagsvold & Wiebe 2011), it is possible that these raptors were able to associate moving machines to the availability of food items during harvesting operations.

Estimates of abundance of *C. plancus* in the Cerrado and other regions were mostly done through transect routes. For example, its density at *Parque Nacional das Emas* was estimated as 2.8 ± 1.6 individuals/km^2 (Baumgarten 1998). In the Venezuelan Llanos, Jensen *et al.* (2005) reported less than 20 birds per 22.5 km long counts. Similar surveys conducted in other landscapes reported comparable or lower densities (Albuquerque *et al.* 1986, Hayes 1991, Carvalho & Marini 2007). Thus, the aggregations reported in the current study are the highest densities of foraging *C. plancus* recorded to date, as they usually kept within an area of about 10 ha around the machines.

Figure 1. Numerous Southern Caracaras (*Caracara plancus*) attracted by harvesting activities in soybean fields close to *Parque Nacional das Emas*, southwestern Brazil, in February 2009.

During the removal of soybean vegetation, caracaras tended to keep on the ground of recently harvested fields. Most of them usually kept nearly stopped watching the machine or walking slowly in search of food resources on the ground, as commonly observed in South America (Sazima 2007). Relatively few individuals followed the machines for a few meters by flying or running short distances in an attempt to capture animals flushed due the disturbance on vegetation. Similarly, Sick (1997) reported the following of tractors by this raptor species in search of earthworms during field plowing in Brazil.

The consumption of soybean grains by caracaras has not been observed in this study. On few occasions, caracaras were observed obtaining food resources (unidentified rodents, lizards, birds and large insects, such as beetles and grasshoppers). After holding prey with the bill, caracaras left the aggregations. Likely, these prey were injured or incapacitated by machines. Despite the recording of these feeding events, food availability appeared to not be plentiful in the areas being harvested. This is because most individuals observed in detail after the 10 min counting periods have not obtained food items. This low number of feeding events recorded might not result of the short period of sampling in each plantation. I consider that, as these raptors were numerous, I would often record foraging birds if food items were abundant, even during a short period.

Thus, despite the attraction of outstanding numbers of caracaras to the surrounding of active machines, most caracaras did not obtain large amounts of food during the harvest of soybean fields. This observed low consumption of food items by this raptor species in the studied plantations might result, in part, of applications of agrochemicals to soybean plants. This practice might cause the killing of the invertebrates and vertebrates that arrive in plantations. Further, as the studied plantations were usually at more than 2 km from the park and other native remnants, it is likely that few animals could colonize these exotic fields.

This is because I could observe a few caracaras, groups of the Greater Rhea *Rhea americana*, and pairs of the Yellow-headed Caracara *Milvago chimachima*, the

Red-legged Seriema *Cariama cristata*, the Burrowing Owl *Athene cunicularia* and the Southern Lapwing *Vanellus chilensis* eating numerous prey consecutively by following a machine in early 2007. On this occasion, these birds were at less than 100 m from the park, where agrochemicals were not applied due an agreement between the land owner and the park manager. Therefore, I consider that these bands of plantations free of agrochemicals located adjacent to park boundaries could be colonized by numerous invertebrates and vertebrates due to a short distance from native areas of the park.

The experience with great food availability as result of machine movement juxtaposed to the park might explain this aggregation of caracaras in the studied fields and elsewhere due to learning. Further studies are necessary to verify if this opportunist behavior of *C. plancus* in response to rapid modification of agricultural landscapes in the Cerrado is leading to their intoxication.

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SHORT-COMMUNICATION

Playful waterbird: Australasian Darter (*Anhinga novaehollandiae*) plays with sticks

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ABSTRACT: Play with objects by birds is recorded usually for nestlings and juveniles. This behaviour is regarded as important for motor development and practice of essential skills, mostly foraging and breeding. Play is recorded for the Anhinga (*Anhinga anhinga*) in North America. For the remaining three recognised species play with objects seems unreported. Herein I present events of play with objects by a maturing individual of the Australasian Darter (*Anhinga novaehollandiae*) recorded at the urban area of Sydney, southeastern Australia. In one of the play events, the darter played with a stick it broke from a partly submerged tree it was resting on. In another event, the bird picked a floating pod, tossed it into the air and caught it again. As the Australasian Darter maturing individual possibly was a male, it could be practicing to gather sticks for nest construction, whereas playing with the pod is related to prey handling.

KEY-WORDS: Anhingidae, Australia, play behaviour, play with objects, urban waterbirds.

Play with objects is recorded mostly for nestlings and juvenile birds, and is believed to improve motor development and essential skills needed later in the life cycle, such as prey handling and gathering nest material (Ficken 1977, Burghardt 1998, Kitowski 2005). This play type is recorded for several bird species in various orders, including Suliformes (Schreiber *et al.* 1996, Causey 2002, Mowbray 2002, Sazima 2008, Hobson 2013). Among the four recognised species of the Anhingidae (Kennedy *et al.* 2005, Schodde *et al.* 2012), play is recorded for the Anhinga (*Anhinga anhinga*) in North America (Frederick & Siegel-Causey 2000, Davis-Jr. 2015, Witt 2018). For the remaining three species, I was unable to find reports about play with objects. Herein I present three events of play with objects by a maturing individual of the Australasian Darter (*Anhinga novaehollandiae*) recorded in Sydney, Australia.

I observed the Australasian Darter at the Parramatta River (33º50'0''S; 151º04'3''E, 2 m a.s.l.) in the urban area of Sydney, New South Wales, southeastern Australia. A condominium and a pedestrian path are in front of the observation site, which is close (about 50 m) to a bridge with moderate to heavy traffic. At the opposite side of observation site, the river is bordered by mangroves and is used by cormorants and the darters as a fishing ground. I recorded the Little Pied Cormorant (*Microcarbo melanoleucos*), the Little Black Cormorant (*Phalacrocorax sulcirostris*), and the Great Cormorant (*Phalacrocorax carbo*) fishing, resting, and plumage drying at the same or nearby places as the darter. As records of playing events may be fortuitous and circumstantial (Sazima 2008), the three events were opportunistically observed with bare eye or through a 70–300 mm telephoto lens mounted on a SLR camera from a distance of about 15–20 m. Throughout the observational sessions, I used the "*ad libitum*" and "sequence" samplings (Altmann 1974), which are adequate to record fortuitous or rare events. Voucher digital photographs of the best documented event are on file at the *Museu de Zoologia, Universidade Estadual de Campinas* (ZUEC).

On 13 March and 02 April 2018 I recorded three events of playing with objects by a maturing individual of the Australasian Darter. In two of the events (13 March, at middle afternoon), the darter left the water and perched on a partly submerged dead tree. After shaking the body to pull water excess out from its plumage, the bird carefully scanned its immediate surroundings, and opened the wings to dry the plumage. After two min, the darter looked intently at a slim branch, grabbed it with the bill and broke it (Fig. 1A). With the stick held crosswise in the bill, the darter swayed its head and neck up and down, the wings kept spread during this play (Fig. 1 B–D). After two of these swaying movements, the bird briefly ran the stick on the left wing (Fig. 2) and released the object into the water. The whole sequence lasted two min. Shortly afterwards, the darter broke a smaller stick the same way, balanced it briefly in the bill, and released the object into the water without touching

Figure 1. A maturing Australasian Darter (*Anhinga novaehollandiae*) individual playing with an object. After choosing a stick from its resting perch, the bird holds the object between its mandibles (**A**); with the stick held in the bill, the darter displays swaying movements with the head and neck (**B** & **C**), repeated twice (**D**).

Figure 2. Subsequent to playing with the stick, the darter runs it briefly on the left wing, after which it released the object into the water.

its body as recorded in the previous event. After these two playing sequences, the bird began to preen its plumage meticulously and I left the site.

On 02 April, at late morning, I recorded the third playing event by the same Australasian Darter individual, as recognised by a natural mark on the right foot (a split webbing). The bird was perched on partly submerged dead branch and was preening the plumage, with its wings closed. A floating pod carried by the current drew the attention of the bird, which grabbed it with the bill and tossed the object into the air three times, caught it skilfully during the fall, and released it afterwards into the water. This event lasted less than a minute, after which the bird resumed preening and I left the site.

The behaviour displayed by the Australian Darter undoubtedly qualifies as play, as it meets all of the recent and strict criteria to define play in animals (Burghardt 2006): 1) limited immediate function (do not contribute to survival); 2) endogenous component (voluntary or intentional); 3) structural or temporal differences (exaggerated and awkward); 4) repeated performance (performed similarly); and 5) relaxed field (free of stress such as predator threat). This latter criterion was likely met after the careful scanning of the bird's immediate surroundings.

The present record raises the number of the apparently rare reports of Anhingidae playing with objects. It remains to be verified if this scarcity is due to lack of observational, natural history-focused studies, or if object play is actually rare, or restricted to some individuals, populations, or areas. I am inclined towards the first explanation, since Witt (2018) tells a story about young Anhingas (*Anhinga anhinga*) tossing sticks into the air and trying (and succeeding) to catch them again. Tossing sticks into the air and catching them is also reported for juvenile or subadult Anhingas (Davis-

Jr. 2015). The tossing of sticks by the Anhinga and pods by the Australian Darter are likely related to practicing prey handling, as in the final phase of predation these birds toss a fish up in the air to turn it and catch it again to swallow it head first (Orta 1992, Frederick & Siegel-Causey 2000, Corbo *et al*. 2013, I.S., pers. obs.)

Due to the complexity of sex identification of maturing individuals of the Australasian Darter (Orta 1992, Schodde *et al*. 2012, Dahlem 2018, C.G. Murray pers. comm., I.S., pers. obs.), the sex of the playing bird would be an open question. However, after sightings of additional individuals near the study site from October to December 2018, my assumption is that the observed individual was a male, due to the already well-defined black line extending from the eye to the neck and partly rufous neck (see photos in Dahlem 2018). If the bird was actually a male, then it likely was practicing to gather sticks for nesting, as this part of nest construction is mostly a male role (Orta 1992, Frederick & Siegel-Causey 2000). On the other hand, if the bird was a female, playing with sticks seems to be a slight departure from its role in nest construction later in the life-cycle, as females mostly arrange the sticks the males bring to the nest (Orta 1992, Frederick & Siegel-Causey 2000). Whatever the sex of the playing bird, however, play with objects by the Australasian Darter is herein described and substantiated with photographs. The apparent rarity of object play in Anhingidae, including the Australian Darter, deserves a closer look and further natural history-oriented studies, especially at urban sites that would potentially constrain some behaviour types and increase alert and flight distances (Mikula 2014, Prestes *et al*. 2018).

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Observation of Audouin's Gull *Ichthyaetus audouinii* in Suriname on South American mainland

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ABSTRACT: After a first-year Audouin's Gull *Ichthyaetus audouinii* was spotted in Trinidad on 10 December 2016, a second-year individual was now seen and photographed on 22 March 2018 in the mouth of the Suriname River near Paramaribo in Suriname. This record is the first of this species for that country and for mainland South America.

KEY-WORDS: Laridae, Mediterranean avifauna, Neotropical avifauna, rare vagrant.

Audouin's Gull *Ichthyaetus audouinii* (Payraudeau, 1826) is a large, maritime gull restricted to the Mediterranean Sea and the western coast of Saharan Africa and the Iberian Peninsula. Main breeding areas are the Ebro Delta in northeastern Spain and the Chafarinas Islands off north-eastern Morocco. Main wintering grounds are situated on the Atlantic coasts of north-western and western Africa, down to the south of Gambia and Senegal (Burger *et al.* 2018).

In the afternoon of 10 December 2016, Nigel Lallsingh, a birdwatcher in Trinidad, discovered a striking immature gull amongst a flock of roosting gulls, mainly Laughing Gulls *Leucophaeus atricilla* (Linnaeus, 1758), at the high tide roost in Brickfield (10°20'N; 61°16'W) on the west coast of Trinidad (Lallsing 2018). The gull was absent the following days until it was briefly seen on 14 January 2017. From 30 March to 03 April 2017, it was present at the same roost and seen and photographed by several local birdwatchers. This gull was a large and robust one with a sloping forehead and a long, rather droop-tipped bill. It was appreciably larger than the accompanying Laughing Gulls. It was in transitional plumage, moulting from first-winter to first-summer plumage with faint grey-brown flecking on ear coverts and rear crown. Underparts were dirty white with extensive brownish mottling, and the upperparts were pale grey with large brownish blotching. When seen in March–April, and later on photographs taken in August, face and underparts were already whiter with just subdued pale grey mottling on upper breast and blotching on upperparts restricted to the nape. Mantle and wing coverts were paler grey with a few small brown blotches. Secondaries had white fringes and the inner primaries were much paler in contrast with dark outer ones (Kenefick 2017). These observations were submitted to the South American Classification Committee as proposal 772 (Kenefick 2018) and accepted as the first record of an Audouin's Gull for Trinidad and Tobago, and the first ever sighting of this species for "the Americas".

On 22 March 2018, when bird watching in the mouth of the Suriname River, B.K. accompanied by C.W. spotted a striking large and robust gull amongst a flock of smaller, roosting Laughing Gulls. It was sitting on a wooden construction in front of the police station near the fishing port of Nieuw-Amsterdam, *c.* 10 km downstream of Paramaribo (*c.* 05°53'N; 55°06'W) at the confluence of the Suriname and Commewijne Rivers. Gulls are attracted to this place, where they feed on the waste of returning fishing boats.

Although he did not know about the record on Trinidad, B.K.'s first idea was that it was an Audouin's Gull. They took a digiscope photograph of the gull which they sent to their colleagues of the Vogelbescherming Nederland (BirdLife Netherlands) for further identification. Their colleagues in the Netherlands confirmed the identification as an Audouin's Gull in almost adult plumage. The gull was seen and photographed by several birdwatchers until at least 15 April (A.L. Spaans, pers. comm.). From these photographs, it is obvious that it is an Audouin's Gull moulting from second-winter into second-summer plumage. It had the typical dark primaries of a second-year individual (Fig. 1) and a reddish bill with a black ring and a small yellow tip at the end (Fig. 2). See also

Figure 1. The Audouin's Gull *Ichthyaetus audouinii* in Suriname, photographed in flight showing the typical dark wing pattern of a second-year individual. Photo author: Bert Kasius.

Figure 2. The second-year Audouin's Gull *Ichthyaetus audouinii* in Suriname. Note the adult colour pattern of the bill, dark eyes and grey legs. Photo author: Bert Kasius.

plate 12 and 13 in Malling-Olsen & Larsson (2003).

This observation is the first record for Suriname (Spaans *et al.* 2016) and for mainland South America. There is a possibility that the Audouin's Gull seen in Suriname, was the same as the one seen in Trinidad. The slow moulting after it was seen in first-winter plumage in December 2016 into second-summer plumage in March 2018 is consistent with this possibility. And the distance between the two localities where it was recorded is only 835 km.

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