PONTIFÍCIA UNIVERSIDADE CATÓLICA DO RIO GRANDE DO SUL
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PROGRAMA DE PÓS-GRADUAÇÃO EM ZOOLOGIA

HISTÓRIA NATURAL DO CARDEAL-AMARELO *Gubernatrix cristata* (AVES: THRAUPIDAE) NO BRASIL

Christian Beier

DISSERTAÇÃO DE MESTRADO

PONTIFÍCIA UNIVERSIDADE CATÓLICA DO RIO GRANDE DO SUL
Av. Ipiranga, 6681 – Caixa Postal 1429
Fone: (51) 3320-3500
CEP 90619-900 – Porto Alegre – RS
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Orientadora: Dra. Carla Suertegaray Fontana

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AGRADECIMENTOS

Ao completar mais uma etapa na trajetória da vida, é difícil eu não lembrar de como tudo começou. Antes mesmo de completar 3 anos de idade, já havia comprado a primeira coleção de revistas sobre animais, intitulada “Os Bichos”. Logo em seguida veio outra coleção: “Guia Ilustrado O Mundo dos Animais”. Assim teve início minha curiosidade e paixão por animais e livros. Então quando descobri o que um zoólogo fazia, decidi que era isso que queria fazer. Apesar de alguns desvios e ter levado um pouco mais de tempo, hoje chega a ser difícil de acreditar que realizei meu sonho de infância.

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RESUMO

O cardeal-amarelo, *Gubernatrix cristata*, é um pássaro ameaçado de extinção, que teve suas populações drasticamente reduzidas devido à captura e ao comércio ilegal de fauna silvestre, além da perda de habitat. Informações sobre a história natural da espécie são escassas e frequentemente imprecisas. No intuito de fornecer subsídios para a sua conservação, nós estudamos a autoecologia da população brasileira de cardeal-amarelo. O estudo foi conduzido no município de Barra do Quaraí, no extremo oeste do Estado do Rio Grande do Sul, Brasil, durante duas temporadas reprodutivas (outubro–fevereiro, 2013–2015), após breve projeto-piloto iniciado em 2012. Marcamos 35 (sete fêmeas, 14 machos e 14 filhotes) de 53 indivíduos encontrados, e até setembro de 2015, a população brasileira de cardeal-amarelo era de 38 indivíduos. Monitoramos 30 ninhos ao todo, onde observamos vários aspectos da autoecologia da espécie. Encontramos evidências de que folhas parecem ser um item alimentar importante na dieta da espécie. A razão sexual dos adultos é 1,5:1 e pode chegar à idade de pelo menos 8 anos. Os casais são socialmente monogâmicos e territoriais, com tendência para filopatria dos machos e dispersão das fêmeas. O tamanho médio dos territórios reprodutivos é 18 ha e da área de vida é 27,7 ha. Alguns casais e ninhos (23%) são atendidos por um ou dois indivíduos adicionais (ajudantes de ninho), que contribuem na defesa do ninho e território, e na alimentação dos ninhegos e filhotes após saírem do ninho. A reprodução inicia na primeira semana de outubro, com pico de ninhos ativos na segunda quinzena de novembro e perdura até meados de fevereiro. Os ninhos em forma de taça são construídos em 6 dias pela fêmea, quase todos em *Prosopis affinis*, à altura média de 2,4 m. Três ovos é o tamanho de ninhada, os quais a fêmea incuba por 12,9 dias. A taxa de eclosão é de 76% e os ninhegos saem do ninho após 16 dias. O cuidado é biparental ou cooperativo, e o casal tem maior frequência de visitas ao ninho do que os ajudantes. A taxa de sobrevivência de ninhegos foi 67% com produtividade média de 1,6 filhote por ninho com sucesso, e foi maior nos ninhos atendidos por ajudantes. Registramos segunda postura após um sucesso, onde ajudantes estavam presentes. O intervalo médio entre tentativas foi 15,6 dias e a distância média 220,7 m. O vira-bosta, *Molothrus bonariensis*, parasita os ninhos de cardeal-amarelo, com frequência de 67% e intensidade de 1,9 ovo por ninho parasitado. Ovos furados por fêmeas de vira-bosta levaram ao abandono de 15% dos ninhos parasitados. De seis ninhos onde filhotes de vira-bosta eclodiram, em dois (33%) o cardeal-amarelo teve sucesso. Os ninhegos podem ser parasitados por larvas de mosca (*Philornis* sp.), e ocorreu em 33% dos ninhos onde os ninhegos eclodiram. Predação foi a principal causa de perda de ninhos (73%) e registramos um *Leopardus geoffroyi* predando um ninho com ovos. O sucesso aparente dos ninhos foi 27% e o sucesso de Mayfield foi 18%. A taxa de sobrevivência dos filhotes no primeiro mês fora do ninho foi 62%. Registramos um caso de endogamia, entre pai e filha. Necessidade de grandes áreas de vida e fatores que podem afetar negativamente o sucesso reprodutivo (e.g. endogamia, predação, parasitismo), podem agravar a estado de conservação da população brasileira e da espécie, reforçando a importância dos estudos de autoecologia e sua contribuição para os planos de conservação.

Natural history of Yellow Cardinal *Gubernatrix cristata*

(Aves: Thraupidae) in Brazil

ABSTRACT

The Yellow Cardinal, *Gubernatrix cristata*, is a threatened passerine that had its populations drastically reduced, mainly by illegal capture and wildlife trade, and habitat loss. Natural history information of the species is few and often innacurate. In order to raise awareness of the Yellow Cardinal and provide subsidies for its conservation, we studied the autecology of the Brazilian population of Yellow Cardinal. Our study was conducted in the municipality of Barra do Quaraí, westernmost State of Rio Grande do Sul, Brazil, during two breeding seasons (October to February, 2013–2015), after a brief pilot-study that started in 2012. We ringed 35 (seven females, 14 males and 14 young) out of 53 individuals found, and by September 2015, the whole Brazilian population of Yellow Cardinal had 38 individuals. We monitored 30 nests, where we observed various aspects of species autecology. We found evidence that leaves may be an important food item in species diet. The adults sex ratio is 1.5:1 and the lifespan is at least 8 years. Pairs are socially monogamous and territorial, with male-biased philopatry and female-biased dispersion. Mean size of breeding territories is 18 ha and mean home range is 27.7 ha. Some pairs and nests (23%) are attended by one or two additional individuals (nest helpers), which contribute on nest and territory defence, and on feeding of nestlings and fledglings. Breeding season starts from first week of October, with a peak of active nests in mid-November and lasts until mid-February. The open-cup nests are built in six days by female, almost all of them in *Prosopis affinis*, at mean nest height from ground of 2.4 m. Clutch size is three eggs, which female incubates during 12.9 days. The hatching rate is 76% and nestlings fledge after 16 days. Parental care is biparental or cooperative, and the pair have high frequency of visits to the nest than helpers. Nestling survival rate is 67% with mean productivity of 1.6 fledgling per successful nest, and was higher in nests attended by helpers. We recorded second broods after successful attempts, on which helpers were present. Mean interval between nesting attempts was 15.6 days and mean distance was 220.7 m. Shiny Cowbird, *Molothrus bonariensis*, parasites nests of Yellow Cardinal, with frequency of 67% and intensity of 1.9 egg per parasitized nest. Punctured eggs by female cowbirds led to abandonment of 15% of parasitized nests. From six nests where cowbirds hatched, in two (33%) Yellow Cardinal successfully fledged. Nestlings can be parasitized by botfly larvae (*Philornis* sp.), with prevalence in 33% of nests where nestlings hatched. Predation was the main cause of nest losses (73%) and we recorded a *Leopardus geoffroyi* preying on a nest with eggs. The apparent nest success was 27% and the Mayfield nesting success was 18%. The fledgling survival rate during the first month outside the nest was 62%. We recorded a case of inbreeding, between father and daughter. Large home range needs and factors that may adversely affect breeding success (e.g. inbreeding, predation, parasitism) can aggravate the status of the Brazilian population and species. It reinforces the importance of autecology studies and their contribution to the conservation schemes.

APRESENTAÇÃO

O parque de inhanduvá no Brasil

No extremo oeste do estado do Rio Grande do Sul é encontrado um tipo de vegetação único no Brasil. Trata-se de uma inserção da Província do Espinhal, e mais especificamente do Distrito do Inhanduvá, em território brasileiro, a qual distribui-se mais amplamente na Argentina (Cabrera and Willink 1973). Apresenta um caráter xerofítico com várias espécies de plantas providas de espinhos. A fitofisionomia desta vegetação é a Savana Estépica Parque, que apresenta um estrato lenhoso de arbustos e arvoretas com dominância de poucas espécies, dispersas sobre um estrato herbáceo-gramíneo (IBGE 2012), com pouca ou nenhuma sobreposição de copas.

A formação "Parque de Inhanduvá" já teve uma extensão maior no Rio Grande do Sul em tempos pretéritos, na região entre os rios Ibicuí e Quaraí (Marchiori and Alves 2011a). No entanto, atualmente restaram poucos fragmentos desta vegetação e a maioria está concentrada no município de Barra do Quaraí (Marchiori and Alves 2011b). A maior extensão remanescente está resguardada pelo Parque Estadual do Espinilho (PEE), criado em 1975 (Decreto Estadual nº 23.798, de 12 de março de 1975) e ampliado em 2002 para 1.617,14 ha (Decreto Estadual nº 41.440, de 28 de fevereiro de 2002). A situação fundiária da unidade de conservação não está totalmente resolvida, portanto ainda existem algumas áreas do PEE com presença de gado (bovino e equino), que com o pastejo mantém a relva mais baixa nas mesmas.

Duas feições distintas desta formação ocorrem no PEE. O *ñandubaysal* é a feição predominante, caracterizada pela associação de *Prosopis affinis* Spreng. (inhanduvá) e *Vachellia caven* (Molina) Seigler & Ebinger (espinilho), além de espécies lenhosas menos abundantes e estrato herbáceo bem diversificado. Já o *algarrobal* ocupa uma área menor e é caracterizada pela presença de *Prosopis nigra* (Griseb.) Hieron. (algarrobo), *Aspidosperma quebracho-blanco* Schltdl. (quebracho-branco), *Parkinsonia aculeata* L. (cina-cina) e *Acanthosyris spinescens* (Mart. & Eichler) Griseb. (sombra-de-touro), além das espécies da formação anterior. Esta última está associada a relevo mais plano e com presença de manchas de solo mais

alcalino (*blanqueales*), onde se desenvolvem apenas os vegetais mais tolerantes à salinidade, com rarefação do estrato herbáceo. Reforçando o aspecto xerofítico da vegetação, também há abundância de cactos terrestres, como *Cereus hildmannianus* K. Schum. (tuna) e *Opuntia elata* Link & Otto ex Salm-Dyck (arumbeva) (Marchiori and Alves 2011b).

Espécie foco do estudo: cardeal-amarelo

O cardeal-amarelo, *Gubernatrix cristata* (Vieillot, 1817), é a única espécie do gênero monotípico *Gubernatrix* Lesson, 1837. O macho possui topete e garganta pretos, com dorso oliváceo e ventre amarelo. A fêmea possui o mesmo padrão, diferindo por apresentar branco na sobrancelha e na estria malar e cinza no peito e flancos (Sick 1997, Ridgely and Tudor 2009). Além da bela plumagem, o macho possui um canto potente e melodioso (Dias 2008, Ridgely and Tudor 2009). A deficiência de informações a respeito de *G. cristata* é notável. As informações disponíveis na literatura restringem-se basicamente a registros de ocorrência, sistemática, registros de hibridação, ameaças e estado de conservação.

Quanto à sistemática, a espécie já foi alocada em Richmondeninae, Fringillidae, subfamília que corresponde a Cardinalidae. Foi removida desta, pois dados morfológicos não suportavam tal posição (Jaramillo 2011, Orenstein 2011). Permaneceu em Emberizidae por muito tempo, mas em uma revisão filogenética recente foi proposto que *Gubernatrix* pertence a Thraupidae (Barker *et al.* 2013), corroborado por outro estudo que coloca *Gubernatrix cristata* como espécie-irmã de *Hedyglossa (Diuca) diuca*, e estes como grupo-irmão de *Neothraupis fasciata* (Burns *et al.* 2014).

Habita áreas semiabertas com arbustos ou árvores esparsas (Belton 1994, Dias 2008, Ridgely and Tudor 2009). Se alimenta geralmente andando no solo (Sick 1997), de sementes e insetos. Não há mais detalhes sobre os requisitos de habitat e hábitos alimentares da espécie.

A informação mais comum sobre a espécie são registros de ocorrência, algumas vezes sem nenhuma informação adicional. A distribuição geográfica de *G. cristata* descreve um arco desde o litoral do Rio Grande do Sul e Uruguai, passando pelo centro da Argentina até as províncias de La Pampa e Rio Negro ao sul. No

Uruguai a espécie tem registros para os departamentos de Maldonado (Gerzenstein 1967), Rocha, Treinta y Tres, Lavalleja, Rio Negro e Paysandú (Arballo 1990). A Argentina comporta a maior extensão da distribuição da espécie, tendo esta sido registrada nas províncias de La Pampa (Pereyra 1923, Bertonatti and López Guerra 1997, Pessino *et al.* 2002, Pessino 2006), Entre Rios (Camperi 1992, Canavelli *et al.* 2004), Córdoba (Castellanos 1934), Salta (Höy 1969), Buenos Aires, Rio Negro (Bertonatti and López Guerra 1997, 1998; Seewald and Pérez 2009), Santa Fé (Darwin 1839, Giai 1950), e recentemente em Mendonça (Sosa *et al.* 2011). No Brasil a espécie possui registros apenas para o estado do Rio Grande do Sul, para as regiões da Serra do Sudeste, litoral sul e fronteira oeste (Belton 1994, Bencke *et al.* 2003). Os registros mais recentes estão restritos ao extremo oeste do Estado, no município de Barra do Quaraí (Bencke *et al.* 2003, Dias 2008).

Alguns registros de indivíduos livres são atribuídos à prováveis escapes ou solturas, já que foram feitos muito distantes da área de distribuição conhecida. Há registros para as províncias de Tucumán (Vides-Almonacid 2001) e de Chubut (Rubio 2003), na Argentina. No Brasil, um indivíduo foi observado em outubro e novembro de 2005 no Parque Marechal Mascarenhas de Moraes, em Porto Alegre, capital do Rio Grande do Sul (Scherer *et al.* 2010).

Registros de nidificação são relatados para as províncias argentinas de Córdoba (Castellanos 1934), Salta (Höy 1969) e Santa Fé (De La Peña 1981). Tais registros são antigos e não apresentam maiores detalhes sobre a reprodução da espécie, exceto o último que descreve o ninho e os ovos de *G. cristata*. Sendo o ninho descrito como uma taça composta por palitos na parte externa e palha, musgo e cerdas na parte interna. Os ovos possuem campo azul-esverdeado e pintas pretas (De La Peña 1981). Belton (1994) apenas relata que em julho a espécie não está no período reprodutivo, pois um macho coletado em 1973 tinha os testículos inativos.

Hibridação entre *Gubernatrix cristata* × *Hedyglossa diuca minor* (Bonaparte, 1850) tem sido registrada na Argentina, nas províncias de Buenos Aires, Rio Negro e La Pampa (Bertonatti and López Guerra 1997, 1998; Pessino *et al.* 2002, Pessino 2006). Estes híbridos apresentam coloração cinza e branca como para *H. diuca*, mas com o topete e garganta pretos característicos de *G. cristata* (Pessino 2006). Eles parecem sobreviver bem em liberdade, porém não se sabe da sua fertilidade. A causa

da hibridação seria a sobrecaptura de machos de *G. cristata* para o comércio ilegal de aves silvestres (Bertonatti and López Guerra 1997). Tal fato agrava ainda mais o estado de conservação da espécie.

A captura e comércio ilegal de *G. cristata* fez com que as populações na natureza reduzissem drasticamente ao longo de poucas décadas. No Brasil, a espécie já era considerada rara nas décadas de 1970 e 1980 (Dias 2008). A perda e a fragmentação do seu habitat natural também são apontadas como causas do seu declínio populacional. A população mundial de *G. cristata* é estimada entre 1.000 e 2.000 indivíduos maduros (BirdLife International 2015). No Uruguai estima-se que não existam mais do que 300 indivíduos em liberdade (Azpiroz *et al.* 2012). A redução no tamanho populacional e a persistência das ameaças citadas coloca o cardeal-amarelo entre as espécies ameaçadas de extinção, sendo enquadrada como "Em Perigo" globalmente (BirdLife International 2015) e como "Criticamente em Perigo" no Brasil (Serafini *et al.* 2013).

Organização e estrutura da dissertação

Esta dissertação de mestrado é composta por dois artigos científicos sobre a história natural de *G. cristata* no extremo sul do Brasil. Em breve, ambos artigos serão submetidos para o periódico *Bird Conservation International*, tendo sido redigidos em inglês.

O primeiro artigo (**Capítulo 1**) descreve aspectos demográficos da população brasileira de *G. cristata*, tais como tamanho populacional, longevidade, sistema social e territorialidade. Além disso, apresenta o primeiro registro de reprodução cooperativa na espécie, com a presença de ajudantes de ninho. Um relato com as primeiras observações desse comportamento foi apresentado durante o XX Congresso Brasileiro de Ornitologia, em novembro de 2013, em Passo Fundo – RS.

O segundo artigo (**Capítulo 2**) é referente à biologia reprodutiva, com a descrição de vários aspectos como período reprodutivo, ninhos, ovos, filhotes, sobrevivência e parasitismo de ninhos, bem como alguns dados qualitativos sobre a alimentação da espécie. Resultados parciais desse estudo foram apresentados na forma de pôster durante o *X Neotropical Ornithological Congress* e XXII Congresso Brasileiro de Ornitologia, realizado em julho de 2015, em Manaus – AM.

Os artigos estão organizados na ordem em que serão submetidos para publicação (1 e 2), portanto apenas o Capítulo 2 pode citar o Capítulo 1. A citação está como Beier *et al.* 2016. Alguns aspectos da biologia reprodutiva da espécie apresentados no Capítulo 2 são citados no Capítulo 1, para ajudar na compreensão dos resultados, onde a citação usada é Beier and Fontana, *in prep*. Após os dois capítulos são apresentadas as Conclusões Gerais do trabalho. Para ilustrar alguns dos aspectos relatados foi elaborado um Apêndice Fotográfico.

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CAPÍTULO 1.

Cooperative breeding and demography of Yellow Cardinal *Gubernatrix cristata* in Brazil

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Cooperative breeding and demography of Yellow Cardinal *Gubernatrix cristata* in Brazil

Christian Beier*, Márcio Repenning, Maurício da Silveira Pereira, André Pereira and Carla Suertegaray Fontana

PUCRS – Pontifícia Universidade Católica do Rio Grande do Sul, Programa de Pós-Graduação em Zoologia, Museu de Ciências e Tecnologia, Laboratório de Ornitologia. Avenida Ipiranga, 6681, CEP 90619-900, Porto Alegre, Rio Grande do Sul, Brasil.

* Author for correspondence; email: beier.ornito@gmail.com

Summary

We studied some aspects of autecology of the Brazilian population of Yellow Cardinal, *Gubernatrix cristata*, such as demography, territoriality and social system. The study was conducted in the municipality of Barra do Quaraí, western Rio Grande do Sul, Brazil, during two breeding seasons (October to February, 2013–2015), after a brief pilot-study started in 2012. We ringed 35 (seven females, 14 males and 14 young) out of 53 individuals found, and by September 2015, the Brazilian population of Yellow Cardinal had 38 remaining individuals. Adult sex ratio was 1.5:1 and the lifespan was at least 8 years. Pairs are socially monogamous and territorial, with male-biased philopatry and female-biased dispersal. The mean territory size was 18 ha and mean home range was 27.7 ha. Some pairs and nests (23%) were attended by one or two additional birds (nest helpers), which contributed on nest and territory defence, and provisioning of nestlings and fledglings. Parental care was biparental or cooperative, and the pair had high frequency of visits to the nest than helpers. Mean nest productivity was 2 fledglings/successful nest attended by helpers, and 1 fledgling/successful nest not attended by helpers. We recorded second broods after a successful attempt, only when helpers were present. Apparent success of nests with and without helpers were 57% and 31%, respectively. Overall Mayfield nesting success was 18%, 40% for nests with and 13% without helpers. We recorded a case of inbreeding, between father and daughter. The species need for large home ranges and factors that may adversely affect the breeding success

(e.g., inbreeding, predation, parasitism) can aggravate the status of the Brazilian population and species. It reinforces the importance of autecology studies and their contribution to the conservation schemes.

Keywords: nest helpers, small population, home range, breeding territory.

Resumo

Nós estudamos alguns aspectos da autoecologia da população brasileira de cardeal-amarelo, *Gubernatrix cristata*, tais como demografia, territorialidade e sistema social. O estudo foi conduzido no município de Barra do Quaraí, no extremo oeste do Estado do Rio Grande do Sul, Brasil, durante duas temporadas reprodutivas (outubro–fevereiro, 2013–2015), após breve estudo-piloto iniciado em 2012. Marcamos 35 (sete fêmeas, 14 machos e 14 filhotes) de 53 indivíduos encontrados, e até setembro de 2015, a população brasileira de cardeal-amarelo tinha 38 indivíduos remanescentes. A razão sexual dos adultos é 1,5:1 e pode chegar à idade de pelo menos 8 anos. Os casais são socialmente monogâmicos e territoriais, com tendência para filopatria dos machos e dispersão das fêmeas. O tamanho médio dos territórios reprodutivos é 18 ha e da área de vida é 27,7 ha. Alguns casais e ninhos (23%) são atendidos por um ou dois indivíduos adicionais (ajudantes de ninho), que contribuem na defesa do ninho e território, e na alimentação dos ninhegos e filhotes após saírem do ninho. O cuidado é biparental ou cooperativo, e o casal tem maior frequência de visitas ao ninho do que os ajudantes. A produtividade média dos ninhos com ajudantes foi 2 filhotes/ninho com sucesso, e dos ninhos sem ajudantes foi 1 filhote/ninho. Registramos segunda postura após um sucesso, onde ajudantes estavam presentes. O sucesso aparente dos ninhos com ajudantes foi 57% e sem ajudantes foi 31%. O sucesso de Mayfield foi 18%, 40% para ninhos com e 13% sem ajudantes. Registramos um caso de endogamia, entre pai e filha. Necessidade de grandes áreas de vida e fatores que podem afetar negativamente o sucesso reprodutivo (e.g., endogamia, predação, parasitismo), podem agravar a estado de conservação da população brasileira e da espécie, reforçando a importância dos estudos de autoecologia e sua contribuição para os planos de conservação.

Palavras-chave: ajudantes de ninho, população pequena, área de vida, território reprodutivo.

Introduction

The Yellow Cardinal, *Gubernatrix cristata*, is a passerine of temperate South America and its natural history is relatively unknown. Occurs in savannas in Argentina, Uruguay and southern Brazil (Jaramillo 2011). Due to their colour and song, they are often captured for illegal trade in wildlife (Serafini *et al.* 2013). Illegal trapping and wildlife trade, along with habitat loss, were the main causes of the great populational decline for this species, now considered as globally (EN) and regionally threatened (BirdLife International 2015), and endangered in Argentina and Uruguay (López-Lanús *et al.* 2008, Azpiroz *et al.* 2012), and critically endangered in Brazil (Serafini *et al.* 2013).

Home range is an area where an individual restricts its activities during the year or period. When part of or all home range is defended against other conspecifics it is defined as a territory (Nice 1941, Odum and Kuenzler 1955). Home range is a cognitive map of resources that individuals keep up-to-date to fulfil their requirements (Powell and Mitchell 2012). Social and breeding behaviour affect the territorial and home range dynamics, like their sizes, boundaries, acquisition, dispersal and so forth. Natural habitats are usually fragmented to some degree. Small patches may not have sufficient area for home ranges and also increase predation and parasitism near edges (Beier *et al.* 2002), as well as the patch isolation may have negative effects on dispersal (Pavlacky Jr. *et al.* 2012).

Cooperative breeding is a social system characterized by a breeding pair and one or more individuals that did not breed, but collaborate to rear a brood. These individuals are called nest helpers (hereafter, helpers). Why some individuals tend to postpone their own reproduction and help to rear a brood from others have intrigued scientists for decades. Studies have tried to explain how the cooperative breeding evolved (Poiani and Jermiin 1994, Du Plessis *et al.* 1995, Arnold and Owens 1998, Heinsohn and Legge 1999, Doerr and Doerr 2006, Russell *et al.* 2007, Hatchwell 2009, Cockburn and Russell 2011, Jetz and Rubenstein 2011, Feeney *et*

al. 2013, Downing *et al.* 2015, Drobniak *et al.* 2015), but life-histories differ considerably between species and there is not a one-size-fits-all hypothesis (Cockburn 1998, Berg *et al.* 2012, Gamero *et al.* 2014). There is more than 10,000 extant bird species in the world, and 9% is estimated to present cooperative breeding (Cockburn 2006), 18.5% of oscines (Cockburn 2003) and 6% (218 spp.) of Neotropical birds (Jetz and Rubenstein 2011). The Neotropics is the region with highest biodiversity on Earth, but it is the relatively less studied (Stutchbury and Morton 2001). The effective number of species that breed cooperatively may be slightly higher as the breeding systems and natural histories of more birds are being described.

Here, we describe cooperative breeding in the Yellow Cardinal for the first time. We compare breeding and success between pairs with and without helpers to determine the potential benefits of cooperation. We also examine demography of the Brazilian population of the cardinal, and place cooperation in terms of social system and breeding territories. We then interpret these new findings in the context of conservation of this threatened species.

Methods

Study area. The study was carried out in Barra do Quaraí, state of Rio Grande do Sul. From four study sites, three are located at Espinilho State Park (ESP; 30°12'S, 57°30'W), and one at São Marcos Ranch (SMR), adjacent to the ESP. Only one site at ESP is not grazed by livestock. The mean annual rainfall is 1,300 mm and it is highly variable between years. Mean annual temperature is 24.3°C, with frost in winter, and occasionally > 40°C in summer. The vegetation is a savanna dominated by *Prosopis affinis* and *Vachellia caven* and is the largest among the last remnants of that type of savanna in southern Brazil (Marchiori and Alves 2011).

Data collection. We began with a pilot study from November 2012 until January 2013. We then carried out observations from October to February, during two breeding seasons (2013–2015) of the only known population of Yellow Cardinal in Brazil. Population size, sex ratio, and longevity were estimated using banded birds, and unmarked individuals when it was possible to identify them by unique

marks on plumage. We searched for Yellow Cardinals at the beginning of each breeding season (October) and captured adults using mist nets and marked with an aluminium ring (standard CEMAVE/ICMBio; the Brazilian Banding Agency) and a unique combination of coloured plastic rings. Ten days old nestlings or chicks that just fledged were also marked. We measured birds (wing chord, tail length, tarsus length, bill and culmen length, nostril to bill tip, and total length; following Eck *et al.* 2011) using a precision calliper (0.1 mm) and a ruler (1.0 mm). Body mass was measured using a precision dynamometer (0.5 g).

Individual behaviour was observed while monitoring nests, or focal-individual when away from the nest. Observations of parental care were mainly in the morning, from sunrise until 11h00, or afternoon, from 17h00 until sunset, using binoculars (12×50 mm) and spotting telescope (25–60×). We used a camcorder at one nest, with mean recording time of 72 ± 21.7 min (50–100 min; n = 5) every 2–3 days. We divided nestling stage in two nestling phases: initial (1–8 days) and final (9–16 days), and calculated the visit rate for each individual and phase.

We considered breeding territory as the maximum area that a male defended and where it nested (Nice 1941, Welty and Baptista 1988) and home range as the area frequently used but not necessarily defended (Odum and Kuenzler 1955, Powell and Mitchell 2012). When found, we noted the coordinates of family groups or individuals using a handheld GPS. We estimated the area of breeding territories using Minimum Convex Polygon at 95% confidence (MCP 95%) (Odum and Kuenzler 1955). We estimated home range size using Fixed Kernel Density Estimation at 95% probability of occurrence (KDE 95%), and kernel bandwidth calculated by Least Squares Cross Validation (LSCV) (Seaman *et al.* 1999, Jacob and Rudran 2006). We used only data from individuals with more than 25 locations due to minimum sample size limitations of KDE (Seaman *et al.* 1999). Breeding territory and home range estimations were calculated using package *adehabitatHR* (Calenge 2006) in R (R Core Team 2015).

Productivity was calculated as the mean number of fledglings by all successful nests. We calculated the apparent success (Marini *et al.* 2010), as the ratio between the number of successful nests and all monitored nests. Complementarily, we

calculated Mayfield nesting success (Mayfield 1975), with modifications to compare nests with and without helpers (Hensler and Nichols 1981).

Statistical analysis. To assess differences on morphometric measurements between sexes and parental care between nestling phases we used the non-parametric Mann-Whitney *U*-test (or Wilcoxon rank-sum test). Comparison of the frequency of visits to the nest of each group member (male, female and helper) were done with Kruskal-Wallis *H* tests, followed by post-hoc pairwise Mann-Whitney *U*-tests. Values are presented as mean ± SD and considered statistically significant when $P < 0.05$.

Results

Capture, morphometric and demographic data. We captured and marked 35 birds (seven adult females, 14 adult males, and 14 young). We also recognized 18 unmarked individuals (seven females, four males, and seven young). Of the 53 birds found in this study, 15 disappeared, and the remaining 38 were the known population of Yellow Cardinal in Brazil at that time. We found a secondary sex ratio of 1.5:1 (21/14). A male captured as adult in 2008 was last seen in February 2015 and so was at least eight years old.

There is no sexual dimorphism with respect to body mass (males: 47.8 ± 2.8 g, $n = 9$; females: 47.9 ± 3.5 g, $n = 4$). Sexual dimorphism was found in other variables, including wing chord (males: 94.9 ± 2.9 mm, $n = 9$; females: 89.9 ± 2.5 mm, $n = 4$; $U = 2.5$, $P = 0.02$) and tarsus length (males: 27.0 ± 0.8 mm, $n = 9$; females: 25.4 ± 1.0 mm, $n = 4$; $U = 4.5$, $P = 0.04$).

Social system. The Yellow Cardinal is socially monogamous and the mated pairs may stay together for more than one breeding season, and only two divorces were observed. Additionally, two males lost their mates and mated again. In 2013, from nine mating pairs, one female disappeared and one divorced. After a successful nest, the divorced female and her two offspring disappeared in December 2013, but all three were seen again in October 2014. At that time, the female had found another male, and the two offspring became helpers. In 2014, one female at a nest was lost to predation and second female divorced. The remaining pairs remained together.

The divorced female in 2014 was later found paired in a neighbouring territory in 2015. On a territory where both individuals of the pair were marked, we ringed a nestling at the nest in January 2013. In May 2013, the female disappeared, but the young was observed with the male. In October 2013, we found father and daughter on their territory and apparently paired, which was confirmed in December 2013 when we found a nest with nestlings. This male remained alone during the second breeding season. It is the first record of inbreeding in the Yellow Cardinal. A fledgling from this pair was ringed, but all young and the female were not seen since January 2014.

Nest helpers. In 2012, we found a group with an adult male, an adult female and a male helper in first basic plumage with some grey patches. We observed three pairs accompanied by male helpers from December 2012 to January 2013. We found 30 nests in two breeding seasons (2013–2015), of which seven were attended by helpers. One mating pair was attended by a female helper in the first season (2013). Two male helpers attended a mating pair in the second season (2014–2015), but apparently only one of them fed the nestlings.

Helpers were observed contributing in territory and nest defence, feeding nestlings and caring of fledglings. In the latter case, a mating pair had a successful nesting attempt in December 2012 and re-nested in January 2013. The helper attended the first nest but not the re-nesting attempt, because it was taking care of fledglings.

Fledglings may stay in the natal territory for up to 10 months (n = 1 female). Apparently, helpers are offspring of the mating pair, and it was confirmed in one case where helpers were marked as nestlings. In other cases, helpers were in first basic plumage, which we assume that they were offspring of the previous breeding season of the breeding pair.

A male was found in October 2013 defending a small territory. It budded (i.e. when an individual inherits part of the mating pair territory) from the territory where it was helper in the previous breeding season (2012-2013). This male did not mate, then it returned to its natal territory as helper, where it stayed at least until February 2014. In October 2014, this male was found alone on its previous territory.

Later in the season (November 2014), we found it in another territory and paired with an unmarked female, where it had two breeding attempts.

Productivity and nesting success. Mean productivity per successful nest was 1.6 ± 0.74 fledglings (n = 8). Successful nests without helpers fledged a mean of one chick (4 fledglings/4 nests), and with helpers fledged two (8 fledglings/4 nests). The apparent success of nests with and without helpers were 57% (4/7) and 31% (4/13), respectively. The Mayfield Nesting Success was 40% and 13% for nests with and without helpers, respectively (18% for all nests). There was no difference between nests with and without helpers in probability of survival for incubation (0.544 ± 0.239 *vs.* 0.403 ± 0.117; z = 0.53; P = 0.60), nor nestling stage (0.732 ± 0.231 *vs.* 0.318 ± 0.125; z = 1.58; P = 0.11).

Parental care. We observed about 12 hours of parental care at three nests and recorded 6 hours at one nest. The total frequency of visits to the nest was 12.28 ± 5.26 visits/h and we found significant difference between initial and final nestling phases (9.91 ± 3.88 vs. 16.0 ± 5.16 visits/h; U = 14, P = 0.03, n = 18). Males made 4.39 ± 1.69 visits/h, females 5.06 ± 3.13 visits/h and helpers 2.83 ± 1.72 visits/h (Figure 1). There was significant difference on visit rate between family members during the whole nestling period (H_2 = 7.92; P = 0.02), specially between helpers and females (2.83 ± 1.72 vs. 5.06 ± 3.13 visits/h; U = 89.5; P = 0.02), and helpers and males (2.83 ± 1.72 vs. 4.39 ± 1.69 visits/h; U = 84; P = 0.01). Only females increased significantly their visit rate from initial to final nestling phase (3.64 ± 2.58 vs. 7.29 ± 2.69 visits/h; U = 12.5; P = 0.02). There was no difference between frequency of visits per group member on initial phase (H_2 = 4.32; P = 0.12), but there was significant difference on final phase (H_2 = 7.75; P = 0.02) between helpers and females (3.71 ± 1.38 vs. 7.29 ± 2.69 visits/h; U = 5; P = 0.01).

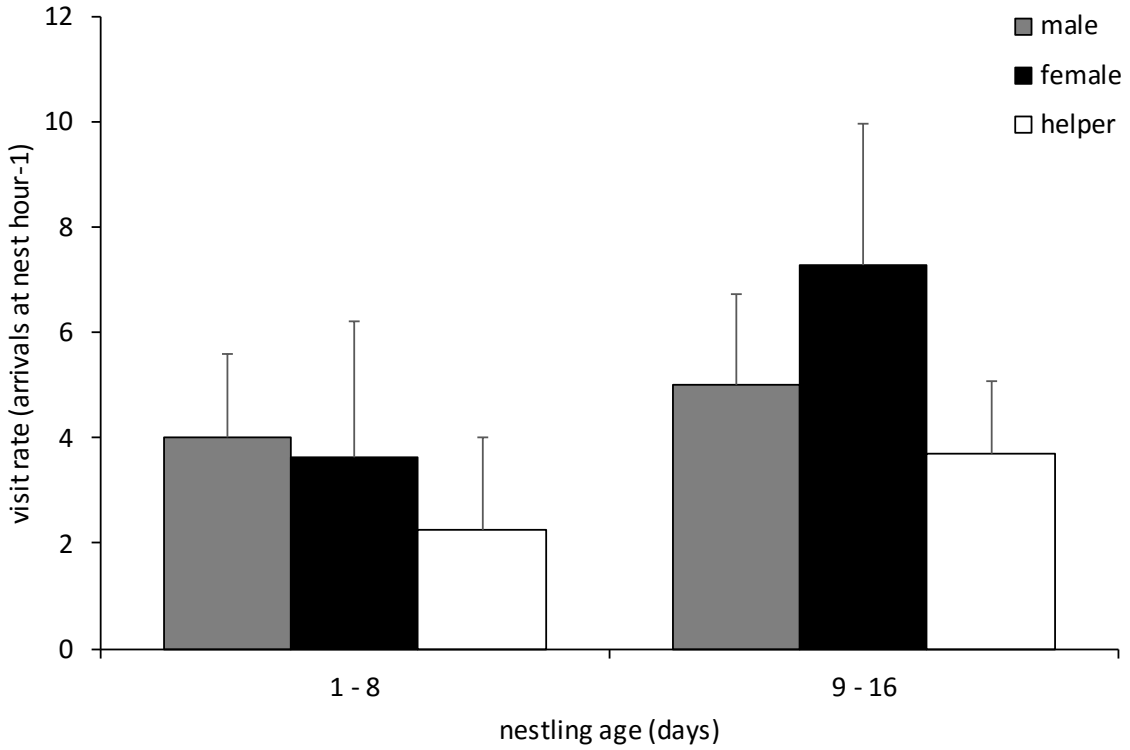

Figure 1. Frequency of visits to the nest of male (*grey bars*), female (*black bars*), and helper (*white bars*) on nestling age of the Yellow Cardinal. Bars represent mean and SD.

Breeding territories. Mean estimated breeding territory size was 17.9 ± 5.6 ha (11.9–28.4 ha; *n* = 9). Mean home range size was 27.7 ± 9.1 ha (14.5 – 41.9 ha; *n* = 9; Figure 2). Breeding territories were relatively stable and defended year-round. A yearling female was marked in October 2013 and found later paired with a male two territories away from her natal territory in November 2013. The mean distance between simultaneous nests of different breeding pairs/territories was 443 ± 155 m (215–628 m; *n* = 6).

Birds are territorial, with both sexes defending the territory. Encounters between individuals of different territories were noted (*n* = 8), where at least 50% (*n* = 4) resulted on agonistic interactions and chasing. In one case (January 2012), two males stepped into another pair's territory, where it had an active nest, and they were readily chased and expelled by the breeding pair. In another case, a mating pair with two juveniles came into a neighbour territory. Agonistic interactions occurred inside the invaded territory, where only adults engaged in fight, accompanied by juveniles from safe distance. Three days later we found these two pairs fighting in

the same site. Encounters that ended without chasing or fight and individuals gone on opposing directions, we considered as territory boundaries.

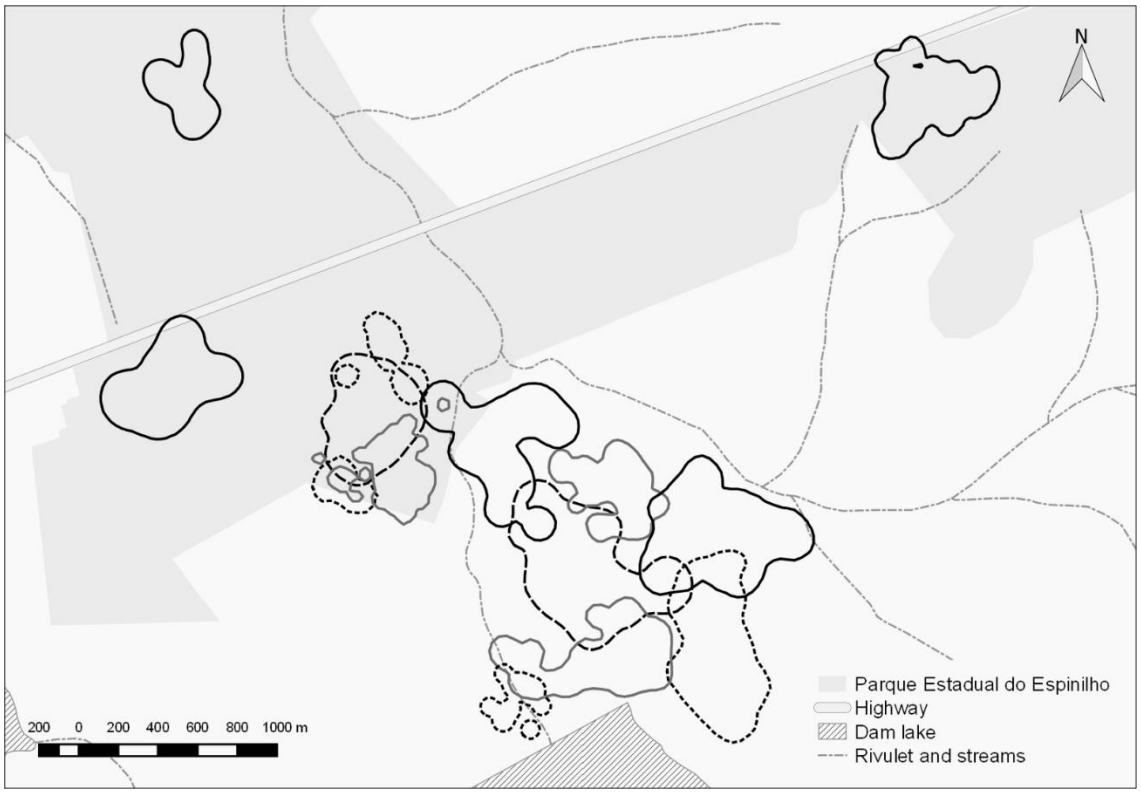

Figure 2. Distribution of home ranges of the breeding pairs of Yellow Cardinal, in the municipality of Barra do Quaraí, State of Rio Grande do Sul, Brazil. Shaded area represents the protected area of Parque Estadual do Espinilho.

The number of nine breeding territories during the first season increased to 12 territories in the second season. The main cause was males that were helpers or alone on first season found females to mate on second season. Two of these males were alone on isolated territories and moved into larger available areas. Other two males were helpers on a prior season and budded a territory, but moved to other areas (one territory far from natal ground) and paired with unmarked females (November 2014).

We noted some movements outside territories for some individuals. One case was in winter (July 2015), when a pair was found alongside a vicinal dirty road, where they gone about 700 m far from their territory. The pair was apparently foraging on rice seeds of a harvested field, with other bird species, as Red-crested Cardinal, Saffron Finch, Shiny Cowbird and Bay-winged Cowbird. Other case was

noted during the second breeding season at a stream between two territories (about 200 m from both territorial boundaries). There was a tree with dark purple and ellipsoid fruits (*Chrysophyllum marginatum*) at the stream bank. In 12 November 2014, we observed a widowed male feeding on those fruits, and the tree was east of its territory. In 15 November 2014, we encountered two males of a territory south of the tree. In both situations, the individuals did not show any territorial behaviour.

Discussion

We present here the first study about the Brazilian population of the Yellow Cardinal. We report that the remaining population is very small in Brazil and we confirmed a case of inbreeding, the first in the wild. We also found that the Yellow Cardinal defends large territories, fledglings show delayed dispersal and with male-biased philopatry. And we show that the species may breed cooperatively with nest helpers.

We believe that the entire Brazilian population of Yellow Cardinal was monitored. Small populations are likely to have genetic and demographic problems through time, such as inbreeding (Lande 1988, Stacey and Taper 1992, Pimm *et al.* 1993), which we observed in this population. Unmarked individuals that appear in definitive basic plumage may be immigrants from Argentina (about 4 km). Other possible explanation is that they are offspring of previous breeding seasons, but it did not explain the origin of all unmarked individuals as almost all fledglings were marked since this study started.

The small bias towards males on adult sex ratio (1.5:1) that we found, despite the small sample and not being significant, may be caused by the tendency for males to become helpers (Doerr and Doerr 2006) and female-biased adult mortality (Székely *et al.* 2014). For White-banded Tanager, *Neothraupis fasciata*, a related species, the primary sex ratio was 1:1, including all nestlings of all clutches (Gressler *et al.* 2014). Apparently, Yellow Cardinal is a species with female-biased dispersal, and males tend to be philopatric. Dispersal is a critical event in the life of an individual, with high inherent risks that tend to reduce the survival of dispersing birds. And the opposite is true for philopatric individuals, which tend to have higher

survival rates. White-banded Tanager have female-biased dispersal (Duca 2007) with slightly lower survival rates for females when fledglings (less than 2 months old) and small biases on sex ratio towards males as a result of higher survival rates of the philopatric sex, being 15% higher for subadult males than for subadult females (Gressler 2012). Female-biased adult sex ratios are also associated to higher divorce rates (Liker *et al.* 2014). We found a relatively low divorce rate (14%), which corroborates this proposition.

Mortality rates are unknown for the Yellow Cardinal, and in our study, it was not possible to estimate adult survival rates due to difficulties to distinguish between mortality and dispersal, and the short-term monitoring. However, adult survival seems to be high in the Brazilian population, whereas all nine adults marked in the first breeding season were found and monitored in the second season. We estimated the longevity for a male (about 8 years old) based on ringing data and plumage, but this individual may be older since we do not know how old it was when it was marked. A wild female of Northern Cardinal (*Cardinalis cardinalis*), a passerine with similar body size, was reported more than 15 years old (Klimkiewicz and Futcher 1987). Birds marked as nestlings are excellent opportunities to obtain more precise data on lifespan, as for other life-history traits, by means of continuous monitoring.

While there was no sexual dimorphism with respect to body mass (as in Argentina, Domínguez *et al.* 2015), we did find a difference in wing and tarsus measurements. In Thraupidae, most species exhibit slight or no sexual dimorphism in body mass (Hilty 2011). We found sexual dimorphism for wing chord and tarsus length. Sexual size dimorphism is reported more frequently for species with monomorphic plumage (Faria *et al.* 2007, Chiarani and Fontana 2015). Székely *et al.* (2007) suggests that wing and tarsus lengths may be related to mating competition, where larger individuals have an advantage.

Parental care is unknown in nearly half (4,313 species) of the 9,456 species of birds for which parental care was summarized (Cockburn 2006). Included in the unknown is the Yellow Cardinal, which we can now say is socially monogamous with occasional helpers at nests. Phylogeny may play a role alongside environmental conditions on cooperative breeding occurrence (Edwards and Naeem 1993), and it

could emerge or disappear within a lineage (Berg *et al.* 2012). Recent molecular phylogenies found that *Gubernatrix*, *Hedyglossa* (*Diuca*) and *Neothraupis* compose a monophyletic clade (Barker *et al.* 2013, Burns *et al.* 2014), and cooperative breeding was already reported for *Neothraupis* (Alves 1990, Manica and Marini 2012).

We noted that individuals could begin the season alone on their own territory and become helpers later in the same season. Nests with helpers had twice the productivity as those with only the pair. Since we do not have data for parental care in nests without helpers, we were not able to identify the cause of increase in productivity by helper presence. The White-banded Tanager had similar productivity with and without helpers, but with helpers, parental effort by the adult male decreased (Manica and Marini 2012). Load lightening hypothesis predicts that one or both parents could reduce their contribution to the nest due to the extra food delivered by helpers, increasing parent survival (Manica and Marini 2012). Other possible effects of helper presence are reduced maternal allocation of resources on eggs (Paquet *et al.* 2013), and reduced rates of nest predation (Schaub *et al.* 1992) and brood parasitism (Canestrari *et al.* 2009). We observed post-fledging care by helpers, which allows breeders to perform more breeding attempts, as well as it may increase their survival (Langen 2000). More data on parental care for Yellow Cardinal is needed in order to understand how productivity and survival are affected by helpers.

We found that breeding territories were close together on park-like vegetation, with almost no unoccupied area between them, which may indicate habitat saturation. High adult survival rates and habitat saturation are possible causes of cooperative breeding (Arnold and Owens 1998), as it is for *Neothraupis fasciata* (Alves 1990, Manica and Marini 2012). The Brazilian population of Yellow Cardinal has high rates of brood parasitism by Shiny Cowbird (*Molothrus bonariensis*) (Beier and Fontana, *in prep.*). The presence of helpers may reduce nest parasitism (Feeney *et al.* 2013).

Breeding territory and home range sizes may be considered large for a passerine of its size (47 g). However, our estimations could be biased due to small sampling effort, and may be considered with caution specially for home ranges. Other grassland birds have smaller territories and home ranges. It was estimated

that mean territory size for Lesser Grass-finch (20 g) is 1.1 ha (maximum 2.4 ha) (Chiarani and Fontana 2015), 3.7 ha for White-banded Tanager (Duca 2007). Chiarani and Fontana (2015) found that 83% of Lesser Grass-finch territories had the same males defending it in both breeding seasons. Pereira (2015) found a density of 1 territory/100 ha for Yellow Cardinal in the same study site, reflecting its large territories. Dardanelli *et al.* (2006) studied the minimum area requirements of a bird community in Argentina, and they found that, from 54 woodland species, 80% needed no more than 3 ha. However, they also found that nine species needed fragments of 80 ha or more, six of which also occur in our study site (*Accipiter striatus*, *Melanerpes cactorum*, *Leptasthenura platensis*, *Drymornis bridgesii*, *Lepidocolaptes angustirostris*, and *Suiriri suiriri*).

Delayed and female biased dispersal is reported for other cooperatively breeding birds (Woolfenden and Fitzpatrick 1984, Duca 2007). Delayed dispersal is also commonly associated with cooperative breeding (Koenig *et al.* 1992), but some species delay dispersal without helpers (Ekman and Griesser 2016). Some cooperatively breeding species are able to expand and defend larger territories due to increased group size. Consequently, groups with larger territories increase the chances territory budding by helpers (Woolfenden and Fitzpatrick 1984).

Conservation actions. Some findings of our study are of conservation concern for this species: small population size, inbreeding, relatively large breeding territories, and saturated habitat. A captive-breeding program of Yellow Cardinal is underway in Brazil, with planned releases of captive-bred individuals in sites with historical occurrence of the species (Serafini *et al.* 2013). Habitat loss and fragmentation due to land use conversion (e.g., from livestock to monocultures and forestry) and bird trapping still being main conservation problems for the Yellow Cardinal in some regions. Demographic parameters, such as adequate home range needs, must be considered when defining how and where to release captive-bred Yellow Cardinals. We highly recommend further studies on habitat selection by Yellow Cardinal, as well as studies to understand the role of helpers and the continuous monitoring of the Brazilian population.

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Conflict of interest

None.

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CAPÍTULO 2.

Natural history of Yellow Cardinal *Gubernatrix cristata* in Brazil, with emphasis on breeding biology

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Natural history of Yellow Cardinal *Gubernatrix cristata* in Brazil, with emphasis on breeding biology

Christian Beier* and Carla Suertegaray Fontana

PUCRS – Pontifícia Universidade Católica do Rio Grande do Sul, Programa de Pós-Graduação em Zoologia, Museu de Ciências e Tecnologia, Laboratório de Ornitologia. Avenida Ipiranga, 6681, CEP 90619-900, Porto Alegre, Rio Grande do Sul, Brasil.

* Author for correspondence; email: beier.ornito@gmail.com

Summary

The threatened Yellow Cardinal (*Gubernatrix cristata*) has a small geographic range in Brazil and neighbouring Uruguay and Argentina. We studied the autecology of the Brazilian population of Yellow Cardinal in the municipality of Barra do Quaraí, westernmost State of Rio Grande do Sul, Brazil, during two breeding seasons (Oct–Feb, 2013–2015). We monitored 30 nests, where we observe various aspects of autecology of the species, including feeding habits, nests, eggs, nestlings, nesting cycle, and breeding success. We found evidence that leaves appear to be an important food item. Breeding season starts from the first week of October, with a peak active nests in mid-November and lasts until mid-February. Female built the open-cup nests in six days. Almost all nests are on *Prosopis affinis*, at mean nest height of 2.4 m from the ground. Clutch size is three eggs, and female incubated for 12.9 days. Hatching rate was 76% and nestlings fledged after 16 days. Nestling survival rate was 67% with mean productivity of 1.6 fledgling per successful nest. We recorded second broods associated with helper presence. Mean interval was 15.6 days and mean distance was 220.7 m between nesting attempts. Shiny Cowbird, *Molothrus bonariensis*, parasites nests of Yellow Cardinal, with frequency of 67% and intensity of 1.9 egg per parasitized nest. Eggs punctured by female cowbirds led to abandonment of 15% of parasitized nests. From six nests where cowbirds hatched, in two of which (33%) the Yellow Cardinal fledged. Parasitism in nestlings by botfly larvae (*Philornis* sp.) occurred with prevalence of 33% of nests that had nestlings. Nest predation was the main cause of nest losses (73%) and we recorded

a *Leopardus geoffroyi* preying on a nest with eggs. Apparent nesting success was 27% and overall Mayfield nesting success was 18%. Fledgling survival rate during the first month outside the nest was 62%. We found differences between Brazilian (e.g. occurrence of second broods, higher brood parasitism rates, and longer breeding season) and Argentinian populations.

Keywords: nesting success, brood parasitism, *Molothrus bonariensis*, feeding habits.

Resumo

O cardeal-amarelo, *Gubernatrix cristata*, é um pássaro ameaçado com distribuição restrita na Argentina, no Uruguai e no Brasil. Nós estudamos a autoecologia da população brasileira de cardeal-amarelo, no município de Barra do Quaraí, extremo oeste do Estado do Rio Grande do Sul, Brasil, durante duas temporadas reprodutivas (outubro–fevereiro, 2013–2015). Monitoramos 30 ninhos ao todo, onde observamos vários aspectos da autoecologia da espécie, incluindo hábitos alimentares, ninhos, ovos, ninhegos, períodos de nidificação, e sucesso reprodutivo. Encontramos evidências de que há variação sazonal na dieta e folhas parecem ser um item alimentar importante durante o inverno. A reprodução inicia na primeira semana de outubro, com pico de ninhos ativos na segunda quinzena de novembro e perdura até meados de fevereiro. A fêmea constrói os ninhos em forma de taça em 6 dias. Quase todos ninhos são construídos em *Prosopis affinis*, à altura média de 2,4 m acima do solo. Três ovos é o tamanho de ninhada, os quais a fêmea incuba por 12,9 dias. A taxa de eclosão é de 76% e os ninhegos saem do ninho após 16 dias. A taxa de sobrevivência de ninhegos foi 67% com produtividade média de 1,6 filhote por ninho com sucesso. Registramos segunda postura após um sucesso, onde ajudantes estavam presentes. O intervalo médio entre tentativas foi 15,6 dias e a distância média 220,7 m. O vira-bosta, *Molothrus bonariensis*, parasita os ninhos de cardeal-amarelo, com frequência de 67% e intensidade de 1,9 ovo por ninho parasitado. Ovos furados por fêmeas de vira-bosta levaram ao abandono de 15% dos ninhos parasitados. De seis ninhos onde filhotes de vira-bosta eclodiram, em dois (33%) o cardeal-amarelo teve sucesso. O parasitismo em ninhegos por larvas de mosca (*Philornis* sp.), ocorreu em 33% dos ninhos onde os ninhegos eclodiram.

Predação foi a principal causa de perda de ninhos (73%) e registramos um *Leopardus geoffroyi* predando um ninho com ovos. O sucesso aparente dos ninhos foi 27% e o sucesso de Mayfield foi 18%. A taxa de sobrevivência dos filhotes no primeiro mês fora do ninho foi 62%. Encontramos diferenças entre as populações brasileira (e.g. segunda ninhada após sucesso, maiores taxas de parasitismo de ninhos por vira-bosta, e período reprodutivo mais longo) e argentina.

Palavras-chave: sucesso de nidificação, parasitismo de ninhos, *Molothrus bonariensis*, hábitos alimentares.

Introduction

The threatened Yellow Cardinal, *Gubernatrix cristata*, is a passerine whose geographic range in Brazil is restricted to the state of Rio Grande do Sul (and is found in adjacent Uruguay and Argentina). It inhabits savanna throughout its geographic distribution, from Salta and Corrientes to Rio Negro provinces in Argentina, Uruguay, and southern Brazil. Bird trapping and habitat loss led to drastic population decline of Yellow Cardinal in all its range (Dias 2008, Ridgely and Tudor 2009, Azpiroz *et al.* 2012, Serafini *et al.* 2013).

Now globally endangered, the only study of its breeding biology took place in Argentina (Domínguez *et al.* 2015). Information for Brazilian populations are few and often inaccurate (BirdLife International 2015). Studies of breeding biology and life-history comparisons between populations enable early identification of threats, even before occurrence of any evident population decline (Martin and Geupel 1993). Therefore, here we describe the natural history of the only known Brazilian population of Yellow Cardinal, especially regarding to its breeding biology and, additionally, report unknown aspects of its diet and foraging, in order to aggregate technical information aiming the global species conservation.

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; 30°12'S, 57°30'W), and one at São Marcos Ranch (SMR), adjacent to the ESP. Accumulated annual rainfall is 1,300 mm, with wide interannual variation. Mean annual temperature is 23.4°C, with negative temperatures and frost formation on winter, and above 40°C on summer. The vegetation is characterized by an insertion of *Espinal* Province (Cabrera and Willink 1973) grasslands with scattered thorny trees and shrubs, dominated by *Prosopis affinis* and *Vachellia caven*. This is one of the last and the largest reminiscent of this vegetation in Brazil. Three areas were grazed by cattle.

We studied the breeding biology of the Yellow Cardinal in Brazil, during two breeding seasons (2013–2015), from October through February. The first season (October 2013 to February 2014) was hotter and dryer, with accumulated rainfall of 721.6 mm (about 45 days without rain on our study area), and mean temperature 25.3°C (5.9–39.5°C; maximum 46°C taken by a camera trap) for this period. Rainfall was greater during the second breeding season (October 2014 to February 2015), with accumulated rainfall of 910.6 mm and mean temperature 24.9°C (11.2–36.8°C) (EMBRAPA 2015).

We searched for individuals at the beginning of each breeding season (October). Individuals found were captured using mist nets and marked with a numbered aluminium ring (standard CEMAVE/ICMBio, the Brazilian Banding Agency) and a unique combination of coloured plastic rings. We banded nestlings at 10 days of age or if captured soon after fledging.

Nest search. We searched for nests mainly observing the mating pair, following the female and/or another individual carrying materials for nest building or feeding the nestlings. We searched only in areas with park-like vegetation. Each nest found was georeferenced. Nest monitoring was through visits every 2–3 days (rarely 4–5 days), when we noted the nest status and contents (number of eggs and/or nestlings), from the day that nest was found until it became inactive.

Breeding season. We considered the breeding season length as the period of days between the beginning of construction of the first nest to the day the last nest ended, for both breeding seasons together. To estimate the day when the first nest construction was initiated, we used the mean duration for each nest period

(construction, laying, incubation and nestling). Last day of breeding period was estimated using the approximated date when the last nest active was depredated.

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

Clutch size, incubation and nestlings. Clutch size was noted at all nests and we considered only the nests without evidence of partial losses during egg laying. The clutch was considered complete after two consecutive visits without increase in number of eggs, and only from nests found during building, laying, or up to 4 days after incubation started, in order to avoid underestimates due to partial losses of eggs or nestlings (Lopes and Marini 2005). The 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 the moment of hatching. The nestling stage starts at hatching and ends with fledging, and nests observed at both events were used to estimate its duration. 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 the number of hatchlings, considering only nests where we observed the hatching. We calculated the fledgling survival as the ratio between the number of young that survived 30 days after fledging 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 (~10 days), which we considered sufficient time for the chick be able to follow its parents and to be more easily seen.

Re-nesting. We calculated the mean interval of time and distance between nesting attempts of the same female on each breeding season. Although not all 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).

Brood parasitism. Shiny Cowbirds, *Molothrus bonariensis* (hereafter, cowbirds), often parasitize Yellow Cardinal nests. The frequency of parasitism was the proportion of nests that had at least one egg of cowbirds. For intensity of parasitism, we used the mean number of cowbird eggs per parasitized nests, considering only nests without partial clutch losses.

Botflies (*Philornis* sp.) may also infest nestlings. The prevalence of botfly parasitism was calculated as the ratio between the number of parasitized nests and the number of nests where nestlings hatched. We compared the probability of success for nestling stage between parasitized and unparasitized nests (Mayfield 1975, Hensler and Nichols 1981).

Nest survival. We considered the nest as depredated when eggs or nestlings too young to fledge vanished (nests with egg remains were also considered as depredated). Nests were considered to be abandoned if their contents remained with no sign of parental care. Other possible causes of nest losses were nestling death and the brood parasite success. We installed camera-traps at some nests to identify nest predators. A nest was considered successful when at least one nestling of Yellow Cardinal (not cowbird) fledged. We calculated the apparent success as the ratio between the number of successful nests and the total number of monitored nests (Marini *et al.* 2010). We also estimated the Diary Survival Rates (DSR) and the probability of success for incubation and nestling periods, and calculated Mayfield's nesting success (Mayfield 1975), with modifications to compare DSR and probability of success of each nest period (Hensler and Nichols 1981). Only nests with known faiths were used to estimate nest survival.

Feeding habits. We followed individuals of Yellow Cardinal and did qualitative observations *ad libitum* while birds were foraging, using binoculars (12×50 mm) and spotting telescope (25–60×).

Statistical analysis. To assess differences on distance between successful and unsuccessful attempts we used non-parametric Mann-Whitney *U*-test (or Wilcoxon

rank sum test). Values are presented as mean ± SD and considered statistically significant when $P < 0.05$.

Results

Nest search. We found 32 nests, 14 in 2013–2014 of nine breeding pairs and 18 in 2014–2015 of 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.

Breeding season. Nesting began on October 3 and lasted until February 12, for a duration of 131 days. We estimated the nest building initiation date based on the mean duration of nesting stages and plumage development of fledglings, for a mating pair found with two fledglings in November 2014. The peak of active nests was at late November (Figure 1).

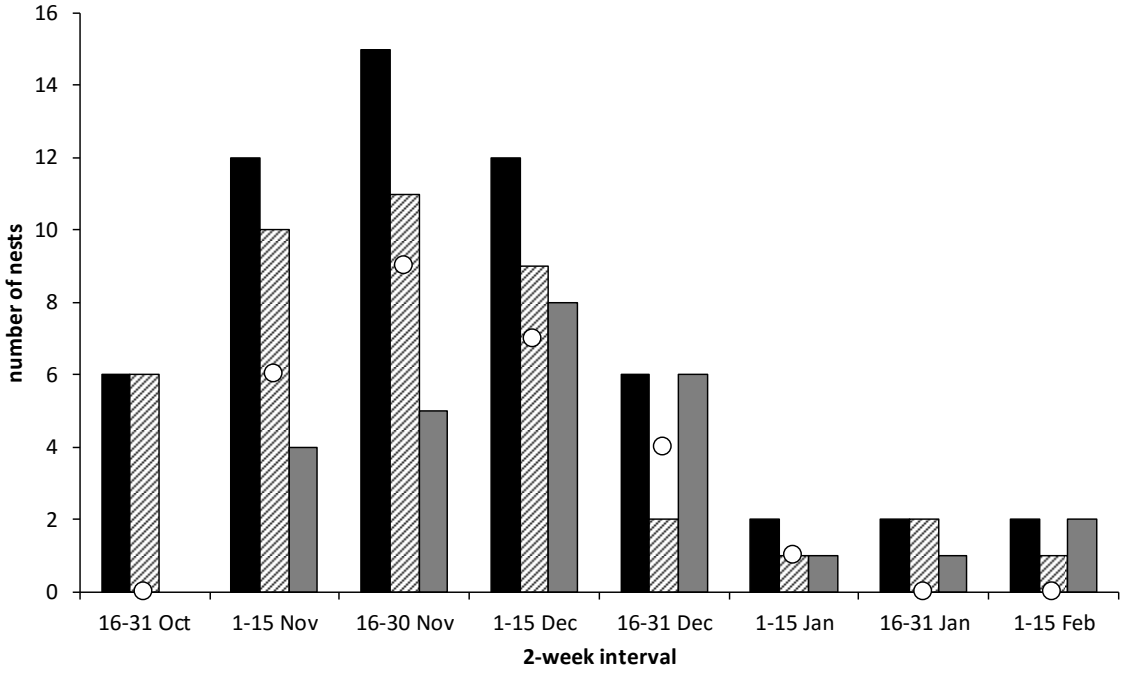

Figure 1. Number of nests of Yellow Cardinal by nesting stage (laying/incubation: *hatched bars*; nestling stage: *grey bars*), total active nests (*black bars*), and nests parasitized by cowbirds (*white dots*) by 2-week intervals during two breeding seasons (2013–2015) in Barra do Quaraí, State of Rio Grande do Sul, Brazil. Data from both breeding seasons were combined.

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. A nest was built in six days, 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 in *Prosopis affinis* trees (97%), and one nest was built in *P. nigra*.

Eggs are ovoid with light blueish-green background colour and black spots (sometimes it could have a few streaks) distributed over the entire surface or concentrated at the blunt pole (Figure 2). 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 (*n* = 7 eggs from 3 nests).

Clutch size, incubation and nestlings. Mean clutch size was 2.95 ± 0.52 eggs (2–4 eggs; mode = 3 eggs; *n* = 19), laying one egg per day. The incubation lasted 12.86 ± 0.9 days (12–14 days; *n* = 7) and only the female incubates the eggs. Hatching rate was 0.76 ± 0.25 (*n* = 14 nests) and there was no difference between unparasitized and parasitized nests (unparasitized: 0.8 ± 0.16, *n* = 6; parasitized: 0.73 ± 0.31, *n* = 8; *U* = 23, *P* = 0.95). Hatchlings were orange skinned, with light grey down feathers on the head and back, red-carmine mouth, yellowish gape, and open their eyes around 7 days old. The nestlings remained in the nest for 16.0 ± 1.26 days (15–18 days; *n* = 6). Nestling survival rate of successful nests was 0.67 ± 0.28 (*n* = 6). Mean productivity for successful nests was 1.6 ± 0.74 fledglings (*n* = 8) and 2.6 ± 1.82 fledglings (*n* = 5) for each female. Yellow Cardinal presented biparental care with both parents feeding the nestlings, and some nests were attended by helpers, which contributed for brood provisioning and nest and territorial defence (for details see Beier *et al.* 2016). The fledging survival rate was 62% (8/13 fledglings).

Figure 2. Nest of Yellow Cardinal in the municipality of Barra do Quaraí, State of Rio Grande do Sul, Brazil, with two host eggs and one brood parasite egg (*top*). One host egg was punctured by female cowbird (*bottom*).

Re-nesting. We observed up to three nesting attempts performed by the same female. From all nesting attempts, 40% was re-nesting, 35.7% (5/14) in 2013–2014 and 43.8% (7/16) in 2014–2015 breeding seasons, eight pairs with one re-nesting attempt and two attempts by two pairs. We observed re-nesting attempts after a successful attempt (n = 2) in two breeding pairs, on both cases helpers were assisting the pair. Other two re-nesting attempts occurred after successful attempts, but the fledglings not survived the first month after fledge, then we did not consider it as second broods. Mean interval between re-nesting attempts was 15.6 ± 10.1 days (6–36 days; n = 11), and there was significant difference between re-nesting after successful (n = 4) and unsuccessful (n = 7) attempts (25.2 ± 10.3 days vs. 10.1 ± 4.3 days; U = 1.5; P = 0.02). Mean distance between re-nesting 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), for nests where cowbirds laid at least one egg. Intensity of parasitism was 1.9 ± 1.3 egg per parasitized nest (1–4 eggs; *n* = 13). Three cowbird eggs measured 25.1 ± 0.56 mm in length, 20.4 ± 0.06 mm in width and 5.23 ± 0.12 g of mass. Nests where cowbirds hatched, in 33% (2/6) Yellow Cardinal was successful, while three were predated and in one, all nestlings died. In one nest, a cowbird hatched about 4 days after two Yellow Cardinals hatch, it was not seen in the nest on following visit (3 days later), and we found the cowbird nestling corpse at the bottom of the nest after Yellow Cardinals fledged. Cowbird females could puncture the host eggs, which occurred in 15% (3/20) of parasitized nests, followed by nest abandonment. Punctured eggs were often consumed by ants. Four parasitized nests (20%; 4/20) were successful (unparasitized successful nests: 40%; 4/10). Cowbird eggs were never rejected. Parasite eggs were white or creamy fully covered by brown spots (Figure 2), except for one egg that was white with a single brown spot.

Prevalence of botfly parasitism was 33% of nests (6/18). In one nest the nestlings were cowbirds and were depredated. The earliest nest with botflies was recorded on November 7 and the latest on December 18. Four parasitized nests (80%; *n* = 5) were successful and one nest was lost. We marked one nestling with 19 botfly larvae; it fledged but died soon after.

Nest survival. The main cause of nest loss was predation (73%), followed by egg puncture (14%), nestling death (9%) and success of nest parasite (4%). One Geoffroy's Cat (*Leopardus geoffroyi*) was recorded by the camera trap preying on a nest that contained eggs at the time. The nest was about 1.8 m above ground on a fork of the main tree trunk.

Only eight nests (26.7%; *n* = 30) were successful, four (28.6%; *n* = 14) in 2013–2014 and four (25.0%; *n* = 16) in 2014–2015 breeding seasons. The DSR was 0.938 ± 0.018 during incubation and 0.948 ± 0.016 during nestling stage. The probability of survival during incubation was 0.431 ± 0.105 (*n* = 193 nest-days) and during nestling stage was 0.425 ± 0.117 (*n* = 193 nest-days). The Mayfield Nesting Success was 18.31% (23.65% in 2013–2014 and 12.32% in 2014–2015). There was no difference between the breeding seasons of 2013-2014 and 2014–2015 in DSR or probability of survival for incubation (0.568 ± 0.146, *n* = 113 nest-days *vs.* 0.285 ±

0.138, *n* = 80 nest-days; *z* = 1.41; *P* = 0.16) and nestling stage (0.416 ± 0.167, n = 91 nest-days *vs.* 0.432 ± 0.166, n = 102 nest-days; *z* = 0.07; *P* = 0.95).

Mayfield Nesting Success was 24% for unparasitized and 15% for parasitized nests. There was no difference between the probability of success of unparasitized and parasitized nests during incubation (0.492 ± 0.178 *vs.* 0.395 ± 0.132; *z* = 0.44; *P* = 0.66) and nestling stage (0.485 ± 0.179 *vs.* 0.391 ± 0.154; *z* = 0.40; *P* = 0.69). For *Philornis* parasitism, the probability of success during nestling stage was 0.279 ± 0.129 for unparasitized and 0.691 ± 0.183 for parasitized nests, and there was no significant difference between them (*z* = 1.84; *P* = 0.07).

Feeding habits. We observed Yellow Cardinal birds feeding on seeds (e.g. Poaceae, leftover seeds on a rice field), arthropods, leaves (e.g. *Prosopis* spp., Poaceae), and fruits (e.g. *Chrysophyllum marginatum*). Individuals foraged on the ground, where grass was sparse or short, and they were often accompanied by other bird species, such as Red-crested Cardinal and Saffron Finch. Leaf consumption was more evident in October, at the beginning of breeding season, when the bill and faeces were tinged green. Fruit consumption was observed outside breeding territories in November 2014. A few times (*n* = 5) we noted individuals catching insects in the air, making a short flight from the ground or a perch.

Discussion

We provide here new information on natural history for Yellow Cardinal, and more specifically for its Brazilian population. Although a similar study has been conducted in Argentina (Domínguez *et al.* 2015), relatively close to our study site, we show differences in certain reproductive aspects between both populations (e.g. longer breeding season, higher rates of brood parasitism, re-nesting after successful attempts). It highlights the importance of autecology studies in different populations of a species, to understand the patterns and processes of spatio-temporal variation and its implications for species and ecosystems conservation.

Previous information about breeding biology of the Yellow Cardinal was limited to nest description (De La Peña 1981), a few nesting records without details (Castellanos 1934, Höy 1969) and breeding status of collected specimens (Belton

1994). Domínguez *et al.* (2015) published the first detailed study of breeding biology for Yellow Cardinal, for a population in Corrientes province, Argentina (in two study sites, about 130 and 180 km towards northwest from our site). Despite the relative proximity of these populations, we found some remarkable differences between them.

The breeding season was around 45 days longer in Brazil than in Argentina (Domínguez *et al.* 2015). And was shorter than for Red-crested Cardinal, *Paroaria coronata* (146 days, Oct–Feb; Segura *et al.* 2015), Stripe-tailed Yellow-finch, *Sicalis citrina* (152 days, Dec–May; Gressler and Marini 2011), and Lesser Grass-finch, *Emberizoides ypiranganus* (153 days, Oct–Mar; Chiarani and Fontana 2015). Tropical Thraupidae from Brazilian Cerrado usually breed from August to December with shorter breeding periods and high variation between years depending on rainfall, as for White-rumped Tanager, *Cypsnagra hirundinacea* (90–100 days; Santos and Marini 2010), and White-banded Tanager, *Neothraupis fasciata* (77–91 days; Duca and Marini 2011). Auer *et al.* (2007) found shorter breeding seasons for 18 passerine species of a subtropical montane forest in north-western Argentina, where the mean duration was 50 days, with maximum of 85 days for Spotted Nigthtingale-Thrush, *Catharus dryas*. The peak of breeding activity in November is similar for many species in southern grasslands, considering initiated or active nests (Chiarani and Fontana 2015, Segura *et al.* 2015), or brood patch (Repenning and Fontana 2011).

The nests and eggs were similar to previous descriptions and measurements (De La Peña 1981, Domínguez *et al.* 2015). Domínguez *et al.* (2015) also found more nests on *Prosopis affinis* (76%), followed by 15% on *Vachellia caven*. Although *V. caven* occurs on our study area, we did not found any nest on that tree species. *P. affinis* is the more abundant tree in the park-like vegetation at our study site, corresponding to 78%, while *V. caven* for only 8% (Marchiori *et al.* 1985). The former appears to be a pioneer species, which is more abundant on regeneration areas, with relative density of 66% versus 2% of *P. affinis* (Redin *et al.* 2011). In a pilot-study in 2012, we found two nests (n = 8) on cactus *Cereus hildmannianus* (CB, M. S. Pereira and M. S. Borba, unpublished data). Pereira (2015) associated breeding territories of Yellow Cardinal to areas with higher arboreal coverage. The

preference to nest on a supporting plant species may be related to nest concealment (Martin and Roper 1988, Martin 1993) or the most common potential nest site, reducing the probability of predation (Martin 1993, Liebezeit and George 2002). Other possible explanation is that it could be related to individual preferences or learning. Because only one nest was not on *P. affinis* we were not able to test these hypotheses. Non-systematic observations indicated that males followed females but did not engage on nest building or incubation, which is characterized as mate-guarding and it is a type of indirect parental care, since male vigilance allows female to increase its foraging efficiency and then incubation attentiveness (Fedy and Martin 2009). Nest building was faster for Lesser Grass-finch (4.3 days), a species with less than half the body mass of Yellow Cardinal (20 g vs. 47 g; Chiarani and Fontana 2015).

Clutch size was the same that which found in Argentina for Yellow Cardinal (3 eggs; Domínguez *et al.* 2015), and for other Thraupidae (Alves 1990, Santos and Marini 2010, Gressler and Marini 2011, Chiarani and Fontana 2015, Segura *et al.* 2015) and Neotropical open-nesting passerines (Mason 1985; Yom-Tov *et al*. 1994; Auer *et al*. 2007). Savanna and grassland birds tend to have larger clutches than rain forest birds (Yom-Tov *et al.* 1994).

The duration of incubation (12.9 days) was similar to that found in Argentina for Yellow Cardinal (12.5 days; Domínguez *et al.* 2015). It was longer than for Red-crested Cardinal (11.9 days; Segura *et al.* 2015) and Stripe-tailed Yellow-finch (11.8 days; Gressler and Marini 2011), and it was shorter than for Lesser Grass-finch (13.7 days; Chiarani and Fontana 2015), and White-rumped Tanager (16 days; Santos and Marini 2010). Incubation periods for most Thraupidae range from 12 to 14 days, exceptionally up to 17 days for Swallow Tanager, *Tersina viridis*, a cavity-nesting species (Hilty 2011). Shorter incubation period is attributed to high predation rates on this nesting stage (Martin *et al*. 2007, Martin and Briskie 2009). Hatching rate (76%) was smaller than for Red-crested Cardinal (84%; Segura *et al.* 2015) and Lesser Grass-finch (94%; Chiarani and Fontana 2015). Domínguez *et al.* (2015) also found no significant difference between hatching rates of parasitized and unparasitized nests (68% vs. 77%).

The nestling period of Yellow Cardinal lasted long than in Argentina (16 days vs. 14 days; Domínguez *et al.* 2015) and Red-crested Cardinal (14 days; Segura *et al.* 2015). And it was also longer than for Lesser Grass-finch (11 days; Chiarani and Fontana 2015), White-rumped Tanager (12 days; Santos and Marini 2010), and Stripe-tailed Yellow-finch (13 days; Gressler and Marini 2011). Nestling periods of Thraupidae are variable, ranging from 13 to 20 days for *Tangara* species (including former *Thraupis*; Hilty 2011). As in incubation, nestling periods seems to be shorter where nest predation is high in that nesting stage, like in open habitats (Martin and Briskie 2009, Santos and Marini 2010). Conversely, longer nestling periods increase the amount of time feeding and defending nestlings, which may also increase post-fledging survival rates (Martin 2014, Lloyd and Martin 2016).

The mean productivity per successful nest was similar to that found in Argentina (1.6 fledgling/nest; Domínguez *et al.* 2015), and lower than for Lesser Grass-finch (2 fledglings/nest; Chiarani and Fontana 2015). Nestling survival (67%) was equal to that found in Argentina (67%; Domínguez *et al.* 2015), and lower than compared to Red-crested Cardinal (81%; Segura *et al.* 2015) and Lesser Grass-finch (83%; Chiarani and Fontana 2015).

We found higher frequency and intensity of brood parasitism by cowbirds than in Argentinian population (67% vs. 33%, 2 eggs/parasitized nest vs. 1 egg/parasitized nest, respectively), but lower rates of nest abandonment (15% vs. 54%) due to egg puncturing by female cowbirds (Domínguez *et al.* 2015). Azpiroz (2015) reported cowbird parasitism in four nests (out of 17 nests) of Yellow Cardinal in Uruguay. Shiny Cowbird is a generalist brood parasite and its eggs were found in nests of more than 260 bird species (Lowther 2016), and have an incubation period of 11–12 days (Fraga 2011). The main impact of Shiny Cowbirds that parasite hosts with similar or larger body masses is the egg puncturing, which increases the probability of nest abandonment (Massoni and Reboreda 2002, Reboreda *et al.* 2003, Domínguez *et al.* 2015). Common Diuca-finch, *Diuca diuca*, is an effective host for cowbirds (Fraga 2002) and experiences similar impact due to egg puncturing, with 48% brood parasitism in Chile (Marin 2011). Chiarani and Fontana (2015) found no parasitized nests by cowbirds for Lesser Grass-finch, maybe because Shiny Cowbird have low abundances locally in upland grasslands of

north-eastern Rio Grande do Sul (E. Chiarani 2015, verbally). Domínguez *et al.* (2015) found no evidence of egg ejection or nest abandonment due to parasitism. Kilner (2003) found that Brown-headed Cowbird (*Molothrus ater*) nestlings are more successful in nests of hosts with similar or intermediate body size. Yellow Cardinal and females of Shiny Cowbirds (nominate subspecies) have similar body sizes, which are 47 g and 45 g, respectively (Fraga 2011). Cavalcanti and Pimentel (1988) found that Thraupidae are heavily parasitized by cowbirds and an increase of brood parasitism with habitat fragmentation in Brazilian Cerrado.

Prevalence of botfly parasitism was greater in Brazil (33%) than in Argentina (22%), it was observed during a longer period (~40 days vs. 14 days), and it had higher apparent success on infested nests (80%, n = 5 vs. 50%, n = 4; Domínguez *et al.* 2015). Domínguez *et al.* (2015) found no significant difference between parasitized (25%) and unparasitized nests (78%). Chiarani and Fontana (2015) observed botfly parasitism on Lesser Grass-finch with 4% of nests losses due to botfly infestation and subsequent nestling death, though a nestling that had 35 botfly larvae successfully fledged (E. Chiarani 2015, verbally). Rabuffetti and Reboreda (2007) found up to 58% of botfly prevalence in Chalk-browed Mockingbirds (*Mimus saturninus*) in Argentina, varying with the year and incresing with time of breeding. Mean intensity of botfly parasitism was 21 larvae per chick, and was higher for failed nests (37 vs. 10), and the majority of infested nests failed due to early infestation (Rabuffetti and Reboreda 2007). Salvador and Bodrati (2013) noted botfly parasitism in 80 bird species in Argentina, of which 12 Thraupidae species. Botfly parasitism may have negative effects on nestling survival and increase nest abandonment after all nestlings died (Dudaniec and Kleindorfer 2006, Rabuffetti and Reboreda 2007). We believe that the death of a nestling at nest in December 2014 was due botfly infestation, and the breeding pair re-nested in January 2015. Domínguez *et al.* (2015) suggest that after all nestlings died due to botfly infestation at an advanced stage of nesting cycle, it may reduce the probability of re-nesting. However, the number of nesting attempts made by a female may be more related to seasonal timing (Wingfield and Farner 1979, Arnold *et al.* 2010) and physiological conditions (Bicudo *et al.* 2010).

We observed more re-nesting attempts (40% of all nesting attempts) and longer mean interval between attempts (16 days), but less attempts per pair during a breeding season (3 attempts) than in Argentina (30%; 12 days; and 4 attempts per pair; Domínguez *et al.* 2015). Red-crested Cardinals re-nested with up to eight nesting attempts for a single pair during a breeding season, with mean interval of 8 days after unsuccessful and 28 days after successful attempts (Segura *et al.* 2015). Lesser Grass-finch made up to four nesting attempts during a breeding season, with mean interval of 3 days after unsuccessful and 25 days after successful attempts (Chiarani and Fontana 2015). Multiple nesting attempts per breeding season may be a strategy to compensate high rates of nest predation (Slagsvold 1984, Martin 1996, 2014, Di Giacomo *et al.* 2011).

Nest predation is the main cause of nest losses for the majority of bird species (Ricklefs 1969), as it was in our study. Nest predation events are difficult to witness, and many breeding biology studies infer predation from evidences (e.g. nest disturbance and remains), but it is not a reliable method to identify nest predators (Marini and Melo 1998, Thompson *et al.* 1999). Geoffroy's Cat preys primarily on small rodents and birds are its second main prey in spring and summer (Canepuccia *et al.* 2007, Bisceglia *et al.* 2008), eventually also preying on nestlings (Santillán *et al.* 2014). França *et al.* (2009) recorded 14 nest predation events directly during 5 years, in the Brazilian Cerrado biome, and passerines were the main nest predators, including Thraupidae. In our study site, we could list as potential nest predators of Yellow Cardinal, some snakes (e.g. *Phyllodryas patagoniensis*, *Chironius maculoventris*, and *Leptophis ahaetulla*), small mammals (e.g. marsupials and rodents), and other birds (e.g. raptors, Brown Cacholote *Pseudoseisura lophotes*, woodcreepers, Great Kiskadee *Pitangus sulphuratus*, Rufous-browed Peppershrike *Cyclarhis gujanensis*, and cuckoos).

The apparent nest success of Argentinian population of Yellow Cardinal was 24% (Domínguez *et al.* 2015), slightly lower than Brazilian population (27%), Red-crested Cardinal (26%; Segura *et al.* 2015), and Stripe-tailed Yellow-finch (29%; Gressler and Marini 2011). Chiarani and Fontana (2015) found an apparent success of 42% for Lesser Grass-finch. Apparent nest success tends to overestimate the real nest survival due to some nests that were not found early on incubation and leading

to underestimation of lost nests during egg laying and incubation (Mayfield 1961). Chiarani and Fontana (2015) found nests of Lesser Grass-finch mainly during building and incubation (74%), and Mayfield's Nesting Success was 39%, with higher probability of success during incubation (85%) than nestling stage (46%). Martin (1995) found mean breeding success of 40% for shrub-nesting birds in shrub/grassland habitats. Therefore, we can state that Yellow Cardinal very low nesting success (18%) worsened by chick losses soon after fledging (38%), which could overestimate the actual nest productivity and success (Chiarani and Fontana 2015).

Despite being only opportunistic and qualitative, our observations on feeding habits reinforces the importance of some food items on Yellow Cardinal diet. To this day, we knew that the species feeds mainly on seeds, and additionally on fruits and arthropods (Bencke *et al.* 2003, Dias 2008, Jaramillo 2011). We found that leaves appear to be a relevant food item on its diet, with some evidence to seasonal variation on diet, as leaf consumption seems to be more frequent on winter and beginning of spring. Jaramillo (2011) proposes that Yellow Cardinal may feed on *Prosopis* seeds or catch insects attracted to this tree, and he calls attention to the need of field observations to understand the close relationship between the two species. Our observations are not conclusive, though we believe that is a complex relationship, since *Prosopis* trees can provide many resources to Yellow Cardinal, such as food (leaves, seeds, insects), nest sites, shelter, high perches to watch and display, among others. Further studies on Yellow Cardinal feeding habits must assess the proportions of each food item and its seasonal variation.

Conservation actions. The Yellow Cardinal is threatened in many ways, some threats are known and others still need to be unveiled. Continuous monitoring and protection of habitat and populations of Yellow Cardinal are of prime importance to ensure its conservation. Pereira (2015) found that Yellow Cardinal and other threatened bird species are associated with short grass, which is maintained mostly by cattle grazing on our study area. The removal of cattle may lead to the development of taller grass and shrub encroachment, and consequently bird species that forage on the ground could be evicted from this area. Conservation schemes have to take into account vegetation management to prevent potential impacts on

populations of ground-foraging birds. Further studies are needed, especially to understand how botfly and brood parasitism affects the breeding success, as well as climate effects on breeding, feeding habits and other traits of Yellow Cardinal autecology.

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Conflict of Interests

None.

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CONCLUSÕES GERAIS

O presente estudo traz novas informações sobre a história natural do cardeal-amarelo (*Gubernatrix cristata*), e mais especificamente da população brasileira da espécie. Apresentamos o primeiro registro de reprodução cooperativa para cardeal-amarelo, o qual é um sistema reprodutivo incomum entre as espécies de aves. As hipóteses sobre a origem e perpetuação desse sistema se baseiam no fato que para um indivíduo postergar sua própria reprodução, este deve se beneficiar de alguma maneira. Do mesmo modo que o casal que aceita a permanência do ajudante também o faça por benefícios inerentes à presença dele. Os ajudantes de ninho de cardeal-amarelo parecem aumentar de alguma forma a produtividade e o sucesso dos ninhos por eles assistidos. No entanto, mais estudos são necessários para verificar os processos envolvidos e possíveis benefícios inconspícuos.

Devido à população ser bastante reduzida, fomos capazes de contar todos os indivíduos da mesma com certa confiança, e verificamos que há mais machos do que fêmeas adultos. Um casal precisa de uma área relativamente grande para seu território reprodutivo em uma vegetação bastante restrita, especialmente no Brasil. Estas informações demográficas são particularmente importantes para a conservação do cardeal-amarelo. Há evidências de saturação de habitat, que pode estar relacionada com o tamanho da área de vida individual. O menor número de fêmeas também pode limitar o número de territórios reprodutivos, motivando os machos a permanecerem por mais tempo em seus territórios natais quando não encontram uma fêmea para parear. O registro de um caso de endogamia pode estar relacionado com alguns desses fatores, sendo mais frequente em populações pequenas e pode acarretar em problemas genéticos dentro da população, bem como acelerar o processo de extinção. Estudos genéticos e de seleção de habitat são imprescindíveis para a orientação de planos de manejo e conservação da espécie.

Apesar de várias semelhanças, alguns aspectos da biologia reprodutiva do cardeal-amarelo diferem entre as populações do Brasil e da Argentina. A duração do período reprodutivo e as taxas de parasitismo de ninho por *Molothrus bonariensis* são maiores no Brasil. A realização de nova tentativa de nidificação após uma tentativa com sucesso não foi registrada na Argentina, e ocorreu apenas quando ajudantes estavam auxiliando o

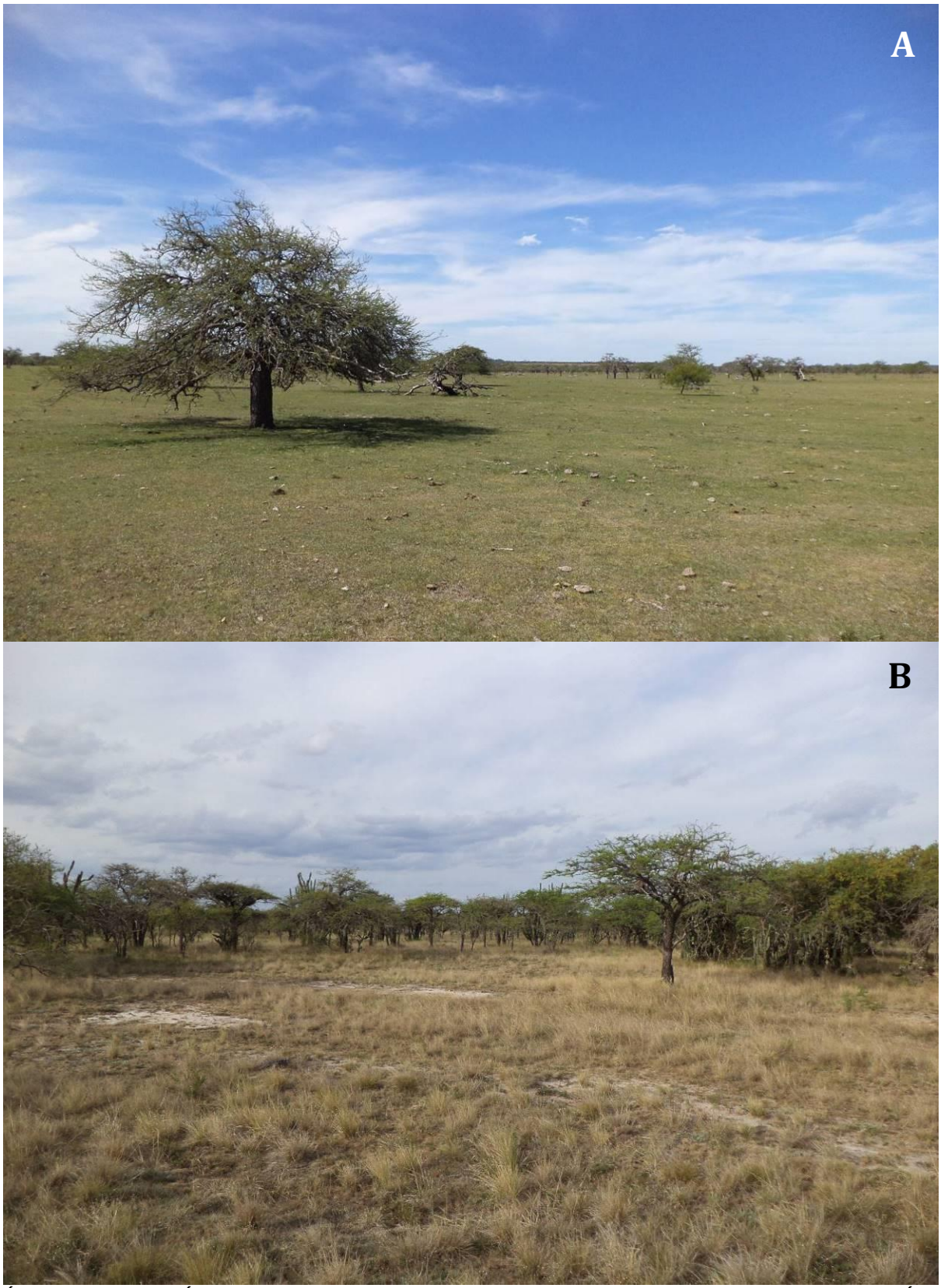
casal reprodutor. Como no estudo da Argentina, também encontramos tendências ao declínio do sucesso de nidificação nos ninhos parasitados por *M. bonariensis*. Larvas de moscas *Philornis* sp. também podem ter contribuído para redução da sobrevivência de filhotes dentro e logo depois de sair do ninho. Predação foi a causa mais comum de perda de ninhos. Registramos um gato-do-mato-grande (*Leopardus geoffroyi*) predando um ninho com ovos, no entanto não conseguimos confirmar a identidade de outros predadores de ninho. Estudos mais detalhados são recomendados avaliando o impacto do parasitismo por *M. bonariensis* e *Philornis* sp., e determinando os principais predadores de ninhos de cardeal-amarelo, a fim de verificar a necessidade de manejo dos parasitas e predadores para aumentar o sucesso reprodutivo da espécie. No entanto, é ineficiente aumentar a produtividade sem conservar e aumentar a área de habitat necessária para o estabelecimento de novo territórios.

Vários pesquisadores procuraram pelo cardeal-amarelo em território brasileiro durante anos e sem sucesso. Apesar de relatos esporádicos de avistamento da espécie na região do Rio Grande do Sul conhecida como Serra do Sudeste, sua presença não foi confirmada e a possibilidade de que esta população foi extinta não está descartada. A captura e o comércio ilegal de aves silvestres, as principais causas do declínio populacional do cardeal-amarelo, ainda são comuns em determinadas regiões da sua distribuição, apesar dos esforços dos órgãos fiscalizadores para inibir essa atividade. Educação ambiental é provavelmente a solução mais eficiente para mudar a forma com que as pessoas veem as aves, não como mercadorias ou colecionáveis, especialmente por meio das novas gerações.

A experiência de poder conviver com estas belas aves em seu habitat natural é algo inestimável. São seres sociáveis, cooperativos e flexíveis. A população brasileira habita uma região que pode ter um clima extremo impiedoso, mas o cardeal-amarelo parece adaptado para isso, ao menos até certo ponto. Em tempos de mudanças climáticas, estudos que avaliem como a espécie reage ao clima extremamente variável são recomendados também. Além disso, outras espécies simpátricas de aves, e outros animais e plantas, também estão ameaçadas e/ou não há muitos dados sobre suas autoecologias, e necessitam de mais atenção.

APÊNDICE FOTOGRÁFICO

Espécie foco do estudo: cardeal-amarelo, *Gubernatrix cristata*. (A) Casal de cardeal-amarelo, macho à esquerda e fêmea à direita; (B) Grupo familiar de cardeal-amarelo, composto por um casal reprodutor, dois ajudantes de ninho machos e uma fêmea jovem de 6 meses de idade (topo da imagem).



Área de estudo: (A) Área com gado, onde o pastejo mantém a relva baixa, formação *ñandubaysal*; (B) Área do Parque Estadual do Espinilho adquirida pelo Governo Estadual do Rio Grande do Sul, sem gado, formação *algarrobal*. Manchas de solo alcalino (*blanqueales*) reduzem a cobertura vegetal e é onde o cardeal-amarelo forrageia nessas áreas.

Ninho, ovos, filhotes e parasitas de ninho: (A) Ninho e ovos de cardeal-amarelo; (B) Filhote de cardeal-amarelo pouco tempo após a eclosão, e ovo de parasita de ninhos *Molothrus bonariensis* (à esquerda do ninhego); (C) Ninhada destruída com um ovo de cardeal-amarelo e quatro ovos de *M. bonariensis*, inclusive o ovo branco; (D) Ninhegos de cardeal-amarelo (à direita) e de *M. bonariensis* (à esquerda) do mesmo ninho, onde o parasita desapareceu e o ninho teve sucesso; (E) *Fledgling* de cardeal-amarelo pouco depois de sair do ninho; (F) *Fledgling* de cardeal-amarelo cerca de 15-20 dias após sair do ninho.

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