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ORIGINAL ARTICLE

SURVEYING POPULATIONS OF RED-BILLED CURASSOWS (*CRAX BLUMENBACHII*) IN THE ATLANTIC FOREST OF BRAZIL

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Abstract· Threatened species are frequently difficult to monitor, leading to a lack of information for the selection of the best conservation strategies. A case in point is the Red-billed Curassow (*Crax blumenbachii*, Cracidae, Galliformes), whose populations have declined due to deforestation of the northern Atlantic Forest and increased poaching in the late 1960s. The species is presently absent from most forest fragments within its geographic range, occurring only in forest remnants on the states of Bahia and Espírito Santo, Brazil. In this study, we estimated encounter rates and recorded the periods of activity of the Red-billed Curassow in three large Atlantic Forest fragments in the northeastern Brazilian state of Bahia, using line-transect sampling. The northern region of Serra do Conduru State Park (0.29 sighting/10 km) and Descobrimento National Park (0.27 sighting/10 km) presented slightly greater encounter rates of this endangered cracid, compared to the Una Biological Reserve (0.13 – 0.20 sighting/10 km). We recorded Red-billed Curassows throughout the day, mainly between 10:00–11:00 h and 14:00–17:00 h. Our study is the first step for long-term monitoring of the Red-billed Curassow. These findings serve as baseline information, which may contribute to future assessments of the conservation status and support future conservation actions for the species.

Resumo · Levantamento de populações do mutum-de-bico-vermelho (*Crax blumenbachii*) na Mata Atlântica do Brasil

Espécies ameaçadas são frequentemente difíceis de monitorar, causando carência de informações para selecionar as melhores estratégias de conservação. Esse é o caso do mutum-de-bico-vermelho *Crax blumenbachii* (Cracidae, Galliformes), cujas populações têm declinado devido ao desmatamento do norte da Mata Atlântica e o aumento da caça ilegal no final da década de 1960. A espécie está atualmente ausente na maioria dos fragmentos florestais de sua distribuição geográfica, ocorrendo somente em remanescentes florestais dos estados da Bahia e Espírito Santo, Brasil. Neste estudo, estimamos as taxas de encontro e registramos o período de atividade do mutum-de-bico-vermelho em três fragmentos grandes de Mata Atlântica no estado da Bahia, nordeste do Brasil, usando o método de transectos lineares. A região norte do Parque Estadual da Serra do Conduru (0,29 avistamento/10 km) e o Parque Nacional do Descobrimento (0,27 avistamento/10 km) apresentaram taxas de encontro levemente maiores deste cracídeo ameaçado quando comparadas com a Reserva Biológica de Una (0,13 – 0,20 avistamento/10 km).Registramos mutuns ao longo do dia, principalmente entre 10:00–11:00 h e 14:00–17:00 h. Nosso estudo é o primeiro passo para o monitoramento de populações silvestres do mutum-de-bico-vermelho em longo prazo. Esses achados fornecem informações básicas e podem contribuir com avaliações futuras do estado de conservação, além de apoiar futuras ações de conservação para a espécie.

Key words: Atlantic Forest · Cracidae · Encounter rates · Game bird · Galliformes · Line transect

INTRODUCTION

The order Galliformes comprises a highly threatened group of birds due to hunting and habitat loss, which is often caused by agricultural expansion (Keane et al. 2005). Of the 287 recognized species, 78 (27%) are included in the IUCN Red List (Baillie et al. 2004), thus making conservation actions crucial. For the effective conservation of these species, surveying and monitoring their populations over time is required (Aebischer & Baines 2008, McGowan et al. 2012).

In Brazil, a great effort to survey galliform populations has been conducted, especially for cracids (e.g., Galetti et al. 1997, Guix et al. 2002, Peres & Nascimento 2006, Parry et al. 2007, Haugaasen & Peres 2008, Bernardo et al. 2011a, Desbiez &

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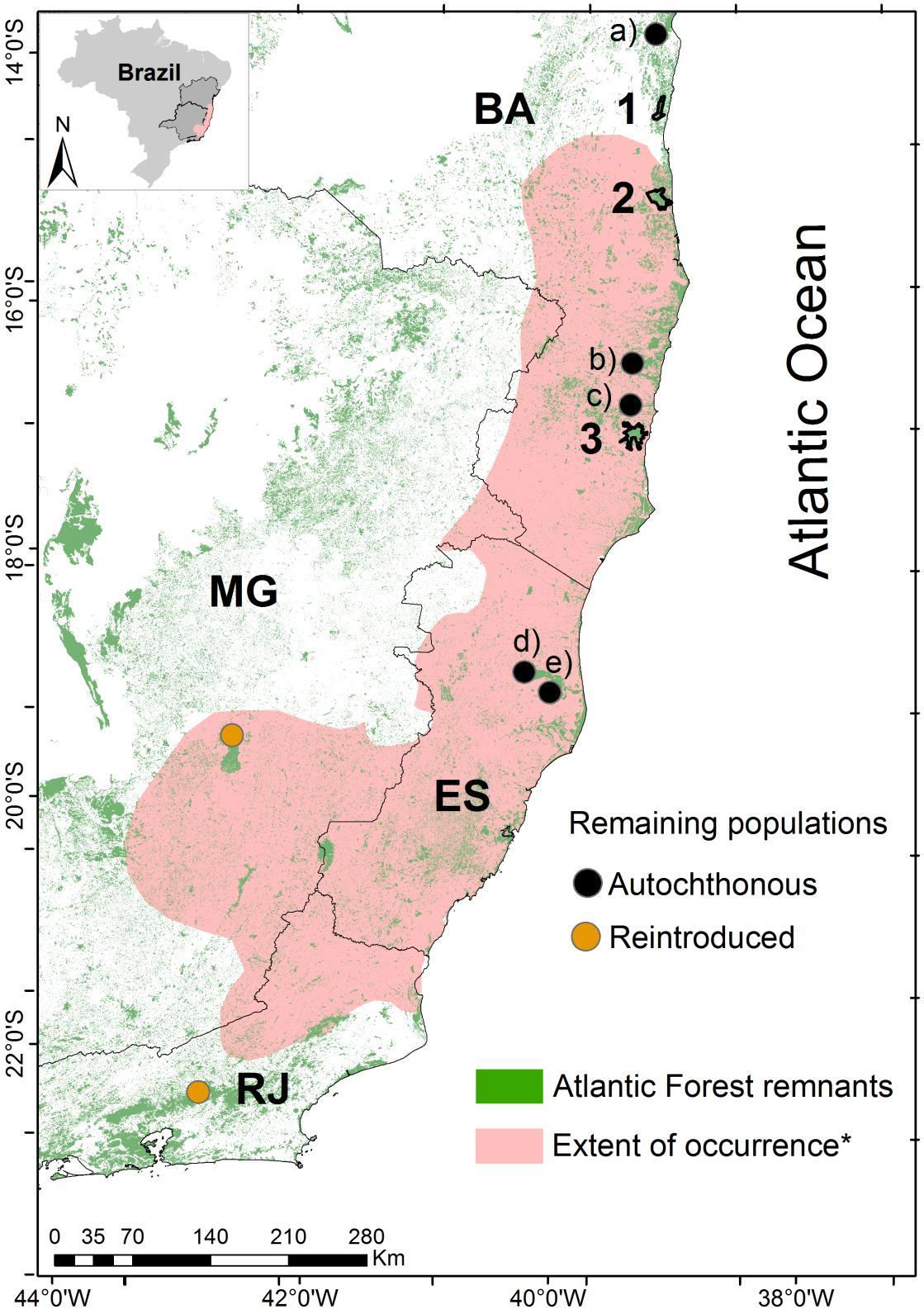

Figure 1. Location and boundaries of each forest fragment surveyed in this study in northeastern Brazil (1 = Serra do Conduru State Park, 2 = Una Biological Reserve, 3 = Descobrimento National Park). In addition, we highlight other areas of presence (autochthonous and reintroduced) of the Red-billed Curassow (*Crax blumenbachii*) in its entire distribution (*Note that the extent of occurrence of the IUCN does not consider some areas with confirmed presence of the species; Birdlife International 2019), where BA= Bahia state, MG = Minas Gerais state, ES = Espírito Santo state, RJ = Rio de Janeiro state, a) Michelin Ecological Reserve, b) Pau Brasil National Park, c) Monte Pascoal National Park, d) Sooretama Biological Reserve and Cupido farm, and e) Vale Natural Reserve. Modified after data provided by the SOS Mata Atlântica (www.sosma.org.br) and Birdlife International (2019).

Bernardo 2011). The country harbors 28 galliform species, all of which are experiencing population declines, even species not listed as threatened (with the exception of the Crested Bobwhite, *Colinus cristatus*; IUCN 2019). However, reliable data to estimate long-term population trends at the national level are not available. This is crucial to decide on appropriate local conservation strategies, especially for endemic species at high risk of extinction.

The Red-billed Curassow (*Crax blumenbachii*) is one of the most globally threatened cracids, classified as endangered by the International Union for the Conservation of Nature (IUCN 2019) and as critically endangered in Brazil (ICMBio 2018). The species is a large frugivorous bird endemic to the lowland Atlantic Forest. Like other large-bodied

Table 1. Compilation of available encounter rates (Vis - only sightings and Vis/Aur - visual plus aural records/10 km) of autochthonous Red-billed Curassow (*Crax blumenbachii*) populations detected during line transects in forest remnants located in the states of Bahia (BA) and Espírito Santo (ES), Brazil. Method codes are as follows: LT - line transect and four non-standard methods: HT – hiking trail, O – occasional record, and I – interview. NA – not available or not applicable due to lack of data. References: [1] Collar & Gonzaga (1988), [2] Chiarello (1999), [3] Chiarello (2000), [4] Alves et al. (2015), [5] Alvarez & Develey (2010), [6] K. M Flesher pers. com., and [7] Gatto et al. (2007). *Although the study used linear transects, the author also considered occasional sightings recorded before or after transect sampling.

Patch	Encounter rate		N sighting	N aural record	Sampling effort (km)	Patch size (ha)	Study period	Transects/ trails length (km)	Method	Reference
	Vis	Vis/Aur								
Vale Natural Reserve, ES	NA	NA	9	7	116	23,000	1985	NA	HT	[1]
	4.77*	NA	31	NA	64.9	23,000	1994–1996	1.5–2.0	LT, O	[2],[3]
	0.48	0.62	42	12	868.6	23,000	2012–2013	4.0	LT	[4]
Sooretama Biological Reserve, ES	0.75*	NA	5	NA	66.1	24,250	1994–1996	1.5–2.0	LT, O	[2],[3]
Michelin Ecological Reserve, BA	NA	NA	15	NA	950	3,711	1997–2009	NA	HT, I, O	[5], [6]
Capitão Reserve, BA	0.45	0.45	1	0	22.2	6,258	2006–2007	1.9–2.1	LT	[7]
N. Serra do Conduru State Park, BA	0.29	0.58	6	6	205.5	9,688	2012–2013	0.5–7.0	LT	**This study**
Una Biological Reserve, BA	0.13	0.13	4	0	307.5	11,967	2005–2006	0.5–7.5	LT	**This study**
	0.20	0.33	6	4	300.6	18,715	2013–2014	0.5–7.6	LT	**This study**
Descobrimento National Park, BA	0.27	0.27	9	0	328.8	24,084	2008–2009	0.5–4.0	LT	**This study**

frugivores, the species can swallow fruits of a wider range of sizes, including large-seeded fruits not easily dispersed by small-gaped frugivores (Galetti et al. 2013, Vidal et al. 2013). While large frugivores can damage large seeds, there is evidence that large-seeded plants rely on these animals for seed dispersal (Brooks & Strahl 2000, Vidal et al. 2013, Harrison et al. 2013). Thus, the extinction of large fruit-eating species in already defaunated areas may further reduce seed dispersal and, ultimately, natural regeneration of large-seeded hardwood plants (Galetti et al. 2013, Bello et al. 2015, Peres et al. 2016).

The current geographic distribution of the Red-billed Curassow encompasses remnants of the Brazilian Atlantic Forest, one of the Earth's most threatened hotspots (Mittermeier et al. 2004). Intense deforestation and poaching have been the main drivers of local extinctions of Red-billed Curassow populations in the southern and western parts of its range, including the states of Rio de Janeiro and Minas Gerais (Sick 1997, Brooks & Fuller 2006). Presently, only reintroduced populations are found in this region (Bernardo et al. 2011b), while remaining autochthonous populations are limited to forest fragments in the states of Bahia and Espírito Santo (IBAMA 2004, Figure 1).

Our objective for this study was to estimate encounter rates of the Red-billed Curassow in three of the largest protected areas in the northern Atlantic Forest. Our results provide: i) the first estimates of encounter rates of the Red-billed Curassow, using a standardized method in the northern extension of species occurrence and (ii) the first data series of population monitoring of this game bird in the Atlantic Forest.

METHODS

Study Areas. Our study was conducted in three large fragments of the lowland Atlantic Forest located in southern Bahia, northeastern Brazil (Figure 1, Table 1). These included the Descobrimento National Park (39° 18' 10" W, 17° 04' 13" S), Una Biological Reserve (39° 06' 15" W, 15° 10' 41" S) and the northern part of Serra do Conduru State Park, including the Alto da Esperança farm and the Capitão Reserve (39° 05' 36" W, 14° 26' 55" S). These areas encompass forest remnants with autochthonous populations of the Red-billed Curassow. Information on these populations is scarce, particularly populations in Conduru, a region not included in the proposed distribution by the IUCN (BirdLife International 2019, Figure 1).

The altitude of the study areas ranges from 0 to 500 m a.s.l., ambient temperatures are 24°C, and average annual rainfall is 1800 mm (Martini et al. 2007). The vegetation is dominated by dense ombrofilous forests with patches of secondary forest in different successional stages (Martini et al. 2007). Plantations of cacao (*Theobroma cacao*), rubber (*Hevea brasiliensis*), palm oil (*Elaeis guineensis*), and jackfruit (*Artocarpus heterophyllus*) are commonly found in the Una Biological Reserve.

Population Surveys. We used the line-transect distance sampling method (Buckland et al. 1993) to survey Red-billed Curassows following the standardized method derived by Peres & Cunha (2011). Six observers, well-trained in distance sampling techniques and cracid identification, conducted the bird surveys at the three study sites. Survey effort at each site ranged from 205.5 to 328.8 km (Table 1).

The areas were systematically surveyed between 05:00 h and 18:00 h (UTC-3), with sampling effort evenly distributed during the day. We recorded the geographic location, time and day of records, number of sightings and aural records (Figure 2). Transect length varied from 1 to 7.5 km. Although it is easy to identify males and females of this species due to sexual dimorphism, we did not report gender ratios because we were not able to distinguish sexes in all occasions given the shy behavior of Red-billed Curassows on the study sites. Surveys in southern Conduru, northeastern Descobrimento and the central part of Una were not conducted due to frequent presence of tourists, residents or inaccessibility. Thus, surveys were concentrated in areas with limited human access, on trails and little disturbed areas. Finally, Una was surveyed during two periods (2005–2006 and 2013–2014, Table 1), providing the first data series on population monitoring of a game bird in the Atlantic Forest.

Data Analysis. Given the reduced number of sightings, we were unable to estimate the density of Red-billed Curassows in our study areas. Therefore, we reported only encounter rates (records/10 km of transect). Given that some studies neither report aural records, or do not take them into account when calculating relative abundances or densities (Table 1), we have provided two measures of encounter rates. One measure considers only visual records, while the

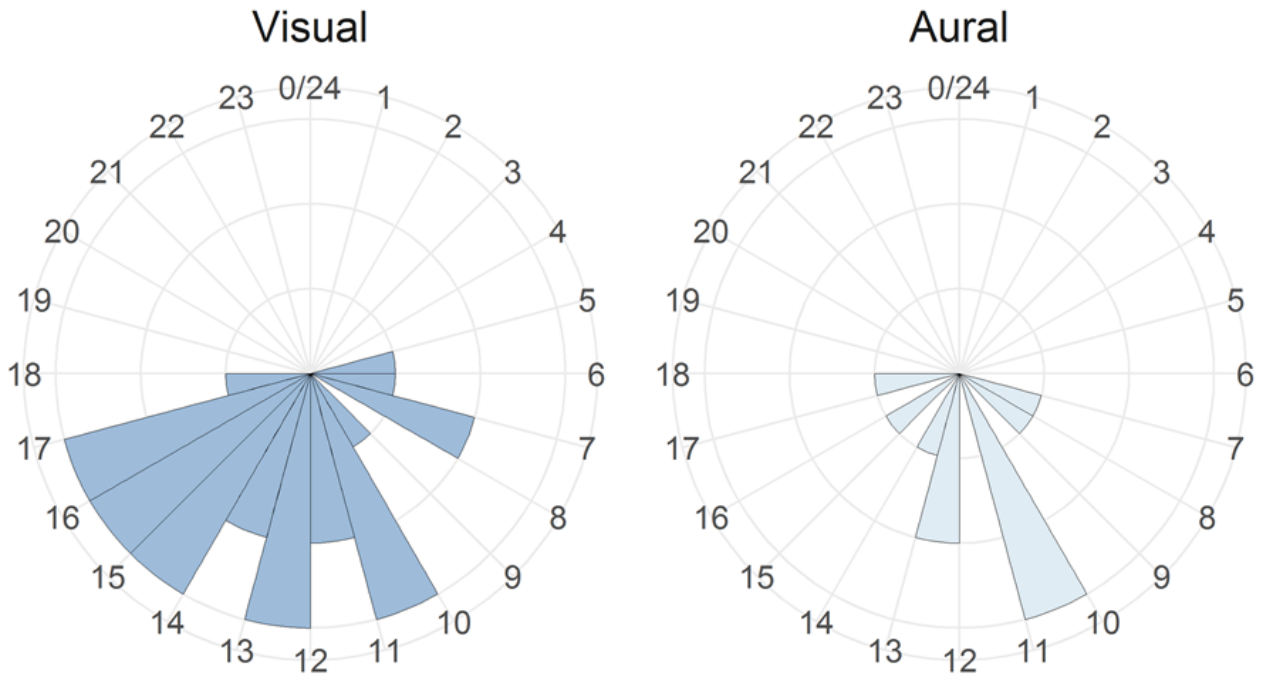

Figure 2. Overall records of Red-billed Curassows (*Crax blumenbachii*, 1-h intervals, between 2005 and 2014) obtained by pooling up all the data of our study areas in the Atlantic Forest of northeastern Brazil. Records ranged to 0 to 3 ones (length of blue bars).

other considers visual and aural records. Finally, we have presented rose diagrams (Figure 2) to describe the time of our visual and aural detections during the day in our study areas using the R- package ggplot2 (Wickham & Chang 2016, R Core Team 2016).

RESULTS

We obtained 25 visual detections and 10 aural records of Red-billed Curassows in the Atlantic Forest reserves sampled in southern Bahia (Table 1). In the northern region of Conduru, we recorded 6 visual detections (two of which were males) in trails of Capitão Reserve. We recorded 5 visual detections in Una in 2005–2006 (including one male), 6 in Una in 2013–2014 (four males and two females), and nine in Descobrimento (two individuals of undetermined sex together and two males, Table 1). The northern Conduru showed the greatest encounter rate in Bahia, followed by Descobrimento. The data series in the Una Biological Reserve revealed similar encounter rates along the years, ranging from 0.13 in 2005 to 0.20 sighting/10 km in 2013, and from 0.13 to 0.33 record/10 km (i.e., visual and aural), respectively (Table 1).

DISCUSSION

We expected greater encounter rates of Red-billed Curassows given that our sampling efforts were located in one of the best preserved regions in the Brazilian Atlantic Forest (Ribeiro et al. 2009) and our study areas included regions classified as a priority for the species. These sites represent localities that were large enough for viable populations of Red-billed Curassows and include highly suitable habitats (Bonfim et al. 2019). However, we recorded the lowest encounter rates of Red-billed Curassows compared to other areas where the species has been surveyed, such as the Vale Natural Reserve and Sooretama Biological Reserve (Table 1). Results did not change when including the aural records in the abundance calculation. Therefore, our results suggest that these populations may be more vulnerable and in need of greater attention. Furthermore, we documented gunfire (i.e., shotgun) and found remains of hunting camps during line transect sampling the northern region of Serra do Conduru (Capitão Reserve) and Una, where we recorded the highest encounter rate of Red-billed Curassows in our surveys. Additionally, hunting has also been reported for Descobrimento (Alvarez & Develey 2008).

Hunting is a pervasive threat to large-bodied species of animals in the Atlantic Forest which, along with habitat loss, has either driven local extinctions, or strong population declines of these animals in our study areas, such as tapirs (*Tapirus terrestris*, Canale et al. 2012, Bogoni et al. 2018). In addition, intense deforestation during the 1960s and 1970s in southern Bahia, followed by increased road access, resulted in the increased hunting pressure of many game species, including the Red-billed Curassow (Mendonça et al. 1993, IBAMA 2004). Thus, we emphasize the need to monitor these species in order to evaluate the hunting impact on the population status over time.

Available data for the Red-billed Curassow is scarce and mostly consists of occasional records, which limit comparisons using encounter rates (Table 1). Thus, we recommend increased survey efforts for Red-billed Curassows using line transects. Our results have contributed to the first data series for the species in Una (2005–2006 and 2013–2014). This area is one of the most frequently mentioned areas when it comes to Red-billed Curassow conservation, since researchers and park staff occasionally report the species in the main unpaved road of the reserve near the Maruim River, which is why we expected greater encounter rates at Una. Previous reports may reflect repeated observations of the same group of individual birds given the territorial behavior of curassows

and their regular use of the same pathways (Bernardo et al. 2011b).

Finally, we highlight the importance of surveying cracids during the day, instead of limiting samplings to crepuscular hours at dawn and dusk. In Vale (Espírito Santo state), Red-billed Curassows were photographed more often in the early morning and late afternoon (Srbek-Araujo et al. 2012). However, our results are similar to previous studies on cracids using motion-activated cameras. These devices detected these birds throughout the day, including the Great Curassow (*Crax rubra*) in the forests of Costa Rica (Lafleur et al. 2014) and El Salvador (Sermeño 1997), and the Bare-faced Curassow (*Crax fasciolata*) in Argentina (Fernández-Duque et al. 2013).

Our study is a starting point in the long-term monitoring of populations of Red-billed Curassows, taking into account that the comprehensive knowledge of the status of the remaining populations is necessary to decide on any site-specific strategies and to evaluate their effectiveness.

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