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SHORT NOTE

CONTRIBUTION OF CITIZEN SCIENCE TO THE KNOWLEDGE OF THE DIET OF THE BLUE-AND-YELLOW MACAW *ARA ARARAUNA* IN AN URBAN AREA OF CENTRAL WESTERN BRAZIL

Sabrina Cristiane Appel[1] · **Grasiela Edith de Oliveira Porfirio**[1*]

[1] Pós-graduação em Recursos Naturais. Universidade Federal de Mato Grosso do Sul. Avenida Costa e Silva s/n. CEP 79070-900. Campo Grande, MS, Brasil.

E-mail: Grasiela Edith de Oliveira Porfirio · grasi_porfirio@hotmail.com

Abstract · We recorded the food items consumed by the Blue-and-yellow Macaw *Ara ararauna* in the urban area of Campo Grande, from photographic records released on the platforms WikiAves, iNaturalist, and eBird by professional and amateur photographers. We retrieved 47 foraging records of Blue-and-yellow Macaw and we identified 18 species of plants in its diet. The species with the highest frequency of consumption were *Terminalia catappa* (17.0%) and *Acrocomia aculeata* (14.9%). Fruits and seeds were the most consumed plant parts, and around 72% of the diet was composed by parts of native plant species. As there is no previous information available on the diet of this species in the urban area of Campo Grande, the records released on the platforms helped us answer several important questions regarding its feeding habits. We highlight the importance of planting native species in urban afforestation, as well as the maintenance of urban parks and green areas, to maintain the population of the Blue-and-yellow Macaw in the city.

Resumo · A contribuição da ciência cidadã para o conhecimento dos hábitos alimentares de *Ara ararauna* em uma área urbana do Centro-Oeste do Brasil.

Objetivamos analisar os recursos alimentares consumidos pela Arara Canindé *Ara ararauna* na área urbana de Campo Grande, a partir dos registros fotográficos divulgados nas plataformas WikiAves, iNaturalist e eBird por fotógrafos profissionais e amadores. Recuperamos 47 registros de forrageio da arara canindé e identificamos 18 espécies de plantas em sua dieta. As espécies com maior frequência de consumo foram *Terminalia catappa* (17,0%) e *Acrocomia aculeata* (14,9%). Frutos e sementes foram as partes vegetais mais consumidas, e cerca de 72% da dieta foi composta por partes de espécies vegetais nativas. Como não há informações prévias disponíveis sobre a dieta dessa espécie na área urbana de Campo Grande, os registros divulgados nas plataformas nos ajudaram a responder várias questões importantes sobre seus hábitos alimentares. Destacamos a importância do plantio de espécies nativas na arborização urbana, bem como a manutenção de parques urbanos e áreas verdes, para manter a população da arara canindé na cidade.

Key words: *Campo Grande · Cerrado · Conservation · Frugivory · Psittacidae*

Urbanization constitutes a major threat to biodiversity at the global level (McDonald et al. 2008, Soulsbury & White 2015). Nevertheless, it is well documented that some wildlife species can benefit from and even persist on the remnant forest fragments found in urban or peri-urban areas (Hamer & Mcdonnell 2010, Evans et al. 2011, Rucco et al. 2020). Therefore, as the rate of urbanization is increasing worldwide, there is an urgent need to understand wildlife interactions and adaptations to the urban environment, in order to promote its conservation (Soulsbury & White 2015).

Campo Grande, the capital city of Mato Grosso do Sul state, is a located in the western Brazilian Cerrado (20 28'09"S, 54 37'23" W). With a total area of 8,092.95 km² and 916,001 inhabitants (IBGE 2021), Campo Grande is nationally recognized for the diverse array of wildlife living in its urban area (Ferreira et al. 2010, Mamede & Benites 2018). According to Benites et al. (2014), nearly 400 bird species have been recorded in the county, and the most common psittacids in the city are the Blue-and-yellow Macaw *Ara ararauna* and the Red-and-green Macaw *Ara chloropterus*. Such wildlife diversity may be attributed to the existence of several patches of native forested areas (squares, forested fragments, and urban parks) within this urban area; however, as in most urban centers, exotic plant species can also be found.

The emblematic Blue-and-yellow Macaw usually nests in the trunks of dead palm trees (Barbosa 2015, Mamede & Benites 2018). Because of its touristic appeal, the Blue-and-yellow Macaw was designated as the symbol bird of the city in 2015 by the Municipal Law of Campo Grande nº 5.651 (DIOGRANDE 2015, Calderan et al. 2019). In Brazil, this species is mostly found in the central part of the country, in the Cerrado, in the Amazon, and is marginally distributed in the Atlantic Forest, particularly in the

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states of São Paulo and Minas Gerais (Antas & Palo Jr 2009, Wikiaves 2021). Even though the Blue-and-yellow Macaw is not enlisted in the List of Endangered Species of the Chico Mendes Institute for Biodiversity Conservation (ICMBio 2018), the removal of its natural habitat and its trafficking to other countries constitute a conservation concern (Barros & Catojo 2018, Barros & Purificação 2020). Although this species is classified globally as Least Concern, it has a decreasing population trend and the main threats to its long-term survival are related to illegal trade (BirdLife International 2023). Despite that, several actions, particularly those aimed at ecotourism and bird watching have also contributed to the conservation of the species at local scales (Mamede & Benites 2018).

Citizen science, a term with multiple origins coined in the mid-1990s (Riesch & Potter 2014), may be widely defined as the participation of the general public in scientific research (Irwin 1995). When applied to the field of conservation, citizen science can be understood as an extensive collaboration between scientists and citizens (Couvet et al. 2008) that contributes to generate new knowledge for both science and the participating citizens (Riesch & Potter 2014). Over the years, the environmental and urban characteristics of Campo Grande have favored a growing number of birdwatchers (Mamede & Benites 2018), and it is common for them to register and share their sightings on online citizen science platforms, such as WikiAves (https://www.wikiaves.com.br), eBird (https://ebird.org, Sullivan et al. 2009), and iNaturalist (https://www.inaturalist.org).

Here we present a practical example that demonstrates how citizens may help scientists to understand and fill in information gaps about wildlife (Irwin 1995, Hernández-Brito et al. 2021). We aimed to analyze food resources consumed by the Blue-and-yellow Macaw in the urban area of Campo Grande, based on photographic records uploaded on the WikiAves, eBird, and iNaturalist platforms by professional and amateur photographers. Our goal was to answer the following questions: (i) which items make up the diet of the Blue-and-yellow Macaw in the city of Campo Grande? (ii) which food items are the most frequently consumed? (iii) what is the proportion of native and exotic species consumed by macaws? and (iv) what is the food niche breadth of this species in the urban area? As there is no previous information available on the diet of the Blue-and-yellow Macaw in the urban area of Campo Grande, our analysis aimed to fill an information gap to contribute to future management and conservation strategies for the species.

To carry out this study, the three platforms were accessed to select the records of Blue-and-yellow Macaw in Campo Grande, MS, Brazil, and following this screening, we selected those in which this species was registered foraging. Dates covered by the records ranged from 2006 to 2021 for WikiAves; 2013 to 2022 for iNaturalist, and 2016 to 2022 for eBird. Plant species and their origins were classified according to Lorenzi (2002) as native or exotic to Brazil or Cerrado, and plant species were identified using guides (Lorenzi 1992, Lorenzi et al. 2004). As the analysis was based on photographic records, each bird was considered to be feeding when it had a food item in its beak or held it with its foot. We considered date and locations of pictures to avoid pseudoreplication in our analysis. The records obtained were analyzed based on their frequency of occurrence (frequency of a particular item among the total number of records obtained). To assess the proportional use of native or exotic fruits, we compared the number of feeding records for each fruit type, using a Chi-

Table 1. Records of food items consumed by the Blue-and-yellow Macaw (*Ara ararauna*) in the urban area of Campo Grande, Mato Grosso do Sul, Brazil, according to data deposited on WikiAves, iNaturalist, and eBird between 2006 and 2022. Plant species and origin classified according to Lorenzi (2002). E= exotic; N= native.

Family	Species	Popular name (origin)	N (%)	Part consumed
Arecaceae	*Cocos nucifera*	Coco (E)	1 (2.1)	Fruit
	Archontophoenix cunninghamiana	Palmeira Real (E)	1 (2.1)	Fruit
	Acrocomia aculeata	Bocaiúva (N)	7 (14.9)	Fruit
	Syagrus romanzoffiana	Jerivá (N)	4 (8.5)	Fruit
	Roystonea oleracea	Palmeira-imperial (E)	3 (6.4)	Seeds
	Mauritia flexuosa	Buriti (N)	1 (2.1)	Fruit
Fabaceae	*Albizia hasslerii*	Farinha-seca (N)	3 (6.4)	Seeds
	Dipteryx alata	Cumbaru (N)	2 (4.3)	Seeds
	Inga edulis	Ingá (N)	1 (2.1)	Fruit
	Hymenaea courbaril	Jatobá (N)	2 (4.3)	Fruit
	Machaerium acutifolium	Jacarandá (N)	2 (4.3)	Fruit
Anacardiaceae	*Anacardium occidentale*	Caju (N)	1 (2.1)	Fruit
	Mangifera indica	Manga (E)	3 (6.4)	Fruit
	Spondias sp.	Cajá (N)	2 (4.3)	Fruit
Combretaceae	*Terminalia catappa*	Sete-copas (E)	8 (17.0)	Seeds
Myrtaceae	*Psidium guajava*	Goiaba-vermelha (N)	1 (2.1)	Fruit
Bignoniaceae	*Handroanthus heptaphyllus*	Ipê-rosa (N)	4 (8.5)	Flower
Caryocaraceae	*Caryocar brasiliense*	Pequi (N)	1 (2.1)	Seeds
Total	-	-	**47 (100%)**	

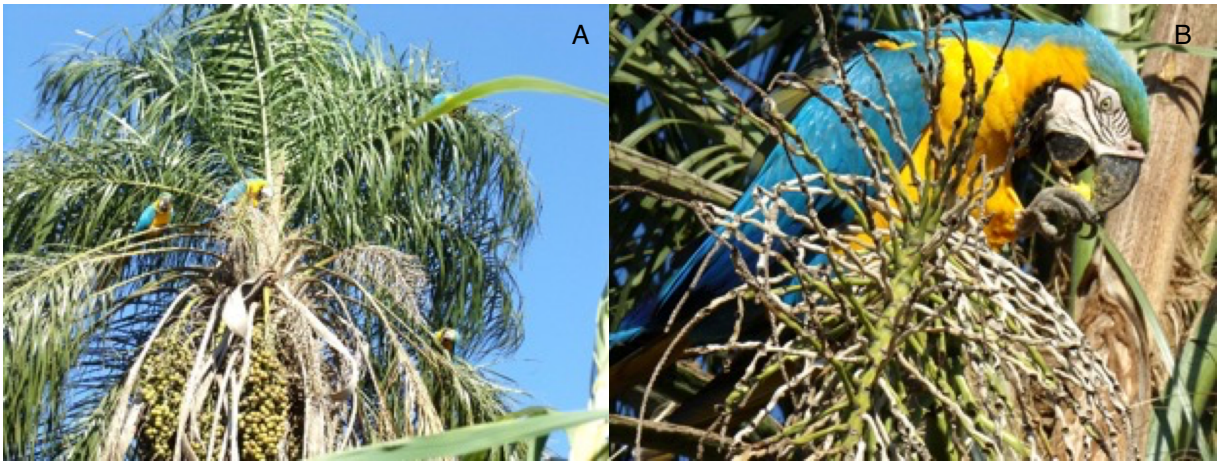

Figure 1. Blue-and-yellow Macaw *Ara ararauna* (Linnaeus, 1758) consuming the fruit of *Acrocomia aculeata* (1A and 1B), in the urban area of Campo Grande, Mato Grosso do Sul, Brazil. Credits: Sabrina Cristiane Appel.

square test performed in R software (R Development Core Team 2019). We also evaluated the breath of the Blue-and-yellow Macaw diet using Levin's Niche Breadth Index (Krebs 1989) calculated in Microsoft Excel. Values close to 0 indicate a specialized diet, while values close to 1 indicate a broad diet (Santos & Ragusa-Netto 2014).

Considering the three platforms accessed in this study, we obtained 442 records of Blue-and-yellow Macaw in Campo Grande (N = 349 from WikiAves; N = 49 from iNaturalist; N = 44 from eBird). In 10.6% of these records (N = 47), macaws were recorded foraging (Table 1). We identified 18 plant species in the diet of Blue-and-yellow Macaw in the urban area of Campo Grande. Plant species with the highest frequency of consumption were the exotic "Sete Copas" (*Terminalia catappa*, N = 8; 17.0%) and the native "Bocaiúva" (*Acrocomia aculeata*, N = 7; 14.9%) (Figure 1). Arecaceae (N = 6) and Fabaceae (N = 5) were the most common plant families represented in the diet of the Blue-and-yellow Macaw (Table 1*).* Moreover, from the 18 parts of plants identified, fruits (N = 12; 66.7%) and seeds (N = 5; 27.8%) were the most consumed plant items, and flowers corresponded to 5.5% of the parts of plants consumed (N = 1). A single species of flower (*Handroanthus heptaphyllus*) was observed to be consumed (N = 4 independent records; 8.5% of total) (Table 1). Around 72.2% of the macaws' diet was composed of native plants (X^2 = 47; df = 17, *P* = 0.0001). The niche breadth of *A. ararauna* was B' = 0.60.

The results obtained through our analysis demonstrated a generalist diet for the Blue-and-yellow Macaw in the urban area of Campo Grande, similar to patterns observed in other areas of Brazil (Tubelis 2009, Santos & Ragusa-Netto 2014). By analyzing the data available on the WikiAves, iNaturalist, and eBird platforms, we identified 18 plant species consumed by the Blue-and-yellow Macaw. The diversity on its diet, however, may even be larger, considering that Santos & Ragusa-Netto (2014) identified 21 plant species consumed by this species in another urban area of the state of Mato Grosso do Sul. Plant diversity observed in our study may be lower due to the lack of systematization in our data collection and sampling effort, since we only analyzed records deposited on citizen science platforms; Santos & Ragusa-Netto (2014) conducted a field study in which they established four transects (each one of 12 km long) to sample fruiting plants and to record the feeding habits of this macaw, during 40 monthly hours of observations over one year, at the urban area of Três Lagoas, another city of Mato Grosso do Sul state. In the absence of information from systematic collections, however, this study provides an interesting overview of the diet of Blue-and-yellow Macaw in the urban area of Campo Grande.

With subtle differences in the consumption of plant species, possibly related to the availability of food resources, the diet of the Blue-and-yellow Macaw was widely based on fruits and seeds, as reported in other studies in both natural and urban areas (Tubelis 2009, Santos & Ragusa-Netto 2014, Barros & Purificação 2020). Therefore, the consumption of several species of fruits and their seeds, as revealed by the values of niche breadth index, reinforces the generalist feeding habits of this species (Galetti 1997, Lee et al. 2014, Santos & Ragusa-Netto 2014, Barros and Purificação 2020). In addition, the analyzed data also supports the importance of Arecacea and Fabaceae in the diet of this species, as previously suggested by Ragusa-Netto (2006) and Santos & Ragusa-Netto (2014).

According to our analysis, the seeds of *T. catappa* and the fruits of *A. aculeata* were the most frequently consumed food items by the Blue-and-yellow Macaw in Campo Grande. In Três Lagoas, however, the most consumed food item were the seeds of *Caryocar brasiliense*, while the seeds of *T. catappa* was one of the least consumed species (Santos & Ragusa-Netto 2014). These differences probably reflect differences in availability in urban areas, as *T. catappa* trees are commonly used in urban afforestation of Campo Grande. Furthermore, our results agreed with the study of Santos & Ragusa-Netto (2014), because we observed that the fruit of *A. aculeata* is one of the most important items included in the diet of Blue-and-yellow Macaw, and as previously described this macaw acts as an efficient disperser of these diaspores (Silva et al. 2021).

Another interesting finding in our study was the high proportion of native plants consumed by Blue-and-yellow Macaws in Campo Grande, when compared with the proportion of exotic species. Although the consumption of exotic species has been reported for this macaw (Santos & Ragusa-

Netto 2014), this species rarely feeds on exotic plants (Matuzak et al. 2008, Santos & Ragusa-Netto 2014). Therefore, given the high consumption of native species from the Cerrado in the urban area, it is important to highlight that Campo Grande maintains a substantial diversity of native species that favors the persistence of the Blue-and-yellow Macaws. Even when foraging on exotic plants, these macaws play an efficient role as key dispersers of native palm seeds (Baños-Villalba et al. 2017, Silva et al. 2021).

Based on records from open repositories, we conclude that the Blue-and-yellow Macaw is a generalist species whose diet was similar to that reported in natural environments, and it included a high proportion of fruits and seeds of native species from the Cerrado. For this reason, we recommend the continued planting of native species in urban afforestation, as well as the maintenance of urban parks and green areas in Campo Grande to maintain the population of the Blue-and-yellow Macaw in the city.

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