Seasonal variation in the predation on avian resources by the Toco Toucan (*Ramphastos toco*) in Brazil, based on community science data

Variación estacional de la depredación de recursos aviares por parte del Tucán toco (*Ramphastos toco*) en Brasil, basado en datos de ciencia participativa

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Abstract

Ramphastidae (Piciformes) is a family endemic to the Neotropics, and includes 36 species. Although they are classified primarily as frugivorous birds, they also feed on invertebrates and small vertebrates. The objective of this study was to examine the consumption of avian resources by the Toco Toucan (*Ramphastos toco*), the most common Ramphastidae in non-Amazonian Brazil. A search for photographic records of this species was done in April 2022 in WikiAves, the largest community science database regarding Brazilian birds. A total of 271 photographs had evidence of feeding activities. Most of them involved non-avian resources (85%), such as fruits, while a minor portion referred to avian resources (15%). These 42 records involving avian resources were more numerous in October-December than in other periods of the year. They showed the consumption of eggs (50%), nestlings (45%), and juvenile or adult birds (5%). These feeding records included species of the families Tyrannidae, Columbidae and Icteridae, having the Great Kiskadee (*Pitangus sulphuratus*) as the most common prey species. On the other hand, records involving non-avian resources occurred throughout the year. As a result, the proportion of photographs with avian resources was higher in October-December than in other periods. This relatively high frequency of avian resources in the diet of the Toco Toucan coincides with their nesting period in Brazil. With our study, we confirm the usefulness of community science to improve our knowledge regarding the diet and feeding ecology of Neotropical birds.

Key words: citizen science, diet, egg, feeding ecology, nestling, Ramphastidae

Resumen

La familia Ramphastidae (Piciformes) es endémica al Neotrópico e incluye 36 especies. Aunque son consideradas principalmente aves frugívoras, también se alimentan de invertebrados y pequeños vertebrados. El objetivo de este estudio fue examinar el consumo de recursos aviares por parte del Tucán toco (*Ramphastos toco*), el Ramphastidae más común en el Brasil no amazónico. En abril de 2022 se realizó una búsqueda de registros fotográficos de esta especie en WikiAves, la mayor base de datos de ciencia ciudadana sobre aves brasileñas. Un total de 271 fotografías tenían evidencia de actividades de alimentación. La mayoría involucraba recursos no aviares (85%), como frutas, mientras que una porción menor se refería a recursos aviares (15%). Estos 42 registros que involucran recursos aviares fueron más numerosos en octubre-diciembre que, en otros períodos del año, demostrando el consumo de huevos (50%), polluelos (45%) y aves juveniles o adultas (5%). Estos registros de alimentación incluyeron especies de las familias Tyrannidae, Columbidae e Icteridae, teniendo al Bichofué (*Pitangus sulphuratus*) como la especie de presa más común. Por otro lado, los registros que involucraban recursos no aviares ocurrieron a lo largo del año. Como resultado, la proporción de fotografías con recursos aviares fue mayor en octubre-diciembre que en otros períodos. Esta frecuencia relativamente alta de recursos aviares en la dieta del tucán toco coincide con su período de anidación en Brasil. Con nuestro estudio reconfirmamos la utilidad de la ciencia participativa para mejorar nuestro conocimiento sobre la dieta y la ecología alimentaria de las aves neotropicales.

Palabras clave: ciencia ciudadana, dieta, huevo, ecología alimentaria, polluelo, Ramphastidae

Introduction

Citizen science, also called community science, refers to the contribution of citizens to scientific research (Bonney *et al.* 2009, Bela *et al.* 2016, Chandler *et al.* 2017). This collective activity includes creating and maintaining online platforms that receive millions of wildlife records obtained by thousands of contributors (Sullivan *et al.* 2009, Turnhout *et al.* 2016, Johnson *et al.* 2021). Regarding Brazilian birds, a significant platform harbors records of more than 1900 species gathered throughout the country - WikiAves (de Camargo Barbosa *et al.* 2021). Researchers can use photographic records of this platform to investigate aspects of the natural history of numerous species (Tubelis 2023). This avifauna includes the popular and charismatic Ramphastidae family, with about 60,450 photographs on this platform (WikiAves 2023). This set of records can improve the knowledge of their ecological interactions, such as predation and seed dispersion, as numerous photographs show their food items.

The Ramphastidae family belongs to the Order Piciformes and includes birds known as toucans and aracaris, which comprise five genera and 36 species restricted to the Neotropics (Winkler *et al.* 2020). They occur widely from southern Mexico to northern Argentina and southern Brazil, except in dry forest regions and highlands (Short & Horne 2001). These birds have colorful plumage and an enormous bill that play important roles concerning feeding behavior, communication, thermoregulation of the body, and fighting conspecifics (Sick 1997, Tattersall *et al.* 2009, Guaraldo *et al.* 2019). Toucans and aracaris rely on a wide range of forests and other wooded habitats (Short & Horne 2001, Winkler *et al.* 2020). They nest in cavities of tree trunks, termite nests, and rocky crevices (Sick 1997, Winkler *et al.* 2020, Tubelis 2022).

Most species are mainly frugivorous but feed on bird eggs, chicks, invertebrates, small lizards, and frogs (Winkler *et al.* 2020). Some items are entirely swallowed after being positioned in the tip of the bill, while others are picked apart before consumption (Winkler *et al.* 2020). Although toucans are conspicuous birds, detailed studies on their feeding ecology remain scarce. For example, in Costa Rican forests, Howe (1977) showed that toucans and aracaris can be abundant tree visitors that process undamaged seeds, thus being important dispersers. Further, through notations of stomach contents on museum specimen labels, Remsen *et al.* (1993) revealed the highly frugivorous diet of toucans. Also, Galetti *et al.* (2000) identified fruits of more than 50 plant species in the diet of toucan communities found in the Brazilian Atlantic Forest. Some studies in a few Neotropical locations also provided brief comments on consuming unusual food items, such as flowers, insects, small mammals, and lizards (Skutch 1955, 1971, Riley & Smith 1986, Silva & Azevedo 2012). Even geophagy has been eventually recorded for some species of toucans (Matinata & Perrella 2020).

Twenty-two species of the Ramphastidae family occur in Brazil (Stotz *et al.* 1996, Pacheco *et al.* 2021). The Toco Toucan *Ramphastos toco* is the largest species, and its geographic distribution substantially overlaps with that of the Cerrado region and adjacent biomes (Sedgwick 2020). It relies less on forests than other ramphastids and occurs in nearby open habitats and urban wooded areas (Sick 1997, Tubelis 2022). In the Pantanal wetland, Toco Toucans were observed foraging mainly on fruits of *Genipa americana*, *Ficus* spp., and *Cecropia* spp. trees and it is noted that toucans move among habitats seasonally in search of abundant fleshy fruits (Ragusa-Netto 2006). In this region, the abundance of Toco Toucans in forest patches was positively influenced by the availability of fleshy fruits, especially those of *Ficus* spp. trees (França *et al.* 2009). In central Cerrado, the abundance of Toco Toucans had substantial temporal and spatial variations, which coincided with the availability of specific fruits such as those of *Virola sebifera* in gallery forests and *Schefflera macrocarpa* in woodland savannas (Ragusa-Netto 2008). Also, in the Cerrado, Ragusa-Netto (2013) showed that the seasonality influenced the occurrence of Toco Toucans in a range of forest types in fruit abundance and diversity.

As a result, most detailed studies on the feeding ecology of the Toco Toucan focused on its frugivorous diet rather than dealing with the consumption of animal food items. Other information on its feeding

ecology is available as qualitative data in books about regional avian faunas that mention fruits as their primary food items and the eventual consumption of avian resources such as eggs and nestlings (*e.g.*, Antas & Cavalcanti 1988, Sick 1997, Antas 2004). Thus, their role in animal predation needs to be better examined. We supposed that this scarcity of quantitative information on the diet of toucans could be mitigated through the use of community science data, as recently occurred for bird species of other families found in Brazil (*e.g.*, Crozariol & Gomes 2010, Teixeira *et al.* 2019, Tubelis & Sazima 2021, Tubelis & Wachlevski 2021, de Souza *et al.* 2022, Gomes & Tubelis 2022, Costa & Tubelis 2023).

In this study, we examined the avian diet of the Toco Toucan in Brazil using photographic records gathered by community scientists. We hypothesized that seasonal variations in the diet of Toco Toucans occurred throughout the year because the availability of vegetal and animal resources varies seasonally in Brazil; for example, numerous land birds nest during or near the spring (September-December), thus leading to the abundance of eggs and nestlings during this period (Sick 1997). We examined seasonal variation in the number of records with evidence of consumption of avian resources (eggs and birds of variable age). We compared them with those involving non-avian resources. Examining the proportion of these two resource types among food items along the year would allow the study of temporal variation in its diet. We discuss our results regarding the feeding ecology of toucans in the Neotropics.

Methods

Data gathering.- We based this study on a compilation of photographic records with evidence of the Toco Toucan feeding activities in Brazil. We obtained records in April 2022 through a search in WikiAves (https://www.wikiaves.com.br) – a community science project organizing the largest digital voucher database concerning Brazilian birds. It currently harbors approximately 4,652,000 records of more than 1,950 species through the contribution of about 45,800 observers. Other platforms (eBird Brasil, iNaturalist and Macaulay Library) were not searched due to the relatively low number of photographs of the Toco Toucan in Brazil.

For the WikiAves search, we selected "Registros" (Records) and then "Busca Avançada" (Advanced Search). The scientific name of the species was typed in the "Espécie" (Species) field, and then the "Alimentando-se/Caçando" (Feeding/ Foraging) filter was selected. The resulting photographs were carefully examined to select only those with evidence of feeding activities (here called "feeding records"). This filter eases the search for feeding records, as about 16,000 Toco Toucan records were available in WikiAves during the search period. Feeding activities included Toco Toucans: (1) holding known food items (fruit, seeds, flowers, buds, invertebrates or vertebrates, including their eggs) with the bill and/or foot, (2) with the bill open, expecting for a falling food item, (3) with pieces of fruits on the bill, and perched on a tree having the same fruit, and (4) directing the bill towards open (damaged) fruits of a tree. This study did not include photographs of toucans perched on fruiting trees without evidence of feeding activities. The same occurred for records with birds foraging on artificial feeders. These were noted when photographs showed toucans and food items on wooded structures made by man and when cut bunches of coconuts were hanging on tree branches, a common fact around lodges in southern Brazil.

When we could note that two or more photographs obtained in each municipality, on the same day, referred to the same feeding event, only one was selected. This was done to avoid repetitions/replicates that could overestimate the consumption of a given food item in each period. We contacted the authors of the selected photographs in cases of doubt about feeding activities, and to confirm the identification of bird species being preyed. We received permission from community scientists to include their photographs in this paper. Information on municipalities and biomes was obtained in IBGE-Instituto Brasileiro de Geografia e Estatística (https://cidades.ibge.gov.br/).

Data analysis.- We grouped feeding records into two categories, based on the type of food resource being

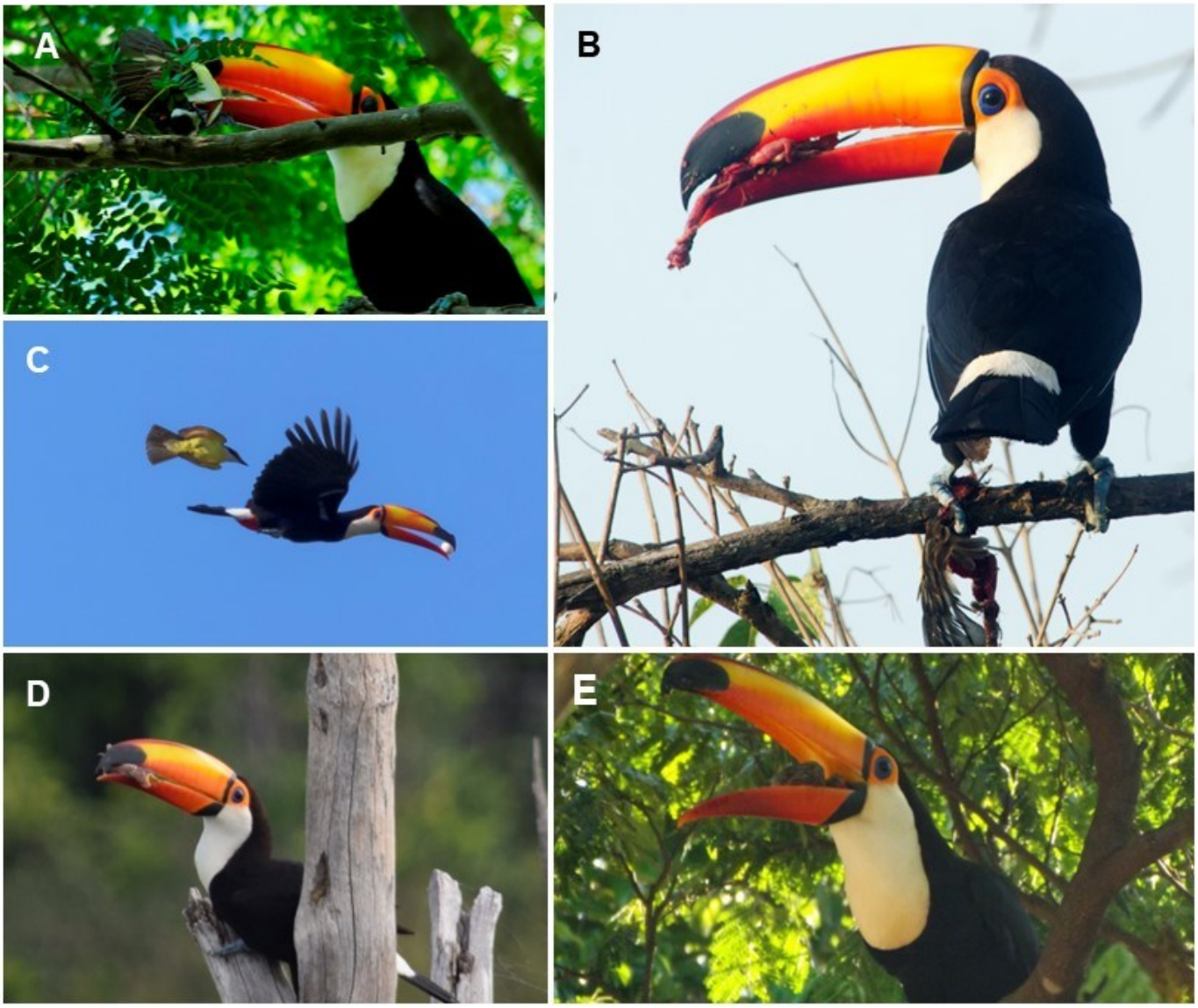

Figure 1. Photographic records of the Toco Toucan (*Ramphastos toco*) consuming avian resources and obtained by community scientists in Brazil. An individual preying on a juvenile Great Kiskadee (*Pitangus sulphuratus*) at Barretos, SP **(A)** An adult Kiskadee being consumed at Miranda, MS **(B)** An individual with an egg is being persecuted by a Great Kiskadee at Campinas, SP **(C)** An individual preying on a nestling at São Salvador de Tocantins, TO **(D)** An individual eating a nestling at Nova Andradina, MS **(E)** Photographs (A) Guilherme Soares/WA835089 (B) Francisco Petinha Lira/WA1941489 (C) Humberto Mancuso/WA4162973 (D) Nicola Aidinis/WA3598959 (E) Alex Polatto Carvalho/WA1154627.

consumed by toucans: (1) "feeding records involving avian resources", *i.e.*, photographs with toucans consuming eggs, nestlings, or juvenile and adult birds (Fig. 1); (2) "feeding records involving non-avian resources", *i.e.*, photographs with toucans consuming food resources other than those related to birds, such as fruits, flowers, buds, invertebrates, and other vertebrates. The seasonal occurrence of feeding records involving avian and non-avian resources was examined by grouping them in months (*e.g.*, January, May). For each month, we also evaluated the proportion of avian resources in the diet of the Toco Toucan. We used the Chi-square test to compare the number of records involving avian and non-avian resources. This analysis was done with the BioEstat Program (Ayres *et al.* 2007), considering a significance level of 5%. We considered that, for each month of the year, the number of feeding records with avian

and non-avian resources would represent the proportion of these two types of food items in the diet of Toco Toucans during a specific period.

Results

We examined 2,042 photographs of the Toco Toucan deposited in the WikiAves database. Of these, we included in our analysis a total of 271 (13%) referred to feeding records obtained by community scientists in Brazil between 2008 and 2022. Most of them (n=229, 85%) involved non-avian resources; they comprised fruit (n=219), flowers and buds (n=4), invertebrates (n = 4), frogs (n=1), and lizards (n=1). On the other hand, a minor portion (n=42, 15%) of the total feeding records referred to avian resources. These avian resources were obtained in 37 municipalities in the Atlantic Forest, the Cerrado, the Pantanal, and in their ecotones (Appendix 1).

Feeding records involving avian resources were more numerous (88%) between October and December than in other periods of the year (Fig. 2). They were scarce (12%) between January and May and absent between June and September. Of these 42 feeding records, those with the consumption of eggs (50%) and nestlings (45%) were more numerous than those showing the predation of juvenile or adult birds (5%, one record of each) (Fig. 2, Appendix). Thirteen (31%) of these records allowed the identification of the bird species being preyed. These feeding records included species of the families Tyrannidae (11 records), Columbidae (n=1), and Icteridae (n=1). The Great Kiskadee *Pitangus sulphuratus* was the species most often present in the feeding records involving avian resources (Appendix).

Conversely, feeding records involving non-avian resources occurred throughout the year (Fig. 2). The proportion of avian resources in the diet of the Toco Toucan was higher in October-December than in other periods. During these three months, differences between the number of feeding records involving avian and non-avian resources were not significant. For other months of the year, the number of feeding records involving non-avian resources was significantly higher than those with avian resources (Table 1).

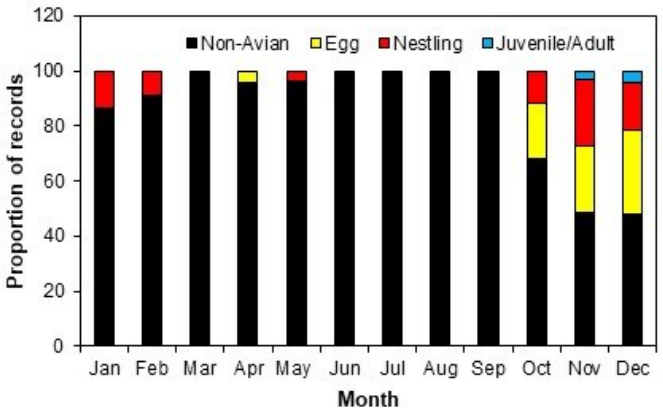

Figure 2. Seasonal variation in the proportion (%) of feeding records of the Toco Toucan (*Ramphastos toco*) with non-avian (black bars) and avian (colored bars) resources obtained by community scientists in Brazil. Records were gathered in the WikiAves database in April 2022.

Discussion

Our study represents one of the most extensive samples of the Toco Toucan food items, partly because photographs were gathered over 14 years by community scientists producing about 270 feeding records. Also, this study produced the most significant sample of animal food items consumed by Toco Toucans, as most detailed studies on its feeding ecology quantified the consumption of fruits (*e.g.*, Ragusa-Netto 2006, 2008, 2010, Santos & Ragusa-Netto 2013). As an exception, Pizo *et al.* (2008) showed that Toco Toucans were responsible for the predation of about 12% of the eggs of the Hyacinth Macaw (*Anodorhynchus hyacinthinus*) in the Pantanal wetland. Furthermore, our approach based on community science data allowed the acquisition of records over an extensive area in Brazil, leading to data acquisition in several situations and periods.

The consumption of avian eggs and nestlings by Toco Toucans and other ramphastids has been reported in a few books or studies (*e.g.*, Antas & Cavalcanti 1988, Sick 1997, Antas 2004, Sedgwick 2020, Winkler *et al.* 2020). Our study is the first to quantify the consumption of these food items – feeding records indicate that eggs and nestlings are consumed in similar frequencies, which might occur because Toco Toucans can gather any of them easily with the bill after finding and reaching a nest. Due to their large

size, Toco Toucans could fly carrying eggs and nestlings of medium-sized and small birds. Thus, the list of four bird species preyed on by Toco Toucans obtained in this study might increase considerably with further records, combining community science and conventional ornithological studies. To reinforce this, Sick (1997) mentioned the predation of eggs and nestlings of species such as *Pachyramphus* spp (Tityridae), the Yellow-rumped Cacique (*Cacicus cela*) (Icteridae), and the Hooded Siskin (*Spinus magellanicus*) (Fringillidae) not photographed by citizen scientists. Also, nest predation by Toco Toucans can involve large bids such as the Hyacinth Macaw (Pizo *et al.* 2008), suggesting a wide spectrum of potential items to be preyed by Toco Toucan.

On the other hand, the predation of juveniles and adults outside the nests, as shown in two records of our study, appears to be uncommon. Previous studies have not reported this behavior by *Ramphastos* species (Sedgwick 2020, Winkler *et al.* 2020). As our approach has not involved observations in the field, we could not know how the predation of a juvenile and an adult Great Kiskadee occurred. However, the photograph's author informed us that numerous birds were mobbing (*sensu* Cunha & Fontenelle 2014) against the Toco Toucan in the tree canopy when the juvenile was captured. As Toco Toucans often attack nests of the Great Kiskadee (Sick 1997), future studies could examine if predation events are involved in defensive behavior against toucans. This low proportion of feeding records with juveniles and adults of other species in the diet of toucans might result, in part, in greater difficulties in preying on them when compared with the gathering of eggs and nestlings. As nests of the Great Kiskadee often appear as large objects on isolated tree canopies and poles and are built with malleable vegetal material (Sick 1997), they might be easily detected and have their content preyed by Toco Toucans.

Community scientists obtained photographs of Toco Toucans throughout the year in Brazil, as indicated by feeding records with non-avian resources. Thus, the concentration of feeding records involving avian resources between October and December indicates that Toco Toucans feed on them mainly during this 3-month period. This result is in agreement with our hypothesis – that would occur a seasonal variation in the diet of Toco Toucans along the year. We consider unlikely that this pattern would result of citizen´s preferences for gathering photographs of different food items in different periods of the year. This period coincides with the breeding season of numerous bird species in Brazil (Sick 1997); thus, the availability of eggs and nestlings explains partially their occurrence in the diet mainly in the latter months of the year.

Table 1. Values of the Chi-square test used for comparing the numbers of feeding records involving avian and non-avian resources in the diet of the Toco Toucan in Brazil, based on citizen science data (n=271) gathered in the WikiAves database in April 2022.

Month	χ^2	P value
January	8,06	0,0045
February	7,36	0,0067
March	25	<0.0001
April	21,16	<0.0001
May	27	<0.0001
June	23	<0.0001
July	32	<0.0001
August	15	<0.0001
September	17	<0.0001
October	3,24	0,0719
November	0,03	0,8618
December	0,04	0,8348

Our sample indicates that Toco Toucans feed mainly on non-avian resources during most of the year (January-September). As most of these records involved the consumption of fruits, our results agree with previous studies that reported the highly frugivorous diet of toucans (*e.g.*, Howe 1977, Remsen *et al.* 1993). On the other hand, avian and non-avian resources in their diet occurred in comparable proportions between October and December. This period coincides with the breeding season of Toco Toucans in Brazil (Short & Horne 2001, Tubelis 2022). Thus, avian resources bring nutritional benefits for breeding adults and nestlings during significant energy requirements. Sick (1997) reported that

nestlings are greedy for meat. This result of avian resources as frequent food items for three months is a piece of novel information about the diet of toucans. This occurred because our study appears to be the first to focus on avian resources, as previous studies examined mainly or only the consumption of vegetal resources (*e.g.*, Howe 1977, Ragusa-Netto 2006, 2008, 2013). As citizen scientists gather photographic records of high quality throughout the year when considering large scales (Tubelis 2023), our approach is adequate to investigate aspects of the diet of toucans. As toucans are beautiful and charismatic birds, the obtention of large amounts of their feeding records through community science is promising.

Community science projects can produce substantial amounts of data that scientists can use to research wildlife found around the world (Sullivan *et al.* 2009, Chandler e*t al.* 2017, Callaghan *et al.* 2018). WikiAves and other databases harbor millions of digital vouchers of birds found in Brazil through the contribution of thousands of community scientists. Although some recent studies have used photographic records of WikiAves to investigate aspects of the feeding ecology of Brazilian birds (*e.g.*, Teixeira *et al.* 2019, Tubelis & Wachlevski 2021, Gomes & Tubelis 2022, Costa & Tubelis 2023), the amount of information about food items available in this database remains substantially underused by researchers. Our study suggests that professional ornithologists could benefit significantly by using records on platforms such as WikiAves to increase the knowledge on aspects of the feeding ecology of birds. Although most Neotropical countries do not have an outstanding national platform, as occurs with WikiAves for Brazil, substantial amounts of data on some species can be obtained, for example, in eBird, iNaturalist and Macaulay platforms (eBird 2023, iNaturalist 2023, Macaulay Library 2023). Additionally, creating national platforms and spreading incentives relative to birdwatching and community science would improve knowledge of the national avifaunas among Neotropical countries.

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Literature cited

Antas, P.T.Z. 2004. Pantanal - guia de aves. SESC, Rio de Janeiro.

Antas, P.T.Z. & R.B. Cavalcanti. 1998. Aves comuns do planalto central. Editora Universidade de Brasília, Brasília.

Ayres, M., M.M. Ayres, D.L. Ayres & A.S. Santos. 2007. BioEstat 5.0 – Aplicações estatísticas na área das ciências biomédicas. Sociedade Civil Mamirauá/MCT-CNPq/ Conservation International, Belém.

Bela, G., T. Peltola, J.C. Young, B. Balázs, I. Arpin, G. Pataki, J. Hauck, E. Kelemen, L. Kopperoinen, A. Van Herzele, H. Keune, S. Hecker, M. Suškevičs, H.E. Roy, P. Itkonen, M. Külvik, M. László, C. Basnou, J. Pino & A. Bonn. 2016. Learning and the transformative potential of citizen science. Conservation Biology 30:990-999. https://doi.org/10. 1111/cobi.12762

Bonney, R., C.B. Cooper, J. Dickinson, S. Kelling, T. Philips, K. rosenberg & J. Shirk. 2009. Citizen science: a developing tool for expanding science knowledge and scientific literacy. BioScience 59:977-984. https:// doi.org/10.1525/bio.2009.59.11.9

Callaghan, C.T., J.M. Martin, R.E. Major, & R.T. Kingsford. 2018. Avian monitoring - comparing structured and unstructured citizen science. Wildlife Research 45:176. https://doi.org/10.1071/wr17141

Chandler, M., L. See, K. Copas, A.M.Z. Bonde, B.C. López, F. Danielsen, J.K. Legind, S. Masinde, A.J. Miller-Rushing, & G. Newman. 2017. Contribution of citizen science towards international biodiversity monitoring. Biological Conservation 213:280-294. https://doi.org/10.1016/ j.biocon.2016.09.004

Costa, F.M.O. & D.P. Tubelis. 2023. Citizen science for the study of birds in distinct biomes: diet of the Rufous-tailed Jacamar (*Galbula ruficauda*) (Aves, Galbulidae) in Brazil. International Journal of Zoology and Animal Biology 6:0000456. https://doi.org/10.23880/izab-16000456

Crozariol, M.A. & F.B.R. Gomes. 2010. Insetívoro ou Oportunista? A dieta do joão-bobo, *Nystalus chacuru* (Galbuliformes: Bucconidae). Atualidades Ornitológicas 154:4-5.

Cunha, F.C.R. & J.C.R. Fontenelle. 2014. Registros de tumulto em aves no Brasil: uma revisão usando a plataforma WikiAves. Atualidades Ornitológicas 177:46-53.

de Camargo Barbosa, K.V., P.F. Develey, M.C. Ribeiro & A.E. Jahn. 2021. The contribution of citizen science to research on migratory and urban birds in Brazil. Ornithology Research 29:1-11. https://doi.org/10.1007/ s43388-020-00031-0

de Souza, E., J. Lima-Santos, O.M. Entiauspe-Neto, M.M. dos Santos, P.R. de Moura & E. Hingst-Zaher. 2022. Ophiophagy in Brazilian birds: a contribution from a collaborative platform of citizen science. Ornithology Research 30:15-24. https://doi.org/10.1007/s43388-022-00082-5

eBird. 2023. Discover a new world of birding. https://ebird.org/home. Downloaded on 15 August 2023.

França, L.F., J. Ragusa-Netto, & L.V. Paiva. 2009. Toco Toucan (*Ramphastos toco*) frugivory and abundance in two habitats at South Pantanal. Biota Neotropica 9: bn02109022009.

Galetti, M., R. Laps & M.A. Pizo. 2000. Frugivory by toucans (Ramphastidae) at two altitudes in the Atlantic Forest of Brazil. Biotropica 32:842-850.

Gomes, T.V. & D.P. Tubelis. 2022. Knowledge of tropical birds through citizen science data: trophic habit of the Roadside Hawk (*Rupornis magnirostris*) (Aves, Accipitridae) in the Caatinga and the Atlantic Forest, Brazil. International Journal of Zoology and Animal Biology 5: 000409. https://doi.org/10.23880/izab-16000409

Guaraldo, A.C., L.M.C. Antqueves & L.T. Manica. 2019. Beyond a feeding and thermoregulatory structure: toucan's bill as a sword and pincer. Revista Brasileira de Ornitologia 27:145-148.

Howe, H.F. 1977. Bird activity and seed dispersal of a tropical wet forest tree. Ecology 58: 539.550.

iNaturalist. 2023. A community for naturalists. https://www.inaturalist.org/. Download on 15 August 2023.

Johnson, N., M.L. Druckenmiller, F. Danielsen & P.L. Pulsifer. 2021. The use of digital platforms for community-based monitoring. BioScience 71:452-466. https://doi.org/10.1093/biosci/biaa162

Macaulay Library. 2023. A scientific archive for research, education, and conservation, powered by you. https://www.macaulaylibrary.org/. Downloaded on 15 August 2023.

Matinata, B.S. & D.F. Perrella. 2020. First record of geophagy by a Ramphastidae species (Piciformes). Ornithology Research 28:174-177. https://doir.org/10.1007/s43388-020-00027-w

Pacheco, J.F., L.F. Silveira, A. Aleixo, C.E. Agne, G.A. Bencke, G.A. Bravo, G.R.R. Brito, M. Cohn-Haft, G.N. Maurício, L. N. Naka, F. Olmos, S.R. Posso, A.C. Lees, L.F. Figueiredo, E. Carrano, R.C. Guedes, E. Cesari, I. Franz, F. Schunck & V.O. Piacentini. 2021. Annotated checklist of the birds of Brazil by the Brazilian Ornithological Records Committee-Second edition. Ornithology Research 29:94-105. https://doi.org/10.1007/s43388-021-00058-x

Pizo, M.A., C.I. Donatti, N.M.R. Guedes & M. Galetti. 2008. Conservation puzzle: endangered Hyacinth Macaw depends on its nest predator for reproduction. Biological Conservation 141: 792-796.

Ragusa-Netto, J. 2006. Abundance and frugivory of the Toco Toucan (*Ramphastos toco*) in a gallery forest in Brazil´s southern Pantanal. Brazilian Journal of Biology 66: 133-142.

Ragusa-Netto, J. 2008. Toco Toucan feeding ecology and local abundance in a habitat mosaic in the Brazilian Cerrado. Ornitologia Neotropical 19:345-359.

Ragusa-Netto, J. 2010. Figs and the persistence of Toco Toucan (*Ramphastos toco*) at dry forests from western Brazil. Ornitologia Neotropical 21:59-70.

Ragusa-Netto, J. 2013. Frugivory by Toco Toucan (*Ramphastos toco*) inhabiting a mountain chain in the Brazilian Cerrado. The Wilson Journal of Ornithology 125: 616-626.

Remsen, J.V., M.A. Hyde & A. Chapman. 1993. The diets of Neotropical trogons, motmots, barbets and toucans. Condor 95:178-192.

Riley, C.M. & K.G. Smith. 1986. Flower eating by Emerald toucanets in Costa Rica. Condor 88:396-397.

Santos, A.A., J. Ragusa-Netto. 2013. Toco Toucan (*Ramphastos toco*) feeding habits at an urban area in central Brazil. Ornitologia Neotropical 24:1-13.

Sedgwick, C.W. 2020. Toco Toucan (*Ramphastos toco*), version 1.0. In: T. S. Schulenberg (ed.). Birds of the World. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.toctou1.01. Downloaded on 04 March 2023.

Short, L.L. & J.F.M. Horne. 2001. Toucans, Barbets and Honeyguides. Ramphastidae, Capitonidae and Indicatoridae. Oxford University Press, Oxford.

Sick, H. 1997. Ornitologia brasileira, uma introdução. Editora Nova Fronteira, Rio de Janeiro.

Silva, J.N. & C.S. Azevedo. 2012. *Rattus rattus* (Mammalia: Rodentia) predation by *Ramphastos vitellinus* (Aves: Ramphastidae) in Santa Teresa municipality, Espírito Santo, Brazil. Revista Brasileira de Ornitologia 20:156-157.

Skutch, A.F. 1955. Life history of the Blue-throated Toucanet. The Wilson Bulletin 56:33-151.

Skutch, A.F. 1971. Life history of the Kell-billed Toucan. Auk 88:381-424.

Stotz, D.F., J.W. Fitzpatrick, T.A. Parker III, & D.K. Moskovits. 1996. Neotropical Birds. Ecology and Conservation. The Chicago University Press, Chicago.

Sullivan, B. L., C.L. Wood, M.J. Iliff, R.E. Bonney, D. Fink & S. Kelling. 2009. eBird: a citizen-based bird observation network in the biological sciences. Biological Conservation 142:2282-2292. https://doi.org/10.1016/j.biocon.2009.05.006

Tattersall, G.J., D.V. Andrade & A.S. Abe. 2009. Heat exchange from the toucan bill reveals a controllable vascular thermal radiator. Science 325:468-470.

Teixeira, F.D., E.P. Mesquita, M.A. Ferreira & F.C. Araújo. 2019. Diet of the Ornate Hawk-Eagle (*Spizaetus ornatus*). Revista Brasileira de Ornitologia 27:31-39.

Tubelis, D.P. 2022. Breeding aspects of the Toco Toucan and the Chestnut-eared Aracari (Aves, Ramphastidae) in the Brazilian Cerrado. International Journal of Zoology and Animal Biology 5: 000358. https://doi.org/10.23880/izab-16000358

Tubelis, D.P. 2023. Spatiotemporal distribution of photographic records of Brazilian birds available in the WikiAves citizen science database. Birds 4:28-45. https://doi.org/10.3390/birds4010003

Tubelis, D.P. & I. Sazima. 2021. Nuptial gifts among Brazilian cuckoos: an outline based on citizen science. Ornithology Research 29:188-192. https://doi.org/10.1007/s43388-021-00072-z

Tubelis, D.P. & M. Wachlevski. 2021. Citizen science for the knowledge of tropical birds: the diet of the Maguari Stork (*Ciconia maguari*) in the Pampa ecoregion of southern Brazil. North-west Journal of Zoology 17: 106–110.

Turnhout, E., A. Lawrence & S. Turnhout. 2016. Citizen science networks in natural history and the collective validation of biodiversity data. Conservation Biology

30:532-539. https://doi.org/10.1111/cobi.12696WikiAves. 2023. Ramphastidae. https://www.wikiaves.com.br/midias.php?tm=f&t=b. Downloaded on 15 August 2023.

WINKLER, D.W., S.M. BILLERMAN, & I.J. LOVETTE. 2020. Toucans (Ramphastidae), version 1.0. In: S. M. Billerman, B. K. Keeney, P. G. Rodewald, & T. S. Schulenberg (eds.). Birds of the World. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.rampha1.01. Downloaded on 04 December 2022.

Appendix 1. Photographic records (n=42) with evidence of feeding activities of the Toco Toucan (*Ramphastos toco*) obtained by citizen scientists in Brazil between 2011 and 2021, with information on the date and location of records, avian resources, and bird species preyed by toucans. **Biome:** (AF) Atlantic Forest, (CE) Cerrado, (PA) Pantanal; two biomes separated by a bar (/) indicate an ecotonal region. **Food item:** (A) adult/juvenile, E (egg), N (nestling). **Preyed species:** the signs (*) and (+) indicate that the identification was provided by the author of the photograph and/or by us, respectively. Records were listed according to the food item, then by the biome, and then randomly. Records were gathered in the WikiAves database by TMAO in April 2022.