Citizen science for the knowledge of tropical birds: the diet of the Maguari Stork (*Ciconia maguari*) in the Pampa ecoregion of southern Brazil

Dárius Pukenis TUBELIS[1*] and Milena WACHLEVSKI[2]

1. Department of Biosciences, Universidade Federal Rural do Semi-Árido, Mossoró, RN, 59625-900, Brazil.
2. Laboratory of Animal Behavior and Ecology, Department of Biosciences, Universidade
Federal Rural do Semi-Árido, Mossoró, RN, 59625-900, Brazil.
* Corresponding author, D.P. Tubelis, E-mail: darius.tubelis@gmail.com

Abstract. The Maguari Stork (*Ciconia maguari*) occurs extensively in South America where it inhabits mainly wetlands. Despite being common in some regions, information on several aspects of its ecology is lacking. The objective of this study was to investigate the diet of Maguari Storks in the Pampa ecoregion of southern Brazil using citizen science. A compilation of records of foraging birds was done in two on-line databases - WikiAves and e-Bird Brasil. A total of 36 records, obtained by citizens between 2008 and 2020, reported storks holding preys with their bills. The most frequent food item was the *muçum* fish (*Synbranchus marmoratus*), representing 39% of the preys. Squamate reptiles and anuran amphibians comprised 33% and 19% of the food items, respectively. Most preys had a serpentiform body shape, being represented mainly by *muçum* and snakes. This study suggests that our knowledge regarding the natural history of Brazilian birds can increase through citizen science.

Key words: bird, Ciconiidae, citizen science, feeding ecology, humid area.

Introduction

Storks comprise 19 species that usually hunt in humid areas, using tactile foraging techniques to gather their food items, vertebrates and invertebrates (Winkler et al. 2020). Most information on their feeding ecology results from studies on their foraging habits and diet, especially for species of the genus *Ciconia* in Europe (e.g. Moreno-Opo et al. 2011, Milchev et al. 2013, Tryjanowski et al. 2018) and Asia (e.g. Zhou et al. 2013, del Hoyo et al. 2020). On the other hand, lesser information is available for stork species occurring in the southern hemisphere (Winkler et al. 2020).

The Maguari Stork (*Ciconia maguari*) is one of the three species of the family Ciconiidae that inhabits South America (Remsen et al. 2020). It is widely distributed and considered a Least Concern species, as a stable population trend was observed (IUCN 2020, Schulenberg 2020). Maguari storks use a wide range of freshwater wetlands, including native grasslands, marshes, small rivers, lagoons, and exotic pastures (Kahl 1971, Gimenes & Anjos 2011, Elliott et al. 2020a, BirdLife International 2021). They can be found solitary, in pairs or in aggregations with up to dozens of individuals (Antas 2004, Mata et al. 2006, Tavares & Siciliano 2013).

According to general references, Maguari Storks usually forage in shallow water (Elliott et al. 2020a, Schulenberg 2020). A detailed 5-year study based on more than 300 samples conducted in the Venezuelan Llanos has shown that food items fed to nestlings are mainly amphibians, tadpoles and fish (Thomas 1984). For this same region, Thomas (1986) reported a bolus regurgitated by an adult consisting mainly of aquatic rodents. In Brazil, the analysis of the stomach content of a road-killed adult Maguari Stork found in the Pampa eco-region has shown the importance of elongated preys in their diet, especially Amphisbaenians (Tozetti et al. 2011). Further, major books provided qualitative information, reporting that Maguari Storks feed mainly on aquatic invertebrates, amphibians, aquatic snakes and fish (Sick 1997), while their major preys in the Pantanal wetland are amphibians (Antas 2004).

Information about the diet of adult Maguari Storks has been provided in general references as qualitative data (Elliott et al. 2020a, Schulenberg 2020). Except a detailed study of nestling feeding (Thomas 1984), quantitative results involving food items of adults have been shown only occasionally, based on a few samples, and were restricted to a small number of localities. This scarcity of studies about Maguari Storks might result, in part, from their behavior. This is because birds might fly away as the observer approaches (Tryjanowski et al. 2020), thus making the obtention of information even more difficult. We believed that this paucity of information about the diet of adults could be reduced through the use of data gathered by birdwatchers. This is because citizen science has been proved to contribute important data for the knowledge and conservation of birds worldwide (Sullivan et al. 2009, Sekercioglu et al. 2012, Gorta et al. 2019, Neate-Clegga et al. 2020), similarly to the use of social media in studies of animal behavior (e.g. Dylewski et al. 2017). We assumed that the use of data from citizen science could help to examine the diet of adult Maguari Storks considering samples obtained through both large spatial and temporal scales.

This study aimed to examine the diet of Maguari Storks in the Pampa ecoregion of Rio Grande do Sul state, in southern Brazil, through the use of data provided by citizen science. Besides identifying the food items, we hypothesized that serpentiform preys would be frequent in their diet, as animals with this form have been identified as important food items by Tozetti et al. (2011) in this Brazilian region. Results were discussed in terms of the diets of storks in South America and *Ciconia* species worldwide.

Material and Methods

Study Area

Rio Grande do Sul state, in southern Brazil, is covered by two ecoregions: the Atlantic Forest and the Pampa (IBGE 2004) (Figure 1). The Pampa occupies 63% of the area of Rio Grande do Sul state, which was originally covered by natural grasslands (IBGE 2004). These grass-
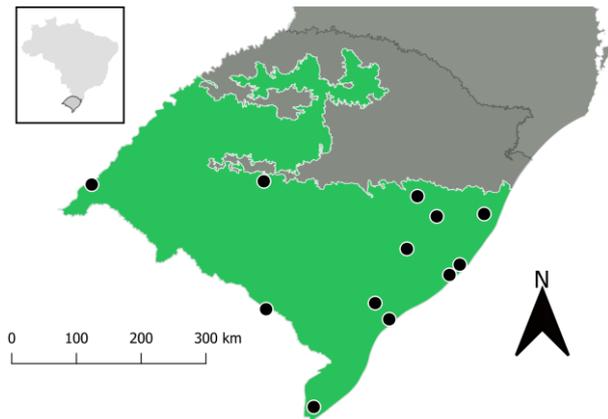
Figure 1 Geographic distribution of records of feeding Maguari Storks (*Ciconia maguari*) in 12 municipalities (black dots) in the Pampa eco-region (green), Rio Grande do Sul state, southern Brazil. The Rio Grande do Sul state is mainly covered by the Pampa biome (green) and the Atlantic forest (gray). Records (n = 36) were obtained by citizens between 2008 and 2020, and gathered in the WikiAves and e-Bird databases in March 2020.

Table 1. Prey items (n = 36) of the Maguari Stork (*Ciconia maguari*) recorded by citizens between 2008 and 2020 in 12 municipalities located in the Pampa ecoregion, in southern Brazil. Records were gathered in the WikiAves and e-Bird databases in March 2020.

Taxon	Body Format	Records
Actinopterygii		
Characiformes		
Erythrinidae		
Hoplias cf. *malabaricus*	Non-serpentiform	1
Synbranchiformes		
Synbranchidae		
Synbranchus marmoratus Bloch, 1795	Serpentiform	14
Amphibia Anura		
Hylidae		
Pseudis sp.	Non-serpentiform	1
Leptodactylidae		
Leptodactylus sp.	Non-serpentiform	1
Unidentified	Non-serpentiform	5
Reptilia Squamata Serpentes		
Colubridae		
Unidentified	Serpentiform	1
Dipsadidae		
Helicops carinicaudus (Wied, 1824)	Serpentiform	2
Pseudoboini unidentified	Serpentiform	1
Xenodontinae unidentified	Serpentiform	1
Unidentified snakes	Serpentiform	7
Unidentified animals	Non-serpentiform	2
Total		36

lands are phytogeographically distinct from those found in central Brazil, being similar to grasslands occurring in Uruguay (Andrade et al. 2019). The Pampa's climate is classified according to Köppen as a subtropical climate without a dry season, and with hot or temperate summers; mean annual precipitation ranges between 1,000 mm and 2,200 mm, while mean annual temperatures range from 11 °C to 20 °C (Alvares et al. 2013).

Data collection
Records (photographs) obtained in this study were gathered from the e-Bird (https://ebird.org/brasil/home) and WikiAves (https://www.wikiaves.com.br) databases between 18 and 23 March 2020. All photographs of Maguari Storks taken in Rio Grande do Sul were examined. Then, we selected all records showing evidence of feeding events by these storks in the Pampa ecoregion. When two or more photographs of foraging storks were taken on the same day in a given municipality, only one of them was randomly selected to avoid repetition of the same feeding event. However, these replicates were considered for the identification of food items, as they usually showed preys in different positions.

Data Analysis
Based on their body shape, preys were classified into two categories: 1) animals with an elongated body, lacking developed members such as legs and arms (here called "serpentiform"); 2) animals with a non-elongated body, having poorly or well-developed members such as fins, legs or arms (here called "non-serpentiform"). The numbers of food items in the two body shape categories were compared using the Chi-square test, performed in BioEstat 5.3 (Ayres et al. 2007). A level of significance of 5% was considered in this study.

We identified the taxonomic of preys recorded by diagnosis characters and, at the lowest possible taxonomic level. The taxonomic nomenclature follows Fricke et al. (2020) for ray-finned fishes, Segalla et al. (2018) for amphibians, and Costa & Bérnils (2018) for reptiles.

Results

Information on a total of 36 feeding events of *C. maguari* in the Pampa ecoregion of Brazil were obtained from citizen data (Table 1, Fig. 1). These events were recorded between 2008 and 2020 in humid areas and grasslands located in 12 munic-ipal-ities, of which Mostardas (10 records), Rio Grande (8) and Tavares (8) had the largest numbers of records. Most preys (94.4%) were vertebrates, and comprised ray-finned fishes Actinopterygii (41.7%), reptiles Squamata (33.3%) and, amphibians Anura (19.4%) (Table 1). The other two (5.6%) food items could not be identified, and might be invertebrates or vertebrates.

Fish preys mainly comprised of *Synbranchus marmoratus* (Figure 2A), representing 38.9% of the total prey numbers. Only one more fish was consumed, *Hoplias* cf. *malabaricus* (Figure 2B). Only two frogs consumed could be identified to the genus level, *Leptodactylus* sp. and *Pseudis* sp., comprising 28.6% of all anurans (n = 7 records) (Figure 2C). All reptiles preyed were Serpentes (Squamata). Dipsadidae represented 11.1% of the snakes recorded. Two individuals of this family could be identified to the species level, both *Helicops carinicaudus* (Figure 2D). The other serpents comprised one individual of Colubridae (8.3%), and 58.3% of snakes could not be identified (Table 1).

The vast majority of food items consumed (n = 26; 72%) had a serpentiform body shape, while a minor portion (n = 10; 28%) corresponded to non-serpentiform animals; this difference was significant (χ^2 = 7.111, df = 1; P = 0.008). Most of the non-serpentiforms (70%) were amphibians, fish represented only 10%; and the remaining 20% could not be identified, possibly vertebrates or invertebrates. In relation to serpentiform preys, about 54% of them were represented by the fish *Synbranchus marmoratus* and 46% were Squamata.

Discussion

Diet of Maguari Storks
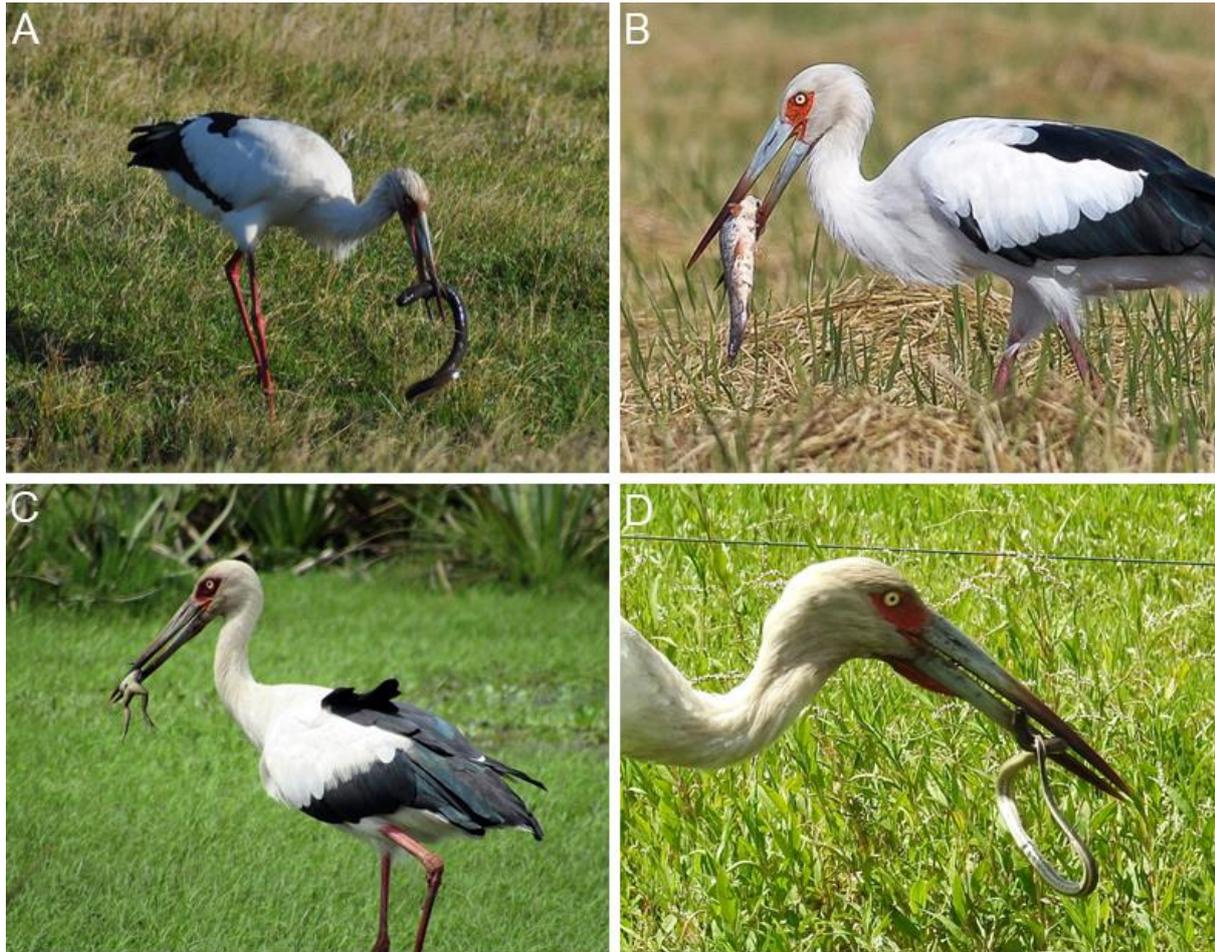The predominance of fish and Serpentes among food items

Figure 2 Prey items of Maguari Storks (*Ciconia maguari*) recorded by citizens in the Pampa ecoregion, Rio Grande do Sul state, southern Brazil: a serpentine muçum fish (*Synbranchus marmoratus*) at Rio Grande municipality (photo by Vinícius Soares) (A); a fish (*Hoplias* cf. *malabaricus*) at Mostardas municipality (photo by José Luiz Kachimareck) (B); an anuran at Rio Grande municipality (photo by Carlos Eduardo Simões da Silva) (C); a snake (*Helicops carinicaudus*) at Aceguá municipality (photo by Laudelino Moura Junior) (D).

observed in our study differs considerably from the relatively high quantities of amphibians and tadpoles consumed by the nestlings (Thomas 1984). Selection of such smaller prey items than elongated fish and Serpentes by adults to feed the nestlings may lead to these differences.

Our results also differ from those obtained by Thomas (1986) in Venezuela, who reported a bolus regurgitated by an adult mostly containing aquatic rodents. No mammals have been detected in the Pampa ecoregion as preys of Maguari Storks in this study. Although we recorded a wide prey diversity for Maguari Storks in the Pampa ecoregion, we did not document any amphisbaenians. This contrasts with the study of a single individual run over in the same ecoregion, which found 20 specimens of this reptile in the examined stomach (Tozetti et al. 2011). This indicates that the composition of food items of this stork is even more diverse than is currently known. These remarkable differences might have occurred, in part, because previous studies were based on the stomach content from one stork individual, and thus might represent the finding of a place having numerous rodent and amphibaenian preys. On the other hand, our study involved prey consumed by Maguari Stork through extensive spatial range and long temporal scale.

Further, several books provided qualitative information,

reporting that Maguari Storks feed mainly on aquatic invertebrates, amphibians, aquatic snakes and fish in Brazil (Sick 1997). Also, amphibians were considered their major preys in the Pantanal wetland (Antas 2004). Our results contrast with theirs, but are similar with those of Tozetti et al. (2011) as Serpentes represented about 33% of the prey items in our study, and approximately 25% of the volume and mass of stomach content in their study.

Also, the consumption of plant matter by Maguari Storks as reported by Sick (1997) has not been observed in our study. The opportunistic foraging tactics of Maguari Storks (Elliott et al. 2020a), and temporal and spatial variation in prey availability might contribute to this considerable variation in the proportion of distinct food items in the diets of Maguari Storks inhabiting different regions.

Diet of storks in South America
The diets of the other South American Ciconiids, the Jabiru (*Jabiru mycteria*) and the Wood Stork (*Mycteria americana*), have been investigated in a few studies. In the Venezuelan Llanos, the diet of Wood Storks comprised mainly fish, represented by several species (Gonzalez 1997). This dominance of fish preys in the diet of Wood Storks nearly reached 100% during the dry season; in the rainy season, fish represented

about 50% of the food items, while invertebrates (crabs and insects) corresponded together to near 45% of the captured preys (Gonzalez 1997). In the Brazilian Pantanal wetland, Wood Storks also consumed fish, but no species identification was provided (Antas 2004). Thus, in comparison with the Wood Stork, the diet of the Maguari Stork in the Pampa appears to rely less on fish, as it comprised of only about 40% of the food items. Other major difference between the diet of these two stork species is the frequent consumption of crabs and insects by Wood Storks in the Llanos (Gonzalez 1997), in fact not detected for Maguari Storks in our study.

In the Brazilian Pantanal wetland, Sick (1997) reported the consumption of fish, snakes, small alligators and turtles by the Jabiru Stork, but has not quantified the food items. Also, Antas (2004) reported that the Jabiru feeds mainly on fish, of which *Synbranchus marmoratus* is the most frequent prey, as occurred also in our study. However, the fish *Hoplias malabaricus* was considered a frequent food item in the Pantanal (Antas 2004), but was only eventually recorded in our sample for Maguari Storks. Other major difference was that the frequent consumption of snakes and amphibians observed in the Pampa has not been reported for the Jabiru (Antas 2004). For Jabirus inhabiting the Llanos, most of the diet is fish, including *Synbranchus marmoratus* and *Hoplias malabaricus* in the dry season; on other hand, eels, amphibians and crabs are more common preys during the rainy season (Elliott et al. 2020e). As a consequence, both stork species have fish as their major food items, but the frequency of consumption of snakes is higher for Maguari Storks than for Jabirus. Thus, the available information suggests the occurrence of a dietary niche segregation (sensu Mansor et al. 2018) among the three South American stork species.

Ciconia species and serpentiform preys

More than 70% of the food items of Maguari Storks in the Pampa had a serpentiform body shape, and included the *muçum* fish and a range of Serpentes species in comparable proportions. Similarly, elongated preys accounted for about 75% of the total volume and mass of preys found in the stomach of a Maguari Stork road-killed in the Pampa; in this case, an Amphisbaenian species (*Amphisbaena trachura*) and five species of snakes comprised these serpentiform preys (Tozetti et al. 2011).

A diet based mainly on serpentiform preys, as observed in our study, appears not to occur for most of the other six *Ciconia* species inhabiting other regions. For example, the widely distributed Black Stork *Ciconia nigra* relies mostly on fish, while non-serpentiform preys are not major food items (revised by Elliott et al. 2020b). Within a similar geographic distribution, the White Stork *Ciconia ciconia* is considered opportunist, as they prey on a wide range of large invertebrates and small vertebrates, and carrion; a preference for serpentiform animals has not been observed (revised by Elliott et al. 2020d). In Africa, the Abdim's Stork *Ciconia abdimii* consumes mainly large insects, including caterpillars, that are much smaller than the serpentiform preys recorded in our study (revised by Elliott et al. 2020c). In Africa and Asia, the Woolly-necked Stork *Ciconia episcopus* feeds mainly on fish, frogs, toads and invertebrates, while snakes are not major food items (revised by del Hoyo et al. 2020). In Indonesia, the poorly known Storm's Stork *Ciconia stormi* apparently feeds mainly on fish (revised by Elliott et al. 2020f). On the other hand, the Oriental Stork *Ciconia boyciana* feeds on a variety of vertebrates and invertebrates, and mostly on the Weatherfish *Misgurnus fossilis*, a serpentiform fish that inhabits fresh water lakes and marshes (revised by Elliott et al. 2020g). This result can be considered as similar to those observed for Maguari Storks in our study. The preference for serpentiform animals might bring benefits related to foraging efficiency and ingestion.

Data from citizen science

Citizen science can provide data for scientific studies through the contribution of thousands of volunteers in numerous regions (Sullivan et al. 2009, Chandler et al. 2017, Callaghan et al. 2018), as also occurs with information available in social media (e.g. Dylewaski et al. 2017). Databases such as those of e-Bird Brasil and WikiAves harbor millions of records of Brazilian birds, and the use of this extraordinary information has great potential for increase. We encourage Brazilian ornithologists to make a greater use of data gathered by citizens, to improve the knowledge on the natural history of tropical birds.

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