

Breeding biology of the Maguari Stork *Ciconia maguari* (Aves, Ciconiidae) in the Pampa, and an outline in other Brazilian biomes

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Abstract. The Maguari Stork (*Ciconia maguari*) is one of the three species of the family Ciconiidae that occur in South America. Despite abundant in landscapes dominated by wetlands and grasslands, detailed studies on its biology are scarce. This study is aimed at investigating aspects of the breeding of Maguari Storks in Brazil. Photographic records were searched in the WikiAves database. A total of 65 records, obtained by citizens along 13 years in 32 municipalities, showed evidences of breeding activities in Brazil. Most (86%) of these records were gathered in the Pampa biome, in southern Brazil. Nests were large platforms and contained 1-3 young. Nests built on the ground were in grasslands or reed patches. Those built on shrubs were at boundaries between lakes and grasslands, and were often in colonial nesting sites with egrets and herons. Incubation occurred between July and November, and nestlings were found between August and December. Juveniles able to fly were recorded between late October and February. Most records of breeding activities were obtained at sites located < 300 m above sea level. As the Maguari Stork is a conspicuous and charismatic species, its conservation could substantially benefit from the awareness of landowners to promote eco-tourism in their properties, attracting birdwatchers. For this, it should be ensured the integrity of grasslands, marshes, and lakes with microhabitats often used for nesting (woody plants and reed patches).

Keywords. Aves; Citizen science; Humid area; Nest; Reproduction.

INTRODUCTION

Three species of Ciconiiformes and Ciconiidae are found in South America: the Maguari Stork *Ciconia maguari* Gmelin, 1789, the Jabiru *Jabiru mycteria* Lichtenstein, 1819, and the Wood Stork *Mycteria americana* Linnaeus, 1758 (Remsen *et al.*, 2020). They are large wading birds with long legs, neck and bill, plumage mostly white, and with a less extensive black (Hancock *et al.*, 1992; Mata *et al.*, 2006; Winkler *et al.*, 2020).

The Maguari Stork occurs extensively in northern and southern South America, mainly east of the Andes (van Dort, 2022), and is considered a Least Concern species due to its stable population trend (BirdLife International, 2021). They are found in a wide range of habitats, including wetlands, marshes, swamps, lagoons, grasslands, pastures, and grassy fields (Gimenes & Anjos, 2011; van Dort, 2022). They occur solitary, in pairs or in aggregations with tens of individuals (Belton,

1984; Antas, 2004; Tavares & Siciliano, 2013). Maguari Storks usually feed on vertebrates such as frogs, fish and snakes, with the eventual consumption of aquatic invertebrates (Thomas, 1984; Sick, 1997; van Dort, 2022). In the Brazilian Pampa, they feed mainly on serpentiform prey, including amphibia, eels and snakes (Tozetti *et al.*, 2011; Tubelis & Wachlewski, 2021).

The breeding biology of Maguari Storks was investigated in details by three studies in the Llanos of Venezuela (Thomas, 1984, 1986; González, 1998), while there is some brief information available in major publications regarding the Brazilian avifauna (*e.g.*, Sick, 1997), or biomes such as the Pampa (Belton, 1984) and the Pantanal (Antas, 2004). Further, some information is available for Argentina or in reviews dealing specifically with the breeding biology of storks (*e.g.*, Kahl, 1971; Hancock *et al.*, 1992; van Dort, 2022).

Maguari Stork nests are round platforms built on marshes, grasslands, floating vegetation, and

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woody vegetation, and can occur singly or in colonies (Kahl, 1971; Thomas, 1984, 1986; González, 1998; Antas, 2004). Clutch size is usually three eggs, and nests can have up to 4 eggs; incubation lasts for about 30 days (Kahl, 1971; Thomas, 1986; González, 1998). Nestlings have an initial white plumage, and then become blackish (Sick, 1997; Antas, 2004; van Dort, 2022). Young leave their nest at the age of 59-74 days (González, 1998). When juveniles age about three months, their plumage looks like that of the adults (Thomas, 1984). The breeding season of the Maguari Stork occurs mainly between June and December in Venezuela and Argentina (Kahl, 1971; Thomas, 1984, 1986; González, 1998). Information on the breeding season in Brazil is apparently restricted to the Pampa biome, in southern Brazil, where nests with eggs and young were found between August and October (Belton, 1984).

Overall, the breeding of Maguari Storks has not been examined in detail in several South American regions. This study aimed to investigate breeding aspects of the Maguari Stork in Brazil. We considered that it would be possible through the use of citizen science data, as observers gather photographic records of birds throughout the nation (de Camargo Barbosa *et al.*, 2021; WikiAves, 2022). Besides assessing the distribution of records with evidence of breeding activities (here called “breeding

records”), we aimed to investigate its breeding biology in detail in biomes with substantial amounts of data. We examined the seasonal occurrence of incubating adults, and young at different developmental stages. Aspects of nest structure, content and position in the habitat also were investigated. Further, we examined the distribution of records in relation to altitude, as these storks have often been found in lowlands, up to 700 m a.s.l. (Belton, 1984; Stotz *et al.*, 1996; Sick, 1997). Results were discussed in terms of the breeding biology of Maguari Storks in South America.

MATERIAL AND METHODS

Study Area

The Pampa is restricted to the state of Rio Grande do Sul, where it occupies 176,000 km², mainly on its central and southern portions (ICMBio, 2022; MMA, 2022). This extension corresponds to 63% of this state and to 2% of the Brazilian territory. Altitudinal variation is not remarkable, and landscapes are usually at < 600 m above sea level (Alvarez *et al.*, 2013). The Pampa lies in the Humid Sub-Tropical Zone; the Climate is *Cfa*, according to the



Figure 1. Nestlings and black young of the Maguari Stork (*Ciconia maguari*) recorded by citizens in the Pampa, Rio Grande do Sul state, southern Brazil. (A) a nestling with black and white downy plumage at Quaraí (photo by Cícero Corrêa); (B) nestlings with black downy plumage at Dom Pedrito (photo by Diego Oliveira); (C) two black young in a nest at Cachoeira do Sul (photo by Remo Farina Junior); (D) a black young at Quaraí (photo by Cícero Corrêa). Records were gathered in the WikiAves database, except for B.

Köppen's classification. This means an oceanic climate, without dry season, and with hot summer (Alvarez *et al.*, 2013). Coldest months occur from May to August, when temperatures usually vary between -3°C and 18°C. The summer, from December to February, has temperatures above 22°C. The mean annual temperatures range between 16°C and 20°C, while the annual rainfall often varies between 1,300 and 1,900 mm (Alvarez *et al.*, 2013).

Pampa's landscapes are originally dominated by native grasslands, that have been historically modified by exotic pastures, agriculture and exotic forests (Echer *et al.*, 2015). Humid areas, such as marshes, channels, wet grasslands, ponds and other water bodies cover about 10% of the biome (Cunha *et al.*, 2015; Echer *et al.*, 2015). Humid areas with permanent water can have emergent herbaceous or woody plants and are regionally known as *banhados vegetados* ("vegetated swamps"; Guadagnin, 2015). Less than 30% of the native landscapes remain moderately modified and only 3% of the Pampa extension lies within conservation units (ICMBio, 2022; MMA, 2022).

Data collection and analysis

We included in this study photographic records of the Maguari Stork obtained in the WikiAves database (<https://www.wikiaves.com.br>) through a search conducted between 01 and 08 June 2020. This Brazilian database currently harbors about 4,270,000 records of 1,957 species, and counts with contributions of near 43,000 citizens. This record compilation comprised all photographs of the species obtained in Brazil, involving or not evidences of breeding activities. Records reporting breeding activities were those involving courtship behavior, copulation, nest building, nests, eggs and/or young at variable stages of development, and were here called "breeding records".

When two or more photographs were obtained by citizens in a given municipality in a given year, we verified if they were replicates of the same bird or nest by examining details of plumage, nest structure, and surrounding habitat. When replicates occurred, only one was selected, and included in this study. We contacted authors to ask about the position of nests in the habitat. We received permission from authors to include photographs of their authorship in this paper.

Young were grouped into five categories of age/development: (1) "nestlings", *i.e.*, small storks found in the nests, with a white or black downy plumage, a very short and black bill, and a yellow gular patch (Fig. 1A, B); (2) "black young", *i.e.*, birds found in or outside nests, with bill and length about half of adult bills, with black downy plumage, and orange or black gular patch (Fig. 1C, D); (3) "black juveniles", *i.e.*, young with the size comparable to that of the adults, but with a black head with some small white patches, a black neck, black breast and belly, and a back mostly black (Fig. 2A, B); (4) "intermediate juveniles", *i.e.*, young with the size comparable to that of adults, head and neck with a mix of whitish and dark colors in comparable proportions, and breast and belly mostly black but with some white patches (Fig. 2C, D);

(5) "white juveniles", *i.e.*, young with the size comparable to that of adults, but with a nearly totally white head and neck, while the belly, breast and back were white with some black patches (Fig. 2E, F).

These five categories based on size, format, and color of birds were adopted to avoid dealing only with a broad "young" category. With these categories, we expected to obtain more refined information about the seasonal occurrence of young in distinct phases of development, besides knowing the developmental stage in which they keep relying on the nest, and become able to fly. The seasonal distribution of records of young, or incubating adults, was examined by dividing each month in three periods: I = days 1-10; II = days 11-20; and III = days 21-31. Breeding records also were grouped into six altitudinal categories: 0-100 m, 100-200 m, 200-300 m, 300-400 m, 400-500 m, and > 500 m, according to the information on their municipalities (Cidade Brasil, 2022). Their altitudinal distribution was examined through the percentage of breeding records obtained in each altitudinal category.

RESULTS

Maguari Storks in Brazil

A total of 2,657 photographic records of the Maguari Stork were gathered by citizens in Brazil, and included in this study. Most of them (~57%) were obtained in the Pampa, while the Atlantic Forest and the Pantanal had intermediate numbers (~10-20%). Fewer photographic records occurred in the Cerrado and Amazonia, and none were obtained in the Caatinga (Table 1). Of the total, 65 (2.4%) were breeding records. Considering only them, the dominance of photographs obtained in the Pampa became even greater (~86%). As other biomes had three or less (< 5%) breeding records (Table 1, Appendix), this study focused on Maguari Storks found in the Pampa.

Maguari Storks in the Pampa

Breeding season

The 56 breeding records of Maguari Storks were obtained in 24 municipalities located in the Pampa

Table 1. Number of photographic records of the Maguari Stork (*Ciconia maguari*) obtained by citizens in the six Brazilian biomes between 2007 and 2019. Breeding records are those with evidence of breeding activities. Data was gathered in the WikiAves database in June 2020.

Biome/Brazil	Total	Breeding records
Pampa	1511 (56.9%)	56 (86.2%)
Atlantic Forest	565 (21.3%)	3 (4.6%)
Pantanal	306 (11.5%)	3 (4.6%)
Cerrado	144 (5.4%)	1 (1.5%)
Amazonia	131 (4.9%)	2 (3.1%)
Caatinga	0 (0%)	0 (0%)
Brazil	2657	65

(Appendix). They occurred between mid-July and mid-February, and involved a range of breeding activities. Copulation was recorded only once in early October. Nine photographs of incubating storks were taken between mid-July and early November, and were more frequent between late August and mid-October (Fig. 3; Appendix).

Further, six breeding records were of nestlings (Fig. 3; Appendix). They occurred between early August and late

December, with a peak between mid-September and mid-October. The record obtained in December 2015 (WA1958589) is relatively delayed due to the destruction of an active nest by water a few weeks earlier in the breeding season of a pair (Cícero Corrêa, *pers. comm.*). Black young were documented in seven breeding records obtained between early November and late January (Fig. 3).

Thirty-two breeding records were of juveniles (Appendix). They were recorded between late September

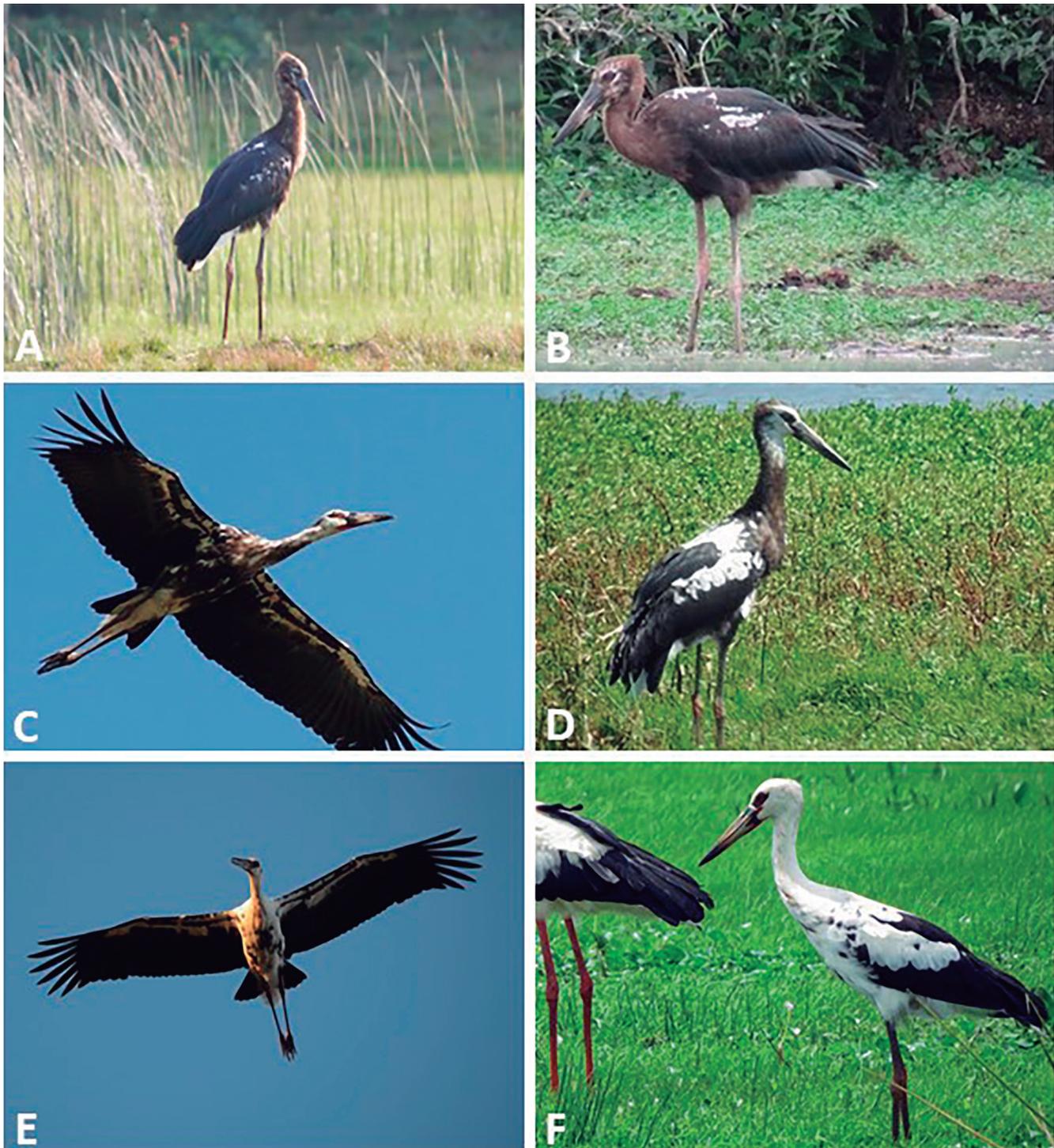


Figure 2. Juveniles of the Maguari Stork (*Ciconia maguari*) recorded by citizens in the Pampa, Rio Grande do Sul state, southern Brazil. (A) a black juvenile at Dom Pedrito (photo by Diego Oliveira); (B) a black juvenile at Dilermando de Aguiar (photo by Thiago Weigert); (C) an intermediate juvenile flying at Mostardas (photo by Clécio Gomides); (D) an intermediate juvenile at Caçapava do Sul (photo by Guilherme Durante); (E) a white juvenile flying at Júlio de Castilhos (photo by Firmino Costa); (F) a white juvenile at Rio Grande (photo by Rafael Weber). Records were gathered in the WikiAves database, except for A and B.

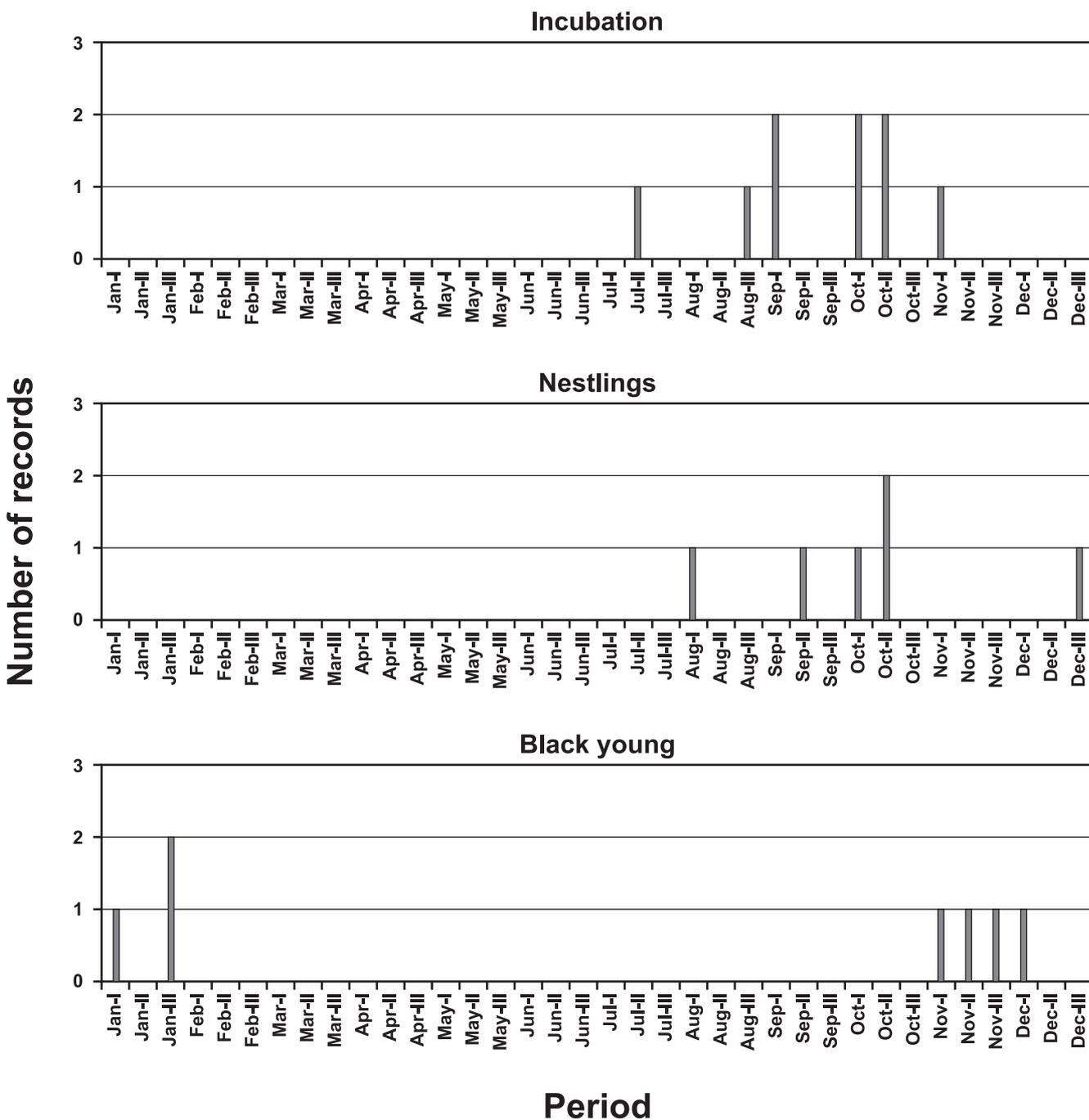


Figure 3. Seasonal occurrence of records of the Maguari Stork (*Ciconia maguari*) involving incubation, nestlings, and black young in the Pampa biome, in Rio Grande do Sul state, southern Brazil. Records were obtained by citizens and gathered in the WikiAves database in June 2020. Arabic numerals after each month represent 10-days long periods – (I): days 1-10, (II): days 11-20, (III): days 21-31 of each month.

and mid-February, being more numerous between mid-November and late December (Fig. 4). Breeding records of black juveniles ($n = 9$) occurred between late September and mid-December, and were more numerous in December. Breeding records of intermediate juveniles ($n = 17$) were obtained between late October and mid-February, and more common in November and December. The six breeding records of white juveniles occurred from early December to early February. As a consequence, December was the only month of the year in which the three phases of juveniles were found in the Pampa (Fig. 4; Appendix).

Nests

A total of 23 nests were found by citizens in the Pampa region. Fifteen (65%) of them were built on the ground, of which eight (53%) were in reed patches, while seven (47%) were in grassland patches (Fig. 5, Appendix). These nests built on the ground were large and isolated platforms. On the other hand, eight (35%) nests were built on tall shrubs. One of them occurred singly during the incubation period (Fig. 5E), while others were in colonial nesting sites, and had nestlings, black young and black juveniles. They were among nests of Great Egrets

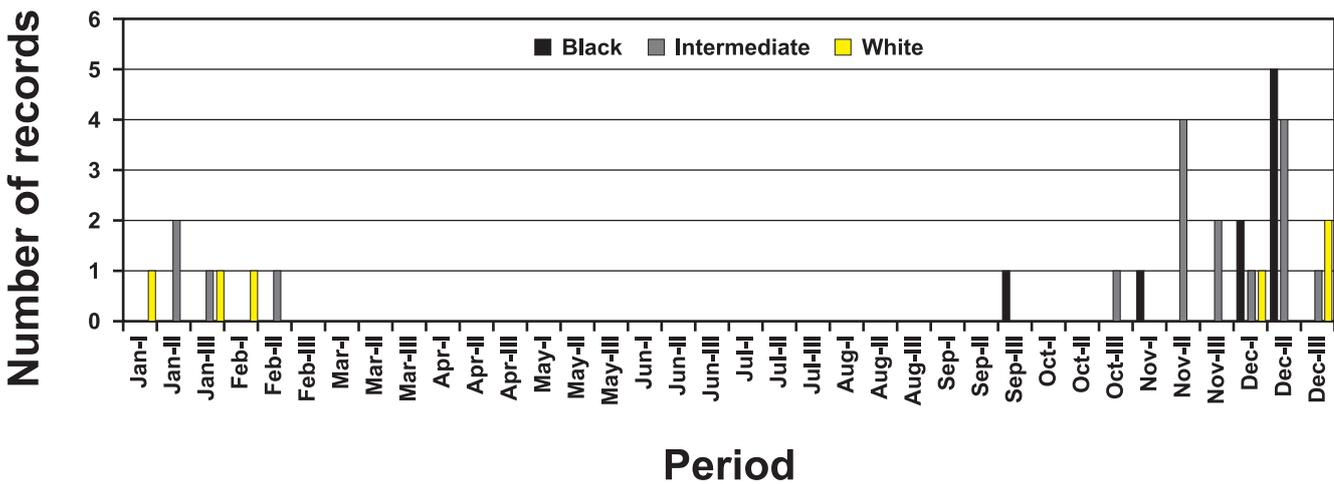


Figure 4. Seasonal occurrence of records of the Maguari Stork (*Ciconia maguari*) involving juveniles in the Pampa biome, in Rio Grande do Sul state, southern Brazil. Records were obtained by citizens and gathered in the WikiAves database in June 2020. Arabic numerals after each month represent 10-days long periods – (I):– days 1-10, (II): days 11-20, (III): days 21-31 of each month.

Ardea alba Linnaeus, 1758 and Cocoi Herons *Ardea cocoi* Linnaeus, 1766 (Fig. 6).

These tall shrubs used as substratum for nests were located at boundaries between grasslands and artificial lakes (Fig. 6D; Appendix). Two species could be identified. One nest was on higher parts of a *Phyllanthus sellowianus* (Klotzsch) Müll.Arg., Phyllanthaceae (WA3115322). Another nest was built on a *Sebastiania schottiana* (Müll. Arg.) Müll.Arg., Euphorbiaceae (WA1460435). Both species are known regionally as *sarandis*, and were estimated as 2.5 m in height.

No nests had exposed eggs. Two nests (9%) were empty – one was recorded during the nest building phase, and the other was found after being destroyed by water. Most nests ($n = 12$, 52%) had variable numbers of young, while nine (39%) nests had an incubating adult. Six nests had 1-3 nestlings, and half of them had two nestlings. Four nests had three black young each, while a nest had only two. A nest had three black juveniles (Appendix).

Altitudinal variation

Municipalities with breeding records of Maguari Storks were mainly concentrated in the central portion of the Pampa (Fig. 7). Other sites with breeding records were spottily distributed along its western, southern and eastern limits. The proportions of breeding records in each altitudinal category were: 0-100 m (27%), 100-200 m (43%), 200-300 m (21%), 300-400 m (2%), 400-500 m (3%) and > 500 m (4%). As a consequence, 91% of the breeding records occurred at 0-300 m a.s.l. municipalities, with 47% of these records obtained at 100-200 m a.s.l. sites (Appendix).

DISCUSSION

Records in Brazil

The 65 records obtained by citizens along 13 years represent the largest sampling of breeding activities of

Maguari Storks in Brazil. The information generated by them was substantially more detailed than that provided by previous studies in the Brazilian territory (e.g., Belton, 1984; Antas, 2004; Moura, 2009). The small proportion (2.4%) of breeding records within the whole set of photographic records of the species indicates that gathering further records by citizens or scientists over large spatial scales will be a hard task. Reinforcing this is the approach by Moura (2009) in the Pampa, that involved searches for nests through a range of interviews, questionnaires, and other communication actions by contacting citizens, conservationists and scientists.

The concentration of breeding records of the Maguari Stork in the Pampa might represent a combination of its high abundance and intense birdwatching in this biome. This is because Sick (1997) pointed out its outstanding numbers in the Pampa, and Rio Grande do Sul is a region visited by numerous birdwatchers (de Camargo Barbosa *et al.*, 2021). Unexpectedly, relatively few records have been obtained by citizens in the Pantanal wetland, where the species occurs in abundance (Sick, 1997; Antas, 2004). However, Antas (2004) had informed that known breeding sites are rare in the Pantanal. Probably, characteristics of the Pantanal, such as difficulties relating to transport, contribute to the relatively low number of records obtained in this region. Further investigations in the Pantanal and other biomes are welcome to identify sites where Maguari Storks breed.

Breeding season

In Venezuela, Kahl (1971) reported estimated periods of egg-laying for July-September. Belton (1984) reported the occurrence of nests with eggs and young between August and October in the Brazilian Pampa. Also, Kahl (1971) found nests of Maguari Storks with eggs and nestlings in August and September in the Corrientes province, Argentina. Maguari Storks laid eggs between May and November in the Venezuelan Llanos (Thomas, 1984). The breeding season lasted about four months, was

influenced by rainfall, and inexperienced storks led to delays in the beginning of breeding activities (Thomas, 1986). As a result, it was observed substantial variation in the breeding phenology among years in the Llanos of Venezuela (Thomas, 1984, 1986).

Thus, the recording of incubation in five months of the year (July-November) in the Pampa might result, in part, of the 13-year period of data acquisition by citizens. Also, the destruction of a nest, as observed in this study, can lead to delayed records of breeding records due to a second nesting attempt by a given pair of storks. This

long period of detection of incubating storks appears to lead to comparable periods of young detection. The relatively shorter period with black young (only three months) might result, partly, of the low number of records obtained. The monitoring of nests and young would be necessary to know the length of the breeding season in a given year and how it is influenced by environmental variables in the Pampa and other Brazilian biomes.

Records of incubating Maguari Storks obtained by citizens in the winter (July-August) indicate that early

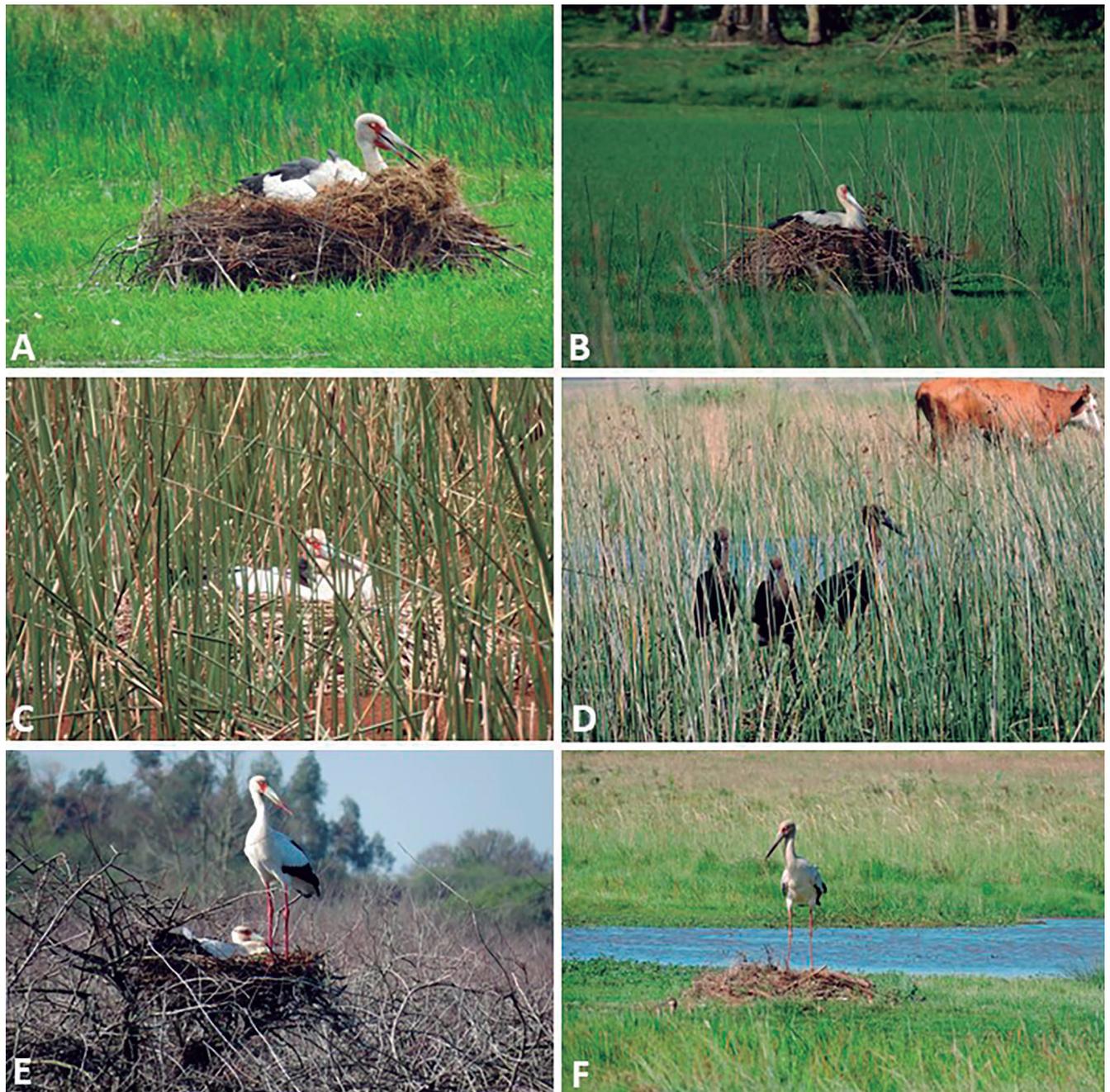


Figure 5. Range of situations in which nests of the Maguari Stork (*Ciconia maguari*) were found occurring singly in Pampa landscapes, Rio Grande do Sul state, southern Brazil. (A) a ground nest in a wet grassland at Aceguá (photo by Cláudio Alves Branco); (B) a ground nest among sparse *junquinhos* plants within a wet grassland patch at Dom Pedrito (photo by Diego Oliveira); (C) a ground nest within a *junca* vegetation patch within a grassland at Lavras do Sul (photo by Jonas John); (D) a ground nest among dense *junca* vegetation within a lake at Quaraí (Photo by Cícero Corrêa); (E) an arboreal nest built on shrubs at Dilermando de Aguiar (Photo by Thiago Weigert); (F) a ground nest destroyed by the rising of the water level at Quaraí (photo by Cícero Corrêa). Records were obtained by citizens, and gathered in the WikiAves database in June 2020.



Figure 6. Aspects of colonial nesting sites (*ninhas*) in which Maguari Storks (*Ciconia maguari*) built nests in the Pampa, Rio Grande do Sul state, southern Brazil. (A) a nest with two nestlings at Dilermando de Aguiar (photo by Thiago Weigert); (B) black young in nests at São Gabriel (photo by Felipe Almansa); (C) a nest with three black juveniles at Rosário do Sul (photo by Lauren Rumpel); (D) a general view, outside the breeding season, of a lake bordered by gray shrubs (yellow arrows) commonly used by Maguari Storks for nesting at Rosário do Sul (photo by Lauren Rumpel). Photographs were gathered in the WikiAves database, except for D.

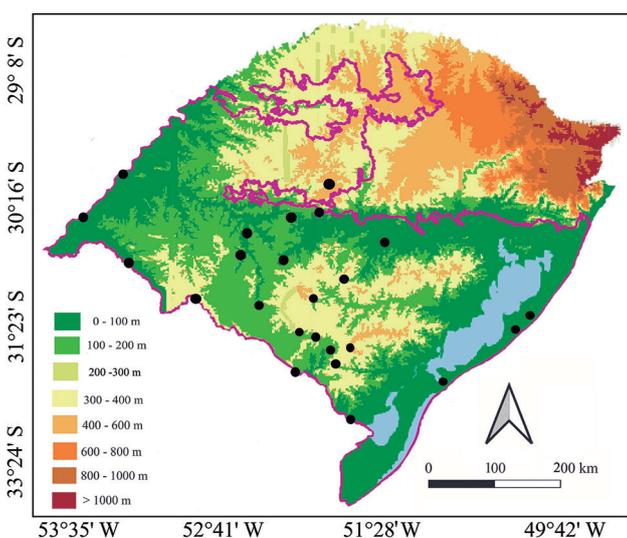


Figure 7. Geographic distribution of the Pampa biome (purple line) in the state of Grande do Sul state, with municipalities (black dots) in which records with documented evidences of breeding activities of the Maguari Stork (*Ciconia maguari*) were obtained by citizens in Brazil between 2007 and 2019. Records were gathered in the WikiAves database in June 2020. The blue color refers to areas of the continent reached by the water from the ocean.

breeding activities such as pairing, copulation and incubation might occur since June in the Pampa (see references in the Introduction). This means the onset of the breeding season prior to that of most species inhabiting the Pampa, that tend to breed in the austral spring and summer (Maurício *et al.*, 2013). Belton (1984) had not recorded eggs of the Maguari Stork in July or November in the Pampa, as occurred in our study.

According to the breeding records, black young and, less often, black juveniles were associated with nests. This indicates that young care by adults in nests occurs at least until these two stages of development. Thus, the breeding season of Maguari Storks might span to at least December in the Pampa, when black juveniles were later recorded. The intermediate and white juveniles are evidence of breeding activities, as they show different phases of plumage succession. However, observations of young care by adults would be necessary to know how long the dependence of juveniles on parents lasts for. Breeding records in biomes other than the Pampa occurred in months that lie within the period of gathering of such records in this biome. As these records were few, further samplings by citizens are necessary to examine

differences in the breeding season of Maguari Storks among Brazilian biomes.

Nests

Nests found by citizens in the Pampa are similar in structure to those found in Argentina and Venezuela (Kahl, 1971; Thomas, 1984, 1986; González, 1998). They were built on the ground or on woody vegetation in the Pampa; near two thirds of these nests were built on the ground. This pattern contrasts with results obtained by Kahl (1971), that found only ground-nests in Argentina. Antas (2004) also reported exclusively the occurrence of ground-nests in the Brazilian Pantanal. Nests built on the ground were in grasslands or in reed patches in the Pampa and other biomes. Vegetation can reduce nest visibility, when taller than the height of incubating adults and young. Similarly, ground-nests were built in shallow water of treeless marshes, and were closely surrounded by 2.0-2.5 m tall marsh vegetation (Kahl, 1971). Nests are also built on floating islands formed by aquatic vegetation, and in denser portions of extensive marshes (Antas, 2004).

Near a third of the nests found in the Pampa were built on shrubs, and the two nests found in the Cerrado and the Pantanal had tree canopies as substratum (Appendix). Zahl (1950) apud Kahl (1971) found nests of Maguari Storks placed "atop round-topped bushes" rose about 1.8 m out of the water in Venezuelan marshes. Also in Venezuela, nests were built only on bushes or in small trees measuring 1.4-6.3 m in height (Thomas, 1984, 1986). In the Pampa, Moura (2009) recorded nests of Maguari Storks in trees. The two records of nests obtained by citizens in the Cerrado and Pantanal were in tree canopies.

It would be interesting to compare the nesting success of Maguari Storks in the range of nest positions found in South America, including colonial nesting, and different nest substratum. This is because the surrounding water of floating islands, the tall herbs of marshes and lakes, and the woody plants used as substratum might promote distinct and better protection against potential nest predators, when compared with ground nests exposed in short grassland patches, as found in the Pampa. These differences would occur because nest position and substratum can influence breeding success in *Ciconia* storks (e.g., González, 1998; Vergara & Aguirre, 2006).

Young

The plumage of young recorded by citizens was similar to those reported for Maguari Storks inhabiting Venezuela and Argentina (Kahl, 1971; Thomas, 1984). However, results of our study partly disagree with those obtained by Thomas (1984), that informed that young are confined to their nests until they are able to fly. This is because a black young and several black juveniles photographed by citizens were walking through grasslands

and marshes. However, as most black young and a group of three black juveniles were found in nests, their still rely on nests during these phases of development. No black juveniles were detected during flight. Thus, apparently, Maguari Storks are independent of nests when they start to fly, and with white and dark plumage in comparable proportions (intermediate juveniles) in the Pampa.

As the finding of three young in nests was common in this study, Maguari Storks appear to breed successfully in the Pampa. This because mean clutches of 3 and 4 eggs have been reported for the Venezuelan Llanos and the Brazilian Pantanal (Thomas, 1984; Antas, 2004). Also, cases of nestling loss were eventual during the monitoring of 123 nests in Venezuela, highlighting an effective protection by parents (Thomas, 1984). The search for nests in June-July would likely allow the monitoring of clutches since egg laying, thus leading to solid conclusions on the success of distinct phases of the breeding of Maguari Storks in different Brazilian biomes.

Nesting in colonies

Ground-nests recorded by citizens occurred only isolated in Pampa landscapes. This result contrasts with the reporting of colonies of nesting Maguari Storks in other regions. Kahl (1971) reported loose colonies of storks nesting on the ground in northeastern Argentina. In Venezuela, Thomas (1984, 1986) reported that Maguari Storks nest solitary or in colonies with 5-15 nests in which sometimes nests were 0.5 m apart. Also, Antas (2004) mentioned the occurrence of colonies formed by 5-20 ground nests of co-specifics, distant tens of meters from each other in the Pantanal.

The absence of nesting colonies of co-specifics in our study might result of the natural rarity of colonies in Pampas and other landscapes (Kahl, 1971; Antas, 2004). Also, it would be unlikely having two or more nests in a given photograph, as citizens always focused a single nest. Systematic surveys through the Pampa and other biomes would be necessary to identify sites with nesting colonies of Maguari Storks in Brazil.

Nests built on shrubs and recorded by citizens were often found in colonies with egrets and herons in the Pampa. Similarly, Moura (2009) had recorded Maguari Storks nesting in colonies with Cocoi Egrets and the Roseate Spoonbill *Platalea ajaja* Linnaeus, 1758 in southeastern Pampa. On the other hand, two studies of nesting egrets and herons in this region of Rio Grande do Sul state have not mentioned the presence of nesting Maguari Storks among them (Gianuca, 2010; Scherer, 2010). Similarly, Maguari Storks are not mentioned in mixed-colonies in Pantanal wetlands (Yamashita & Valle, 1990; Willis, 1995).

Altitudinal variation

Most records were < 300 m a.s.l., mainly at 100-200 m a.s.l. sites. Stotz *et al.* (1996) also reported the

occurrence of Maguari Storks in lowlands, up to 700 m. Lowlands predominate in the Pampa (Alvarez *et al.*, 2013), and thus these storks might breed throughout lowlands of this region. This is because native grasslands are the major original matrix type, and marshes, lagoons and other humid areas with bordering woody plants used for nesting are common through the Pampa (Echer *et al.*, 2015; HBEI, 2020).

Conservation issues

As few breeding records have been obtained by citizens in the Atlantic Forest, the Amazon, the Pantanal and the Cerrado, this study focuses only on the conservation of Maguari Storks in the Brazilian Pampa. As *Ciconia* storks have home ranges larger than 5,000 ha around the world (*e.g.*, Jiguet & Villarubias, 2004; Zurell *et al.*, 2018), individuals of Maguari Storks also might occupy extensive areas in Pampa's landscapes. Therefore, it is probable that storks found in conservation units of integral protection, such as Estação Ecológica do Taim and Parque Nacional da Lagoa do Peixe, include in their home ranges portions of the surrounding non-protected landscapes. Due to this, the creation of a system of governmental conservation units of integral protection aiming the protection of large populations of Maguari Storks in the Pampa sounds impossible. Therefore, the survival of breeding pairs and young in this biome will require actions in numerous private properties. This suggestion is reinforced by the finding of breeding evidences throughout most of this Brazilian region.

Previous studies of populations and communities of native grasslands birds in the Pampa have suggested that their survival would benefit from the conciliation between economic development and biodiversity conservation (Develey *et al.*, 2008; Azpiroz *et al.*, 2012; Dias *et al.*, 2014; Fontana *et al.*, 2016). A similar recommendation has been proposed by Tavares *et al.* (2015), when concerned about the conservation of aquatic birds in coastal lagoons.

We agree with these studies and suggest that landowners could receive economic benefits by promoting eco-tourism in their properties. As major habitats used by Maguari Storks – marshes, grasslands and lagoons – are spread throughout the Pampa, it would be possible to have patches of these landscape elements protected in numerous private properties. The attraction of birdwatchers to farms would not be relied only on Maguari Storks, as these habitats used by them also are requirements for a diverse range of aquatic and grassland birds (Develey *et al.*, 2008; Azpiroz *et al.*, 2012; Dias *et al.*, 2014; Tavares *et al.*, 2015; Fontana *et al.*, 2016). This approach of sustainable use of biodiversity also would benefit Maguari storks in regions beyond and Pampa's limits, such as the Pantanal wetland, where this species and birdwatchers are abundant. The charisma of storks among children would favor birdwatching activities by families in private land.

CONCLUSIONS

This study suggests that citizen science can substantially contribute to the knowledge of aspects of the breeding of Maguari Storks. Some studies conducted recently in Brazil also have successfully used photographs gathered by citizens to study the breeding of species such as the Helmeted Manakin *Antilophia galeata* (Marçal & Lopes, 2019), the Orinoco Goose *Neochen jubata* (Tubelis *et al.*, 2020), and the Horned Screamer *Anhima cornuta* (Tubelis, 2020). In these studies, data obtained by citizens complemented samples produced by scientists, or represented the whole set of records. Therefore, photographs available in databases such as those of WikiAves can substantially contribute to the knowledge of aspects of the natural history of bird species found in Brazil.

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APPENDIX

Breeding records ($n = 65$) of the Maguari Stork (*Ciconia maguari*) recorded by citizens in Brazil between 2007 and 2019, with information on the location of records in 32 municipalities, states and biomes, elevation of the site, date of records, the type of breeding evidence, nest substratum, and the habitat where birds and nests were found. Data was gathered in the WikiAves database in June 2020. Records were listed according to the type of breeding evidence and then chronologically. Biome: (AF) Atlantic Forest, (AM) Amazonia, (CE) Cerrado, (PA) Pantanal, (PP) Pampa. When young were found in a nest, the record was placed in the category "Nest". The term "CN" indicates that the nest was in a colonial nest site, while the sign "?" indicates that it was not possible to obtain the information.

	Code	Municipality	State	Biome	Elevation (m)	Date	Breeding evidence	Nest substratum	Habitat
Nest	WA201261	Tavares	RS	PP	13	10 Aug 2010	nest with 3 nestlings	ground	grassland
	WA926504	Pedras Altas	RS	PP	368	20 Oct 2012	incubating adult	ground	juncal
	WA1057178	Poconé	MT	PA	153	22 Jul 2013	nest with 2 adults	tree canopy	?
	WA1058790	Quirinópolis	GO	CE	540	13 Aug 2013	nest with 1 adult	tree canopy	?
	WA1439128	Hulha Negra	RS	PP	196	22 Aug 2014	incubating adult	shrubs	?
	WA1460435	Rosário do Sul	RS	PP	125	21 Sep 2014	nest with 3 black juveniles – CN	shrubs	?
	WA1558502	Dom Pedrito	RS	PP	141	04 Nov 2014	incubating adult	ground	grassland
	WA1589757	Quaraí	RS	PP	112	21 Jan 2015	nest with 3 black young	ground	juncal
	WA1807957	Quaraí	RS	PP	112	23 Aug 2015	nest building	ground	juncal
	WA1823410	Quaraí	RS	PP	112	05 Sep 2015	incubating adult	ground	juncal
	WA3177936	Lavras do Sul	RS	PP	277	17 Oct 2015	nest with 1 chick and 1 adult	ground	juncal
	WA1940132	Quaraí	RS	PP	112	06 Dec 2015	nest destroyed by water	ground	grassland
	WA1958589	Quaraí	RS	PP	112	25 Dec 2015	nest with 1 chick	ground	grassland
	WA2366118	Candiota	RS	PP	220	13 Nov 2016	nest with 3 black young – CN	shrubs	grassland-water boundary
	WA2396063	Cachoeira do Sul	RS	PP	68	08 Dec 2016	nest with 2 black young – CN	shrubs	grassland-water boundary
	WA2773598	Candiota	RS	PP	220	09 Nov 2017	nest with 3 black young	shrubs	grassland-water boundary
	WA2795691	São Gabriel	RS	PP	114	26 Nov 2017	nest with 3 black young – CN	shrubs	grassland-water boundary
	WA3041561	Dilermando de Aguiar	RS	PP	127	19 Jul 2018	incubating adult	shrubs	?
	WA3115322	Dilermando de Aguiar	RS	PP	127	19 Sep 2018	nest with 2 nestlings – CN	shrubs	grassland-water boundary
	WA3152565	Aceguá	RS	PP	104	08 Oct 2018	incubating adult	ground	grassland
WA3211793	Bagé	RS	PP	212	19 Oct 2018	nest with 2 nestlings	ground	grassland	
WA3486067	Quaraí	RS	PP	112	07 Sep 2019	incubating adult	ground	juncal	
WA3517379	Jaguarão	RS	PP	26	05 Oct 2019	nest with 2 nestlings	ground	juncal	
WA3517163	Jaguarão	RS	PP	26	05 Oct 2019	incubating adult	ground	juncal	
WA3529610	Aceguá	RS	PP	104	11 Oct 2019	incubating adult	ground	grassland	
Black young	WA1567478	Pinheiro Machado	RS	PP	439	03 Jan 2015	1 black young	n.a.	?
	WA1994858	Quaraí	RS	PP	112	21 Jan 2016	1 black young	n.a.	grassland
Black Juveniles	WA1223650	Santa Maria	RS	PP	151	14 Dec 2013	1 black juvenile	n.a.	grassland
	WA1552760	Rio Grande	RS	PP	5	20 Dec 2014	1 black juvenile	n.a.	marsh
	WA2409959	Dilermando de Aguiar	RS	PP	127	19 Dec 2016	1 black juvenile	n.a.	grassland
	WA2814145	Bagé	RS	PP	212	06 Dec 2017	1 black juvenile	n.a.	grassland
	WA3595425	Santana do Livramento	RS	PP	208	15 Dec 2017	1 black juvenile	n.a.	marsh
	WA3207914	Júlio de Castilhos	RS	PP	513	08 Nov 2018	1 black juvenile	n.a.	marsh
	WA3241037	Bagé	RS	PP	212	08 Dec 2018	1 black juvenile	n.a.	grassland
Intermediate Juveniles	WA50000	Lavras do Sul	RS	PP	277	16 Nov 2007	3 intermediate juveniles	n.a.	grassland
	WA273470	Caracará	RR	AM	48	28 Nov 2010	1 intermediate juvenile	n.a.	sky
	WA590935	Mostardas	RS	PP	17	14 Jan 2011	1 intermediate juvenile	n.a.	grassland
	WA481915	Uruguaiana	RS	PP	56	22 Oct 2011	1 intermediate juvenile	n.a.	grassland
	WA496266	Santana do Livramento	RS	PP	208	13 Nov 2011	3 intermediate juveniles	n.a.	grassland
	WA1200401	Rio Grande	RS	PP	5	24 Dec 2013	1 intermediate juvenile	n.a.	sky
	WA1529875	Itaqui	RS	PP	57	22 Nov 2014	1 intermediate juvenile	n.a.	sky
	WA1546413	Jaguarão	RS	PP	26	14 Dec 2014	1 intermediate juvenile	n.a.	grassland
	WA1592885	Aceguá	RS	PP	104	25 Jan 2015	1 intermediate juvenile	n.a.	bare ground near water
	WA1610913	Quaraí	RS	PP	112	14 Feb 2015	2 intermediate juveniles	n.a.	water
	WA3433134	Cacequi	RS	PP	103	28 Nov 2015	1 intermediate juvenile	n.a.	grassland
	WA1987956	Rio Grande	RS	PP	5	16 Jan 2016	2 intermediate juveniles	n.a.	grassland with shrubs
	WA3327288	Caçapava do Sul	RS	PP	444	14 Nov 2018	1 intermediate juvenile	n.a.	grassland
	WA3189313	Quaraí	RS	PP	112	19 Nov 2018	2 intermediate juveniles	n.a.	grassland
	WA3216128	Tavares	RS	PP	13	18 Dec 2018	1 intermediate juvenile	n.a.	grassland
	WA3222191	Mostardas	RS	PP	17	20 Dec 2018	1 intermediate juvenile	n.a.	grassland
WA3599974	Santa Maria	RS	PP	151	08 Dec 2019	1 intermediate juvenile	n.a.	sky	
WA3651990	Mostardas	RS	PP	17	18 Dec 2019	1 intermediate juvenile	n.a.	sky	
White Juveniles	WA242133	Miranda	MS	PA	137	12 Nov 2010	1 white juvenile	n.a.	grassland
	WA1586924	Bagé	RS	PP	212	22 Jan 2014	2 white juveniles	n.a.	grassland
	WA1477721	Bonfim	RR	AM	79	08 Oct 2014	1 white juvenile	n.a.	sky
	WA2026741	Mundo Novo	MS	AF	311	13 Dec 2015	1 white juvenile	n.a.	sky
	WA1960304	Terra de Areia	RS	AF	7	23 Dec 2015	1 white juvenile	n.a.	grassland
	WA2015416	Lavras do Sul	RS	PP	277	05 Feb 2016	2 white juveniles	n.a.	water
	WA2429421	Rio Grande	RS	PP	5	07 Jan 2017	1 white juvenile	n.a.	grassland
	WA3206636	Júlio de Castilhos	RS	PP	513	08 Dec 2018	1 white juvenile	n.a.	sky
	WA3610059	Araranguá	SC	AF	9	14 Dec 2019	1 white juvenile	n.a.	sky
WA3620083	Santa Maria	RS	PP	151	26 Dec 2019	1 white juvenile	n.a.	grassland	
Other	WA997002	Poconé	MT	PA	153	05 Jun 2013	courtship behavior	n.a.	grassland
	WA3136879	Aceguá	RS	PP	104	05 Oct 2018	copulation	n.a.	marsh
	WA2399609	Santana do Livramento	RS	PP	208	13 Dec 2016	1 intermediate and 4 black juveniles	n.a.	grassland