Research, Society and Development, v. 9, n. 10, e4479108555, 2020
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Changes in composition of aquatic bird assemblages associated with changing in water levels in the Aquatic Terrestrial Transitional Zone of the Pantanal wetland Brazil

Mudança na composição de assembleia de aves aquáticas associadas com mudanças no nível de água em uma Zona de Transição Terrestre Aquática no Pantanal de Mato Grosso, Brasil

Cambio en la composición del ensamblaje de aves acuáticas asociadas con cambios en el nivel del agua en un Zona de Trasición Terrestre Acuática en el Pantanal de Mato Grosso Brasil

Received: 09/17/2020 | Reviewed: 09/18/2020 | Accept: 10/02/2020 | Published: 10/04/2020

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Abstract
The Pantanal wetland Mato Grosso, Brazil is among the largest floodplains in the world, with a mosaic of different habitats and rich aquatic and terrestrial biota. The habitat mosaics are found in the Chacororé and Sinhá Mariana lake System. These parental lakes of the Cuiabá River, a left tributary of the Upper Paraguay River, are known for their aquatic productivity and scenic beauty. The

characteristics of these lakes and their floodplains are showed through the difference between their waters, the diversity of the aquatic macrophytes communities, fish communities and aquatic birds. Our study looked at changes in limnological variables as well as diversity of aquatic birds, during high water or flooded phase; medium water or receding phase; and the low water or dry phase. We used a temporary small lagoon in the floodplain of this system as our study area. The flood pulse is the main ecological factor affecting the Pantanal; it modifies ecological process and species composition. The water depth decreases during the season, decreasing electrical conductivity, dissolved phosphate and nitrate, water transparency, dissolved oxygen and biomass of aquatic macrophyte; and increasing calcium, total phosphorus and total nitrogen. We also observed increase in species richness and abundance of aquatic birds during the receding phase. Results show that the number of species (density) of aquatic birds increased from 10 to 30 species and the numbers of individuals from 40 to 936. The maximum richness and abundance of aquatic birds was registered during the receding phase.

Keywords: Brazil; Pantanal; Aquatic birds; Limnology; Wetland.

Resumo

O Pantanal Mato-Grossense, Brasil representa a maior planície alagável do mundo, incorporando um mosaico de diferentes habitats, sustentando uma rica biota aquática e terrestre. O mosaico de habitats é bem representado pelo sistema de baías Chacororé-Sinhá Mariana. As lagoas parentais do Rio Cuiabá, tributário esquerdo do Rio Paraguai, é conhecido por sua produtividade e beleza cênica. As características destes lagos e sua planície de inundação é evidenciada pela diferença entre as características limnologicas, a diversidade da comunidade de macrófitas aquáticas, comunidade de peixes e aves aquáticas durante a cheia, enchente e estiagem. Foi usado um lago temporário na planície de inundação deste sistema como área de estudo. O pulso de inundação e a composição das espécies. A profundidade da água diminui durante o período hidrológico, diminuindo a condutividade elétrica, ortofosfato e nitrato, transparência da água, oxigênio dissolvido e biomassa de macrófitas aquáticas e aumenta o cálcio, fósforo total e nitrogênio total. Observou-se também o aumento da riqueza e abundância de espécies de aves aquáticas durante a vazante. Os resultados mostram que o número de espécies de aves aquáticas aumentou de 10 para 30 e o número de indivíduos de 40 para 936. A riqueza máxima e abundância máxima de aves aquáticas foi registrada durante a vazante.

Palavras-chave: Brasil; Pantanal; Aves aquáticas; Limnologia; Áreas alagáveis.

Resumen

El Pantanal Mato-Grossense, em Brasil representa la mayor planície alagable em el mondo, incorporando un mosaico de diferentes hábitats, sosteniendo una rica biota acuática y terrestre. El mosaico de hábitats está bien representado por el sistema de la bahía de Chacororé-Sinhá Mariana. Las lagunas parentales del río Cuiabá, el afluente izquierdo del río Paraguay, es conocida por su productividad y belleza escénica. Las características de estos lagos y su llanura de inundación se evidencian por la diferencia entre las características limnológicas, la diversidad de la comunidad de macrófitos acuáticos, la comunidad de peces y aves acuáticas durante las inundaciones, inundaciones y sequías. Un lago temporal fue utilizado en la llanura de inundación de este sistema como un área de estudio. El pulso de inundación y la composición de la especie. La profundidad del agua disminuye durante el período hidrológico, disminuyendo la conductividad eléctrica, ortofosfato y nitrato, la transparencia del agua, el oxígeno disuelto y la biomasa de macrofitos acuáticos y aumenta el calcio, el fósforo total y el nitrógeno total. También hubo un aumento en la riqueza y abundancia de especies de aves acuáticas durante el período de baja agua. Los resultados muestran que el número de especies de aves acuáticas aumentó de 10 a 30 y el número de individuos de 40 a 936. La máxima riqueza y la máxima abundancia de aves acuáticas se registró durante el.

Palabras clave: Brasil; Pantanal; Aves acuáticas; Limnologia; Zonas inundadas.

1. Introduction

The Brazilian Pantanal, is the largest floodplain in the world. It is a mosaic of different habitats with a rich aquatic and terrestrial biota. It is an inland delta, where many rivers converge on the main river channel, the Upper Paraguay River. Habitats within this landscape can be found in the Chacororé and Sinhá Mariana lake system. These parental lakes of the Cuiaba River, a tributary of the Upper Paraguay River, are known for their aquatic productivity and scenic beauty. The water characteristics of these lakes and their floodplains are demonstrated through the difference in their waters, the diversity of the aquatic macrophytes, fishes and aquatic birds' communities (Frota *et al* 2020; Ghosh; Biswas 2015; Schmidt-Mumm; Janauer 2014; Nunes; Da Silva 2005).

Studies estimate 730 regional species, including migrants, accidentals visitors and introduced species, with 500 species in the Pantanal region alone, of these 500 species, about 80 are aquatic (Da Silva *et al*., 2001). In an environment with a large number os bird species, to know the behavior and ecology of these species are very important to think on conservation and management of the Pantanal species.

The objective of this study was to examine relationship between flood stage, water characteristics and avian assemblage diversity and species composition.

2. Metodology

This study was made using field research, by survey of bird abundance and species and water samples collects, that were analysed in laboratory for nutrient concentration. Is characterized as quali-quanti research (Pereira *et al* 2018).

A bird census was conducted during each hydrological period in order to obtain the number of the aquatic birds. During the high and receding phase, the census was conducted by boat around the lake during the early morning and in the afternoon. In the dry phase, observers walk around the dry lakes. All species observations around the edge of the lake were confirmed with binoculars (7x50mm) transects were defined with a GPS. The systematic ordination of the birds was done according to Sick (1997).

To the fields water samples were collected in the "lago dos Sonhos", the collects were realized during dry season (august) and during the raining season (March) and the receding phase was collected on may in the littoral region.

The Physical-Chemical variables of water were measured in field, the method are described in Nunes & Da Silva (2005) by using a set of specific equipment for the analyses of the water of the ATTZ: pHmeter 320 SET/WTW, Oximeter 196 WTW, conductivity, 196 WTW, Mercury Bulb Thermometer, Termistor of the oximeter 196 WTW, rope with weight and band measure, Secchi disk, to measure the water transparency and depth Turbidimeter 2100 – HACH.

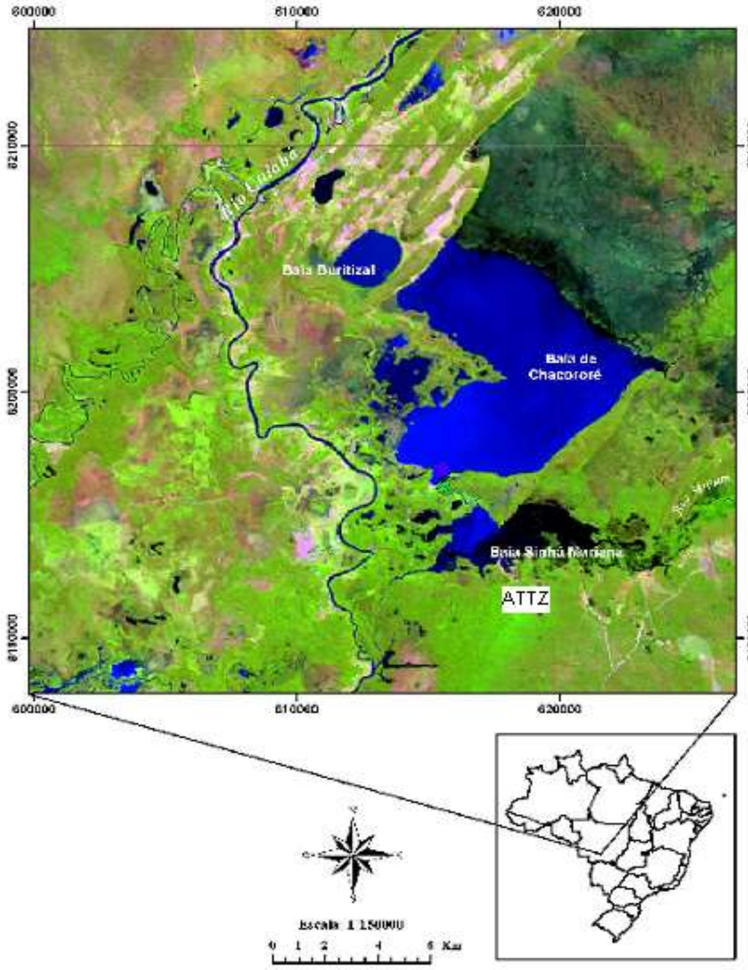
The particulate nitrogen was analyzed using methodology described from Anderson and Ingram, 1996. The ammonium ion, nitrate, total phosphorous and the orthophosphate were analyzed using methods from Carmouze (1994).

2.1 Study area

The Chacorore-Sinhá Mariana lake system is located between the 16º 14' and 16º 16' South and 55º 57' and 55º 58' West, in the basin of the Cuiaba river in the municipality of Santo Antonio de Leverger and Barão de Melgaço, Mato Grosso state. This lake system connects with Cuiabá

River, through a complex network of channels locally called “corixos”. The Chacororé lake is characterized by high available nutrients, conductivity, turbidity and low transparency of the water, while Sinhá Mariana lake is characterized by black water, low nutrients concentration, conductivity, turbidity and very high transparency (Nunes; Da Silva 2005) (Figure 1).

Figure 1 - The study area (ATTZ) in the Chacororé-Sinhá Mariana lake system, Pantanal, Barão de Melgaço, Mato Grosso state, Brazil. (July 2001).



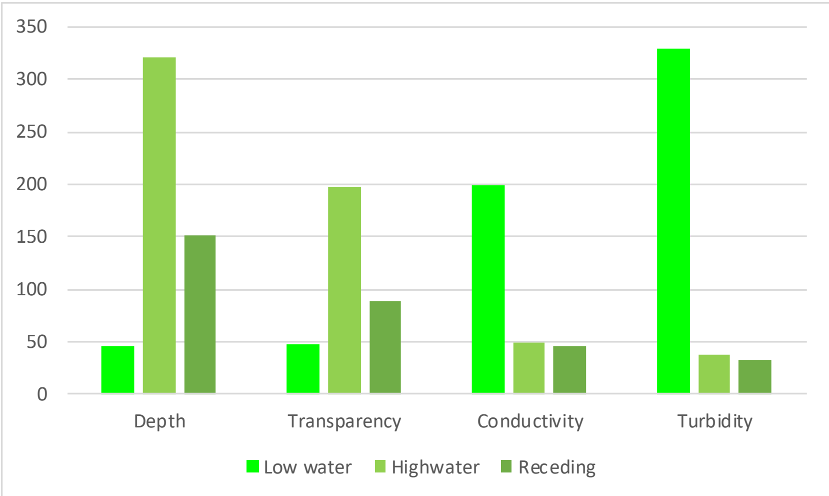
Source: Josué Ribeiro da Silva Nunes

The period of high water occurs between January and March and the receding phase April to June. During this time the water accumulates in the ATTZ (Aquatic Terrestrial Transition Zone), forming a small lake in a basin that we call “Lake of the Dreams” in the figure 1 we show where is located this sample site.

3. Results and Discussion

The limnology of ATTZ depends on the connectivity with the lakes or rivers, the geology and the rate of decomposition of the aquatic macrophytes and terrestrial herbaceous plants grow up, respectively, during flooding and drying periods. The connectivity into the lake of the Dreams comes from the Sinhá Mariana Lake, through a decrease elevation. The difference on water level, between the low and high water periods, was 3m. Transparence Secchi followed the same patterns the water level, raising the higher water and decreasing as the water diminished. In the flood phase, just species, which dive for fish, can remain in the area, for example *Phalacrocorax brasilianus. Anhinga anhinga*, *Sterna superciliaris* e *Megacerile torquata* that uses the high transparency for foraging.

Figure 2 - Values of Depth (cm), Transparency (cm), Conductivity (πs.cm^{-1}) and Turbidity (NTU), of the ATTZ during Low water of 2001 and High water and Receding water of 2003 in the Chacororé-Sinhá Mariana Lake System.

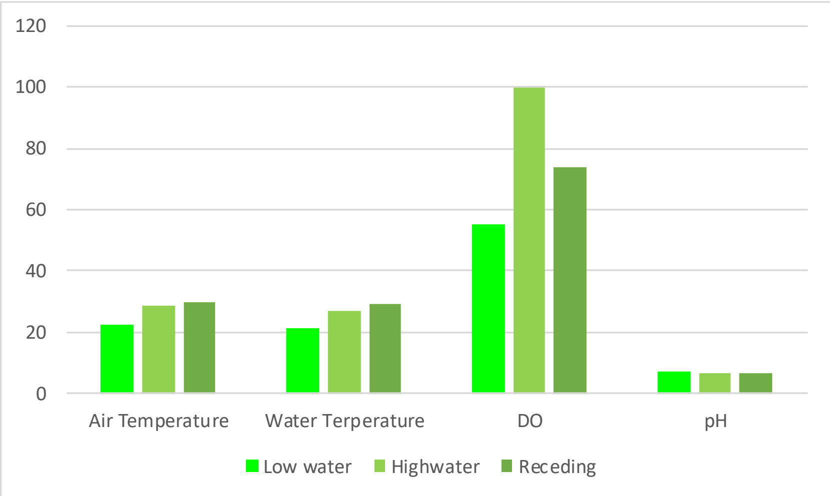


Source: Authors.

Conductivity and the turbidity were much higher in the low water (Figure 2), showing the high amount of nutrient and suspended materials in the water during this time. Our results indicate that the pattern in the Pantanal is related to the flood pulse, conductivity and turbidity. This indicates that there is a positive relationship between conductivity and the flood pulse when the system is controlled by geologic factors, and a negative relationship in lakes controlled by animals. The number of species and abundance during dry period was intermediary, but interesting, because the species, which appears during this phase, hunting by passing the beak into the water and it, is not necessary an optimal vision focus.

The air and water temperature not showed a high variation during the three phases of research in this area (Figure 3). It seems not affect the presence or absence of the birds on the area. The range of variation of air temperature were between 22,5ºC on low water to 30ºC on receding phase. Water temperature variate from 21 ºC to 29ºC on receding phase.

Figure 3 - Values of air and water temperature (^{0}C), Dissolved oxygen (%) and pH of the ATTZ during Low water of 2001 and High water and Receding water of 2003 in the Chacororé-Sinhá Mariana Lake System.



Source: Authors.

Dissolved Oxygen concentrations were greater during high water period (100%) when compared to the low water period (55%); this concentration favors for the aquatic animal that depends of the dissolved oxygen like fishes and affect directly the aquatic birds that feeds on fish. For pH there no variation during water level variation keeping near of neutral condition.

Studies made in this system of lakes and another one show similar pattern for the limnological variables (Lemke *at al* 2017; Da Silva; Esteves 1995). The results found for conductivity is opposite to the results obtained for Acurizal e Porto de Fora lakes (Da Silva; Esteves 1995); and Sinhá Mariana lakes (Nunes; Da Silva, 2005) Where conductivity is higher during the low water, when the population densities of the animals is larger (Smith 2016).

The results obtained were similar to the observation made by Nunes; Da Silva (2005); Gasim *et al* (2015), they found that oxygen concentrations were greater during high water

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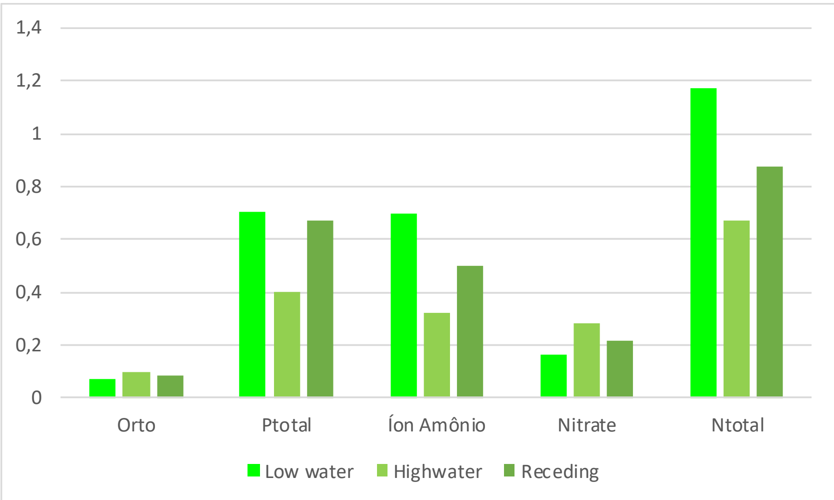
period (100%) when compared to the low water period (55%). pH did vary among the flood stage which was similar to what Cabrera; Soo-Lee (2018), Nunes; Da Silva (2005), observed when studying this area and another. These values for particulate and dissolved nutrients were higher for the same system investigating by Rattan & Chambers (2017); Da Silva *et al* (2006) and Nunes & Da Silva (2005).

Total nitrogen was 1.171mg.L^{-1} in the low water and 0.668mg.L^{-1} in the high water and 888 mg.L^{-1} during receding period (Figure 4). Dissolved nitrogen shown similar standard following total nitrogen. The receding phase shown always an intermediary concentration of nutrients, what seems to be important, because in this phase, it was found the highest number of species and abundance, what means that this concentration is good enough for maintain the elevated number of bird species and abundance.

Figure 4- Values of Dissolved phosphorous (Orthophosphate, mg.L^{-1}), ion ammonium (mg.L^{-1}), nitrate (mg.L^{-1}), total nitrogen (mg.L^{-1}) and total phosphorous (mg.L^{-1}) of the ATTZ during Low water of 2001 and High water and Receding water of 2003 in the Chacororé-Sinhá Mariana Lake System.

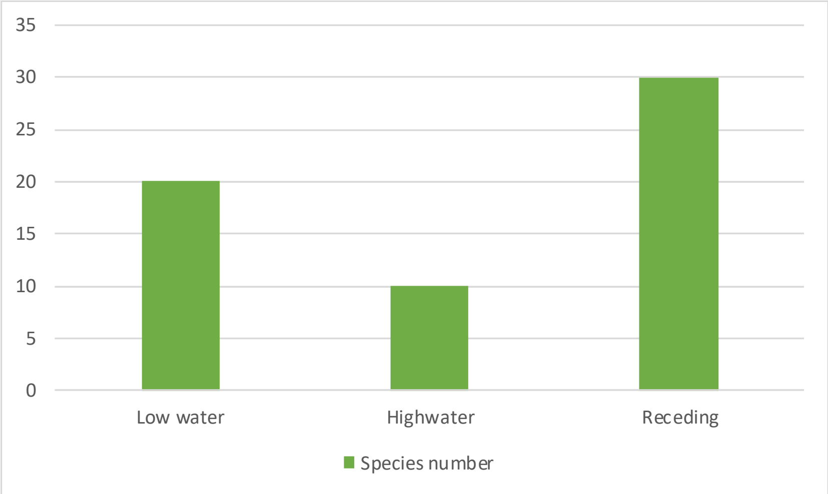


Source: Authors.

Total phosphorous was 0.703 mg.L^{-1} in the low water and 0.453 mg.L^{-1} in the high water, during receding the concentration was 0,689 mg.L^{-1} dissolved phosphorous did not show any variation among hydrological cycles.

The table 1 and 2 shows the number of species on each hydrological periods, and Figure 5 and 6 show the type and number of bird species observed in the lake of Dreams during the flood stages. During the period of receding water, the largest number of species was observed being 30, during high water the smallest number of species observed were10, while during dry period the number of species was 20.

Figure 5 - Specie number during Low water of 2001 and High water and Receding water of 2003 in the Chacororé-Sinhá Mariana Lake System.



Source: Authors.

The number of individuals was also higher in the receding phase (936); the most abundant specie was *Phaetusa simplex* (225 individuals), *Sterna superciliaris* (211 individuals) and *Ryncops niger* (162 individuals) it occurs because the lake was isolated in the receding phase and the fishes and mollusks stayed restricted in it serving as food to birds. High water period showed the smallest number of individuals. *Phalacrocorax brasilianus, Ardea cocoi, Ardea alba, Egretta thula Sterna superciliaris* and *Ceryle torquata* occurred in all periods of observation. However, the number of individuals varies during the flood stage.

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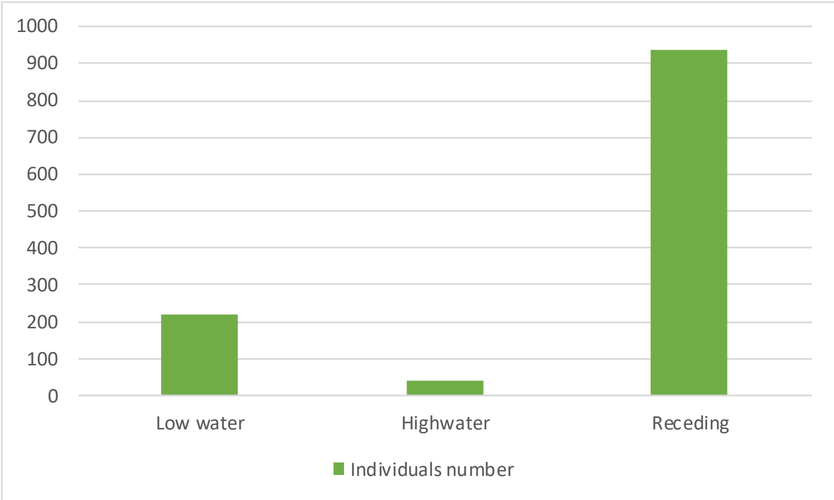
Figure 6 - Number of individuals during Low water of 2001 and High water and Receding water of 2003 in the Chacororé-Sinhá Mariana Lake System.



Source: Authors.

Shannon diversity was higher during receding phase and lower during the high water periods. In the receding phase, the number of individuals was four times higher on the low water period, 23 times higher than high water period. Receding and low water periods decrease water volume, concentration of fish populations improving foraging conditions for aquatic birds. Limnological conditions associated with, dissolved oxygen, water temperature and transparency, all of which improves the survival of a great concentration of fish. Those serve as basic food for aquatic birds.

Table 1 - Number of individuals, species and diversity observed in the receding, low and high water period.

	Receding	Low Water	High Water
Number of individuals	936	220	40
Number of species	30	20	10
Shannon Diversity	2.29	2.11	1.51

Source: Authors.

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Diversity was higher during receding (2,29) and low water (2,11) periods. The number of individuals was four times higher on the receding period and 23 times higher than high water period. Receding and low water periods decrease depth and water volume favoring fish concentration and adequate foraging conditions to aquatic birds. Receding water is the period that most favors abundance of aquatic birds due to limnological conditions such as water volume, depth, dissolved oxygen, water temperature and transparency, all of which guarantees the survival of a great concentration of fish. Those serve as basic food for aquatic birds.

Table 2 - Number of bird species observed in the ATTZ at the Chacororé-Sinhá Mariana Lake System.

Species	Portuguese name	Ingles name	Receding	Low water	High water
PELECANIFORMES					
Phalacrocoracidae					
Phalacrocorax brasilianus	Biguá	Olivaceous Cormorant	28	13	30
Anhingidae					
Anhinga anhinga	Biguatinga	Anhinga	9		4
CICONIFORMES					
Ardeidae					
Ardea cocoi	Garça-maguari	White-necked Heron	2	3	3
Ardea alba	Garça-branca-grande	Great Egret	41	1	2
Egretta thula	Garça-branca-pequena	Snowy Egret	34	2	2
Butorides striata	Socozinho	Striated Heron	13		

Botaurus pinnatus	Socó-boi-baio		2		
Nycticorax nycticorax	Aquá (garça-dorminhoca)	Black-crowned Night-Heron	5		
Threskornithidae					
Phimosus infuscatus	Tapicuru-frango-d'água	Bare-faced Ibis	8		
Theristicus caudatus	Curicaca	Buff-necked Ibis	5	9	
Platalea ajaja	Colhereiro	Roseate Spoonbill	33	9	
Mesembrinibis cayennensis	Frango d'água	Green Íbis		3	
Ciconidae					
Mycteria americana	Cabeça-seca		6	1	
Jabiru mycteria	Tuiuiú		2	1	
ANSERIFORMES					
Anatidae					
Dendrocygna autumnalis	Marreca-peba	Black-bellied Whistling Duck	16		
Dendrocygna viduata	Irerê	White-faced Whistling Duck	12	12	
Dendrocygna bicolor		Fulvous Whistling Duck	21		
Cairina moschata	Pato-do-mato	Muskovy Duck	15		2
Amazoneta brasiliensis	Sinhazinha	Brasilian Duck		82	

Anhimidae					
Chauna torquata	Inhuma, tacha	Southern Screamer	2		
FALCONIFORMES					
Acciptridae					
Rostrhamus sociabilis	Caramujeiro	Snail Kite	2		2
Busarelus nigricollis	Gavião-belo	Black-collared Hawk			3
GRUIFORMES					
Aramidae					
Aramus guaraúna	Carão	Limpkin	1		
Rallidae					
Aramides cajanea	Saracura	Grey-necked Wood-Rail		2	
CHARADRIIFORMES					
Jacanidae					
Jacana jacana	Cafezinho	Wattled Jaçanã	11		
Charadriidae					
Vanellus chilensis	Quero-quero	Pied Plover	1	26	
Charadrius collaris	Batuira-de-coleira	Collared Piover	20	2	
Recurvirostridae					
Himantopus melanurus	Maçarico, Perna-longa	Common Stilt	14	2	

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Laridae					
Sternula superciliaris	Trinta-réis-anão	Yellow-billed Tern	211	35	40
Phaetusa simplex	Trinta-réis-grande	Large-billed Tern	255	12	
Rynchopidae					
Rynchops niger	Trinta-réis-preto, Talhamar	Black Skimmer	162	2	
CORACIIFORMES					
Alcedinidae					
Megaceryle torquata	Martim-pescador-grande	Ringed Kingfisher	1	1	2
Chloroceryle amazona	Martim-pescador-verde	Amazona Kingfisher	1		
Chloroceryle americana	Martim-pescador-pequeno	Green Kingfisher	3		
PASSERIFORMES					
Troglodytidae					
Donacobius atricapilla	Capivareiro	Black-capped Mockingthrush		2	

Source: Authors.

The highest numbers of birds were observed along the shoreline of the lake, most likely because these areas are shallow enough to allow the aquatic birds to walk and look for food, the same pattern was observed by Almeida *et al* (2018), Jones *et al* (2017), Golden Gate Aldubon Society (2016).

Antas *et al* (2016), Ribeiro & Ferreira (2014) showed that small bodies water with depths of 1m or less attract a large density of aquatic birds, mainly herons, that prefer to forage in environment with shallow depth and without vegetation or grasses in the border areas. *Egretta thula* feeds in areas without or with very little river-side vegetation, and were rarely found in groups, with exception of areas with big concentrations of fish, *Ardea cocoi* feed in the same body of water that *Ardea alba* prefers, i.e. also in shallow water without vegetation (Willard 1985).

Many bird species forage using vision, making transparency and depth important determinants of foraging areas. According to Whingham *et al.* (2001), many aquatic bird species use the depth and the variation of the water level as parameter to delimitate the foraging area and/or breeding area.

The maintenance of this kind of habitat favors the life strategies of many aquatic birds, which depends on the quality of habitats defined by limnologicals variables, mainly depth, transparency, turbidity and dissolved oxygen.

Willard (1985), showed that piscivorous species can be divided into four classes based on foraging bahavior: 1 – *Swimming* – American Anhinga and Olivaceous Cormorant, look for prey under water, demanding a high depth and transparency; 2 – *wading* – such as *Tigrisoma* spp, *Ardea, Egretta, Butorides,* which use habitats without vegetation and low depth.

The class 3 – *Wait Perch* – Kingfishers, which wait on a branch and then dive to capture identified prey, making availability of perches important, and 4 – *icruising* – common behavior to *Pandion haeliaetus,* which conducts aerial/visual hunts and therefore needs habitat with high transparency and low turbidity. Kushlan *et al.* (1988), showed that the differences in the length of foraging and the behavior linked to foraging of species hunting in the same place, worked so that Ardeidae and Alcedinidae avoided direct competition.

4. Conclusions

This study shows that the flood stage affects limnological conditions, concentration, and number of species and abundance of aquatic birds in the ATTZ of the lake system Chacororé-Sinhá Mariana. During shallow water, low and receding water periods, diversity and abundance of birds are high. Changes in the flood pulse that favors the extremes of water permanence or completely dryness may affect these variables and diminish the ecological and touristy value of the system.

We consider importante the maintaence of this kind of research in the area, to understand the dinamyc of the waterfowla under the changes of the water level and the climate changes in the Pantanal region, the major understanding permiss us to plan the better way to protected this área.

Acknowledgments

We thank UFMT/IB – Post graduation in Ecology and Conservation of Biodiversity and the Pantanal Ecology Project/FAPEMAT – Project "Basis to the Biodiversity monitoring in the surround of Ecological Station of the Taiamã and the System of Chacororé – Sinhá Mariana lakes in the Mato-grossense Pantanal.

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