ORNITOLOGÍA NEOTROPICAL
(2017) 28: 89–96

ORIGINAL ARTICLE

Sociedad de Ornitología Neotropical

IMPORTANCE OF RESERVOIRS FOR WATERBIRDS IN SEMI-ARID BRAZIL

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ABSTRACT · To investigate the value of water reservoirs for waterbirds in semi-arid lands, we studied the waterbird community in semi-arid of Paraíba, Brazil, and compared the results with other assemblages both in semi-arid and humid regions of Neotropics. Birds were counted during 15 months in 12 reservoirs belonging to the Piranhas-Açu River basin. We counted 4111 waterbirds and recorded 36 species. The most abundant species, such as Wattled Jacana (*Jacana jacana*) and Common Gallinule (*Gallinula galeata*), were strongly tied to aquatic vegetation. All species have wide distribution, far beyond the borders of the semi-arid region. Abundance and richness of waterbirds in Paraíba are lower than in more humid regions of Neotropics. Species composition in all semi-arid sites studied seems to be a reduced version of assemblages in surrounding humid regions. Nevertheless, reservoirs may become important alternatives as feeding and breeding sites where the natural environments are insufficient to sustain waterbird populations.

RESUMO · A importância dos açudes para as aves aquáticas no semiárido brasileiro
Para investigar a importância de açudes para aves aquáticas em regiões semiáridas, estudamos a comunidade de aves no semiárido da Paraíba, Brasil, e comparamos os resultados com outras assembleias em regiões semiáridas e úmidas dos neotrópicos. Durante 15 meses foram realizados censos da avifauna em 12 açudes na bacia do rio Piranhas-Açu. Foram registradas 4111 aves e 36 espécies. As espécies mais abundantes, como a Jaçanã (*Jacana jacana*) e a Galinha-d'água (*Gallinula galeata*), foram associadas às macrófitas. Todas as espécies possuem vasta distribuição geográfica, ultrapassando as fronteiras da região semiárida. A abundância e a riqueza foram menores que aquelas encontradas em regiões úmidas. A composição de espécies nas regiões semiáridas estudadas compreende uma versão reduzida das assembleias das regiões úmidas. Todavia, os açudes podem se tornar alternativas importantes como locais de alimentação e reprodução onde os ambientes naturais são insuficientes para manter as populações de aves.

KEY WORDS: Aquatic Birds · Artificial Habitats · Caatinga · Drylands · Paraíba · Richness

INTRODUCTION

New aquatic systems have been built and managed for human benefit worldwide. Fortunately, as byproduct, many of them also play a role in biodiversity conservation, for example, the artificial wetlands have proved to be beneficial for several species of waterbirds (Sebastián-González et al. 2010, Pérez-García et al. 2014). Reservoirs, rice fields, or agricultural ponds are some examples of man-made wetlands that are used by waterbirds as alternative places to feed, breed, and rest (Múrias et al. 2002, Ma et al. 2004).

Building reservoirs in arid or semi-arid lands may turn environments with historical absence or low abundance of aquatic birds into key areas for conservation (Roshier et al. 2001, Yerokhov 2006, Kreuzberg-Mukhina 2006). In northeastern Brazil, the semi-arid conditions led private initiatives and governments to build thousands of reservoirs to store water for urban and rural use. Reservoirs have been built since the mid-19th century, and by 1990, about 60,000 reservoirs were estimated in semi-arid Brazil (Cavalcanti 1988, Gurgel 1990), exceeding the amount of natural lakes in the region (Maltchik 2003).

As expected, building reservoirs has concurrently increased the area of suitable habitats for waterbirds (Sick 2001) and created a huge mosaic of fragments used by them. However, the waterbird communities dwelling

Receipt 8 August 2016 · First decision 19 January 2016 · Acceptance 14 June 2017 · Online publication 21 June 2017

Communicated by Kaspar Delhey

these man-made habitats are poorly known, and few studies have estimated species richness and abundances. Here, we studied the community of aquatic birds of the Piranhas-Açu watershed, in a semi-arid region of the state of Paraíba, northeastern Brazil. We estimated the richness of species and the abundance of each species in the community, and compared than with waterbird communities in other regions of Brazil to verify whether the semi-arid reservoirs harbor a unique waterbird assemblage or a similar version of surrounding assemblages.

METHODS

The drainage basin of Piranhas-Açu (06°45'56.62"S, 37°51'40.57"W), Paraíba, Brazil, drains a region of tropical savanna (Aw) and hot semi-arid climates (BSh; Peel et al. 2007) with 500–700 mm of annual rainfall. The region holds intermittent rivers, which were dammed in several levels to store water. Most lentic waterbodies are artificial reservoirs with dendritic shape, shallow depth, and a semi-natural appearance (i.e., vast vegetation cover, mud and gravel substrate, and forested margins). They are used mainly as water supply for cattle and crops, and for fishing (Gurgel 1990), and have no water level management.

Two rectangular sample plots were established in the study area, each with about 50 km² and 9 km far away from each other, one in the sub-drainage basin of Mofumbo River (plot A), with 45 reservoirs, and another in the sub-drainage basin of Piancó River (plot B), with 56 reservoirs. Within each plot, we choose six reservoirs, totaling 12 sampling units (Figure 1). As the reservoirs sizes varied widely, we stratified the sampling across small (area < 1 ha), medium (1 ha ≤ area < 5 ha), and large (area ≥ 5 ha) reservoirs, choosing four reservoirs of each size class.

Waterbirds were counted visually, with the aid of binoculars (10x50 mm) and a spotting scope (20–60x60 mm), from vantage points on the margins of reservoirs (Bibby et al. 1992). In each waterbody, we set 1 to 10 vantage points according to reservoirs sizes. Each count lasted 10 minutes and was carried out in the morning (05:30–09:00 h EST). To improve the chances of detecting secretive species (e.g., some rails) at the end of each visual count, we played the vocalizations of species with likely occurrence. In addition, the observer walked along dense vegetation patches to flush hidden birds. The counts were carried out monthly from September 2013 to November 2014, totaling 169 censuses.

The abundance of each species was expressed as the average of birds per month. The frequency of occurrence was expressed as the percentage of censuses where a particular species was present relative to the total amount of censuses. The estimator *Jackknife 1* was used to estimate the species richness. Although some were present in the reservoirs, the following birds were excluded from the estimates of abundance, frequency, and richness: (i) arboreal Passeriformes and Cuculiformes, because our census technique was not suitable to quantify them; (ii) domesticated waterfowl, because the occurrence and abundance of these birds are independent of ecology; and (iii) the species seen only outside the plots.

We applied a Correspondence Analysis (CA) to compare the species composition with other wetland bird communities in Brazil. We used data of occurrence found in literature on the Pantanal (Morrison et al. 2008), Amazonian lakes (Cintra 2012), and coastal lagoons in southern Brazil (Guadagnin et al. 2005), along with four semi-arid regions, which comprised: (i) natural temporary ponds in the state of Pernambuco (Farias 2007); (ii) reservoirs and temporary ponds near the São Francisco River, the largest perennial river in semi-arid Brazil, in Pernambuco (Olmos et al. 2005); (iii) the Sobradinho lake, a large water reservoir along the São Francisco river (Nascimento & Schulz-Neto 2000); and (iv) reservoirs in the state of Ceará (Olmos et al. 2005).

To avoid the effect of sampling size on abundances we used a matrix with presence and absence of species in each region. The CA was performed using the software R 3.3.1 with the package Vegan 2.4-3 (Oksanen et al. 2017). Ellipsoid hulls were drawn on the ordination plot using the function *ordiellipse* to highlight the position of semi-arid and humid regions. The Kaiser-Guttman criterion was used to decide how many axes to interpret (Borcard et al. 2011).

RESULTS

We recorded 36 species of waterbirds (Appendix 1). Among these, 29 were included in the estimates of abundance, frequency, and richness. The *Jackknife 1* estimation resulted in 30 (± 1 SD) species, which suggests an accurate sampling. We counted an average of 274 (± 87 SD) birds per month, comprising a total of 4111 sightings throughout the study. The most abundant species was the Wattled Jacana (*Jacana jacana*), comprising 23.1% of all sightings, with a monthly average of 63 (± 17 SD) individuals. Following the Wattled Jacana, the most abundant species were Common Gallinule (*Gallinula galeata*; 11.8%), Least Grebe (*Tachybaptus dominicus*; 10.7%), and Black-necked Stilt (*Himantopus mexicanus*; 9.5%).

The Wattled Jacana was also the most frequent species, occurring in 86.3% of the 169 censuses (Appendix 1), followed by Great Egret (*Ardea alba*; 59.7%), Striated Heron (*Butorides striata*; 55.0%), and Common Gallinule (43.2%). Ten species were present every month: Least Grebe, Pied-billed Grebe (*Podilymbus podiceps*), Neotropic Cormorant (*Phalacrocorax brasilianus*), Rufescent Tiger-Heron (*Tigrisoma lineatum*), Striated Heron, Great Egret, Snowy Egret (*Egretta thula*), Common Gallinule, Black-necked Stilt, and Wattled Jacana. All reservoirs harbored aquatic birds, but none harbored all the species recorded during the study. Only four species fre-

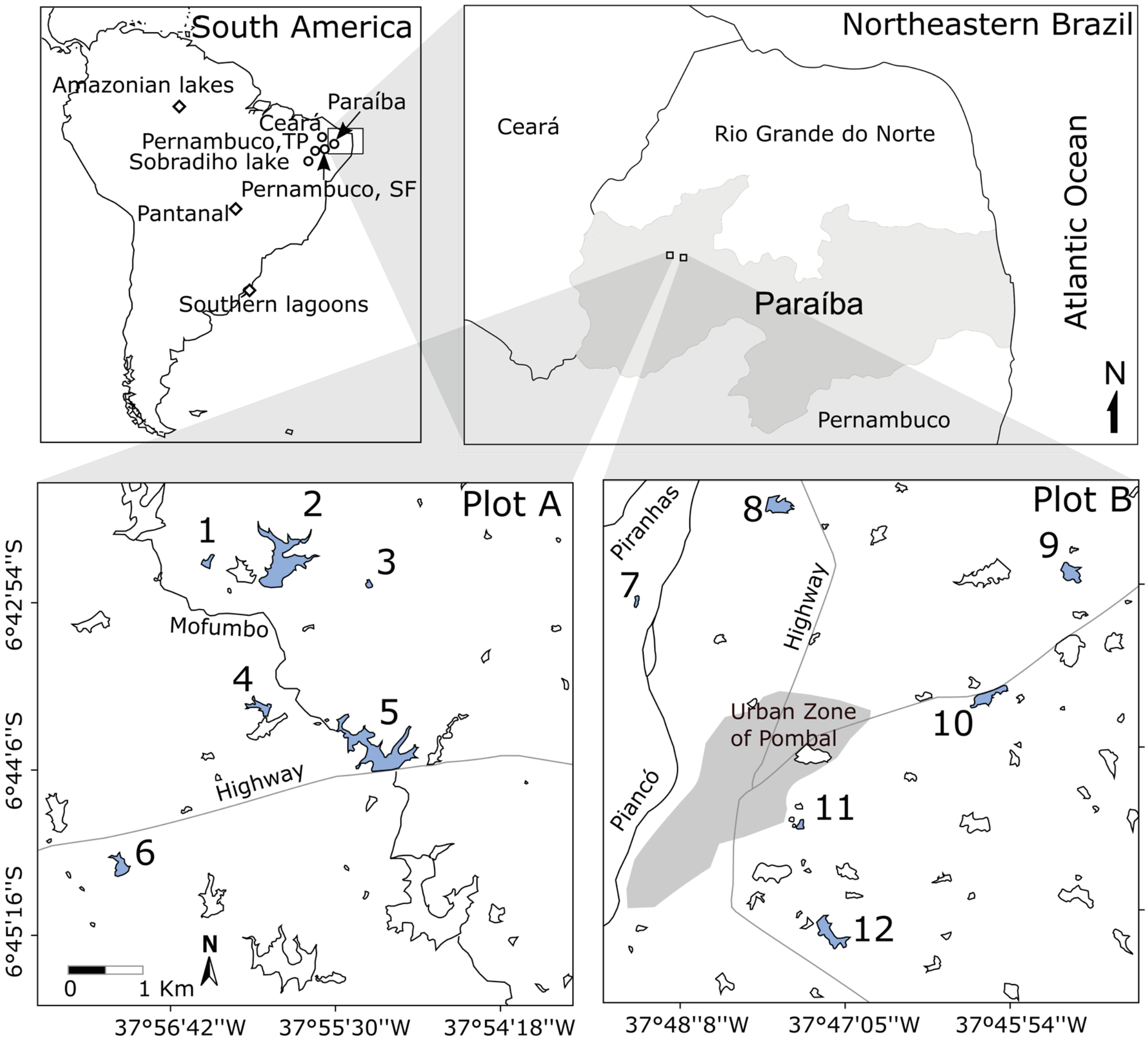

Figure 1. Location of study plots where the waterbird community was surveyed in the semi-arid region of Paraíba, Brazil. Plot A shows the sub-basin of the Mofumbo River, and Plot B shows the sub-basin of the Piancó River. The reservoirs chosen for sampling are highlighted in light blue and numbered. In the South America panel, diamonds (humid sites) and circles (semi-arid sites) indicate sites used for comparison in the CA. "TP" and "SF" refer to different studies carried out in the state of Pernambuco, the first refers to surveys in natural temporary ponds and the second to surveys in water reservoirs near São Francisco River.

quented all reservoirs, Striated Heron, Great Egret, Snowy Egret, and Wattled Jacana.

The Kaiser-Guttman criterion suggested the interpretation of the three first axes of the CA (average eigenvalue = 0.25; Appendix 2). Theses axes together explained 72.8% of the variation in the composition of the waterbirds communities (Figure 2). The first (30.7%) and third (17.7%) axes separated the three humid regions (Pantanal, southern lagoons, and Amazonian lakes), each one with an exclusive group of species (for species and sites scores see Appendixes 3 and 4). All humid regions together harbored 53 species that were absent in semi-arid regions. Along the first and third axes, the semi-arid sites gathered in the center of the graphic, which suggests a high similarity among them and shows the sharing of species with the humid regions.

The second axis (24.3%) detached semi-arid sites from humid sites showing that semi-arid region harbor species with wide distribution in South America, such as Common Gallinule, Least Grebe, Pied Lapwing (*Vanellus cayanus*), and Black-necked Stilt. Only seven species were exclusive from the semi-arid sites included in this study: Comb Duck (*Sarkidiornis melanotos*), White-cheeked Pintail (*Anas bahamensis*), Southern Pochard (*Netta erythrophthalma*), Masked Duck (*Nomonyx dominicus*), Paint-billed Crake (*Mustelirallus erythrops*), Purple Gallinule (*Porphyrio martinica*), and Pied Lapwing (*Vanellus cayanus*).

DISCUSSION

Our estimates show that reservoirs in semi-arid Brazil are important to hundreds of aquatic birds. Due to

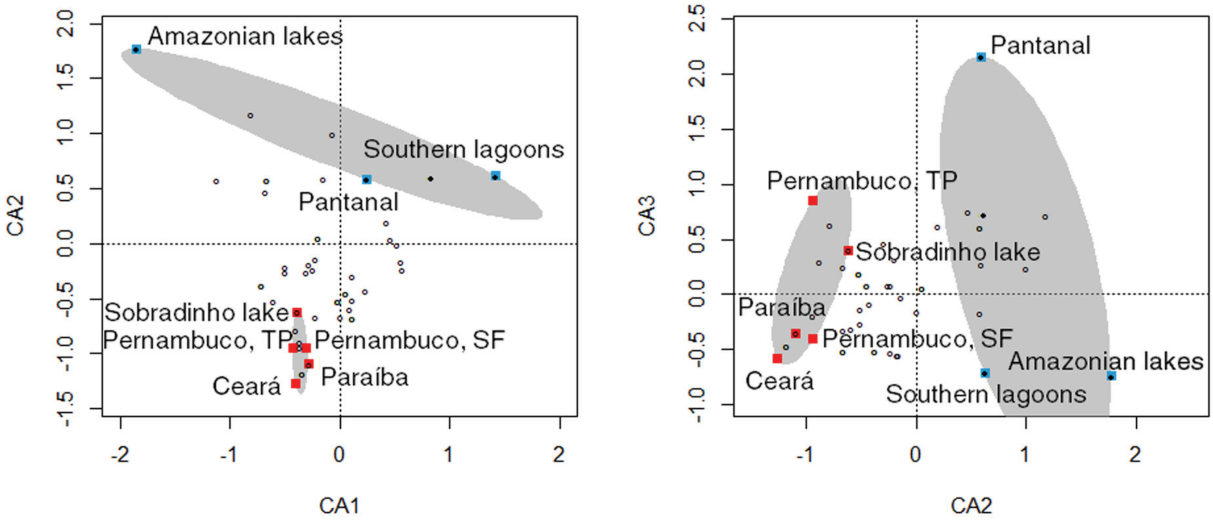

Figure 2. Result from Correspondence Analysis summarizing variation in waterbird species composition among selected Brazilian wetlands. Each species is shown as an open circle. Filled black circles are groups of overlapping species (see appendix 3 for species scores). Ellipsoid hulls (shaded area) enclose all sites with the same climate: semi-arid (red squares); humid (blue squares). See Figure 1 for the location of sites and explanation of abbreviations.

the building of reservoirs, several species have colonized an area previously devoid of perennial waters. The pattern of species dominance in the semi-arid of Paraíba may be related to the strong presence of aquatic vegetation in the sampled reservoirs, which favored species that forage on floating vegetation, such as Wattled Jacana and Common Gallinule (Sigrist 2009), and species that dive to collect prey in submerged vegetation, such as Least Grebe (TALC pers. observ.).

All species recorded in Paraíba have wide distributions exceeding the borders of the semi-arid in northeastern Brazil. Also, almost all of them have most of their distribution outside dry regions, including pantropical species, such as Great Egret and White-faced Whistling-Duck (*Dendrocygna viduata*), and long-distance migratory shorebirds, such as Solitary Sandpiper (*Tringa solitaria*) and Lesser Yellowlegs (*Tringa flavipes*) (Hayman et al. 1986).

The result of CA shows that the waterbird communities in semi-arid Brazil comprise a reduced version of the surrounding waterbird assemblages by lacking many species, like Jabiru (*Jabiru mycteria*) and Maguari Stork (*Ciconia maguari*), which are abundant in the Pantanal, Great Grebe (*Podicephorus major*) and Coscoroba Swan (*Coscoroba coscoroba*), found in southern lagoons, and Green Ibis (*Mesembrinibis cayennensis*) and Yellow-billed Tern (*Sternula superciliaris*), common in the Amazonian lakes. The seven species that, in our analysis, were exclusive to the semi-arid region, actually are wide spread in South America (see distribution maps in Sigrist 2009), and their apparent absence in the humid sites may be due to failures in detection of the studies we included in the CA.

Most species are more abundant in watersheds of other major Brazilian ecosystems. For example, Morrison et al. (2008) counted 95,319 waterbirds in the Pantanal wetlands; Cintra (2012) reported 3,626 individuals during only four censuses in the Amazon basin; and Guadagnin et al. (2005) recorded 142,000 birds in coastal lagoons of southern Brazil. Also, species richness was lower in northeastern Brazil than in more humid Neotropical regions. For example, 66 species are found in coastal lagoons in southern Brazil (Guadagnin et al. 2005), 48 species in the Amazon basin (Cintra 2012), and 135 in the Pantanal (Donatelli et al. 2014). The lower richness in arid and semi-arid lands is not surprising due to the low number of natural waterbodies and their ephemeral feature.

Our results show that the reservoirs in semi-arid Brazil provide environment for several aquatic birds that expand their distributions as new habitats are created. However, information is still lacking to assert if these habitats are beneficial to the birds or if they act as ecological traps. For example, the reservoirs in semi-arid Brazil may be detrimental to waterbirds when a severe drought reduces the habitat availability to a level that forces residential species to move away from their home ranges. Such severe droughts occur in northeastern Brazil with a rough frequency of 10 years (Cavalcanti 1988). Water shortage in arid regions, made worse by the use for urban and rural supply, has already led to declines in richness and abundance of waterbirds in wetlands of Australia (Kingsford & Thomas 1995), so reservoirs in regions with dry climates need careful management to ensure the permanence of waterbirds.

We witnessed reproduction of several species in the region (Cardoso & Loures-Ribeiro in prep.), which may suggest a beneficial role of the reservoirs, but only a more detailed study could answer if the local populations have higher or lower fitness (i.e., in terms of natality and mortality rates) than in more humid regions. If the reservoirs are beneficial, they could act as alternative habitats for feeding and breeding, and also as refuges for waterbirds during severe droughts. In this sense, the managing of reservoirs in arid and semi-arid lands could become part of conservation plans when natural wetlands are insufficient to maintain the viability of populations.

ACKNOWLEDGMENTS

We thank the Federal University of Paraíba for funding the project. Special thanks are given to Rossana B. Cardoso and Maria M. L. Cardoso for their precious support during field work.

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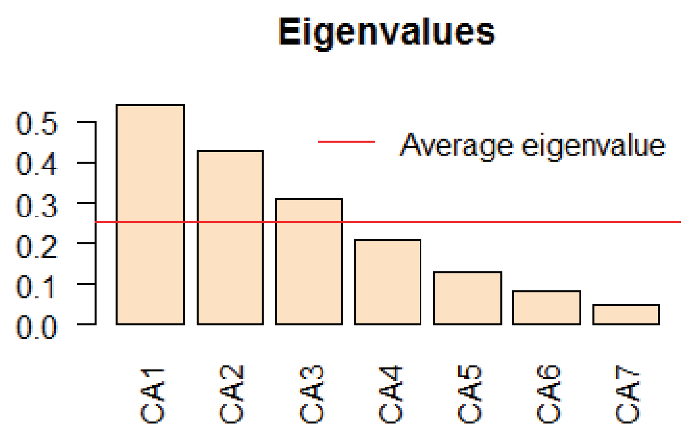
Appendix 1. List of species, average monthly abundance, standard deviation (±), and frequency of occurrence (f_{oc}) of waterbirds recorded in 12 reservoirs in the semi-arid region of Paraíba, Brazil, between September 2013 and November 2014. Species are ordered by abundance.

Species	Abundance (mean ± SD)	f_{oc}	Species (cont.)	Abundance (mean ± SD)	f_{oc}
Jacana jacana	63.4 ± 17.4	86.4	*Megaceryle torquata*	1.2 ± 1.6	8.9
Gallinula galeata	32.6 ± 17.7	43.2	*Botaurus pinnatus*	0.9 ± 1.1	5.3
Tachybaptus dominicus	29.5 ± 25.8	27.8	*Tringa flavipes*	0.7 ± 1.0	4.1
Himantopus mexicanus	26.1 ± 15.9	37.3	*Porphyrio martinica*	0.7 ± 0.8	4.1
Amazonetta brasiliensis	20.3 ± 16.8	34.9	*Mustelirallus erythrops*	0.5 ± 0.7	3.6
Ardea alba	16.2 ± 19.4	59.8	*Chloroceryle americana*	0.3 ± 0.5	2.4
Phalacrocorax brasilianus	15.7 ± 20.3	18.9	*Nycticorax nycticorax*	0.3 ± 0.6	1.8
Egretta thula	11.3 ± 12.4	36.1	*Nomonyx dominicus*	0.3 ± 0.8	1.2
Butorides striata	11.2 ± 5.7	55.0	*Ardea cocoi*	0.1 ± 0.4	1.2
Dendrocygna viduata	8.3 ± 9.4	13.0	*Dendrocygna autumnalis*	0.1 ± 0.5	0.6
Podilymbus podiceps	7.7 ± 6.6	27.2	*Dendrocygna bicolor*	0.1 ± 0.3	0.6
Tachycineta albiventer	6.2 ± 6.2	22.5	*Cairina moschata*		
Vanellus cayanus	4.9 ± 5.5	11.2	*Anhinga anhinga*		
Tigrisoma lineatum	4.3 ± 1.8	32.5	*Crotophaga major*		
Tringa solitaria	4.2 ± 4.5	14.2	*Furnarius figulus*		
Aramus guarauna	3.4 ± 1.8	18.3	*Certhiaxis cinnamomeus*		
Chloroceryle amazona	2.2 ± 2.1	16.0	*Fluvicola nengeta*		
Rostrhamus sociabilis	1.5 ± 1.3	8.9	*Arundinicola leucocephala*		

Appendix 2. Eigenvalues for the axes of the Correspondence Analysis (Figure 2), in which we compared the waterbird species composition among selected Brazilian wetlands. We used the average eigenvalue to assess the number of interpretable axes. According to Kaiser-Guttman criterion, axes with values above the average represent an important variation of the data and may be used for interpretation of the relationships among species and sites.



Appendix 3. Species scores in the Correspondence Analysis summarizing variation in waterbird species composition among selected Brazilian wetlands. Genus names were abbreviated to reduce the table width. Species are ordered according to Remsen et al. (2017).

Species	CA1	CA2	CA3	Species (cont.)	CA1	CA2	CA3	Species (cont.)	CA1	CA2	CA3
A. cornuta	-1.9	1.8	-0.7	*G. galeata*	0.0	-0.7	-0.3	*M. americana*	0.8	0.6	0.7
C. torquata	0.8	0.6	0.7	*P. martinica*	-0.3	-1.2	-0.5	*P. brasilianus*	-0.2	0.1	0.1
D. bicolor	0.1	-0.7	-0.5	*F. leucoptera*	1.4	0.6	-0.7	*A. anhinga*	-0.1	0.6	0.3
D. viduata	0.0	-0.5	0.2	*H. fulica*	-1.9	1.8	-0.7	*T. lineatum*	-0.5	-0.3	0.1
D. autumnalis	-0.5	-0.2	0.3	*P. dominica*	0.8	0.6	0.7	*T. fasciatum*	-1.9	1.8	-0.7
C. melancoryphus	1.4	0.6	-0.7	*P. squatarola*	1.4	0.6	-0.7	*A. agami*	-1.9	1.8	-0.7
C. coscoroba	0.8	0.6	0.7	*V. cayanus*	-0.4	-0.9	0.3	*B. pinnatus*	0.6	-0.2	-0.5
S. melanotos	-0.4	-0.8	0.6	*C. collaris*	0.2	-0.4	-0.1	*N. nycticorax*	0.1	-0.5	-0.3
C. leucophrys	1.4	0.6	-0.7	*H. mexicanus*	-0.2	-0.7	0.2	*B. striata*	-0.3	-0.3	-0.4
A. brasiliensis	0.0	-0.5	0.2	*H. himantopus*	1.4	0.6	-0.7	*A. cocoi*	-0.2	0.1	0.1
A. flavirostris	1.4	0.6	-0.7	*N. phaeopus*	0.2	0.6	2.2	*A. alba*	-0.3	-0.2	0.1
A. georgica	1.4	0.6	-0.7	*L. haemastica*	-0.8	1.2	0.7	*S. sibilatrix*	1.4	0.6	-0.7
A. bahamensis	-0.4	-0.6	0.4	*A. interpres*	0.2	0.6	2.2	*E. thula*	-0.2	-0.1	0.0
A. versicolor	1.4	0.6	-0.7	*C. canutus*	1.4	0.6	-0.7	*E. caerulea*	1.4	0.6	-0.7
A. platalea	1.4	0.6	-0.7	*C. bairdii*	1.4	0.6	-0.7	*P. chihi*	1.4	0.6	-0.7
N. peposaca	1.4	0.6	-0.7	*C. fuscicollis*	-1.9	1.8	-0.7	*M. cayennensis*	-1.9	1.8	-0.7
N. erythrophthalma	-0.4	-0.9	-0.2	*C. subruficollis*	0.2	0.6	2.2	*P. infuscatus*	0.8	0.6	0.7
H. atricapilla	1.4	0.6	-0.7	*C. melanotos*	0.8	0.6	0.7	*T. caerulescens*	1.4	0.6	-0.7
N. dominicus	-0.3	-1.2	-0.5	*G. paraguaiae*	0.5	0.0	-0.2	*T. caudatus*	0.2	0.6	2.2
O. vittata	1.4	0.6	-0.7	*A. macularius*	-0.7	0.5	0.8	*P. ajaja*	0.8	0.6	0.7
R. rolland	1.4	0.6	-0.7	*T. solitaria*	0.1	-0.3	0.5	*P. haliaetus*	-0.7	0.6	0.6
T. dominicus	0.1	-0.6	-0.3	*T. melanoleuca*	0.4	0.2	0.6	*R. sociabilis*	0.0	-0.5	0.2
P. podiceps	0.1	-0.7	-0.5	*T. flavipes*	0.5	0.0	0.4	*C. buffoni*	1.4	0.6	-0.7
P. major	1.4	0.6	-0.7	*J. jacana*	0.0	-0.5	0.1	*M. torquata*	-0.6	-0.5	-0.1
O. hoazin	-1.9	1.8	-0.7	*C. maculipennis*	1.4	0.6	-0.7	*C. amazona*	-0.3	-0.2	-0.6
A. guarauna	0.0	-0.5	0.1	*L. dominicanus*	1.4	0.6	-0.7	*C. americana*	-0.7	-0.4	-0.5
A. ypecaha	0.6	-0.2	-0.6	*S. superciliaris*	-0.1	1.0	0.2	*C. inda*	-1.9	1.8	-0.7
A. cajaneus	-1.1	0.6	-0.2	*P. simplex*	-0.7	0.6	0.6	*C. aenea*	-1.9	1.8	-0.7
A. saracura	1.4	0.6	-0.7	*R. niger*	0.8	0.6	0.7	*T. albiventer*	-0.7	-0.4	-0.5
P. melanops	1.4	0.6	-0.7	*E. helias*	-1.9	1.8	-0.7	*S. militaris*	-1.9	1.8	-0.7
M. erythrops	-0.3	-1.1	-0.4	*C. maguari*	0.8	0.6	0.7				
P. sanguinolentus	1.4	0.6	-0.7	*J. mycteria*	0.2	0.6	2.2				

Appendix 4. Site scores in the Correspondence Analysis summarizing variation in waterbird species composition among selected Brazilian wetlands. See Figure 1 for the location of sites and explanation of abbreviations.

Sites	**CA1**	**CA2**	**CA3**
Paraíba	-0.3	-1.1	-0.4
Southern lagoons	1.4	0.6	-0.7
Amazonian lakes	-1.9	1.8	-0.7
Pantanal	0.2	0.6	2.2
Pernambuco, TP	-0.4	-0.9	0.8
Ceará	-0.4	-1.3	-0.6
Pernambuco, SF	-0.3	-0.9	-0.4
Sobradinho lake	-0.4	-0.6	0.4