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Composition and Structure of the Lacustrine Bird Communities of Seasonally Flooded Wetlands of Western Brazilian Amazonia at High Water

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Abstract.—We describe and analyze the bird community composition of the lacustrine water bodies of the seasonally flooded wetlands of the Mamirauá and Amanã Reserves, Amazonas, Brazil. Bird surveys were conducted in 54 water bodies within four water body systems aboard a speedboat, in July 2003, at the peak of the high water season. We recorded 2,823 individuals representing 79 bird species associated with aquatic environments, mostly resident; of these, 34 were aquatic (exclusively associated with aquatic environments), and 19 were primarily piscivorous. The aquatic bird communities of Mamirauá and Amanã comprise a few abundant species and a higher number of rare species. Seven species accounted for 71.7% of all 34 aquatic birds recorded. In general, the more elongated the water bodies, the lower the aquatic and piscivorous bird species richness, and the lower the bird abundance. Piscivorous bird abundance was not significantly related to water body shape. Matrices of bird species by water body were subjected to multivariate analysis using Principal Co-ordinate Analysis (PCoA). For the quantitative data (species abundance) and qualitative data (species presence/absence), the composition of the community of aquatic birds changed significantly among lacustrine water body systems, and was significantly affected by water body shape. The quantitative and qualitative composition of the piscivorous bird community did not change significantly among water body systems, and were not affected by water body shape. The numerical analyses revealed a remarkably different behavior of the communities of aquatic birds and piscivorous birds, the former changing significantly with lacustrine water body morphology and local geography (water body system), and the latter being relatively insensitive to variation in these parameters. Water body shape is one of the determinants of aquatic bird community composition in the seasonally flooded wetlands of this part of Amazonia. *Received 21 June 2006, Accepted 8 December 2006.*

Key words.—aquatic birds, piscivorous birds, community composition, lacustrine water bodies, water body shape, Mamirauá, Amanã, Amazonia, Brazil.

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Studies on how communities are organized in structure and species composition are critical to understand the interactions between the populations that comprise them, and to explain local and regional biodiversity (Ricklefs and Schluter 1993; Willig *et al.* 2003). Ecological analyses of factors affecting bird communities have been undertaken mostly in the temperate northern hemisphere. In tropical rain forest regions, studies on dynamics of bird communities have concentrated mostly in terrestrial systems. For instance, in South America, particularly in the Amazonian basin, there are several studies describing the organization of forest and savanna bird communities (Terborgh *et al.* 1990; Cohn-Haft *et al.* 1997; Petermann 1997; Borges and Carvalhães 2000; Sanaiotti and Cintra 2001), analyzing the relationship between community composition and forest structure (Pearson 1971; Novaes 1973; Cintra 1997; Banks-Leite 2004; Naka 2004), and the effects of human-induced habitat alteration, such as anthropogenic secondary forest succession, fire (Borges and Stouffer 1999; Cintra and Sanaiotti 2005), forest fragmentation (Bierregaard 1990; Stouffer and Bierregaard 1995), and forest logging (Johns 1991; Guilherme and Cintra 2001).

Although aquatic environments represent 6%, or 300,000 km^2, of Brazilian Amazonia, and birds associated with aquatic environments affect the distribution and abundance of organisms in lower trophic levels (Steinmetz *et al.* 2003), there are few studies on Amazonian aquatic bird community ecology (Willard 1985; Rosenberg 1990). In Brazilian Amazonia, previous studies were conducted at the Mamirauá Sustainable Development Reserve (Pacheco 1993, 1994; Santos 1998), Ilha da Marchantaria (Petermann 1997), Jaú National Park (Borges and Carvalhães 2000), and Anavilhanas Biological Station (Cintra *et al.* 2007). Only two of these studies analyzed how the composition of bird communities changes among different aquatic environments.

The wetlands of the Mamirauá and Amanã Sustainable Development Reserves, western Brazilian Amazonia, are composed of hundreds of water bodies, distributed over a vast landscape in a gradient differing in size, shape, water properties, and other factors. Relating this environmental *continuum* to attributes of bird species, such as variation in presence/absence and/or abundance across the landscape, may help understand the structure and composition of bird assemblages. Since most aquatic bird are good colonizers, opportunistic, and widespread in the Amazonian region (Stotz *et al.* 1996; Petermann 1997), we hypothesize that their community composition is relatively homogeneous among aquatic water bodies throughout the floodplain.

In this study, we investigated how the richness, abundance, and composition, of the communities of aquatic birds of Mamirauá and Amanã Sustainable Development Reserves, change on a local and regional spatial scale among the lacustrine water body systems, and evaluate the effect of water body shape on these communities.

METHODS

Study Area

Bird surveys were conducted at the water bodies of the Focal Areas of the Mamirauá and Amanã Sustainable Development Reserves, Amazonas, Brazil (Figs. 1 and 2). The area surveyed approaches 1,500 km^2, and is comprised approximately between 2°40'S, 65°05'W and 3°10' S, 64°45'W (Mamirauá Reserve), and 2°20'S, 65°00'W and 2°50'S, 64°20'W (Amanã Reserve). The lowlands and their forests of the Solimões-Japurá River delta that compose the Focal Area of Mamirauá Reserve are seasonally flooded by white, silty waters of Andean origin (Fittkau *et al.* 1975; Sioli 1984; Junk and Furch 1985), and are accordingly designated várzea (Prance 1980; Pires and Prance 1985; Ayres 1993). Usually, water level peaks in June-July, and is lowest in October-November. These lowlands are crossed by a complex network of water bodies of different types, with different locally attributed designations. Channels and paranãs are linear and relatively fast-flowing water courses, connecting two rivers, two stretches of the same river, or a river with another water body. The locally called lakes are not true lakes in the traditional limnological sense, because they are connected to other water bodies at least during the

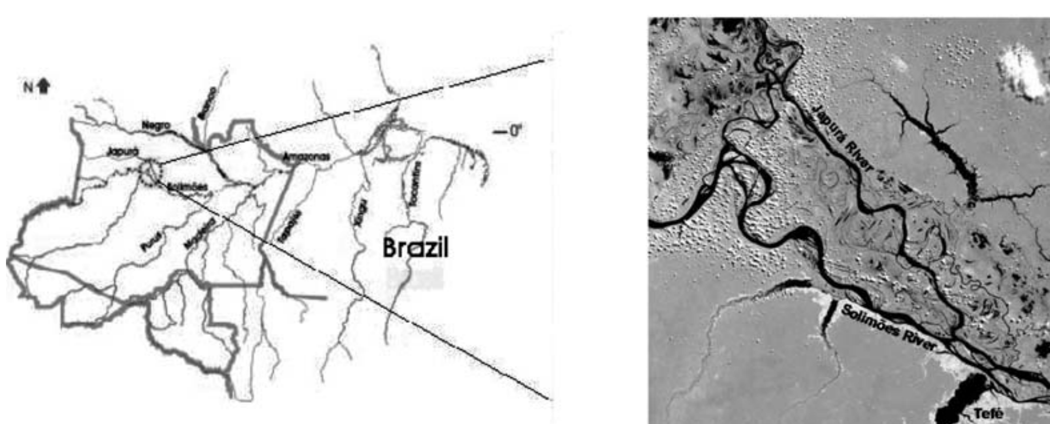

Figure 1. Location of the study area in Brazilian Amazonia. Satellite image showing the location of the Focal Areas of the Mamirauá and Amanã Reserves (taken from TRFIC-BSRI-MSU - Michigan State University website). Mamirauá Reserve is the river delta delimited by the Rivers Solimões, Japurá, and the smaller channel connecting the two large rivers on the upper left corner. Amanã Reserve lies on the other side of River Japurá, opposite from Mamirauá Reserve, and occupies the upper right third of the image. Lakes Amanã and Urini are the two arms of the large black "L" at Focal Area of Amanã Reserve, Amanã running approximately northwest-southeast, and Urini east-west.

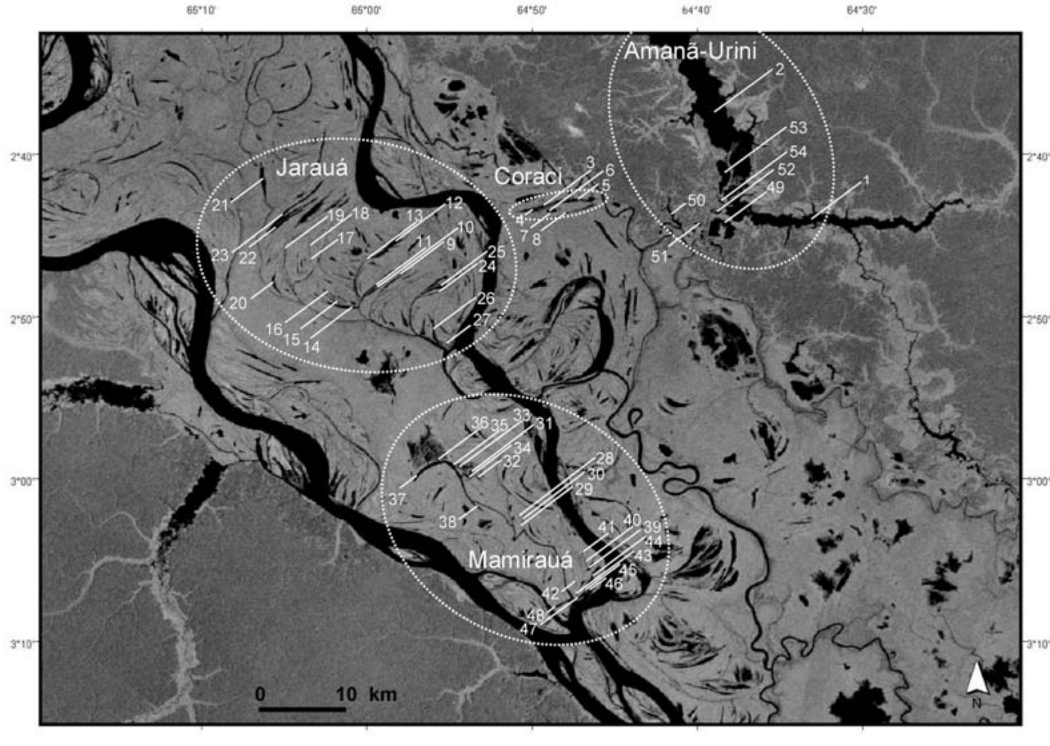

Figure 2. Location of the 54 water bodies studied within the water body systems Jarauá, Mamirauá, Coraci, and Amanã-Urini. Their numbers are given in Appendix 1, together with their geographical coordinates.

annual floods; nevertheless, lakes and their side branches (ressacas) are slow or non-flowing, may be roundish, elliptical, or longish, and most often do not connect to rivers directly (Henderson *et al.* 1998). They are delimited by forest, usually in the form of levees, and are more isolated from rivers than other water bodies, which render them a lacustrine nature, and the focus of this study. The Quaternary history of sedimentation and erosion has arranged the water bodies and associated seasonally flooded forest into dendritic formations, known as lake systems (Henderson 1999), or water body systems; there are eight main water body systems at the Focal Area of Mamirauá Reserve, two of which (Mamirauá and Jarauá) were surveyed (Figs. 2 and 3). The Coraci system of lakes of the adjoining the Focal Area of Amanã Reserve, on the left margin of the lower Japurá River, is also várzea, and its water bodies and associated forests are broadly similar to those at the Mamirauá Reserve. The Lakes Amanã and Urini (Amanã Reserve) seem to have been stretches of the Japurá River bed in the Pleistocene, and the surrounding landscape appears to have been várzea in the past (Rodrigues and Nelson, unpubl. manuscript; G. Irion and F. Wittman, pers. comm.). These lakes formed as the result of fluctuations in the river level and accompanying processes of erosion and sedimentation, and are usually designated blocked valley lakes (Henderson *et al.* 1998). The lakes' hydrology awaits detailed characterization, but they seem to receive white water at least during the high water season, from the Japurá River via connecting channels, or from the adjoining modern várzea. However, they also receive black water from smaller forest streams, locally known as igarapés, during at least part of the year (pers. obs.). Forests seasonally flooded by black waters are designated igapó (Prance 1980; Pires and Prance 1985; Ayres 1993). The forests that border Lakes Amanã and Urini and the lower course of their tributaries are thus of a mixed nature between várzea and igapó to a still unknown degree. The seasonally flooded forests of Amanã Reserve are embedded in a matrix of upland (terra firme) forest, which covers most of the Reserve. Ongoing plant surveys and the measurement of several habitat variables at these forest types will soon allow a fine knowledge basis of the várzea-igapó-terra firme landscape mosaic of the Amanã-Urini catchment basin, and indeed, of the entire Focal Area of Amanã Reserve.

Bird Surveys

Bird surveys were conducted daily, between 06.30 h and 18.00 h, in the period of 10-25 July 2003, during the peak of the high water season. At this time, the forest floor of the várzea and igapó is completely submerged, or almost so, and most migrant birds are not present in the area. Water level at high water in the year of the study was typical for the area (unpubl. data). Surveys were done aboard a 30 hp outboard speedboat, most of the time at a speed of 15-20 km/h. Birds were recorded with 10 × 50 and 8-20 × 50 binoculars, sometimes using a portable hand-counter. The data was written in a form containing the potential bird list of the area, and complemented the observations; an assistant drove the boat.

Figure 3. Aerial view of the typical várzea (flooded forest) habitat of the Mamirauá and Amanã Reserves study area, showing isolated water bodies (photos by L. C. Marigo).

For every sighting, the species, number of birds, and microhabitat were recorded. Birds cruising the area high above were not counted. Speedboat surveying is not an adequate method for small and secretive birds. Hence, like other studies (e.g., Guadagnin *et al.* 2005), we did not count passerines and other birds, unless they were readily and unambiguously identifiable. All the other birds seen were included in the counts. Surveys were conducted in a very short period, but covered a large area; hence, a snapshot of the aquatic bird community in the two Reserves could be obtained. This approach is convenient in studies where birds are not captured and marked, and avoids recording the same bird twice and overestimating count numbers. Over ten years experience studying birds associated with aquatic environments in Amazonia suggests that numbers do not change drastically year after year at high water (e.g., Cintra *et al.* 2007). Therefore, it is believed that the effect of seasonality on bird community composition is negligible. However, bird numbers clearly increase for several species (e.g., ducks, cormorants, egrets, kites, jacanas) at low water. Community composition in the low water season will be analyzed and compared with that of the high water season in a forthcoming manuscript.

Birds were surveyed in four systems of water bodies: Amanã-Urini, Coraci, Jarauá and Mamirauá, covering the entire spectrum of water body typologies, or nearly so. The sample unit was the water body, which was circumnavigated completely, travelling at a distance of about ten to 15 m from the shore. A Garmin 76 GPS was used to record their geographical coordinates in order to obtain water body positions (Appendix 1), and names used by local people were adopted.

Most bird species sampled were aquatic, in the sense that the resources they use are found chiefly in water bodies. Other species sampled seldom, or never, actually wade in water; they feed on leaves (Horned Screamer *Anhima cornuta*, Hoazin *Opisthocomus hoazin*), insects and fruits (e.g., Red-capped Cardinal *Paroaria gularis*), and vertebrates (e.g., Black Hawk *Buteogallus urubitinga*) in the environs of water bodies, and are better characterized as non-aquatic (Remsen and Parker 1983). However, in the real world, they all compose the community of birds present in association with water bodies in Amazonia and other Neotropical aquatic environments (Stotz *et al.* 1996). During the reproductive season, all of them construct their nests in the marginal vegetation along the aquatic environments (unpubl. data). Thus, all these species were included in the analyses.

The unit of effort was the entire water body. At the Mamirauá Reserve, water bodies of a variety of sizes were sampled (see Appendix 1). As water body area increases, bird species richness and abundance is expected to increase concomitantly, as predicted by the theory of island biogeography (MacArthur and Wilson 1967). To make comparable bird species richness and abundance, and community composition, of water bodies of different sizes (areas), not only within this study, but also with other studies, sampling effort was standardized by dividing the number of individuals of each bird species by the sizes (areas) of the water bodies in which the species occurred. Species densities obtained were then used in the quantitative statistical analyses.

The approach used in this study assumes that birds potentially could use the entire water body area. However, kingfishers and other birds commonly use trees along lake margins; herons and egrets (Great Egret *Ardea alba*, Rufescent Tiger-heron *Tigrisoma lineatum*, Striated Heron *Butorides striatus*), rails (*Porphyrula* spp.), the Jacana (*Jacana jacana*), and the Sungrebe (*Heliornis fulica*) use floating meadows in the central part of the lakes; piscivorous hawks (e.g., Black-collared Hawk *Busarellus nigricollis* and Osprey *Pandion haliaetus*) are commonly observed perched in dead trees, wherever they are located; and terns use the center and margins of lakes and rivers. Any bird counting method in Amazonian aquatic systems needs to consider these differences in species distribution. Since central and peripheral parts of water bodies alike were surveyed, the influence of these differences in local species distribution on the results is likely negligible.

Statistical Analysis

Of the several water body types surveyed, only results for lacustrine water bodies are presented, thus excluding rivers, paranãs, channels, and other formations with faster water flow. The aquatic bird community composition, richness and abundance was compared among 54 lacustrine water bodies within the four water body systems (Amanã-Urini, Coraci, Jarauá, and Mamirauá). The geographical coordinates of the 54 water bodies are in Appendix 1.

The aquatic bird community composition was compared among lacustrine water bodies of different shapes. The program Global Mapper (version 5.10; 2004) was used to estimate water body dimensions (area and perimeter) on a satellite image, kindly provided by the Mamirauá Sustainable Development Institute.

The shape index (SI) of Patton (1975), adapted for metric units, was used:

$$SI = P / 200 (\pi A)^{0.5}$$

where: SI = lacustrine water body shape index; P = perimeter of the lacustrine water body in kilometers; π = 3.1416; A = area of the lacustrine water body in km^2, to estimate the shapes of lacustrine water bodies, or their deviation from a circle (a circular water body assuming an SI = 1.0, and all other shapes assuming higher values).

Of the total community (birds associated with aquatic environments), statistical analysis was restricted to only two groups of species: those always associated to the aquatic environment, hereafter called the aquatic bird community, and the primarily piscivorous species, hereafter called the piscivorous bird community, which is a subgroup of the former, and includes the nine species considered piscivorous by Peterman (1997). The constituting species of each community are marked as A (aquatic) and P (piscivorous) in the "Aq./Pisc." column of Appendix 2, which lists all the birds associated with aquatic environments.

Simple linear regressions were used to look for relationships between bird richness and abundance and water body shape. The program Systat (Wilkinson 1998) was used to run these analyses.

Qualitative matrices with species presence/absence and quantitative matrices with species abundance, by lacustrine water body and water body system, were constructed for the aquatic and the piscivorous bird communities. In the matrices, the quantitative values (number of birds recorded) for each species were divided by water body area to obtain bird densities, which were then used in the multivariate analysis to test the null hypothesis that bird community composition was similar among water body systems.

To compare aquatic bird community composition among the lacustrine water bodies systems at Mamirauá and Amanã Reserves, all quantitative and qualitative data matrices constructed from the bird surveys were subjected to Principal Co-ordinate Analysis (PCoA), also known as metric or classic multidimensional scaling, and available in the program PATN (Pattern Analysis Package, Belbin 1982). PCoA is similar in approach and interpretation to Principal Component Analysis. The difference is that, in PCoA, the distances between the bird communities in the graph can be ecological distance measures other than the Euclidian distance. The distributions of aquatic and piscivorous species densities generally do not conform to the assumptions of multivariate inferential analysis such as Multivariate Analysis of Variance (MANOVA) (Legendre and Legendre 1998). Therefore, PCoA was performed on the dependent variables to obtain linear, orthogonal variables (axes) describing the bird community composition that met the assumptions of the multivariate inferential analyses (Anderson and Willis 2003). The four axes derived from the PCoA analysis were used in the MANOVA analyses because together these axes explained about 67% of the variance in the original variables for quantitative data, and 87% of the variance for qualitative data (see Results).

The Bray-Curtis index is calculated according to the formula:

$$D = \sum | {}^{D}ik - {}^{D}jk | / \sum \{{}^{D}ik - {}^{D}jk\}$$

where: ${}^{D}ik$ = the data value for the i^{th} row and k^{th} column of the data matrix; ${}^{D}jk$ = the data value for the j^{th} row and k^{th} column of the data matrix.

This index was used to describe dissimilarity between water bodies in water body systems. When used on presence-absence data, the Bray-Curtis index is known as the Sorensen distance measure (Legendre and Legendre 1998). The index is available in the program PATN (Belbin 1982). The Bray-Curtis coefficient has been recommended and used in ecological gradient studies (Minchin 1987; MacNally 1994), and, in Amazonia, with plants (Magnusson *et al.* 1999), insects (Lima *et al.* 2000), and birds (Cintra 1997; Guilherme and Cintra 2001; Cintra *et al.* 2007).

The association measures were transformed using the Gower Corrections option in TRNA, available in PATN (Belbin 1982). Finally, the resulting PCoA scores were used as dependent variables in models of MANOVA and multiple regression. *A posteriori* Pillai-Trace tests were used to verify whether MANOVA revealed significant differences among water bodies in water body systems, and to evaluate the effects of water body shape on bird community composition (when using multiple regression). The Pillai-Trace statistics has been shown to be less sensitive to deviations from assumptions than other multivariate statistics (Olson 1976; Johnson and Field 1993). Mantel tests, also available in PATN, were run to search for spatial autocorrelation of the aquatic and piscivorous communities and distance between water bodies.

RESULTS

General Results

Seventy nine bird species associated with aquatic environments were recorded at Mamirauá and Amanã Reserves (Appendix 2). Of these, 70 species were recorded in 54 lacustrine water bodies. None of them is endemic to the Reserves, and none is listed as threatened. The Whistling Heron (*Syrigma sibilatrix*), the Crested Eagle (*Morphnus guianensis*), and the Golden-winged Parakeet (*Brotogeris chrysopterus*), are new records for the area.

Most species recorded were permanent residents. Thirteen (17%) are considered southern austral partial migrants (Stotz *et al.* 1996; see Appendix 2); four species (5%) are considered northern Neotropical migrants (Great Egret, Snowy Egret *Egretta thula*, Black Skimmer *Rynchops nigra*, Osprey) by Stotz *et al.* (1996), but the first three occur in the area year-round, and hence were considered resident. The families Psittacidae, Accipitridae and Ardeidae had the highest species richness, with eleven (13.9%), ten (12.7%), and eight (10.1%) species, respectively.

The accumulation curves of aquatic bird species and of their subset, the piscivorous species, increased until they reached a plateau after five water bodies surveyed, after which they continued to increase, but less than before (Fig. 4).

Of the ten most abundant aquatic and piscivorous species, eight are among the ten with highest abundances among the 79 species associated with aquatic environments (Appendix 2). These species (Jacana, Large-billed Tern *Phaetusa simplex*, Striated Heron, Great Egret, Horned Screamer, Neotropic Cormorant *Phalacrocorax brasilianus*, Greater Ani *Crotophaga major*, Limpkin *Aramus guarauna*) summed up 1,560 individuals, representing over three quarters (76.9%) of all aquatic birds recorded for the 34 species used in the analysis (2,028).

Structure of the Communities of Birds Associated with Lacustrine Water Bodies

The waterbird communities of Mamirauá and Amanã comprise a few abundant species and a higher number of rare species. Of the ten most abundant species in lacustrine water bodies, seven were strictly aquatic. Of these, four were piscivorous (Large-billed Tern, Striated Heron, Great Egret, and Neotropic Cormorant). The Large-billed Tern was the most abundant species (265 individuals). The Jacana, the Striated Heron, the Great Egret, the Smooth-billed Ani *Crotophaga ani*, the Horned Screamer, and the Neotropic Cormorant, were among the ten most abundant birds. The Sungrebe and the Gray Hawk *Buteo nitidus* were among the ten rarest species in both (Appendix 2).

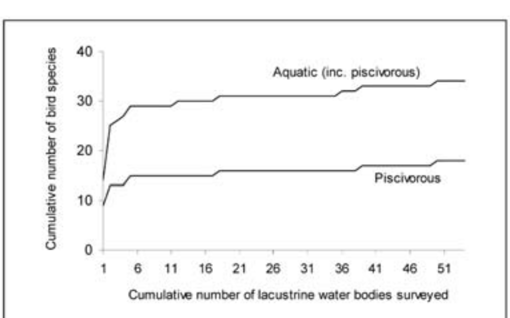

Figure 4. Saturation curve for the survey data from the Mamirauá and Amanã Reserves, showing bird species richness in relation to number of water bodies surveyed (sampling effort). The rate of increase in bird species number starts stabilizing after five water bodies surveyed.

In the 54 lacustrine water bodies, the aquatic bird species richness ranged from two (Lake Pauzal) to 22 (Lake Amanã), and the abundance ranged from three (Lake Pagão) to 310 individuals (Lake Amanã). The piscivorous bird species richness ranged from one (Lakes Atravessado, Promessa, Sarapião and Caxingubal) to ten (Lakes Amanã and Mamirauá), and the abundance ranged from one (the four preceding lakes) to 230 individuals (Lake Amanã). From the 70 bird species recorded in the 54 lacustrine water bodies (Appendix 2), there were 22 (31.4%) omnivorous-insectivorous species; 17 (24.3%) piscivorous species; 16 (22.8%) frugivorous species; eight (11.4%) carnivorous species; three (4.3%) scavenger species; two (2.9%) malacophagous species, and two (2.9%) folivorous species.

Effect of Water Body Shape on the Aquatic and Piscivorous Bird Richness and Abundance

Water body shape ranged from 1.210 (close to round) to 6.790 (elongate). The aquatic bird community species richness was significantly related to water body shape ($r^2 = 0.601$; N = 54; $P < 0.001$), shape explaining 36.1% of the total variation. Aquatic bird abundance was also significantly related to water body shape ($r^2 = 0.360$; N = 54; $P < 0.01$), but shape explained only 13.0% of the total variation (see Fig. 5).

For the piscivorous bird community, species richness was also significantly related to water body shape ($r^2 = 0.550$; N = 53; $P < 0.001$), explaining 35.3% of the total variation in species richness. Piscivorous bird abundance was not significantly related to water body shape ($r^2 = 0.253$; N = 52; n.s., see also Fig. 5). (The reason for using N = 52 in this analysis is due to the removal of Lake Anágua Comprido, an outlier that was destabilizing the

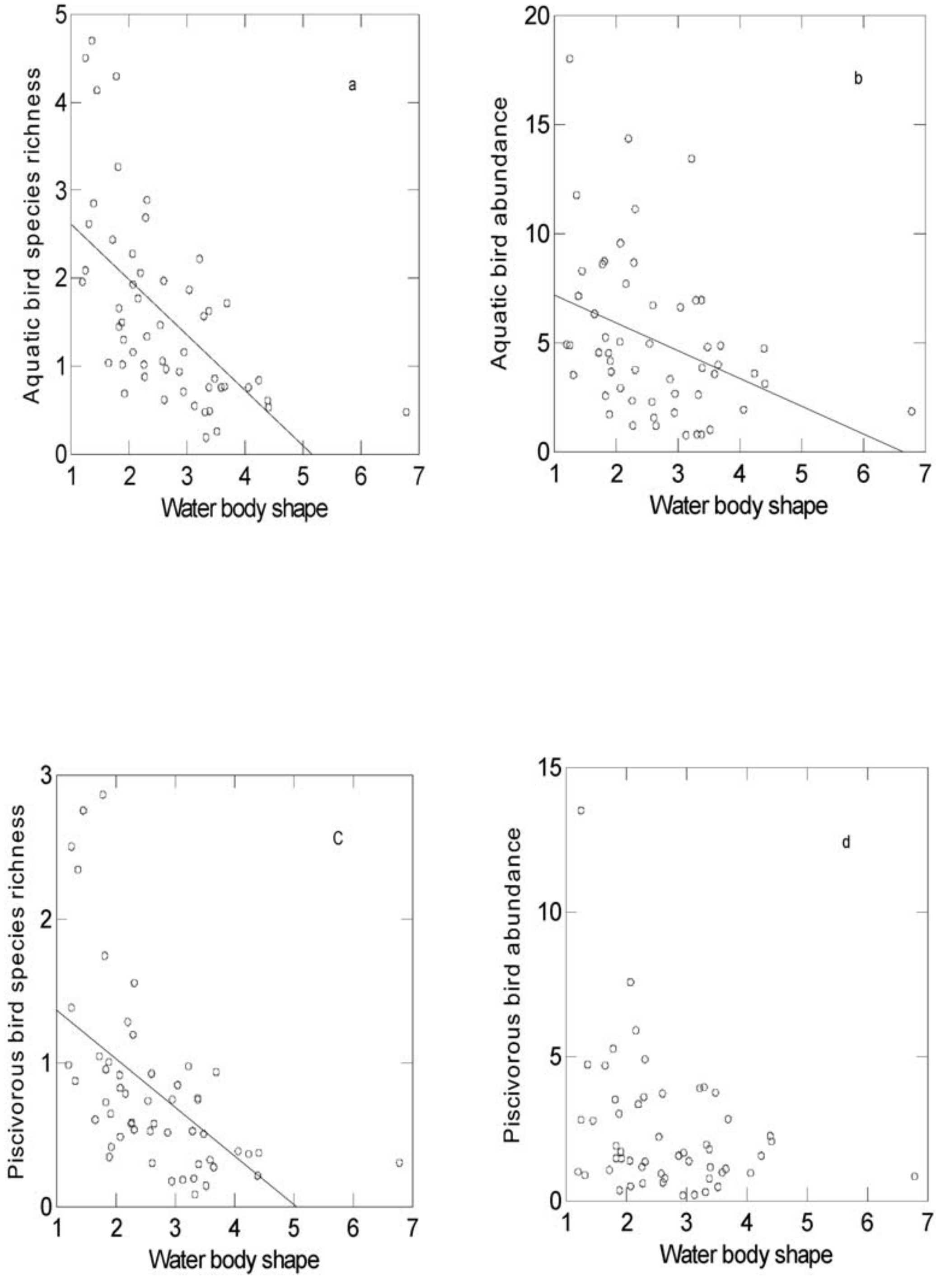

Figure 5. Relationships between aquatic and piscivorous bird species richness and abundance, and water body shape. Sample size is 54 water bodies. Water body shape varied between 1.210 (close to round) and 6.790 (long). The effect of water body area was removed *a priori* by dividing the original values of bird richness and abundance by water body area; consequently, the variation in bird richness and abundance is small.

model, and forcing the relationship to be significant.)

Comparison of the Aquatic Bird Community Composition among Lacustrine Water Body Systems

The four PCoA axes captured much of the variance (differences between bird communities) in the original variables for quantitative data (cumulative proportion of total variance C_{PV} = 0.68), and presence-absence data (C_{PV} = 0.67) (see also Table 1).

There was a significant but weak relationship between distances in the quantitative aquatic bird community composition and distances between water bodies (Mantel test: r = 0.09; P < 0.001), indicating some degree of spatial autocorrelation. The relationship between distances in the qualitative aquatic bird community composition and distances between water bodies was not significant (Mantel test: r = 0.012; n.s.), indicating no spatial autocorrelation.

Because the correlations for quantitative aquatic bird community composition were so weak, and the relationship between qualitative aquatic bird community composition and distance between water bodies was not significant, multivariate analyses were run to compare the quantitative and qualitative bird community composition among water body systems, and evaluate the effects of water body shape on them. The relationship between water body shapes and distances between water bodies was not significant (Mantel test: r = 0.011; n.s.).

For the quantitative data (matrix of bird species abundances), the composition of the aquatic bird community was significantly different between the lacustrine water body systems. For the qualitative data (matrix of bird species presence/absence), the composition of the aquatic bird community was also significantly different among systems (Table 2, Fig. 6).

Comparison of the Piscivorous Bird Community Composition among Lacustrine Water Body Systems

The four PCoA axes captured much of the variance in the original variables for quantitative data (Cumulative proportion of total variance (C_{PV}) = 0.80) and presence-absence data (C_{PV} = 0.87) (see Table 1). The relationships between distances in the shapes of the 53 water bodies (one did not have piscivorous species) and distances between water bodies was not significant (Mantel test: r = 0.011; n.s.). For the quantitative data (matrix of bird species abundances), the composition of the piscivorous bird community was not significantly different among the lacustrine water body systems. For the qualitative data (matrix of bird species presence/absence), the composition of the piscivorous bird community was also not significantly different among systems (Table 2).

Effects of Water Body Shape on Composition of the Aquatic and Piscivorous Bird Community

For both species presence/absence and species abundance, the aquatic bird community composition changed significantly with water body shape (Table 2). For the quantita-

Table 1. Variance values resulting from Principal Coordinate Analysis (PCoA) of the qualitative and quantitative matrices of aquatic and piscivorous bird communities of Amazonian lacustrine environments.

Aquatic					Piscivorous				
PCoA Vectors									
1	2	3	4	Total	1	2	3	4	Total
Quantitative									
0.33	0.14	0.12	0.09	0.68	0.38	0.19	0.14	0.10	0.81
Qualitative									
0.23	0.17	0.15	0.13	0.68	0.29	0.22	0.20	0.17	0.88

Table 2. Results of the multivariate analysis of variance (MANOVA) performed to test the effect of the water body system (Amanã-Urini, Coraci, Jarauá, and Mamirauá), and of the multiple regression performed to test the effect of lacustrine water body shape, on the composition of the communities of aquatic and piscivorous birds. The first figure in the DF columns is the degrees of freedom of the treatment; the second, of water bodies. Both analyses were performed on scores resultant from Principal Coordinate Analysis (PCoA); See Methods for details.

	Qualitative				Quantitative			
	Pillai-Trace	F	DF	P	Pillai-Trace	F	DF	P
Aquatic birds								
Water body system	0.564	2.839	4; 49	0.002	0.464	2.241	4; 49	0.013
Water body shape	0.244	3.955	4; 49	0.007	0.301	5.264	4; 49	0.001
Piscivorous birds								
Water body system	0.301	1.339	4; 48	n.s.	0.345	1.561	4; 48	n.s.
Water body shape	0.099	1.321	4; 48	n.s.	0.018	0.218	4; 48	n.s.

tive and qualitative data, the piscivorous bird community composition did not change significantly with water body shape (Table 2).

Plots of densities of individual species against water body shape revealed three groups of species (Fig. 7). One, in the upper part of Fig. 7, consists of omnivorous-insectivorous (Sungrebe, Red-capped Cardinal, White-winged Swallow *Tachycineta albiventer*, and Black-bellied Whistling Duck *Dendrocygna autumnalis*), folivorous (Hoatzin), and piscivorous species (White-necked Heron *Ardea cocoi* to Little Blue Heron *Florida caerulea*) that occur mostly at higher densities in more elongated water bodies. Another group of species includes carnivorous top predators (Yellow-headed Caracara *Milvago chimachima* and Black Hawk), large-bodied folivores (Horned Screamer), malacophages (Limpkin) and piscivores (Ringed Kingfisher *Ceryle torquata*, Great Egret, and Striated Heron) that occur across most of the gradient in water body shape. And a group of species in the lower part of Fig. 7, with one malacophagous (Snail Kite), two omnivorous-insectivorous (Muscovy Duck *Cairina moschata* and Jacana), and ten piscivorous species (from Black-collared Hawk to Whistling Heron), which occurred at higher densities mostly in rounded water bodies.

DISCUSSION

The communities of birds associated with aquatic environments at Mamirauá and Amanã Reserves comprise few abundant species and a higher number of rare species. This is a typical pattern of large animal communities, not only in the tropics, but also in subtropical and temperate latitudes (Terborgh *et al.* 1990, 1997; Ricklefs and Schluter 1993).

In this study, the aquatic bird species accumulation curve increased steadily until five water bodies had been surveyed; thereafter, it started approaching an asymptote, although more species were added even after 49 water bodies. The same was true for the piscivorous bird accumulation curve, although it was somewhat flatter (Fig. 4). This indicates that other species that were present in the area during the high water season could potentially have been added. Indeed, some species not recorded in the survey have been seen by several investigators in the area (Pacheco 1993, 1994; P. Santos, R. Cintra, A. Melo, pers. obs.), and also in other conservation units in central and western Brazilian Amazonia (Cohn-Haft *et al.* 1997; Borges *et al.* 2001; Cintra *et al.* 2007); for example, Agami Heron (*Agamia agami*), Wood Stork (*Mycteria americana*), and Green-and-rufous Kingfisher (*Chloroceryle inda*). Other species (e.g., the Agami Heron, Wood Stork), were not censussed well by our methods. This not withstanding, the species accumulation curves indicated that we captured the essence of the aquatic and piscivorous bird communities in our surveys.

There are about 292 species of aquatic birds in South America (Stotz *et al.* 1996). Of the 79 species associated with aquatic environments that we recorded at Mamirauá and

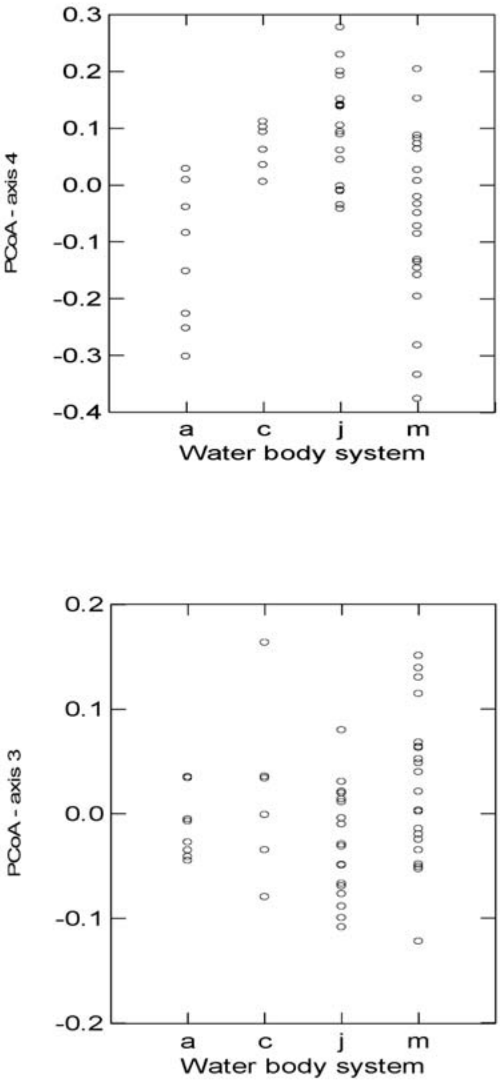

Figure 6. Variation of quantitative (PCoA 3) and qualitative (PCoA 4) aquatic community composition in relation to water body systems (a = Amanã; c = Coraci; j = Jarauá; m = Mamirauá). Here we used only the PCoA scores that showed significant relationship in Manova analyses. They were used to illustrate Manova results from Table 2. Since these were not significant for piscivorous birds, they are not shown.

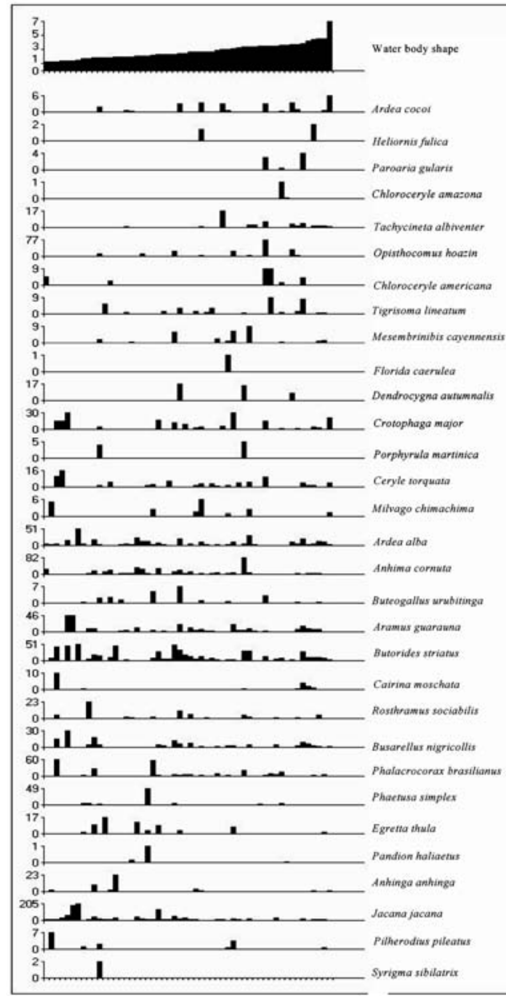

Figure 7. Aquatic bird species distribution in relation to water body shape. For each species, bars give bird numbers per water body. Species with very low densities were not included.

Amanã, 34 (43.0%) are dependent on aquatic habitats, of which 17 (21.5%) are mainly piscivorous (Schubart *et al.* 1965), representing 11.6% and 5.8% of the continental total, respectively. All 34 aquatic species are abundant, widespread, and occur in most aquatic environments at Mamirauá and Amanã (Pacheco 1993, 1994; Santos, unpubl. data) and in Amazonia (Novaes 1973; Pinto 1978; Caparella 1991; Cohn-Haft *et al.* 1997; Petermann 1997; Borges and Carvalhães 2000; Cintra *et al.* 2007). Some are distributed from Mexico to Argentina (Stotz *et al.* 1996), and a few are cosmopolitan (e.g., Great Egret and Osprey). Of the abundant species, none was restricted to any major river or water body system, even within families of primarily piscivorous birds, such as egrets and herons (Ardeidae) and kingfishers (Alcedinidae). This lack of specific affinities agrees with Stotz *et al.* (1996) for South American aquatic birds.

As in other environments that are seasonally flooded by large Amazonian rivers, some bird groups are lacking in Mamirauá and Amanã throughout the year (e.g., large storks), and some others are absent, or present in very low numbers, in certain parts of the year (e.g., sandpipers, plovers, ducks, and cormorants, at high water). In his intensive and detailed study at Ilha da Marchantaria, Central Amazonia, Petermann (1997) also found seasonal changes in the composition of the wetland bird fauna, with lower numbers of species occurring during the high water period (flood pulse).

Some of the rarest species in our surveys—Mealy Parrot *Amazona farinosa*, Gray-headed Kite *Leptodon cayenensis*, Crested Eagle, Great Potoo *Nyctibius grandis*, Toco Toucan *Ramphastos toco*, Yellow-billed Tern *Sterna superciliaris*, and the Whistling Heron—are also uncommon in other natural, undisturbed bird communities across Amazonia (R. Cintra, unpubl. data). This suggests that the recording of a few individuals only for some species was not an artifact of sampling, but an indication that the waterbird communities of Mamirauá and Amanã are relatively well structured and pristine. Of these, an interesting result was the observation of four Whistling Herons, a species that to our knowledge was previously unknown to Amazonia (del Hoyo *et al.* 1992, p. 405). We saw one individual at the Lake Periquito Redondo, Mamirauá Reserve (3°04'86"S, 64°45'98"W), another one at the Paranã do Amanã, Amanã Reserve (2°42'88"S, 64°37'50"W), and two others at the Paranã do Castanho, Amanã Reserve (2°44'78"S, 64°30'71"W). Another new record for Amanã Reserve (although it had already been seen at the neighbor Mamirauá Reserve by Pacheco, 1994, and P. Santos, unpubl. data) is the Toco Toucan: we saw three individuals at the Lake Patá, Coraci, Amanã Reserve (2°43'89"S, 64°50'35"W). The Crested Eagle is typical of upland forests; the bird sighted was probably wandering in the flooded forests. The Wattled Curassows (*Crax globulosa*) were observed in the forested margin of a ressaca, a microhabitat that the species seems to privilege (Santos 1998). Curassows and other large frugivores, such as the tinamous, chachalacas, and guans, are usually the first birds to be hunted down to local extinction following human occupation (Bierregaard 1990; Robinson and Terborgh 1990); the presence of this game bird at the Mamirauá indicates that some forest areas are still intact for the ecological requirements of this species, and face little hunting pressure (Strahl and Grajal 1991; Santos 1998).

Tonn *et al.* (1990) suggested that morphometric features of lakes are important determinants of bird and fish community structure in north-central Alberta, Canada; probably, environmental conditions at the margins of round and shallow lakes are more homogeneous, and littoral production is higher, than in deeper lakes, that may have a greater amount of pelagic habitat relative to littoral zone (Paszowski and Tonn 2000). In northern European and eastern North American lakes, water chemistry, such as pH and nutrient load, were found to be the main determinants (Blancher *et al.* 1992; Kauppinen and Väisänen 1993; Suter 1994), and in Florida, environmental variables such as water body depth, productivity, and proportion of microhabitats, have also been found to be important (Riffell *et al.* 2001). At least for wading birds in wet years in the Everglades, bird abundance was found to be correlated with water depth, vegetation types and areas with higher nutrient enrichment (Crozier and Gawlik 2002).

In our study, multivariate analysis results suggest that, in general, aquatic bird community composition changed considerably across the floodplain landscape. It showed significant differences in species composition among lacustrine water body systems, both quantitatively and qualitatively (Table 2). Although we did not measure productivity of water bodies, we believe that the changes in the aquatic bird community composition along the gradient of the four water body systems may be, among other things, a consequence of differences in water productivity, as found for fish by Henderson and Crampton (1997). Because white water lakes have higher productivity than black water lakes (Fittkau *et al.* 1975; Junk and Furch 1985), and may have higher ecological carrying capacity, they may support more aquatic bird species and abundance. In other water systems in North America and Europe, it has been demonstrated that aquatic environments bearing higher productivity and nutrient enrichment determine wading bird abundance (Riffell *et al.* 2001; Crozier and Gawlik 2002).

Our study indicates that the aquatic bird community was affected by water body shape: the more rounded the shape, the more the aquatic bird community changed. Bird richness and abundance tended to decrease with the increase in water body shape complexity (Fig. 5), certainly influencing the changes that bird community composition also undergoes with water body shape. These results surprised us, because the more complex the shape of the aquatic environment is, the higher the diversity of microhabitats is to be expected, and in consequence, the higher the species richness and abundance (Terborgh *et al.* 1990). However, aquatic birds tend to be very territorial during the high water season, when most food resources are dispersed throughout the landscape. Their territories tend to be linear, located in the forest-water ecotone. In elongated water bodies, opposite margins are usually closer than in roundish ones, and aquatic birds tend to defend both margins instead of only one. This inter and intraspecific competition for space (namely, to gain access to food resources) may make habitats more difficult to colonize by dispersers coming from other water bodies. This may help explain the differences in waterbird species richness and composition between long and round water bodies. Although we have not analyzed the spatial distribution of each individual species, during our surveys we often noticed an "even distribution" of several egrets, herons, kingfishers, and allies in the margins of long water bodies.

None of the analyses for the piscivorous bird community composition yielded significant results. This pattern may be due to a more homogeneous distribution of their food resources in the aquatic environment, and from wider movements of these predators following movements of fish assemblages, which can be affected by vegetation. For example, working in our study area, Henderson and Crampton (1997) observed that fish aggregate in floating meadows, and leave them at night to forage in open water. In addition, in Ecuadorian Amazonia, fish community structure is affected by the area of stream bottom covered by leaves, which is strongly correlated to canopy forest cover (Bojsen and Barriga 2002). Although in a quite different system, in northern Alberta, Canada, the communities of fish and aquatic birds studied by Paszkowski and Tonn (2000) showed similar patterns to the ones we found. In the Everglades, prey composition and availability has also been demonstrated to be an important factor affecting wading bird distribution and abundance (Kushlan *et al.* 1975). However, prey abundance changes quickly, and wading birds can, in a short period, exhaust prey in an area and then move to another one (Strong *et al.* 1997; Bancroft *et al.* 2002).

Several factors have been speculated as determinant in the composition of aquatic birds in Brazil (e.g., Guadagnin *et al.* 2005). The results of this study strongly suggest that, during the high water season, the environmental heterogeneity created by differences in the spatial distribution and morphometry (shape) of lacustrine water bodies is an important determinant of the aquatic bird community composition in the seasonally flooded wetlands of western Brazilian Amazonia.

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Appendix 1. The lacustrine water bodies where birds were sighted. The sequence after each number gives the following information: name, water body system (A = Amanã-Urini, C = Coraci, J = Jarauá, M = Mamirauá) (see definitions in Methods), geographical coordinates (latitude, longitude), and water body area (km^2).

1 Urini A 2°42’90”S, 64°37’29”W, 23.3; **2** Amanã A 2°42’87”S, 64°37’77”W, 103; **3** Curuçá C 2°43’19”S, 64°49’06”W, 0.11; **4** Buiuçu C 2°43’44”S, 64°49’38”W, 0.54; **5** Taiassu C 2°42’65”S, 6447’42”W, 1.49; **6** Branco C 2°43’41”S, 64°48’63”W, 0.42; **7** Paracuuba C 2°43’93”S, 64°48’92”W, 0.02; **8** Patá C 2°43’89”S, 64°50’35”W, 0.93; **9** Panema J 2°50’28”S, 64°59’55”W, 0.43; **10** Artur J 2°49’00”S, 65°00’01”W, 0.30; **11** Água Verde J 2°48’87”S, 65°00’03”W, 0.37; **12** Tucuxi 1 J 2°46’02”S, 64°58’75”W, 0.88; **13** Tucuxi 2 J 2°50’23”S, 64°59’78”W, 2.25; **14** Maciel J 2°49’52”S, 64°00’38”W, 0.75; **15** Samaumeirinha J, 2°49’26”S, 65°01’57”W, 0.30; **16** Sarapião J 2°48’99”S, 65°01’80”W, 0.25; **17** Panelão 1 J 2°48’18”S, 65°04’26”W, 0.54; **18** Panelão 2 J 2°46’61”S, 65°03’19”W, 0.24; **19** Jaraqui J 2°45’75”S, 65°04’75”W, 0.32; **20** Cedrinho J 2°48’81”S, 64°04’68”W, 0.81; **21** Baixo J 2°42’77”S, 65°05’93”W, 1.3; **22** Samaúma 1 J 2°44’82”S, 65°05’54”W, 1.14; **23** Samaúma 2 J 2°43’56”S, 65°04’65”W, 2.03; **24** Itu 1 J 2°51’16”S, 64°56’84”W, 1.26; **25** Itu 2 J 2°48’89”S, 64°56’80”W, 0.69; **26** Caetano J 2°51’63”S, 64°55’55”W, 0.76; **27** Mojuí J 2°51’99”S, 64°55’15”W, 0.22; **28** Pauzal M 3°02’48”S, 64°50’59”W, 0.02; **29** Pagão and Pauzal M 3°03’19”S, 64°50’39”W, 0.11; **30** Pagão M 3°02’92”S, 64°50’37”W, 0.17; **31** Atravessado M 2°59’87”S, 64°53’58”W, 0.06; **32** Arati M 2°59’72”S, 64°53’58”W, 0.09; **33** Anágua Comprido M 2°59’81”S, 64°53’83”W, 0.25; **34** Anágua Redondo M 2°59’89”S, 64°54’08”W, 0.2; **35** Miuá M 2°59’34”S, 64°54’51”W, 0.18; **36** Saracura M 2°58’98”S, 64°55’56”W, 0.4; **37** Mamirauá M 3°01’29”S, 64°53’58”W, 2.59; **38** Iuíri M 3°01’37”S, 64°53’63”W, 0.31; **39** Periquito Redondo M 3°04’86”S, 64°45’98”W, 0.51; **40** Periquito Comprido M 3°05’70”S, 64°46’59”W, 0.18; **41** Promessa M 3°05’61”S, 64°46’80”W, 0.30; **42** Bararuá M 3°06’66”S, 64°47’16”W, 0.21; **43** Matamatá M 3°07’22”S, 64°47’00”W, 0.07; **44** Tracajá M 3°07’06”S, 64°46’77”W, 0.91; **45** Caxingubal M 3°06’81”S, 64°46’29”W, 0.08; **46** Mateiro M 3°06’68”S, 64°46’30”W, 0.09; **47** de Fora M 3°07’41”S, 64°47’19”W, 0.78; **48** da Vila M 3°07’61”S, 64°47’59”W, 0.44; **49** Itanga A 2°44’95”S, 64°39’18”W, 4.57; **50** Capitão A 2°44’52”S, 64°40’88”W, 1.35; **51** Teodora A 2°44’43”S, 64°39’33”W, 0.42; **52** Arati A 2°43’54”S, 64°38’67”W, 0.23; **53** Seringa A 2°42’05”S, 64°38’14”W, 3.88; **54** Laguinho A 2°42’31”S, 64°38’65”W, 0.68.

Appendix 2. The species of birds associated with aquatic environments at the Mamirauá and Amanã Reserves, western Brazilian Amazonia, total numbers recorded in lacustrine water bodies (lakes) (NB), body weights in grams (Wgt.), the strictly aquatic and/or piscivorous (Aq./Pisc.) species used in statistical analyses, their statuses in the study area, the designations and number (NL) of lacustrine water bodies in which they occurred, and the percentage (%) of this number relative to the total number of lacustrine water bodies (= N × 100/54) (see code meanings at the end of the table).

	Scientific name	Bird species Portuguese common and/or local (*) name	English name	NB	Wgt.	Aq./Pisc.	Status	Lacustrine water bodies in which birds occurred (see names, types, and locations in Appendix 1)	NL	%
1	*Jacana jacana*	Jaçanã, piaçoca*	Jacana	329	120	A	r, b	1-18, 19, 20, 22-28, 30-37, 39-54	51	94.4
2	*Phaetusa simplex*	Gaivota*	Large-billed Tern	266	240	A, P	r, b	1, 2, 12, 23, 31, 30, 36, 37, 39, 50, 52, 5	12	22.2
3	*Butorides striatus*	Socozinho	Striated Heron	230	175	A, P	r, b	1-15, 17, 18-22, 24-27, 30, 32-34, 36-40, 42-44, 48-51	41	75.9
4	*Ardea alba*	Garça-branca-grande	Great Egret	204	885	A, P	ps+, b	1-15, 17, 18, 20, 21, 22-24, 33, 34, 36, 39, 43-45, 46-50, 52-54	37	68.5
5	*Crotophaga ani*	Anu-preto	Smooth-billed Ani	197	95		r, b	1-5, 8-10, 12-15, 19-21, 22-27, 33, 36-39, 43, 44, 46, 48, 51, 52-54	34	63.0
6	*Coragyps atratus*	Urubu	Black Vulture	184	1,350		r, b	2, 9, 11, 12, 14, 19, 21, 23, 25-27, 37, 42, 50, 53	15	27.8
7	*Anhima cornuta*	Alencorne*	Horned Screamer	178	3,100	A	r, b	1-3, 9-15, 17, 21, 23, 24, 27, 30, 33, 35-39, 42, 44, 45, 47, 47, 49-54	33	61.1
8	*Phalacrocorax brasilianus*	Biguá, miuá*	Neotropic Cormorant	129	1,300	A, P	r, b	2, 3, 5, 8, 10-13, 19, 21, 24, 26, 29, 30, 33, 34, 36, 37, 42, 44, 47, 48, 50, 53	24	44.4
9	*Crotophaga major*	Coroca*	Greater Ani	119	170	A	r, b	1, 2, 8, 12, 13, 15, 19, 23-25, 30, 31, 33, 34, 36, 37, 39, 41-43, 53	21	38.9
10	*Aramus guarauna*	Carão	Limpkin	105	1,200	A	r, b	2, 3, 9-25, 27-28, 36-38, 43, 44, 46-48	29	53.7
11	*Progne chalybea*	Andorinha-grande	Gray-breasted Martin	90	39		u	2, 6, 37	3	5.6

Bird species: common names according to Willis and Oniki (1991) and Pacheco (1994); * names used by local inhabitants; English names according to Hilty (2003); NR = New record for the Mamirauá and/or Amanã Reserve. Wgt.: weight data for *Ara ararauna* and *A. manilata* taken from Roth (1984); weight data for other species taken from Hilty (2003). Aq./Pisc.: A: species strictly associated with aquatic environments (aquatic bird community); P: primarily piscivorous species (piscivorous bird community). Status in the study area (following Pacheco 1994): b = breeding confirmed; ps+ = resident year-round, but related mostly with the low water season; r = resident year-round; rs = resident year-round, with population augmented by austral migrants; u = unknown; v = vagrant; vn = boreal migrant.

Appendix 2. (Continued) The species of birds associated with aquatic environments at the Mamirauá and Amanã Reserves, western Brazilian Amazonia, total numbers recorded in lacustrine water bodies (lakes) (NB), body weights in grams (Wgt.), the strictly aquatic and/or piscivorous (Aq./Pisc.) species used in statistical analyses, their statuses in the study area, the designations and number (NL) of lacustrine water bodies in which they occurred, and the percentage (%) of this number relative to the total number of lacustrine water bodies (= N × 100/54) (see code meanings at the end of the table).

	Scientific name	Bird species Portuguese common and/or local (*) name	English name	NB	Wgt.	Aq./Pisc.	Status	Lacustrine water bodies in which birds occurred (see names, types, and locations in Appendix 1)	NL	%
12	*Opisthocomus hoazin*	Cigana	Hoatzin	87	820	A	r, b	1, 4, 9, 12, 13, 15, 19, 23, 30, 36, 39, 44	12	22.2
13	*Busarellus nigricollis*	Gavião-panema*	Black-collared Hawk	65	650	A, P	r, b	1-3, 8-15, 17, 18, 25, 24, 26, 27, 30, 33, 34, 37, 39, 43, 44, 49, 50, 53	27	50.0
14	*Columba cayennensis*	Pomba	Pale-vented Pigeon	52	230		r	1, 2, 23, 29, 33, 37	6	11.1
15	*Cacicus cela*	Japiim*	Yellow-rumped Cacique	46	80		r, b	2, 4, 5, 7, 9, 10, 16, 18, 23-26, 29, 41-45, 49, 52	20	37.0
16	*Rostrhamus sociabilis*	Gavião-caramujeiro	Snail Kite	40	345	A	ps+, b	1, 2, 9-11, 13, 21-23, 27, 28, 35, 37, 46, 48, 49	16	29.6
17	*Ceryle torquata*	Ariramba-grande*	Ringed Kingfisher	36	300	A, P	r	1, 2, 8, 9, 12, 16-19, 24, 25, 31, 34, 37-40, 44, 48-51, 53, 54	24	44.4
18	*Tachycineta albiventer*	Andorinha-de-rio	White-winged Swallow	34	17	A	r, b	2, 4, 5, 8, 9, 12, 13, 18, 19-21, 23, 24, 37, 41	15	27.8
19	*Amazona festiva*	Papagaio*	Festive Parrot	30	400		r, b	2, 11, 13, 16, 18, 22, 24, 41, 49	9	16.7
20	*Buteo magnirostris*	Gavião-pega-pinto*	Roadside Hawk	28	265		r, b	1, 10, 12, 13, 18, 24, 25, 28, 33, 34, 36, 37, 45, 49, 52	15	27.8
21	*Ardea cocoi*	Maguari*	White-necked Heron	25	2,100	A, P	r, b	1, 2, 5, 8, 10, 12, 19, 21, 22, 37, 39, 41, 49, 50	14	25.9
22	*Bubulcus ibis*	Garça-dos-bois*	Cattle Egret	25	340		r, b	1, 5, 10, 13, 46, 54	6	11.1
23	*Egretta thula*	Garça-branca-pequena	Snowy Egret	25	330	A, P	ps+, b	2, 3, 5, 10, 15, 33, 35, 36, 46, 53, 54	11	20.4
24	*Ara macao*	Arara-vermelha	Scarlet Macaw	18	1,000		r	1, 2, 8, 18, 49	5	9.3
25	*Mesembrinibis cayennensis*	Corocoró, curubá*	Green Ibis	18	720	A	r, b	5, 9, 13, 15, 30, 37, 39, 44, 49, 50	10	18.5

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Appendix 2. (Continued) The species of birds associated with aquatic environments at the Mamirauá and Amanã Reserves, western Brazilian Amazonia, total numbers recorded in lacustrine water bodies (lakes) (NB), body weights in grams (Wgt.), the strictly aquatic and/or piscivorous (Aq./Pisc.) species used in statistical analyses, their statuses in the study area, the designations and number (NL) of lacustrine water bodies in which they occurred, and the percentage (%) of this number relative to the total number of lacustrine water bodies (= N × 100/54) (see code meanings at the end of the table).

	Scientific name	Bird species Portuguese common and/or local (*) name	English name	NB	Wgt.	Aq./Pisc.	Status	Lacustrine water bodies in which birds occurred (see names, types, and locations in Appendix 1)	NL	%
26	*Tigrisoma lineatum*	Socó-boi, socó-onça*	Rufescent Tiger-heron	18	840	A, P	r, b	5, 10, 13, 14, 18, 21, 22, 23, 25, 29, 35-38	14	25.9
27	*Ara ararauna*	Arara-canindé	Blue-and-yellow Macaw	17	1,000		v	5, 8, 54	3	5.6
28	*Buteogallus urubitinga*	Gavião-preto	Black Hawk	16	1,100	A	r, b	1, 2, 10, 12, 13, 19, 23, 39, 47, 48, 50, 51, 53	13	24.1
29	*Milvago chimachima*	Caracaraí*	Yellow-headed Caracara	16	325	A	r, b	2, 6, 8, 9, 12, 25, 48, 50	8	14.8
30	*Dendrocygna autumnalis*	Marrequinha*	Black-bellied Whistling-duck	15	740	A	ps+, b	4, 10, 36	3	5.6
31	*Anhinga anhinga*	Anhinga, Carará*	Anhinga	12	1,200	A, P	ps+	3, 6, 8, 12, 24, 25, 32, 36, 37, 51	10	18.5
32	*Pilherodius pileatus*	Garça-morena*	Capped Heron	12	550	A, P	r, b	2, 5, 6, 15, 39, 50, 53	7	13.0
33	*Chloroceryle americana*	Ariramba-pequena*	Green Kingfisher	11	27	A, P	r	18, 19, 29, 37, 51, 54	6	11.1
34	*Cathartes burrovianus*	Urubu-de-cabeça-amarela	Lesser Yellow-headed Vulture	10	950		r	2, 8, 39, 49, 50, 53	6	11.1
35	*Cairina moschata*	Pato-selvagem*	Muscovy Duck	9	3,000	A	r, b	2, 17, 18, 23, 24, 34, 36, 53	8	14.8
36	*Cathartes aura*	Urubu-de-cabeça-vermelha	Turkey Vulture	8	1,500		r	19, 24, 53	3	5.6
37	*Paroaria gularis*	Cardeal-da-Amazônia	Red-capped Cardinal	8	22	A	r, b	2, 18, 19, 37	4	7.4
38	*Brotogerys chrysopterus* NR	Periquito-de-asa-dourada	Golden-winged Parakeet	7	55		u	1, 2, 21	3	5.6
39	*Daptrius ater*	Cancão-de-anta*	Black Caracara	7	350		r	2	1	1.9
40	*Ictinia plumbea*	Cauré*	Plumbeous Kite	7	245		rs, b	2, 12, 19, 30	4	7.4
41	*Ramphastos tucanus*	Tucano*	Red-billed Toucan	7	600		r	2, 30, 40	3	5.6
42	*Ara manilata*	Maracanã-do-buriti	Red-bellied Macaw	6	420		u	39	1	1.9
43	*Ara severa*	Maracanã-guaçu,	Chestnut-fronted Macaw	6	335		r, b	43	1	1.9
44	*Aratinga leucophthalmus*	Maracanã*	White-eyed Parakeet	6	160		r	1	1	1.9
45	*Graydidascalus brachyurus*	Curica*	Short-tailed Parrot	6	—		r, b	9, 15, 30	3	5.6

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Appendix 2. (Continued) The species of birds associated with aquatic environments at the Mamirauá and Amanã Reserves, western Brazilian Amazonia, total numbers recorded in lacustrine water bodies (lakes) (NB), body weights in grams (Wgt.), the strictly aquatic and/or piscivorous (Aq./Pisc.) species used in statistical analyses, their statuses in the study area, the designations and number (NL) of lacustrine water bodies in which they occurred, and the percentage (%) of this number relative to the total number of lacustrine water bodies (= N × 100/54) (see code meanings at the end of the table).

	Scientific name	Bird species Portuguese common and/or local (*) name	English name	NB	Wgt.	Aq./Pisc.	Status	Lacustrine water bodies in which birds occurred (see names, types, and locations in Appendix 1)	NL	%
46	*Psarocolius decumanus*	Japó-preto, japó	Crested Oropendola	6	300		u	2, 18, 23, 41	4	7.4
47	*Brotogerys sanctithomae*	Periquito*	Tui Parakeet	4	65		r, b	24, 25, 36	3	5.6
48	*Campephilus melanoleucos*	Pica-pau-de-cabeça-vermelha	Crimson-crested Wood-pecker	4	250		r	1, 2	2	3.7
49	*Gymnoderus foetidus*	Anambé-pombo	Bare-necked Fruitcrow	4	345		r, b	12, 29	2	3.7
50	*Porphyrula martinica*	Galo-d'água-azul	Purple Gallinule	4	220	A	v	36, 39	2	3.7
51	*Chloroceryle amazona*	Ariramba-média*	Amazon Kingfisher	3	110	A, P	r	1, 37	2	3.7
52	*Crax globulosa*	Mutum-piuri*	Wattled Curassow	3	3,000		r	19	1	1.9
53	*Heliornis fulica*	Patinha-do-igapó*	Sungrebe	3	130	A	r, b	12, 24	2	3.7
54	*Pandion haliaetus*	Gavião-caipira	Osprey	3	1,500	A, P	vn	1, 49, 54	3	5.6
55	*Pteroglossus castanotis*	Araçari-castanho	Chestnut-eared Araçari	3	250		r	35, 39	2	3.7
56	*Stelgidopteryx ruficollis*	Andorinha-serradora-do-sul	Rough-winged Swallow	3	15	A	r, b	2	1	1.9
57	*Buteo nitidus*	Gavião-pedrês	Gray Hawk	2	475		u	7, 9	2	3.7
58	*Geranospiza caerulescens*	Gavião-pernilongo, gavião	Crane Hawk	2	330	A	r	2	1	1.9
59	*Herpetotheres cachinnans*	Acauã	Laughing Falcon	2	560		r	37	1	1.9
60	*Piaya cayana*	Titicuã*	Squirrel Cuckoo	2	95		r	5, 39	2	3.7
61	Unidentified Cotingidae	Anambé	—	2	—		u	15	1	1.9
62	*Amazona farinosa*	Moleiro*	Mealy Parrot	1	620		v	41	1	1.9
63	*Florida caerulea*	Garça-azul	Little Blue Heron	1	320	A, P	u	50	1	1.9
64	*Leptodon cayenensis*	Gavião-de-cabeça-cinza	Gray-headed Kite	1	410-605		r	41	1	1.9
65	*Morphnus guianensis* NR	Gavião-real	Crested Eagle	1	1,500		u	17	1	1.9
66	*Nyctibius grandis*	Urutau-grande	Great Potoo	1	550		r, b	31	1	1.9
67	*Ramphastos toco*	Tucanuçu	Toco Toucan	1	—		u	8	1	1.9
68	*Ramphastos vitellinus*	Tucano-rouco*	Channel-billed Toucan	1	350		u	24	1	1.9

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	Scientific name	Bird species Portuguese common and/or local (*) name	English name	NB	Wgt.	Aq./Pisc.	Status	Lacustrine water bodies in which birds occurred (see names, types, and locations in Appendix 1)	NL	%
69	*Sterna superciliaris*	Gaivotinha*	Yellow-billed Tern	1	46	A, P	r, b	2	1	1.9
70	*Syrigma sibilatrix* NR	Maria-faceira	Whistling Heron	1	370	A, P	u	39	1	1.9
71	*Chloroceryle aenea*	Ariramba-miudinha*	American Pygmy Kingfisher	—	15		r	unrecorded in lacustrine water bodies	—	—
72	*Chordeiles rupestris*	Bacurau-de-praia	Sand-colored Nighthawk	—	20		ps+, b	”	—	—
73	*Elanoides forficatus*	Gavião-tesoura	Swallow-tailed Kite	—	420		v	”	—	—
74	*Eurypyga helias*	Pavãozinho*	Sunbittern	—	220		r	”	—	—
75	*Falco rufigularis*	Caurèzinho*	Bat Falcon	—	130		u	”	—	—
76	*Melanerpes cruentatus*	Picapau-de-barriga-vermelha	Yellow-tufted Woodpecker	—	58		r, b	”	—	—
77	*Pyrrhura melanura*	Periquito*	Maroon-tailed Parakeet	—	—		u	”	—	—
78	*Rynchops niger*	Corta-água*	Black Skimmer	—	280		ps+, b	”	—	—
79	*Sarcoramphus papa*	Urubu-rei	King Vulture	—	3,300		u	”	—	—
			Total	1,823						

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