Birds as indicators of wetland status and change in the North Rupununi, Guyana

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ABSTRACT

In financially and human capacity poor countries, there is an important need to monitor the status of resource rich ecosystems in the face of growing extractive activities in simple and inexpensive ways. In this study we explore the potential of using birds as indicators of ecosystem change in the wetland systems of the North Rupununi, Guyana, where local communities rely heavily on wetland resources for their subsistence activities. This is done by (1) assessing what environmental factors determine bird communities at different spatial and temporal scales; and (2) identifying indicator groups and/or species for ecosystem status. We surveyed 31 wetland sites over two years, taking monthly recordings of both the environmental features of waterbodies using a modified version of the River Habitat Survey and bird species counts. Using multivariate analyses, we found that large-scale habitat type, namely forest and savanna, and waterbody type, namely pond or main river channel, were the main factors affecting bird species distribution. At the smaller scale, habitat features around the waterbody and seasonality become important factors. We were able to identify lists of bird species associated with different waterbody types, and we present this as a checklist for future monitoring. We hope these findings can be integrated into the adaptive management and sustainable livelihood goals of the local stakeholders through linking monitoring with tourism and local school curriculum activities.

INTRODUCTION

Change, as a result of environmental, social, economic and political drivers, is occurring in many natural resource management situations around the world. To understand how natural resource management situations are changing over time involves monitoring i.e. undertaking and analysing regular observations to detect change. This information can then be used to development adaptive management planning for future actions. For most natural systems, it is virtually impossible to have a comprehensive understanding of how the whole system works and behaves, and its consequent state. In an ideal world you would monitor all structures and processes within these systems and then go on to identify typical structures and processes. This is simply not possible within complex natural systems such as tropical wetlands. There are far too many structures and processes operating at a range of spatial and temporal scales to monitor, and these change and adapt with inherent fluctuating environmental conditions. In many cases we are therefore forced to significantly simplify our understanding of these natural systems; appropriate indicators need to be developed which can be used to describe their status.

Some of the considerations of choosing indicators include their ability to interpret key drivers of natural systems and their "user-friendliness" (human capacity, logistics and financial resource requirements). In many parts of the world, monitoring is extremely problematic because of these issues (Danielsen *et al*., 2005), yet these are usually places where monitoring is most urgent due to the high dependency of livelihoods on local natural resources and the increasing pressures on these.

One such location is the North Rupununi District in south-west Guyana. The area is comprised of a mosaic of savannas, wetlands and forests, criss-crossed by an intricate network of rivers and creeks. This diversity of habitats supports a huge biodiversity of both terrestrial and aquatic life, and provides a wealth of natural resources for the Makushi and Wapishana peoples that inhabit the area. However, with growing threats of logging, mining and oil exploration in the region and limited government capacity to adequately monitor the environmental and social impacts of these activities, the local communities are looking to collect monitoring information on ecosystem status, so as to inform their natural resource and livelihood activities decision-making. The wetland areas in particular are critical for subsistence fishing (60% of local diets is from fish (Mistry, *et al,* 2004)), as well as for potential commercial fishing, and for growing local enterprises such as ecotourism and the aquarium fish trade.

It is within this context that a project funded by the Darwin Initiative (DEFRA, UK Government) was initiated and a range of indicators to monitor wetland change were developed through a UK-Guyana stakeholder collaboration (NRAMP Partnership, unpublished data; note that indicators of community status were also developed but are not discussed here).

Taking into consideration the problems of monitoring in the North Rupununi context, one of the indicators chosen for 'appropriate' monitoring of the wetlands was birds. Birds have been used as bioindicators in a number of other studies (Furness and Greenwood, 1993) and have more recently been used as national indicators for sustainable development within the UK (DEFRA, 2007). Although there are some problems with monitoring birds (Verner, 1985), they are a useful taxonomic group to monitor as they are often well known, easily recognisable, simpler to locate than many other groups, can be valuable indicators of the state of particular habitats and are also key species for education and public awareness (Bibby *et al*., 2000). Birds are sensitive to both direct and indirect environmental influences (Adamus and Brandt, 1990). They can indicate changes in: vegetation extent, pattern and structure (Finch, 1991); standing water extent, depth, duration and seasonal frequency (Wakeley and Roberts, 1994); water quality (Hoyer and Canfield, 1994); and disturbance (Craig and Barclay, 1992). Birds are therefore valuable as ecosystem change indicators because they often respond to cumulative effects of environmental influences on the system (Sekercioglu, 2006).

Therefore, within the North Rupununi context, the aims of this study were: (1) to assess which environmental factors determine bird communities at different spatial and temporal scales; and (2) to identify indicator groups and/or species, defined as typical groups and/or species for monitoring ecosystem change.

METHODS

Study area

The North Rupununi District is situated in south-west Guyana (04º N 05', 59º W 02') and comprises savanna, tropical lowland forest and wetland vegetation types. Mean annual rainfall is between 1600mm and 1900mm, peaking during the rainy season months between May and September (Hawkes and Wall, 1993). The waterways respond to this seasonality with water levels rising in the rivers and creeks during the rainy season and flooding the savannas and forest, and then receding during the dry season, leaving isolated waterbodies such as ponds.

Sampling

Criteria for the selection of monitoring sites were developed in collaboration with stakeholders from the local communities, the Iwokrama International Centre and the University of Guyana. Satellite images, resource maps and local knowledge of the area were used to identify potential monitoring sites using the criteria of waterbody hydrogeomophic type (e.g. permanent pond, pond that dries out, river, creek etc.) and habitat type (forest or savanna). The hydrogeomorphic waterbody classification developed for the North Rupununi describes the different combinations of hydrological regime and geomorphic setting found across the region. Hydrology, geomorphology and habitat type are recognised as important determinants of ecosystem functioning and have been used as indicators of ecosystem functioning within functional assessment approaches (Brinson *et al.*, 1993; Maltby *et al.,* 1996; Simpson, 2000). Maintenance of ecological functioning within a system is important in securing overall ecosystem health. Secondary criteria used for site selection included the presence of land use activities in and around the waterbodies and the accessibility of the site. Once a list of potential sites was complied, a two week field trip to a total of 47 sites was undertaken. This reconnaissance trip allowed the identification of sites for monitoring, based on whether they fitted the criterion and whether they were actually accessible both in the dry and wet seasons. At the end of the trip, 33 sites were chosen to conduct monthly monitoring activities, but after the first twelve months of monitoring, two sites were dropped after consideration of site representation and logistical difficulties. As such, monthly data was collected for 31 sites between March 2004 and April 2006.

To assess what environmental factors determine bird community abundance and distribution at different spatial and temporal scales, a monitoring scheme was required to characterise these variables. A modified version of the River Habitat Survey was adopted (Raven *et al.,* 1998). This monitoring approach has been developed in the UK to provide a national survey tool that describes the character and quality of habitats, the modifications affecting them, and has allowed the creation of a database of river habitats so that regular monitoring of the state of river systems can take place. It has provided a system for classifying rivers according to their habitat quality and allowed relationships to be determined between habitat, biological and chemical quality (Raven *et al.,* 1997). Modified versions of the River Habitat Survey have been used in a number of countries to assess river systems and to assess the relationship of land use change amongst habitats, invertebrates and birds (e.g. Manel *et al.,* 2000).

For the purposes of this project, the basic form of the River Habitat Survey was maintained but within each section, categories were amended to reflect the different vegetation types, geomorphic setting and hydrological attributes found in the North Rupununi. The River Habitat Survey records over 120 variables describing the channel, flow character, banks and catchment within three main sections (for full methods see Environment Agency, 1997). Spot checks were used to record channel and bank material, features, vegetation types and flow type within the channel. For this part of the survey, adjustments were made to some descriptors so that other waterbodies such as lakes and ponds could be assessed. Water depth was recorded in the middle of the waterbody and at the same place every month. As a result of extensive flooding into surrounding vegetation during the wet season, waterbody size could not be ascertained during this period. A 500m 'sweep-up' assessment was also used to record the predominant habitat features such as surrounding vegetation structure, bank profiles, extent of larger scale channel features and human activities.

In addition to the environmental characteristics, species information was also collected. There are a range of different survey methods that can be used to monitor birds such as aerial surveys, flight path observations, nesting/roosting sight observations, transects and point counts. These methods, and when to use them, are discussed in detail in Bibby *et al*. (2000). For the purposes of this project, the transect method and point count methods which rely on the visual and hearing senses of the observer/s, were employed. All monitoring surveys were carried out by trained and experienced field workers and local community members who have an intimate knowledge of the species found in their environment. The bird surveys were conducted over one day a month between 06:00–08:00hrs and 16:00–18:00hrs, and the species and number of individuals present at the waterbody were recorded. Flying birds were excluded unless they were obviously hunting or feeding. Within river geomorphic types, two kilometre transects were undertaken using a boat at low speed. Within basin geomorphic types, observations were made from a set of points along the perimeter of the waterbodies.

Data analysis

All monitoring data were regularly entered into a Microsoft Access database. For each survey visit bird data was collected at sunrise and sunset, so two data sets were entered. Correlation analysis was used to test for daytime effects by examining the relationships between the relative abundance of different bird species by daytime. We found no significant daytime effects, therefore the data were pooled for further analyses. In addition, species and environmental variables observed on <5% (<30 occurrences) of the sites were made supplementary, having no influence on further analyses. The matrices of data were a) the environmental matrix - values for each River Habitat Survey variable per month per site, and b) the bird matrix - abundance of individual bird species per month per site. The characteristics of each monitoring site are shown in Table 1.

To understand what factors are determining the variation in bird communities in the North Rupununi wetlands, and to help identify indicators, a series of ordination analyses were carried out. A multivariate statistical software package CANOCO 4 (ter Braak and Smilauer, 1998) was used with the environmental and bird matrices. In all cases, log transformation was applied to the bird matrix to account for the multiplicative variation in bird abundances. All other default commands were used.

Ordination analyses were carried in four steps. Since there were a large number of environmental variables measured through the River Habitat Survey method, and many of these would be autocorrelated, the first step in the analysis involved taking a "common-sense" approach to sorting out the correlations between the environmental variables, so as to choose a much more limited subset of environmental variables *a priori*. To judge the correlations among the variables, the environmental matrix was subject to Principal Component Analysis (PCA) with centring and standardisation to correspond to a "PCA on a matrix of correlations (between variables)" (Lepš and Šmilauer, 2003, Petr Šmilauer, personal communication, 2006). The correlation matrix from the PCA results was then subject to hierarchical clustering using the average linkage clustering, with the original "r" values being replaced with the square root of 1-r*r (Petr Šmilauer, pers. com., 2006). Then using a combination of prior knowledge of variables, the exploratory PCA axes scores and the groups identified by the clustering, a subset of variables was selected (see Table 2).

Following the identification of the main environmental variables, Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA) (Kent and Coker, 1992) were used to investigate the relationships between the bird species variation and the environmental variable data. The DCA analysis involved all the monitoring sites – results from the first axis then determined sub-groups of monitoring sites for further DCA analysis.

The TWINSPAN classification method (from Two Way Indicator Species Analysis – software program is of same name) (Kent & Coker, 1992) was then used at the sub-group level to identify bird groupings and indicator species. The pseudospecies cut levels 0, 1, 10, 100 and 1000 were used to correspond to a logarithmic transformation as the abundance of different bird species sometimes different by several orders of magnitude. All other default commands were used.

RESULTS

During our sampling we counted 45,567 bird individuals of 214 different species, including four species, the Great Blue Heron (*Ardea herodias),* Orange-chinned Parakeet *(Brotogeris jugularis*), Powerful Woodpecker (*Campephilus pollens)* and Red-capped Cardinal (*Paroaria gularis),* currently not found in the Guyana Bird Checklist (Braun *et al*. 2000) (Table 3).

PCA of environmental variables

The PCA axes indicated that on the first axis the main habitat type was the controlling factor, with flooded savanna at one end of the axis and forest at the other. This is supported by the cluster analysis which also differentiated the first division with savanna and forest. Axis 2 of the PCA seemed to represent the waterbody type, with ponds at one end of the axis and the main river channel at the other (and other waterbody types grouped together in the centre of the axis). However, the cluster analysis showed that in the second and third divisions, ponds that dry out, permanent ponds and the main river channel are the distinctive waterbody types, appearing in separate groups to the others.

DCA and CCA of all bird species and main environmental variables

Using the main controlling environmental variables highlighted in italics in Table 2, a DCA ordination was carried out on the bird species data (the length of the longest axis provides an estimate of the beta diversity in the data set and the value of 5.4 suggests that the use of unimodal ordination methods is appropriate here). In this analysis, the environmental data does not influence the species and sample ordination, but is projected on to the ordination diagram.

The results indicated that the first axis represented a significant proportion of variation, with an eigenvalue of 0.598, whereas the second and third axes explained significantly less, with eigenvalues 0.260 and 0.204 respectively. The projection of the environmental variables revealed that the first axis was negatively correlated with flooded forest and non-flooded forest and positively correlated with flooded savanna (Figure 1). Inspection of the general distribution of the samples and species supports this interpretation – samples from forest sites, including A7, A8 and D1 for example, were found on the left hand side of the first axis, whereas samples from D7, D8 and D9 savanna sites were found on the right hand side of the axis (Figure 2); similarly lowland rainforest species such as the Band-rumped Swift, Crimson Topaz, Black-necked Aracari, Black-headed Parrot and the Plumbeous Pigeon were found on the left hand side of axis 1 whereas typical flooded savanna/scrub species including Eastern Meadowlark, Red-breasted Blackbird, Crested Bobwhite, Bicolored Wren and White-headed Marsh-Tyrant were found on the right hand side of axis 1.

The Monte Carlo permutation test of the CCA on the same data set indicated that both the test on the first axis and the test on all axes (on the trace) were highly significant (P = 0.002 with 499 permutations), although the F value was much higher for the test on the first axis (F = 31.752) than for the test on the trace (F = 9.159). The significance of the second axis was tested by using the axis 1 sample scores as a covariable and carrying out another CCA. The result indicated that the second axis was also significant (F = 21.299, P = 0.002). Forward selection was used to build a simpler model of the environmental variables and understand the relative importance of each. The conditional effects indicated that the flooded savanna, ponds that dry out, flooded forest and main river channel variables (F = 22.66-8.60, P = 0.002) were the most important.

Levels 1-3 sub-divisions of the monitoring sites

The results of the first analysis indicated that there were distinct savanna and forest assemblages of birds, and an intermediate mixed group. Therefore using the axis 1 CCA scores, the sites were divided up into three groups for further analysis: flooded savanna group – sites B7, D4, D5, D6, D7, D8, D9; flooded forest group – sites A1, A2, A3, A4, A5, A7, A8, A9, C3, C5, C6, D1; and Intermediate group – sites B1, B2, B3, B4, B5, B6, B8, B9, C1, C4, D2, D3. For each group of these groups, a DCA using only the waterbody types as the environmental variables was carried out. This second stage of the analysis identified distinct sub-groups on the first axis associated with waterbody type, namely ponds and main river channel waterbodies (Table 4); these were then used for further DCA and classification analyses using all the environmental variables (excluding vegetation and waterbody type) to identify local factors determining bird species in the waterbody types (Table

5). This third stage of the analysis showed that within flooded savanna, further sub-divisions of the sites according to local habitat conditions can be made for the ponds that dry out, and wet/dry season sub-divisions for the main river channel waterbodies. In the flooded forest, the main river channel waterbodies can be further sub-divided according to local habitat characteristics, as can the forest ponds that dry out and permanent ponds. Table 5 also gives the common bird groups associated with each level 3 sub-group and associated species identified through the classification analyses.

DISCUSSION

Environmental determinants of bird communities in the North Rupununi

At the regional scale, this study shows that habitat determines the composition of avifauna in the North Rupununi wetlands. The macro-scale vegetation, in terms of whether the wetland is situated within flooded savanna or flooded forest, is the overriding factor influencing bird communities. Within flooded savanna habitats, birds are determined by the geomorphic characteristics of the waterbody and can be divided into bird communities of ponds and those of main river channel and associated waterbodies. Within these two geomorphic divisions, bird communities are further influenced by local habitat characteristics of ponds, such as presence of trees around the pond, and seasonality for the main river channel and associated waterbodies. Within flooded forest habitats, birds are again influenced by the geomorphic characteristics of the waterbody and can be divided into bird communities of ponds and those of main river channel and associated waterbodies. However, unlike the flooded savanna habitats, seasonality does not seem to have a large influence at the local level in flooded forest habitats – the local habitat characteristics are the most important factors influencing bird communities both within ponds and main river channel waterbodies. Spatial variability of environmental determinants therefore seems to be important for predicting bird species composition (Bohning-Gaese, 1997), over and above the importance of temporal variability.

The importance of habitat type for bird communities of the North Rupununi wetlands is in line with various other recent tropical avifaunal studies (Davidar et al., 2001; Gillespie & Walter, 2001; Kessler *et al*., 2001; Waltert *et al*., 2005; Rompré *et al*., 2007). In particular, characteristics of floristic diversity, composition and structure have been associated with tropical bird species richness and composition (e.g. Terborgh, 1985; Freifeld, 1999). Within the North Rupununi, there are major compositional and structural differences between flooded savanna and flooded forest vegetation and these are undoubtedly affecting the bird species present in those two habitats. At this scale, habitat structure is probably key for bird communities (Terborgh, 1985), and a strong association between bird species composition and the development of a closed canopy and more complex habitat structure has been documented in regenerating forests (e.g. Bowman *et al*., 1990; Blankespoor, 1991; Andrade & Rubio-Torgler, 1994; Dunn, 2004). At the local scale, Table 5 shows that particular habitat features in and around waterbodies are determining the bird communities. For example, within flooded savanna ponds, the complexity of vegetation structure around the ponds, such as extent of trees and shrubs and presence of climbers, seems to be critical to the bird communities. On the other hand, within flooded forest ponds and main river channel waterbodies, the floristic composition of the surrounding vegetation identified by the dominant tree species, seems to be significant.

In this strongly seasonal environment, we expected a large difference in bird communities between the dry and wet seasons to be apparent at the scales analysed.

However, seasonality only seemed to have an influence at the local scale (third level of analysis) and only in flooded savanna main river channel and associated waterbodies. This would suggest that within flooded savanna areas, the habitats surrounding and within the main river channel and associated waterbodies are relatively homogenous, and thereby seasonality becomes influential to bird communities. That is not to say that seasonality is insignificant to birds in flooded savanna ponds, flooded forest ponds and main river channel waterbodies. However, in these sites, bird communities are affected much more by differences in habitat resources than annual temporal resource fluctuations.

Birds as indicators of wetland status

The Rupununi wetland landscape is a complex patchwork of interrelated elements, with variation relating to predominant vegetation, waterbody geomorphic characters, flooding regime, topographic situation and geographical location. With numerous variables working at the same time, it is difficult to decipher clear cause and effect of the environmental variables and the relative importance of each. In addition, there are few published data on the resources critical to bird assemblages in Guyana, so our discussion is supported by local stakeholder knowledge and somewhat speculative. The results of the study indicate that the bird communities found in the North Rupununi wetlands are closely tied to the local habitats in which they forage, roost and nest, in particular the vegetation characteristics of those habitats. This implies that they are potentially good indicators of overall vegetation composition and structure and whether this vegetation is supporting food webs to the bird trophic level.

Savanna ponds that dry out

One of the key habitat features influencing bird communities in ponds that dry out is the extent to which the ponds are surrounded by trees. Ponds that are characterised by having continuous and structurally diverse vegetation, for example with climbers and tall grasses, are ideal for parrots, tyrant flycatchers and tanagers (Type 1) providing food and nesting resources. Key species such as the Orange-winged Parrot (*Amazona amazonica*), and the Brown-throated Parakeet (*Aratinga pertinax*) feed on the fruits and seeds of many different types of native trees and bushes and generally nests in tree holes or palm stub cavities (Hilty, 2003).

With a reduction in tree cover around the waterbody, and an increase in shrubs and/or grassy vegetation, the new world blackbirds become more dominant within the bird communities (Types 2 and 3) probably feeding on the seeds and insects of grasses. Within these more open areas, the Red-bellied Macaw (*Orthopsittaca manilata*) is found to be associated with ponds that dry out surrounded by palms of *Mauritia flexuosa*. The Red-bellied Macaw is closely associated with this palm species as it feeds on its seeds, uses the palm for roosting and whose cavities are used for nest sites and breeding.

Many species, primarily waterfowl and shorebirds, benefit from (or tolerate) reduced ground cover and increased openings in dense stands of vegetation. The classification analyses identify the White-faced Whistling Duck (*Dendrocygna viduata*) as being associated with the more open Type 3 pond; it feeds mainly on terrestrial, aquatic and semi-aquatic plant seeds in the dry season with occasional consumption of macroinvertebrates (Petrie, 2005).

The Great Egret (*Ardea alba*) and Limpkin (*Aramus guarauna*) are probably better indicators of ponds that dry out with a large extent of grassy surroundings. These marshy areas have a regular supply of macroinvertebrate food resources for these birds - the Limpkin in particular eats mostly large Pomacea snails. The Bicolored Wren (*Campylorhynchus griseus*), also associated with savanna ponds that dry out, relies on seeds and insects, and particularly favours palms.

Savanna main river channel and associated waterbodies

Birds are affected both directly and indirectly by hydrologic changes. Species that are likely to be the most sensitive indicators of water levels might be those that (a) nest along water edges, (b) feed on mudflats (e.g., shorebirds), (c) require a particular combination of wetland hydroperiod types in a region (e.g. Kantrud & Stewart 1984).

In the savanna main river channel and associated waterbodies, the Greater Ani (*Crotophaga major*) is probably a good wet season indicator. It tends to nest along river water edges and is a migrant during the rainy season. In the dry season within savanna rivers, storks, terns, skimmers, plovers and swallows are common bird groups. However, the classification analyses show that higher numbers of the Black Vulture (*Coragyps atratus*) and Osprey (*Pandion haliaetus*) are indicators of dry season in these waterbodies. Black Vulture numbers are thought to increase because they are attracted to debris left by fisherman that clean and smoke fish on the exposed sand banks within the river. Although some Ospreys are resident all year round in Guyana the numbers increase during the dry season as individuals migrate from North America. Rusty-margined Flycatcher (*Myiozetetes cayanensis*), is a species typically found along river edges where trees are present. Although this species is more strongly associated with the dry season it is unclear to the reason why. It is thought that this species migrates within the region, as numbers fluctuate locally, but its migration patterns have yet to be determined (Hilty, 2003).

Forest main river channel and associated waterbodies

Within flooded forest, three types of main river channel and associated waterbody types were identified from the analyses. The classification analyses show that parrots, barbets/toucans and swallows are common bird groups of forest river areas dominated by trees of *Inga* spp., *Eperua* spp. and *Mora excelsa*. Indicator species are higher numbers of the White-winged Swallow (*Tachycineta albiventer*) and White-banded Swallow (*Atticora fasciata*). These species both feed over water and are seldom found far from river waterbodies. They use branches over water to perch and nest in river banks or dead trees.

Within areas of forest dominated by trees of *Eperua* spp. and *Mauritia flexuosa*, with a sandy bottom substrate, there are still many parrots, and barbets/toucans, but in these habitats kingfishers and terns/skimmers are also prevalent. The indicator species for these areas is the Large-billed Tern (*Phaetusa simplex*), which probably needs river sandbars for roosting and resting.

The final forest river and associated waterbody type is one characterised by the presence of *Victoria amazonica*, floating vegetation, water hyacinth and a clay bottom substrate. Common bird groups in these waterbodies include storks, herons and ducks. The indicator species are higher numbers of the Wattled Jacana (*Jacana jacana*), and Anhinga (*Anhinga anhinga*) and the Black-collared Hawk (*Busarellus nigricollis*). The Wattled Jacana is closely associated with vegetation-choked shorelines and forages by walking across vegetation and pecking for insects. Anhinga is also known to be common along sluggish waterways – the Black-collared Hawk is also common in waterbodies with sluggish water especially with emergent or floating vegetation.

Forest ponds that dry out and permanent ponds

Parrots and barbets/toucans are again common bird groups in forest ponds that dry out. These sites are characterised by having an extent of fallen trees and coarse woody debris around the waterbody, *Mora excelsa* and climbers dominating the bank vegetation. The indicator species is the Mealy Parrot (*Amazona farinosa*) which feeds on a wide range of fruits, seeds and flowers, mostly of large canopy trees. In the forest permanent ponds, characterised by *Genipa americana* and *Mauritia flexuosa* around the waterbody, emergent waterbody vegetation and a stable earth bank, a diverse range of bird groups are present including terns/skimmers, plovers, herons, kingfishers and New World blackbirds. Indicator species include the Pale-vented Pigeon (*Columbo cayennensis*), Striated Heron (*Butorides striatus*) and Great Kiskadee (*Pitangus sulphuratus*). The Pale-vented Pigeon may be feeding on seeds and small fruits of Byrsonima, Solanum, Trema and melastome berries. The Striated Heron prefers muddy waterbodies and fishes from dead trees lying in the water. Although the Great Kiskadee is often found around habitation, within forested areas it is more commonly found around still water (Hilty, 2003).

A wetland monitoring checklist for the North Rupununi

The appearance of some indicator species within different waterbody types and the overlap in common bird groups between waterbody types suggests that many birds are using a range of habitats for their resource needs. This, together with the limited ecological knowledge of many of the birds found in this study, has meant that it is not possible to identify particular bird species as indicators. Roberts *et al*. (2007) have also recently shown that simple species lists can potentially generate useful data for monitoring long-term trends. Therefore, a checklist of the ‘typical’ bird species assemblage of different waterbody types is probably the best approach for practical monitoring of wetland status in our case. Within the North Rupununi, we have developed a checklist of ‘typical’ bird species for different waterbody types as one of a suite of indicators of overall wetland status (Table 6) (other indicators include wetland biophysical characteristics and Black Caiman (*Melanosuchus niger*) populations). Current impacts from human activities (both direct and indirect e.g. climate change) are limited at present, so species numbers from the particular waterbody type checklists, provide a useful baseline. The assumption we make is that if current species numbers are maintained within a specific waterbody then the bird species indicator suggests that particular ecosystem processes and/or habitats have not been compromised.

The role of birds in natural resource management and sustainable livelihoods in the North Rupununi wetlands

The most important result of this study is that the North Rupununi wetlands are highly diverse, both in terms of the different types of waterbodies as well as bird species. Particular characteristics of the waterbody including the vegetation in and around the waterbody, as well as bank material, make them unique, and the bird assemblages are probably dependent at different times and in various cycles on this assortment of environments. This suggests that to support species diversity and local livelihoods, enough land must be set aside to allow for redundancy in waterbody types so that if one type is lost, others with similar characteristics would be able to maintain the same species assemblage. Interannual fluctuations in bird numbers are likely to be smaller in landscapes containing intact wetland complexes, because the complexes support a ‘shifting mosaic’ of water depths that provide at least minimally suitable habitat in the face of environmental variability (Skagen & Knopf, 1994). In other words, damaging any single waterbody without the availability of alternative waterbodies with identical conditions may result in the long-term loss of distinct and unique bird species communities.

The North Rupununi is diverse not only in terms of its ecosystems and habitats, but also in the interests of various local, national and international stakeholders. Although the high biodiversity of the region is recognised - for example the Guyanese government has chosen the Rupununi wetlands as one of two proposed sites for accession to the RAMSAR Convention - there are also local, national and foreign bids for large-scale exploitation of natural resources in the region, particularly timber, minerals and oil, which all threaten the integrity of the wetlands and local subsistence livelihoods. At the same time, there are few resources, a lack of infrastructure and a low capacity within the country to undertake comprehensive monitoring programmes. Within this context, it has been recognised as vitally important by both government and local communities to develop a set of indicators of ecosystem change that can contribute to natural resource and adaptive management decision-making at various scales. For example, assessments of the impact of activities such as mining, local community developments such as fisheries or ecotourism and Environmental Impact Assessments for proposed industrial and forestry developments using the wetland indicators (including the bird checklist) are currently being promoted in Guyana.

In a region like the North Rupununi where government resources to undertake any form of monitoring are limited, it has fallen to local communities to act. However, even at this local level, resources and capacity are limited, so finding ways of integrating monitoring with livelihood activities has a greater probability of being sustainable in the long term. Many of the local communities have started or are developing plans for ecotourism activities in the region. Although many tourists come to see the El Dorado ‘giants’, for example the Black Caiman (*Melanosuchus niger*), Giant Otter (*Pteronura brasiliensis*) and Giant River Turtle (*Podocnemis expansa*), bird watchers are probably the single largest group of tourists currently visiting the North Rupununi and have been recently highlighted by the Guyanese Tourism Authority for future investment (Vanda Radzik, personal communication, 2007). Collecting regular data on bird species by bird watchers using the checklist could help to feed into resources for tourists, such as bird lists, sightings and distributions, as well as provide vital information on ecosystem status. Birds can also play a key role in education and awareness raising. Incorporating bird monitoring into school national science curriculum activities is a way of building the capacity of local school children for future adaptive management, while at the same time providing basic information on the status of bird species. These are some of the activities currently being developed by the Darwin Wetlands Project in Guyana. It is hoped that by linking community monitoring of indicator bird species with livelihood activities and education, regular information regarding the status of the North Rupununi system can be collected and potential negative impacts identified at an early stage, to ensure the long-term sustainability of the region.

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Table 1. Monitoring site and their characteristics, where FF = flooded forest, NFF = non-flooded forest, FS = flooded savanna, MRC = main river channel, , COC = cut-off channel (inlet with connection to river), Creek = Creek, FCSR = Former channel (separate from river), OBLSR = Ox-bow lake (separate from river), FC = Former channel, OBL = Ox-bow lake, PP = Permanent pond and PDO = Pond that dries out.

Code of monitoring site	Name of monitoring site	Dominant vegetation surrounding site	Type of waterbody
A1	Dixie Pond	FF	PDO
A2	Cowhead	FF	MRC
A3	Stanley Lake	FF	COC
A4	Burro Burro	FF	MRC
A5	Siparuni	FF	MRC
A7	5 Miles Swamp	NFF	PP
A8	8 Miles Swamp	NFF	PP
A9	Paddle Rock Pond	FF	FC
B1	Devil Pond	FF	OBSLR
B2	Wagon	FS	MRC
B3	Pygmy Inlet	FS	COC
B4	Yakarinta Landing	FS	MRC
B5	Yakarinta Pond	FS	FCSR
B6	Hunt Oil Land	FS	MRC
B7	Iguana Pond	FS	FCSR
B8	Kwaimatta Landing	FS	MRC
B9	Semonie Creek	FS	Creek
C1	Crash Water Creek	FF	Creek
C3	Rewa River	FF	MRC
C4	Grass Pond	FF	FC
C5	Small Black Water Pond	FF	FC
C6	Sand Landing	FF	MRC
D1	Corkwood Swamp	FF	PDO
D2	Itch Pond 3	FS	PDO
D3	Surama Pond	FF	PP
D4	Marvin Pond	FS	PDO
D5	Cajueiro	FS	OBL
D6	Airstrip Pond	FS	PP
D7	El Dorado	FS	PDO
D8	Amoco	FS	PDO
D9	Diamond W	FS	PDO

Table 2. The groupings of environmental variables as a result of PCA and hierarchical clustering analyses. The variables shown in italics are the main determining variables on axes 1 and 2.

Group 1		**Group 2**		
Group 1a	**Group 1b**	**Group 2a**	**Group 2b**	**Group 2c**
FS General scrub species present around waterbody; burning occurring around waterbody; trapping occurring around waterbody	*PDO* Extent of trees around waterbody isolated/scattered; bank material gravel/sand; ranching occurring around waterbody; *Mauritia flexuosa* present around waterbody; 'busy-busy' in waterbody; Bottom substrate silt/mud	*FF* *MRC* Water depth; Extent of trees around waterbody continuous; fallen trees around waterbody; exposed bank side roots; *Eperua* spp. present around waterbody; *Inga* spp. present around waterbody; bottom substrate bedrock; *Sterculia* spp. present in waterbody; tourism activities around waterbody	*FC* *COC* *OBL* *FCSR* *Creek* *OBLSR* *Genipa americana* present around waterbody; *Eperua spp.* present around waterbody; *Chlorocardium rodiei* present around waterbody; *Guadua* spp. present around waterbody; *Astrocaryum aculeatum* present around waterbody	*NFF* *PP* *Cecropia* spp. present around waterbody; *Vismia* spp. present around waterbody; *Goupia glabra* present around waterbody; plant gathering occurring around waterbody; tourism activities occurring around waterbody

Table 3. The bird species found in this study (names from Braun, *et al.*, 2000).

Common name	**Scientific name**
Tinamous	**Tinamidae**
Great Tinamou	*Tinamus major*
Variegated Tinamou	*Crypturellus variegatus*
Undulated Tinamou	*Crypturellus undulatus*
Cormorants	**Phalacrocoracidae**
Neotropic Cormorant	*Phalacrocorax brasilianus*
Anhingas	**Anhingidae**
Anhinga	*Anhinga anhinga*
Herons	**Ardeidae**
Zigzag Heron	*Zebrilus undulatus*
Rufescent Tiger Heron	*Tigrisoma lineatum*
Fasciated Tiger-Heron	*Tigrisoma fasciatum*
Cocoi Heron	*Ardea cocoi*
Great Blue Heron	*Ardea herodias*
Great Egret	*Ardea alba*
Snowy Egret	*Egretta thula*
Little Blue Heron	*Egretta caerulea*
Tricolored Heron	*Egretta tricolor*
Cattle Egret	*Bubulcus ibis*
Striated Heron	*Butorides striatus*
Agami Heron	*Agamia agami*
Capped Heron	*Pilherodius*
Black-crowned Night Heron	*Nycticorax nycticorax*
Yellow-crowned Night Heron	*Nyctanassa violacea*
Boat-billed Heron	*Cochlearius cochlearius*
Ibises	**Threskiornithidae**
Buff-necked Ibis	*Theristicus caudatus*
Sharp-tailed Ibis	*Cercibis oxycerca*
Green Ibis	*Mesembrinibis cayennensis*
Roseate Spoonbill	*Ajaia ajaja*
Whispering Ibis	*Phimosus infuscatus*
Storks	**Ciconiidae**
Wood Stork	*Mycteria americana*
Maguari Stork	*Ciconia maguari*
Jabiru	*Jabiru mycteria*
Vultures	**Cathartidae**
King Vulture	*Sarcoramphus papa*

Black Vulture	*Coragyps atratus*
Turkey Vulture	*Cathartes aura*
Lesser Yellow-headed Vulture	*Cathartes burrovianus*
Greater Yellow-headed Vulture	*Cathartes melambrotus*

Ducks, Geese	**Anatidae**
White-faced Whistling-Duck	*Dendrocygna viduata*
Black-bellied Whistling-Duck	*Dendrocygna autumnalis*
Muscovy Duck	*Cairina moschata*
Blue-winged Teal	*Anas discors*

Hawks, Eagles	**Accipitridae**
Osprey	*Pandion haliaetus*
Swallow-tailed Kite	*Elanoides forficatus*
Snail Kite	*Rostrhamus sociabilis*
Plumbeous Kite	*Ictinia plumbea*
Hook-billed Kite	*Chondrohierax uncinatus*
Crane Hawk	*Geranospiza caerulescens*
Savanna Hawk	*Buteogallus meridionalis*
Common Black Hawk	*Buteogallus anthracinus*
Great Black Hawk	*Buteogallus urubitinga*
Black-collared Hawk	*Busarellus nigricollis*
Gray Hawk	*Asturina nitida*
Roadside Hawk	*Buteo magnirostris*
White-tailed Hawk	*Buteo albicaudatus*
Crested Eagle	*Morphnus guianensis*
Black Hawk-Eagle	*Spizaetus tyrannus*
Pearl Kite	*Gamsonyx swainsonii*

Falcons, Caracaras	**Falconidae**
Black Caracara	*Daptrius ater*
Red-throated Caracara	*Ibycter americanus*
Northern Crested-Caracara	*Caracara cheriway*
Yellow-headed Caracara	*Milvago chimachima*
Crested Caracara	*Caracara plancus*
Barred Forest-Falcon	*Micrastur ruficollis*
Slaty-backed Forest-Falcon	*Micrastur mirandollei*
Laughing Falcon	*Herpetotheres cachinnans*
American Kestrel	*Falco sparverius*
Bat Falcon	*Falco rufigularis*

Curassows, Guans	**Cracidae**

Little Chachalaca	*Ortalis motmot*
Marail Guan	*Penelope marail*
Spix's Guan	*Penelope jacquacu*
Blue-Throated Piping-Guan	*Pipile cumanensis*
Black Curassow	*Crax alector*
Quails	**Odontophoridae**
Crested Bobwhite	*Colinus cristatus*
Rails	**Rallidae**
Gray-necked Wood Rail	*Aramides cajanea*
Purple Gallinule	*Porphyrula martinica*
Azure Gallinule	*Porphyrula flavirostris*
Sungrebes	**Heliornithidae**
Sungrebe	*Heliornis fulica*
Sunbitterns	**Eurypygidae**
Sunbittern	*Eurypyga helias*
Limpkins	**Aramidae**
Limpkin	*Aramus guarauna*
Trumpeters	**Psophidae**
Gray-winged Trumpeter	*Psophia crepitans*
Plovers	**Charadriidae**
Southern Lapwing	*Vanellus chilensis*
Pied Lapwing	*Hoploxypterus cayanus*
Jacanas	**Jacanidae**
Wattled Jacana	*Jacana jacana*
Sandpipers	**Scolopacidae**
Solitary Sandpiper	*Tringa solitaria*
Gulls, Terns, Skimmers	**Laridae**
Yellow-billed Tern	*Sterna superciliaris*
Least Tern	*Sterna antillarum*
Large-billed Tern	*Phaetusa simplex*
Black Skimmer	*Rynchops niger*
Pigeons, Doves	**Columbidae**
Pale-vented Pigeon	*Columba cayennensis*
Ruddy Pigeon	*Columba subvinacea*
Plumbeous Pigeon	*Columba plumbea*
Eared Dove	*Zenaida auriculata*

Common Ground-Dove	*Columbina passerina*
Plain-breasted Ground-Dove	*Columbina minuta*
Ruddy Ground-Dove	*Columbina talpacoti*
Blue Ground-Dove	*Claravis pretiosa*
White-tipped Dove	*Leptotila verreauxi*

Parrots	**Psittacidae**
Blue-and-yellow Macaw	*Ara ararauna*
Scarlet Macaw	*Ara macao*
Red-and-green Macaw	*Ara chloropterus*
Red-bellied Macaw	*Ara manilata*
Red-shouldered Macaw	*Ara nobilis*
Brown-throated Parakeet	*Aratinga pertinax*
Painted Parakeet	*Pyrrhura picta*
Green-rumped Parrotlet	*Forpus passerinus*
Orange-chinned Parakeet	*Brotogeris jugularis*
Golden-winged Parakeet	*Brotogeris chrysopterus*
Sapphire-rumped Parrotlet	*Touit purpurata*
Black-headed Parrot	*Pionites melanocephala*
Caica Parrot	*Pionopsitta caica*
Blue-headed Parrot	*Pionus menstruus*
Dusky Parrot	*Pionus fuscus*
Blue-cheeked Parrot	*Amazona dufresniana*
Festive Parrot	*Amazona festiva*
Yellow-crowned Parrot	*Amazona ochrocephala*
Orange-winged Parrot	*Amazona amazonica*
Mealy Parrot	*Amazona farinosa*
Red-fan Parrot	*Deroptyus accipitrinus*

Cuckoos	**Cuculidae**
Squirrel Cuckoo	*Piaya cayana*
Little Cuckoo	*Piaya minuta*
Greater Ani	*Crotophaga major*
Smooth-billed Ani	*Crotophaga ani*

Typical Owls	**Strigidae**
Great Horned Owl	*Bubo virginianus*

Potoos	**Nyctibiidae**
Common Potoo	*Nyctibius griseus*

Oilbirds	**Steatornithidae**
Oilbird	*Steatornis caripensis*

Swifts	**Apodidae**
Band-rumped Swift	*Chaetura spinicauda*

Hummingbirds	**Trochilidae**
Reddish Hermit	*Phaethornis ruber*
Crimson Topaz	*Topaza pella*
Trogons	**Trogonidae**
White-tailed Trogon	*Trogon viridis*
Violaceous Trogon	*Trogon violaceus*
Motmots	**Momotidae**
Blue-Crowned Motmot	*Momotus momota*
Kingfishers	**Alcedinidae**
Ringed Kingfisher	*Ceryle torquata*
Amazon Kingfisher	*Chloroceryle amazona*
Green Kingfisher	*Chloroceryle amazona*
Green-and-rufous Kingfisher	*Chloroceryle inda*
American Pygmy Kingfisher	*Chloroceryle aenea*
Puffbirds	**Bucconidae**
Swallow-winged Puffbird	*Chelidoptera tenebrosa*
Black Nunbird	*Monasa atra*
Jacamars	**Galbulidae**
Green-tailed Jacamar M	*Galbula galbula*
Great Jacamar M	*Jacamerops aurea*
Paradise Jacamar	*Galbula dea*
Barbets, Toucans	**Ramphastidae**
Black-necked Aracari	*Pteroglossus aracari*
Green Aracari	*Pteroglossus viridis*
Channel-billed Toucan	*Ramphastos vitellinus*
Red-billed Toucan	*Ramphastos tucanus*
Toco Toucan	*Ramphastos toco*
Guianan Toucanet	*Selenidera culik*
Woodpeckers	**Picidae**
Chestnut Woodpecker	*Celeus elegans*
Cream-colored Woodpecker	*Celeus flavus*
Ringed Woodpecker	*Celeus torquatus*
Lineated Woodpecker	*Dryocopus lineatus*
Crimson-crested Woodpecker	*Campephilus melanoleucos*
Powerful Woodpecker	*Campephilus pollens*

Red-necked Woodpecker	*Campephilus rubricollis*
Yellow-Tufted Woodpecker	*Melanerpes cruentatus*
Golden-spangled Piculet	*Picumnus exilis*

Ovenbirds	**Furnariidae**
Yellow-chinned Spinetail	*Certhiaxis cinnamomea*

Woodcreepers	**Dendrocolaptidae**
Wedge-billed Woodcreeper	*Glyphorynchus spirurus*
Chestnut-rumped Woodcreeper	*Xiphorhynchus pardalotus*

Typical Antbirds	**Thamnophilidae**
Mouse-coloured Antshrike	*Thamnophilus murinus*

Ground Antbirds	**Formicariidae**
Spotted Antpitta	*Hylopezus macularius*

Tyrant Flycatchers	**Tyrannidae**
Vermillion Flycatcher	*Pyrocephalus rubinus*
White-headed Marsh-Tyrant	*Arundinicola leucocephala*
Pied Water-Tyrant	*Fluvicola pica*
Great Kiskadee	*Pitangus sulphuratus*
Lesser Kiskadee	*Philohydor lictor*
Rusty-margined Flycatcher	*Myiozetetes cayanensis*
Sulphury Flycatcher	*Tyrannopsis sulphurea*
Tropical Kingbird	*Tyrannus melancholicus*
Fork-tailed Flycatcher	*Tyrannus savana*
Thrush-like Mourner	*Schiffornis turdinus*
Screaming Piha	*Lipaugus vociferans*
Bright-rumped Attila	*Attila spadiceus*
Cinnamon Attila	*Attila cinnamomeus*
Black-tailed Tityra	*Tityra cayana*

Cotingas	**Cotingidae**
Guianan Red-Cotinga	*Phoenicircus carnifex*
Spangled Cotinga	*Cotinga cayana*
White Bellbird	*Procnias alba*
Capuchinbird	*Perissocephalus tricolor*
Purple-throated Fruitcrow	*Querula purpurata*

Manakins	**Pipridae**

Golden-headed Manakin	*Pipra erythrocephala*

Jays	**Corvidae**
Cayenne Jay	*Cyanocorax*

Swallows	**Hirundinidae**
Gray-breasted Martin	*Progne chalybea*
Brown-chested Martin	*Progne tapera*
White-winged swallow	*Tachycineta albiventer*
Blue-and-white Swallow	*Notiochelidon cyanoleuca*
White-banded Swallow	*Atticora fasciata*

Wrens	**Troglodytidae**
Black-capped Donacobius	*Donacobius atricapillus*
Bicolored Wren	*Campylorhynchus griseus*

Thrushes	**Turdidae**
Pale-breasted Thrush	*Turdus leucomelas*
White-necked Thrush	*Turdus albicollis*

Mockingbirds	**Mimidae**
Tropical Mockingbird	*Mimus gilvus*

Wood Warblers	**Parulidae**
River Warbler	*Phaeothlypis rivularis*

Tanagers	**Thraupidae**
Burnished-buff Tanager	*Tangara cayana*
Blue-gray Tanager	*Thraupis episcopus*
Palm Tanager	*Thraupis palmarum*
Silver-beaked Tanager	*Ramphocelus carbo*
Blue Dacnis	*Dacnis cayana*

Cardinals, Grosbeaks and Saltators	**Cardinalidae**
Red-capped Cardinal	*Paroaria gularis*

Emberizine Finches	**Emberizidae**
Chestnut-bellied Seed-Finch	*Sporophila castaneiventris*
Ruddy-breasted Seedeater	*Sporophila minuta*
Grassland Sparrow	*Ammodramus humeralis*
Wedge-tailed Grass-Finch	*Emberizoides herbicola*

New World Blackbirds	**Icteridae**

Eastern Meadowlark	*Sturnella magna*
Red-breasted Blackbird	*Sturnella militaris*
Giant Cowbird	*Scaphidura oryzivora*
Moriche Oriole	*Icterus chrysocephalus*
Yellow Oriole	*Icterus nigrogularis*
Campo Oriole	*Icterus jamacaii*
Yellow-rumped Cacique	*Cacicus cela*
Red-rumped Cacique	*Cacicus haemorrhous*
Crested Oropendola	*Psarocolius decumanus*
Green Oropendola	*Psarocolius viridis*

Table 4. Summary of the second level sub-divisions of the monitoring sites based on the bird data

	Flooded savanna group (first axis eigenvalue = 0.372)	**Flooded forest group (first axis eigenvalue = 0.471)**	**Intermediate group (first axis eigenvalue = 0.332)**
Sub-groups	PDO *Sites D7, D8*	PDO and PP *Sites A7, A8, D1*	MCR and associated waterbodies/Savanna/Forest *Sites B1, B2, B3, B4, B5, B6, B8, B9, C1, C4*
	PDO, PP and OBL *Sites D4, D5, D6, D9*	Intermediate/PDO *Sites A1, A9*	PP / Forest *Site D3*
	FCSR *Site B7*	MRC, COC and FC *Sites A2, A3, A4, A5, C3, C5, C6*	PDO / Savanna *Site D2*

Table 5. Classification of waterbodies based on all bird species. Note for indicator species, it is the presence of a species that is indicative (TWINSPAN pseudospecies 1), except for those species in italics which are also indicators by having larger numbers of individuals (TWINSPAN pseudospecies 2-4).

Vegetation	Waterbody type	Sub-type	Local habitat features	Dominant human activities in and around waterbody	Key bird groups identified from classification analyses	Indicator species identified from classification analyses	Example from study
Flooded savanna	Ponds that dry out	Type 1	Surrounded by continuous trees Climbers on trees Bottom features areas covered vegetation	Trapping Human settlements Burning Land transportation	Parrots Tyrant Flycatchers Tanagers	Orange-winged Parrot *Brown-throated Parakeet*	Itch Pond 3
		Type 2	Palm species	Ranching Hunting Human settlements Burning Land transportation	Herons Parrots New World Blackbirds	Red-bellied Macaw	El Dorado Amoco
		Type 3	Isolated and scattered trees Bank vegetation climbers Composite bank profile Cobble bank material	Ranching Trapping Human settlements Burning Land transportation Firewood gathering	Tyrant flycatchers New World Blackbirds	White-faced Whistling Duck	Marvin Pond
		Type 4	Gentle bank profile Water hyacinth	Burning Land transportation	Herons Swallows	Bicolored Wren	Diamond W

			Bottom substrate gravel and pebble			Great Egret Limpkin	
	Permanent pond		As above	Burning Land transportation Subsistence fishing	As PDO Type 4	As PDO Type 4	Airstrip Pond
	Former channel separate from river		Guav and scrub species Emergent and floating waterbody vegetation including Victoria amazonica and floating grass Stable earth bank and bottom substrate clay	Subsistence fishing Hunting Burning Land transportation	Kingfishers Ibises Herons	Dominated by waterbirds	Iguana Pond
	Main river channel and associated waterbodies	Type 1	Wet season	Subsistence fishing Burning Land transportation	Ducks/Geese Parrots Cuckoos	*Greater Ani*	Wagon Pygmy Inlet Yakarinta landing Yakarinta Pond Hunt Oil Landing Kwaimatta Landing Semonie Creek
		Type 2	Dry season		Storks Terns/Skimmers Plovers Swallows	*Black Vulture* *Osprey* Rusty-margined Flycatcher	
Flooded	Main river	Type 1	Inga, Walla, Mora species	Subsistence fishing	Many parrot species	*White-*	Burro

forest	channel (and associated waterbodies)			Tourism boat trips	Barbets/Toucans Swallows	*winged Swallow* *White-banded Swallow*	Burro Siparuni
		Type 2	Walla, Palm species Bottom substrate sand	Subsistence fishing Hunting	Parrots Barbets/Toucans Kingfishers Terns/Skimmers	Large-billed Tern	Cowhead Stanley Lake Rewa River Small Black Water Pond Sand Landing
		Type 3	Victoria amazonica Floating vegetation Water hyacinth Clay bottom substrate	Subsistence fishing Hunting Trapping Local recreation	Storks Herons Ducks	*Wattled Jacana* *Anhinga* Black-collared Hawk	Devil Pond Crashwater Creek Grass Pond
	PDO		Extent of trees around waterbody fallen trees and coarse woody debris Mora species Climbers dominate bank vegetation	Subsistence fishing Tourism	Parrots Barbets/Toucans	Mealy Parrot	Dixie Pond Paddle Rock Pond 5 Miles Swamp 8 Miles Swamp

					Corkwood Swamp
PP	Lana and Palm species Emergent waterbody vegetation Stable earth bank	Subsistence and commercial fishing Tourism Local recreation Farming	Terns/Skimmers Plovers Herons Kingfishers New World Blackbirds	Pale-vented Pigeon Striated Heron Great Kiskadee	Surama Pond

Table 6. Checklist of 'typical' birds for different waterbody types of the North Rupununi wetlands.

Vegetation	Waterbody type	Typical birds	Sub-types based on habitat characteristics	Typical birds
Flooded savanna	Ponds that dry out and permanent ponds	Black Caracara Purple Gallinule White-tipped Dove Red-and-green Macaw Brown-throated Parakeet Orange-winged Parrot Red-billed Toucan Lesser Kiskadee Rusty-margined Flycatcher Palm Tanager Silver-beaked Tanager Pale-breasted Thrush Campo Oriole Red-bellied Macaw Red-shouldered Macaw Eastern Meadowlark Red-breasted Blackbird	Surrounded by continuous trees with climbers on the trees, giving waterbody greater structural diversity	Black Caracara Purple Gallinule White-tipped Dove Red-and-green Macaw Brown-throated Parakeet Orange-winged Parrot Red-billed Toucan Lesser Kiskadee Rusty-margined Flycatcher Palm Tanager Silver-beaked Tanager Pale-breasted Thrush Campo Oriole
		White-faced Whistling-Duck Savanna Hawk Blue-gray Tanager Muscovy Duck	Surrounded by grass-dominated vegetation and abundance of *Mauritius flexuosa* palm species	Red-bellied Macaw Red-shouldered Macaw Eastern Meadowlark Red-breasted Blackbird
		Cocoi Heron Great Egret Snail Kite	Surrounded by isolated and scattered trees with climbers and vegetated bank	White-faced Whistling-Duck Savanna Hawk
		Crested Bobwhite		

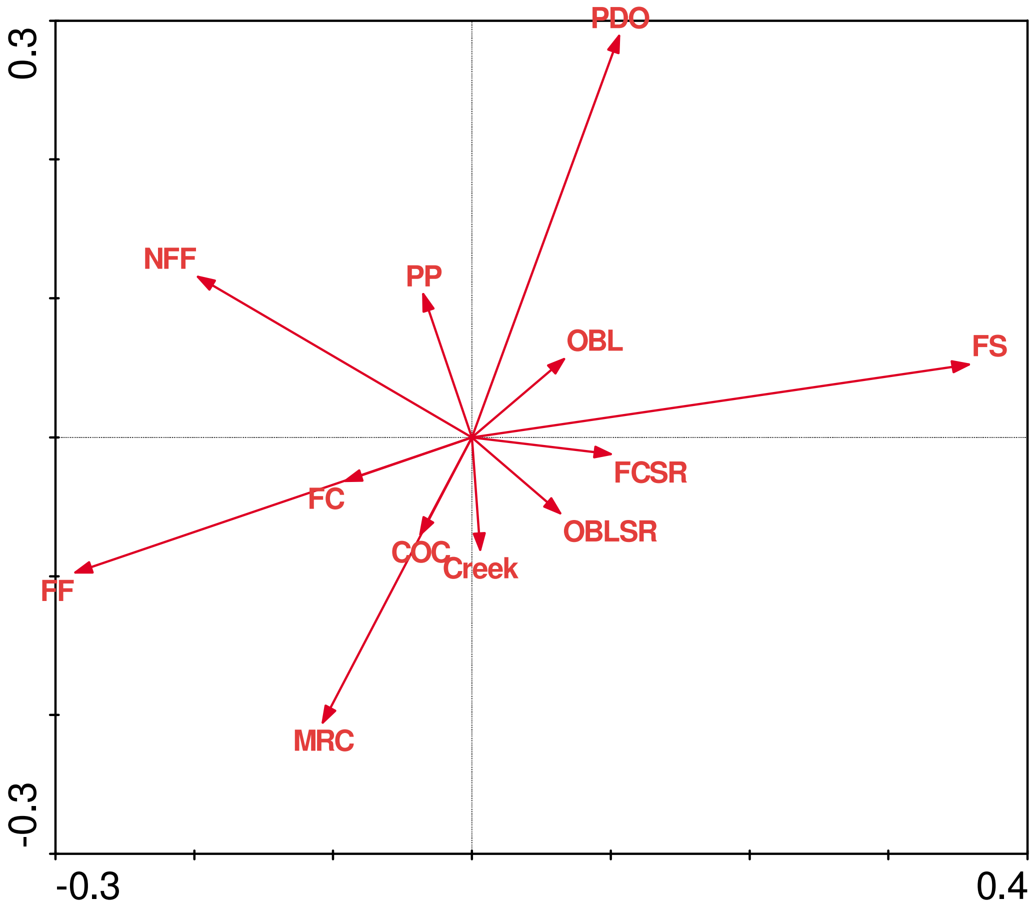
		Limpkin Yellow-crowned Parrot Smooth-billed Ani Bicolored Wren		Lesser Kiskadee Blue-gray Tanager Palm Tanager
			Surrounded by large expanses of grass-dominated vegetation and gentle bank profile	Muscovy Duck Cocoi Heron Great Egret Snail Kite Crested Bobwhite Limpkin Red-shouldered Macaw Yellow-crowned Parrot Smooth-billed Ani Bicolored Wren
	Main river channel and associated waterbodies	Black-bellied Whistling-Duck Mealy Parrot Greater Ani Smooth-billed Ani Little Blue Heron Black Vulture Osprey Roadside Hawk Yellow-headed Caracara Crested Caracara Pied Lapwing Green Kingfisher Rusty-margined Flycatcher	Wet season	Black-bellied Whistling-Duck Mealy Parrot Greater Ani Smooth-billed Ani
			Dry season	Little Blue Heron Black Vulture Osprey Roadside Hawk Yellow-headed Caracara Crested Caracara Pied Lapwing Green Kingfisher

				Rusty-margined Flycatcher
Flooded forest	Main river channel (and associated waterbodies)	Golden-winged Parakeet Blue-headed Parrot Dusky Parrot Mealy Parrot Red-billed Toucan Screaming Piha White-winged swallow White-banded Swallow Large-billed Tern Neotropic Cormorant Anhinga Muscovy Duck Rufescent Tiger Heron Great Egret Black-crowned Night Heron Jabiru Black-collared Hawk Sungrebe Wattled Jacana Brown-throated Parakeet Smooth-billed Ani Yellow-chinned Spinetail Great Kiskadee Rusty-margined Flycatcher Red-capped Cardinal Campo Oriole	Inga, Walla, Mora species dominate forest surrounding waterbody	Golden-winged Parakeet Blue-headed Parrot Dusky Parrot Mealy Parrot Red-billed Toucan Screaming Piha White-winged swallow White-banded Swallow Large-billed Tern
			Waterbody shoreline filled with floating vegetation such as Victoria amazonica and Water hyacinth	Neotropic Cormorant Anhinga Muscovy Duck Rufescent Tiger Heron Great Egret Black-crowned Night Heron Jabiru Black-collared Hawk Sungrebe Wattled Jacana Brown-throated Parakeet Mealy Parrot

				Smooth-billed Ani Yellow-chinned Spinetail Great Kiskadee Rusty-margined Flycatcher Red-capped Cardinal Campo Oriole
	Ponds that dry out	Mealy Parrot Screaming Piha Black-necked Aracari Silver-beaked Tanager Green Oropendola Neotropic Cormorant	Mora species dominate vegetation surrounding waterbody and lots fallen trees and debris Climbers dominate bank vegetation	Mealy Parrot Screaming Piha Black-necked Aracari Silver-beaked Tanager Green Oropendola
	Permanent ponds	Cocoi Heron Great Egret Striated Heron Green Ibis Pale-vented Pigeon Great Kiskadee Tropical Kingbird Red-capped Cardinal Giant Cowbird	Lana and Palm species dominate vegetation surrounding waterbody and emergent waterbody vegetation Stable earth bank	Neotropic Cormorant Cocoi Heron Great Egret Striated Heron Green Ibis Pale-vented Pigeon Great Kiskadee Tropical Kingbird Red-capped Cardinal Giant Cowbird

Figure 1. Environmental variables projected on to a DCA ordination of the bird data for all monitoring sites. Codes are given in Table 1.

Figure 2. Sample ordination diagram from the CCA of the bird data showing the samples divided into habitat groups.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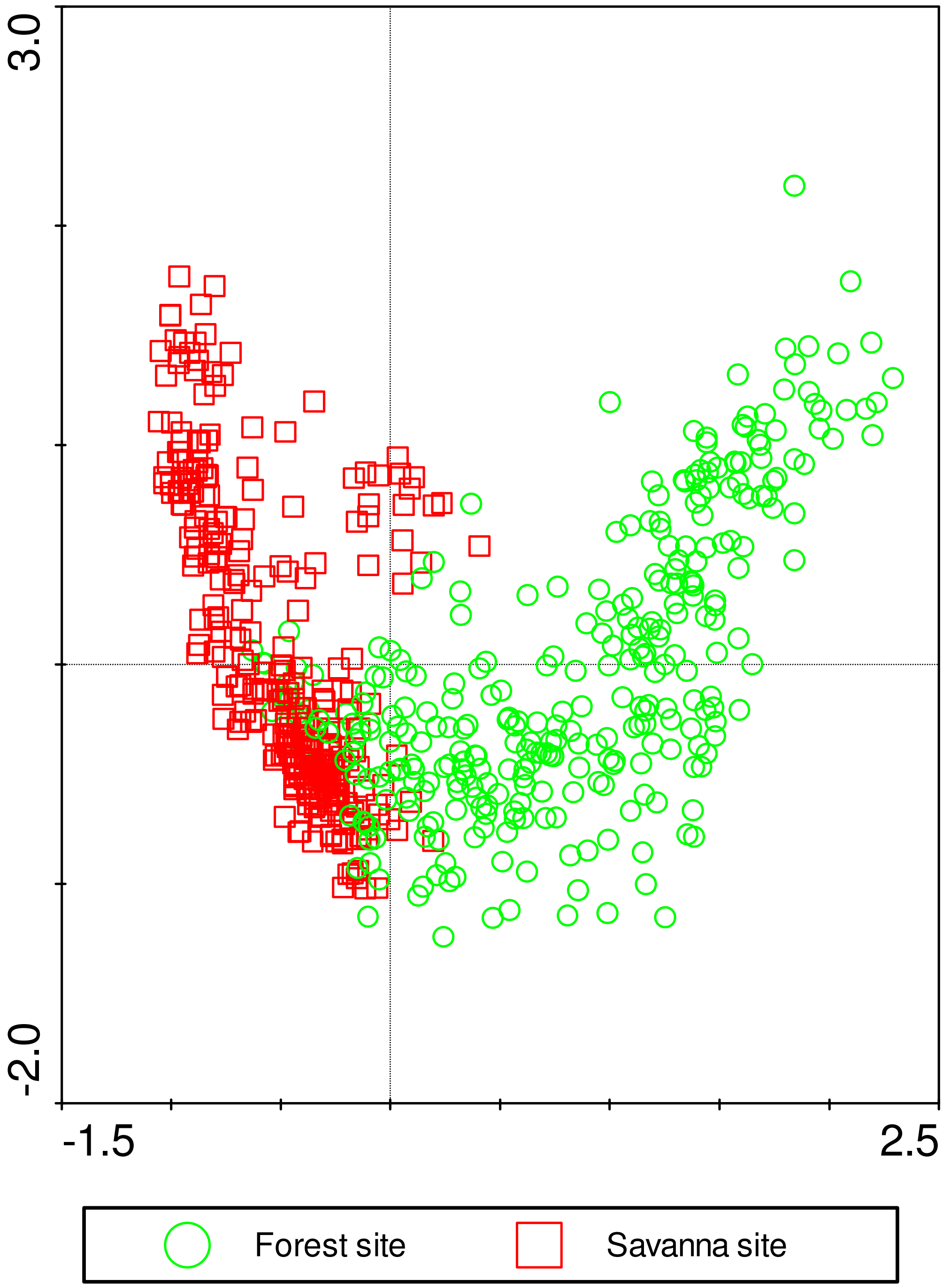
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Forest site
Savanna site