Ya'axché Conservation Trust

Annual Biodiversity Synthesis Report

2010

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In fulfilment of reporting requirements of the Maya Golden Landscape Biodiversity Research, Inventory and Monitoring Strategy and Protocols (BRIM)

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Contents

Acronyms

BNR	Bladen Nature Reserve
BRIM	Ya'axché's Biodiversity Research, Inventory and Monitoring strategy (Wicks 2009)
CRFR	Columbia River Forest Reserve
ENS	Effective Number of Species (or True Diversity)
GSCP	Golden Stream Corridor Preserve

1. Introduction

The Ya'axché Conservation Trust (Ya'axché) is a community-orientated NGO that works to protect the forests of southern Belize through biodiversity research & monitoring, sustainable land-use management and strategic advocacy and awareness. Its geographical focus is the Maya Golden Landscape, which encompasses two protected areas in Toledo, the southernmost district of Belize, and the buffer communities around these (see Figure 1). The Golden Stream Corridor Preserve (GSCP) is a 15,000 acre preserve owned and managed by Ya'axché that forms part of the connection between the Maya Mountain Massif and the coastal ecosystems of the Caribbean Sea. The Bladen Nature Reserve is a 100,000 acre strictly protected nature reserve, owned by the Government of Belize and co-managed by Ya'axché since 2008.

Since 2006, Ya'axché has been developing a biodiversity monitoring system to keep track of changes in the natural environment that could indicate unsustainable human impacts. The system has always consisted of approximately eight monitoring transects, on which bird and mammal species have been recorded during several subsequent transect visits per year. However the frequency of data gathering and locations of these transects has been fluctuating over the years, and did not correspond with what other management agencies' approaches. Recognizing this shortcoming, and as a necessary planning exercise when Ya'axché accepted co-management of the Bladen Nature Reserve in 2008, a Biodiversity Research, Inventory and Monitoring strategy (BRIM)was drafted by Ya'axché, Fauna & Flora International and Toledo Institute for Development and Environment (TIDE) in 2009. This strategy details the questions that the involved NGOs face when managing their protected areas, and distils a number of target groups (e.g. vegetation, birds, mammals) to be monitored to find answers to these questions. It also provides short outlines of the methodology to be used, and general guidelines for the analysis of the gathered data. The BRIM also prescribes the annual analysis of the data, to facilitate comparison among years and provide information to guide the management.

Figure 1 - Location of the Maya Golden Landscape and its protected areas

So far, Ya'axché has collected data on birds and mammals using transect monitoring throughout the Maya Golden Landscape. The resulting data since 2006 have been prepared and analysed preliminary, but still need to be revisited. However, the BRIM requirement to report the findings in an annual Biodiversity Synthesis Report has not been met, and the current report is a first step towards the fulfilment of that requirement. The data management system for the biodiversity data has been revised in late 2010, and all 2010 data have been retrospectively entered in the new database. Therefore, 2010 was chosen as the year for which to produce the first Biodiversity Synthesis Report. The goal of the reports is to enable comparison of biodiversity among years, and equally important, to record and illustrate the development of the monitoring program at Ya'axché over the coming years.

2. Methodology

Similar to the five previous years of data collection, the biodiversity monitoring in 2010 involved birds and mammals as focal groups. They were monitored with, respectively, transect point counts and sign transects, which are located in and around the protected areas managed by Ya'axché. Birds were detected using sight and sound cues, while mammals were detected using direct sightings, foot prints and an array of different signs such as faeces, smell, sound, scratch marks, etc. For both focal groups a previously generated list of indicator species was used and recordings are limited to the selected species (see Table 1 and Table 2). These species lists are taken from Ya'axché's Biodiversity Research, Inventory and Monitoring strategy (BRIM). There is a consensus within Ya'axché that these lists need to be revised, and efforts are underway to find the most effective way to achieve this. For the current Biodiversity Synthesis report, species lists are used as they are presented underneath.

Table 1 - Selected mammal indicator species

Mammal species	Rationale for monitoring
Agouti	Human animal conflict - pest in farms
Brown Brocket Deer	Conservation value
Howler Monkey	Forest health/composition and structure
Coati	Human animal conflict - pest in farms
Collared Peccary	Hunting indicator, Human animal conflict - pest in farms
Jaguar	Prey base, Human animal conflict. Not monitor but just record?
Naked-tailed Armadillo	Rare (but not eaten)
Nine-banded Armadillo	Hunting indicator –lowlands
Paca	Forest health, hunting indicator (management effectiveness)
Puma	Prey base, Human animal conflict. Not monitor but just record?
Red Brocket Deer	Hunting (management effectiveness), Human animal conflict
Spider Monkey	Forest health/composition and structure
Tapir	Healthy riverbanks -riparian forests, Human animal conflict
White-lipped Peccary	Connectivity, Forest health/composition and structure
White-tailed Deer	Hunting (management effectiveness), Human animal conflict

Table 2 - Selected bird indicator species

Bird species	Rationale for monitoring
American Redstart	Migratory quality
Black and White Warbler	Migratory quality
Blue-gray Gnatcatcher	Migratory quality
Bronzed Cowbird	Brood parasite - follows disturbance e.g. cattle
Brown hooded Parrot	Forest health
Cerulean Warbler	Migratory quality, vulnerable status
Chestnut-sided warbler	Migratory quality
Common Yellowthroat	Migratory quality
Crested Guan	Disturbance + lack of hunting indicator
Dickcissel	Migratory quality
Golden-winged Warbler	Migratory quality
Grace's Warbler	Migratory quality,
Great Curassow	Disturbance + lack of hunting indicator
Great Tinamou	Disturbance + lack of hunting indicator
Hooded warbler	Migratory quality
Keel-billed Motmot	Forest health
Keel-billed Toucan	Forest health/composition and structure

Kentucky Warbler	Migratory quality
Little Tinamou	Forest health, Human animal conflict
Louisiana Waterthrush	Migratory quality
Magnolia warbler	Migratory quality
Northern Waterthrush	Migratory quality
Painted Bunting	Migratory quality
Plain-bellied Chachalaca	Forest composition/structure
Prothonotary Warbler	Migratory quality
Slaty-breasted Tinamou	Disturbance + lack of hunting indicator
Swainson's Warbler	Migratory quality
Wood Thrush	Migratory quality
Worm-eating Warbler	Migratory quality

A more detailed description of the methodology used can be found in the BRIM. Some points of attention are pointed out in Section 2.2.

2.1.Data collection

The core biodiversity data that was collected is (1) the number of species observed and (2) the number of individuals observed per species. All biodiversity data for 2010 was collected over a total of 8 transects that, as a rule, measure 1000m each. One exception to this rule was transect BNR1, which measured only 500m, and any visit done to BNR1 is consequently treated as only half a transect visit (see Table 3).

Table 3 - Transect information

Transect Name	Length (m)	Area	Land administration	Land Form	Ecosystem
BNR1	500	Bladen	Nature Reserve	valley	Primary forest on karst hills with riparian parts; little disturbance risk
BNR2	1000	Bladen	Nature Reserve	footridge or slope	Primary forest on karst hills; little disturbance risk
CRFR1	1000	Columbia river	Forest reserve	valley	Primary forest on karst hills; little disturbance risk
CRFR2	1000	Columbia river	Forest reserve	valley	Primary forest on karst hills; little disturbance risk
CRFR3	1000	Columbia river	Forest reserve	valley	Primary forest on karst hills; recovering from slight hurricane impacts
CRFR4	1000	Columbia river	Forest reserve	valley	Primary forest on karst hills; recovering from slight hurricane impacts
GSCP1	1000	Golden Stream	Private Protected Area	Coastal plain	Secondary forest on karst foothills; recovering from heavy hurricane impact
GSCP2	1000	Golden Stream	Private Protected Area	Coastal plain	Secondary forest in coastal plain; recovering from heavy hurricane impact

A map showing the location of the transects is presented in Figure 2.

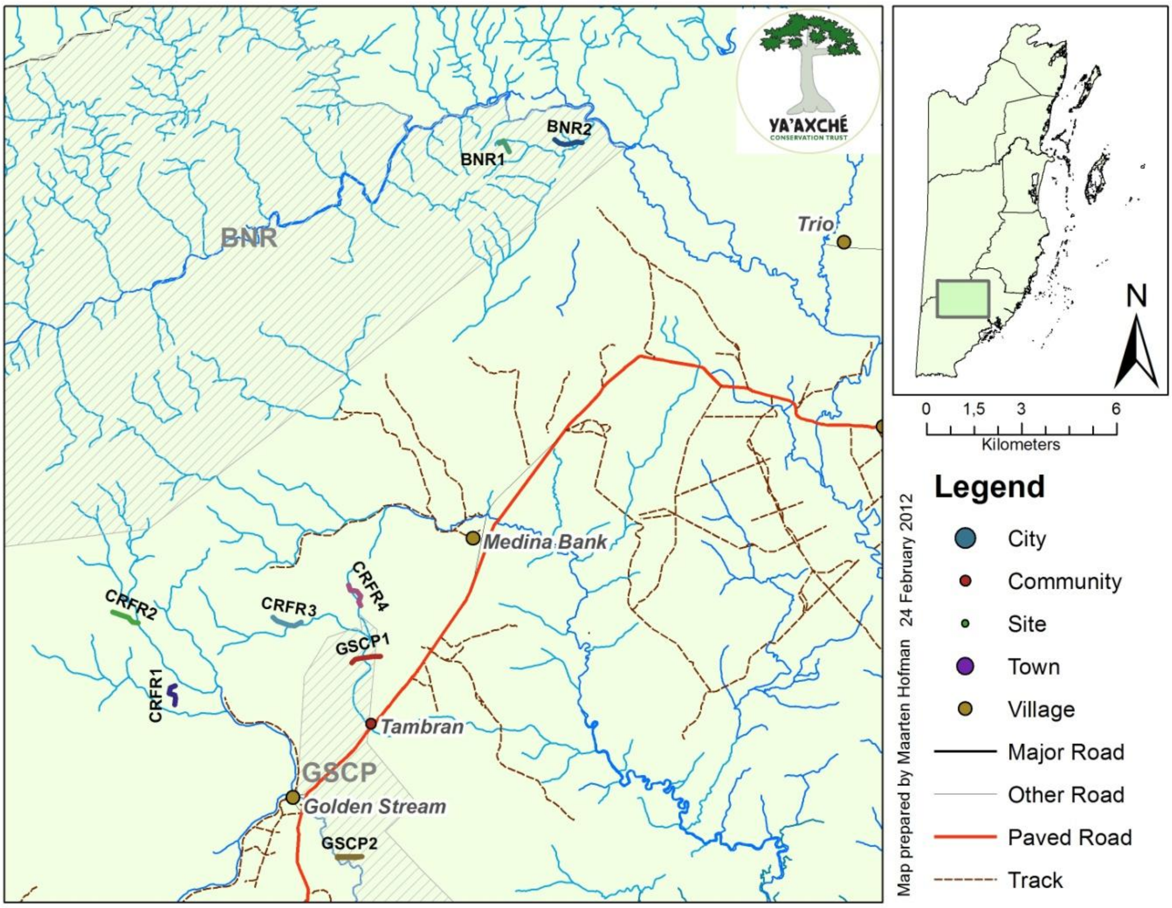

Figure 2 - Location of biodiversity monitoring transects (for 2010) in relation to protected areas (only approximate location for transect BNR1)

The transects were each visited between one and five times over the course of the year. A single complete transect visit actually consists of a Morning visit and an Evening visit, during each of which the same protocols are followed. Birds are recorded on both morning and evening sessions, while mammals are recorded on only one of these, whichever one is done first. Every month between zero and six transects were visited, resulting in a total of 54km of transect covered in 2010 (see Table 4).

Table 4 - Monitoring effort (*transect BNR1 is counted as half a transect)

Monitoring effort	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
# of visits performed*	4.5	4.5	5.5	0	2	3.5	1	0	1	3.5	0	1.5	27
# of m transect done	9000	9000	11000	0	4000	7000	2000	0	2000	7000	0	3000	54000
# of observations done	110	136	146	0	40	57	14	0	5	135	0	29	672
# of obs/visit	24.4	30.2	26.5	0	20.0	16.3	14.0	0	5.0	38.6	0	19.3	24.9
# of obs/1000m	12.2	15.1	13.3	0	10.0	8.1	7.0	0	2.5	19.3	0	9.7	12.4

A total of 672 observations of birds and mammals were done on these transect visits, whereby more transects visited did not necessarily mean more observations done (Figure 3).

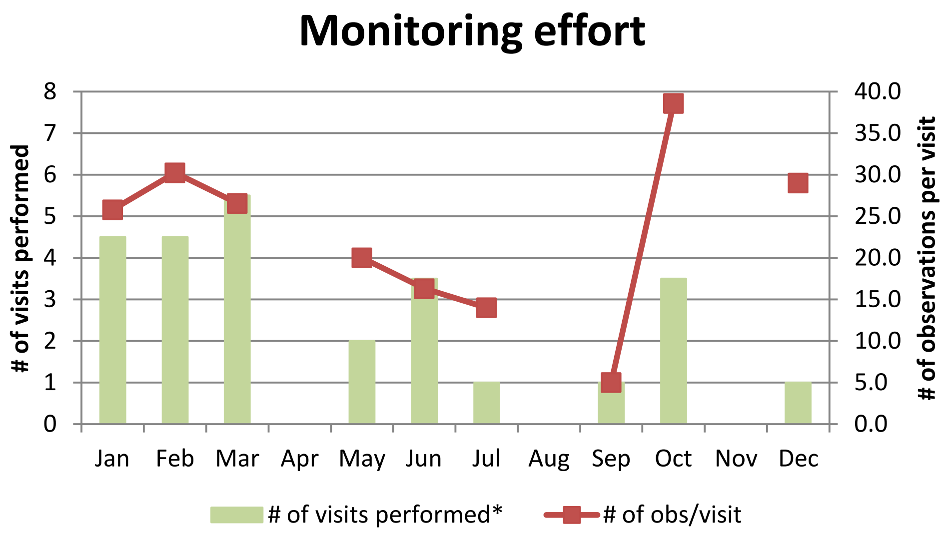

Figure 3 - Monitoring effort

2.2.Data quality

Overall, as is apparent from Figure 3, the transect visit frequency has been highly irregular. Detection probabilities of mammal tracks or birds might differ among ecosystems (i.e. secondary forest with dense undergrowth vs open primary forest), between dry and rainy seasons, etc, which is partially accounted for by doing the same transect on different times of the year. The absence of consistent data throughout the year, or per transect, results in considerable limitations when interpreting the obtained results. Any conclusions from these data are therefore to be interpreted with caution.

More specifically, a number of issues arose while collecting or analysing data. For example, there was no evaluation done of bird or mammal track knowledge among the observers and thus there is no way of accounting for observer bias in the data.

Some observations lacked important information such as the species name and the number of individuals observed in both birds and mammals. Observations that lacked a species name were discarded for the analysis; observations that lacked number of individuals were set conservatively to '1'. The latter was the case for about 4% of the bird observations and 11% of mammal observations. In birds, 86% of observations involved a single individual, in mammals 88%. The error of assigning the value '1' to unknown number of individuals is therefore not expected to be a gross underestimate of the actual numbers.

2.3.Data analysis

For the analysis of the data the instructions in the BRIM were used as a guide, but with major modifications.

Mammal and bird data was analysed separately for both focal groups. Most analyses were done per transect, thereby pooling together the data from all visits for each transect. This was done initially to speed up the process of determining the validity of the approach suggested in the BRIM, specifically the comparison of the different biodiversity indices proposed. It was also considered a suitable way to achieve a good overview of larger scale differences between transects, and between the Protected Areas.

2.3.1. Actual number of observed species

The actual number of species observed is the raw biodiversity data that is a sample of the total actual biodiversity of the ecosystems. It was calculated for every transect based on all species for which at least one individual was observed on any of the visits to that transect.

2.3.2. Relative abundance

Relative abundance of every species (p_i) was calculated per transect (as opposed to per transect visit) as 'the number of individuals of focal species *i*' (n_i) divided by 'the total number of individuals observed' (N) on the transect.

$$p_i = n_i / N$$

This approach differs from what is suggested in the BRIM (= number of individuals of focal species *i* divided by the total number of transects visited), but is based on notions explained in Hill (1973), Jost (2006) and Tuomisto (2010), which represent the internationally recognised methodology. The relative abundances were plotted in pie charts per transect to compare species diversity and abundance among the transects.

2.3.3. Diversity indices

Since the actual number of species observed is only a sample of the actual diversity out there, it is necessary to estimate the actual diversity from the sampled data in order to compare among areas or years. To that end, several diversity indices have been developed that provide a scale on which to compare the biodiversity of different areas. These indices always take into account the rarity of species (or relative abundance), as this is a property that will determine the likelihood of the species showing up in the sample. Therefore rarity is inevitably linked to the index of actual diversity inferred from a sample. An index of biodiversity thus reflects both the number of species in a community and how they are proportionate to each other. The index values will generally not be in full accordance with the actual number of species observed, because the latter does not take into account the rarity of species.

Diversity indices suggested in the BRIM include Simpson's index and Shannon's index. Simpson's diversity index can be calculated in two different ways. One first way assumes that individuals observed once are not recounted during one sample session, which is a relevant assumption at the low sample sizes that usually occur in observational field data like ours, and is calculated as mentioned in the BRIM and Simpson (1949),

$$l = \frac{\sum_{i=1}^{R} n_i(n_i - 1)}{N(N - 1)}$$

where R stands for species Richness, i.e. the actual number of species observed. This is presumably the best way of calculating Simpson's index for the current dataset.
We also calculated the index in the alternative way, which uses the relative abundance as calculated above (Simpson, 1949),

$$\lambda = \sum_{i=1}^{R} p_i^2$$

to investigate the difference between the two indices for our dataset.
Shannon's index was calculated according to the BRIM and Jost (2006) as

$$H = -\sum_{i=1}^{R} p_i \ln p_i$$

2.3.4. Effective Number of Species (or 'True Diversity')

Whereas both Simpson's indices result in values between zero and one, Shannon's index usually yields numbers between 1.5 and 4.5. Comparing these indices is thus impossible without some sort of standardization. A suitable way of doing that is to transform these indices into 'Effective Number of Species' (ENS) (Hill, 1973; Jost, 2006). The effective number of species is the hypothetical number of species that would be present if all species would occur at equal abundance (e.g. 5 species each occur at a relative abundance of 0.20). In that way, a comparison can be made in terms of number of species, instead of working with index values.

As suggested by Jost (2006), both Simpson's indices were transformed by taking the inverse:

$$\frac{1}{l} \; or \; \frac{1}{\lambda}$$

while Shannon's index was transformed using

$$\exp(H) = e^{H}$$

Eventually, the diversity indices and their corresponding ENS were plotted against the actual number of observed species for comparison.

After evaluation of this comparison, the ENS was calculated for every transect visit (as opposed to the pooled data per transect) from Shannon's diversity index, and the mean ENS per transect was calculated. This number represents the average effective number of species per transect that was encountered at any one morning or evening visit.

2.3.5. Species accumulation curves

Importantly, since not all transects have an equal number of transect visits, abundance data cannot be interpreted easily. Transects that have been visited once, cannot possibly have uncovered the same number of species than transects that have been visited four times or more. Although there are systematic ways to account for this difference, we have decided to not go into these calculations for now and instead resort to presenting species accumulation curves that enable the reader to account for this effect while interpreting associated graphs. Species accumulation curves display the cumulative increase of detected species on a transect as subsequent visits are performed.

2.3.6. Migratory birds

Ideally, trends in the abundance of migratory birds would be calculated over a range of years once sufficient years of data are available. However, the way data is currently collected on the transects does not allow for the calculation of absolute abundances. This means we cannot infer a rise or decline in abundance of a certain species, we can only detect the change of their relative proportion in the total pool of selected indicator species. We plotted the relative abundance of all selected migratory species through the year.

2.3.7. Game species

Similar to the migratory species, absolute abundances are not available for game species. Relative abundances have been set out per transect as an indication of where the ecological communities contain the highest proportion of these species.

3. Biodiversity results

The results of the data analysis are presented for birds and mammals in an analogous way, starting with general statistics on the actual number of species, followed by a site comparison using relative abundances, and a closer look at the effective number of species calculated from the different indices.

3.1. Birds

Out of all bird species on the target list, a total of 19 bird species were detected during 2010, with a total of 514 individual birds observed (Table 5).

Table 5 - Bird observations and diversity

Bird diversity	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
Actual # of species observed	12	5	14	14	10	10	11	10	19
# of individuals observed	52	21	62	29	112	87	84	67	514

3.1.1. Site comparison

Comparing the relative abundances among different transects is done using pie charts (Figure 4), because they give an overview of species richness and relative abundance in a comprehensible way.
BNR2 forms a clear illustration of how to compare sites. The transect has a lot fewer species detected, which results in higher relative abundances: the proportion of Hooded warblers and Magnolia warblers is bigger than on any other transect. However, many species that most probably are present, will not have been detected during the single visit for this transect. Therefore it seems wise to exclude the BNR2 transect from further comparisons (see Figure 4).

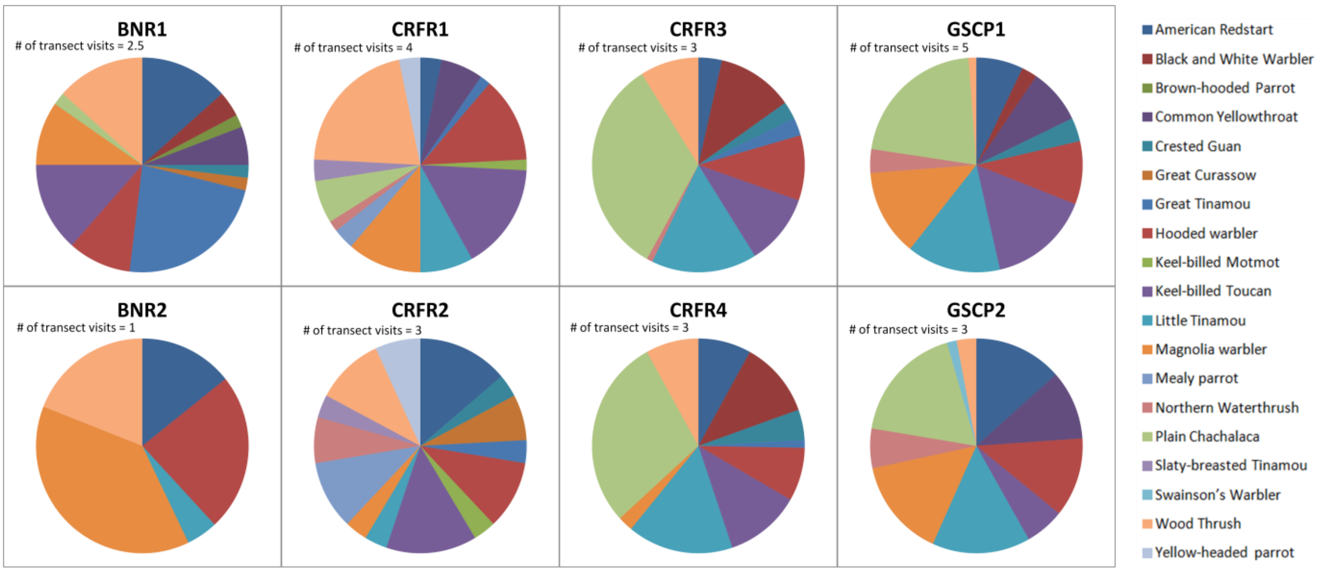

Figure 4 - Relative abundance of bird species per transect

Starting from the other end, there are striking similarities between GSCP1 and GSCP2 transects. A similar number of species has been detected and their proportional abundance is similar as well. In an analogous way, CRFR3 and CRFR4 correspond in species richness and relative abundance. Note the absence or very low numbers of disturbance-sensitive or primary forest species in these four transects (e.g. Brown-hooded parrot, Great currasow, Slaty-breasted tinamou, etc), and the abundance of Plain chachalacas. On the other hand, CRFR1, CRFR2 and BNR1 are more similar to each other than to the four previously discussed transects, and contain more of the primary forest species. We hypothesise that this difference is due to the impact of hurricane Iris (2001), which destroyed most of the lowland forest around the Golden Stream area and up to the foothills where CRFR3 and CRFR4 are located. The BNR transects, CRFR1 and CRFR2 were less affected by Iris due to their slightly more sheltered location, and thus contain older, more intact forest.
Important remarks for these graphs are that, according to Ya'axché's expert bird observer, the Yellow-headed parrots are highly unlikely to occur in the habitat CRFR1 and CRFR2 transects, and

were probably an erroneous identification. More likely the parrots observed were Mealy parrots. Similarly, some of the detected Keel-billed motmots (BNR1 and CRFR1) might actually have been Tody motmots.

3.1.2. Diversity indices

The effective number of species per transect has been calculated using three different diversity indices, as described in the methodology Section 2. Shannon's index weighs every species by its relative abundance and is considered the better representation of diversity and (in)equality of relative abundances. The two Simpson's indices give proportionally more weight to more abundant species and will in general yield lower values of ENS. In accordance with these expectations, Shannon's index yields the highest ENS of the three indices (note the exception of CRFR2 where no species is exceptionally more abundant than all others), while Simpson's index (*l*) and (*λ*) respectively yield slightly and more substantially lower ENS (Figure 5).
BNR1, CRFR1 and CRFR2 clearly house the highest actual number of species, which is reflected to some extent in the ENS estimates, although the index calculation, monitoring effort, chance and environmental variables affect the estimates and add to the observed variation. Not surprisingly, there were fewer species detected during the single visit to transect BNR2 than during the combined visits of any other transect. Given the similarity in habitat, the ENS of BNR1 was expected to be around the same level as in CRFR1 and CRFR2. The reason for it being lower could be the difference in length of the transect (500m vs 1000m).

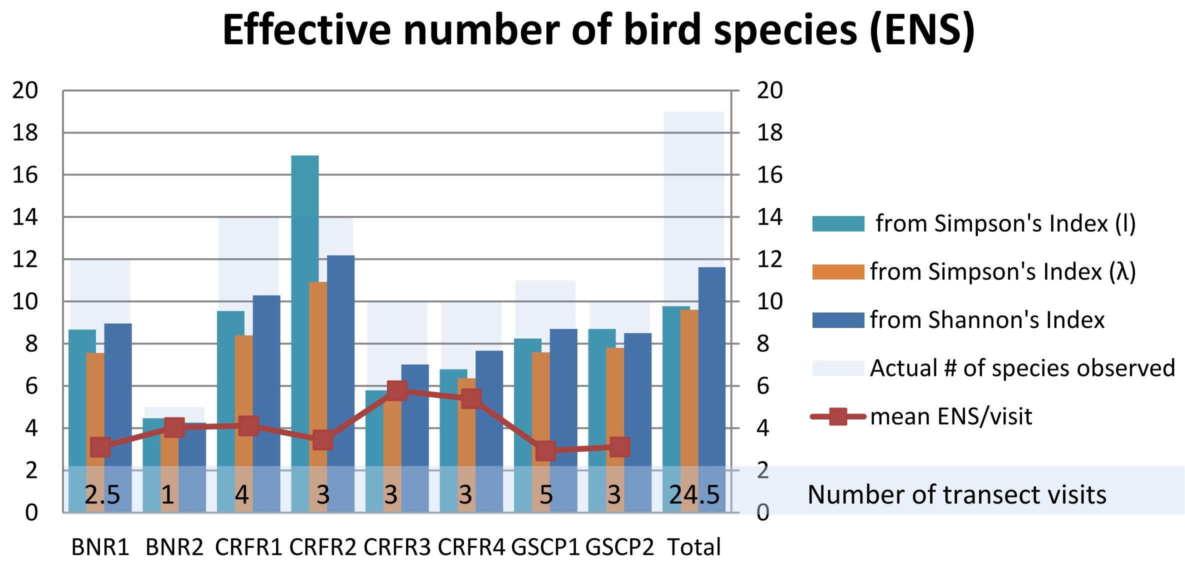

Figure 5 - Effective number of bird species per transect

Of the three measures of ENS, the one calculated from Shannon's index correlates most with the actual number of species observed (ρ=0.91), whereas Simpson's index (*l*) correlated the least (ρ=0.60).

To asses to what extent other species will be detected if more visits had been done to BNR2, and whether a lot more species would have been detected at the other transects, a species accumulation curve was drawn (Figure 6). The curve seems to reach an asymptote of 12 species at the 5th visit, whereas on average only six species are detected after one visit. It is thus to be expected that BNR2 would hold more species than currently detected. Note that few transects (only two) were visited five times. The last values might therefore have been different if more transect would have been visited five times, which could substantially alter the shape of the curve.

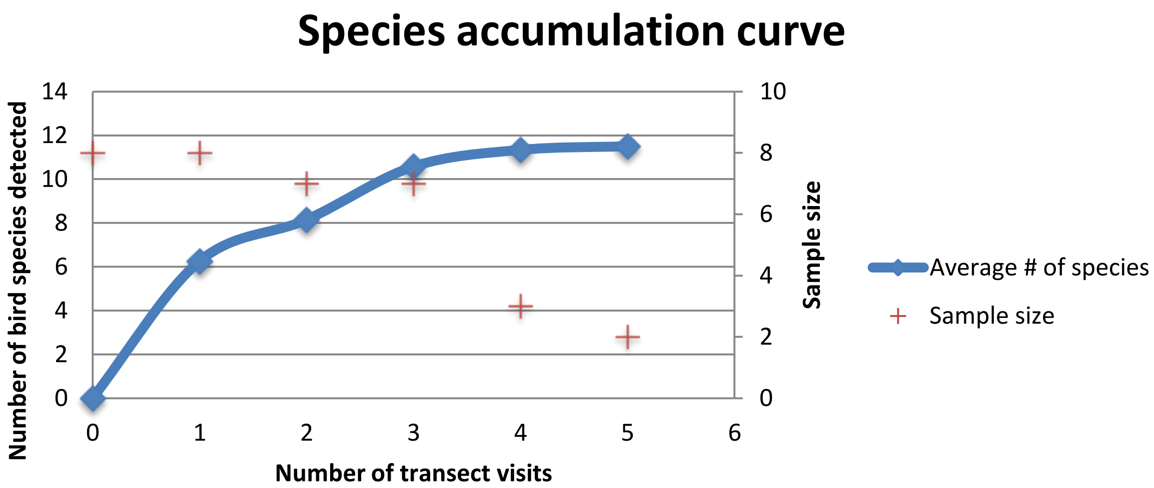

Figure 6 - Bird species accumulation curve

All the figures above are concerned with the analysis of the visit data pooled per transect to speed up the comparison process. Equally interesting is the calculation of **the ENS of every single morning and evening visit**. Here we have used Shannon's index to calculate the ENS, which was judged most accurate given our comparison above. From the ENS of all visits, a mean ENS per visit can be calculated for every transect (see Figure 5), which tells us how many hypothetical, equally abundant species have been detected on an average visit. The graph suggests that going on transects CRFR3 or CRFR4 would maximise the effective number of species to be seen during a single visit, while the least can be expected at GSCP1 (although you might also detect many species, of which one is a lot more abundant than all the others).

3.1.3. Migratory birds

Having a closer look at the migratory birds is suggested in the BRIM, although it doesn't detail how. Only eight out of 19 selected migratory bird species were observed. Possible reasons for this low proportion are varied. Some species on the list occur primarily in pine forest, savannah or roadside habitats, where none of Ya'axché's 2010 transects are located. The target list was initially compiled with the goal of streamlining Ya'axché's terrestrial monitoring with that of sister-NGO Toledo Institute for Development and Environment (TIDE), which has a more marine focus. TIDE's terrestrial protected areas contain some habitats that are not present in Ya'axché's areas, explaining the presence of seemingly irrelevant species in the target list.

Table 6 - Distribution of transect visits with bird data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
BNR1													5
BNR2													1
CRFR1													4
CRFR2													3
CRFR3													3
CRFR4													3
GSCP1													5
GSCP2													3
Total	5	5	6	0	2	3	1	0	0	4	0	1	

Also, only half of the transects have been visited in both spring (Feb-Mar) and autumn (Sept-Oct) migration peaks. CRFR2, CRFR3 and CFRF4 have only been visited in the spring migration peak, and

BNR2 has been visited only in December (see Table 6). Some transient birds on the list pass by in Belize during short migration peaks and thus have a higher chance of passing by unnoticed. And lastly, some species are just very uncommon in Belize.

We consider two relevant graphs here that tell us on which transects or in which months of the year the highest number of individuals of migratory bird species have been observed. As can be expected from migrants, none of the species have been detected all through the year, and observation peaks roughly coincide with migration peaks (Feb and Oct) (Figure 7), despite the missing data for April, August, September and November introducing a lot of uncertainty.

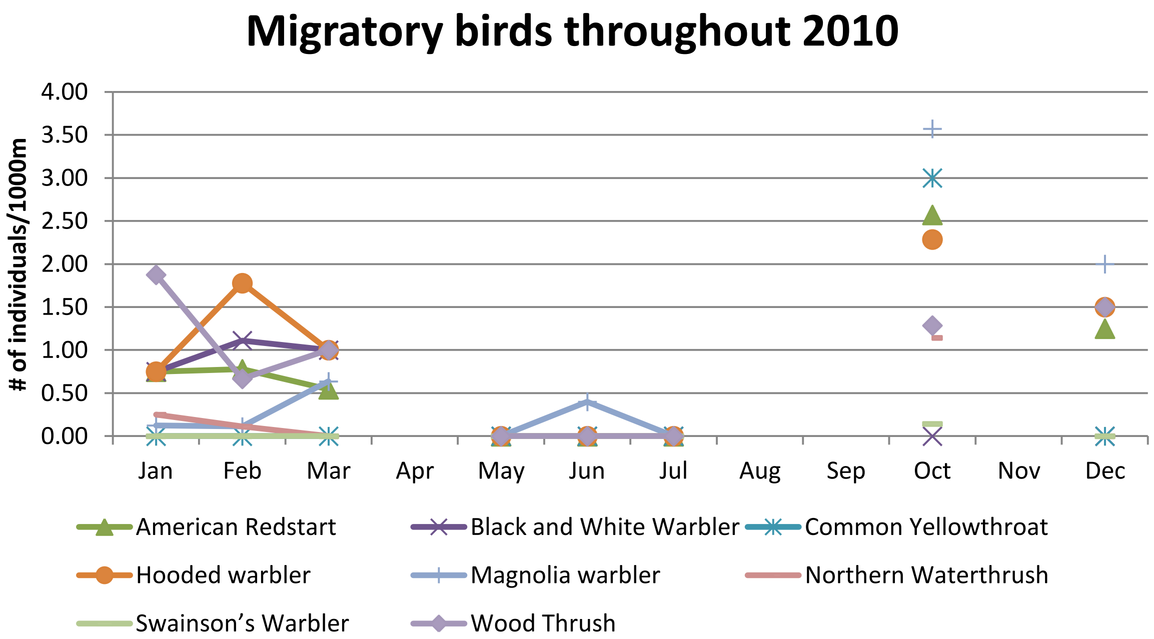

Figure 7 - Encounter rates of migratory birds throughout 2010

The single visit to BNR2 yielded the highest number of individuals for Magnolia warbler, Hooded warbler, Wood thrush and American redstart, but no other migrants were observed (Figure 8). CRFR2 and GSCP1 host remarkably low numbers of migrants despite a reasonable number of transect visits. A number of species are fairly widespread (e.g. American redstart, Hooded warbler, Wood thrush), whereas others occur more localised (Black-and-white warbler, Northern waterthrush, Common Yellowthroat), although these differences might reflect observer skills or effort rather than actual distribution or abundance.

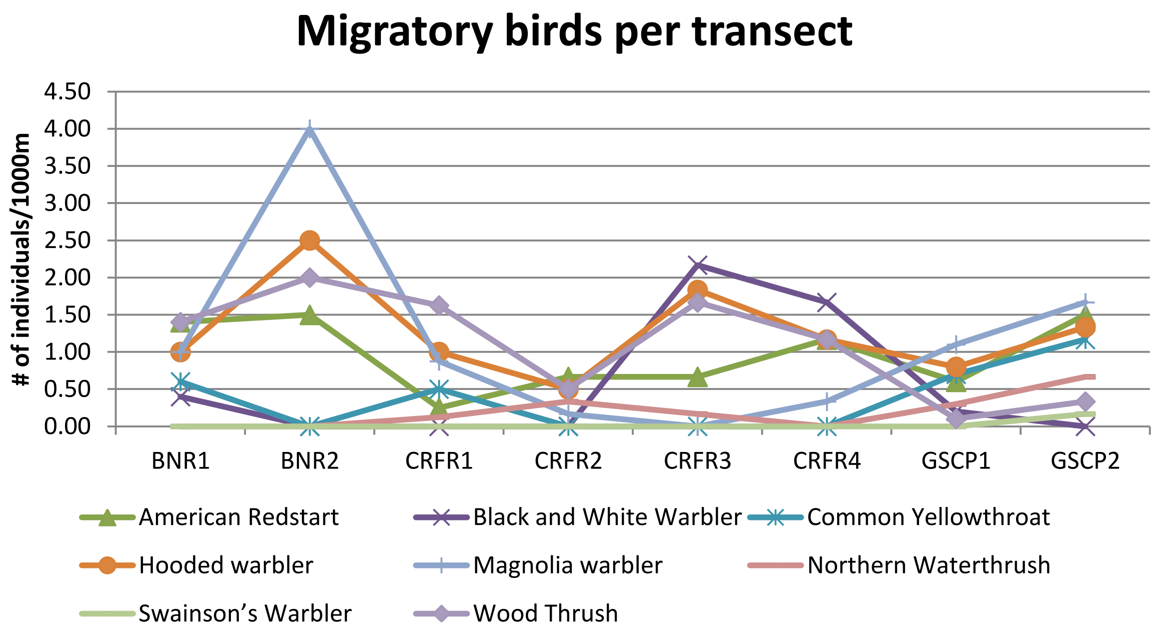

Figure 8 - Encounter rate of migratory birds per transect

3.1.4. Game birds

Here again the variation in the data is probably at least in part due to the variation in data collection efforts, rather than actual distribution or abundance of the species (Figure 9). In general, the encounter rate of most species is fairly low. Note the absence of Crested guan in BNR and adjacent parts of CRFR (1&2) though, despite the supposed lack of disturbance (e.g. hunting) in the primary forest of that area. Due to their tendency to move around in groups of 5 or more individuals, numbers of Plain chachalaca are expected to be higher than other similar but solitary species. They abound in areas with medium disturbance levels that are recovering from hurricane damage, such as GSCP1&2 and CRFR3&4 where they reach encounter rates of 6.2 and 4.2 individuals per 1000m respectively (values outside graph area).

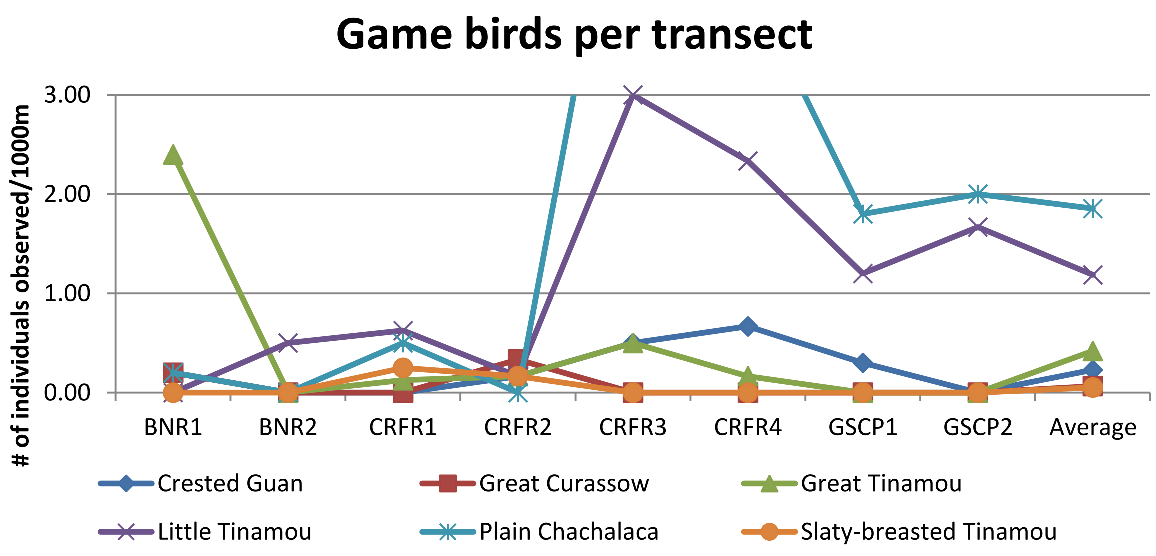

Figure 9 - Encounter rate of game birds per transect (Values outside graph area:

Plain Chachalaca – CRFR3: 6.2; CRFR4 4.2)

3.2. Mammals

A total of 13 mammal species were detected, which is a good proportion out of 15 target species, and a total of 317 individuals were observed. This includes four single observations of tracks of White-lipped peccary herds up to 60 individuals strong, boosting the overall number of individuals observed.

Mammal diversity	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
Actual # of species observed	9	2	6	7	7	9	10	7	13
# of individuals observed	31	8	9	20	76	119	37	17	317

3.2.1. Site comparison

In a single glance over Figure 10, it is clear that BNR2 needs more visits to achieve a comparable species diversity to the other transects. Again, we decided to disregard it in the comparison. The overwhelming abundance of White-lipped peccary in CRFR3, CRFR4 and to a lesser extent GSCP1 is obvious as well. Their abundance in these areas (and their absence in the least hurricane-impacted, more mountainous transects) is possibly due to the availability of food sources in Cohune palm dominated secondary forest.

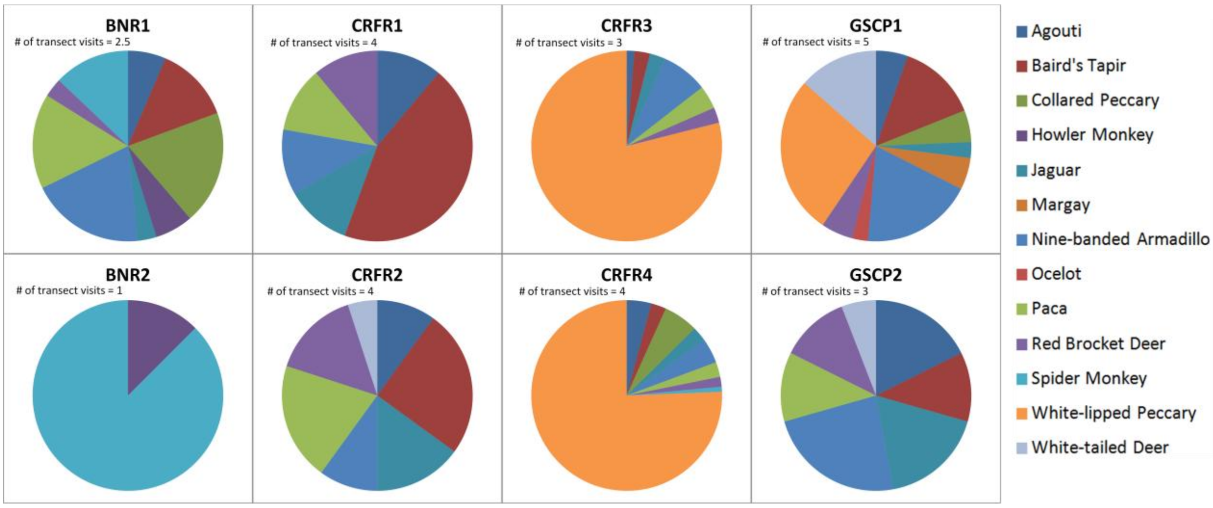

Figure 10 - Relative abundance of mammal species per transect

Tracks of a White-lipped peccary herd estimated to be 60 individuals strong were observed on transect CRFR4 in January. One day later, tracks of presumably the same herd were observed on transect CRFR3, and thus recorded a second time. 10 days later, tracks of about 10 individuals were recorded on GSCP1, and another two weeks later, fresh tracks of an estimated 30 individuals were seen on the CRFR4 transect again. We assume that a relatively big herd of White-lipped peccaries roamed the area for a while in the beginning of the year in loose formations of up to 60 individuals.
However, observing these amounts of White-lipped peccary in a small number of observations severely skews the relative abundance of all other species and makes comparison of relative abundances among transects tricky. Therefore, we opted to present a second version of relative abundance pie charts, excluding the White-lipped peccary observations (Figure 11).

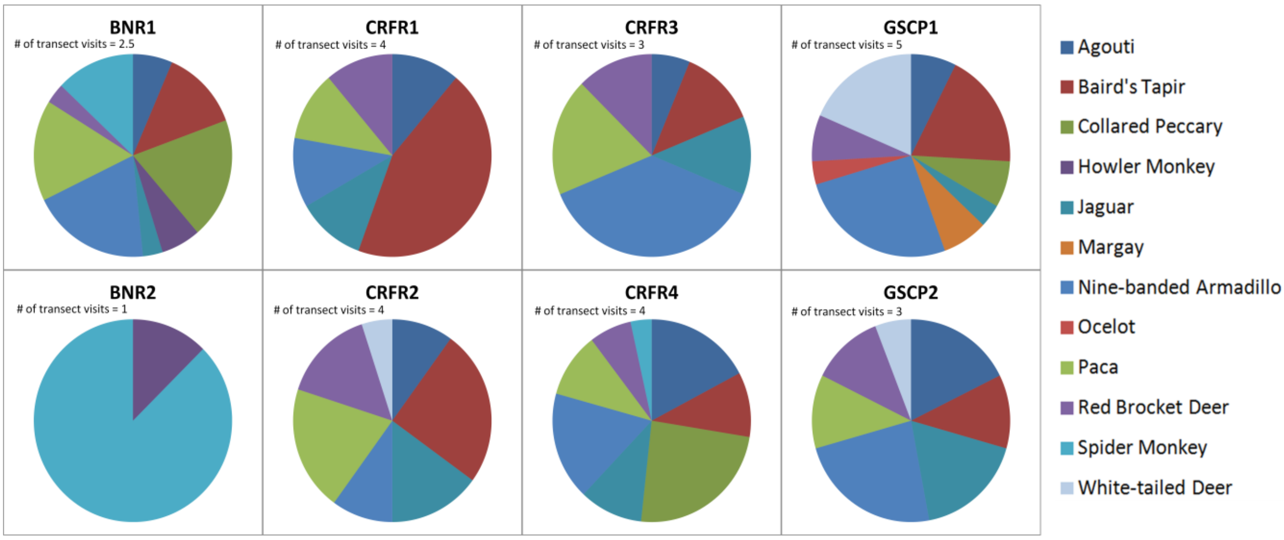

Figure 11 - Relative abundance of mammal species, excluding White-lipped peccary

In this case, no clear patterns are discernible in the species diversity and abundance. Howler monkeys were only detected on BNR transects, while Spider monkeys occurred in BNR and CRFR4. Both primates are absent in the secondary forests of other transects, probably due to a lack of canopy structure. It is remarkable that three cat species (Jaguar, Ocelot and Margay) were detected in GSCP1, where the highest number of transect visits was conducted. This suggests that additional visits to the other transects might reveal more species present as well, which is in accordance with the species accumulation curve (Figure 12) showing no signs of reaching an asymptote even after five visits.

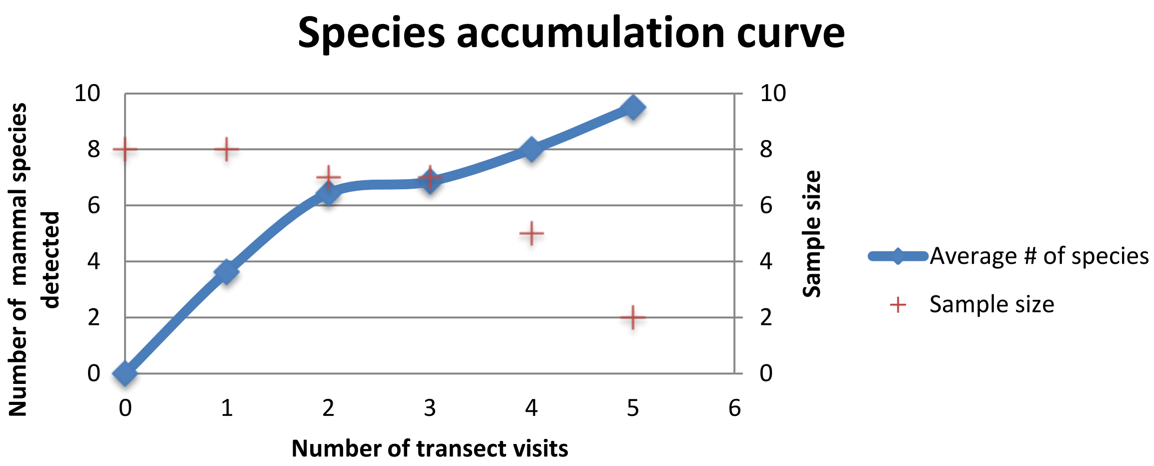

Figure 12 - Mammal species accumulation curve

3.2.2. Diversity indices

For mammals, champions in actual number of species observed are BNR1, CRFR4 and GSCP1 (see Figure 13). However, due to the high proportion of White-lipped peccaries (which affects the diversity indices), the ENS for the transects where these animals were observed is low, especially for CRFR3 and CRFR4. The correlation coefficient for the ENS calculated from Shannon's index is a meagre 0.63, and for Simpson's (*l*) as low as 0.43. With the White-lipped peccaries excluded, the ENS is a lot more in line with the actual number of species observed (ρ=0.99 and ρ=0.91 respectively), and differences between transects are relatively small (see Appendix I).

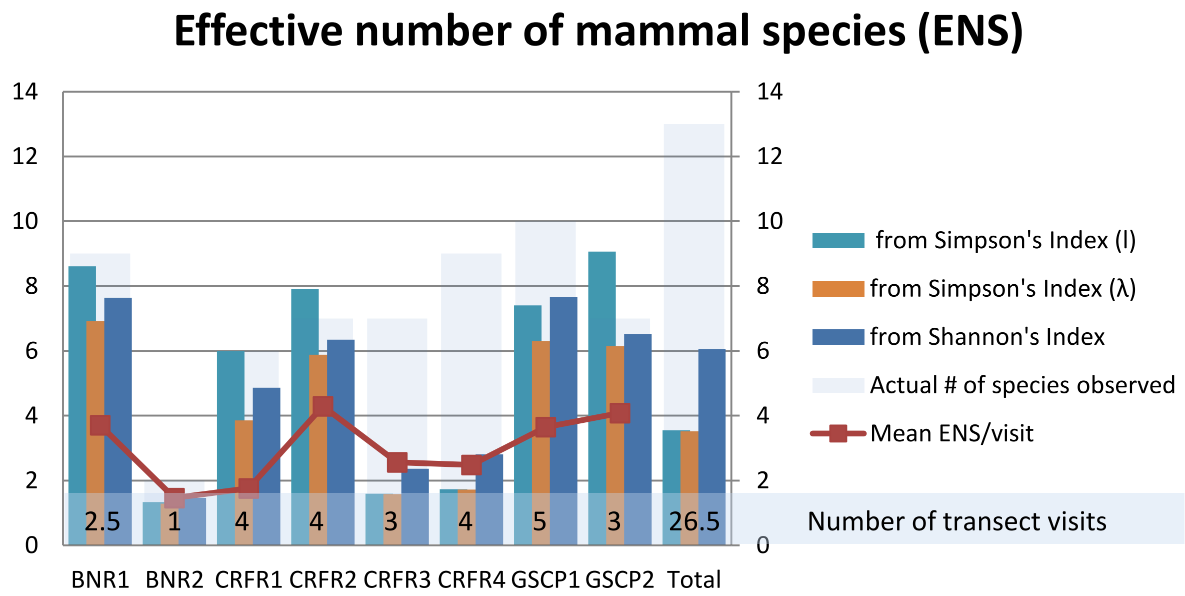

Figure 13 - Effective number of mammal species per transect

3.2.3. Game mammals

On average, most encountered species were White-lipped peccary, Nine-banded armadillo, Baird's tapir and Paca (Figure 14). White-lipped peccaries were encountered at 20 and 22 individuals/1000m on CRFR3 and CRFR4 respectively, and reach an overall average encounter rate of 5.6 ind/1000m (SD ±9.10) (values outside graph area). BNR1 has highest encounter rates of all most common species, except for White-lipped peccary. Red brocket deer and Tapirs seem to occur at all transects at similar encounter rates, whereas Collared peccaries share their area of activity with White-lipped peccary.

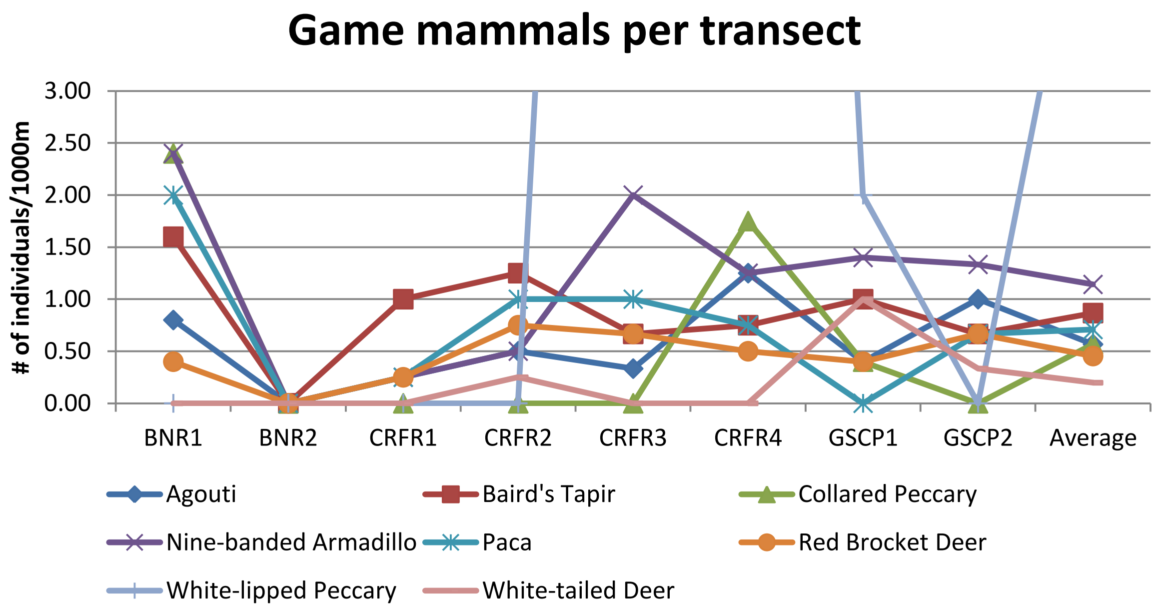

Figure 14 - Encounter rate of mammal species per transect (based on sightings, tracks and signs). Values outside graph area: White-lipped peccary – CRFR3: 20; CRFR4: 22.

4. Conclusions

In general, the CRFR1 and CRFR2 have highest bird diversity, whereas BNR1 and the GSCP transects seem to harbour highest mammal diversity. The effects of hurricane Iris are reflected in species composition in both birds and mammals. Migratory birds are detected in migration peak periods and to a lesser extent throughout the winter months. Despite concerns about the consistency of data gathering and the quality of the data, these results are largely in accordance with expectations.

The true value of the annual Biodiversity Synthesis Reports lies in the continued and consistent analysis of gathered biodiversity data over the span of several years. Once data from additional years will be available and analysed, opportunities to detect trends will arise (with the exception of abundance trends – see Section 5.2).

5. Recommendations

5.1. The Biodiversity Research, Inventory and Monitoring strategy

Only eight out of 19 migratory bird species was observed. This is an indication of a high number of irrelevant species on the list as mentioned in Section 3.1.3. Likewise, a number of practical issues warrant the revision mammal target list. The difference between jaguar and puma tracks, or between Nine-banded and Naked-tailed armadillo tracks is hard to tell, and it might be more appropriate to lump these species together. If direct sightings of either of the two similar species are recorded, the actual species observed could be specified in the 'Notes' section of the observation. In short, both lists of target species could use an update. At the time of writing, efforts are underway by the University of Belize to develop a national biodiversity monitoring strategy, which will presumably include a national target species lists for both birds and mammals. It might be worth to await these before adjusting the current lists.

Ideally, trends in absolute abundances would be calculated. However, the current monitoring system is not set up for that. What is needed for calculations of absolute abundances? One option involves recording the exact angle of the direction in which the observation was made and finding the distance between the observer and the animal using a range finder (small laser beam device). The exact position of the observer needs to be known as well. Simple trigonometry would enable the calculation of the approximate location of the sighting. In combination with home range size and other ecological characteristics of the species and the landscape, abundance could be inferred. Alternatively, the observer would record the exact angle and estimate the perpendicular distance between the animal and the imaginary straight line along which the transect proceeds. The latter method has the advantage of needing less equipment (range finder), but increases uncertainty of the location. Notably, these techniques are only valuable for actual sightings of animals. In practice that means mostly birds would be suitable since they can be located by sound or sight, whereas direct sightings of mammals are rare in dense forest. The obstacle for implementation of these techniques has been the level of training of the observers and lack of equipment. Also, the recent update of the biodiversity monitoring database has been accompanied by a number of changes in data entry protocols and has precluded changes in the actual monitoring protocols in order not to confuse the observers. For mammal tracks, methods might exist to calculate absolute abundance, but might require the relocation of some transects or a considerable increase in number of transects done. This should be further investigated. In short, including absolute abundance estimates comes at considerable cost and low confidence data. It needs to be given serious consideration before it can be included.

The two previous points highlight the pressing need for revising the BRIM thoroughly, verifying applied methodologies and their suitability for the stated objectives. Reorganising the BRIM objectives into more defined categories of work would make the BRIM more logically structured and more accessible. For example, assessing management effectiveness is hardly a part of biodiversity monitoring, rather a part of monitoring and evaluation of the Protected Areas Management programme.

5.2. Data analysis

Admittedly, the terminology of a transect visit is confusing. For birds, a transect visit is in fact composed of two visits of the transect, one in the morning and one in the evening. For mammals, only one visit is done, and morning or evening is irrelevant. A more logical way to classify and analyse data would be to regard every morning and evening visit as a single transect visit for both mammals and birds.

Since no single biodiversity index can be considered perfect, it makes sense to rely on more than one to draw any conclusions. However, the simultaneous use of three different diversity indices is unnecessarily complicated. We consider using Shannon's index because its unbiased handling of relative abundances, and Simpson's index (*l*) (rather than λ) because individuals observed once are not recounted during one sample session. Alternative ways of representing the indices could be investigated.

The calculation of ENS for every morning and evening visit should allow us to partition the variation in ENS to distinguish effects of different visit variables (e.g. weather conditions, observer, time of the day, etc.). In general, NGO-based monitoring schemes are limited in time and funds, and yield too few data points to confidently perform these statistical tests. Nonetheless, it would be worth to find out the correct statistical procedure to obtain this information, and interpret it in the knowledge that assumptions are presumably not met.

As exemplified by transect BNR2, the number of transect visits does influence species richness and relative abundances. Species accumulation curves offer a way to control for the unequal number of transect visits, because they allow for predicting the number of species still to be detected at a given number of transect visits. However, working with species accumulation curves like that is potentially statistically weak. Finding out the best way to control for unequal number of transect visits would be a valuable improvement.

Something that is being developed at the time of writing is species identification tests to assess observers' identification skills. However, for now, the way to use these assessments is still unclear. Ways to control for observer bias should be researched and checked for feasibility.

So far, the possibility and usefulness of presence/absence analysis have not been considered. An initial investigation should shed light on the role this kind of analysis can play in acquiring relevant information for protected area management.

References

Hill, M. O. (1973). Diversity and evenness: a unifying notation and its consequences. *Ecology*, *54*(2), 427-432.

Jost, L. (2006). Entropy and diversity. *Oikos*, *113*(2), 363-375. doi:10.1111/j.2006.0030-1299.14714.x

Simpson, E. H. (1949). Measurement of diversity. *Nature*, *163*(4148), 688–688. Nature Publishing Group.

Tuomisto, H. (2010). A diversity of beta diversities: straightening up a concept gone awry. Part 2. Quantifying beta diversity and related phenomena. *Ecography*, *33*(1), 23-45. doi:10.1111/j.1600-0587.2009.06148.x

Appendix I: species observation tables

Bird tables

Number of individuals	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
American Redstart	7	3	2	4	4	7	6	9	42
Black and White Warbler	2				13	10	2		27
Brown-hooded Parrot	1								1
Common Yellowthroat	3		4				7	7	21
Crested Guan	1			1	3	4	3		12
Great Curassow	1			2					3
Great Tinamou	12		1	1	3	1			18
Hooded warbler	5	5	8	3	11	7	8	8	55
Keel-billed Motmot			1	1					2
Keel-billed Toucan	7		10	4	12	10	13	4	60
Little Tinamou		1	5	1	18	14	12	10	61
Magnolia warbler	5	8	7	1		2	11	10	44
Mealy parrot			2	3					5
Northern Waterthrush			1	2	1		3	4	11
Plain Chachalaca	1		4		37	25	18	12	97
Slaty-breasted Tinamou			2	1					3
Swainson's Warbler								1	1
Wood Thrush	7	4	13	3	10	7	1	2	47
Yellow-headed parrot			2	2					4
Total	52	21	62	29	112	87	84	67	514
Species richness	**12**	**5**	**14**	**14**	**10**	**10**	**11**	**10**	**19**

Relative abundance (p_i)	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
American Redstart	0.13	0.14	0.03	0.14	0.04	0.08	0.07	0.13	0.08
Black and White Warbler	0.04	0.00	0.00	0.00	0.12	0.11	0.02	0.00	0.05
Brown-hooded Parrot	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Yellowthroat	0.06	0.00	0.06	0.00	0.00	0.00	0.08	0.10	0.04
Crested Guan	0.02	0.00	0.00	0.03	0.03	0.05	0.04	0.00	0.02
Great Curassow	0.02	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.01
Great Tinamou	0.23	0.00	0.02	0.03	0.03	0.01	0.00	0.00	0.04
Hooded warbler	0.10	0.24	0.13	0.10	0.10	0.08	0.10	0.12	0.11
Keel-billed Motmot	0.00	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.00
Keel-billed Toucan	0.13	0.00	0.16	0.14	0.11	0.11	0.15	0.06	0.12
Little Tinamou	0.00	0.05	0.08	0.03	0.16	0.16	0.14	0.15	0.12
Magnolia warbler	0.10	0.38	0.11	0.03	0.00	0.02	0.13	0.15	0.09
Mealy parrot	0.00	0.00	0.03	0.10	0.00	0.00	0.00	0.00	0.01
Northern Waterthrush	0.00	0.00	0.02	0.07	0.01	0.00	0.04	0.06	0.02
Plain Chachalaca	0.02	0.00	0.06	0.00	0.33	0.29	0.21	0.18	0.19
Slaty-breasted Tinamou	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.01
Swainson's Warbler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Wood Thrush	0.13	0.19	0.21	0.10	0.09	0.08	0.01	0.03	0.09
Yellow-headed parrot	0.00	0.00	0.03	0.07	0.00	0.00	0.00	0.00	0.01
Proportionality check	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Bird diversity	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
Actual # of species observed	12	5	14	14	10	10	11	10	19
# of individuals observed	52	21	62	29	112	87	84	67	514
Effective number of species									
from Simpson's Index (*l*)	8.67	4.47	9.55	16.92	5.78	6.79	8.24	8.70	9.78
from Simpson's Index (*λ*)	7.55	3.83	8.39	10.92	5.55	6.37	7.59	7.81	9.61
from Shannon's Index	8.96	4.26	10.30	12.19	7.01	7.67	8.69	8.49	11.62
mean ENS/visit	3.10	4.03	4.11	3.44	5.78	5.40	2.93	3.11	

Migratory birds

# of individuals/1000m	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
American Redstart	0.75	0.78	0.55	-	0.00	0.00	0.00	-	-	2.57	-	1.25
Black and White Warbler	0.75	1.11	1.00	-	0.00	0.00	0.00	-	-	0.00	-	0.00
Common Yellowthroat	0.00	0.00	0.00	-	0.00	0.00	0.00	-	-	3.00	-	0.00
Hooded warbler	0.75	1.78	1.00	-	0.00	0.00	0.00	-	-	2.29	-	1.50
Magnolia warbler	0.13	0.11	0.64	-	0.00	0.40	0.00	-	-	3.57	-	2.00
Northern Waterthrush	0.25	0.11	0.00	-	0.00	0.00	0.00	-	-	1.14	-	0.00
Swainson's Warbler	0.00	0.00	0.00	-	0.00	0.00	0.00	-	-	0.14	-	0.00
Wood Thrush	1.88	0.67	1.00	-	0.00	0.00	0.00	-	-	1.29	-	1.50
Total	4.50	4.56	4.18	-	0.00	0.40	0.00	-	-	14.00	-	6.25

# of individuals/1000m	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Average
American Redstart	1.40	1.50	0.25	0.67	0.67	1.17	0.60	1.50	0.97
Black and White Warbler	0.40	0.00	0.00	0.00	2.17	1.67	0.20	0.00	0.55
Common Yellowthroat	0.60	0.00	0.50	0.00	0.00	0.00	0.70	1.17	0.37
Hooded warbler	1.00	2.50	1.00	0.50	1.83	1.17	0.80	1.33	1.27
Magnolia warbler	1.00	4.00	0.88	0.17	0.00	0.33	1.10	1.67	1.14
Northern Waterthrush	0.00	0.00	0.13	0.33	0.17	0.00	0.30	0.67	0.20
Swainson's Warbler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.02
Wood Thrush	1.40	2.00	1.63	0.50	1.67	1.17	0.10	0.33	1.10
Total	5.80	10.00	4.38	2.17	6.50	5.50	3.80	6.83	5.62

Game birds

# of individuals/1000m	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Average
Crested Guan	0.20	0.00	0.00	0.17	0.50	0.67	0.30	0.00	0.23
Great Curassow	0.20	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.07
Great Tinamou	2.40	0.00	0.13	0.17	0.50	0.17	0.00	0.00	0.42
Little Tinamou	0.00	0.50	0.63	0.17	3.00	2.33	1.20	1.67	1.19
Plain Chachalaca	0.20	0.00	0.50	0.00	6.17	4.17	1.80	2.00	1.85
Slaty-breasted Tinamou	0.00	0.00	0.25	0.17	0.00	0.00	0.00	0.00	0.05
Total	3.00	0.50	1.50	1.00	10.17	7.33	3.30	3.67	3.81

Mammal tables

Number of individuals	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
Agouti	2		1	2	1	5	2	3	16
Baird's Tapir	4		4	5	2	3	5	2	25
Collared Peccary	6					7	2		15
Howler Monkey	2	1							3
Jaguar	1		1	3	2	3	1	3	14
Margay							2		2
Nine-banded Armadillo	6		1	2	6	5	7	4	31
Ocelot							1		1
Paca	5		1	4	3	3		2	18
Red Brocket Deer	1		1	3	2	2	2	2	13
Spider Monkey	4	7				1			12
White-lipped Peccary					60	90	10		160
White-tailed Deer				1			5	1	7
Total	31	8	9	20	76	119	37	17	317
Species richness	**9**	**2**	**6**	**7**	**7**	**9**	**10**	**7**	**13**

Relative abundance (p_i)	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
Agouti	0.06	0.00	0.11	0.10	0.01	0.04	0.05	0.18	0.05
Baird's Tapir	0.13	0.00	0.44	0.25	0.03	0.03	0.14	0.12	0.08
Collared Peccary	0.19	0.00	0.00	0.00	0.00	0.06	0.05	0.00	0.05
Howler Monkey	0.06	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Jaguar	0.03	0.00	0.11	0.15	0.03	0.03	0.03	0.18	0.04
Margay	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.01
Nine-banded Armadillo	0.19	0.00	0.11	0.10	0.08	0.04	0.19	0.24	0.10
Ocelot	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Paca	0.16	0.00	0.11	0.20	0.04	0.03	0.00	0.12	0.06
Red Brocket Deer	0.03	0.00	0.11	0.15	0.03	0.02	0.05	0.12	0.04
Spider Monkey	0.13	0.88	0.00	0.00	0.00	0.01	0.00	0.00	0.04
White-lipped Peccary	0.00	0.00	0.00	0.00	0.79	0.76	0.27	0.00	0.50
White-tailed Deer	0.00	0.00	0.00	0.05	0.00	0.00	0.14	0.06	0.02
Proportionality check	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Mammal diversity	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
Actual # of species observed	9	2	6	7	7	9	10	7	13
# of individuals observed	31	8	9	20	76	119	37	17	317
Effective number of species									
from Simpson's Index (*l*)	8.61	1.33	6.00	7.92	1.59	1.73	7.40	9.07	3.55
from Simpson's Index (λ)	6.91	1.28	3.86	5.88	1.58	1.72	6.31	6.15	3.52
from Shannon's Index	7.64	1.46	4.86	6.35	2.36	2.81	7.66	6.52	6.06
Mean ENS/visit	3.71	1.46	1.76	4.29	2.56	2.48	3.65	4.08	

Game mammals

# of individuals/1000m	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Average
Agouti	0.80	0.00	0.25	0.50	0.33	1.25	0.40	1.00	0.57
Baird's Tapir	1.60	0.00	1.00	1.25	0.67	0.75	1.00	0.67	0.87
Collared Peccary	2.40	0.00	0.00	0.00	0.00	1.75	0.40	0.00	0.57
Nine-banded Armadillo	2.40	0.00	0.25	0.50	2.00	1.25	1.40	1.33	1.14
Paca	2.00	0.00	0.25	1.00	1.00	0.75	0.00	0.67	0.71
Red Brocket Deer	0.40	0.00	0.25	0.75	0.67	0.50	0.40	0.67	0.45
White-lipped Peccary	0.00	0.00	0.00	0.00	20.00	22.50	2.00	0.00	5.56
White-tailed Deer	0.00	0.00	0.00	0.25	0.00	0.00	1.00	0.33	0.20

White-lipped peccary excluded

Relative abundance (p_i)	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
Agouti	0.06	0.00	0.11	0.10	0.06	0.17	0.07	0.18	0.10
Baird's Tapir	0.13	0.00	0.44	0.25	0.13	0.10	0.19	0.12	0.16
Collared Peccary	0.19	0.00	0.00	0.00	0.00	0.24	0.07	0.00	0.10
Howler Monkey	0.06	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Jaguar	0.03	0.00	0.11	0.15	0.13	0.10	0.04	0.18	0.09
Margay	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.01
Nine-banded Armadillo	0.19	0.00	0.11	0.10	0.38	0.17	0.26	0.24	0.20
Ocelot	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.01
Paca	0.16	0.00	0.11	0.20	0.19	0.10	0.00	0.12	0.11
Red Brocket Deer	0.03	0.00	0.11	0.15	0.13	0.07	0.07	0.12	0.08
Spider Monkey	0.13	0.88	0.00	0.00	0.00	0.03	0.00	0.00	0.08
White-tailed Deer	0.00	0.00	0.00	0.05	0.00	0.00	0.19	0.06	0.04
Proportionality check	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Mammal diversity	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
# of species observed	9	2	6	7	6	8	9	7	12
# of individuals observed	31	8	9	20	16	29	27	17	157
Effective number of species									
from Simpson's Index (a)	8.61	1.33	6.00	7.92	5.71	7.96	7.80	9.07	8.73
from Simpson's Index (b)	6.91	1.28	3.86	5.88	4.41	6.42	6.23	6.15	8.32
from Shannon's Index	7.64	1.46	4.86	6.35	5.13	7.06	7.31	6.52	9.38