Biodiversity Synthesis Report

2011

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Acronyms

BNR	Bladen Nature Reserve
BRIM	Ya'axché's Biodiversity Research, Inventory and Monitoring strategy
CRFR	Columbia River Forest Reserve
ENS	Effective Number of Species (or True Diversity)
GSCP	Golden Stream Corridor Preserve
MGL	Maya Golden Landscape – Ya'axché's working area
REA	Rapid Ecological Assessment
Ya'axché	Ya'axché Conservation Trust

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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 (MGL), 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 Ya'axché's protected areas

So far, Ya'axché has collected data on birds and large mammals using transect monitoring throughout the Maya Golden Landscape. In 2011, bats were added to the monitoring programme, being good indicators of forest health and landscape structure.

The 2010 Biodiversity Synthesis Report (Hofman, 2012) was a first step towards the fulfilment of the BRIM requirement to report the findings annually. The 2011 report will build on this to form a more complete biodiversity report, including the bat monitoring results and weather data. The goal of these 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.

Methodology

Bird and large mammal transects

Similar to the five previous years of data collection, the transect monitoring in 2011 involved birds and large mammals as focal groups. They were monitored with, respectively, transect point counts and sign transects, which are located in and around the protected areas located in the Maya Golden Landscape (Figure 2). 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 2 for mammals and Table 3 for birds). As in the 2010 Biodiversity Synthesis Report (Hofman, 2012), these species lists are taken from Ya'axché's Biodiversity Research, Inventory and Monitoring strategy (BRIM).

However, this year we included a classification of our target species in six indicator groups (Table 1), according to the factor for which a species is considered an indicator. This classification enables us to draw conclusions from the monitoring results. The codes are used in the analysis of the bird and mammal data. For example, an increase in 'Disturbed forest indicators' could indicate habitat destruction, whereas decreased 'Game species' richness would indicate level of hunting pressure.

Table 1. Indicator groups

Code	Class	Description
M	Migration route health indicator	generalist migrant species without specific habitat requirements in Belize
D	Disturbed forest indicator	species from fallow lands, forest gaps, human impacted landscapes
F	Forest health indicator	Species only found in primary forests or undisturbed secondary forest
G	Game species	Regularly collected species
W	Wetland indicator	Species linked to littoral or riparian habitats
P	Pine-savannah indicator	Species linked to pine savannah habitats

The attentive reader will find a slight discrepancy with the lists presented in the 2010 report and the current ones. This is due to a couple of species that are in practice recorded in the database, but are not officially on the target species list. Instead of sticking to the suggested species list (as in 2010), we decided for practical reasons to use the full set of recorded species in the current report. Note that not all species have been classified, indicating that they are rarely recorded, or that they are too much of a generalist species to be allotted to one of the indicator groups.

Table 2. Selected mammal indicator species

Mammal species	Class
Agouti	G
Baird's Tapir	W
Brown Brocket Deer	
Coati	D
Collared Peccary	G
Howler Monkey	F
Jaguar	F
Naked-tailed Armadillo	
Nine-banded Armadillo	G
Ocelot	F
Paca	G
Puma	F
Red Brocket Deer	G
Spider Monkey	F
White-lipped Peccary	G
White-tailed Deer	G

Table 3. Selected bird indicator species

Common Name	Migrant	Class
American Redstart	YES	M
Black and White Warbler	YES	M
Blue-gray Gnatcatcher	YES	P
Bronzed Cowbird	NO	D
Brown-hooded Parrot	NO	F
Cerulean Warbler	YES	F
Chestnut-sided warbler	YES	W
Common Yellowthroat	YES	M
Crested Guan	NO	G
Dickcissel	YES	D
Golden-winged Warbler	YES	F
Grace's Warbler	YES	P
Great Curassow	NO	G
Great Tinamou	NO	G
Hooded warbler	YES	M
Keel-billed Motmot	NO	F
Keel-billed Toucan	NO	
Kentucky Warbler	YES	F
Little Tinamou	NO	F
Louisiana Waterthrush	YES	W
Magnolia warbler	YES	M
Mealy Parrot	NO	F
Northern Waterthrush	YES	W
Painted Bunting	YES	D
Plain Chachalaca	NO	D
Prothonotary Warbler	YES	W
Slaty-breasted Tinamou	NO	F
Swainson's Warbler	YES	F
Wood Thrush	YES	M
Worm-eating Warbler	YES	F
Yellow-headed parrot	NO	P

A more detailed description of the methodology used can be found in the BRIM.

Data collection

The core data collected for birds and large mammals is (1) the number of species observed and (2) the number of individuals observed per species. Data for 2011 was collected over a total of 8 transects, each of which as a rule measures 1000m (see Table 4). 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. All transects are located in wet broadleaf forests under some form of protection.

There exists a gradient of natural and human disturbances among the transects, where the transects in Bladen Nature Reserve are least disturbed and the ones in Golden Stream Corridor Preserve most disturbed. This gradient is not equally prevalent at every transect location and is not quantified other than by calculated damage from hurricane Iris and the estimated proximity of residential and agricultural areas. *The gradient is thus to be considered a rough approximation of disturbance levels.* A map showing the location of the transects is presented in Figure 2.

Table 4. Transect information

Transect Name	Length (m)	Area	Land administration	Disturbance	Ecosystem
BNR1	500	Bladen	Nature Reserve	Minimal	Primary forest on karst hills
BNR2	1000	Bladen	Nature Reserve	Minimal	Primary forest on karst hills
CRFR1	1000	Columbia river	Forest reserve	Minimal; 0-20% hurricane damage (2001); proximity of agriculture	Primary forest on karst hills
CRFR2	1000	Columbia river	Forest reserve	Minimal; 0-20% hurricane damage (2001)	Primary forest on karst hills
CRFR3	1000	Columbia river	Forest reserve	Minimal; 0-20% hurricane damage (2001)	Primary forest on karst hills
CRFR4	1000	Columbia river	Forest reserve	Minimal; 0-20% hurricane damage (2001)	Primary forest on karst hills
GSCP1	1000	Golden Stream	Private Protected Area	60-75% hurricane damage (2001); proximity of village and agriculture	Secondary forest on karst foothills
GSCP2	1000	Golden Stream	Private Protected Area	60-75% hurricane damage (2001); proximity of agriculture	Secondary forest in coastal plain

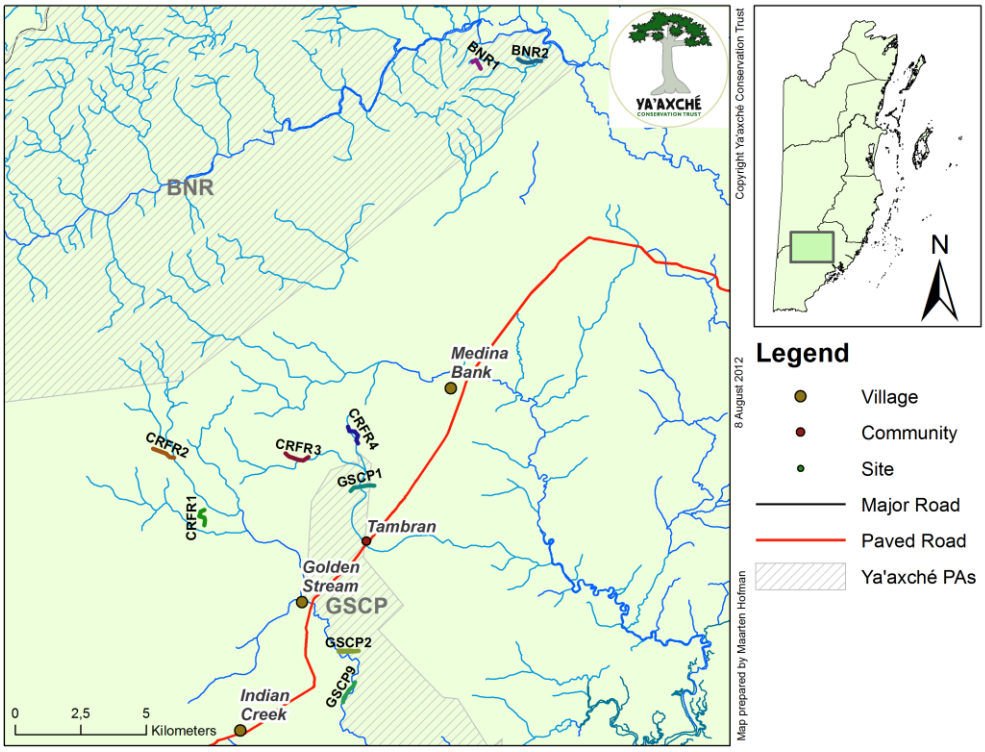

Figure 2. Location of biodiversity monitoring transects (for 2011) in relation to Ya'axché's protected areas

For bird monitoring, the transects are visited two times during the day: early morning and late afternoon. Some transects require a day walk-in, for which the afternoon visit would be performed first and the morning visit the second day, after a night camping. In 2011 the transects were each visited between 2 and 15 times over the course of the year, resulting in a total of 72km of transect covered in 2011 for bird monitoring (see Table 5). Between zero and 13 transect visits were conducted every month (Figure 3).

Table 5. Bird monitoring effort per transect

	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
# of visits performed	2	13	9	6	8	8	12	15	73
# of m transect done	1000	13000	9000	6000	8000	8000	12000	15000	72000
# of observations done	11	122	65	58	81	79	128	125	669
# of obs/visit	5.50	9.38	7.22	9.67	10.13	9.88	10.67	8.33	9.16
# of obs/1000m	11.00	9.38	7.22	9.67	10.13	9.88	10.67	8.33	9.29

A total of 669 observations of birds were done on these transect visits, with in total 9.29 observations per 1000m transect done, whereby more transects visited did not necessarily mean more observations done. Birds seemed to be detected in higher numbers around the migration peaks in March-April and October-November, when more migratory birds are passing through the country (Figure 3).

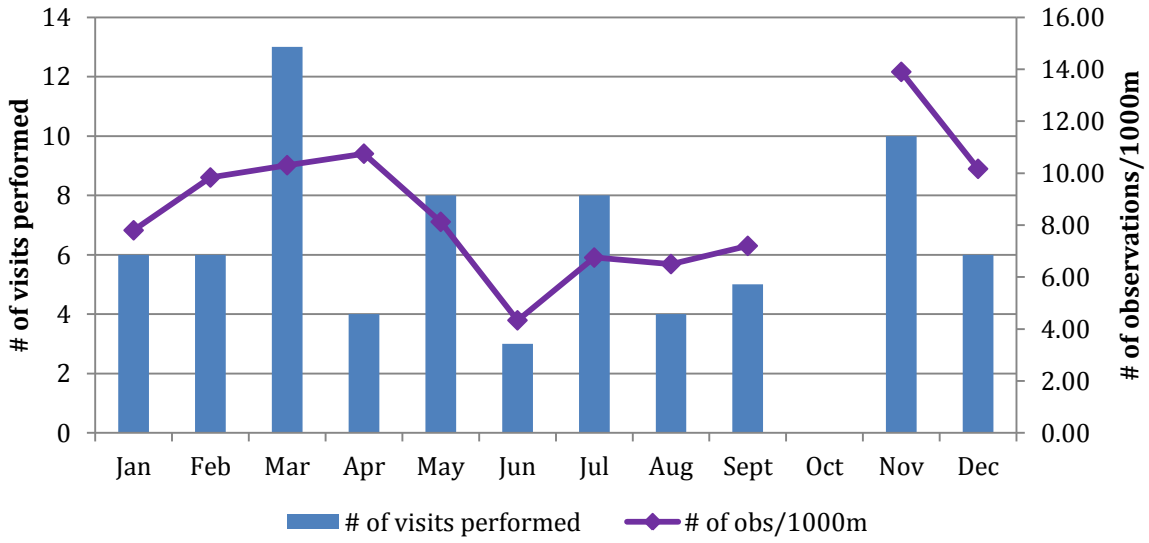

Figure 3. Bird monitoring effort in 2011

The mammal monitoring was combined with the transect visits for bird monitoring, but signs and sightings were only recorded during either the morning or the evening visit. Thus in general the number of transect visits performed per transect is half of that for bird monitoring: from one to eight times, resulting in a total of 37.5km transect covered (Table 6). A total of 189 observations of mammals signs were done, with in total 5.04 observations per 1000m transect done.

Table 6. Mammal monitoring effort per transect

PAM effort/transect	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
# of visits performed	1	6	5	3	4	4	7	8	38
# of m transect done	500	6000	5000	3000	4000	4000	7000	8000	37500
# of observations done	10	23	19	14	22	24	39	38	189
# of obs/visit	10.00	3.83	3.80	4.67	5.50	6.00	5.57	4.75	4.97
# of obs/1000m	20.00	3.83	3.80	4.67	5.50	6.00	5.57	4.75	5.04

On a monthly basis, between zero and seven transect visits were conducted. As in birds, the number of mammal observations did not seem proportional to the number of transect visits. The peak in the summer period could potentially be explained due to the fact that tracks of mammals are usually more readily detected during the wet season (June-October) when muddy trails lead to more obvious footprints (Figure 4).

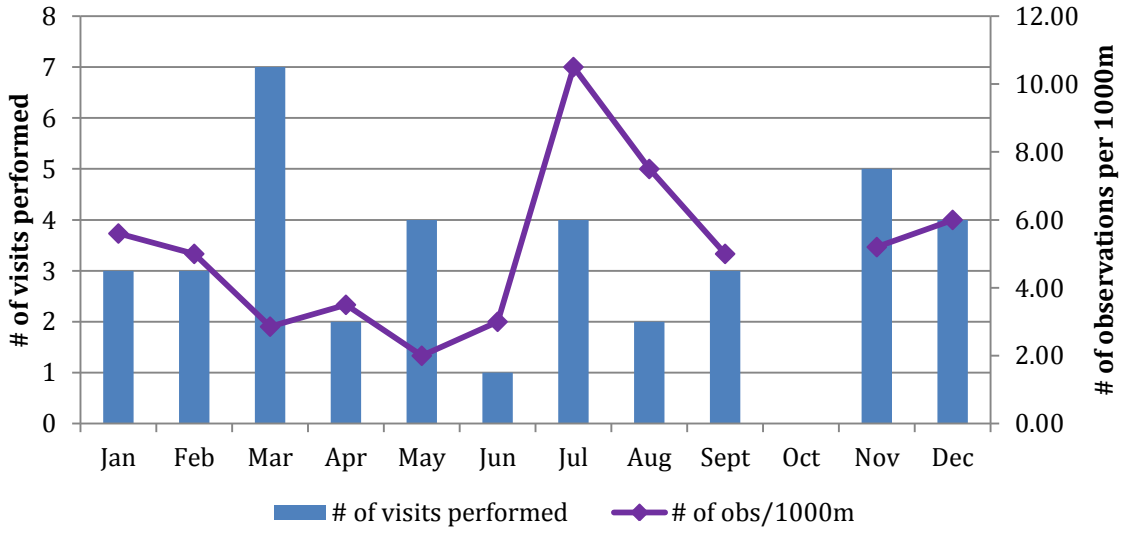

Figure 4. Mammal monitoring effort in 2011

Data quality

Overall, as is apparent from Figure 3 and Figure 4, the transect visit frequency throughout the year has been fairly irregular. There are less missing months than in 2010, but still the lack of a strictly followed monitoring schedule is showing in the graph. 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.

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'. Since over 85% of the observations involved single individuals, the error of assigning the value '1' to records with an unknown number of individuals is not expected to be a gross underestimate of the actual numbers.

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 considered a suitable way to achieve a good overview of larger scale differences between transects, and between the protected areas.

Actual number of observed species (Species Richness)

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.

Relative abundance

Relative abundance of every species (p_i) was calculated per transect 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), Magurran (2004), 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.

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, 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. The alternative Simpson's index uses the relative abundance as calculated above (Simpson, 1949),

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

Shannon's index was calculated according to the BRIM and Jost (2006) as

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

Effective Number of Species (or Hill numbers)

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), aka as 'Hill numbers' (Hill & Mar, 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.

For computational reasons related to the Hill figures (Jost, 2006), we will not consider the first Simpson's index (*l*), and will continue with just the *λ*-variant. As suggested by the same author, Simpson's index is transformed by taking the inverse:

$$\frac{1}{\lambda}$$

while Shannon's index is transformed using

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

to yield the Effective Number of Species.

While the Species Richness does not take into account the rarity (i.e. relative abundance) of species, Shannon's index weighs every species by its relative abundance, and Simpson's index gives proportionally more weight to more abundant species. By plotting this incremental weighing of abundant species, we can get an overview of the importance of one (or a few) dominant species in the community. This graph then displays a so-called **Hill**

series. The Hill series thus shows how evenly distributed the relative abundances are. The more difference between R and λ, the less evenness there is among the relative abundances of the species in the sample; or in other words, the more **dominant** certain species are in the sample.

In practice, Shannon's index is considered the better representation of diversity and (in)equality of relative abundances, and is usually used to compare diversity and evenness among sample locations.

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 or twice, cannot possibly have uncovered the same number of species than transects that have been visited four times or more. We 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.

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.

Wildlife observations

As an addition to the systematic biodiversity monitoring of large mammals and birds, Ya'axché rangers also recorded noteworthy observations made while patrolling the protected areas. The number of patrols, and thus observations, is very irregular and no standardised indices can be derived from these. These observations merely serve as an informal indicator of presence and abundance of wildlife species in the area.

Road crossings

In the frames of the corridor function of Ya'axché's protected areas, opportunistic data was collected on wildlife crossings and casualties along the Southern Highway, and specifically the stretch between the villages of Big Falls and Medina Bank. Data was collected during the daily commute by Ya'axché rangers and other staff between their homes and the field center in the Golden Stream Corridor Preserve. Every 10 days, the staff was asked to report any remarkable road crossings or casualties. Species name, number of individuals and crossing direction (if known) were recorded, as well as the approximate location along the highway.

Bats

Additional to the bird and large mammal monitoring, a bat monitoring component was tested during 2011. Note that data collection during this year was opportunistically, rather than systematically, throughout the protected areas, using a single passive acoustic monitoring station, comprised of an Anabat detector, a CF-ZCAIM recorder (Titley Scientific, Brisbane, Australia) and remotely mounted microphone. The unit was pre-programmed with a beginning and ending recording time to approximately coincide with sunset and sunrise. A total of five locations were sampled in the MGL (Figure 5), with a total sampling effort of 203.75 hours over 19 nights. Survey times per night ranged from 8 to 11.5 hours and from 1 to 6 nights per location (Table 7).

Table 7. Bat monitoring effort in 2011

	Survey nights	Survey hours
Bladen Nature Reserve		
BNR Ranger base	6	63
Total	**6**	**63**
Golden Stream Corridor Preserve		
Foothills cave	1	11.5
GSCP1_200	5	50.75
Paca cave	3	34.5
Warri cave	4	44
Total	**13**	**140.75**
Grand total	**19**	**203.75**

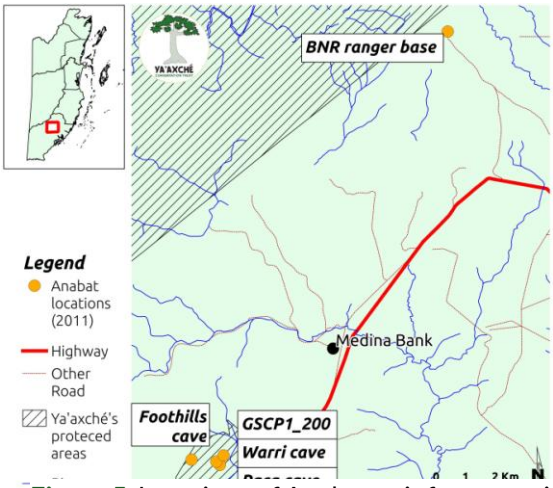

Figure 5. Locations of Anabat unit for acoustic detection of bats in the Maya Golden Landscape

Locations in the Golden Stream Corridor Preserve were all located in the proximity of caves in the foothills of the Maya Mountains. The forest around these caves is recovering from severe hurricane damage, but is relatively undisturbed otherwise. The location in the Bladen Nature Reserve is set in a pine savannah habitat, in close proximity to the pristine broadleaf forests on the foothills of the Maya Mountains.

Data was analysed to species level by Dr. Bruce Miller who reported the number of species detected, species names and their associated Acoustic Activity Index (AI). The Acoustic Activity Index was developed by Miller (2001) as an index of relative abundance and is calculated as

$$AI = \sum p$$

where p stands for any given one-minute time block during which the species was present (i.e. detected at least once). Dividing by the unit effort for the survey standardizes the AI. In this case, the AI (number of one-minute time blocks) was divided by the total survey time at that sample location, to obtain the proportion of one-minute time blocks that a bat species was active during the sample period. Subsequent nights surveyed at one location were treated as a single sample. Hence we obtain a relative version of the AI, which we have termed the Activity Index Percent (AI%):

$$AI\% = \frac{\sum p}{P}$$

where *P* is the total number of one-minute time blocks in the sample.

Weather data

Weather data was collected at the two Ya'axché ranger bases located at Golden Stream Corridor Preserve (W088°47'13.90" N16°22'23.41" [WGS 84]) and Bladen Nature Reserve (W088°42'44.79" N16°32'07.61" [WGS 84]). The weather station in Golden Stream Corridor Preserve was composed of an electronic temperature and humidity device (ECOPLUS™ Thermometer and Hygrometer), and a manually operated rain gauge. At the Bladen Nature Reserve ranger base, only a manually operated rain gauge was available. Data was recorded manually and entered in an excel spreadsheet.

Rapid Ecological Assessment

A Rapid Ecological Assessment was conducted in Snake Creek area of western Bladen Nature Reserve from 13 to 25 October 2011. The expedition was part of a broader initiative to increase knowledge of Bladen's biodiversity, to inform and strengthen its conservation management and builds on information from two previous surveys conducted in the adjacent Central River area. Another important objective of the assessment was the validation of Bladen's prioritization level within the national Key Biodiversity Areas and Maya Mountains Massif Technical assessments – prioritizations based in part on the occurrences of some amphibian species found in and around Bladen, but nowhere else in Belize.

The focal taxon for the Rapid Ecological Assessment was amphibians, but also reptiles and birds were systematically assessed. Amphibians were tested for the presence of chytrid fungus, as part of an ongoing assessment of the prevalence of this potentially fatal infection and its impacts on population viabilities. And as part of a broader regional assessment, amphibian DNA samples were collected in order to examine regional intra-specific variation – and determine whether remote populations of certain species in Belize are indeed the same species as those in Guatemala or Honduras.

Methods used for amphibian and reptile included opportunistic recording, Diurnal Visual Encounter Survey (VES) Transects, Nocturnal Visual Encounter Survey (VES) Transects, audio searches, leaf litter searches, log searches. Birds were recorded by sound and/or sight during early morning and late afternoon transects. More detailed methodologies are presented in the expedition report, which is available on request.

Results

The results of the data analysis are presented for birds and large 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. These results are followed by the bat results and the weather station results.

Birds

Out of all 31 bird species on the target list, a total of 24 bird species (77.4%) were detected during 2011, with a total of 749 individual birds observed (see Table 8).

Table 8. Number of bird species and individuals observed

	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
Total number of individuals	16	145	61	74	82	88	165	118	749
Species Richness	7	17	13	16	14	13	13	15	24
# of visits performed	2	13	9	6	8	8	12	15	73

Already after about six visits to any given transect, most species have been detected. The species accumulation curve (Figure 6) seems to reach an asymptote of on average 12 species at the 5th visit, but then slowly continues to rise.

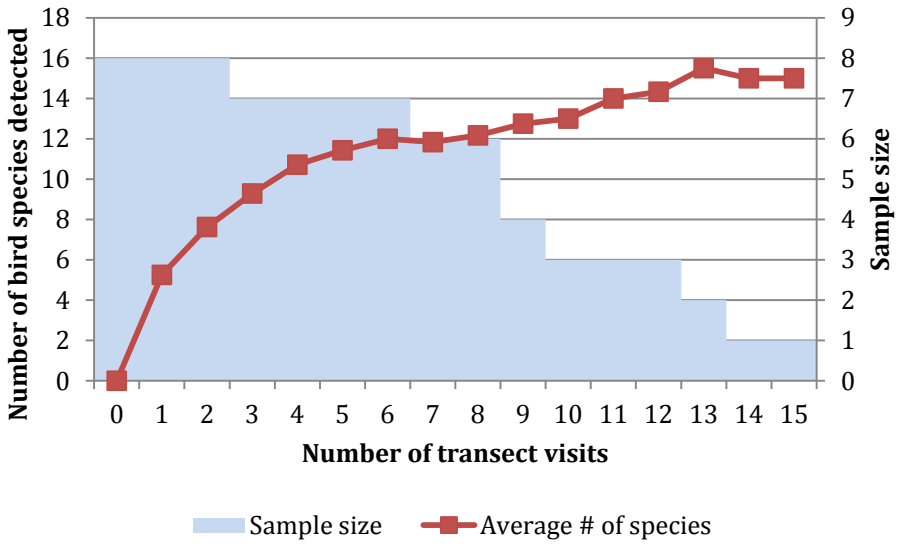

Figure 6. Bird species accumulation curve

Comparing the relative abundances among different transects is done using pie charts (Figure 7), because they give an overview of species richness and relative abundance in a comprehensible way. The plots are organised according to the disturbance gradient resulting from the transect description (Table 4).

BNR1 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 Keel-billed toucans and Wood thrushes is bigger than on any other transect. However, many

species that most probably are present will not have been detected during the two visits for this transect. Therefore it seems wise to exclude the BNR1 transect from further comparisons (see Figure 7).

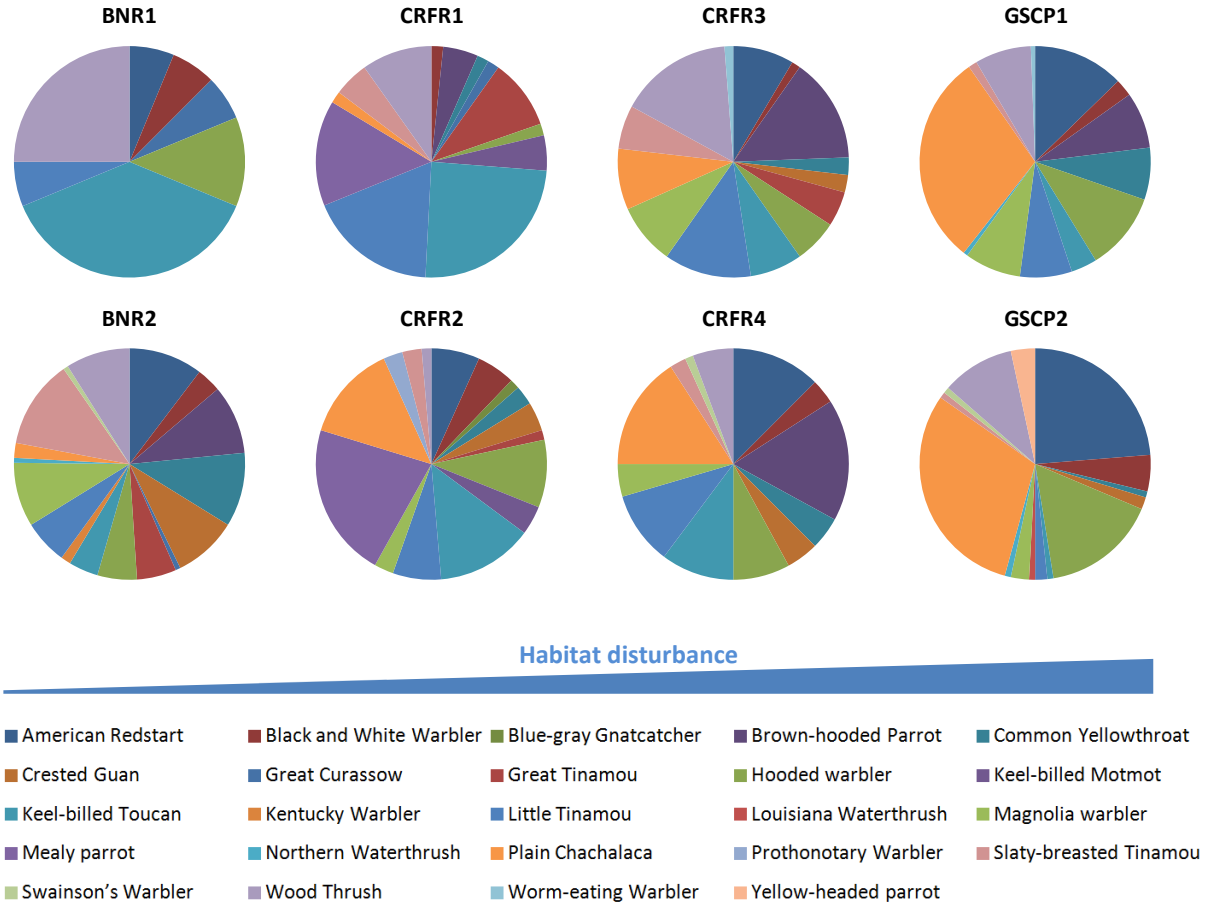

Figure 7. Relative abundance of bird species per transect (Species are ranked alphabetically in charts and legend)

Starting from the other end, there are noticeable similarities between GSCP1 and GSCP2 transects. A comparable number of species has been detected, most of which the same species, although their proportional abundances vary. As in 2010, we note less Plain chachalacas, but more Slaty-breasted tinamous and Crested guans the less disturbed the habitat gets.

Effective Number of Species and Evenness of relative abundances

Recall from the Methodolgy section that we use the Effective Number of Species – or Hill numbers – to illustrate the importance of dominance for the measurement of species diversity in a Hill series graph (Figure 8). Species Richness (R) tells us the actual number of observed species; Shannon's index (*H*) gives more importance to a particular species in proportion to its relative abundance, and Simpson's index (λ) really lets dominance of certain species weigh heavily on its estimated species diversity. As a result, the Hill series will generally show progressively lower estimates of Effective Number of Species, and the slope steepness indicates the level of dominance.

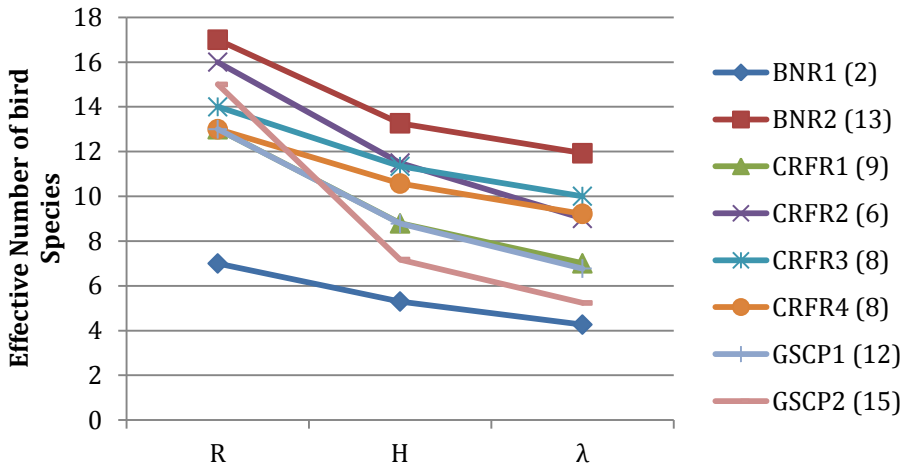

Figure 8. Hill series graph: the Effective Number of bird Species per transect (with number of visits between brackets). R = Species Richness; *H* = Shannon's index; λ = Simpson's index

As mentioned before, BNR1 has had only 2 visits and will not be taken into account for the comparison. It is included here for the sake of illustration: the effect of small sample size yields low ENS. We can clearly see that BNR2 has the highest diversity of target species, and no species is particularly dominant (gentle slopes of the graph). By contrast, even though CRFR2 starts off on a second place for the actual number of species observed, due to the dominance of species such as Mealy parrot, Plain chachalaca and Keel-billed toucan (see Figure 7), it ends up below CRFR3 for Shannon's index and Simpson's index, because they take into account relative abundance. This is exemplified even more clearly by GSCP2. This transect ranks third for Species Richness, but falls back to the last place (omitting BNR1) for the indices: the result of the large proportion of American redstart, Hooded warbler and Plain Chachalaca on the transect dominating over the much less observed Common yellowthroat, Keel-billed toucan, Northern and Louisiana waterthrushes, Slaty-breasted tinnamou and Swainson's warbler (Figure 7). In general, transect BNR2 shows least dominance effects, while transects CRFR1&2 and GSCP1&2 have the most pronounced dominance effects (or in other words: a few species are well represented, while most others are observed only occasionally). With regards to the habitat disturbance gradient mentioned before, we would expect the least disturbed transects to have higher species richness and fewer dominant species: the high diversity would require all species to uptake a fairly specific niche, limiting their scope for population expansion. Due to the more dynamic nature of disturbed areas, generalist species are in advantage and have the possibility to dominate over specialists. The observed dominance effects on our transects arguably follow that prediction, with less dominance in BNR2 than in GSCP1&2.

Migratory birds

We consider a detailed graph here that tells us in which months of the year the highest encounter rates (= number of individuals observed per 1000m transect conducted) of migratory bird have occurred. Encounter rates do not always follow the expected pattern of increase during the migration peak. During the March-April peak, encounter rates decrease, and in September- October peak, important data is lacking for October. During the winter months (Nov-Feb) encounter rates were relatively stable, except for the late

peak in November. We can also see that the number of species observed increases considerably during these peaks, despite the missing data for October (Figure 9). Most commonly observed were American redstart, Black and white warbler, Hooded warbler, Magnolia warbler and Wood thrush.

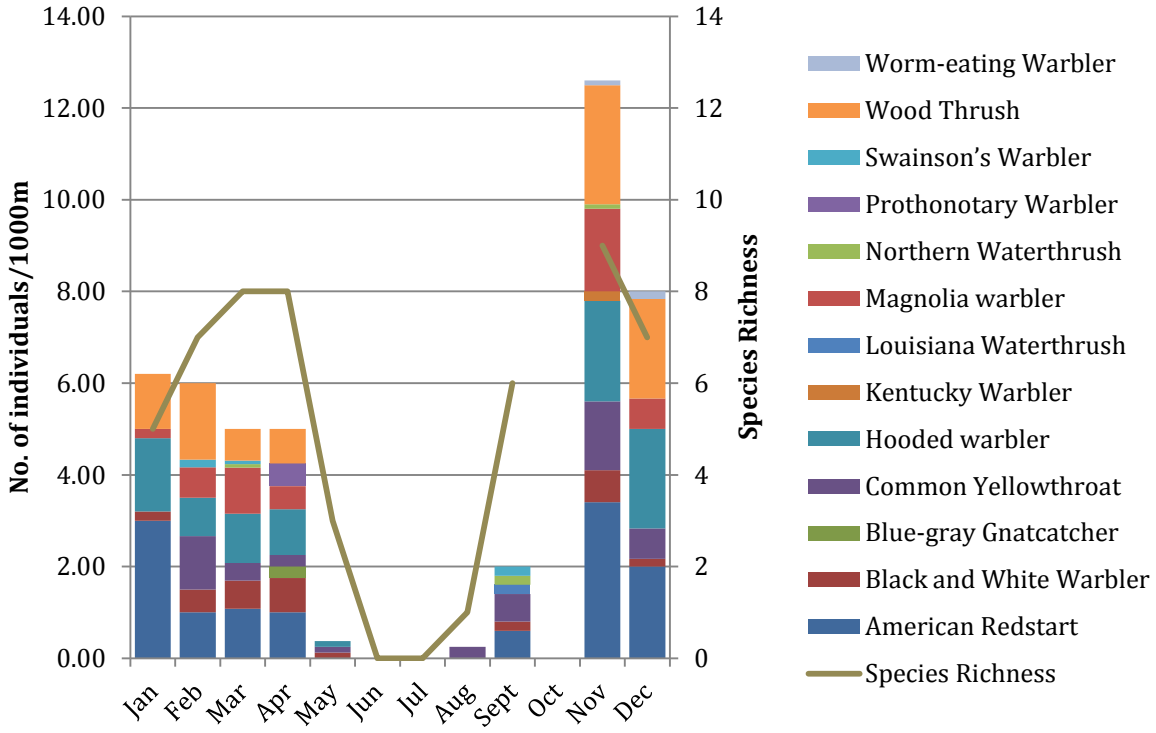

Figure 9. Encounter rates and Species Richness of migratory birds throughout 2011

In order to take into account the effort put into the discovery of these species, Table 9 lists the number of transects that were visited in every month. Putting the two together shows that the encounter rate of migratory birds in a certain month is not dependent on the number of transects visited in that month.

Table 9. Distribution of transect visits with bird data for 2011

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

Indicator groups

Forest health indicator and game species diversity seem to be slightly higher in the less disturbed areas, whereas the single disturbed forest indicator species (Plain chachalaca) occurs in greater densities in the more disturbed areas (Figure 10). Migration route indicator species richness is fairly similar across all transects, accounting for the less sampled transect (BNR1). The lower number for CRFR1 cannot be readily explained and is presumably due to natural variation. No clear impacts of disturbance are discernible for riparian species indicators.

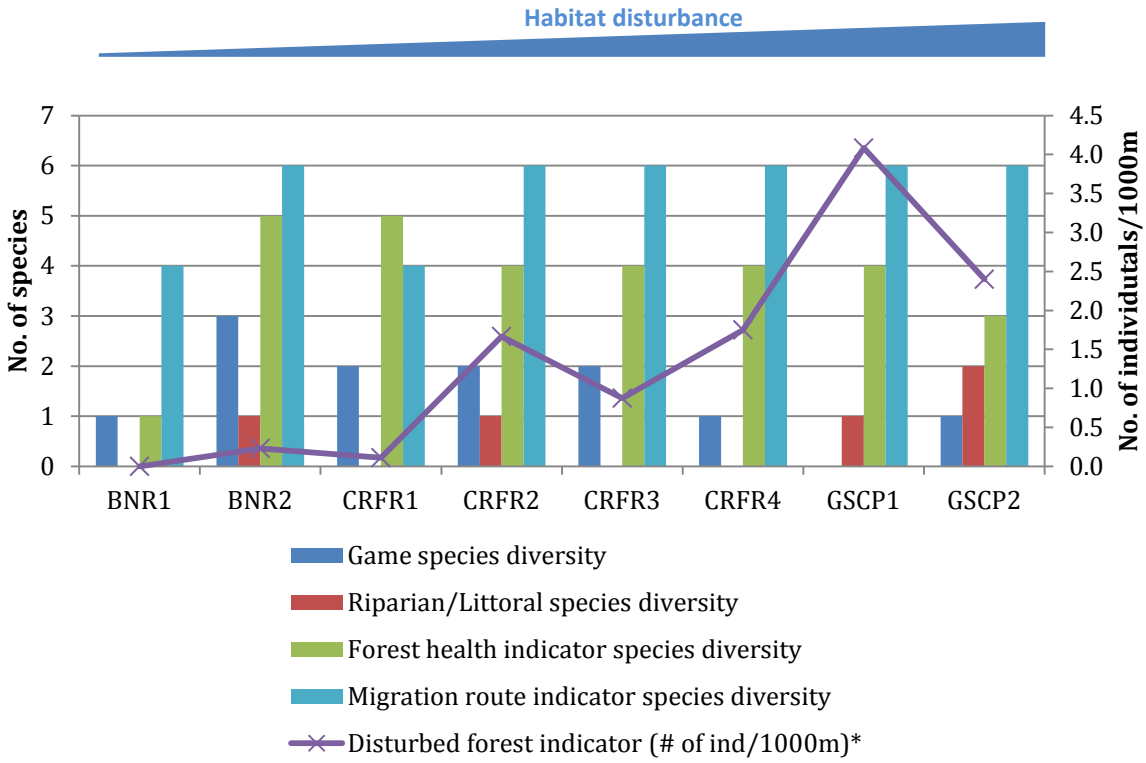

Figure 10. Bird indicator species diversity per transect (*= Plain Chachalaca)

Trends

Out of 19 species observed in both 2010 and 2011, only five had a higher encounter rate throughout the MGL in 2011. The encounter rate of all other species decreased, meaning that less individuals were observed per 1000m transect conducted. There are many reasons that could explain this decrease, e.g. natural population fluctuations, varying monitoring efforts, weather conditions or an actual decreasing trend of populations. Regardless of the cause, these are just speculative trends, as just two years of results are insufficient to draw any conclusions.

Table 10 shows the differences in effort and observations between 2010 and 2011. 24 more transects (23km) were done in 2011, which resulted in increased number of individuals and species observed, but a decline in the number of observations per 1000m.

Table 10. Comparison of bird monitoring effort for 2010-2011. ('0' value indicating no change)

2010-2011	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
# of visits performed	-3	11	1	0	2	2	2	9	24
# of m transect done	-1500	11000	1000	0	2000	2000	2000	9000	23000
# of observations done	-32	102	12	33	2	16	68	69	270
# of obs/1000m	-6.20	-10.62	-6.03	1.33	-16.21	-11.13	-1.33	-10.33	-6.99
# of individuals observed	-36	124	-1	45	-30	1	81	51	235
Species Richness	-5	12	-1	2	4	3	2	5	5

Large mammals

A total of 13 mammal species were detected, which is a good proportion (81.3%) out of 16 target species, and a total of 396 individuals were observed (see Table 11).

Table 11. Number of mammal species and individuals observed

	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
Total number of individuals	64	57	22	95	42	32	45	39	396
Species richness	6	10	6	7	9	8	9	10	13
# of visits performed	1	6	5	3	4	4	7	8	38

Transects with more visits performed generally have higher species richness, indicating that more visits are needed to detect the presence of all target species, as is obvious from the species accumulation graph showing no signs of reaching an asymptote (Figure 11).

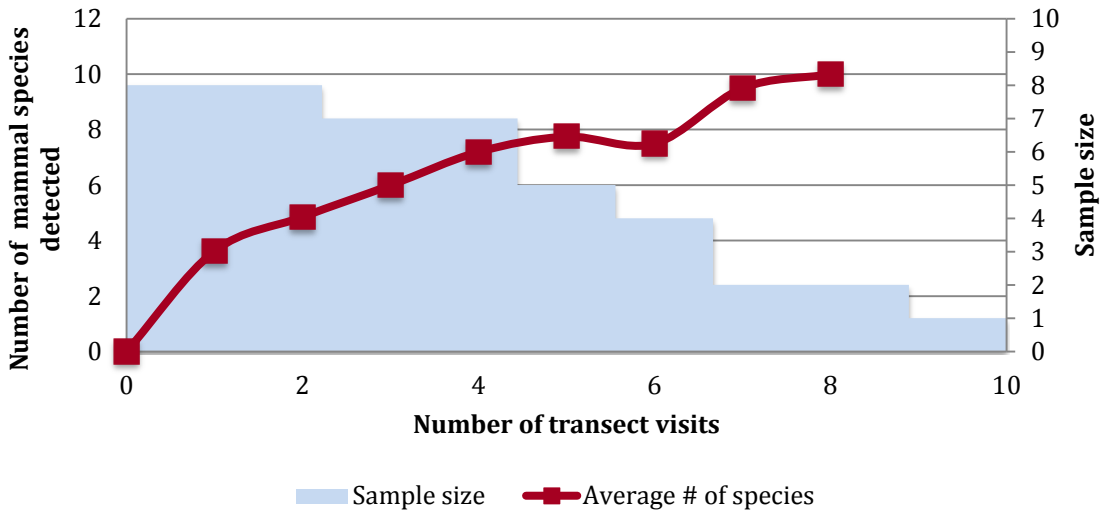

Figure 11. Mammal species accumulation curve

In the comparison of relative abundances, the pie charts are organised according to the disturbance gradient (Figure 12), analogous to the comparison for birds. Similar to 2010, a herd of around 50 White-lipped peccaries roamed the area of Bladen Nature Reserve and Columbia River Forest Reserve throughout the year, and was detected on six separate occasions. This year however, no records were collected from the Golden Stream area.

Nine-banded armadillos are the most abundant species on the GSCP transects and CRFR1, all three of which have agricultural areas nearby (see Table 4). In both 2010 and 2011, the GSCP transects had the highest number of cat species. Note that these transects also had the highest number of visits, as was the case in 2010. The calls of howler monkeys recorded on the GSCP transects are encouraging, as it might be indicating the slow recovery of the forest structure of the area after hurricane Iris in 2001. Baird's tapir, Red brocket deer, Jaguar and Paca occur on almost every transect.

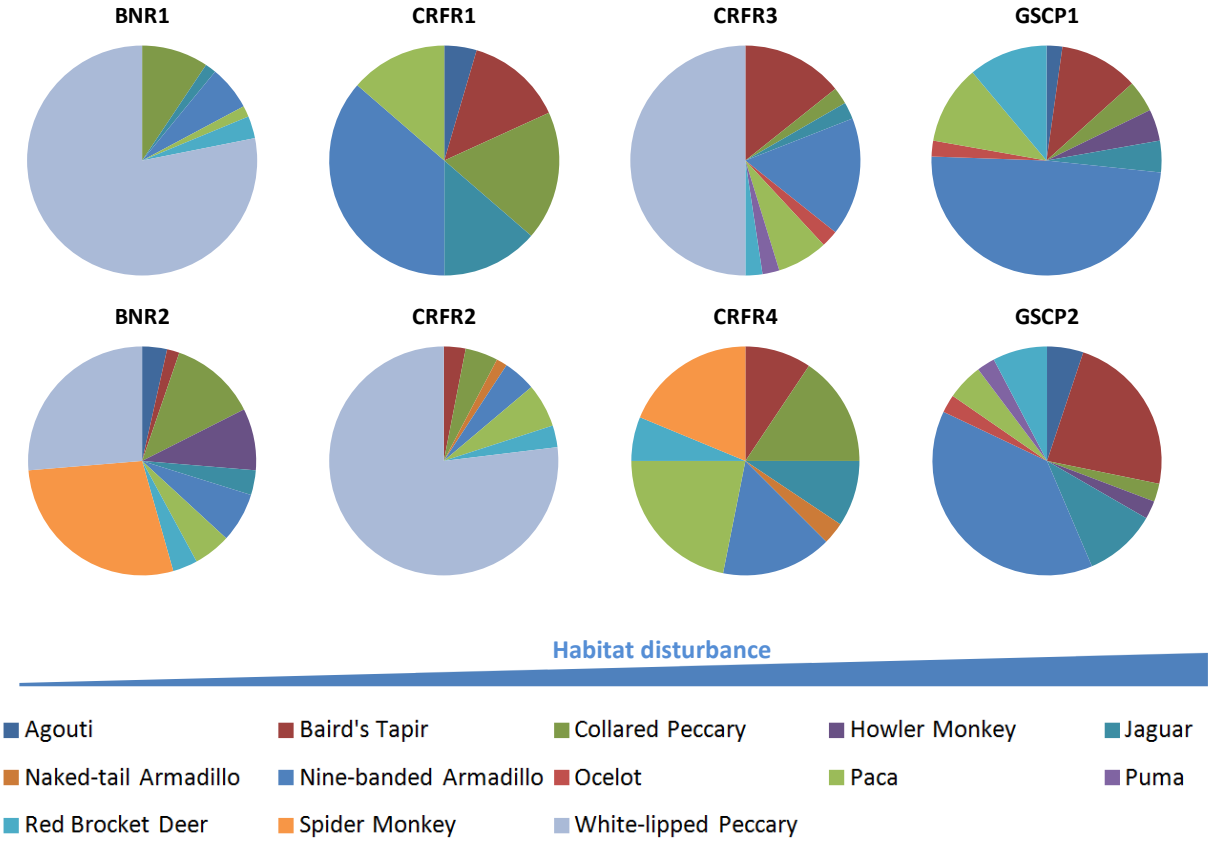

Figure 12. Relative abundance of mammal species per transect (Species are ranked alphabetically in charts and legend)

Effective Number of Species and Evenness of relative abundances

BNR2 comes out as the transect with the highest species diversity and a moderate proportion of dominating species (Figure 13). In general, the target mammal community seems to be more dominated by a small set of species than was the case for the birds. Note the gentle slope of transects CRFR1 and CRFR4, which are exceptions to this rule. From Figure 12, Nine-banded armadillo and White-lipped peccary are the most dominant species.

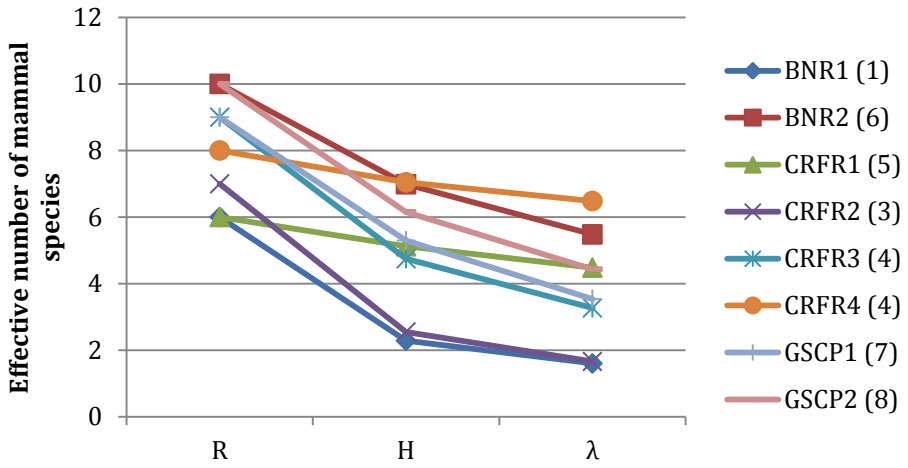

Figure 13. Hill series graph: the Effective Number of mammal Species per transect (with number of visits between brackets). R = Species Richness; *H* = Shannon's index; λ = Simpson's index

Indicator groups

We use the same indicator groups for birds and mammals, although not all groups are represented in the target mammal species list. Specifically, the game species and forest health indicators are best represented in the mammal target species list, and will be focused upon (see Table 1).

At first glance, we might infer higher forest health indicator species richness in more disturbed areas, and more game species in less disturbed areas from Figure 14. However, bearing in mind the species accumulation curve, the species diversity of both indicator groups on BNR and CRFR transects could have been higher if more visits were conducted. This would mean that less disturbed areas would house more game species but not necessarily more forest health indicators. In short, it seems safer to conclude that no clear trends can be detected within the current data set for game and forest health indicators.

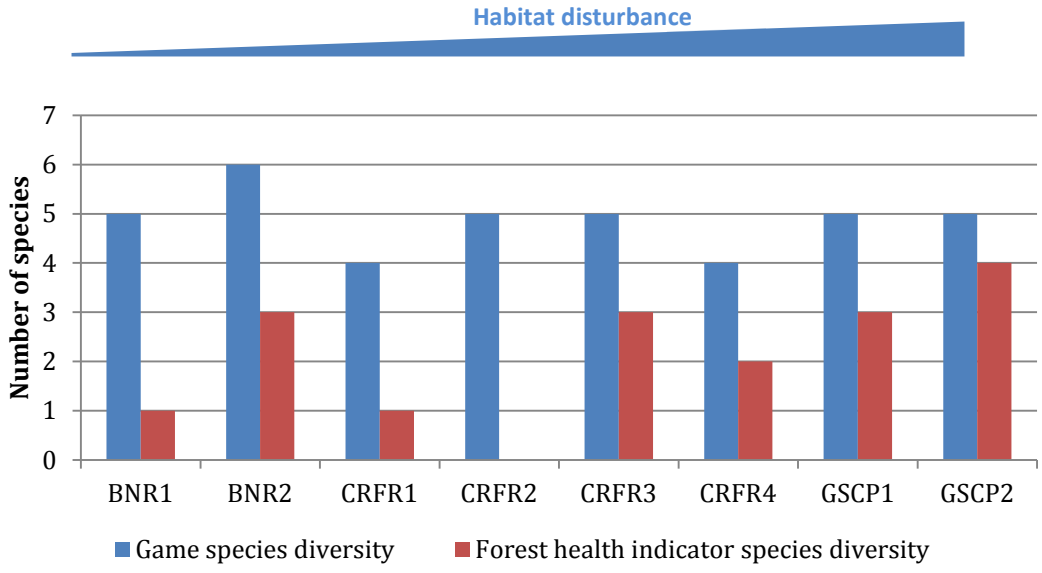

Figure 14. Mammal indicator species diversity per transect

Trends

We note that five species out of 11 detected in both 2010 and 2011 showed a decrease in encounter rate throughout the MGL (Agouti, Baird's tapir, Jaguar, Red brocket deer and White-lipped peccary). As was the case for birds, the increased effort (11km more transect) could be cause for these trends, but again we cannot draw any firm conclusions from this observation. The increased effort resulted in 49 more individuals observed (Table 12), but no extra species.

Table 12. Comparison of mammal monitoring effort for 2010-2011. ('0' value indicating no change)

2010-2011	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
# of visits performed	-1.5	5	1	-1	1	0	2	5	11.5
# of m transect done	-2000	5000	1000	-1000	1000	0	2000	5000	11000
# of observations done	-17	20	-9	-14	0	-8	-1	17	-12
# of obs/1000m	9.20	0.83	-3.20	-2.33	-1.83	-2.00	-2.43	-2.25	-2.54
# of individuals observed	33	49	13	45	-34	-87	8	22	49
Species richness	-3	8	0	0	2	-1	-1	3	0

Wildlife observations

Recording wildlife observations has been much more efficiently done during BNR patrols as compared to GSCP patrols (Table 13). This difference is not necessarily a reflection of patrolling effort, but might rather be explained by the higher expected biodiversity in the nature reserve, and as a consequence an increased preparedness to document it by the field rangers.

A total of 205 observations were made of 24 different species of bird, mammal and reptile species (9, 13 and 2 species respectively). With only 16% of observations done in GSCP, nearly 60% of all species were detected, leaving us to speculate that its species richness might catch up with the species richness in BNR, given more intense recording.

Notable absentees in GSCP are White-lipped peccary, Spider monkey, Kinkajou and Harpy eagle, all of which depend on sufficient forest area, density and structure to thrive, which is currently lacking in the GSCP forests that are recovering from the impacts of hurricane (Cat.4) Iris in 2001.

Table 13. Opportunistically observed wildlife during patrols. (* = no. of herds observed, not individuals; ** = species unknown)

# of observations	BNR	GSCP	Total
Common black hawk	1		1
Crested Guan	24	1	25
Great curassow	29	1	30
Great tinamou	22	4	26
Harpy eagle	1		1
Keel-billed toucan	2		2
Muscovy duck	2	7	9
Slaty-breasted tinamou	3	3	6
Solitary Eagle	1	1	2

# of observations	BNR	GSCP	Total
Agouti	9	7	16
Baird's tapir	5	1	6
Coati	2	2	4
Collared Peccary*	4		4
Howler monkey	13	1	14
Jaguarundi	2	1	3
Kinkajou	1		1
Nine-banded armadillo	2	2	4
Red Brocket Deer	3	1	4

# of observations	BNR	GSCP	Total
Spider monkey	36		36
Tayra		1	1
White-lipped peccary*	3		3
White-tailed deer	5		5

# of observations	BNR	GSCP	Total
Crocodile**	1		1
Green iguana	1		1
Total	**172**	**33**	**205**
Species Richness	**23**	**14**	**24**

Road crossings

The number of observed wildlife crossings and casualties was lower than we had expected from previous informal reports by Ya'axché staff (Figure 15). However, we need to make note that common wildlife casualties such as possums and small birds were not recorded. The numbers in Figure 15 are not representative for the actual crossing rate, since most crossings will occur during night time when less people are likely to observe them.

Big Falls Hicattee	Indian Creek	Golden Stream GSCP	Tambran	Deep river	Medina Bank
	1 Jaguar (↓)	2 Jaguar (↓) 1 White-tailed deer (↑) 1 Gray fox (↓) 1 Skunk (†) 1 Gibnut (†)		1 Jaguarundi (↑) 1 Gray fox (↑)	

Figure 15. Schematic representation of the Southern Highway between Big Falls and Medina Bank villages. Darker shades represent sections of the highway that were more frequently visited; arrows indicate the direction of movement (↓ = south; ↑ = north; † = road kill).

According to informal reports by villagers, White-lipped peccaries once crossed the highway fairly frequently, but haven't been observed crossing in the last 3-5 years. Nonetheless, it is noteworthy that Jaguars are still crossing the stretch of the Southern Highway that runs through the last rainforest connection between the Maya Mountains and the Caribbean lowlands. Collection of crossings and casualties along more intensely used stretches along the Southern Highway would yield an interesting comparison.

Bats

There are over 75 bat species living in Belize with a wide range of ecological requirements. Some are frugivores, some insectivores, some piscivores or nectarivores; some roost in caves, others in trees. Over a total of 13 nights and four (clustered) locations (see Figure 5), only 5 species were detected in GSCP (Table 14). The table shows the Activity Index Percent (AI%) for all species, first per location, and then averaged over all locations, followed by the total number of survey nights. By far the most active species was the Common mustached bat, which was active every night. By exception, the most active species at Paca cave was the Greater white-lined bat, followed by Elegant myotis. Even though the Greater white-lined bat was only recorded on three nights (all at Paca cave), it had a higher AI% then the Elegant myotis, which was active for eight out of 13 nights. Judging from activity patterns, Paca cave might be an important cave for the Greater white-lined bat, while the Foothills cave would be a hotspot for the Common mustached

bat. It is possible that these locations happen to be in the immediate proximity of the main roost of a population of these species, whereas other locations might just be on a flight route for some species. Due to the opportunistic nature of the data, too little data is available to inform us about temporal variability. Nonetheless, the months in which each location was sampled are indicated in Table 14 and Table 15.

Table 14. Activity Index Percent (AI%) for bat species in the Golden Stream Corridor Preserve

	Species	Foothills cave	Paca cave	Warri cave	GSCP1_200	GSCP (avg.)	Total number of nights active
		April	*April*	*May*	*August*	*2011*	*2011*
1	Common mustached bat	25.07%	0.68%	2.12%	1.84%	**7.43%**	13
2	Greater white-lined bat	0.00%	6.28%	0.00%	0.00%	**1.57%**	3
3	Elegant myotis	0.00%	1.50%	0.30%	0.07%	**0.47%**	8
4	40kHz Vespertillionid	0.00%	0.19%	0.00%	0.00%	**0.05%**	1
5	Davy's naked-backed bat	0.00%	0.00%	0.04%	0.00%	**0.01%**	1

During a six-night sampling effort on one location, 16 species were detected in BNR (Table 15), of which the Greater white-lined bat and Greater and Lesser dog-like bats were most active. The difference in species richness between GSCP and BNR was remarkable, and could be due to a more diverse set of microhabitats in the transition zone between broadleaf forest and pine savannah.

Table 15. Activity Index Percent (AI%) for bat species in the Bladen Nature Reserve

	Species	BNR ranger base	Total number of nights active
		May	*2011*
1	Greater white-lined bat	10.19%	6
2	Greater dog-like bat	10.08%	6
3	Lesser dog-like bat	9.18%	6
4	Peter's Ghost-faced bat	4.44%	6
5	Davy's naked-backed bat	2.17%	6
6	45kHz Vespertillionid	1.38%	6
7	Molossid species	1.01%	5
8	Argentine brown bat	0.34%	4
9	Common mustached bat	0.29%	6
10	Black mastiff bat	0.19%	2
11	Southern yellow bat	0.13%	3
12	Elegant myotis	0.05%	2
13	Lesser white-lined bat	0.05%	2
14	Proboscis bat	0.05%	1
15	40kHz Vespertillionid	0.05%	1
16	Northern yellow bat	0.03%	1

Weather

Bladen Nature Reserve

A total annual rainfall of 2136mm was recorded at the ranger base at Bladen Nature Reserve, located in pine savannah area, with a clear distinction between the dry and wet seasons (Figure 16). However, we need to note that data was missing for 62 days (17%) of the year, which means that total rainfall figures will be underestimated.

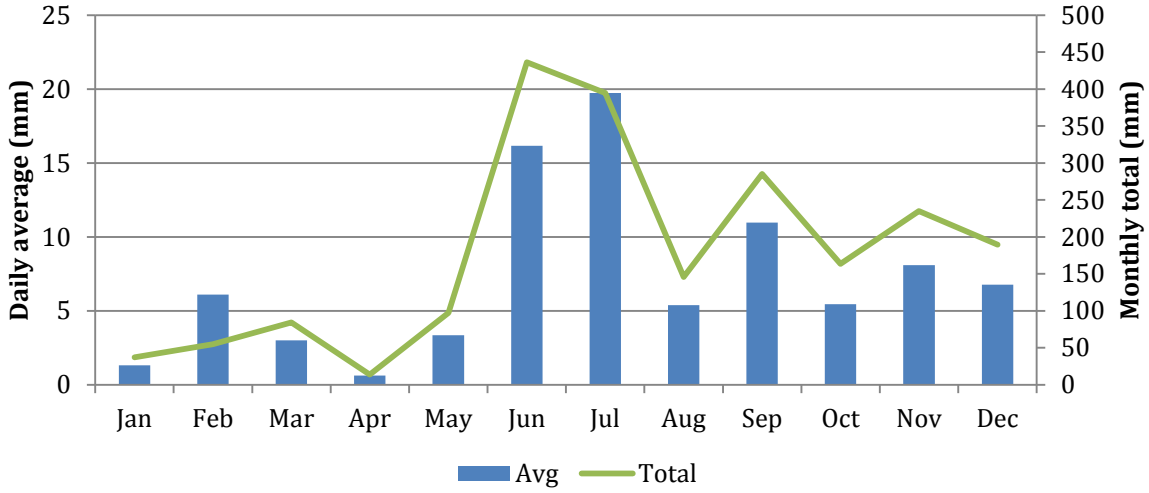

Figure 16. Rainfall data at the Bladen Nature Reserve ranger base for 2011

As a consequence, when compared to long-term reference values (Figure 17), our observed rainfall figures are lower than the figures from the Melinda weather station in Stann Creek (indicated by 'TROP' line in the legend), even though the BNR ranger base is located well south of that, and therefore would be expected to have rainfall falling in between the TROP and PUNTA GORDA lines.

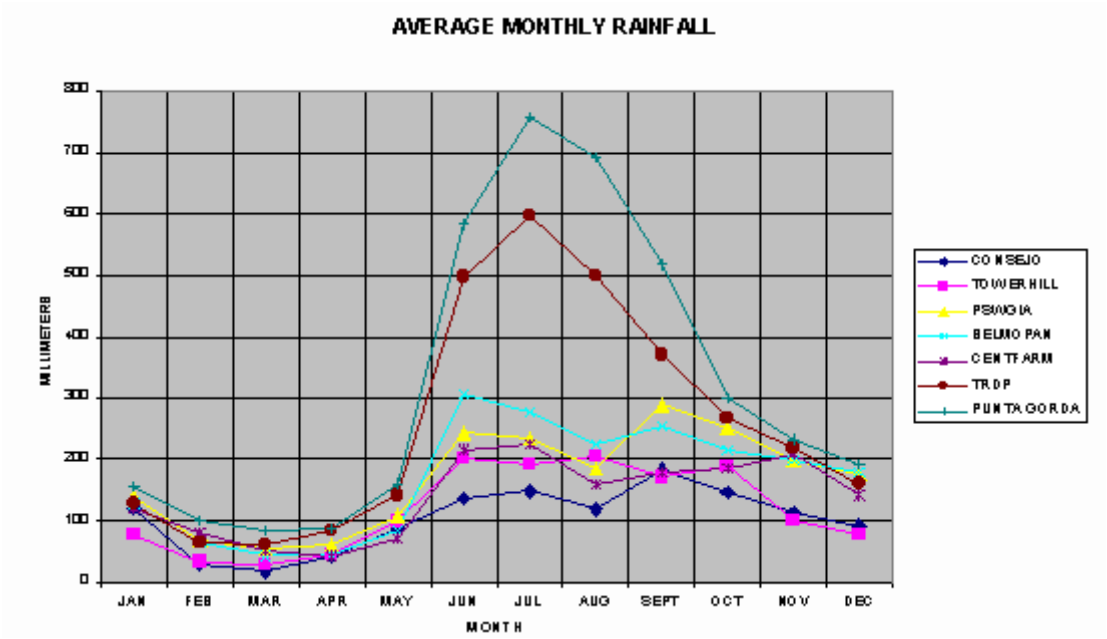

Figure 17. Average monthly rainfall in Belize (source: www.hydromet.gov.bz)

Golden Stream Corridor Preserve

Unfortunately, data from the Golden Stream Corridor Preserve was of insufficient quantity and quality to report this year.

Rapid Ecological Assessment

A total of 14 amphibian and 10 reptile species were recorded on the Snake Creek Expedition. In addition to the species previously recorded in and around Central River, this now brings the Bladen species lists to 18 amphibians and 13 reptiles to date. The known amphibian fauna to date includes 4 salamanders, 6 rain frogs, 1 toad, 4 tree frogs, 1 glass frog and 2 true frogs – of which 1 species is Critically Endangered, 2 are Endangered, 1 is Vulnerable and 7 are Near Threatened (IUCN, 2012).

The reptiles recorded to date include 1 gecko, 4 anoles, 2 skinks, 1 ameiva, 2 Colubrid snakes, 1 coral snake and 2 vipers.

With a total of 106 bird species detected, overall diversity was lower than expected, although it included a number of typical primary forest species (e.g. Black-throated green warbler, Purple-crowned fairy, Black-throated shrike-tanager) some of which are limited to higher elevations (e.g. Violet-crowned woodnimph) and/or lime stone substrate (e.g. Nightingale wren). The very uncommon Scaly-throated foliage gleaner, currently known to occur only on Belize's highest peak Doyle's Delight, was observed as well. Other observations include Barred forest falcon, Mealy parrot, Double toothed kite, Ornate hawk-eagle, Spotted wood-quail, Scaly-throated leaftosser, Northern barred woodcreeper, and all three motmot species occurring in Belize, including the threatened Keel-billed motmot.

Full lists of observed species are available on request.

Conclusions

As in 2010, the major part of Ya'axché's biodiversity monitoring is the large mammal and bird transects. During 2011, a transition was made from a half-length transect BNR1 to a full-length transect BNR2 in Eastern Bladen, which had been established in 2010 (Hofman, 2012). In response to the recommendations from the 2010 report, the analysis of the transect data considered every visit, morning or evening, as a separate sampling event. As compared to 2010, and taking into account the separation of morning and evening transect visits, an increased number of transect visits has resulted in a higher proportion of target bird species detected, while the proportion of target mammal species remained the same. The increased effort also led to a higher total number of individuals observed in birds and mammals alike, even though the number of observations per unit distance decreased.

A novelty for the analysis of the transect data is the introduction of indicator groups, including forest quality and disturbance indicators. We have observed that bird indicator species tend to confirm the habitat disturbance gradient that was identified among the transects, whereas no clear trend was detected among mammal indicator species. Possibly, wider roaming and less territorial mammals might be more resilient to habitat disturbance. Using these groups, we hope to facilitate interpretation of the long-term data, and enhance the applicability of the results to direct strategies for the management of the Protected Areas at Ya'axché.

Diversity indices were presented using a so-called Hill series graph instead of a bar chart to make interpretation easier. The slope of the Hill series graph tells us the level of dominance of a limited number of species over all others in terms of relative abundance. In general, a lower level of dominance indicates a more diverse community – even though there are several reservations to be made to this rule (Magurran, 2004). Our Hill series for birds and mammals do not line up with the identified disturbance gradient. Comparisons with upcoming years will indicate whether some transects display consistently higher level of dominance than others.

Rather than providing a long-term data series, the wildlife observations done during patrols are used as a collection of anecdotal information to highlight uncommon sightings that escape the systematic monitoring in the area. Cases such as the Harpy and Solitary eagles are valuable additional information to Ya'axché's protected areas management team. The same could be argued for the water-bound wildlife such as Muscovy ducks, crocodiles and iguanas. The information can also be used as an approximate early-warning method for unusual distributions, population fluctuations, or hunting pressure. Similar considerations apply to the road crossing data. It is anecdotal data that could act as an early-warning system for the compromised function of the reserves as a biological corridor. A first indication of the degrading corridor function could be the absence of White-lipped peccaries crossing the Southern Highway at the point where crossings are most likely to happen.

Ya'axché's first trials with the Anabat acoustic bat monitoring unit yielded a remarkable difference in species diversity between GSCP and BNR. Speculatively, the difference could be attributed to differences in the diversity of microhabitats and food availability in the two areas. The effects of hurricane Iris (2001) could be of importance here as well.

Unfortunately, consistency and accuracy of weather data collection has been insufficient to present reliable data, and to use any of the data in the interpretation of the biotic monitoring data. The only fair conclusion to draw is that it needs to be improved.

Conducting Rapid Ecological Assessments is a relatively cost-effective tool for NGO's with limited resources to increase the knowledge on the biodiversity of the natural areas they are protecting. In collaboration with independent researchers and national and international research institutes, documenting biodiversity and environmental conditions are a critical part of the protected areas manager's mandate. The REA to the Snake Creek area of the Bladen Nature Reserve has increased our knowledge about the amphibians, reptiles and birds of the more remote and elevated parts of the Crown Jewel of Belize's Protected Area System.

With a full-time staff member designated to oversee Ya'axché's monitoring programme from the second half of 2011 onwards, the programme has seen some improvements happening. Biodiversity data have been analysed retrospectively and analysis methods have been improved. The envisioned reporting schedule, for which this is the second report produced, has been uptaken, and includes data from all different monitoring activities that happen at Ya'axché. Also, data management and storage methods have been updated through the use of standardised data recording spreadsheets and a facelift for the transect monitoring database. Additionally, we increased efforts to train Ya'axché rangers in data extraction, entry and handling skills for the different taxa and their associated methodologies. This has resulted in improved data consistency and accuracy, which should show in the 2012 Biodiversity Synthesis Report coming up.

Recommendations

As was noted in the 2010 report (Hofman, 2012), we were awaiting the conclusion of the National Biodiversity Monitoring Program to inform the adjustment of the target species lists. For now, the most pragmatic approach would be to stick to the current target species lists as presented in this report. Related to this, the revision of the BRIM remains on the agenda as well.

In terms of transect data analysis, a couple of points should be made. First, the presentation of diversity indices using the Hill series graph is one of several approaches possible. The same information could be conveyed by Whittaker plots, which rank species according to their relative abundance, and are used in other biodiversity studies in Belize (Arevalo, 2012). Second, despite efforts to standardise the sample size per transect, the resulting visit frequency was not consistent. It would prove useful to investigate the use of rarefaction methods to make transects or areas directly statistically comparable.

The wildlife observations from on patrols could potentially be dealt with more efficiently using the presence-only date for occupancy modelling. Further research into this option is necessary though.

Plans are being made to check the identification skills of the field rangers to minimise observer bias, and will be reported on in the coming annual reports. It is clear that the abiotic monitoring components (rainfall, temperature and relative humidity) need to be improved.

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Appendix I. Bird observation tables

By transect

PAM effort	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
# of visits performed	2	13	9	6	8	8	12	15	73
# of m transect done	1000	13000	9000	6000	8000	8000	12000	15000	72000
# of observations done	11	122	65	58	81	79	128	125	669
# of obs/visit	5.50	9.38	7.22	9.67	10.13	9.88	10.67	8.33	9.16
# of obs/1000m	11.00	9.38	7.22	9.67	10.13	9.88	10.67	8.33	9.29

Number of individuals	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
American Redstart	1	15		5	7	11	21	28	88
Black and White Warbler	1	5	1	4	1	3	4	6	25
Blue-gray Gnatcatcher				1					1
Brown-hooded Parrot		14	3		12	15	13		57
Common Yellowthroat		15	1	2	2	4	12	1	37
Crested Guan		13		3	2	4		2	24
Great Curassow	1	1	1						3
Great Tinamou		8	6	1	4				19
Hooded warbler	2	8	1	7	5	7	18	19	67
Keel-billed Motmot			3	3					6
Keel-billed Toucan	6	6	15	10	6	9	6	1	59
Kentucky Warbler		2							2
Little Tinamou	1	9	11	5	10	9	12	2	59
Louisiana Waterthrush								1	1
Magnolia warbler		13		2	7	4	13	3	42
Mealy parrot			9	16					25
Northern Waterthrush		1					1	1	3
Plain Chachalaca		3	1	10	7	14	49	36	120
Prothonotary Warbler				2					2
Slaty-breasted Tinamou		18	3	2	5	2	2	1	33
Swainson's Warbler		1				1		1	3
Wood Thrush	4	13	6	1	13	5	13	12	67
Worm-eating Warbler					1		1		2
Yellow-headed parrot								4	4
Total	16	145	61	74	82	88	165	118	749
Species Richness	7	17	13	16	14	13	13	15	24

Effective Number of Species	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2
Species richness (R)	7	17	13	16	14	13	13	15
Shannon's index (*H*)	5.30	13.27	8.79	11.49	11.34	10.57	8.78	7.17
Simpson's index (λ)	4.27	11.93	7.01	9.01	10.01	9.22	6.77	5.23
No. of visits	2	13	9	6	8	8	12	15

Number of individuals/1000m	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Avg	SD
American Redstart	1.00	1.15	0.00	0.83	0.88	1.38	1.75	1.87	1.11	0.59
Black and White Warbler	1.00	0.38	0.11	0.67	0.13	0.38	0.33	0.40	0.42	0.29
Blue-gray Gnatcatcher	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.02	0.06
Brown-hooded Parrot	0.00	1.08	0.33	0.00	1.50	1.88	1.08	0.00	0.73	0.75
Common Yellowthroat	0.00	1.15	0.11	0.33	0.25	0.50	1.00	0.07	0.43	0.43
Crested Guan	0.00	1.00	0.00	0.50	0.25	0.50	0.00	0.13	0.30	0.35
Great Curassow	1.00	0.08	0.11	0.00	0.00	0.00	0.00	0.00	0.15	0.35
Great Tinamou	0.00	0.62	0.67	0.17	0.50	0.00	0.00	0.00	0.24	0.30
Hooded warbler	2.00	0.62	0.11	1.17	0.63	0.88	1.50	1.27	1.02	0.59
Keel-billed Motmot	0.00	0.00	0.33	0.50	0.00	0.00	0.00	0.00	0.10	0.20
Keel-billed Toucan	6.00	0.46	1.67	1.67	0.75	1.13	0.50	0.07	1.53	1.89
Kentucky Warbler	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05
Little Tinamou	1.00	0.69	1.22	0.83	1.25	1.13	1.00	0.13	0.91	0.36
Louisiana Waterthrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.01	0.02
Magnolia warbler	0.00	1.00	0.00	0.33	0.88	0.50	1.08	0.20	0.50	0.44
Mealy parrot	0.00	0.00	1.00	2.67	0.00	0.00	0.00	0.00	0.46	0.96
Northern Waterthrush	0.00	0.08	0.00	0.00	0.00	0.00	0.08	0.07	0.03	0.04
Plain Chachalaca	0.00	0.23	0.11	1.67	0.88	1.75	4.08	2.40	1.39	1.40
Prothonotary Warbler	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.04	0.12
Slaty-breasted Tinamou	0.00	1.38	0.33	0.33	0.63	0.25	0.17	0.07	0.39	0.44
Swainson's Warbler	0.00	0.08	0.00	0.00	0.00	0.13	0.00	0.07	0.03	0.05
Wood Thrush	4.00	1.00	0.67	0.17	1.63	0.63	1.08	0.80	1.25	1.19
Worm-eating Warbler	0.00	0.00	0.00	0.00	0.13	0.00	0.08	0.00	0.03	0.05
Yellow-headed parrot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.03	0.09
Total	16.00	11.15	6.78	12.33	10.25	11.00	13.75	7.87	11.14	2.99

By month

PAM effort	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
# of visits performed	6	6	13	4	8	3	8	4	5	0	10	6	73
# of m transect done	5000	6000	13000	4000	8000	3000	8000	4000	5000	0	10000	6000	72000
# of observations done	39	59	134	43	65	13	54	26	36	0	139	61	669
# of obs/visit	6.50	9.83	10.31	10.75	8.13	4.33	6.75	6.50	7.20	0.00	13.90	10.17	9.16
# of obs/1000m	7.80	9.83	10.31	10.75	8.13	4.33	6.75	6.50	7.20	0.00	13.90	10.17	9.29

Number of individuals	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
American Redstart	15	6	14	4					3	---	34	12	88
Black and White Warbler	1	3	8	3	1				1	---	7	1	25
Blue-gray Gnatcatcher				1						---			1
Brown-hooded Parrot		3	6		5	3	13	4		---	19	4	57
Common Yellowthroat		7	5	1	1			1	3	---	15	4	37
Crested Guan		3	2		5		2	3	5	---		4	24
Great Curassow	1	1	1							---			3
Great Tinamou		2	5	1	6		2		3	---			19
Hooded warbler	8	5	14	4	1					---	22	13	67

Number of individuals	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Keel-billed Motmot				1	5					---			6
Keel-billed Toucan	8	5	9	15	9	1	2	2	3	---	2	3	59
Kentucky Warbler										---	2		2
Little Tinamou	3	2	10	7	12	1	8	7	2	---	2	5	59
Louisiana Waterthrush									1	---			1
Magnolia warbler	1	4	13	2						---	18	4	42
Mealy parrot		6		8	11					---			25
Northern Waterthrush			1						1	---	1		3
Plain Chachalaca	3		69	2	19	1	3	10	6	---	5	2	120
Prothonotary Warbler				2						---			2
Slaty-breasted Tinamou		7	8	2	7	1	2	3	2	---	1		33
Swainson's Warbler		1	1						1	---			3
Wood Thrush	6	10	9	3						---	26	13	67
Worm-eating Warbler										---	1	1	2
Yellow-headed parrot			2						2	---			4
Total	46	65	177	56	82	7	32	30	33	---	155	66	749

Number of ind./1000m	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Avg	SD
American Redstart	3.00	1.00	1.08	1.00	0.00	0.00	0.00	0.00	0.60	---	3.40	2.00	1.10	1.22
Black and White Warbler	0.20	0.50	0.62	0.75	0.13	0.00	0.00	0.00	0.20	---	0.70	0.17	0.30	0.29
Blue-gray Gnatcatcher	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	---	0.00	0.00	0.02	0.08
Brown-hooded Parrot	0.00	0.50	0.46	0.00	0.63	1.00	1.63	1.00	0.00	---	1.90	0.67	0.71	0.64
Common Yellowthroat	0.00	1.17	0.38	0.25	0.13	0.00	0.00	0.25	0.60	---	1.50	0.67	0.45	0.50
Crested Guan	0.00	0.50	0.15	0.00	0.63	0.00	0.25	0.75	1.00	---	0.00	0.67	0.36	0.36
Great Curassow	0.20	0.17	0.08	0.00	0.00	0.00	0.00	0.00	0.00	---	0.00	0.00	0.04	0.07
Great Tinamou	0.00	0.33	0.38	0.25	0.75	0.00	0.25	0.00	0.60	---	0.00	0.00	0.23	0.27
Hooded warbler	1.60	0.83	1.08	1.00	0.13	0.00	0.00	0.00	0.00	---	2.20	2.17	0.82	0.87
Keel-billed Motmot	0.00	0.00	0.00	0.25	0.63	0.00	0.00	0.00	0.00	---	0.00	0.00	0.08	0.20
Keel-billed Toucan	1.60	0.83	0.69	3.75	1.13	0.33	0.25	0.50	0.60	---	0.20	0.50	0.94	1.02
Kentucky Warbler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	---	0.20	0.00	0.02	0.06
Little Tinamou	0.60	0.33	0.77	1.75	1.50	0.33	1.00	1.75	0.40	---	0.20	0.83	0.86	0.57
Louisiana Waterthrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	---	0.00	0.00	0.02	0.06
Magnolia warbler	0.20	0.67	1.00	0.50	0.00	0.00	0.00	0.00	0.00	---	1.80	0.67	0.44	0.57
Mealy parrot	0.00	1.00	0.00	2.00	1.38	0.00	0.00	0.00	0.00	---	0.00	0.00	0.40	0.72
Northern Waterthrush	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.20	---	0.10	0.00	0.03	0.07
Plain Chachalaca	0.60	0.00	5.31	0.50	2.38	0.33	0.38	2.50	1.20	---	0.50	0.33	1.27	1.58
Prothonotary Warbler	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	---	0.00	0.00	0.05	0.15
Slaty-breasted Tinamou	0.00	1.17	0.62	0.50	0.88	0.33	0.25	0.75	0.40	---	0.10	0.00	0.45	0.37
Swainson's Warbler	0.00	0.17	0.08	0.00	0.00	0.00	0.00	0.00	0.20	---	0.00	0.00	0.04	0.07
Wood Thrush	1.20	1.67	0.69	0.75	0.00	0.00	0.00	0.00	0.00	---	2.60	2.17	0.83	0.96
Worm-eating Warbler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	---	0.10	0.17	0.02	0.06
Yellow-headed parrot	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.40	---	0.00	0.00	0.05	0.12
Total	9.20	10.83	13.62	14.00	10.25	2.33	4.00	7.50	6.60	---	15.50	11.00	9.53	4.15

Appendix II. Mammal observation tables

By transect

PAM effort	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
# of visits performed	1	6	5	3	4	4	7	8	38
# of m transect done	500	6000	5000	3000	4000	4000	7000	8000	37500
# of observations done	10	23	19	14	22	24	39	38	189
# of obs/visit	10.00	3.83	3.80	4.67	5.50	6.00	5.57	4.75	4.97
# of obs/1000m	20.00	3.83	3.80	4.67	5.50	6.00	5.57	4.75	5.04

Number of individuals	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Total
Agouti		2	1				1	2	6
Baird's Tapir		1	3	2	6	3	5	9	29
Collared Peccary	6	7	4	3	1	5	2	1	29
Howler Monkey		5					2	1	8
Jaguar	1	2	3		1	3	2	4	16
Naked-tail Armadillo				1		1			2
Nine-banded Armadillo	4	4	8	3	7	5	22	15	68
Ocelot					1		1	1	3
Paca	1	3	3	4	3	7	5	2	28
Puma					1			1	2
Red Brocket Deer	2	2		2	1	2	5	3	17
Spider Monkey		16				6			22
White-lipped Peccary	50	15		50	21				136
Total	64	57	22	65	42	32	45	39	366
Species richness	6	10	6	7	9	8	9	10	13

Effective Number of Species	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2
Species richness (R)	6	10	6	7	9	8	9	10
Shannon's index (*H*)	2.28	6.99	5.12	2.55	4.74	7.04	5.29	6.15
Simpson's index (*λ*)	1.60	5.48	4.48	1.66	3.27	6.48	3.53	4.43
No. of visits	1	6	5	3	4	4	7	8

Number of individuals/1000m	BNR1	BNR2	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	Avg	SD
Agouti	0.00	0.33	0.20	0.00	0.00	0.00	0.14	0.25	0.12	0.13
Baird's Tapir	0.00	0.17	0.60	0.67	1.50	0.75	0.71	1.13	0.69	0.48
Collared Peccary	12.00	1.17	0.80	1.00	0.25	1.25	0.29	0.13	2.11	4.02
Howler Monkey	0.00	0.83	0.00	0.00	0.00	0.00	0.29	0.13	0.16	0.29
Jaguar	2.00	0.33	0.60	0.00	0.25	0.75	0.29	0.50	0.59	0.61
Naked-tail Armadillo	0.00	0.00	0.00	0.33	0.00	0.25	0.00	0.00	0.07	0.14
Nine-banded Armadillo	8.00	0.67	1.60	1.00	1.75	1.25	3.14	1.88	2.41	2.38
Ocelot	0.00	0.00	0.00	0.00	0.25	0.00	0.14	0.13	0.06	0.10
Paca	2.00	0.50	0.60	1.33	0.75	1.75	0.71	0.25	0.99	0.63
Puma	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.13	0.05	0.09
Red Brocket Deer	4.00	0.33	0.00	0.67	0.25	0.50	0.71	0.38	0.85	1.29
Spider Monkey	0.00	2.67	0.00	0.00	0.00	1.50	0.00	0.00	0.52	1.01
White-lipped Peccary	100.00	2.50	0.00	16.67	5.25	0.00	0.00	0.00	15.55	34.59
Total	128.00	9.50	4.40	21.67	10.50	8.00	6.43	4.88	24.17	42.31

By month

PAM effort	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
# of visits performed	3	3	7	2	4	1	4	2	3	0	5	4	38
# of m transect done	2500	3000	7000	2000	4000	1000	4000	2000	3000	0	5000	4000	37500
# of observations done	14	15	20	7	8	3	42	15	15	0	26	24	189
# of obs/visit	4.67	5.00	2.86	3.50	2.00	3.00	10.50	7.50	5.00	0.00	5.20	6.00	5.02
# of obs/1000m	5.60	5.00	2.86	3.50	2.00	3.00	10.50	7.50	5.00	0.00	5.20	6.00	5.11

Number of individuals	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Agouti		1	1	1			2			---	1		6
Baird's Tapir	1		4	1	13		7	1	4	---	4	4	39
Collared Peccary	6	5	2				3	3	4	---	2	4	29
Howler Monkey			4				1	3		---			8
Jaguar	1	1			1	1	3	1	2	---	3	3	16
Naked-tail Armadillo					11					---		1	12
Nine-banded Armadillo	8	3	9	3	12	2	12	9	4	---	8	8	78
Ocelot										---	2	1	3
Paca	1	4	1	2			10	2	2	---	4	2	28
Puma							1			---	1		2
Red Brocket Deer	2	2	2				5		2	---	2	2	17
Spider Monkey			2		4			16		---			22
White-lipped Peccary	50	55					1	10		---		20	136
Total	69	71	25	7	41	3	45	45	18	---	27	45	396
Species richness	7	7	8	4	5	2	10	8	6	---	9	9	13

Number of individuals/1000m	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Avg	SD
Agouti	0.00	0.33	0.14	0.50	0.00	0.00	0.50	0.00	0.00	---	0.20	0.00	0.15	0.20
Baird's Tapir	0.33	0.00	0.57	0.50	3.25	0.00	1.75	0.50	1.33	---	0.80	1.00	0.91	0.94
Collared Peccary	2.00	1.67	0.29	0.00	0.00	0.00	0.75	1.50	1.33	---	0.40	1.00	0.81	0.73
Howler Monkey	0.00	0.00	0.57	0.00	0.00	0.00	0.25	1.50	0.00	---	0.00	0.00	0.21	0.46
Jaguar	0.33	0.33	0.00	0.00	0.25	1.00	0.75	0.50	0.67	---	0.60	0.75	0.47	0.32
Naked-tail Armadillo	0.00	0.00	0.00	0.00	2.75	0.00	0.00	0.00	0.00	---	0.00	0.25	0.27	0.83
Nine-banded Armadillo	2.67	1.00	1.29	1.50	3.00	2.00	3.00	4.50	1.33	---	1.60	2.00	2.17	1.04
Ocelot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	---	0.40	0.25	0.06	0.14
Paca	0.33	1.33	0.14	1.00	0.00	0.00	2.50	1.00	0.67	---	0.80	0.50	0.75	0.73
Puma	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	---	0.20	0.00	0.04	0.09
Red Brocket Deer	0.67	0.67	0.29	0.00	0.00	0.00	1.25	0.00	0.67	---	0.40	0.50	0.40	0.40
Spider Monkey	0.00	0.00	0.29	0.00	1.00	0.00	0.00	8.00	0.00	---	0.00	0.00	0.84	2.39
White-lipped Peccary	16.67	18.33	0.00	0.00	0.00	0.00	0.25	5.00	0.00	---	0.00	5.00	4.11	6.91
Total	23.00	23.67	3.57	3.50	10.25	3.00	11.25	22.50	6.00	---	5.40	11.25	10.42	8.18