Biodiversity Synthesis Report

2013

Olatz Gartzia
Research Coordinator

Ya'axché Conservation Trust
22 Alejandro Vernon Street, P.O. 177
Punta Gorda, Toledo District
Belize

Phone: (+501) 722-0108
Fax: (+501) 722-0108
E-mail: info@yaaxche.org
Web: yaaxche.org

Field work conducted by Ya'axché's ranger team

Anignazio Makin, Indian Creek village
Marcus Cholom, Golden Stream village
Marcos Tut, Trio village
Mateo Rash, Medina Bank village
Octavio Cal, Golden Stream village
Pastor Ayala, Trio village
Rosendo Coy, Indian Creek village
Victor Bonilla, Indian Creek village
Vigilio Cal, Golden Stream village
Zaccheus Cal, Golden Stream village

And supervised by

Marchilio Ack – Head ranger
Maarten Hofman – Senior Research Coordinator
Lee Mcloughlin – Protected Area Manager

Cover photo: Panthera Camera Trap (Loc: Pine Hill), 2013

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Acronyms

AI	Activity Index
AI%	Activity Index Percent
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)
GIS	Geographical Information System
GSCP	Golden Stream Corridor Preserve
IUCN	International Union for Conservation of Nature
MGL	Maya Golden Landscape – Ya'axché's working area
SP	Species Richness
Ya'axché	Ya'axché Conservation Trust

Summary

Ya'axché Conservation Trust is a Belizean community-based NGO that works to protect the forests of the Maya Golden Landscape, which includes several public and private protected lands and surrounding communities. Ya'axché manages The Golden Stream Corridor Preserve (15,000 acres) and co-manages The Bladen Nature Reserve (100,000 acres) in collaboration with the Government of Belize. Since 2006, Ya'axché has been monitoring biodiversity to observe possible changes of the environment and track the effect of unsustainable activities, and of our conservation actions. The Biodiversity Monitoring Program only included bird and mammal transects at first, but over the years we have added other taxa and methods such as freshwater invertebrates, bats, land-snails, vegetation, weather monitoring, road traffic density and road crossings, and finally land-use change monitoring.

In 2013, we have maintained last year's transect efforts. We found that overall, in both bird and mammal transects the savanna had more target species observations. GSCP was the area that showed greater disturbance among the forests we monitor. Camera trap results showed a good diversity of mammal species in all forests.

The most significant finding in 2013 was the first group of Black Howler Monkeys in GSCP since Hurricane Iris in 2001, a sighting which provides useful data on the rates of post-disturbance re-colonization of this species, and proves the importance of Ya'axché's work to conserve this important biological corridor.

This year we have increased by four times bat monitoring efforts, but the amount of species found did not increase greatly. As in previous years, the savanna showed much greater diversity than the forest. We concluded that the bat monitoring methodology may not be the most adequate to monitor our target habitats. On the other hand, snail monitoring area has been extended with the addition of one further plot in Golden Stream Corridor Preserve's foothills, but snail identification skills are still lacking and further training is needed. However, snail specialists working with Ya'axché rangers have found three species new to science.

Data collection from the weather stations in both Golden Stream field station and Bladen ranger base has been consistent throughout the year and a strong drought was recorded in Golden Stream, which resulted in an increase of fires in the MGL.

This year we have not included road traffic monitoring and road-crossings, but while it is a bi-annual survey, we will again next year. The two one-hectare vegetation plots in BNR remain a work in progress and data collection will be complete by the end of April 2014. The results will be included on the 2014 Biodiversity Synthesis Report.

Introduction

Ya’axché Conservation Trust (Ya’axché) is a Belizean community-based NGO that works to protect the forests of southern Belize through biodiversity research and monitoring, sustainable land-use management and strategic advocacy and awareness. Geographically, Ya’axché‘s focal area 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 (IUCN Ia), owned by the Government of Belize and co-managed by Ya’axché since 2008.

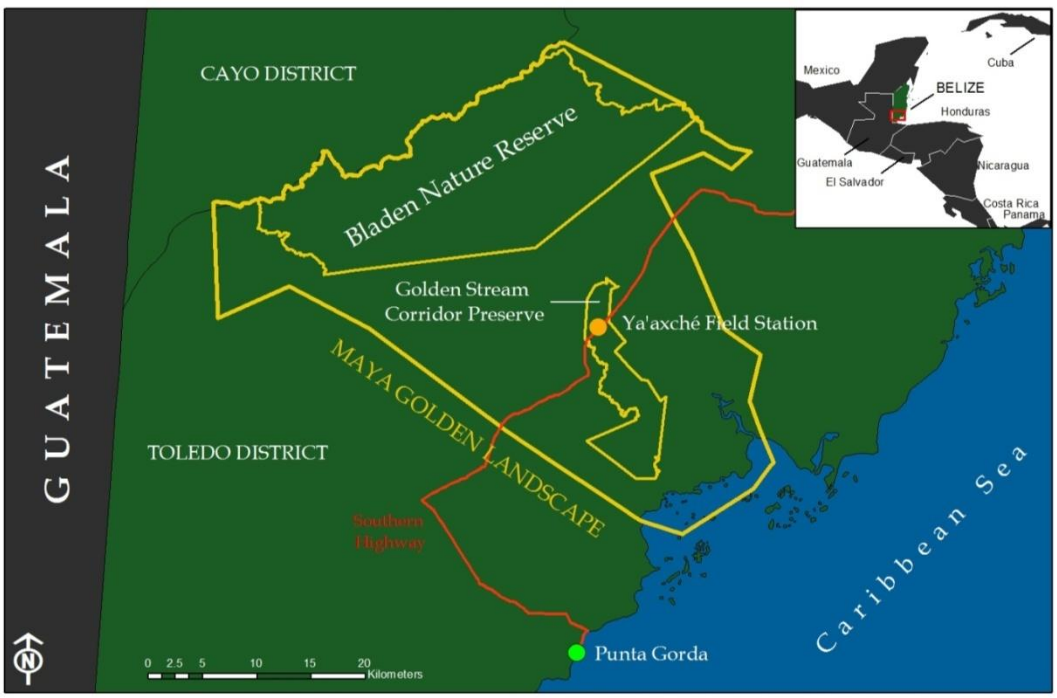

Figure 1. Location of the Maya Golden Landscape and Ya’axché’s protected areas

Over the last eight years, Ya’axché has developed a biodiversity monitoring system to observe possible changes occurring in the natural environment that could indicate unsustainable human activities. When Ya’axché accepted co-management of the Bladen Nature Reserve in 2008, as a necessary planning exercise, a Biodiversity Research, Inventory and Monitoring strategy (BRIM) was drafted by Ya’axché, Fauna & Flora International and Toledo Institute for Development and Environment (TIDE). This strategy details the questions that the involved NGOs face when managing their protected areas, and recommends a number of target groups (e.g. freshwater invertebrates, vegetation, birds, mammals) to be monitored to find answers to these questions. It provides short outlines of the methodology to be used, and general guidelines for the analysis of the data gathered. The BRIM also prescribes the annual analysis of the data, to facilitate comparison among years and provide information to guide the management.

Ya'axché has collected data on birds and large mammals using transect monitoring throughout the Maya Golden Landscape since 2006. From 2009 onwards, the ranger team were trained in freshwater macro-invertebrate sampling and water quality monitoring by Ya'axché's freshwater ecologist, Dr. Rachael Carrie, who also initiated the weather monitoring activities. In 2011, bat monitoring was added to the programme after a multi-day training session in species diversity, field methods and data handling by Dr. Bruce Miller. Additionally, in 2012, a land snail monitoring component was added after training by snail specialists Dan Dourson and Dr. Ron Caldwell. Ya'axché's volunteer botanist, Gail Stott in collaboration with plant ecology consultant Dr. Steven Brewer added vegetation monitoring to the existing programme by establishing two one-hectare Permanent Sample Plots (PSPs) according to international standards. In the same year, we established a baseline of road traffic density in the frames of GSCP's corridor function, and collected anecdotal evidence of highway crossings and casualties. Finally, the involvement of a GIS specialist volunteer, Jaume Ruscalleda, has increased Ya'axché's capacity to use remote sensing and satellite imagery to monitor fire occurrence and incorporate it in this report for a more inclusive landscape-scale monitoring approach.

As a result, the Biodiversity Research, Inventory and Monitoring programme not only monitors species biodiversity in the MGL, but also components that could affect the former, such as freshwater quality, weather, fire and road traffic monitoring.

The 2013 Biodiversity Synthesis report continues with the efforts made through 2010, 2011 and 2012 (Hofman, 2012; Hofman *et al.*, 2013; Hofman, 2013) to ensure the fulfilment of the BRIM requirement to report findings annually. This year, we have included data collected on bird and mammal transects, camera trapping surveys, bat monitoring, wildlife observations, land snail surveys, weather and fire. Unlike last year, we will not include a trend analysis on our findings; this will be included in a separate bi-annual report.

This report has eight chapters including this introduction and the summary. The following chapter consists of an in-depth description of the methodologies used to collect data and the statistical tools used for analysis; this is then presented in the fourth chapter. This is followed by a set of conclusions based on our findings. The next section gives recommendations for the coming years on shortcomings found and how to improve data – in terms of both collection and analysis. After that, a section is included to acknowledge the people and organizations that helped in the fulfilment of this paper. At the end of the report a list of appendices provides information such as raw data and other tables.

Methodology

Bird and large mammal transects

In 2013 transects, as in previous years, a list of birds and large mammals was monitored for data collection. Transects are located in and around the protected areas in the Maya Golden Landscape (Figure 2), they are all 1km in length with stopping points to observe and listen every 200m . Birds were detected using sight and sound cues, while mammals were detected by direct sightings, footprints and an array of different signs including droppings, smell, sound and scratch marks. Only birds and mammals included in the selected species lists (see Table 3 for mammals and Table 4 for birds) were recorded. These species lists were taken from Ya'axché's BRIM strategy, and adapted to the current lists used in the databases.

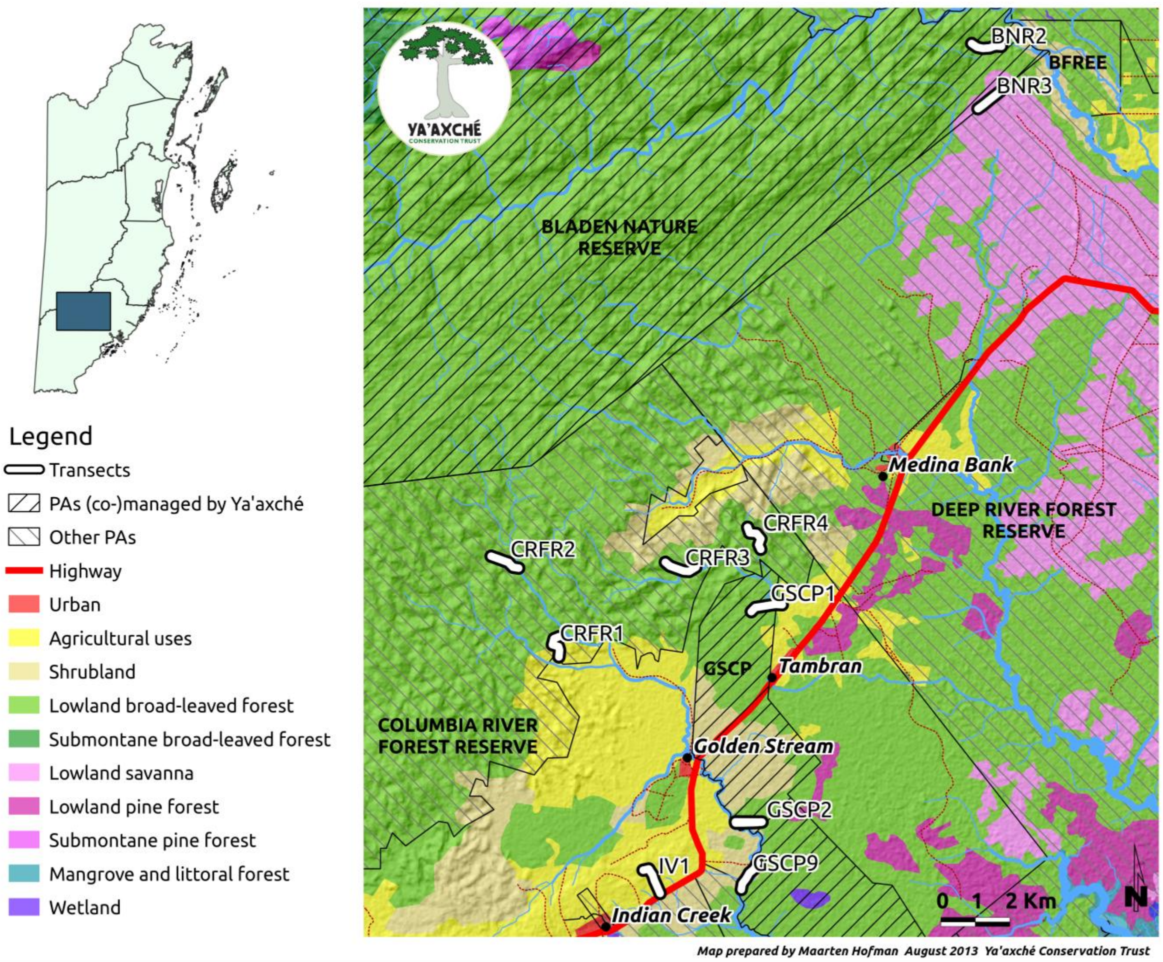

Figure 2. Location of biodiversity monitoring transects and Ya'axché's protected area boundaries.

Our target species list is classified in six indicator groups (Table 1), each species in the list indicates a different aspect according to their habitat and biology. This classification is used 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 degradation, whereas decreased 'Game species' richness could indicate levels of hunting pressure and/or habitat degradation.

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-savanna indicator	Species linked to pine savanna habitats

Species from both mammal and bird lists were assigned an indicator group based on the 'Field guide to the mammals of Central America and Southern Mexico' (Reid 2009) and 'Birds of Belize' (Jones & Gardner 2003) respectively, and validated by the knowledge of the Ya'axché ranger team. Bird classification was also cross-checked by the author of 'Birds of Belize'. Note that not all species were included in this classification, 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.

Note that indicator groups in Table 1 are not equally applicable to the birds and mammals of the Maya Golden Landscape. There are no long-distance mammal migrants and the fairly large roaming distances of some of the species means that their preference for a specific habitat will be less clear (e.g. Red brocket deer prefer forest, but can also be seen in the savanna). We therefore assigned all mammals to either Forest health indicators, Game species or Wetland indicators, and a small number were not assigned to any group.

The distribution of species among indicator groups is presented in Table 2. This table serves as a reference for when the distribution of indicator groups among transects and/or habitats are reported in the results.

Table 2. Distribution of species among Indicator groups

		D	F	G	M	P	W	N/A
Birds	# species	4	9	3	7	3	3	1
	% species	13.3%	30.0%	10.0%	23.3%	10.0%	10.0%	3.3%
Mammals	# species	0	8	5	0	0	2	4
	% species	0.0%	42.1%	26.3%	0.0%	0.0%	10.5%	21.1%

Table 3. Selected mammal indicator species (n=19)

Common Name	Class
Agouti	G
Baird's Tapir	W
Brown Brocket deer	
White –nosed Coatimundi	
Collared Peccary	G
Black Howler Monkey	F
Jaguar	F
Jaguarundi	D
Margay	F
Naked-tailed Armadillo	

Common Name	Class
Neotropical River Otter	W
Nine-banded Armadillo	G
Ocelot	F
Paca	G
Puma	F
Red Brocket Deer	F
Yucatan Spider Monkey	F
White-lipped Peccary	F
White-tailed Deer	G

Table 4. Selected bird indicator species (n=30)

Common Name	Migratory	Class
American Redstart	Y	M
Black and White Warbler	Y	M
Blue-gray Gnatcatcher	Y	P
Bronzed Cowbird	N	D
Brown-hooded Parrot	N	F
Cerulean Warbler	Y	F
Chestnut-sided Warbler	Y	M
Common Yellowthroat	Y	M
Crested Guan	N	G
Dickcissel	Y	D
Golden-winged Warbler	Y	F
Grace’s Warbler	N	P
Great Curassow	N	G
Great Tinamou	N	G
Hooded Warbler	Y	M

Common Name	Migratory	Class
Keel-billed Motmot	N	F
Keel-billed Toucan	N	F
Kentucky Warbler	Y	F
Little Tinamou	N	
Louisiana Waterthrush	Y	W
Magnolia Warbler	Y	M
Northern Waterthrush	Y	W
Painted Bunting	Y	D
Plain Chachalaca	N	D
Prothonotary Warbler	Y	W
Slaty-breasted Tinamou	N	F
Swainson’s Warbler	Y	F
Wood Thrush	Y	M
Worm-eating Warbler	Y	F
Yellow-headed Parrot	N	P

Data collection

Transect location and habitat

Raw data collected for birds and large mammals includes the number of species observed and the number of individuals observed for each species. These transects and their locations were the same as last year's, when BNR1 transect was discarded and new transects in the savanna area (BNR3), village lands (IV1) and south from the southern highway along the Golden Stream riverside (GSCP9) were added. The addition of new transect locations aimed to expand our monitoring programme to take a more landscape-scale approach. Table 1 in Appendix A contains information about each transect and a map showing the location of transects is presented in Figure 2.

Disturbance gradient

There is a disturbance gradient among the transects in forest habitat, caused by both natural and human activities. The transects in Bladen Nature Reserve are the least disturbed and transects in Golden Stream Corridor Preserve are most disturbed. This gradient is not equally prevalent at every transect location and is not quantified other than by calculated damage from hurricane Iris (2001) and the estimated proximity of residential and agricultural areas (see Table 1 in Appendix A). *The gradient is thus to be considered a rough approximation of disturbance levels.*

Transect visit schedule

Transects were visited according to a preset monthly schedule (**Table5**). Exact dates were kept flexible to allow for access uncertainty such as seasonal bad weather and/or other ranger tasks (e.g. expeditions or deep patrols).

For bird monitoring, the transects were visited twice: early morning and late afternoon. Some transects required a day walk-in, for which the afternoon visit would be performed first and the morning visit the second day, after a night camping. The large 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. A more detailed description of the methodology used on the transects can be found in the BRIM strategy.

Table 5.Transect visit schedule 2013; shaded areas indicate periodic inaccessibility and asterisks show Anabat unit deployment.

	Month	BNR 2	BNR 3	GSCP 1	GSCP 2	GSCP9	CRFR 1	CRFR 2	CRFR 3	CRFR 4	IV1	Total
Dry season	Jan	1*	*	1	1	1*	1	1			1	7
	Feb	1	1*		1				1*	1*		5
	Mar	1*	1	1		1	1	1				6
	Apr	1	1		1				1	1		5
	May					1	1*	1*	1			4
Wet season	Jun	1	1		1*				1	1	1	6
	Jul	1*	1*	1*			1	1			1	6
	Aug	1	1		1						1	4
	Sep	1	1	1		1			1	1*	1	7
	Oct	1*	1		1				1*	1	1	6
	Nov	1*				1		1			1	4
	Dec	1*	1		1		1	1	1	1*	1	8
Total		11	9	4	7	5	5	6	7	6	8	68

Data quality

Over the last few years the quality of the data collected on transects and the way it is entered in the database has seen significant improvement (Hofman, 2013). Efforts to organise a transect visit schedule and prioritising these visits over other activities has increased the visit frequency and the number of individuals observed in the last years.

Additionally, we have been running refresher training sessions for the ranger team to enhance data entry skills and to refresh and improve field monitoring techniques, which has increased the level of accuracy and detail in recorded data. This year our botanist Gail Stott also ran a 2-day basic plant ID course and our Protected Areas Manager Lee Mcloughlin introduced the team to the use of SMART - pioneering software designed for use in protected areas - which is used for spatially explicit data entry and organised data. This software has the potential to be a very effective decision making support tool for protected area management and will be implemented by Ya'axché rangers in 2014.

Data analysis

Data analysis uses the instructions in the BRIM as a starting point, but were mostly built on the progress accomplished over the last three Biodiversity Synthesis Reports (Hofman, 2012; Hofman et al., 2013; Hofman, 2013). 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. Additionally, for a more landscape level approach, we have compared the indicator groups between forests, savanna and village land habitat transects, as we did in 2012 Biodiversity Report (Hofman, 2013).

Actual number of observed species (Target Species Richness)

The actual number of species observed is the raw data collected in the field and is considered a sample of the total actual biodiversity of the ecosystems. It was calculated for every transect on which at least one individual of the target species was observed, on any of the visits to that transect. It needs to be stressed that the species richness has an upper limit equal to the number of target species on the lists mentioned above (see Table 3 and Table 4), hence the name Target Species Richness.

Diversity profiles

As in last year's report, we have combined relative abundances, individual diversity indices and the Effective Number of Species per transect into an approach called **Diversity profiles** (Tóthmérész 1995; Magurran 2004; Hill & Mar 1973). The diversity profiles will inform us in an integrated fashion about the species diversity among different transects and the effects of dominance; they visualise the Effective Number of Species calculated from the different diversity indices (Target species richness [R], Shannon's index [*H*] and Simpson's index [$\boldsymbol{\lambda}$]).

In fact, these three diversity measures reflect the same diversity, but, to estimate the Effective Number of Species, they weigh species differently according to their relative abundance (i.e. rarity or dominance). Target species richness counts every species equally, no matter how few times it was detected, and thus does not take into account the relative abundance. Shannon's index weighs every species according to its relative abundance, making the rarest species contribute less to the Effective Number of Species estimate. Simpsons index goes further and gives proportionately more weight to those species with the highest relative abundance, hence amplifying the dominance of certain species. This gradient is called the 'order' of diversity, and is captured using a scaling factor (α), derived from Rényi's entropy (Rényi 1961):

$$D_\alpha = \frac{1}{1-\alpha} \sum_{1=i}^{S} p_i^\alpha$$

Where D_α represents the species diversity of order α, p_i indicates the relative abundance of species *i*, and S stands for the total number of species. When α equals zero, we obtain the Target species richness. When α equals 1, we obtain the Effective Number of Species that corresponds to the exponential of the Shannon's index (e^H). And when α equals 2, we get the Effective Number of Species that is equivalent to the inverse of Simpson's index. If we plot the Effective Number of Species as a function of the value of α, we obtain a diversity profile, which enables us to detect both species richness and dominance effect (or 'evenness' of relative species abundance) at the same time.

The higher the profile is, the higher the diversity. If two diversity profiles cross, the communities have different levels of dominance and are said to be non-comparable (Tóthmérész 1995; Jost 2010). The diversity profiles were plotted using the PASTv2.17c software (Hammer et al. 2001).

Species accumulation curves and rarefaction 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.

In previous years, we have presented a **species accumulation curve** showing the cumulative increase of detected species on transects as subsequent visits are performed. However, after considering this approach inadequate for our analysis, last year we introduced **rarefaction curves** (Gotelli & Colwell 2001; Magurran 2004), which, instead of predicting the total species richness of each transect, allows us to compare species accumulation between transects in a set number of transect visits.

Usually, this set number of transect visits is determined by the transect with the least visits. Rarefaction curves are created by repeatedly drawing a random subset of transect visits from one transect (with varying number of visits per draw), registering the species richness per draw, and then plotting the average number of species found as a function of the number of transect visits. Thus rarefaction generates the expected number of species in a small collection of transect visits drawn at random from the large pool of transect visits of that transect. The rarefaction curves were calculated and plotted using the PASTv2.17c software (Hammer *et al*. 2001).

Indicator Groups

To gauge the effects of habitat disturbance on the species composition, we sum up all individuals observed and calculate the percentage that fall in each Indicator Group. We use percentages to standardize visit frequency and number of species across transects and to compare between transects and habitats.

Camera trapping survey

To supplement our large mammal data obtained in transects, we have made use of 40 camera traps provided by Panthera in August 2013. As for last year, we conducted the camera trap survey in GSCP up to two kilometres north and south of the highway, and in the eastern-most section of BNR. Camera traps were located along our monitoring transects and in other trails throughout both areas, in places where field rangers have been spotting the most animal tracks and signs. Due to the high occurrence of hunter activity in CRFR1 and CRFR2 transects and the resulting high chance of cameras getting lost, these two transects did not have cameras installed on them.

The cameras were placed between 30-50cm height, and facing the trail at an angle of 90° to facilitate identification of individuals (Jaguars). Each camera was left in the field for 2 months, and a monthly visit was carried out in order to change batteries and extract data.

Considering the variety of trapping nights in each area and in order to be able to compare different locations, a factor has been created to standardise data. The coefficient was calculated based on the number of nights traps were out in each Protected Area.

Bats

To continue with the bat monitoring system set up with the help of Dr. Bruce Miller in 2011, a plan to use the transect schedule to achieve maximum surveying frequency was developed. Our equipment consists of a single passive acoustic monitoring station, comprised of an Anabat detector, a CF-ZCAIM recorder (Titley Scientific, Brisbane, Australia) and a remotely mounted microphone. This was taken and set up by our rangers to bird and large mammal transects, in monthly visits according to the schedule (see **Table5** on p.11). The unit was pre-programmed with a beginning and ending recording time to approximately coincide with sunset and sunrise.

The unit records the species-specific ultra-sound echolocation calls, which are visualised and cross-checked with an existing database of species calls to identify to species level. This is done by Dr. Bruce Miller who reports back on 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.

Wildlife observations

To compliment the systematic monitoring transects of birds and large mammals, Ya'axché rangers also record significant opportunistic observations made while carrying out daily patrols in the protected areas. Only actual sightings of animals are recorded; tracks and other signs are ignored. Even though daily patrols are conducted in both GSCP and BNR, their target area and length is tailored to enforcement needs and thus very irregular and unpredictable. Therefore no standardised indices can be derived from the observations. They merely serve as an informal indicator of presence and abundance of wildlife species in the area.

Patrols done in BNR sometimes leave from the Golden Stream field centre and cross the Columbia River Forest Reserve. A small number of sightings done in CRFR when rangers go to long expeditions to Bladen were categorised under BNR.

Land snails

Despite being a complex and understudied group, land snails have been suggested as indicators of environmental health for a very long time because of their direct dependence on the soils and ecosystems they live in (e.g. Douglas 2011; Shimek 1930). They form part of the decomposer community in forest ecosystems, uptake pollutants such as heavy metals and play an important role in calcium cycling by concentrating it in their shells. Because of their limited mobility they can provide useful clues about site history (e.g. fires, clearings, etc.), soil moisture and vegetation cover.

In an attempt to find out more about their potential role in Ya'axché's monitoring system, and to add to the knowledge about the snails of Belize, a total of 6 land snail monitoring plots were established in Bladen Nature Reserve in 2012 in sets of 2 plots, one at the foot of a hill, the other on a slope. This year, one extra plot was established on the foothills in GSCP. Plots are 20x50m in size (marked by GPS, elevation recorded) (see Figure).

Upon plot establishment, the percent canopy cover was assessed using a densitometer at the plot centre and the two endpoints of Line 2. The measurements are averaged to obtain percent canopy cover for the plot.

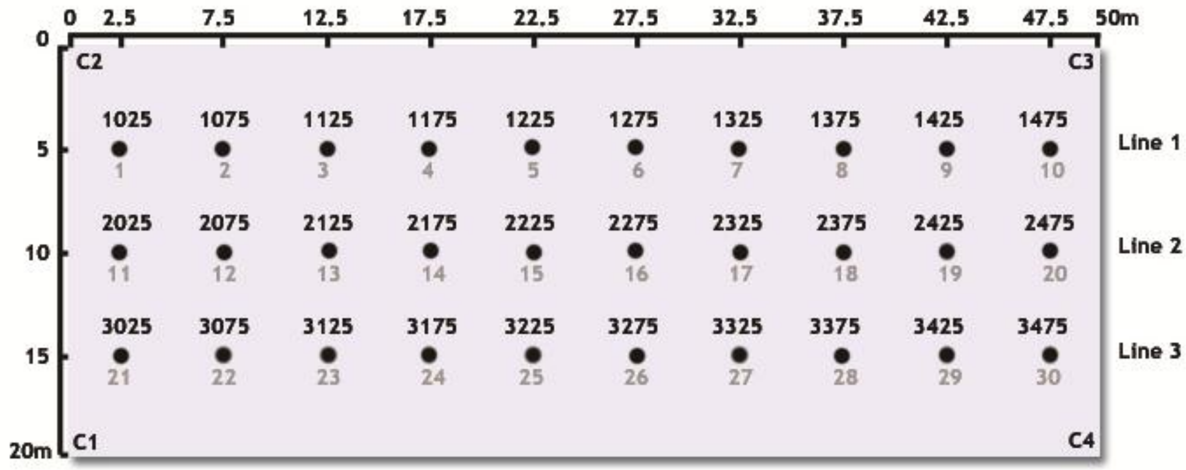

Figure 3 Land snail monitoring plot layout

One leaf litter sample (in a 1L cotton soil sample bag) was collected in each of 10 circular subplots (r=1m) that were randomly selected from a grid of 30 subplots. Within each selected subplot, a $1m^2$ sampling frame was used to asses cover classes of leaf litter, bare ground, rock, coarse woody debris, bryophytes, shrubs and herbs, using the Daubenmire Cover Class Scheme. Four additional leaf litter bags were collected opportunistically from four promising locations within each plot.

For each leaf litter bag collected, at least one micro-habitat was assigned (e.g. under log, rock shelter, base of tree, etc.). During a subsequent search of 20 person-minutes strolling through the plot, any additional snails (not leaf litter) found were collected for identification in the lab.

Upon arrival in the lab, the leaf litter bags were stored in a dry place to be processed. The snails were separated to the finest taxonomic level achievable, stored in a vial with the subplot info included, and entered in an MS Excel data sheet.

After processing a leaf litter bag, a small portion of the leaf litter was put aside and was sent to Dr. Adam W. Rollins, Assistant Professor at Lincoln Memorial University, for his investigations on slime molds or Myxogastrids (formerly known as Myxomicetes).

Weather

Belize's weather is characterised by a rainfall gradient that increases roughly from north to south (see Figure 4). Long-term rainfall data are yearly averages and the countrywide coverage is extrapolated from a set of several weather stations distributed over the country, with a limited set of stations in the southern part of the country.

More detailed weather information would enable a more localised picture of specific circumstances that might inform us about for example farming success or failure rates in certain years. Therefore we gather rainfall, temperature and relative humidity data 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]). Both weather stations are composed of an electronic temperature and humidity device (Digital Hygro-Thermometer, Forestry Suppliers Inc.), and a manually operated rain gauge. Data is recorded manually and entered in a spreadsheet.

In addition to the two manually operated weather stations, two fully automated weather stations were deployed in Bladen Nature Reserve in 2012. The systems consist of four sensors that measure rainfall, wind speed, temperature, relative humidity and Photosynthetically Active Radiation (sunlight), and are attached to a data logger which stores measurements from all sensors every five minutes.

The main purpose of the two automated weather stations was to cover the full NE-SW rainfall gradient that is thought to exist in BNR (see arrows in Figure 4). The first rainfall gradient is expected to arise from clouds blown in with the prevailing NE-winds. The clouds hit the Maya Mountains and run along the Main Divide dropping their rain load as they get blown up the mountains. Similarly, the increasing altitude forces moisture loaded clouds coming from the SE to drop their load as they reach the Main Divide. With the interaction of these two gradients we would expect a local maximum (most rain) on the western end of the Main Divide. We installed the Esmeralda station in the centre of BNR and a second station was meant to be installed at the very western boundary of BNR but was finally set up at Oak Ridge, a more eastern location, at a higher elevation and at a more remote location in BNR. The reason for this location was the presence of Xateros (harvesters of the leaves of the Xaté – or 'fishtail' – palm) in the western boundary of BNR, who have been known to damage, destroy or steal equipment.

Fire

In order to keep track of the extent of fire usage in the Maya Golden Landscape, we use Geographical Information Systems (GIS) software and satellite imagery to compare the status of the vegetation throughout the year. Specifically, we used satellite imagery from USGS Earth Explorer, some prepared by CATHALAC corresponding to some specific dates: December 18th, 2012, March 24th, 2013, April 25th, 2013, May 11th, 2013, June 4th, 2013, July 22nd, 2013 and August 7th, 2013. The lack of dates at the end of the year is due to the absence of cloud free days. However, during these months land use change is unlikely to happen due to high levels of rainfall that discourage slash and burn practices.

Through photo-interpretation of this Landsat 7 and 8 satellite imagery, we obtained the extent and number of areas that showed a clear loss in vegetative cover due to fire. The photo-interpretation was carried out by Ya'axché's experienced GIS specialist, Jaume Ruscalleda.

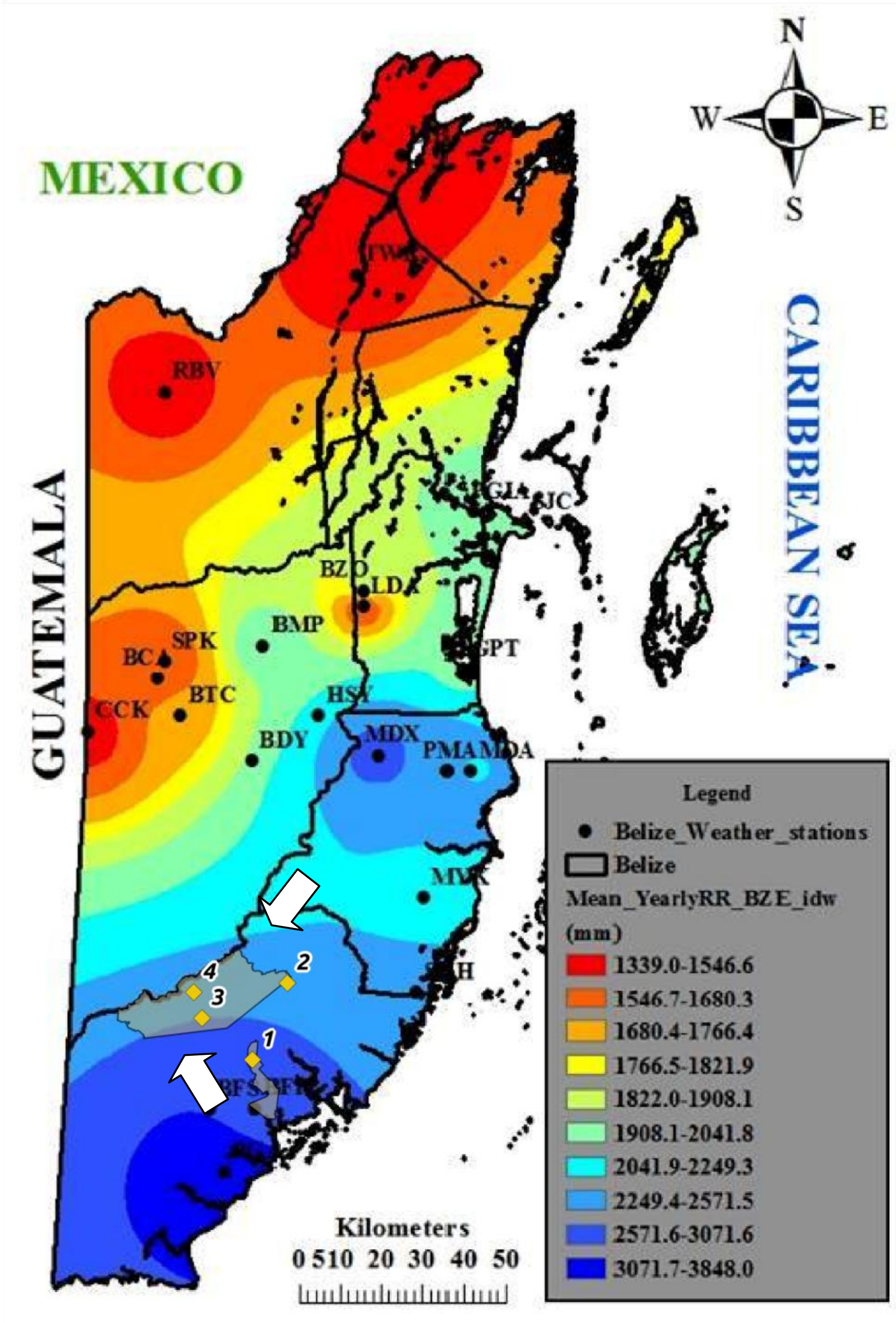

Figure 4. Mean yearly rainfall across Belize for 1951-2013, with rainfall gradients. Bladen Nature Reserve and the Golden Stream Corridor Preserve are indicated by transparent polygons. The four Ya'axché weather stations locations are; (1) Golden Stream field centre, (2) BNR ranger base, (3) Esmeralda and (4) Oak Ridge. Arrows indicate expected local rainfall gradients. Map prepared by Meteorologist Frank Tench (Frutos, 2013)

Results

The results of the data analysis follow the same structure as the methodology section. Data collected in bird and large mammal transects are presented in a similar way; beginning with general descriptive statistics on the actual number of species and followed by a more in-depth analysis using different statistical indices, a habitat comparison using diversity profiles, and a comparison of species accumulation throughout transects. Data collected on other monitoring surveys were analysed in an equally basic manner.

Birds

During the course of 2013, transects were each visited between 8 and 25 times, with an average of 14.2 visits per transect. The total distance covered in transects was 142 km (see Table 6), which maintains the survey effort completed in the previous year.

Table 6. Bird monitoring effort per transect in 2013

	# of visits	# of m transect	Avg. # of obs/1000m
BNR2	25	25,000	10
BNR3	23	23,000	8.52
CRFR1	10	10,000	9.6
CRFR2	13	13,000	11.54
CRFR3	13	13,000	7.92
CRFR4	12	12,000	9.42
GSCP1	8	8,000	9
GSCP2	14	14,000	12.71
GSCP9	9	9,000	11.78
IV1	15	15,000	13.33
MGL	142	142,000	10.38

Of the 30 bird species on the target list, a total of 23 species were detected in 2013, with a total of 1464 individual birds recorded, resulting in an average of 10.3 observations per 1000m transect in all the MGL.

Statistical analysis identified a positive correlation between the number of observations and number of visits (Spearman's ρ=09119; p-value=0.0002). However the number of visits and the average number of observations per 1000m was not correlated (Spearman's ρ=0.152; p-value=0.675). This suggests that the number of visits and observations per transect are two independent variables and therefore comparable. However, the total number of observations between transects cannot be compared without considering the number of visits to each transect.

The largest number of bird observations per 1000m was observed in the Indian Creek village lands transect, followed by the GSCP2, GSCP9 and CRFR2 transects, respectively.

Nevertheless, as we will see later in this section, recording a large amount of individuals in certain transects does not necessarily indicate the presence of more birds or more diversity.

During 2013, the amount of transect visits carried out per month varied between 18 and 6 (see Figure 5), with the highest number of visits done during January and the least during November. We found that the number of transects per month during 2013 was somewhat erratic.

As noted in Figure 5, the number of observations per transect curve plummeted from May to August and increased again in the end of the year despite a decrease in visit number. A similar trend was also seen in target species richness per month. As we will see later, the explanation of this tendency is the increase of migratory bird species during these months.

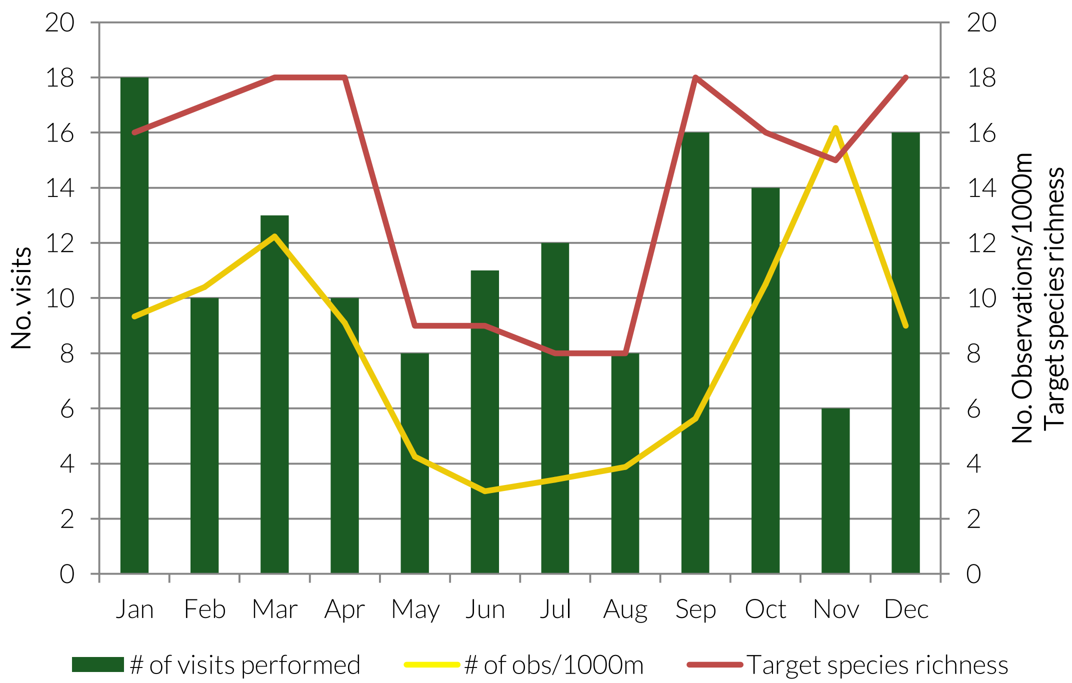

Figure 5. Bird monitoring effort in 2013

Target species richness

As described in the methodology section, the target species list contains many species that are indicators of forest health, but since disturbance and savanna indicator species are also included, we are able to compare the results of the three environments by assembling the transects conducted in each habitat (see Figure 6).

Given the difference in the amount of transects conducted in different landscapes, we compared the average of results in forest transects with single savanna and village land transects. Target species richness measured by the average of forest transects was 14.5 compared with 18 on the savanna transect and 12 on the Indian Creek village lands transect.

As compared to last year, in 2013 there was an increase in species richness in the Savanna, and to a lesser extent in the Village lands.

As explained on 2012 report, we would expect the visibility and sound travel distance to be greater in the Savanna and Village lands habitat as compared to the forest habitat given the openness of the former two, and thus the species richness estimate for Village lands and Savanna to be inflated (Hofman, 2013). On the other hand, using an average of forest transects data can result in a more moderate reflection of the total forest target species richness; although the data set on forest transects has a normal distribution and this statistic is totally applicable, the arithmetic average is still sensitive to outlying values.

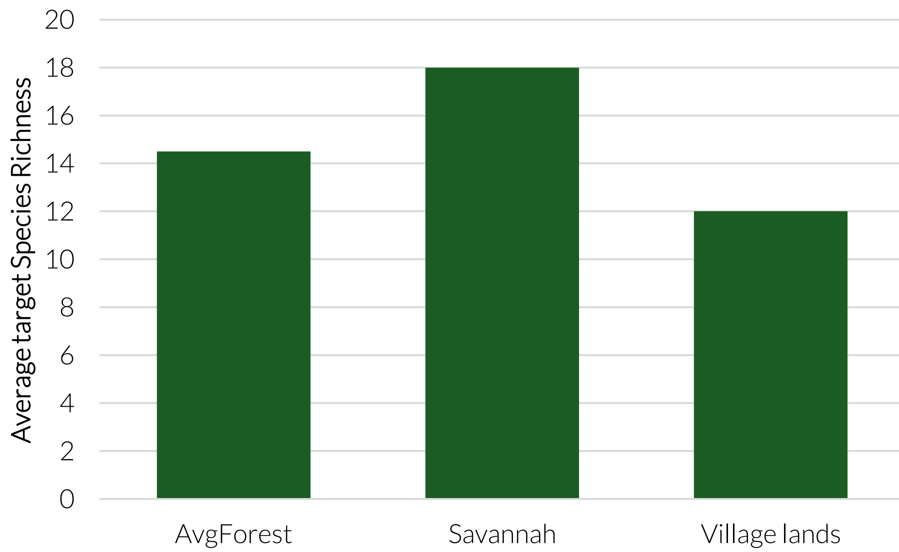

Figure 6. Average target bird species richness per transect in 2013

The total amount of indicator bird species recorded in all forest transects together was 22, collecting all species found in the other two habitats, except Grace's Warbler, one pine-savanna quality indicator detected only in the savanna transect. Considering the facts stated earlier, Figure 6 can only lead us to the conclusion that in 2013 Indian Creek Village transect was the habitat where lesser indicator species were found. Yet, this only means village lands have less of the birds on our indicator species list, which is biased towards forest species and therefore does not count other non-forest species that may be present in village lands.

Sample-based rarefaction curves

For the reasons explained in the methodology section, this year we did not calculate the species accumulation curve like previous years, conversely, we calculated rarefaction curves on each transect (see Figure 7). In this chart, we compare the expected species richness on each transect at the point where the transect with the lowest amount of samples ends. In this case, we compared all transects after 8 samples as this is the minimum amount of visits conducted in 2013.

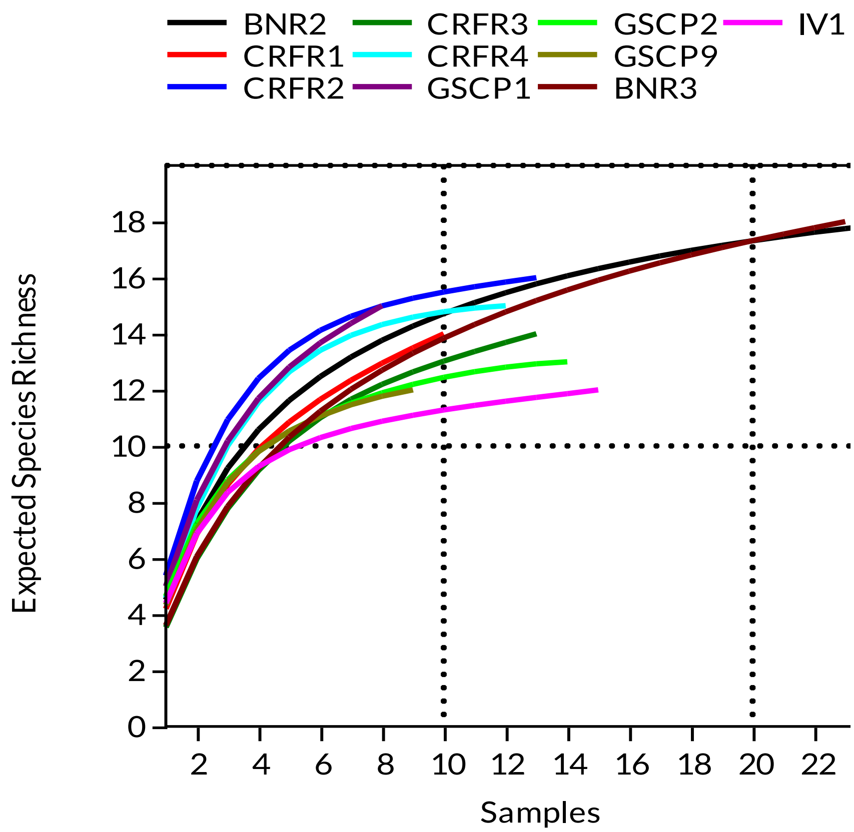

Figure 7. Sample-based rarefaction curves for all transects

To compare expected taxon richness on each transect, we have ranked all transects based the on the amount of species accumulated on the same amount of visits. As we can observe on Table 7, GSCP1 and CRFR2 have the highest amount of expected accumulated indicator species, both with 15 species at 8 samples. CRFR4 follows closely with 14.3 species and BNR2 and CRFR1 are next with around 13 species, followed by BNR3 with 12.7 species. At the end of the ranking, CRFR3, GSCP2 and GSCP9 accumulated between 12.2 and 11.8 species at 8 samples, and finally, Indian Creek village lands stands as last in the ranking with 10.88 species.

Table 7. Transect ranking according to expected bird species richness after 8 transect visits

Ranking	Transect
1	GSCP1
2	CRFR2
3	CRFR4
4	BNR2
5	CRFR1
6	BNR3
7	CRFR3
8	GSCP2
9	GSCP9
10	IV1

As per last year, BNR2 appears in a low position considering it is the least disturbed area of them all. Additionally, the savanna and village land transects (BNR3 and IV1) fall at the second half of the ranking as a result of their low effective number of bird species, which is, at the same time, the consequence of our target bird species list being biased towards forest species.

Diversity profiles

As observed in Figure 8, in 2013, the most species rich transects were BNR3, followed by BNR2 and CRFR2, however, when weighing species dominance, CRFR2 showed low levels of dominance and therefore higher biodiversity. Conversely, BNR2 and particularly BNR3, initially with high target species richness, were more affected when weighing levels of dominance indicating less diversity. BNR2 had an elevated number of Slaty-breasted Tinamous, Wood Thrushes, Brown-hooded Parrots and Great Tinamous. The dominant species in BNR3 was by far the Yellow-headed Parrot, and to a lesser extent, the Plain Chachalaca. The appearance of large numbers of individuals of one single species causes the dominance weighing to affect diversity levels more. Finally, Indian Creek village land transect exhibits the lowest species richness and is among the most influenced by dominance weighting, with high presence of Plain Chachalacas and to some extent Worm-eating Warblers.

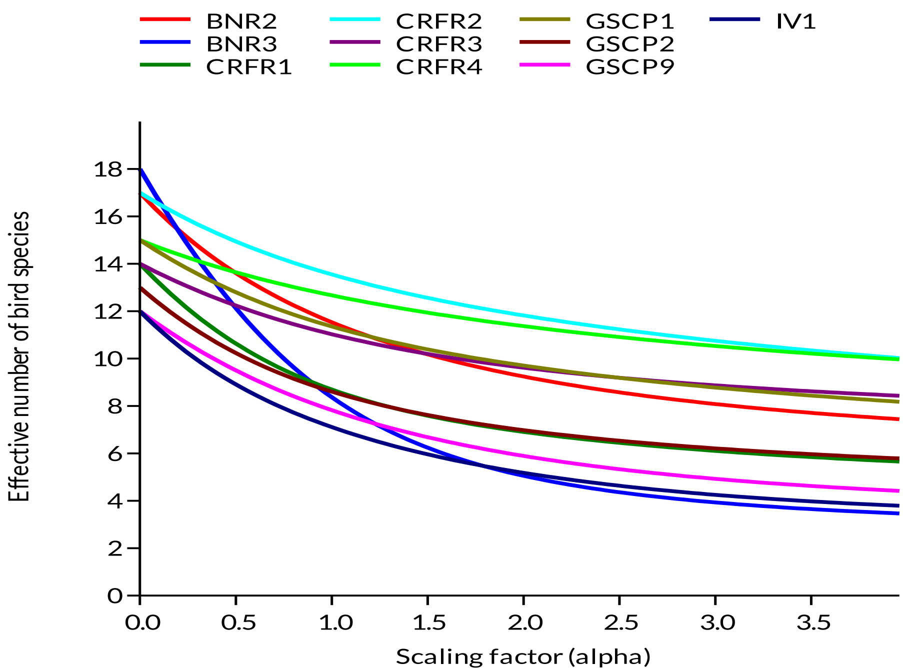

Figure 8. Bird diversity profiles

Migratory birds

When comparing migratory birds only, we found a marked pattern of presence/absence and migration peaks in monthly bird encounter rates per 1000m (see Figure). Statistical analysis revealed that there is no correlation between the number of individuals encountered per 1000m and the number of visit conducted per month (Spearman's ρ=0.576; p-value=0.498), which means we can compare the months without normalising data by visit numbers.

As expected, the higher encounter rates occurred from October to March; during the transition months of April and September, an important decrease in bird encounter rate took place and throughout summer months migratory species practically disappeared from the whole MGL. We can also note that, like previous years, species richness and number of migratory bird species is notably higher after breeding season than before breeding season (i.e. Oct-Nov vs. Jan-Mar). This could be the result of habitat saturation upon arrival; migrant and resident species compete against each other for resources and eventually force some individuals to a partial migration. Additionally, as Kokko (1999) explains, territorial species (males) migrate earlier in breeding season to obtain better nesting sites. On the other hand, birds that are migrating south after the breeding season and once crossed the Gulf of Mexico or the dryer areas of Mexico, need more stopovers to recover energy reserves and continue their way south (Young & Moore, 1997), also, other studies have shown that stopover duration is determined by bird fat stores (Goyman & Spina, 2010). These factors would increase the probability of our rangers targeting more species and individuals.

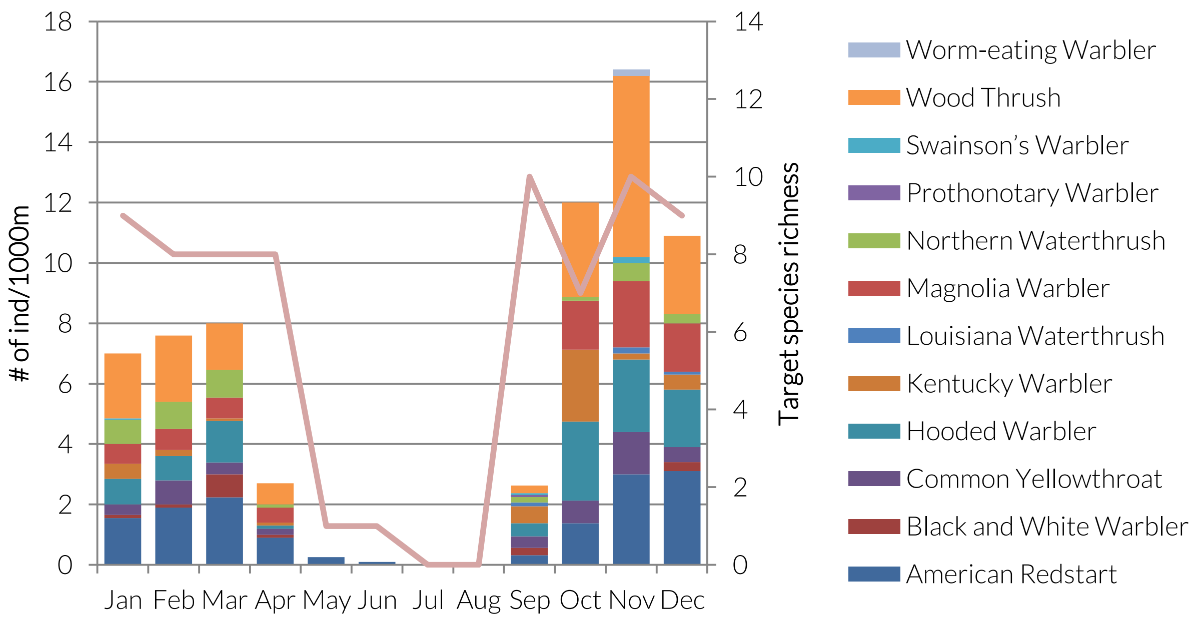

Figure 9. Migrant encounter rate and species richness throughout the year

Indicator groups

Indicator groups provide us with information about the health of the different ecosystems we monitor in the MGL. As explained earlier, given the difference in the amount of transects and visit numbers conducted in different landscapes, the conclusions when comparing these three need to be drawn carefully. In fact, statistical analysis determined a positive correlation between the number of observations and number of visits (Spearman's ρ=0.912; p-value=0.0002), however, the number of visits and the average number of observations per 1000m is not correlated (Spearman's ρ=0.152; p-value=0.675). Therefore, the comparison between the three is done by normalising the results using percentages rather than actual numbers.

Looking at the distribution of individuals from different indicator groups across different habitats (see Figure 3), we observe that in village lands more than a third of individuals were indicators of disturbance and this is more than double the other two habitats. The surplus of disturbance indicator birds in Village lands took the place of game birds which were lacking in IV1, and to a great extent, forest health indicators, which were more abundant in the other two habitats. Nevertheless, almost half of bird individuals in village lands were indicators of migratory route health.

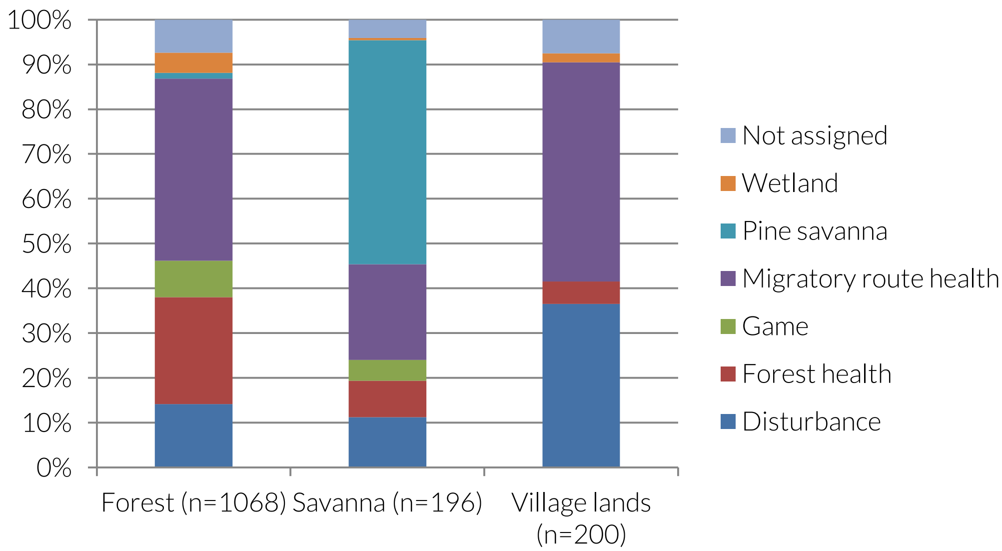

Figure 3. Distribution of individuals among Indicator Groups

On the other hand, the savanna transect shows no wetland indicator species, but half the amount of birds recorded were pine savanna species. Additionally, the proportion of migratory route health individuals was only a fifth in savanna. In forest habitat transects, the individuals classified as forest health indicators increased noticeably to a quarter, and the migratory route indicator proportion went to 40%, which is double that of the savanna. Game species were absent in the Village lands transect and their presence in Savanna and Forest transects was 4.6% and 8.1%, respectively.

The disturbance indicator group is composed of a single species (Plain Chachalaca), but because it is a species living in groups, it still represents a significant percentage of individual appearances in every habitat. Table 7 shows the ranking of disturbance level on each transect according to the appearance of this indicator species per 1000m from 2011 to 2013.

Table 8. Ranking of transect disturbance level according to average disturbance indicator appearance rate per 1000m in the last three years

Ranking	Transect
1	IV1
2	GSCP9
3	GSCP1
4	GSCP2
5	CRFR4
6	CRFR1
7	BNR3
8	CRFR2
9	CRFR3
10	BNR2

Although the ranking is based only on one species, we can observe that the list is consistent with the classification done in previous years based on hurricane damage and agriculture proximity (see table 1. in **Appendix A**). The Village lands transect is the most disturbed of all, while the least disturbed is BNR2. GSCP transects fall among the most disturbed transects and CRFR transects appear as less disturbed.

When comparing the proportion of individuals on each indicator group, per transect and organising them in the disturbance gradient (presented in **Table 7**), the results show a more comprehensive layout of overall tendencies (see **Figure 4**).

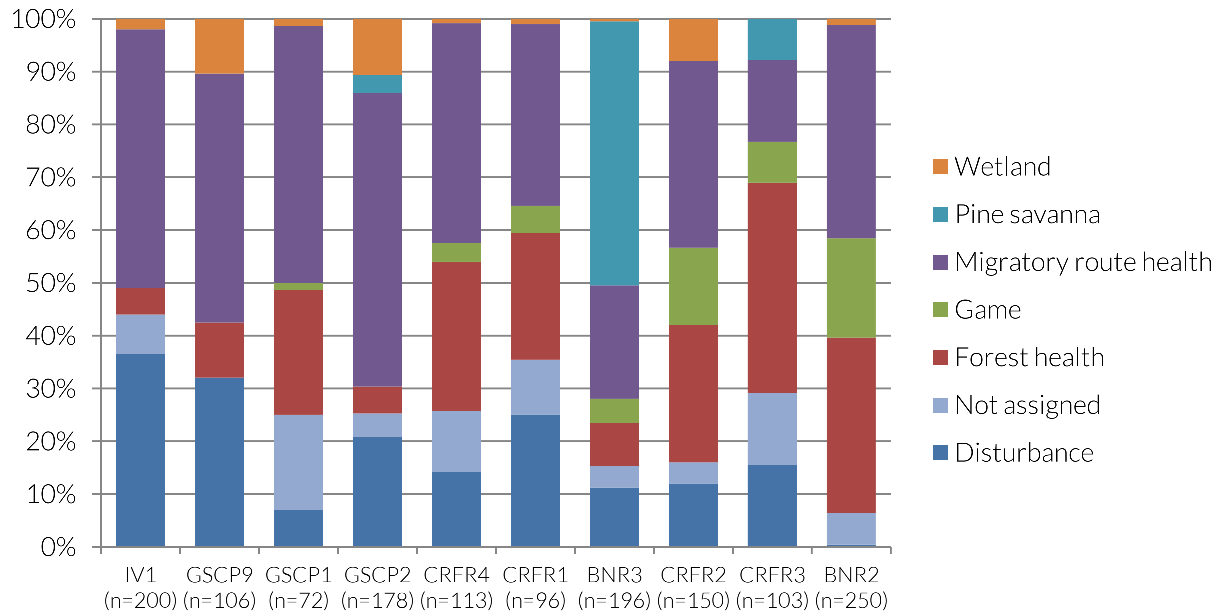

Figure 4. Distribution of individuals within Indicator Groups per transect. Transects are organised in a disturbance level gradient according to disturbance indicator species presence average in the last three years.

As observed in **Figure 4**, when the disturbance indicator individual proportion increases, the opposite happens with forest quality indicator proportions. There are two exceptions to this rule: the savanna transect includes a larger proportion of pine-savanna indicators, and GSCP1 contains a larger proportion of species classified as not assigned or Little Tinamous. In Toledo, subtropical moist lowland forest and scrubland are the primary habitat of Little Tinamous, but they are also successful in plantations and degraded forests (BirdLife International, 2012). Little Tinamous and Plain Chachalacas have a similar feeding ecology, and therefore the former can be occupying the latter niche in GSCP1 area. Also, game indicator species tend to decrease as disturbance increases, and migratory route health indicator proportions - although they are to some extent evenly distributed - tend to slightly increase when disturbance increases. As a remarkable observation, transects in GSCP area show no trace (or a very small proportion) of game species.

For raw data on indicator bird transects see Table 2 in **Appendix A**.

Large mammals

The large mammal transects were only done once per visit, at the same time as either the morning or evening bird monitoring transects, and therefore, the visits performed are generally half of the ones for bird monitoring. During the course of 2013, a total of 67 mammal transect visits were carried out, covering a total of 67km (see Table 9). Different transects were monitored from 4 to 10 times and we had an average of 4.79 observations done per 1000m transect in the whole MGL.

Table 9. Mammal monitoring effort per transect for 2013.

	# of visits	# of m transect	Avg. # of obs/1000m
BNR2	10	10000	6.4
BNR3	9	9000	5.33
CRFR1	5	5000	3.4
CRFR2	6	6000	5.33
CRFR3	7	7000	3.14
CRFR4	6	6000	3.83
GSCP1	4	4000	5.5
GSCP2	7	7000	5.29
GSCP9	5	5000	5.8
IV1	8	8000	3.37
MGL	67	67000	4.79

From the 19 species of mammals on the target species list, a total of 15 were detected, with 321 observations carried out throughout the year and signs of 567 individuals counted. The species not detected during transects included the White-nosed Coatimundi, Jaguarundi, Naked-tailed Armadillo and the Neotropical River Otter. The largest number of target mammal observations per km was done in BNR2, followed by GSCP9, and GSCP1. The transects exhibiting less target mammal observations per 1000m were CRFR3, CRFR1, and IV1.

Statistical correlation test indicated that a positive correlation exists between the number of observations and the number of visits (Spearman's ρ=0.69; p-value=0.027), but the number of visits and the average number of individuals per 1000m was not correlated (Spearman's ρ=0.515; p-value=0.127). As with birds, the number of visits and observations per transect are independent variables and thus comparable.

During 2013, between four and eight transects were conducted every month (see Figure 5), with the greatest number of visits carried out in December. January was the month which observed most sightings per 1000m. There was a significant drop in observations per transect during March, April and May. This was presumably a result of scarce rain during the dry season, and therefore a decrease in animal tracks in dry soil. After the dry season, observations per transect grew incrementally until the end of the year.

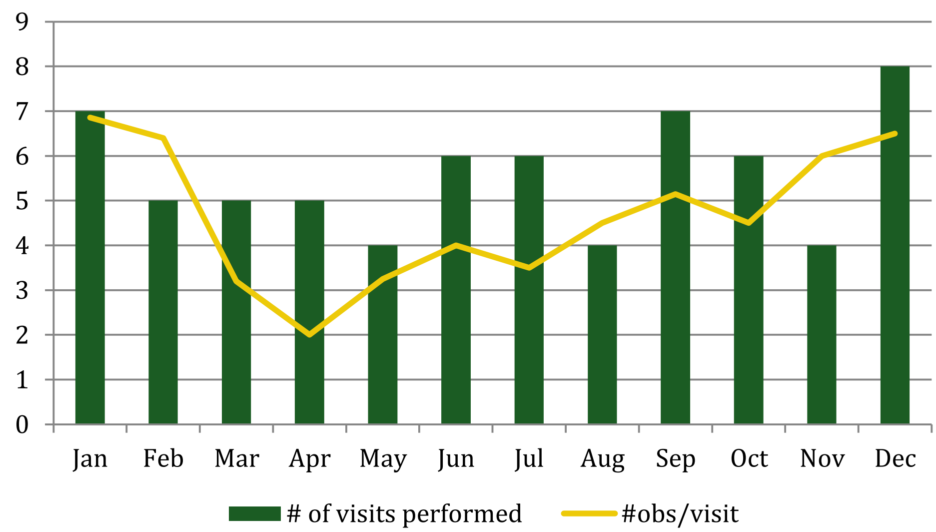

Figure 52. Mammal monitoring effort and observation per 1000m in 2013

Target species richness

As in birds, we compared the results of the three different habitats we monitored in the whole MGL by pooling the transects conducted for each habitat (see Figure 6). Again, given the difference in the amount of transects conducted in different landscapes, we compared the average of results in forest transects with single savanna and village land transects.

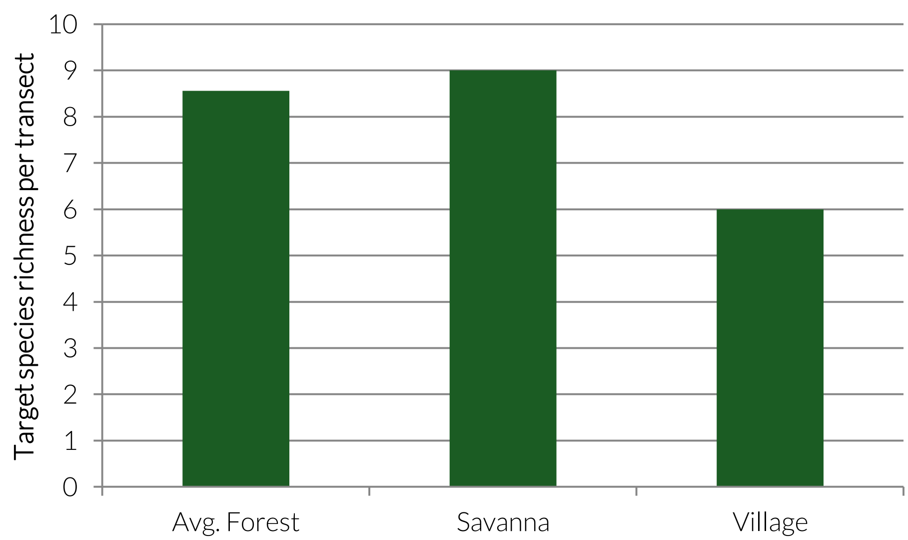

Figure 6. Target mammal species richness per habitat

Target species richness in transects in forest habitat was on average 8.56 species, while in savanna, this value was 9, compared to 6 in village lands. As seen in the results obtained in birds, using an average of forest transects results in a decrease of the total forest target species richness because this statistic is sensitive to extreme values; maximum target species richness occurred in BNR2 with a 12 and the lowest value is in CRFR2 with a 6 (for raw data see Table 3. in **Appendix A**). The total value of target species richness in forest habitat is 15. Additionally, as with birds, we would expect the openness of the Savanna and Village lands to facilitate observation of some target species more easily than in the forest. For example, Black Howler Monkeys can be heard frequently on the Savanna transect, but these calls always come from the nearby forest. The same occurs in Village lands.

Indian Creek Village showed considerably less target species richness that the other two habitats.

Sample-based rarefaction curves

As with birds, we have compared expected species richness on each transect by calculating rarefaction curves (see Figure 7) which helps us compare transects in which different amounts of surveys have been completed. In the case of large mammal transects, the minimum amount of visits conducted in 2013 was 4.

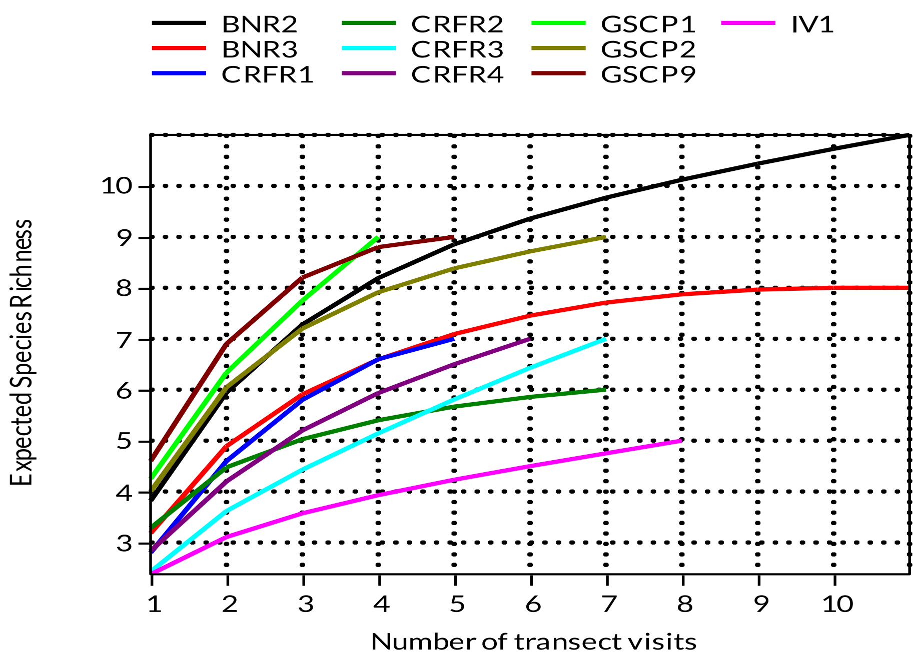

Figure 7. Sample-based rarefaction curves for large mammals in 2013

Table 10. Transect ranking according to expected bird species richness after 8 transect visits

Ranking	Transect	Ranking	Transect
1	GSCP1	6	BNR3
2	GSCP9	7	CRFR4
3	BNR2	8	CRFR2
4	GSCP2	9	CRFR3
5	CRFR1	10	IV1

According to the information in the chart, Table 10 shows a ranking of transects based on their expected taxon richness on the minimum amount of samples (in this case, 4). GSCP1, GSCP9 and BNR2 were the transects that accumulated more species after 4 visits, all between 8 and 9 species. The transects with least species at that same number of visits was Indian Creek Village transect, with 3.93 species recorded in 4 visits.

Looking at protected areas individually, as opposed to the bird species richness rarefaction curves, mammal rarefaction curves show that Golden Stream Corridor Preserve was more rich in target species than Columbia River Forest Reserve after the fourth visit. Additionally, BNR3 transect (Savanna) falls in the second half of the ranking as a result of a low effective number of mammal species, and BNR2 is third with 8.19 species detected.

Diversity profiles

As was observed last year, BNR2 and CRFR3 are by far the transects most affected by species dominance (see Figure 15); the presence of large herds of White-lipped Peccary and,(in the case of BNR2) Yucatan Spider Monkeys, changes the Effective Number of mammal species, as more weighting is given to species presence. To a lesser extent, BNR3 is also affected by species dominance. In this case, as the scaling factor α increases the Effective Number of mammal species declines due to high numbers of Howler Monkeys and Spider Monkeys. Similar results are observed in the Village lands transect (IV1) as a result of a disproportional number of Agoutis and Nine-banded Armadillos.

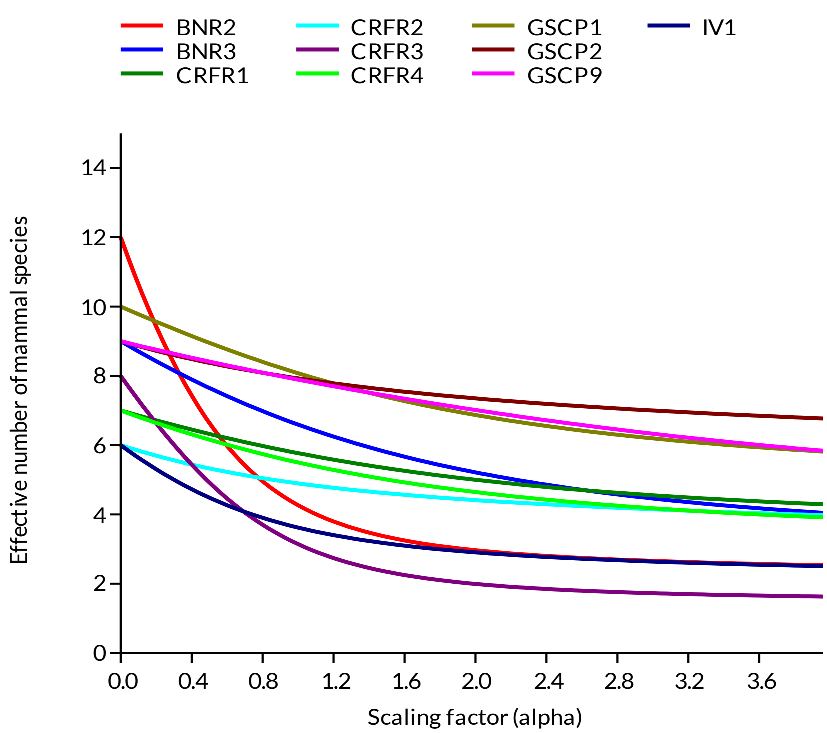

Figure 15. Large mammal diversity profiles in 2013.

On the other hand, all the transects in GSCP - although starting with a target Species Richness lower than BNR2 - are not affected as the scaling factor α increases and therefore have a more proportionate distribution of individual numbers.

Indicator groups

In 2013, on average, more Forest indicator species were recorded in the Savanna transect than in forest transects (see Table 5). In addition, the Savanna transect had less game species than transects in the other two landscapes, while Village lands indicator mammal presence were mainly composed of game species. The only Wetland indicator species (Baird's Tapir) was absent in Village lands and appeared in a low scale in the Savanna transect.

Figure 16 shows a disparity between Village lands and the other two habitats. However Savanna and Forest transects had a very similar structure in terms of species indicator distribution.

Table 5. Average number of indicator species per transect

No. of individuals	Forest (n=8)	Savanna (n=1)	Village lands (n=1)
F	3.375	5	1
G	3.875	3	5
W	1	1	0
N/A	0.25	0	0
All species	8.5	7	6

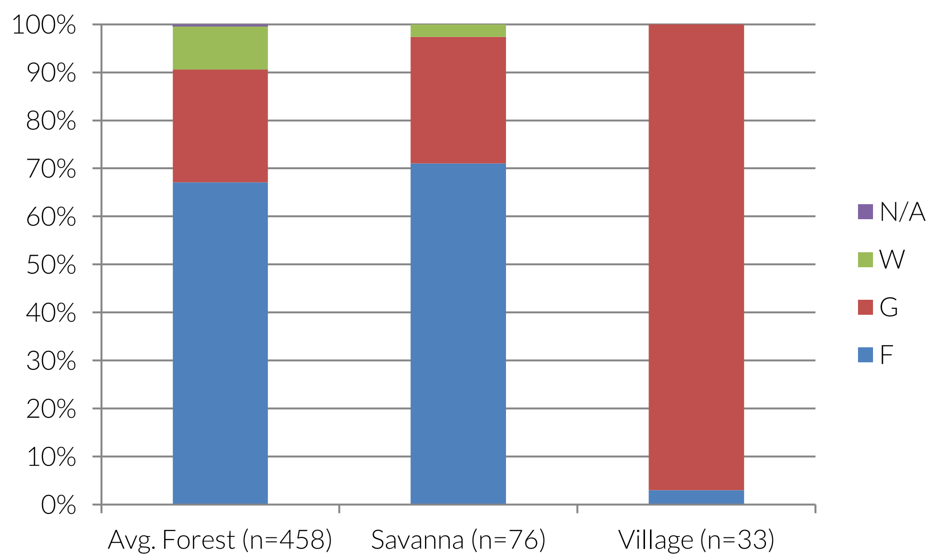

Figure 16. Distribution of individuals among Indicator Groups

To examine the results more thoroughly, Figure 17 shows the number of individuals encountered in each habitat per transect or encounter rate for Forest indicator species. On average, more individuals were recorded in the Savanna transect than in Forest transects, but the amount of species found in forests was more diverse. White-lipped Peccaries, Pumas and Ocelots were not detected in the Savanna. As opposed to 2012's biodiversity monitoring results, signs of Red brocket deer, Margay and Spider Monkeys were detected in the savanna in 2013. Spider Monkey and Howler Monkey were more commonly recorded in the savanna. The openness of this habitat makes the sound travel easier and results in observations of monkey vocalisations that are in fact coming from the nearby forests and not the savanna. Howler Monkeys were the only Forest Health Indicator species recorded in Village lands.

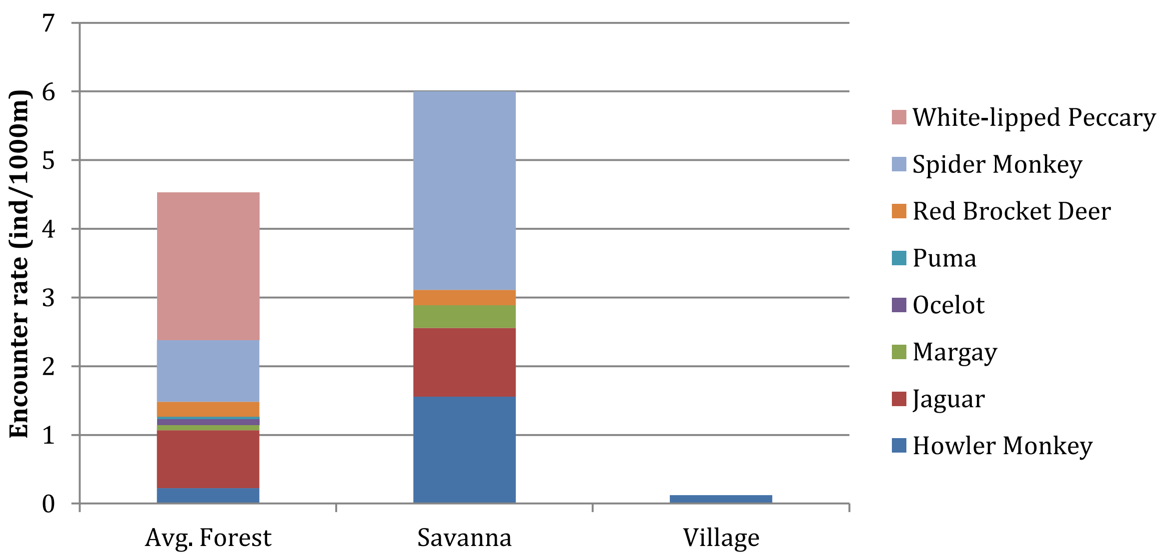

Figure 17. Encounter rate of all Forest health indicator species in different habitats during 2013.

Figure 18 collects Game indicator species encounter rates in the same way as the previous chart. Most individuals were recorded in Village land transects and the amount of species found is as high as in forest transects. The most commonly encountered game indicator species in the village lands were Nine-banded Armadillo and Agouti, which appeared in a higher rate than in the other two habitats. Conversely, Paca had low encounter rates in village lands and Collared Peccary, which last year appeared as scarce in this habitat, has been recorded more times per 1000m than in the forest transects.

As expected, white-tailed deer is more common in the Savanna. The Paca or Gibnut was absent from the Savanna in 2012, but in 2013, the encounter rate of this rodent was nearly as high as in forest transects. Collared Peccary and Agoutis however, were still absent from the Savanna.

The forest transects showed a balanced encounter rates between game indicator species expected to be found in forest habitats.

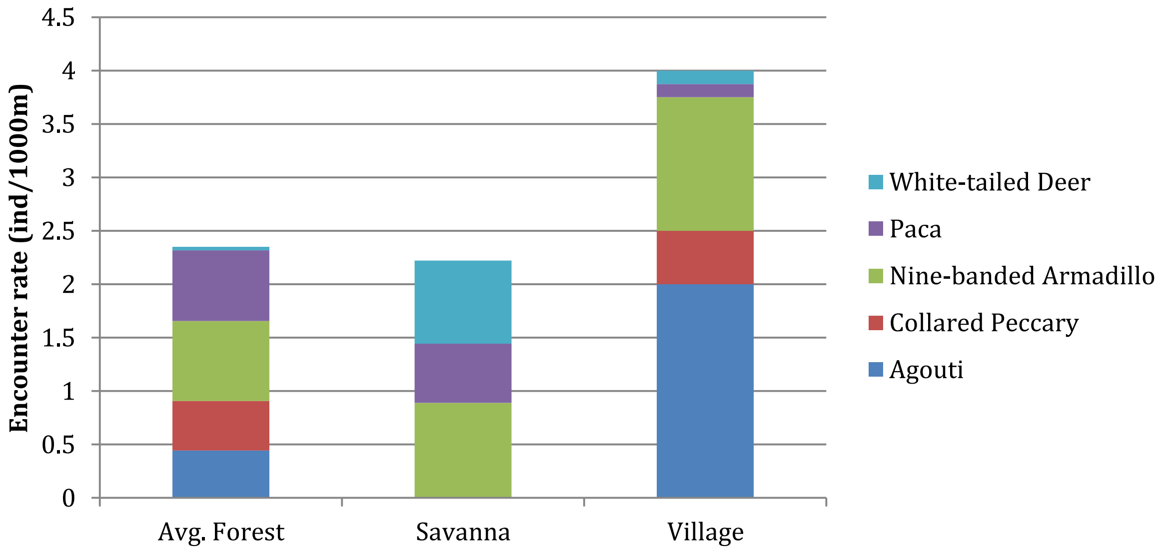

Figure 18. Encounter rate of all Game indicator species across different habitats in 2013.

The encounter rate of Wetland indicator, Baird's Tapir, was identical to 2012's habitat comparison chart (see Figure 19); encounter rate drops from close to 1 individual per 1000m in the forest, to none in village lands. As mentioned in previous Biodiversity reports, there are anecdotal sightings of Tapirs in village lands, and more specifically agricultural fields, where Tapirs are attracted to the high concentration of food, but often results in them being shot in retaliation to the destruction of food crops.

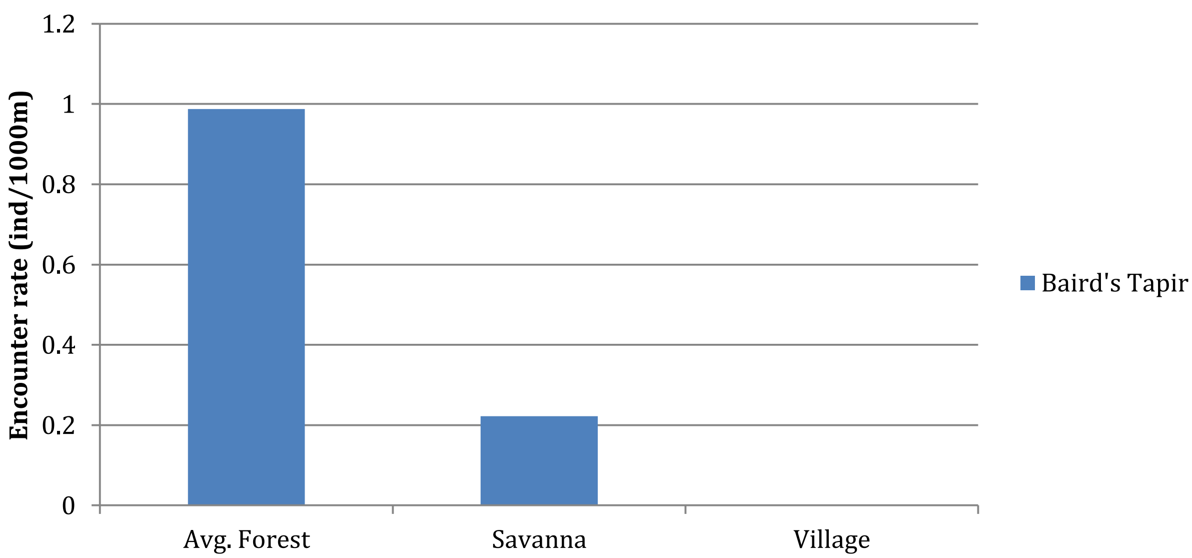

Figure 19. Encounter rate of Baird's tapir, the only Wetland indicator species detected in 2013.

Camera trapping

The cameras were out in the field a total of 1105 days and nights which makes a total of 2,127 'trapping nights' logged. Originally 30 cameras were installed, but three of them were stolen (allegedly by hunters) from two different locations and one was damaged by water at a third location.

Table 12. Species diversity results from the 2013 camera trapping survey. Individual passes (Indiv.) and average herd size (A.H.S.) are a minimum estimate.

	Species	BNR		CRFR		GSCP		Total MGL
		Indiv.	A.H.S.	Indiv.	A.H.S.	Indiv.	A.H.S.	Individuals
Birds	Currasow	10	1	3	1	4	1	17
	Great Tinamou	2	1					2
Mammals	Agouti	5	1	15	1	6	1	26
	Armadillo	2	1					2
	Bat	5	1	1	1	14	1	20
	Coatimundi			1	1	1	1	2
	Collared peccary			5	1	2	1	7
	Gray Fox					1	1	1
	Jaguar	11	1			3	1	14
	Jaguarundi			2	1			2
	Ocelot	3	1	1	1	4	1	8
	Opossum	1	1	1	1			2
	Paca			2	1	2	1	4
	Puma	3	1	12	1	8	1	23
	Racoon					1	1	1
	Red-Brocket Deer	16	1			9	1	25
	Tapir	2	1	3	1	17	1	22
	Tayra			3	1.5			3
	White-lipped peccary	49	6.13	11	3.67	9	3	69
Total		109		60		82		251
Species Richness		12		13		14		19

From the 2127 recorded trapping nights, 664 (31.2%) were at four locations in Bladen Nature Reserve, 249 (11.7%) were in Columbia River Forest Reserve at two different locations and 1214 (57.1%) were at Golden Stream Corridor Preserve in 7 locations (**Appendix B**). All the stolen cameras were lost in GSCP and the camera damaged by water was located in CRFR. The amount of cameras deployed (and therefore locations) in each protected area differed greatly, so in order to make data comparable, a factor based on the number of trapping nights on each area has been used (see Figure 20).

The traps captured a minimum of 251 individuals, with a total of 19 species in all locations; two of which were bird species and 17 mammal species (see **Table 12Error! Not a valid bookmark self-reference.**). The table counts the number of passes of individuals and does not include possible repetitions (i.e. pictures taken with the camera on the other side at the same time, or repeated pictures due to several passes of the same individual in a 30 min time frame). The herd size indicates a minimum average of individuals passing at once in one single pass. BNR was the area where most individuals and species were captured, followed by GSCP and CRFR, consecutively. Yet, GSCP area showed the greatest species richness, and BNR the lowest. However, when looking at data normalised by the trapping time factor, GSCP accounts for a lower percentage of individuals trapped than the other two areas. CRFR camera traps obtained a considerable record of individuals and species of the area. Additionally, some of the mammals on the indicator list that were not reported during transects, were recorded by camera traps; two Jaguarundis (a disturbance indicator) appeared in CRFR4, and one Coatimundi (Not-assigned indicator) was recorded on each GSCP2 and CRFR4 (See **Table 1** in **Appendix B** for individual count on each location).

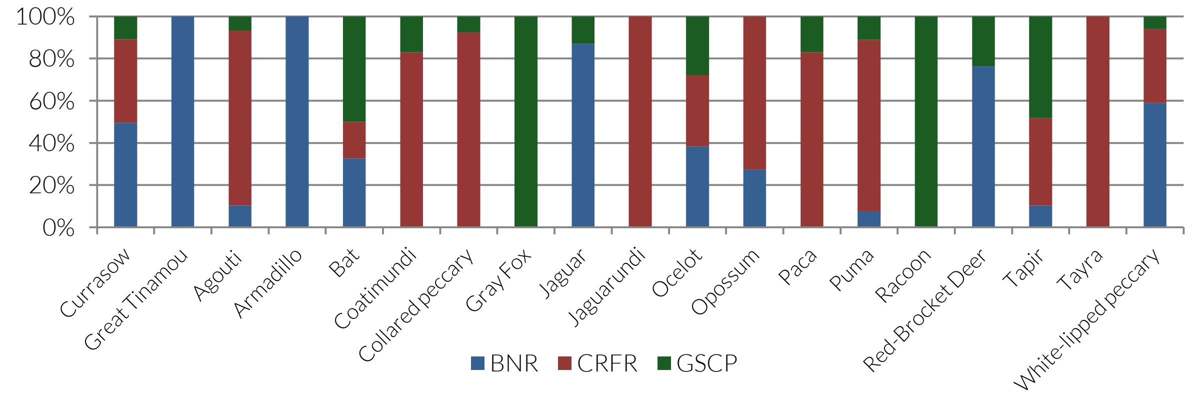

Figure 20. Percentages of individual capture using the normalising factor

The most remarkable result from our 2013 camera trap survey was the presence of White-lipped peccaries in GSCP2 (See **Table 1** in **Appendix B**). The count rose to nine individuals in two different passes. White-lipped peccaries are more usually seen in GSCP hillside north from the highway and hardly ever recorded in southern GSCP.

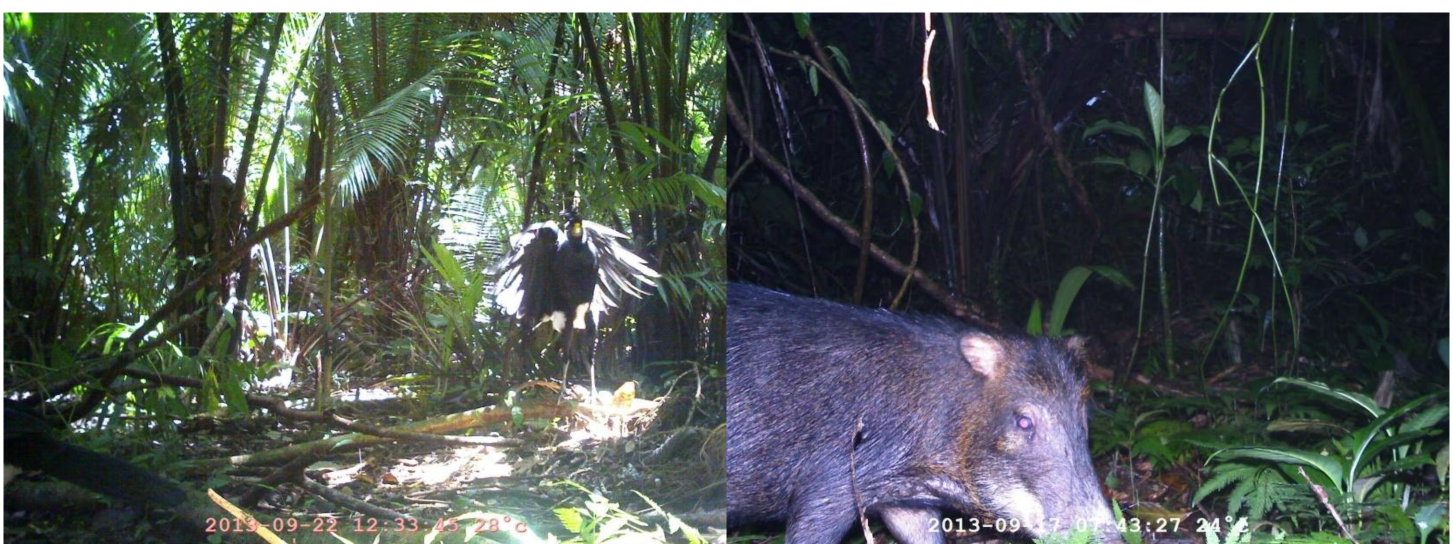

Figure 21. Captures of different cameras. Left; A Curassow in Bladen doing a courtship display. Right; White-lipped Peccary in GSCP2.

Bats

During the course of 2013, the Anabat unit was deployed 21 times, which implies an increase of 400% in our survey efforts in comparison to last year. Our surveys resulted in 190 hours of recorded bat calls in 17 different locations. In addition, the automatic bat detector was deployed at every forest and savanna transect. BNR2 was the transect where the Anabat unit was deployed most (Table 6).

Table 6. Bat monitoring effort in 2013

	Nights	Hours	Locations
BNR2	5	52	5
BNR3	3	33.3	2
Total BNR	8	85.3	7
CRFR1	1	1	1
CRFR2	1	10.9	1
CRFR3	2	22.5	1
CRFR4	4	34.5	3
Total CRFR	8	68.9	6
GSCP1	1	10.1	1
GSCP2	3	15.1	2
GSCP9	1	10.4	1
Total GSCP	5	35.6	4
Grand Total	21	189.8	17

The bats recorded were all insectivores, classified as Least Concern in the IUCN Red List of protected species (2013). These species represent 9 genera in 4 different families; Free-tailed bats (Molossidae), Vesper bats or common bats (Vespertilionidae), Sac-winged bats (Emballonuridae) and Moustached bats, ghost faced bats and naked-backed bats (Mormoopidae).

AI%	BNR2	BNR3	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	GSCP9
Mexican dog-faced bat							0.33		
Northern yellow bat		1.16							
Palla's mastiff bat		0.32						0.15	
Black mastiff bat		1.9							
Peter's ghost-faced bat		0.48							
Elegant myotis		0.63				1.31		27.93	
Hairy-legged myotis		0.45							
Greater dog-like bat	4.23	3.2							
Lesser dog-like bat	2.12	14.99							
Davy's naked-backed bat	7.67	1.73							
Big naked-backed bat		0.46							
Common moustached bat	12.51	0.78	3.33	39.6	11.14	8.26	1.49	0.66	2.56
Yucatan yellow bat		1.29							
Greater white-lined bat	4.5	3.23				50			
Lesser white-lined bat		0.29							
45kHz Vespertillionid		0.46						0.15	
70kHz Vespertillionid						5.56			
Unidentified		0.73					0.16		
Species Richness	5	16	1	1	1	4	3	4	1
Overall AI%	13.24	19.67	3.33	39.6	11.14	12.24	1.98	21.41	2.56

Table 7. Bat diversity and activity in the MGL

In **Table 7**, we can observe that the Common moustached bat was the species most frequently recoded in the whole MGL and that the activity index percent of this species is particularly high in BNR2 and CRFR transects. This species is generally an opportunistic species, abundant in all types of lowland forests and is the most common bat to see commuting along forest-trails (See Table 1 in Appendix C) where we conduct transects and deploy the Anabat unit. Activity index percent for this species is particularly high in CRFR 2. However, there does not seem to be a particular trend among transects with this species; the value of AI% of Common moustached bat does not seem related to bat biodiversity in the transects monitored.

Also in CRFR, transect 4 shows higher bat diversity than other transects in CRFR. However, the Anabat unit was deployed in transect 4 for four nights, whilst the other transects were only monitored for one or two nights. It is perhaps unwarranted to claim at this point that other transects would show the same diversity with equal number of nights surveyed. Additionally, the activity index percent of the Greater white-lined bat is remarkable in this transect. The reason behind that is the record of 9 AI during a night when only 18 minutes of activity where recorded.

On the other hand, GSCP has an overall species richness of 6, which exceeds the one obtained in CRFR (SR= 4). High AI% of *Elegant myotis* was recorded in GSCP2. This species is usually recorded in protected areas throughout its range.

As in previous years, bat diversity is notably higher in the savanna area than in the forests (see **Table 7**). Lesser dog-like bat is remarkably the most predominant bat in the Savanna, followed by the Greater white-lined bat, the Greater dog-like bat, Black mastiff bat and Davy's naked-backed bat, consecutively. All these species, with the exception of Black Mastiff bat, are also present in the nearby BNR3 forest transect and in higher activity levels. These results are consistent with the biology of these species (see Table 1. in **Appendix C**); most of these bats prefer wet lowland forest but also forage in open areas, grasslands and dry shrub. BNR3 in the savanna is therefore an important foraging location for bats.

Nevertheless, other studies have hypothesised that possible biased results are due to the difference of species detectability by static bat detectors in open and closed environments. Acoustic surveys are often biased towards the detection of species with higher intensity calls (Duffy et al. 2000) which tend to be fast-flying bats characteristic of open landscapes (Broders et al., 2004). Additionally, the increase of clutter (vegetation density) could buffer sounds and therefore affect bat detectability by the Anabat unit.

Wildlife observations

Although the recordings from ranger's daily patrols are not included in any form of analysis of general biodiversity, they are useful to record unusual sightings that might be missed during monitoring activities. Table 8 collects the sightings done in both BNR and GSCP. As explained in the methodology section, some sightings were collected in CRFR, and in the table these fall under the BNR section.

The difference in number of observations between BNR and GSCP is considerable. Also meaningful is the critically endangered Harpy Eagle sighting in BNR, as it fits in with the conservation program for this species in the Mayan Mountain Massif (BFREE/Ya'axché Conservation Trust, 2013).

The sighting of Howler Monkeys in GSCP is one of the most substantial findings in the preserve for the last years. The first Howler Monkey observations are being reported in the GSCP area since Hurricane Iris in 2001, which proves the importance of enforcing conservation and tracking wildlife recovery after disturbances (Hofman, 2014).

Table 8. Species sighted during patrolling activities in 2013

		BNR		GSCP	
	Species	# of obs	Avg. group size	# of obs	Avg. group size
Birds	Agami Heron	1	1	1	1
	Crested guan	31	3	4	2.25
	Great curassow	34	2.1	4	1.25
	Great tinamou	15	1.1	4	1
	Harpy Eagle	1	2	-	-
	Ornate Hawk-Eagle	2	1	-	-
Mammals	Agouti	7	1	8	1.12
	Collared peccary	6	2.8	3	3.33
	Howler monkey	12	4.2	1	5
	Jaguar	1	1	2	1
	Neotropical River Otter	1	1	-	-
	Nine-banded armadillo	2	1	1	1
	Red brocket deer	5	1.2	1	1
	Spider monkey	46	5	-	-
	Tapir	2	1	-	-
	White-lipped peccary*	7	-	-	-
	White-tailed deer	5	1	2	2
Reptiles	Central American Snapping Turtle	-	-	1	1
	Total # of obs.	**178**		**32**	
	Species richness	**17**		**12**	

**=Only includes the count of herds*

Land snails

Since 2012, aside from the first test plot established to familiarise our rangers with the methodology, seven more plots have been established. The first two plots; AL (Plot A-Low) and AH (Plot-A High) were set up near the Belize Foundation for Research and Environmental Education (BFREE). The next plots in 2012 were BL-BH and CL-CH, and these were set out in the Richardson's Creek and Quebrada de Oro near Bladen River (see Figure 8). In 2013, the next pair of plots was intended to be established, but for unforeseeable reasons, the expedition had to be cancelled and only samples from one of the plots could be extracted. Plot DL was set up near Jaguar Trail, at the foothills in northern GSCP (Figure 8).

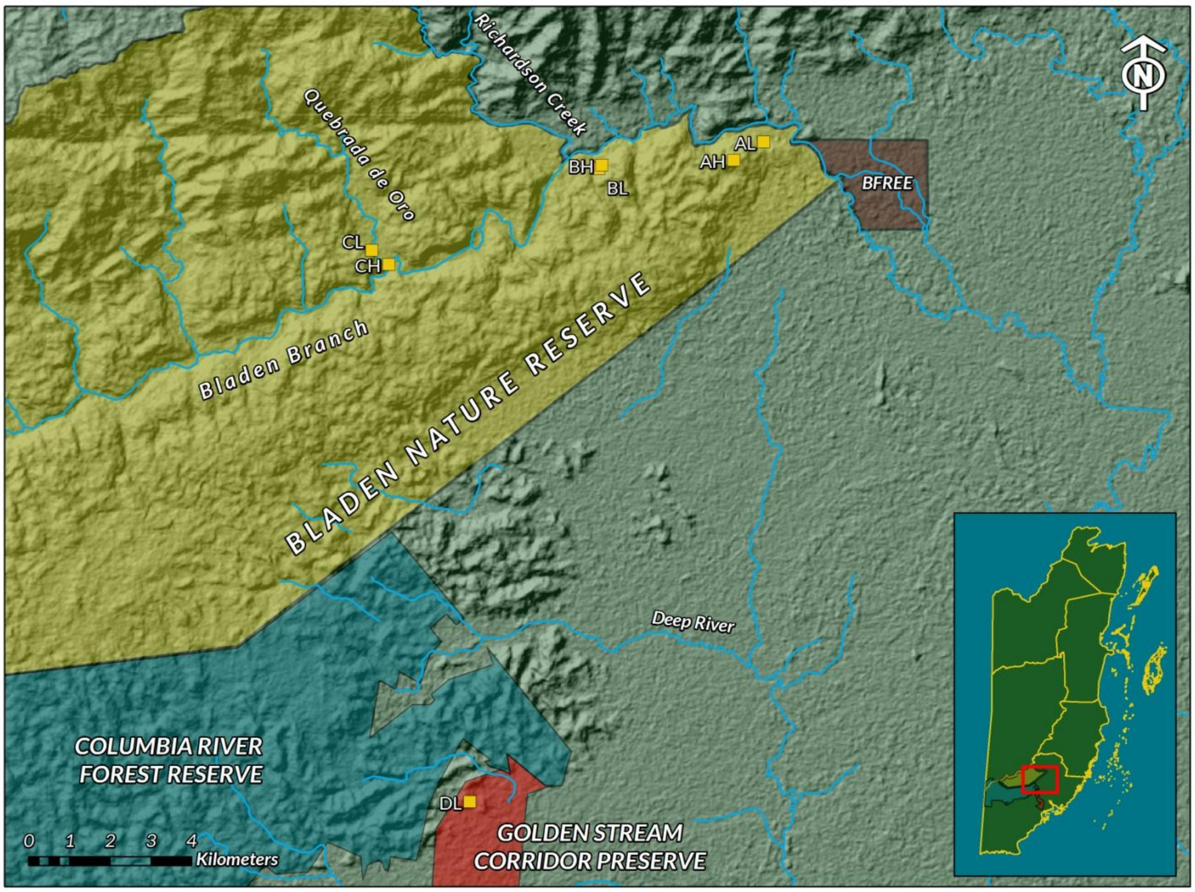

Figure 8. Location of the snail monitoring plots (represented in yellow squares) set up in 2012 and 2013 in Bladen Nature Reserve.

After training with the snail specialists, our rangers were able to adequately complete sample extraction and data collection, but identification skills are still lacking and therefore the complete set of data will not be presented in this report. However, further identification training will be completed in 2014 and consequently all year's data will be accessible in the next Annual Biodiversity report.

From the seven plots already established in Bladen, our rangers collected 69 samples from random subplots; 9 subplots on CH and 10 subplots in the rest of the plots. The subplot missing in CH was lost during the expedition. In these samples a total of 1199 individuals were collected of which our rangers recognised at least 50 species. However, some of the samples were also analysed by snail specialist Dan Dourson (BFREE), and when cross-checking the data-set with the snail samples that where identified by our rangers, an overestimation by our rangers of species number was identified. Our rangers identified 39 species in these plots whereas Dourson identified 31 species, which indicates an overestimation of 20%. The disparity was considered too great to consider the species ID data-set valid and for this reason the data will not be included in the report. As explained in the methodology section, additional bags where collected on each plot from promising locations. A total of 24 bags where collected from all the plots with 391 individuals and our rangers recognised between 10 and 20 different species in each bag.

Additionally, as a result of the land snail monitoring efforts, three new species of snail have been discovered (Figure 9). One of them, *Eucalodium belizensis*, was officially described by Thompson *et al*. (2013); the others are awaiting official description.

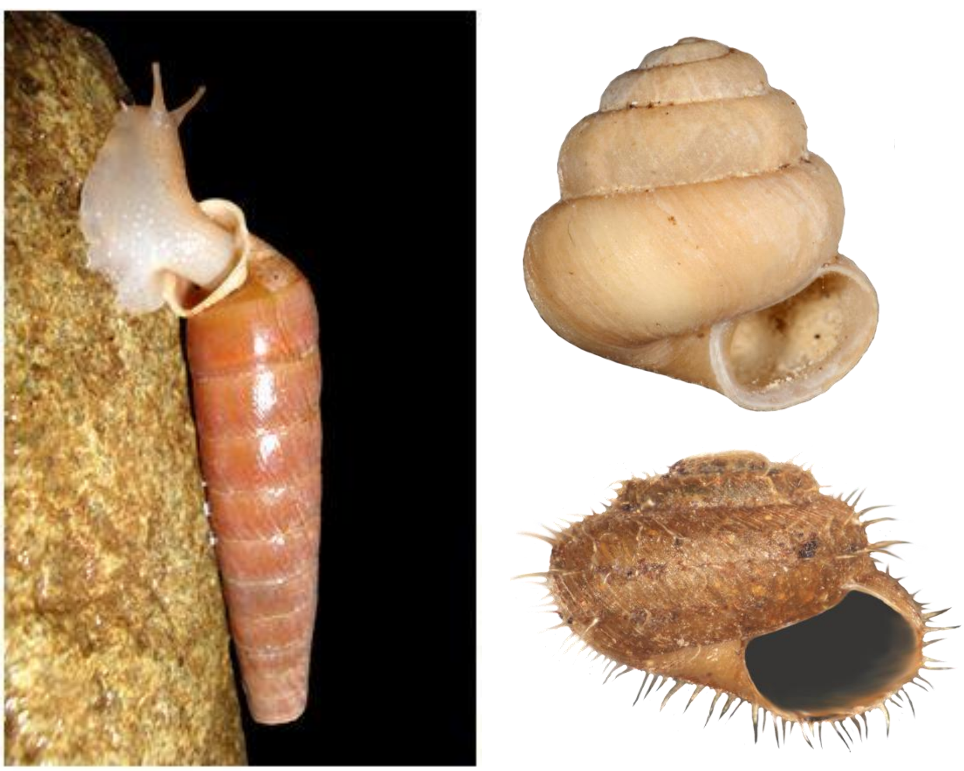

Figure 9. New species found in our snail plots that were never previously described. Left; *Eucalodium Belizensis*. Top Right; *Micronconus* species. Bottom Right; The Hairy Phora (*Thysanophora* species) Photo credit: Dan Dourson

Weather

2013 was a better year in terms of manual data collection. Bladen ranger base and Golden Stream Field Centre had 93.42% and 94.8% respectively of yearly data coverage, as opposed to last year's 77.6% and 90.2%. For more information on missing data see Appendix C.

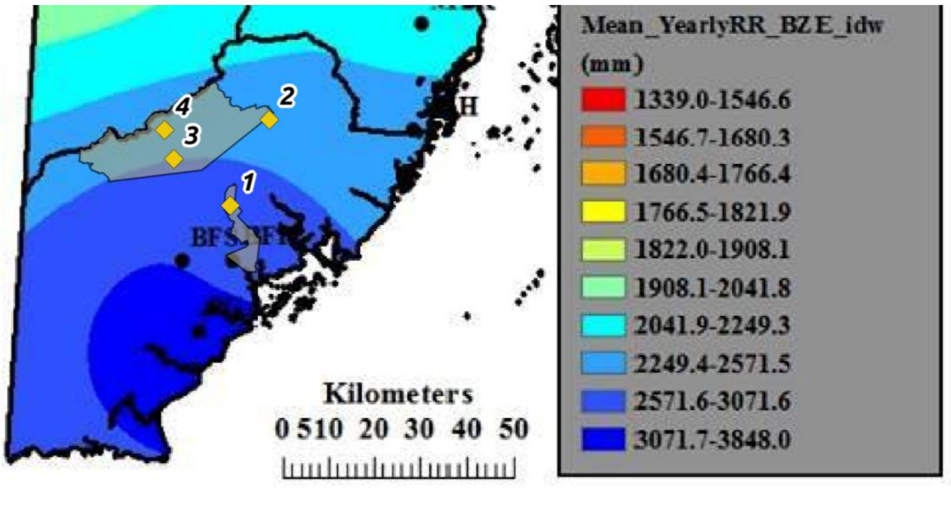

Figure 24. Detail of the mean rainfall map presented earlier (Figure 4 on p.19)

Bladen Nature Reserve ranger base

In 2013, a total of 341 days of rainfall data were recorded 93.42% and totalled an annual rainfall of 2561.7mm. The total amount of rainfall registered in 2013 is consistent with the average rainfall values in the last decades for that region (see

Figure 2). The rainfall pattern throughout the year is also as expected, with low levels of rain during the dry season and considerably wetter the rest of the year (see Figure 25).

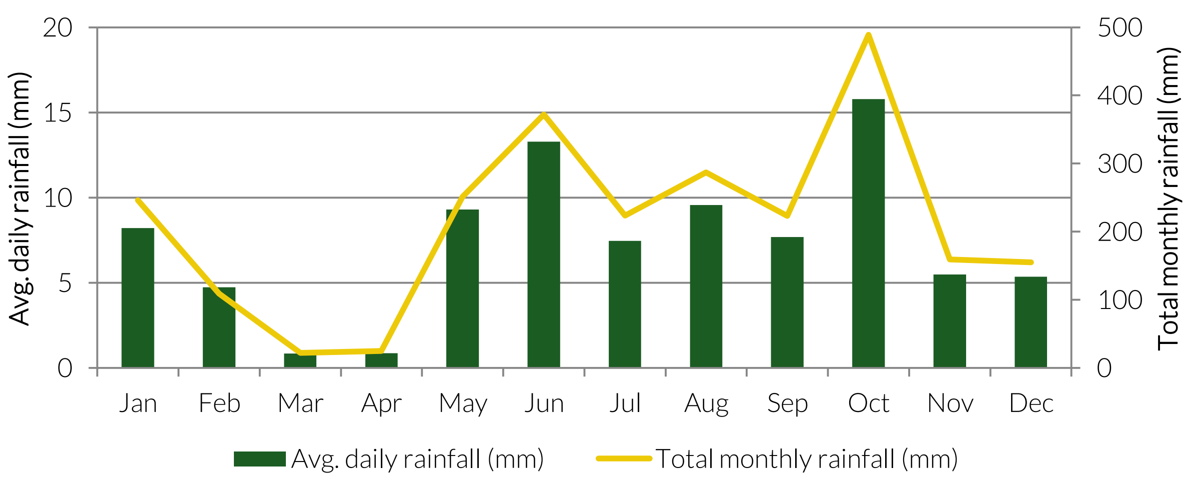

Figure 25. Bladen ranger base rainfall patterns throughout 2013

Golden Stream Corridor Preserve field centre

In 2013, a total of 3081.1mm of rain was registered at the Golden Stream Field Centre. There were 19 days of data missing for rainfall and 28 days of data missing on humidity and temperature. Hence, the amount of rain was distributed along 346 days or 94.8% of the year. The total amount of rainfall registered in 2013 is slightly higher as compared with mean rainfall values in the last 60 years on that area (see

Figure 2). Additionally, in 2013 a pronounced drought can be noticed in Golden Stream during the dry season (Figure 26) as opposed to noteworthy high levels of rainfall during other months.

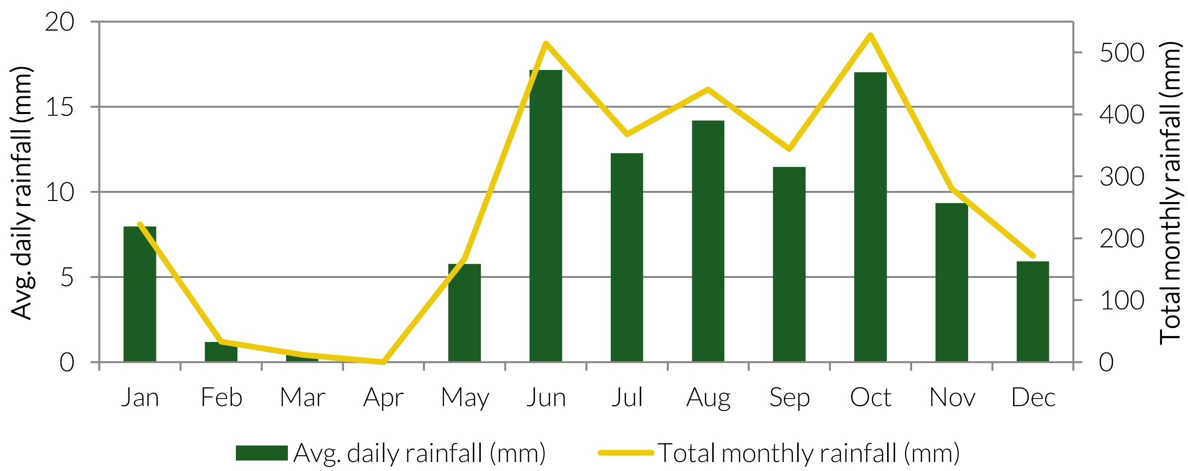

Figure 26. Golden Stream field centre rainfall patterns throughout 2013

Average low and high temperatures and average minimum and maximum humidity for both Bladen Ranger Base and Golden Stream Field Centre are presented in Table 1 and 2 in Appendix D. Raw data is available on request.

<u>Esmeralda and Oak Ridge weather stations</u>

As explained in the methodology section, weather stations store 6 months of data and are checked twice a year to extract data and change batteries. An expedition departed in July 2013 to visit both weather stations but returned with unfortunate results. The Esmeralda station had been positioned in a forest gap in BNR. Despite the fact that deep trenches surround and cross close to the station's location, the area presumably flash-flooded on the 7th of June 2013 and damaged the weather station's data logger. Additionally, the temperature and relative humidity sensor was irreparably damaged by a burrowing insect (presumably a wasp). The damaged sensor and logger were removed from the field, sent to

the manufacturer for repairs and were brought back to Belize in November 2013. The data logger stored data from November 2012 to June 2013 (
Figure). Results obtained indicate a decrease in rain during the dry season, the total monthly rainfall recorded was similar to the one recorded in BNR ranger base. The station will be reinstalled in March 2014.

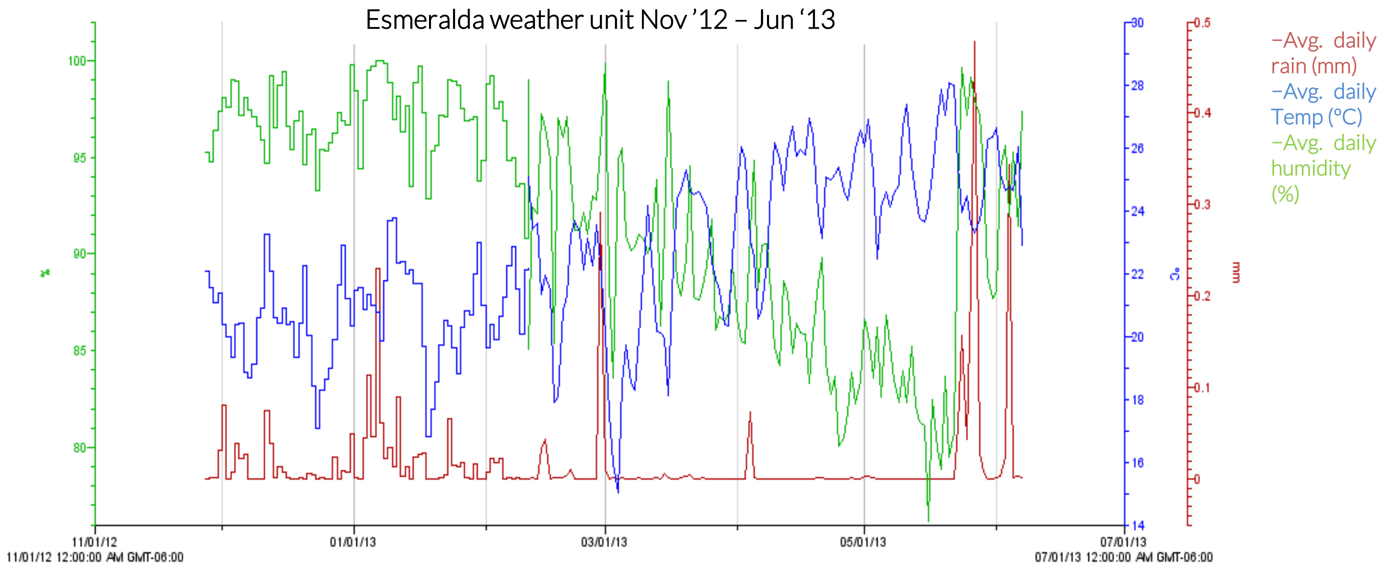

Figure27. Rain, temperature and relative humidity data extracted from the Esmeralda weather station.

The Oak Ridge station was visited during the same expedition, however when the team reached the location, they found that the entire weather station had been removed. From signs in the field, the team estimated that the unit had been removed three months prior to the visit, presumably by Xateros (harvesters of Xate palm leaves) coming into Bladen from the north side of the Main Divide from the direction of a gold mining area. The loss of this very valuable piece of equipment illustrates the severity of the illegal incursions of Xateros in Belize's protected areas.

Fire

The use of fire (slash-and-burn) is a widespread method to clear land for farming among the Q'eqchi' Maya population of rural southern Belize. The satellite pictures of the MGL obtained throughout 2013 identified a total of 200 agricultural fires, with an average size of 6.08 acres and a total of 1,216.85 acres (Standard Deviation, σ=7.70). Figure shows that 98 fires occurred in areas previously used for agriculture (σ=9.84). 102 fires took place in forested areas (σ=4.78), and 32 of these where located in protected areas (σ=3.37), mainly in Deep River Forest Reserve.

Additionally, large areas of escaped fires were recorded in both areas previously used for agriculture and forested areas. They sum 14 in total and account for a total area of 1,584.31 acres (σ=150.32). Four incidents of fire occurred in protected areas (1,114.56 acres, σ=159.97), most of them within CRFR boundaries.

As a consequence of the extended dry season in 2013, the results this year vary greatly from the ones in 2012. In total, 2,752 acres were burned in the whole MGL, which amounts to 0.9% of the MGL, as opposed to the 298 acres burned (0.1%) during 2012.

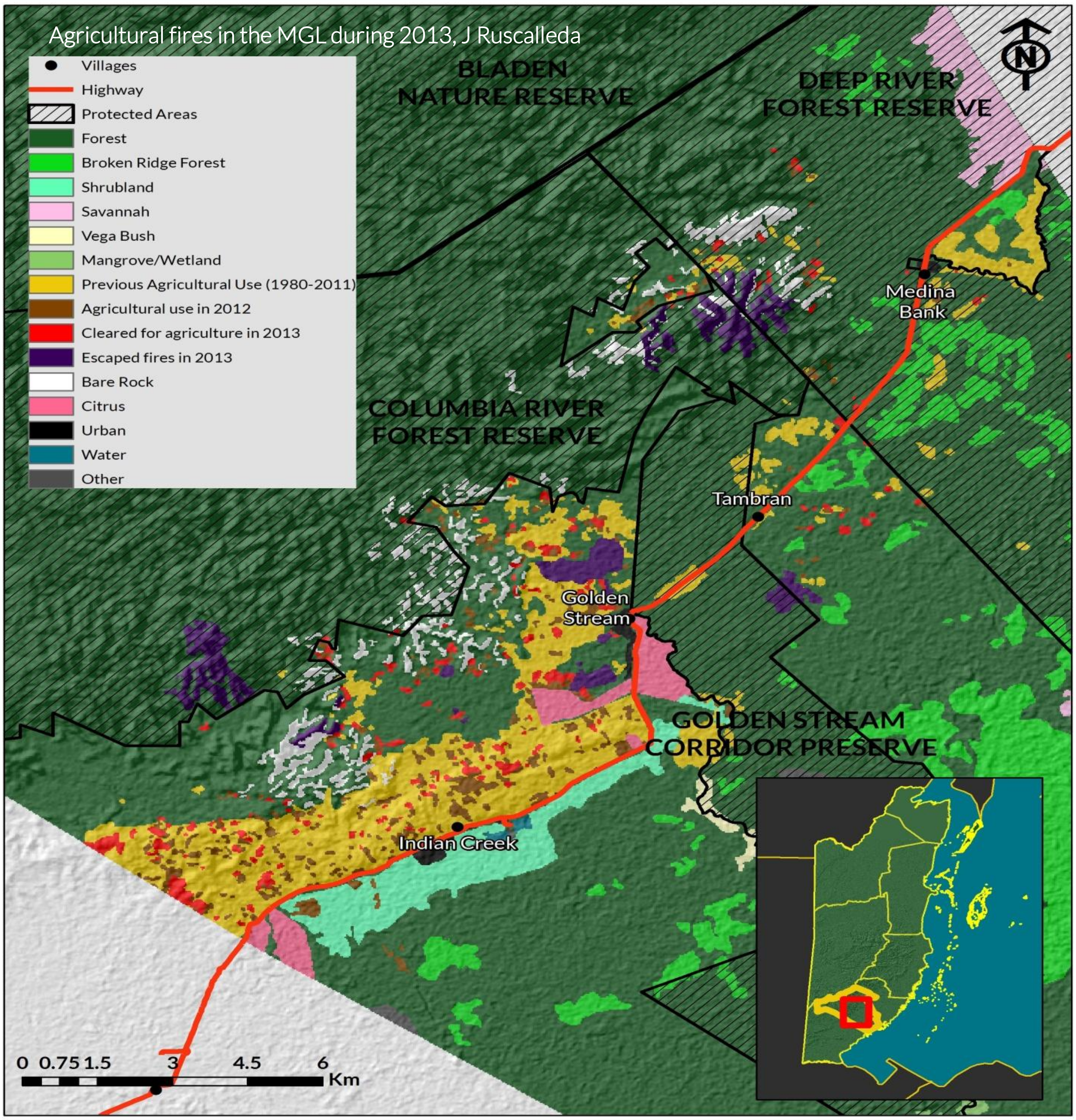

Figure 28. Location and size of agricultural fires in the MGL during 2013

Conclusions

In 2013, we have maintained the trend to increase efforts in biodiversity monitoring. We completed just over the amount of kilometres of transects that were walked last year. Additionally, the components that were added to our monitoring programme are developing and improving to enable us to obtain more reliable data. Bat monitoring efforts have increased by four times as compared to the last two years, and weather data collection has been more consistent. We noticed that the observed patterns are similar throughout the years and follow an outline we expect, indicating our monitoring approach is not been affected by inaccuracies. However, at Ya'axché we are aware that there are still areas in need of examination for increased data improvement and therefore we are still learning from the field and working on designing a Monitoring Program that will collect long-term, high quality data for future reference.

Birds – In 2013, the Savanna transect was more target species rich than the average forest transects, however, we understand that the openness of the Savanna and Village land can affect species detectability, and that using an average to compare the forest transects can result in a more moderate vision of total forest target species richness. Looking at individual transects, BNR3, BNR2 and CRFR2 were the ones that held more target species richness. However, when weighting dominance, BNR3 was the most affected by dominant species indicating less diversity. When looking at indicator species, remarkably few game species were detected in Village lands and GSCP transects. However, some Crested Guans, Great Curassow and Great Tinamous were recorded by our rangers during their daily patrols. Regarding Forest health indicators, GSCP transects are the most disturbed due to low levels of forest indicators encountered and higher number of disturbance indicators. Among the forests, BNR3 and CRFR3 are the least disturbed.

The wildlife sightings records also showed greater diversity in BNR than in GSCP.

Large mammals – As with the data collected for birds, we saw that overall more target species were found in forest transects, but on average forest transects had less target diversity than the savanna. The Village lands transect had the lowest target species. The transects with highest target species richness were BNR2, GSCP1-2-9 and BNR3, but when comparing diversity profiles, BNR2 and 3 are heavily affected by species dominance. Comparing indicator species we saw that opposed to bird species, most mammals in Village lands were game indicators. This is due to the high number of Agoutis and Nine-banded Armadillos observed. These two species appeared in high densities in last year's report too and in higher rates in Village lands than in forest transects. This provides further evidence for the 'meso-predator release effect': due to human disturbance (top-predator), the presence of the meso-predator (e.g. jaguar & puma) decreases in the village lands, which leads to increased numbers of its prey species (armadillo, agouti and collared peccary) aggregating there. They in turn form a higher potential game source for the top-predator (hunters in the village). Conversely, Paca had low encounter rates in Village lands and Collared Peccary, which last year appeared as scarce in this habitat, has a higher appearance rate than in forests. The latter might be because collared peccaries are known to raid crops and are likely to be attracted to the high density of food in the village lands. In regard to forest health indicators, more individuals were recorded in the Savanna than in the forest, but species from the forest recorded in Savanna may be due to the openness of this habitat which makes sightings easier and sounds from the forest travel further. Additionally, camera traps showed a good diversity of mammals in all protected areas. The most significant recordings where the Coatimundis and Jaguarundis that appeared in GSCP2 and CRFR4, indicator species that were not recorded during transects, and the presence of White-lipped peccaries in southern GSCP.

Last but not least, in 2013 our rangers made an observation during a patrol that proves the importance of our work preserving the Biological Corridor; a group of five Howler Monkeys in GSCP – an area where this species has been absent since Hurricane Iris in 2001.

Bats – As a result of extended monitoring effort, this year a total of 17 bat species were identified, as opposed to 13 species in the previous year. Two of the species recorded last year were absent in 2013 (Argentine brown bat and Black-winged little yellow bat), but six bat species that did not appear on last year's results were documented this time round. Si nce we began monitoring with the Anabat unit we have only detected 4 families. As in previous years, the savanna is notably more species rich than any other transect. However, other studies have suggested that the use of passive methods to detect bats such as the Anabat unit is biased to open areas. Additionally, the biology of certain species (i.e. bats flying above canopy and leaf-nosed bats) also affects the detectability of many species by the Anabat unit. As seen in results of CRFR versus GSCP and BNR, with more survey effort expected in the following years and studying the biology and habitat of certain species such as the Common moustached bat, bat data extracted can provide us valuable information of the quality of the area the bats are found.

Snails – After starting the snail monitoring in 2012, our rangers have proven good skills of data collection and sample manipulation. In total, seven plots have been set up, a great amount of data has been collected but snail identification skills were still not sufficient to include any results in this report. However, three new species have been discovered in the plots; one of them, *E. belizensis*, has been officially described (Thompson *et al*., 2003).

Weather – This year we have improved the accuracy and consistency of the data collected leading to more meaningful and reliable information. The most significant output from our monitoring is the pronounced drought registered in Golden Stream.

Fire – The results obtained this year differ greatly from the ones we had in 2012. The pronounced drought during 2013 dry season resulted on alarming data on cleared land and escaped fires, especially in protected areas. The fire risk depends greatly on the weather, which varies every year and hence the difference between this year and last. Significant efforts by Ya'axché to train and equip community-based fire fighting groups are underway in an attempt to reduce the number and size of escaped fires in years with dry conditions such as 2013.

Recommendations

This section includes suggestions to improve data collection and analysis in the biodiversity monitoring programme. Every year our monitoring programme is subject to continuous change as a result of new priorities, new ideas, field techniques or even financial limitations. Although the Biodiversity Research, Inventory and Monitoring strategy was designed for long-term wildlife monitoring it can be improved and adapted as necessary.

Birds and large mammals – As stated throughout this report, we found that the number of transects per month during 2013 was somewhat erratic. In addition, the ranger team needs further training to improve their data-entry skills so that duplicated data and other mistakes are avoided in the future. Furthermore, the data collected in transects contain valuable information which can be used for additional analysis, such as Generalised Linear Models to examine how different factors affect biodiversity data. An analysis of trends of encounter rates could also provide an approximate proxy of population estimates. Finally, the BRIM would need to be revised addressing the new needs of the monitoring programme such as the revision of indicator species.

Additionally, camera trap data should be sent to our collaborating partner Panthera in order to establish a minimum Jaguar population estimate for the MGL.

Bats – Although this year's survey effort has been markedly increased, more consistency is needed in the data that is being collected. The amount of nights and survey locations where the Anabat unit is being deployed needs to be more even throughout transects; some transects in GSCP and CRFR have only been surveyed once in the whole year, whilst others have been monitored for four nights. Additionally, many bats, like birds, are highly seasonal and to increase the probability of recording more species, deployment of the Anabat unit must be distributed evenly throughout the year. On the other hand, additional information should be collected when deploying the Anabat unit, such as weather data on the night the Anabat unit was deployed, since rainy and windy nights can affect bat activity levels.

Monitoring bats using the Anabat system has proven to be cost and labour efficient, however the system is unable to detect many species such as leaf-nosed bats (Phyllostomidae). Phyllostomic bats have been previously used as indicator of habitat disruption (Fenton *et al*., 1992; Castro-luna *et al*., 2007). Therefore, it would be more informative to include supplementary survey methods to the Anabat system such as mist-netting, harp-trapping and radio-tracking. There is great potential for the development of a research proposal that will expand and improve Ya'axche's bat monitoring programme.

Snails – In general, our rangers follow the methodology of data extraction in the field correctly, however, snail taxonomic identification skills are still lacking. In 2014 the snail expert Dr Ron Caldwell is scheduled to provide further training for our rangers, which will be a great opportunity for our rangers to expand their skills. For more consistent results, we should focus on training our rangers to accurately identify snails to family or genus level, as this would reduce mistakes and misidentification rate. Additionally, in order to improve data entry and extraction, a MS Access database should be designed.

Weather – In order to continue to see the improvements in data collection that we have seen this year it will be crucial that data collected from both manual weather stations continues to be recorded on a daily basis. Esmeralda weather station has to be reinstalled in an area where we can be relatively certain that the device will not be threatened by flash-floods.

Fire – The work on quantifying the number and coverage of fires in protected areas needs to be continued, including accounting for the quality of the fires, to see whether fires occur in forested areas or land previously used for agriculture, or to distinguish between escaped and controlled fires. This information together with the weather data, can in the long-term be used for enforcement in conserving the biological corridor, or when designing climate change adaptation policies.

Acknowledgements

To the numerous organisations and persons that have contributed to this piece of work, we are extremely grateful. We cannot list the numbers that have contributed to this area of work at Ya'axché, but we attempt a list of the main supporters and contributors, in alphabetical order:

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- The Protected Areas Conservation Trust (PACT)
- PACT Foundation
- Panthera
- Dr. Ron Caldwell at Lincoln Memorial University – Cumberland Mountain Research Centre
- Shajini Jeganmohan
- Dr. Steven Brewer (BFREE and Copperhead Consulting)

We look forward to maintaining and developing these collaborations and partnerships in the future.

Appendix A (Transects)

Transect Name	Length (m)	Area	Land administration	Disturbance	Ecosystem
BNR2	1000	Bladen	Nature Reserve	Minimal	Primary forest on karst hills
BNR3	1000	Bladen	Nature Reserve	Minimal	Lowland savanna with pine
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
GSCP9	1000	Golden Stream	Private Protected Area	60-75% hurricane damage (2001); proximity of agriculture	Secondary forest along riverside in coastal plain
IV1	1000	Indian Creek	Community lands	60-75% hurricane damage (2001); proximity of highway and agricultural clearings	Mosaic of farms, secondary forest and residential

Table 1. Transect information (Hofman, 2013)

Return to Transect methodology

Sum of Number of individuals	Transects										
	BNR2	BNR3	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	GSCP9	IV1	Total
American Redstart	18	19	17	14	4	14	10	23	18	16	153
Black and White Warbler	5	3	1	2		3	4	2		1	21
Brown-hooded Parrot	28	3		11	11	5	1				59
Common Yellowthroat	11	12	1			2	4	2	4	10	46
Crested Guan	6	4	1	14	3	4					32
Grace's Warbler		21									21
Great Curassow	15	2	1	1	2						21
Great Tinamou	26	3	3	7	3		1				43
Hooded Warbler	11	3	5	10	10	10	8	15	10	21	103
Keel-billed Motmot		1		2	1	6					10
Keel-billed Toucan	4	10	14	8	15	8	7	6	3	3	78
Kentucky Warbler	7	2		4	7	6	7	3	5	7	48

Little Tinamou	15	8	10	6	14	13	13	8		15	102
Louisiana Waterthrush	2							1		1	4
Magnolia Warbler	10	2	2	3		9	5	16	7	20	74
Northern Waterthrush	1	1	1	12		1	1	18	10	3	48
Plain Chachalaca	1	22	24	18	16	16	5	37	34	73	246
Prothonotary Warbler									1		1
Slaty-breasted Tinamou	44		9	14	7	7	1				82
Swainson's Warbler							1		2		3
Wood Thrush	46	3	7	24	2	9	4	41	11	30	177
Worm-eating Warbler									1		1
Yellow-headed Parrot		77			8			6			91
Grand Total	250	196	96	150	103	113	72	178	106	200	1464

Table 2. Total observed bird individuals in 2013

Return to Bird results

Sum of Number of individuals	Transects										
	BNR2	BNR3	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	GSCP9	IV1	Total
Agouti	4			1	2	3	3	6	3	16	38
Baird's Tapir	5	2	3	8	1	8	5	8	8		48
Brown Brocket deer	1		1								2
Collared Peccary	1		5		2	1	2	6	4	4	25
Black Howler Monkey	9	14						2	3	1	29
Jaguar	7	9	6	6	7	3	5	5	2		50
Margay		3	1				1	1			6
Nine-banded Armadillo	2	8	2	11	6	2	3	7	3	10	54
Ocelot	1								3		4
Paca	8	5	2	6	2	6	1	4	5	1	40
Puma							1				1
Red Brocket Deer	4	2		2		1	1	3	1		14
Spider Monkey	69	26			2						97
White-lipped Peccary	100				50						150
White-tailed Deer		7					1			1	9
Grand Total	211	76	20	34	72	24	23	42	32	33	567

Table 3. Total observed mammal individuals in 2013

Return to Large Mammal results

Appendix B (Camera traps)

	BNR CAMERAS				CRFR CAMERAS		GSCP CAMERAS							
	BNR2	BNR3	BNR I	BNR II	CRFR3	CRFR4	GSCP 1	GSCP 2	GSCP 4	GSCP I	GSCP II	GSCP III	GSCP IV	GSCP V
Agouti	3		1	1		15			1	1	3	1		
Armadillo			2											
Bat	1		3	1		1	1	1			3	5		4
Coatimundi						1		1						
Collared Peccary						5			2					
Currasow			5	5	2	1			4					
Gray Fox												1		
Great Tinamou	1		1											
Jaguar	1	7	3						1			2		
Jaguarundi						2								
Ocelot			3			1			2		1			1
Opossum			1			1								
Paca					1	1					1			1
Puma	2		1		2	10		4	1	2			1	
Racoon											2			
Red-brocket Deer	2	2	2	10					3			6		
Tapir				2		3			14		1	2		
Tavra						3								
White-lipped peccary	46		3		11			9						
TOTAL	56	9	25	19	16	44	1	15	28	3	11	17	1	6
Sp. Richness	7	2	11	5	4	12	1	4	8	2	6	6	1	3

Table 1. Total Panthera camera trap captions (count of individuals) in 2013 per location.

Return to Camera Trap Results

Appendix C (Bats)

Common name	Scientific name	Family	Diet	Habitat and behaviour	IUCN(*)
Mexican dog-faced bat	Cynomops mexicanus	Molossidae	Insects	This species can be found in deciduous and evergreen forest and clearings, often near water.	LC
Northern yellow bat	Lasiurus intermedius	Vespertilionidae	Insects	Found in coniferous and broadleaf forest and dry thorn scrub. Usually forage 3-4m above ground level in grassy areas.	LC
Pallas's mastiff bat	Molossus molossus	Molossidae	Insects	Found in urban areas. Forage in open areas, above tree canopies, forest edges and around streams and ponds.	LC
Black mastiff bat	Molossus rufus	Molossidae	Insects	Found in tropical deciduous forests, evergreen, shrubs and secondary vegetation.	LC
Peter's Ghost-faced bat	Mormoops magna	Molossidae	Insects	Occurs in specialised roosts in deep caves of karstic regions, this habitat is very rare.	LC
Elegant myotis	Myotis elegans	Vespertilionidae	Insects	Can be found in deciduous and evergreen lowland forest and openings. Its biology is poorly known.	LC
Hairy-legged myotis	Myotis keaysi	Vespertilionidae	Insects	It inhabits a wide range of forest types, from dry scrubland to tropical wet forests. Its biology is poorly known.	LC
Greater dog-like bat	Peropteryx kappleri	Emballonuridae	Insects	It prefers wet forests, marshes and swamps, but can tolerate dry conditions so is also associated with savannas.	LC
Lesser dog-like bat	Peropteryx macrotis	Emballonuridae	Insects	Most common in seasonally dry areas with limestone caves. Also found in semiarid scrub, wet forest, croplands and grasslands.	LC
Davy's naked-backed bat	Pteronotus davyi	Mormoopidae	Insects	It shows a broad tolerance for habitat types but usually occurs in dry forests. Often forages over water and open areas.	LC
Big naked-backed bat	Pteronotus gymnonotus	Mormoopidae	Insects	Usually found in lowland tropical wet forests and savannas.	LC
Common moustached bat	Pteronotus parnellii	Mormoopidae	Insects	Abundant in all types of lowland forest, also at middle elevations and in disturbed areas. Commonly uses forest-trails to commute and forage.	LC
Yucatan yellow bat	Rhogeessa aeneus	Vespertilionidae	Insects	This species is poorly known. Found in lowland tropical perennifolious and deciduous forest.	LC
Greater white-lined bat	Saccopteryx bilineata	Emballonuridae	Insects	Common in lowland evergreen and semidecidious forest and forest edge. Rare in dry deciduous forest.. Forage near streams and forest clearings.	LC
Lesser white-lined bat	Saccopteryx leptura	Emballonuridae	Insects	Uncommon to locally common in lowland deciduous and evergreen forest. Forage in the forest subcanopy early, then move above canopy later at night.	LC

Table 1. Basic information of bats registered by the Anabat unit in 2013. Information extracted from Reid (1997) and IUCN (2013). (*)Protection status according to the IUCN Red List of protected species. Return to Bat Results

Appendix D (Weather)

	Avg. daily rainfall (mm)	Total monthly rainfall (mm)	Average low temp (°C)	Average high Temp (°C)	Average min humidity (%)	Average max humidity (%)	Days data missing
Jan	8.2	246.00	20.5	36.6	57.37	87.13	1
Feb	4.74	109.00	20.7	40.5	43.96	82.06	5
Mar	0.85	22.00	19.3	40.9	40.50	79.08	5
Apr	0.86	25.00	22.6	42.4	41.31	78.83	1
May	9.30	251.20	21.9	39.3	43.57	80.94	4
Jun	13.29	372.00	25	38.1	50.71	84.32	2
Jul	7.45	223.50	25.5	38	47.62	81.34	2 (1 in rainfall)
Aug	9.57	287.00	24.3	40.2	48.17	80.80	2 (1 in rainfall)
Sep	7.69	223.00	24.1	38.9	52.33	80.60	0 (1 in rainfall)
Oct	15.77	489.00	24.4	38	56.27	85.53	1 (0 in rainfall)
Nov	5.48	159.00	22.5	38.8	52.57	83.83	1
Dec	5.34	155.00	21.8	35.8	54.77	84.77	1 (2 in rainfall)
TOTAL		2561.7					25 (24 in rainfall)

Table 1. Average daily rainfall, low and high temperatures and average minimum and maximum humidity as recorded in Bladen Ranger Base weather station including the number of days data was not collected.

Return to Weather results

	Avg. daily rainfall (mm)	Total monthly rainfall (mm)	Average low temp (°C)	Average high Temp (°C)	Average min humidity (%)	Average max humidity (%)	Days data missing
Jan	7.96	222.80	21	29.6	66.82	88.96	3
Feb	1.18	33.00	21	31.5	55.00	88.74	1 (0 in rainfall)
Mar	0.43	11.60	20	32	47.08	83.27	7 (4 in rainfall)
Apr	0.00	0.00	22.8	36.6	42.61	79.61	12 (7 in rainfall)
May	5.76	167.00	23.5	36.8	41.59	79.24	2
Jun	17.16	514.80	24.3	34.8	54.07	86.60	0
Jul	12.27	368.00	24	33.4	54.90	88.43	1
Aug	14.19	440.00	24.3	32.4	55.19	87.87	0
Sep	11.47	344.00	24.1	35	58.37	87.61	0
Oct	17.03	528.00	24.5	33.7	65.91	89.29	0
Nov	9.34	280.20	23.2	31.6	62.13	88.97	0
Dec	5.92	171.70	22.2	30.6	81.44	90.07	2
TOTAL		3081.10					28 (19 in rainfall)

Table 2. Average daily rainfall, low and high temperatures and average minimum and maximum humidity as recorded in Golden Stream weather station weather station including the number of days data was not collected.

Return to Weather results

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