Biodiversity Synthesis Report
2014

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Rosendo Coy, Indian Creek village
Victor Bonilla, Indian Creek village
Vigilio Cal, Golden Stream village

And supervised by

Marchilio Ack – Head ranger
Lee McLoughlin – Protected Area Manager

Cover photo: American redstart (Kevin Wells)

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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
DBH	Diameter at breast height
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
REA	Rapid Ecological Assessment
SP	Species Richness
PSP	Permanent Sample Plot for vegetation monitoring
Ya'axché	Ya'axché Conservation Trust

Summary

Ya'axché Conservation Trust is a Belizean Community-based NGO that works to protect the watershed of the Maya Golden Landscape, a 770,000 acre mosaic of public and private protected lands and communities within. Ya'axché manages The Golden Stream Corridor Preserve (15,000 acres, private) 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 in the environment and track the effect of unsustainable human activities. The intention of this monitoring is to inform our conservation actions. Initially the Biodiversity Monitoring Program only included bird and mammal transects, 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. Methods include point, transect and plot sampling in the field, digital data management and digital analysis using GIS, covering the entire Maya Golden Landscape.

In 2014, we have increased transect monitoring effort as compared with the previous two years and our analysis continues to develop and yield results which influence our conservation actions. We recorded two new bird target species. Village lands were less target species rich than forested lands and the proportion of forest health indicators gradually decreases as the habitat gets more disturbed. Observations during patrols and from camera traps show a good abundance and diversity of species, with a tendency towards higher diversity in the less disturbed areas. Interesting mammal observations include all five of Belize's wild cat species recorded in transects, a Tamandua captured on a camera trap and the maintenance of the recovering Howler Monkey population in Golden Stream Corridor Preserve.

Bat monitoring was halted in October by a failure of the equipment. Data gathered up to this point showed that unlike other years bat diversity was higher in BNR2. In addition, a species listed as vulnerable by IUCN was detected. To increase bat data quality, Ya'axché has obtained a new bat detector and a new bat monitoring protocol will be implemented after 2015.

Data collection from the weather stations in both Golden Stream field station and Bladen ranger base has been consistent throughout the year. Records have shown a milder dry season in 2014, which probably contributed to a decrease in escaped fires. The automated weather station in Esmeralda suffered water damage from a heavy flood and data could not be downloaded to be included in this report.

This year we have not included data from land snail monitoring plots but we have included road traffic monitoring and wildlife road crossing records. In addition, we have presented the results from the vegetation Monitoring plots in the Bladen Nature Reserve, in which preliminary analysis indicated one of the highest number of tree species in all of Central America.

With the data gathered over the last 6 years, we have established a baseline for many useful indicators, and we have confirmed Ya'axché's ability to maintain and develop a biodiversity monitoring programme. However, we are aware that such a programme is never really completed, and we will continue to build and improve it according to national and international guidelines and adaptive management.

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. Its geographical focus is the Maya Golden Landscape (MGL), which was expanded in 2014 to reflect Ya'axché's growing influence and scope. It encompasses twelve protected areas in Toledo, two of which Ya'axché manages, 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 Cat. 1a), owned by the Government of Belize and co-managed by Ya'axché since 2008.

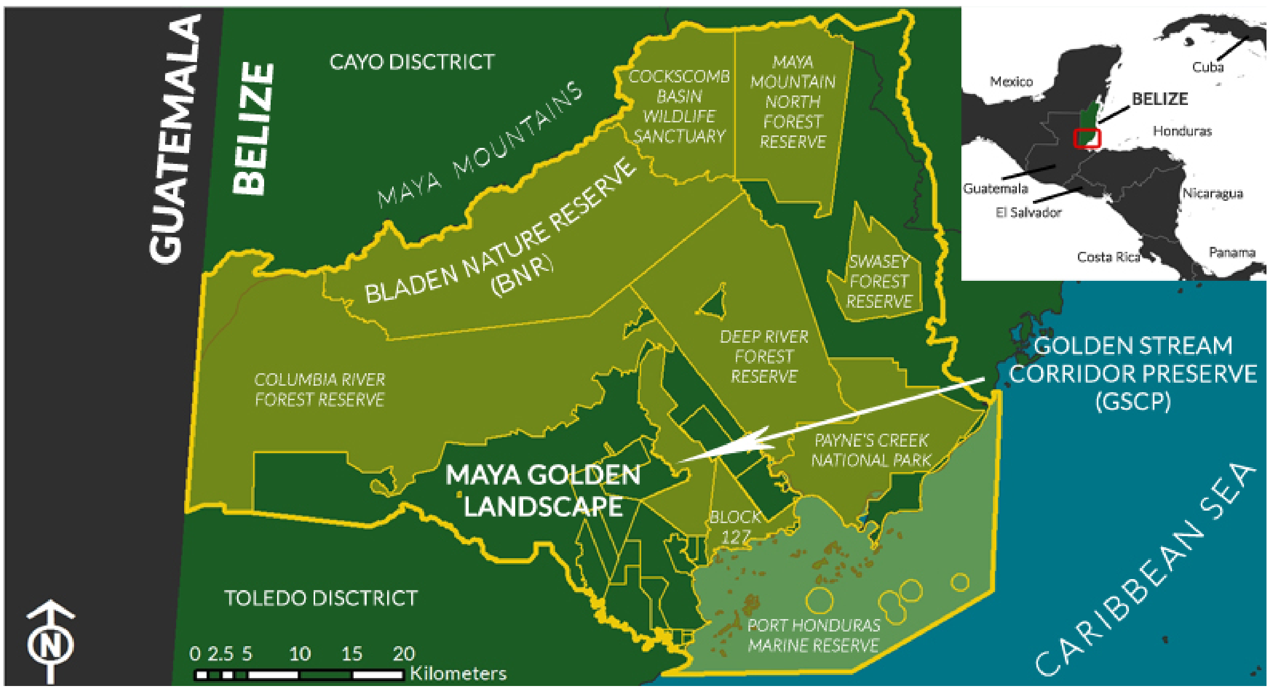


Figure 1. Location of the new Maya Golden Landscape and it's protected areas

Since 2006, Ya'axché has been developing a biodiversity monitoring system to observe possible changes occurring in the natural environment that could indicate unsustainable human activities. When Ya'axché accepted the co-management of the Bladen Nature Reserve in 2008, a Biodiversity Research, Inventory and Monitoring strategy (BRIM) was drafted by Ya'axché, Fauna & Flora International (FFI) and Toledo Institute for Development and Environment (TIDE) as a necessary planning exercise. 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 and 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 trained in freshwater macro-invertebrate sampling and freshwater physicochemical monitoring by Ya'axché's freshwater ecologist, Dr. Rachael Carrie, who also initiated the weather monitoring activities. In 2011, bats were added to the monitoring 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.

Also in 2012, Ya'axché's 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, Ya'axché established a baseline of road traffic density given their potential threat to GSCP's corridor function, and continued collecting anecdotal evidence of highway crossings and casualties.

Finally, the involvement of GIS specialist, Jaume Ruscalleda, has increased Ya'axché's capacity to use remote sensing and satellite imagery to monitor land use and land cover change. One of the main targets of this monitoring is fire. Fire plays an important role in the lives of people in southern Belize. It is regarded as a necessity for successful farming, is used as a hunting technique and to clear vegetation from roadsides. Many people start a fire for these reasons, but are ill-equipped and lack the fire management knowledge to control the fire they started. Escaping fires are therefore one of the main threats to forest and biodiversity conservation in the area. With the inclusion of land-use change monitoring and other abiotic parameter monitoring, we have made a first move towards a more inclusive landscape-scale approach.

As a result, the Biodiversity Research, Inventory and Monitoring programme not only observes changes on species biodiversity in the MGL, but also abiotic components that could affect the former, such as freshwater quality, weather, land-use change and road traffic monitoring.

This report continues the effort made through past 4 years to ensure the fulfilment of the BRIM requirement to report findings annually. This year we have included bird and mammal transects, camera trapping surveys, bat monitoring, wildlife observations, road crossings, road traffic monitoring, vegetation surveys, weather and land-use change. Due to logistical difficulties, we will not include land-snail monitoring.

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 organisations that helped in the fulfilment of this report. 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

As in previous years, transect monitoring in 2014 has involved birds and large mammals as key taxa. Transects are located in and around some of the protected areas in the Maya Golden Landscape (Figure 2), they are transect point counts and sign transects, all 1km in length with stopping points every 200m to observe and listen. Birds were detected using sight and sound cues, while mammals were detected using direct sightings, foot prints and an array of different signs including faeces, smell, sound and scratch marks among others. For both focal groups a previously generated list of indicator species was used and recordings are limited to the selected species (see Table 3 for mammals and Table 4 for birds). These species lists are taken from Ya'axché's BRIM strategy, and adapted to the current lists used in the databases.

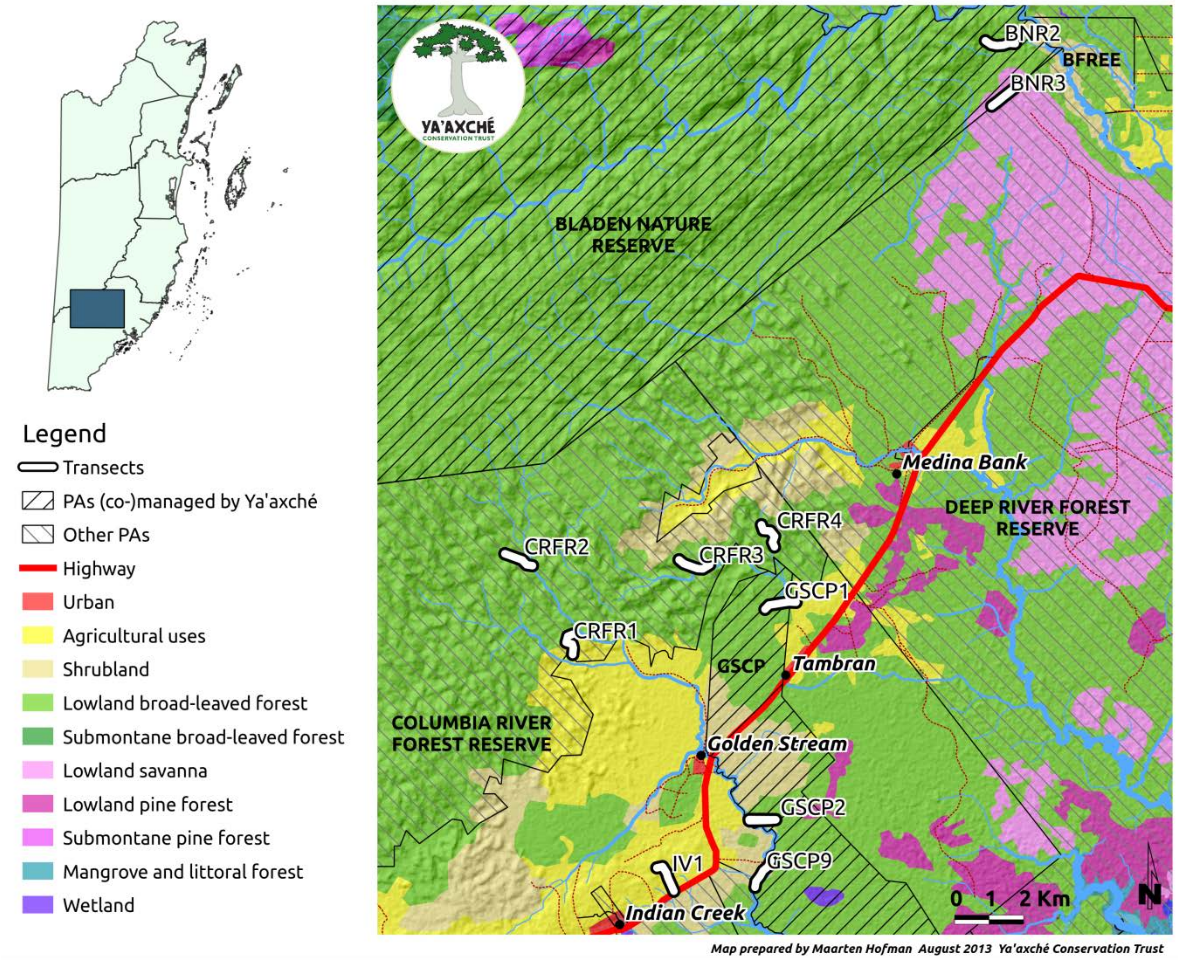


Figure 2. Location of biodiversity monitoring transects

Our target species list is classified in six indicator groups (Table 1), each species in the list indicates a different factor based on their habitat preferences and ecology. This classification taken into account when analysing bird and mammal data and is used to facilitate making conclusions from the monitoring results. For example, the increase in an area of 'Disturbed forest indicators' could indicate habitat degradation, whereas decreased 'Game species' richness could indicate level 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-savannah indicator	Species linked to pine savannah habitats

Species from both mammal and bird lists were assigned to one of the Indicator groups based on respectively the 'Field guide to the mammals of Central America and Southern Mexico' (Reid 2009) and 'Birds of Belize' (Jones & Gardner 2003), and validated by the local knowledge of Ya'axché's field ranger team. Additionally, the bird classification was cross-checked by the author of 'Birds of Belize'. Note that not all species have been classified, indicating that they are rarely recorded, or that they are too much of a generalist species to be allotted to one of the indicator groups.

Not all indicator groups in Table 1 are applicable to the mammals of the Maya Golden Landscape. There are no long-distance 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 will prefer the forest, but can be seen in the savannah). Therefore we assigned all mammals to either Forest health indicators, Game species or Wetland indicators, and a small number were not assigned to any group.

Table 2 shows the distribution of species in the indicator groups and 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%

The tables in the next page present a more detailed species list and in which indicator group each species falls in.

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

Common Name	Class
Agouti	G
Baird's Tapir	W
Brown Brocket deer	
Coatimundi	
Collared Peccary	G
Howler Monkey	F
Jaguar	F
Jaguarundi	D
Margay	F
Naked-tail Armadillo	
Neotropical River Otter	W
Nine-banded Armadillo	G
Ocelot	F
Paca	G
Puma	F
Red Brocket Deer	F
Spider Monkey	F
White-lipped Peccary	G
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
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

The core data collected in transects are the number of species observed and the number of individuals observed per species. The number of transects is 10: four transects in Columbia River Forest Reserve (CRFR 1, 2, 3 and 4), one on the Village lands in Indian Creek (IV1), three in Golden Stream Corridor Preserve (GSCP1, 2 and 9) and two in Bladen Nature Reserve's forest (BNR2) and Savannah (BNR3). The diversity on habitats in our transects makes our monitoring programme to a landscape scale approach. Table 5 contains information about each transect, and a map showing the location of the transects is presented in Figure 2.

Disturbance gradient

Among the transects in forest habitats, a gradient of natural and human disturbances can be observed. The transects in Bladen Nature Reserve are least disturbed and the ones in Golden Stream Corridor Preserve most disturbed. This gradient is not equally prevalent at every transect location and is not quantified other than by calculated damage from hurricane Iris (2001) and the estimated proximity of residential and agricultural areas (see Table 5). *The gradient is thus to be considered a rough approximation of disturbance levels.*

Table 5. Transect information

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 savannah 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

Transect visit schedule

Transects were visited according to a pre-set monthly schedule (Table 6). 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) interfering.

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

Table 6. Transect visit schedule 2014; shaded areas indicate periodic inaccessibility and asterisks show Anabat unit deployment

	Month	BNR2	BNR3	GSCP 1	GSCP 2	GSCP 9	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***	**1**	**6**
	Mar	**1**	**1**	**1**		**1**	**1***	**1***				**6**
	Apr	**1**	**1**		**1***				**1***	**1**	**1**	**6**
	May	**1***	**1**	**1**			**1**	**1***			**1**	**6**
Wet season	**Jun**	**1**	**1***		**1***				**1***	**1**	**1**	**6**
	Jul	**1***	**1***				**1***	**1***			**1**	**5**
	Aug	**1***	**1***		**1**	**1**			**1**	**1**	**1**	**7**
	Sep	**1**	**1***	**1***		**1**	**1**	**1**			**1**	**7**
	Oct	**1**	**1**		**1**				**1**	**1**	**1**	**6**
	Nov	**1**	**1**	**1**		**1**	**1**	**1**			**1**	**7**
	Dec	**1**	**1**		**1**				**1**	**1**	**1**	**6**
Total		**12**	**12**	**5**	**7**	**5**	**6**	**6**	**6**	**6**	**10**	**75**

Data quality

As a result of on-going effort to train Ya'axché field staff on data collection and database management, the quality of the data has significantly improved since the first Biodiversity Synthesis Report was produced for 2010 (Hofman 2012). In addition, following the transect visit schedule and prioritizing it over other activities, allows for a yearly increase of monitoring activities.

Ya'axché has continued running refresher training sessions for the ranger team to enhance data entry skills and field monitoring techniques, which has increased the level of accuracy and detail of their recorded data. As a result, data inconsistencies such as observations without species name or number of individuals observed are virtually eliminated from the database. No observations lacked species name for birds and mammals, and observations that lacked number of individuals in the database were set conservatively to '1'.

With the implementation of SMART, a pioneering software designed for use in protected areas which is used for spatially explicit data entry, a more extensive and detailed data set is expected after 2016.

Data analysis

Data analysis uses the instructions in the BRIM strategy as a starting point, but were mostly built on the progress accomplished over the lasts Biodiversity Synthesis Reports. Analysis was mostly 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 our indicator groups between different habitats (savannah, forests and village lands) as we did in the last two biodiversity reports (Gartzia, 2014; Hofman, 2013).

Actual number of observed species (Target Species Richness)

The actual number of species observed or the target species richness is the simple illustration of the total actual biodiversity of the ecosystems. It is calculated for every transect on which at least one individual of the target species was observed. 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 visualize the Effective Number of Species calculated from the different diversity indices (Target species richness [R], Shannon's index [*H*] and Simpson's index [λ]).

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 many times it was detected, and thus doesn't 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. Simpson's 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 Simpon'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, 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).

Rarefaction curves

Since transects have an unequal 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.

To take this into account, we make use of rarefaction curves (Gotelli & Colwell 2001; Magurran 2004) that allows to compare species accumulation between transects at a set number of transect visits. 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 measure 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

As an effort to supplement our large mammal data obtained in transects, we have made the use of 40 camera traps provided by Panthera in November 2014. As for last year, we conducted a 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 placed on different locations along our monitoring transects and trails where field rangers usually spot abundant animal tracks and signs.

The cameras were placed between 30-50cm height, and facing the trail at an angle of 45° to increase capture probability and to facilitate identification of individuals (jaguars). Cameras were left in the field for two months and were visited every two weeks for battery checks and data extraction.

Due to the high occurrence of illegal activities in CRFR, transects 1 and 2 did not have cameras installed on them. Cameras installed on transect 4 had to be retrieved early after equipment was stolen in CRFR3.

Considering the variability of trapping nights in each location, a factor has been created to standardise data to be able to compare different locations. The coefficient was calculated based on the number of nights the traps were active in each protected area.

Bats

To follow-up with the bat monitoring protocol set up by Dr. Bruce Miller in 2011, Ya'axché has continued collecting bat sound data in our monitoring transects following the transect visit schedule. Our equipment consists of a single passive acoustic detector, comprised of an Anabat detector, a CF-ZCAIM recorder (Titley Scientific, Brisbane, Australia) and remotely mounted microphone. Bat calls were collected only until September 2014 due to a failure in our units' microphone.

This was set up at night on the bird and large mammal transects throughout the year according to the transect schedule. The unit was pre-programmed with a beginning and ending recording time to approximately coincide with sunset and sunrise.

The unit records the ultra-sound echolocation calls, which are unique to each species. These are visualised and cross-checked with an existing database of species calls to identify to species level. Bat call analysis is done by Dr. Bruce Miller who reported the number of species detected, species names and their associated Acoustic Activity Index (AI). The Acoustic Activity Index was developed by Miller (2001) as an index of relative abundance and is calculated as

$$AI = \sum p$$

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

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

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

Wildlife observations

As an addition to the on-going 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 were categorised under BNR.

Highway crossings

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

Road traffic

In the same corridor and road impact framework, an effort was made to establish a baseline to monitor road traffic density on the stretch of the Southern Highway that cuts through the Golden Stream Corridor Preserve. On a larger scale, the Southern Biological Corridor, which is envisioned to connect the Maya Mountains with the Sarstoon Temash National Park is bisected by the Southern Highway in two different locations: GSCP and the area around Eldridgeville, the area northwest of Punta Gorda town.

Additionally, with the new highway connecting the Southern Highway and the Guatemalan border in the west, an increase of traffic between Belize and Guatemala is expected, including on the stretch that bisects GSCP.

For a period of three weeks, one 30-minute monitoring session was conducted per day, according to the schedule in Table 7. The schedule was optimised to sample all days of the week and different times of the day, and with the aim to minimally disrupt the routine patrol and monitoring schedule of the ranger team. The sessions were spread over three parts of the day which each had two possible starting times. Morning sessions were started at 8 or 10am, afternoon sessions at 1 or 4pm, and evening sessions at 6 or 8pm. Traffic density between 8pm and 8am was considered too low to warrant nightly monitoring sessions.

Table 7. Traffic monitoring schedule

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	*Legend*
Week 1	8:00	10:00	13:00	16:00	18:00	20:00	10:00	*Morning*
Week 2	13:00	16:00	18:00	20:00	8:00	10:00	16:00	*Afternoon*
Week 3	18:00	20:00	8:00	10:00	13:00	16:00	20:00	*Evening*

During a monitoring session, the observer noted all vehicles that passed the driveway of the Ya'axché field centre in GSCP in either direction. Vehicles were grouped in six categories: motorcycle, car/pick-up truck, van, freight truck, lorry and crude oil truck. The latter is not a common sight on the Southern Highway, but with drilling activities being initiated in and around the Sarstoon Temash area, we included these in our baseline as a separate category, anticipating that they may become a much more frequent sight in the future.

Vegetation

Plot locations were determined by Dr. Brewer based on existing information on topography, habitats and elevation. Two permanent, one-hectare (100 m x 100 m) plots were established: the first on a limestone slope and the second on a limestone ridge in the north-eastern BNR (see Figure 3a & 3b). Locations were chosen to represent undisturbed limestone forests and the vegetation along a limestone catena, by complementing two existing permanent one-hectare plots on alluvium over limestone at the bottom of the catena established in 1996 by Dr. Brewer.

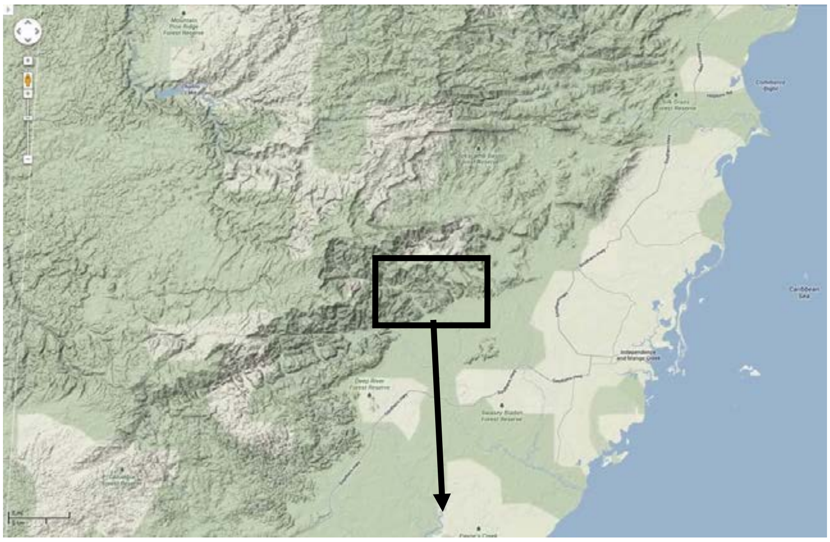


Figure 3a. General location of Bladen Nature Reserve in Southern Belize.

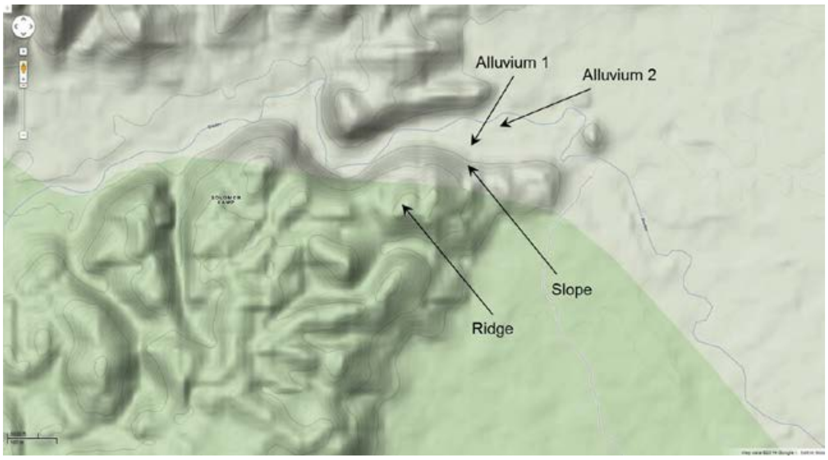


Figure 3b. Location of the four permanent plots in Bladen Nature Reserve (Brewer, 2014)

Plots were established during the 2012 dry season following a standardized methodology used throughout the tropics (Condit 1998). All trees greater than or equal to 5 cm diameter at breast height (‘DBH’; 1.3m above the ground) were tagged with pre-numbered aluminium tags, mapped to the subplot (10m x 10m) level, and identified to species. Where identification of taxa in the field was not possible, voucher specimens (3 sets) were collected and species determinations were made by Dr Brewer at a later date by comparing collected material with specimens held at the herbarium of Missouri Botanical Gardens, USA.

Field identification of stems in the slope plot was completed in April 2013 and in the ridge plot by June 2014 and will be re-measured in 2017. Results were used to calculate different diversity indexes; species richness, Shannon’s entropy, and Simpsons dominance index. Data analysis was carried out using the PAST software (Hammer *et al.*, 2001).

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 in certain years. Therefore we gather rainfall data, 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 was recorded manually and entered in a digital spreadsheet.

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

The two weather stations were placed to detect two rainfall gradients that are 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.

However, one of the weather stations was stolen (presumably by Xatéros, harvesters of Xaté leaves – or 'fishtail' palm) and the other was damaged after a heavy flood. As a result, no data could be extracted and Ya'axché will start looking for funds to replace this equipment.

Land-use change

Shifting-agriculture practices are widespread among the Q'eqchi' Maya population of rural southern Belize. Clearings are done using two methods; slash-and-burn (more common in the dry season) and slash-and-mulch (more common in the wet). Practices involving fire suppose a major threat to forests due to escaped fires. However, both practices reduce forest cover placing biodiversity at risk, for that reason, they are both taken into account in this report.

In order to keep track of the extent of deforestation in the Maya Golden Landscape, we make use of Geographical Information Systems (GIS) 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 four specific dates in 2014: April 28th, August 23rd, October 21st and December 24th.

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 different agricultural practices. The photo-interpretation was done by Ya'axché's experienced GIS specialist, Jaume Ruscalleda.

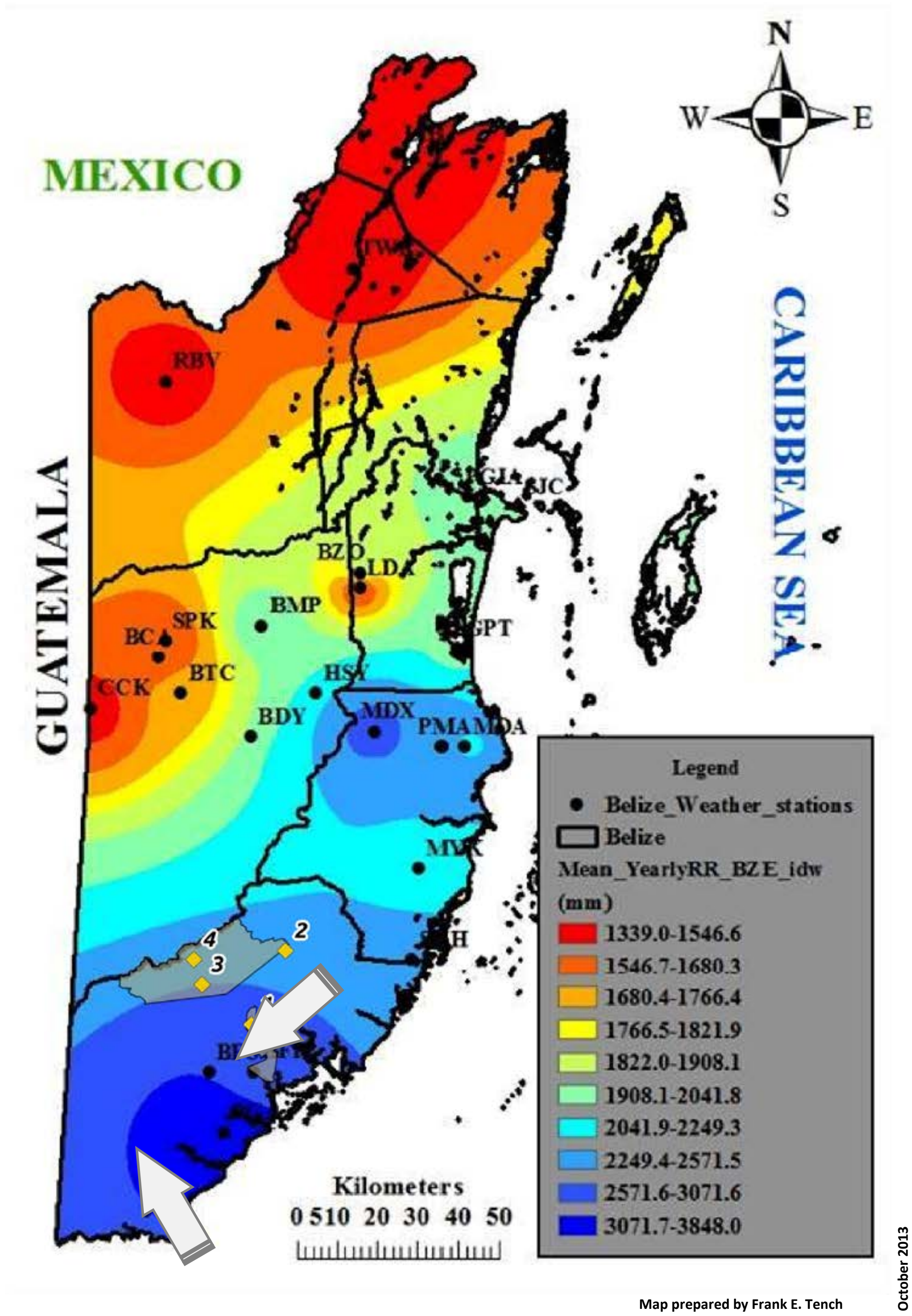


Figure 4. Mean annual rainfall across Belize since 1951, with varying number of year's data availability per weather station. Bladen Nature Reserve and the Golden Stream Corridor Preserve are indicated by transparent polygons. The four Ya'axché weather stations are Golden Stream field centre (1), BNR ranger base (2), and the old Esmeralda (3) and Oak Ridge (4) weather stations. Arrows indicate expected local rainfall gradients. Map prepared by Meteorologist Frank Tench (Frutos, 2013).

Results

The result section follows the same sequence of monitored taxa as the methodology section. Data collected in transects are analysed separating birds and mammals, starting with general descriptive statistics on the actual number of species and followed by a more specific comparative analysis using diversity profiles and species rarefaction curves throughout transects. Data collected on other monitoring surveys are analysed and presented in an equally basic manner.

Birds

Transect were visited between 10 and 24 times each over the course of the year, resulting on a total of 146.8 km of transects completed and an average of 14.9 visit per transect (see Table 8), which slightly increases monitoring effort than the last two years.

Table 8. Bird monitoring effort per transect in 2014

	# of visits	# of m transect	Avg. # of obs/1000m
BNR2	24	23,200	12.80
BNR3	24	24,000	9.96
CRFR1	12	11,400	8.42
CRFR2	12	12,000	8
CRFR3	12	12,000	11.5
CRFR4	12	12,000	12
GSCP1	10	10,000	10.1
GSCP2	14	14,000	12.5
GSCP9	10	10,000	12.6
IV1	19	18,200	11.48
MGL	**151**	**146,800**	**11.04**

Of 30 bird target species, a total of 24 species were detected in 2014, with a total of 1,621 observations recorded, resulting on an average of 11.17 observations per km of transect completed in all the MGL. Statistical correlation test identified a positive connexion between the number of bird observations and number of visits (Spearman's $\rho = 0.805$; $p = 0.0049$), but did not find a correlation between the average number of observations per 1000m (Spearman's $\rho = 0.169$; $p = 0.639$). This means that the number of visits and observations per transect are two independent variables and therefore comparable. On the other hand, 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 on BNR2 transect, followed by GSCP9 and GSCP2. We will see later in this section that having a higher average number of observations per 1000m does not necessarily indicate the presence of more target birds or more target species diversity.

In 2014, between 10 and 14 transect visits were conducted every month (Figure 5). The least monthly number of visits was conducted in July. The greatest number of transects were conducted during January, August and September. Overall, the number of transects per month was more even this year than in previous years.

As noted in Figure 5, the number of observations per transect is greater at the beginning and end of the year, and plunges between April and September. The target species richness per month curve also follows a similar trend. As we will see later, this tendency is due to the increase of migratory bird species during the rainy season.

Figure 5. Bird monitoring effort in 2014

Target species richness

As we already explained in the methodology section, our list of target species for birds is biased towards forest species, but does contain disturbance indicators and savannah species. Therefore, we are able to compare the results of the three different habitats by assembling the transects conducted in each environment. However, we need to take a few factors into account. Firstly, given the difference on the amount of transects conducted in forest habitat, we compare the average target species richness in forest transects with a single savannah and village land transect; using an average value can result in a more moderate reflection of the total forest target species richness because the arithmetic average is sensitive to outlying value. On the other hand, given the openness of the Savannah and Village lands habitats, we would expect the visibility and sound travel distance to be increased in the these environments, which would inflate the species richness estimates.

Figure 6 shows an average of 14.88 target species detected on forest transects, compared with 17 target species detected in the Savannah and 11 in Village lands.

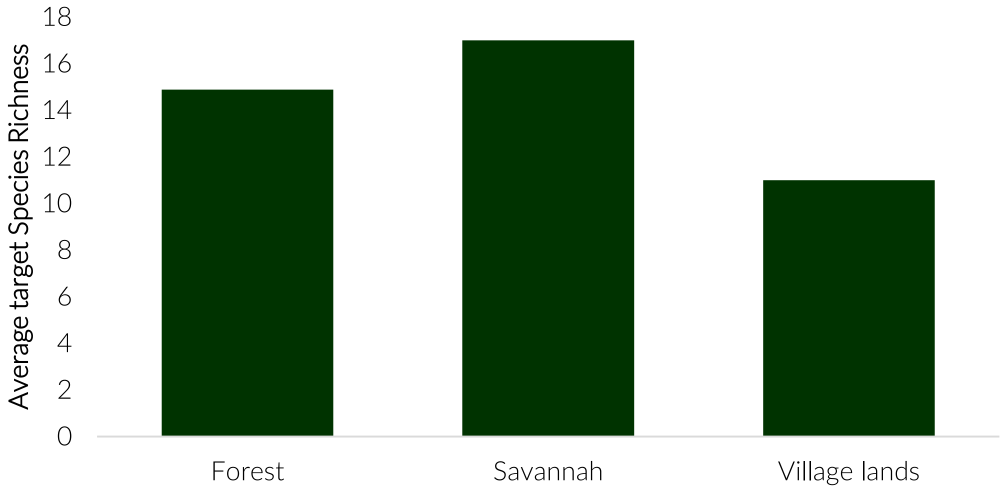


Figure 5. Total target bird species richness per habitat

All forest transects combined yielded a total of 23 target species, collecting all species found in the other two habitats, except one pine-savannah quality indicator species (blue-gray gnatcatcher) recorded exclusively in the Savannah. Therefore, considering the factors stated on the previous page, the only valid conclusion from Figure 6 is that less of our target species were found on Village lands in 2014. Yet, this only means village lands have less of the birds on our target species list, which is biased toward forest species and therefore does not count other non-forest species that may be more abundant in this environment.

Sample-based species rarefaction curves

As in last year we compared target species rarefaction curves on each transect (see Figure 7). For a fair comparison, each transect should have an equal number of visits, therefore we compare all the transects' expected species accumulation at the point where the minimum sample size lays (in this case, the minimum amount of samples was 10, on both GSCP1 and GSCP9).

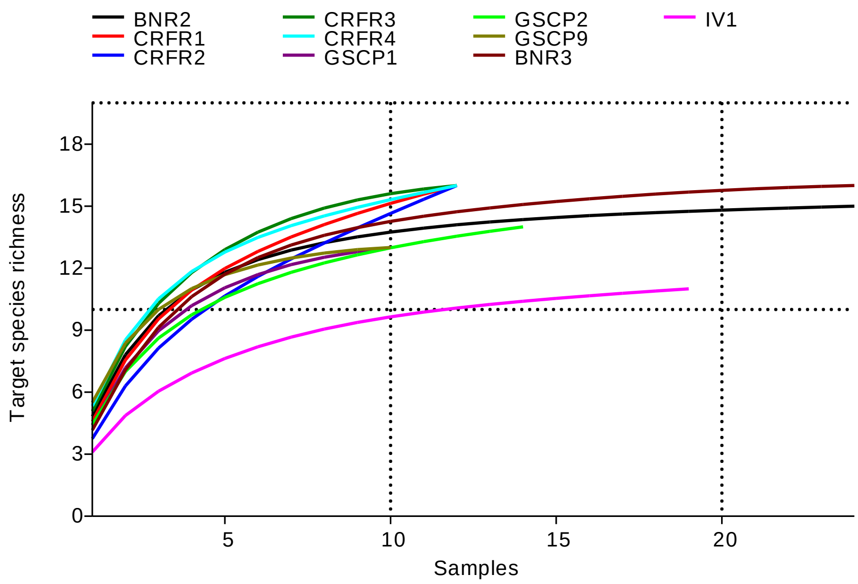


Figure 7. Sample-based rarefaction curves for all transects

Table 9. Transect ranking according to expected bird species richness after 10 transect visits

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

Table 9 shows the ranking in expected species richness of the transects at 10 transect visits. As we can observe in the table, CRFR transects accumulated most species at 10 visits; CRFR3 with a value of 15.9, CRFR4 with 15.3, CRFR1 with 15.1 and CRFR2 with 14.7. BNR3 and BNR2 follow with values of 14.3 and 13.7 respectively. At the end of the ranking Golden Stream Corridors' transects fall together with similar values; GSCP1, GSCP9 accumulated both 13 species, and GSCP2 goes closely behind with 12.9. Finally, Indian Creek village lands transect stands as last in the ranking with a value of 9.6.

As previous years, BNR2 ranks in a low position considering is the least disturbed area. Additionally, savannah and village land transects (BNR3 and IV1) fall at the second half of the ranking as a result of their low effective number of target bird species, which is, at the same time, the consequence of our target list of bird species being biased towards forest species.

Diversity profiles

As last year, BNR3 appears to be most species rich, followed by CRFR2, CRFR3 and CRFR4 (see Figure 8). However, when weighing species dominance, CRFR transects (particularly CRFR3 and CRFR4 transects) showed low levels of dominance and therefore higher biodiversity. Conversely, BNR3, which initially stands as the transect with the highest species richness, is heavily affected by species dominance weighing indicating less diversity. The dominant species in savannah transect (BNR3) was markedly the yellow-headed parrot and, to a lesser extent, the plain chachalaca. Surprisingly, BNR2 lagged behind with a lower species richness that BNR3 and CRFR transects but was moderately affected by dominant species, in this case, wood thrushes and slaty-breasted tinamous were somewhat abundant. GSCP9 and GSCP1 also display low species richness, but they are the sites least affected by species dominance and so making them the transects with more species evenness. The Indian Creek village transect (IV1) has lowest diversity and a steep influence of dominance.

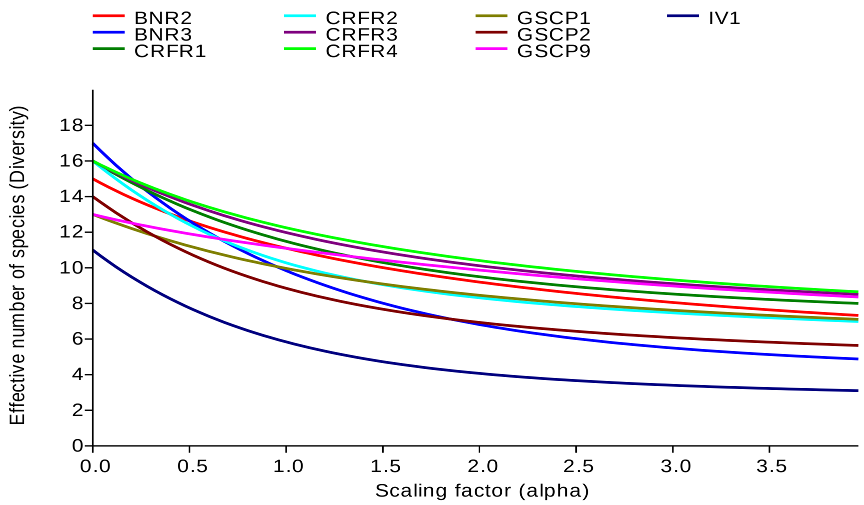


Figure 8. Bird diversity profiles

Migratory birds

To detect bird migratory patterns throughout the year, we compare encounter rates per month of migrant target bird species only. Encounter rates are calculated as the number of individuals recorded per 1000m of walked transect in the MGL. In this case, there was no significant correlation between the number of individuals per 1000m and the number of transect visits per month (Spearman's ρ = 0.309; p = 0.328), which enables us to compare between months without controlling for the number of visits conducted in these months.

As expected, we found a marked pattern of presence/absence migration peak from October to March (Figure 9). Like previous years, species richness and number of migratory bird species are notably higher after breeding season than before. As explained last year, this could be the result of habitat saturation upon arrival; migrant and resident species compete with each other in areas with more resources and eventually force some individuals to migrate partially to areas less resource rich. Other factors could be territorial males to migrate earlier in breeding season to obtain better nesting sites (Kokko, 1999) and the need for birds migrating further south to have more stopovers after crossing the Gulf or the dryer areas of Mexico (Young and Moore, 1997).

Another remarkable observation is the presence of some migrants throughout the year (especially the wood thrush, but also the black and white warbler, Louisiana waterthrush, northern waterthrush and American redstart). Also remarkable observations like the Chestnut-sided warbler in CRFR transects 1 and 3, and the presence of the Blue-gray gnatcatcher in the savannah, which have not been recorded in transects before.

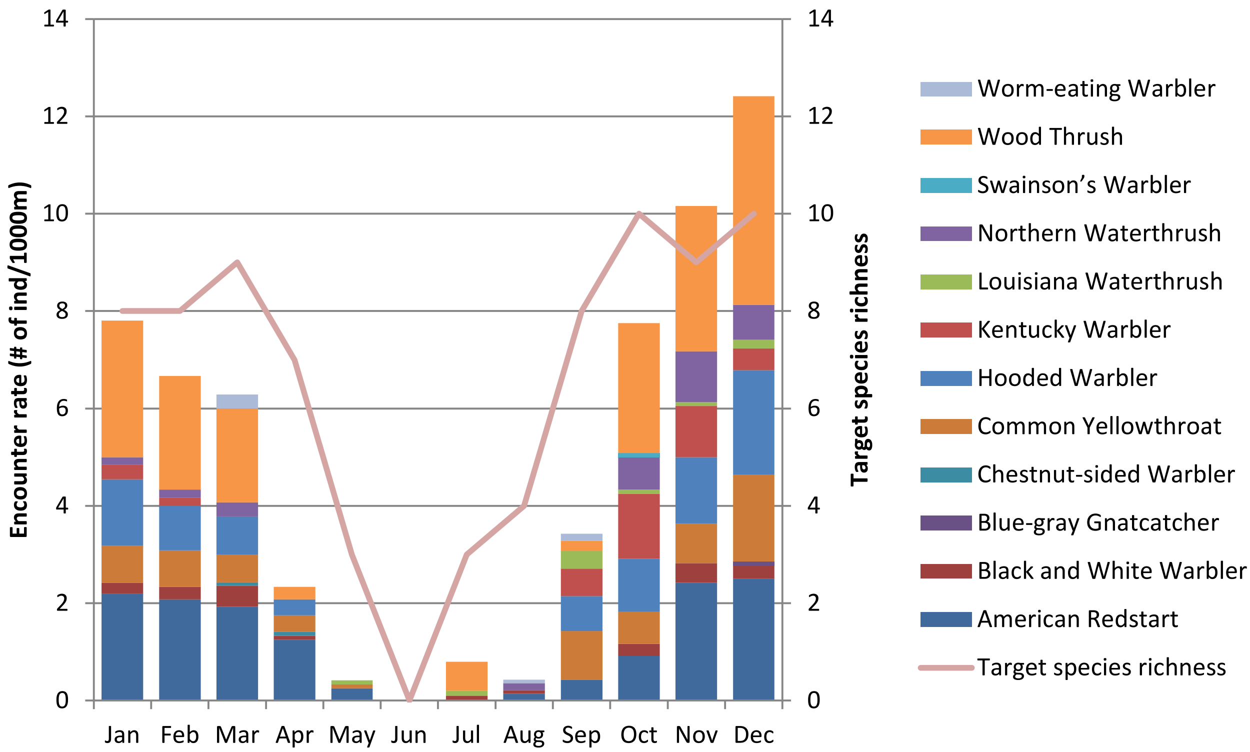


Figure 9. Migrant encounter rate and species richness throughout the year

Indicator groups

Indicator groups give us information about the health of an ecosystem. When comparing different ecosystems, we need to take into account the number of visits done in each habitat; as explained earlier, statistical analysis determined a positive correlation between the number of observations and number of transects. There were 106 transect visits done in the forest habitat, only 24 in the savannah and 19 in village lands habitat. Not surprisingly, more individuals and species were observed in the forest than on the transects in the savannah and village lands. To take these visit differences into account, we standardized the results using percentages rather than standardizing per distance (i.e. encounter rate – number of individuals per 1000m), to avoid the difference in observed number of species affecting the summed encounter rates per Indicator group.

In the next graph, the total number of individuals encountered in each habitat is shown in brackets.

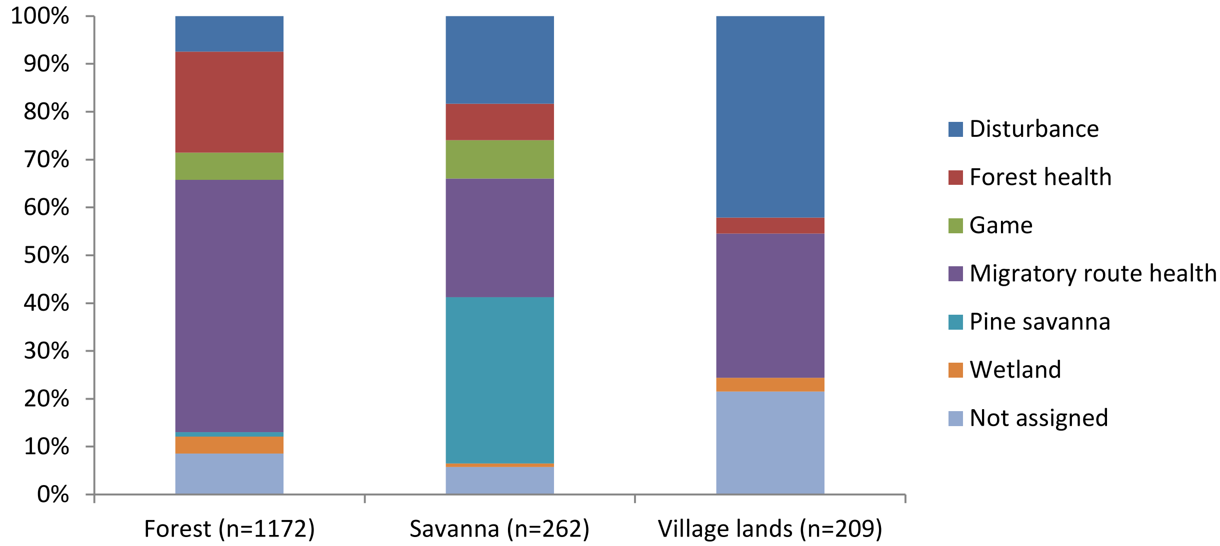


Figure 10. Distribution of individuals among Indicator Groups

Figure 10 shows that in forest transects, more than half (53%) of individuals recorded were migratory route health indicators. On the other hand, forest health indicators accounted only a fifth (21%) of all individuals but disturbance indicators are less present in the forest transects than in the savannah and the village land transects. Moreover, although wetland species accounted minimal percentages in all the habitats, they are greater in the forest habitats than in the other two.

In the savannah, a third (34%) of all individuals detected where pine savannah indicators and very little wetland indicators can be observed. There is also a considerable percentage (25%) of migratory route health indicators, however this is a smaller percentage than is seen in the other two habitats. In addition, game indicators are greater in the savannah than in the other two habitats, but these are all recordings from the nearby forested foothills.

Finally, in village lands, considerably less forest health, game and pine-savannah indicator species were detected, and almost half (42%) of individuals were indicators of disturbance, which are more than double greater than on the other two habitats. However, a third of the individuals found in this habitat were indicators of migratory route health. We can also note than in village lands, species that do not have an assigned indicator are much more abundant than in the other two habitats. Additionally, village lands totally lacked any of the game birds.

To compare the distribution of indicator groups across transects, we arranged the transects in a roughly defined disturbance gradient in forest transects identified in previous Biodiversity Synthesis Reports (Hofman, 2013).

Figure 11 Portrays the proportions of individuals belonging to each indicator group for all forest transects and puts these next to the village lands and savannah transects for reference. Note that many more factors than just this defined disturbance level could be causing the observed pattern of the Indicator groups (weather, monitoring effort, population fluctuations etc.), and we therefore will look at the predominant tendencies rather than to details of every single transect.

The main trend visible in the chart is the decrease of forest health and game availability as the disturbance increases. The opposite trend is observed in the proportions of disturbance and migratory route health indicators. The savannah transect (BNR3) expectedly has a very different composition than all other transects.

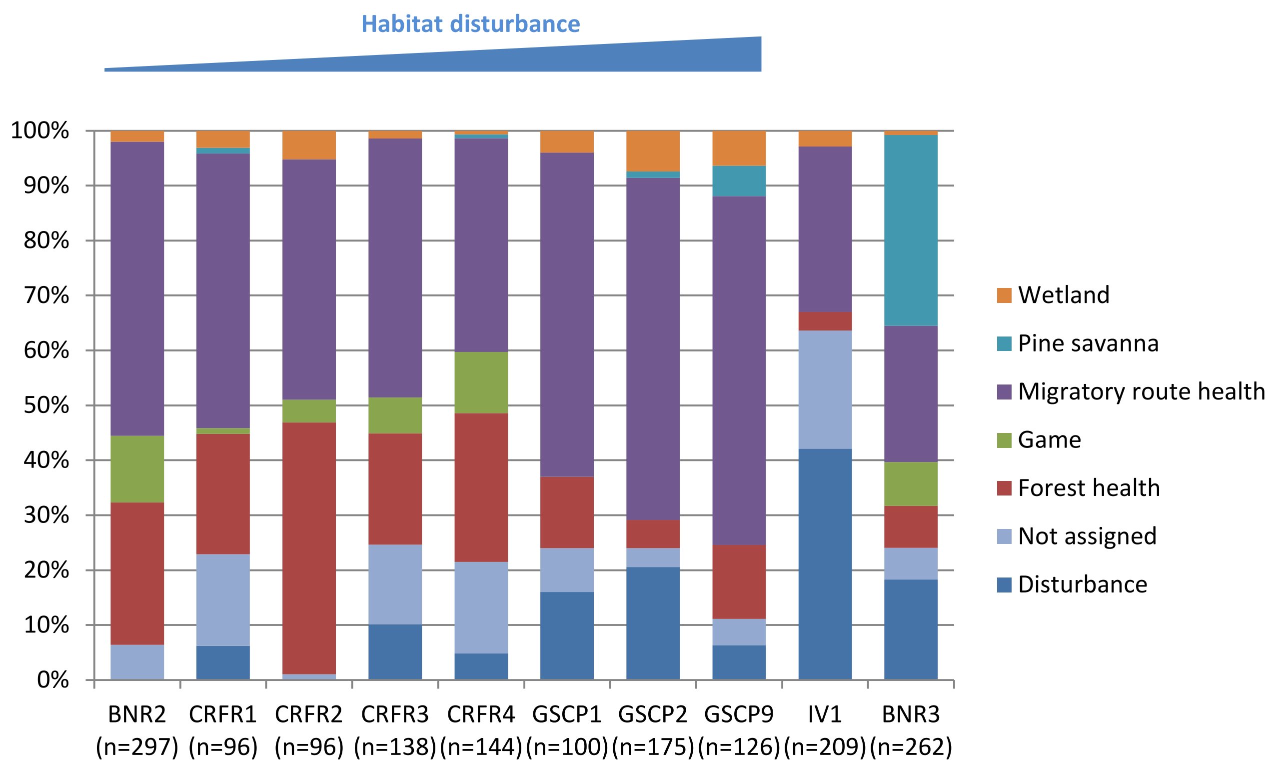


Figure 11. Distribution of individuals among Indicator Groups, looked at per transect. From the left, the first 8 transects indicate a habitat disturbance gradient in the forest. The next transect is on village lands, the last one in savannah.

Again the number of individuals detected on the different transects is shown in brackets. BNR2, BNR3 had 24 transect visits each, IV1 had 19 visits, whereas all other transects were visited between 14 and 10 times over the course of the year (see Table 8).

Large mammals

As with previous years, the number of mammal transect visits remained generally half of that of birds. For 2014 a total of 70 mammal transects were carried out and covering a total of 70km (Table 10). The number of transect visits per general location (i.e. all transects in Bladen) were more consistent than in previous years with a minimum of 5 visits, a maximum of 12 visits and an average of 6.8 observations per 1000m transect in the MGL.

Table 9. Mammal monitoring effort per transect

	# of visits	# of m transects	Avg. # of obs/1000m
BNR2	12	12000	6.7
BNR3	12	12000	6.6
CRFR1	6	6000	4.7
CRFR2	6	6000	5.0
CRFR3	6	6000	8.0
CRFR4	6	6000	6.3
GSCP1	5	5000	10.6
GSCP2	7	7000	6.4
GSCP9	5	5000	4.8
IV1	5	5000	9.4
MGL	70	70000	6.8

Of the 19 target species of mammals, 16 were recorded, with a total of 472 observations made and 811 individual counted. Neo-tropical river otter, naked tailed armadillo and white nosed coatis were not recorded over the one year span. The largest number of mammal observations per km was recorded for GSCP1, IV1, and BNR2. Interestingly, IV1 is within village lands and recorded more observations in less visits than in the previous year. This however is not indicative of higher species richness but rather an increase in the abundance of a few species characteristic of “disturbed” areas. Transects with the least number of mammal observations per km were CRFR1, GSCP9, and CRFR2. GSCP9 in comparison to last year, showed a decline in the number of observations but perhaps largely due to a decrease in the number of visits as compared to the previous year.

There was no significant positive correlation between the number of transect visits and the number of observations per transect or between the number of visits and the average number of individuals per 1000m (Spearman's, ρ = 0.18; p = 0.46) and (Spearman's ρ = -0.11: p = 0.75) respectively. There was, however, a significant positive correlation between the number of transect visits and the number of individuals recorded (Spearman's ρ = 0.75; p = 0.01). Looking closer at the data, it was noted that perhaps one species (white lipped peccary) would likely influence the results of this analysis so the numbers were adjusted to reflect an absence of white lipped peccaries since droves typically range around the hundreds. The results still show a positive correlation between the number of visits and the number of individuals recorded. In fact it resulted in a higher significant positive correlation (Spearman's ρ = 0.91; p <0.05).

During 2014, between four and seven transects were conducted every month (Figure 12) with the greatest number of transects carried out both in August and September and the lowest being in December. November was the month with the greatest number of sightings per 1000m. As in previous years there was a marked decline in sightings between March and May, a result of dry conditions rendering track observations difficult. As the rains increased towards the rainy season and well into the season, the number of sighting in the form of tracks increased dramatically.

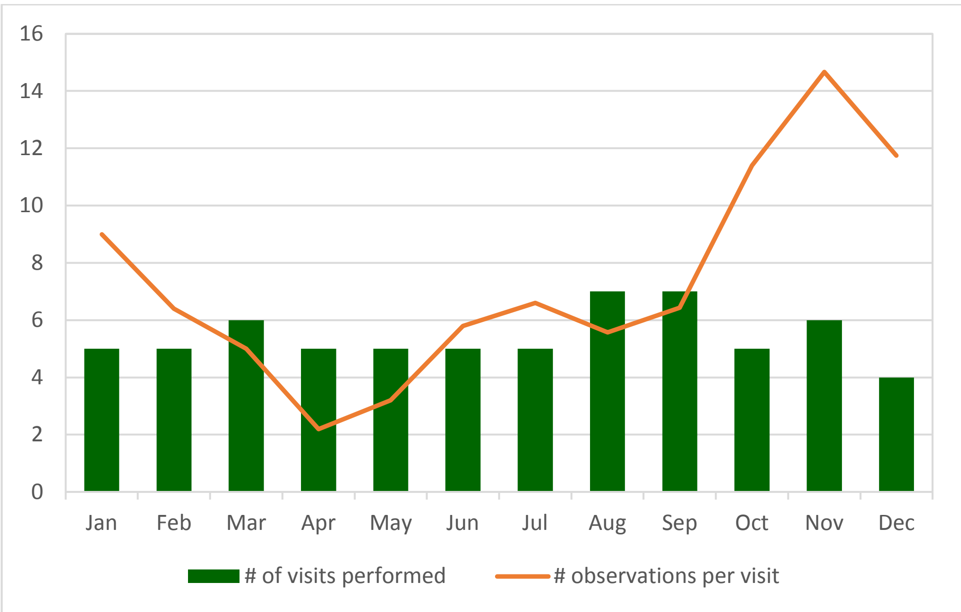


Figure 12. Mammal monitoring effort in 2015.

Target species richness

We compared the three different habitats that we monitor by pooling the transects conducted for each habitat (Figure 13). With different number of transects per habitat, the average result was used for forest habitats and a single transect for both savannah and village habitats. Species richness in the savannah was 12, and in the village it was 7, while the average forest species richness was 9.38. The use of an average forest species richness results in a seemingly lower species richness when compared to the savannah habitat. In general forest habitat transects have a higher species richness when looked at individually. The savannah habitat recorded the two species of monkeys which occasionally venture on the edges of the broadleaf forests bordering the savannah habitat which is not to be interpreted as being howler or spider monkey habitat. Transects GSCP2 and BNR2 both in forest habitat recorded high species richness, 12 and 11 respectively. The total number of species recorded within forest habitats was 16. The village transect recorded the lowest species richness of 7.

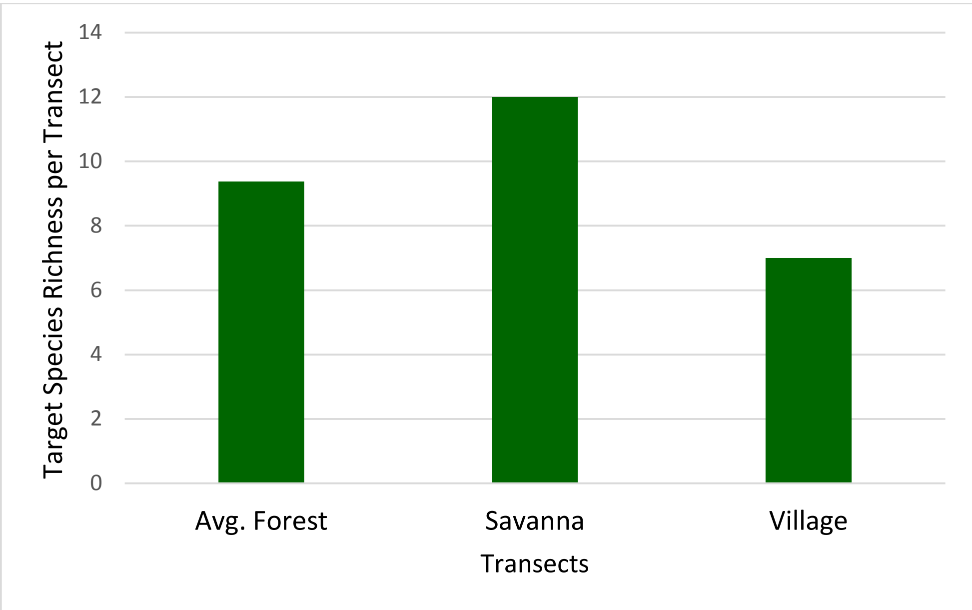


Figure 13. Average target mammal species richness per transect

Species accumulation and rarefaction curves

We calculated the expected species richness for each transect and produced rarefaction curves (Figure 14). This allows the comparison of transects with different sampling efforts as in the total number of visits per transect. Transect visits ranges from a minimum of 5 to a maximum of 12.

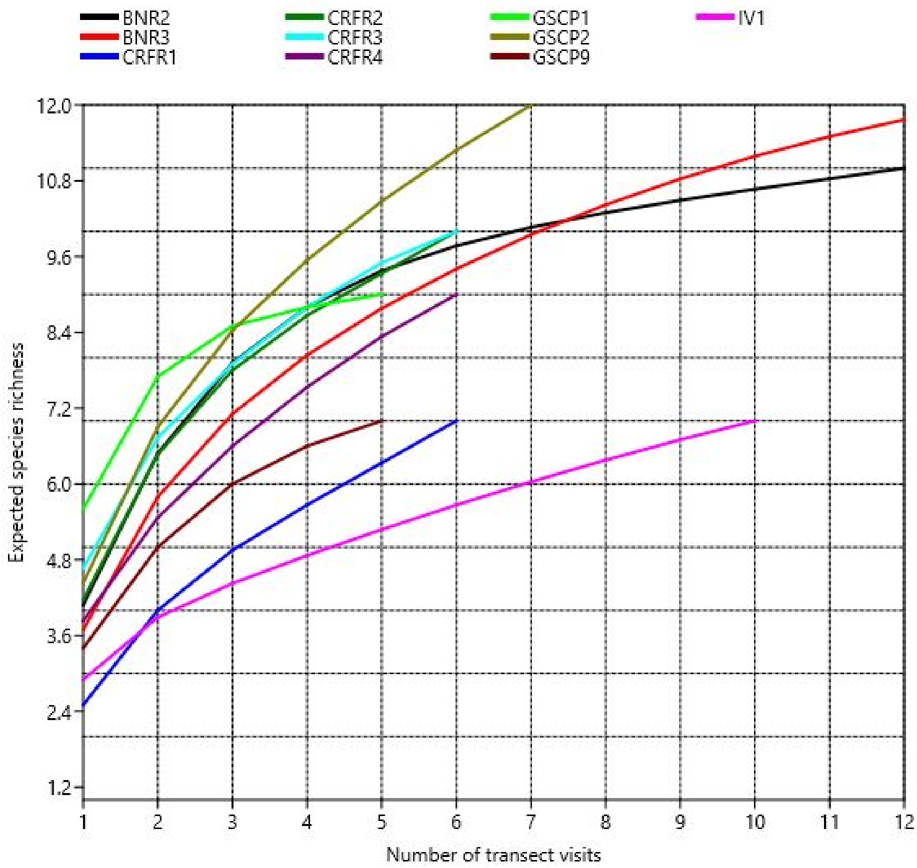


Figure 14. Sample-based rarefaction curves for large mammals

Table 11. Transect ranking according to expected mammal species richness after 5 transect visits

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

Table 11 shows the ranking of transects based on their expected species richness after the minimum number of visits. GSCP2, CRFR3 and NBR2 recorded between 9 and 10 after just 5 visits. As with the previous years' results, the village transect recorded the lowest number at 5.3 after just 5 visits. Looking at individual protected areas there was not a great variation in the number of species recorded after 5 visits, with the lowest number recorded in Columbia River Forest Reserve at 6.3 and the highest in Golden Stream Corridor Preserve at 10.5. Bladen Nature Reserve finds itself in between these two figures with its lowest number at 8.7.

Diversity profile

Species dominance in transects is evident in transects BNR 3 and CRFR2 and is due to the presence of large herds of white lipped peccaries (Figure 15). The effect in diversity profiles is an uneven distribution of relative abundance as has been seen in previous years. As the scaling factor α increases the dominance of white lipped peccaries reduces the effective number of mammal species. A similar pattern is observed with CRFR1 where nine-banded armadillos and pacas are the dominant species. IV1 was much alike with agoutis, pacas and armadillos being the dominant species.

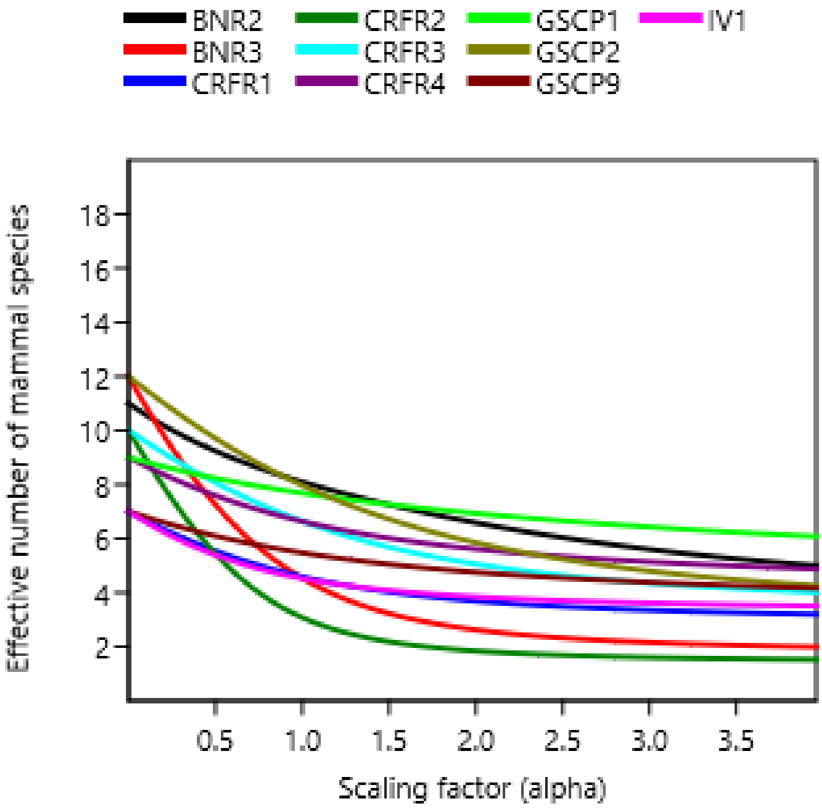


Figure 15. Mammal diversity profiles 2015

Indicator groups

On average the savannah transect had more forest indicator species than the forest transects. The village recorded a similar number of forest indicator species as the average for the forest transects (Table 12). All habitats recorded a similar number of games species ranging from 3 to 3.25 (for the average forest transect). The only wetland indicator species was recorded in both the savannah and the forest transects but was absent from the village lands.

Table 12. Average number of species per transect

Indicator species	Avg. Forest (n=8)	Savannah (n=1)	Village (n=1)
D	0.125	0	0
F	4.875	8	4
G	3.25	3	3
NA	0.125	0	0
W	1	1	0
All species	9.375	12	7

The structure of indicator species varied from habitat to habitat although Forest transects and savannah transects had a similar structure when compare to the village lands where game species were largely the dominant group (Figure 16).

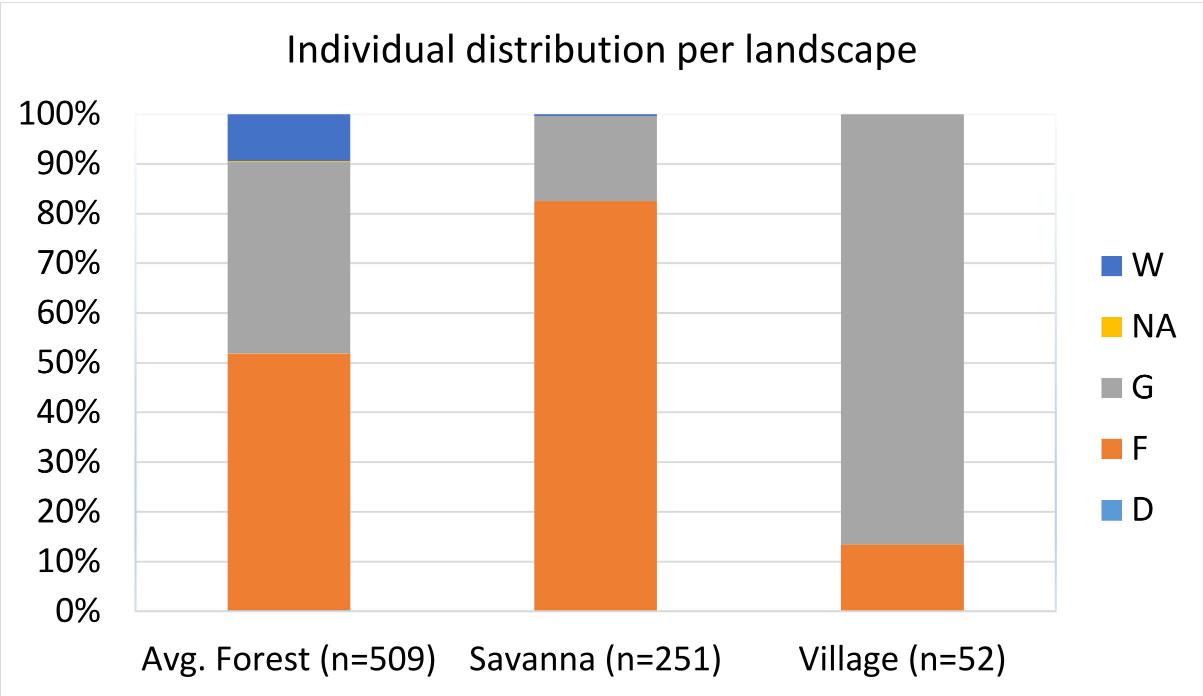


Figure 16. Distribution of individuals among Indicator Groups

To get a clearer understanding of the structure we assessed the encounter rate of individual forest indicator species per 1000m (Figure 17). It is clear that more individuals were recorded within the savannah habitat than in the forest habitat or the village lands but the diversity of species between the forest and savannah transects was similar. It is also clearly evident that white lipped peccaries alter the structure of the indicator species recorded per transect as seen in the savannah and forest transect. This is the result of large droves of white lipped peccaries recorded on a few occasions rather than few individuals several times over the entire monitoring period. The encounter rate for howler monkeys in the savannah was largely due to the openness of the habitat where vocalizations can be hear clearly on the savannah transect but the animals were perhaps actually within the forest habitat. The village transect had a more even distribution of encounter rates for the species that it recorded.

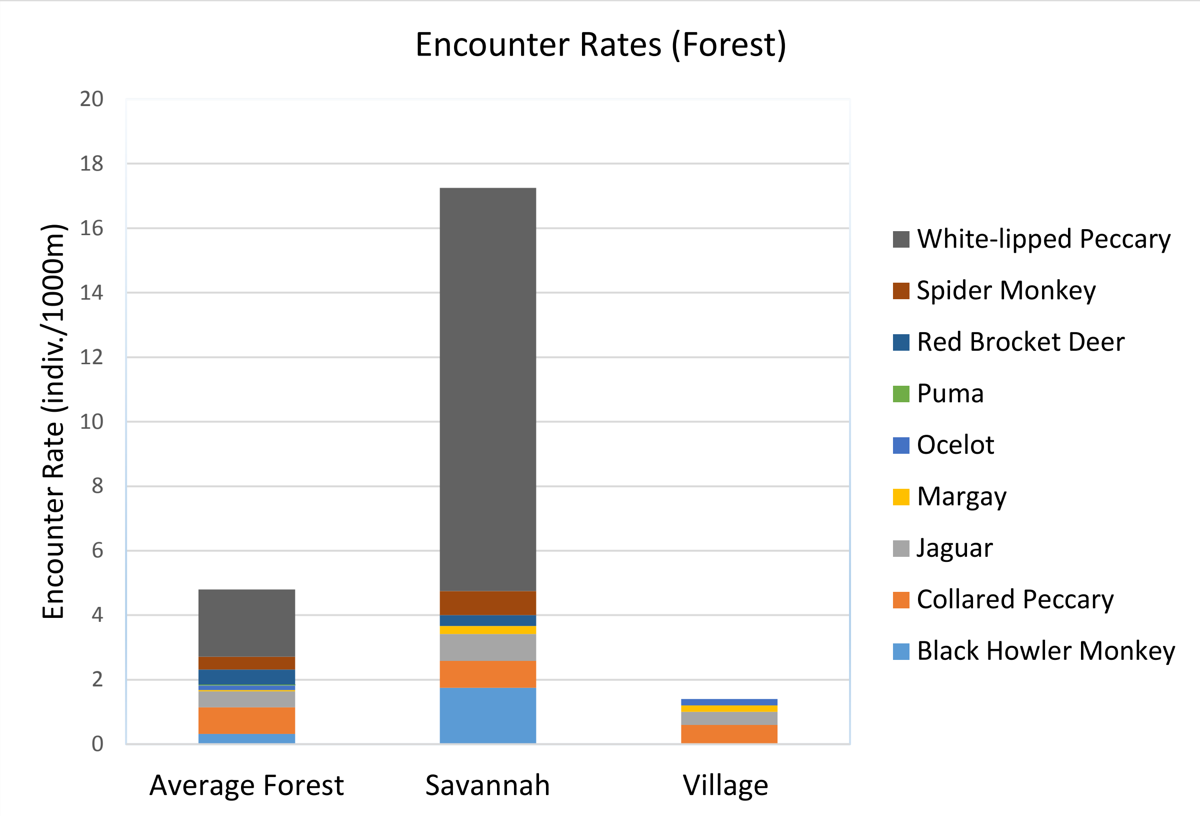


Figure 17. Encounter rate of all Forest health indicator species

The encounter rate for game species was assessed in a similar manner (Figure 18). Encounter rates for game species were higher in village lands with the highest encounter rates being that of pacas followed by armadillos and agoutis. As expected, white tailed deer was more commonly encoutered in the savannah and was absent from village lands.

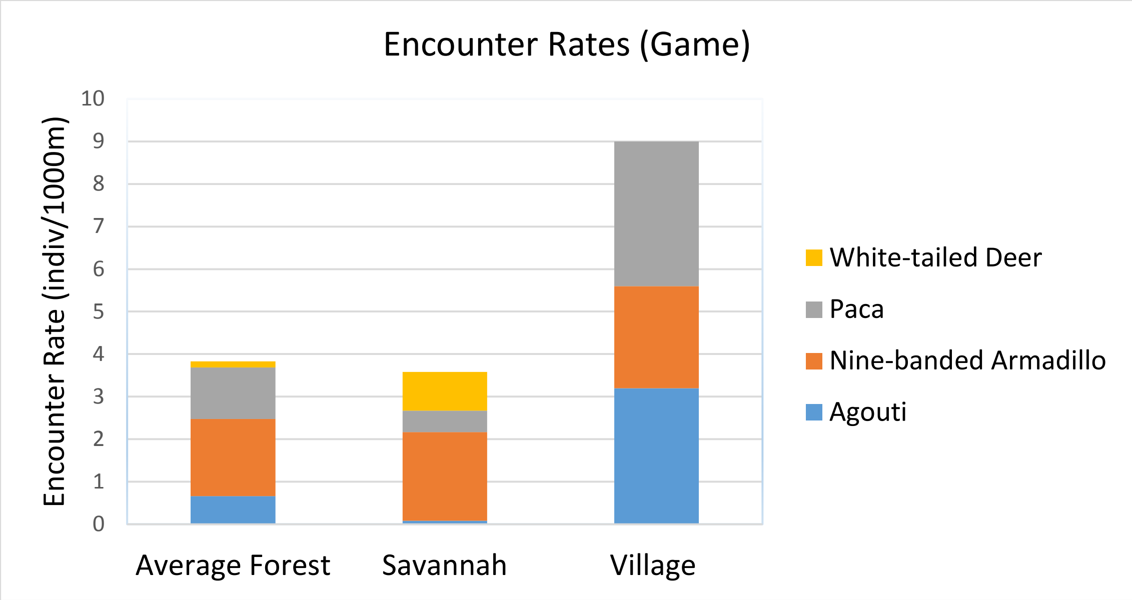


Figure 18. Encounter rate of all Game indicator species

For the past three Biodiversity Synthesis Reports we have reported the same pattern on tapirs within the MGL. Encounter rates for tapirs (the only wetland indicator species) is about 1 tapir in every 1000m within the forest habitats (Figure 19). It is less common in the savannah and totally absent from village lands. It is possible that tapirs are actively avoiding this habitat type but without a more robust sampling method this cannot be statistically proven to be the case. It is understood that tapir raid crops within farm lands (anecdotal farmer reports) and are shot to prevent any further crop raiding.

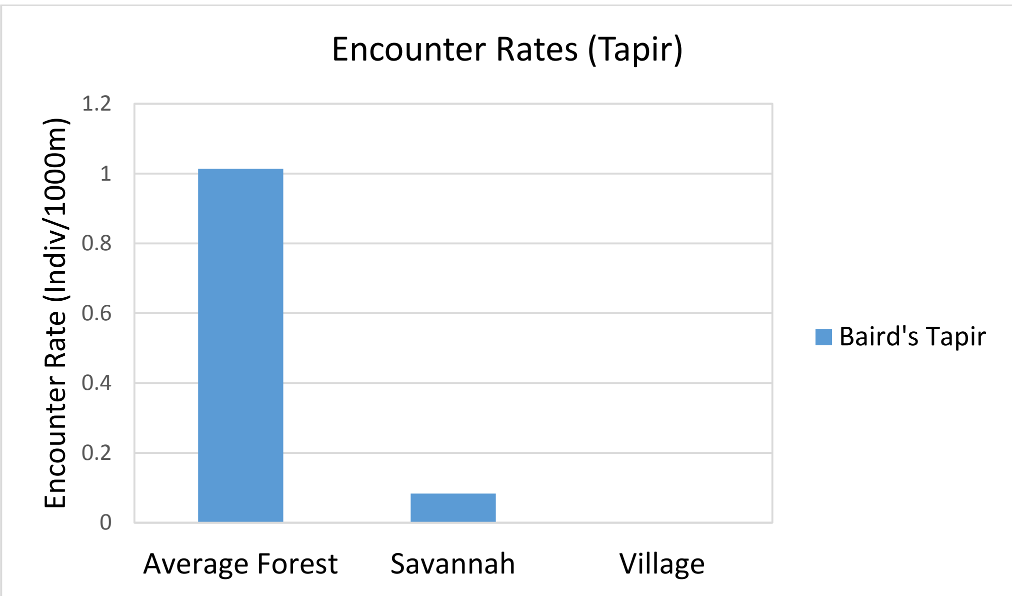


Figure 19. Encounter rate of the only Wetland indicator species detected in 2014, Baird's tapir

Camera trapping

The camera trapping surveys yielded an effort of 1721 of 'trapping nights' - the sum of all nights any one camera was active. Initially 30 cameras were installed, but four of them were stolen and as a result another two were retrieved early. In addition, one of the cameras was damaged by water. From the recorded 1721 nights, 432 nights were at three sites in Bladen Nature Reserve, 160 nights in Columbia River Forest Reserve and the remaining nights in Golden Stream Corridor Preserve. Two of the stolen camera were located in BNR3 transect, and the other two in CRFR3 transect. To avoid further theft, cameras located in CRFR4 where retrieved early.

Table 13. Species diversity results from the 2014 camera trapping survey. Individual passes (Indiv.) and average herd size (A.H.S.) are a minimum estimate.

	Species	BNR		CRFR		GSCP		Total MGL Recordings
		Indiv.	A.H.S.	Indiv.	A.H.S.	Indiv.	A.H.S.	
Birds	Dove	-	-	4	1	-	-	4
	Gray-necked wood rail	-	-	1	1	1	1	2
	Great Curassow	1	1	11	1.6	4	1	16
	Motmot	-	-	1	1	3	1	4
	Plain Chachalaca	-	-	-	-	1	1	1
Mammals	Agouti	-	-	12	1.2	50	1	62
	Bat	4	1	3	1	2	1	9
	Coatimundi	1	1	5	2.5	14	2.3	20
	Collared peccary	7	3.5	2	1	4	1.3	13
	Gray Fox	1	1	-	-	2	1	3
	Jaguar	4	1	2	1	6	1	12
	Jaguarundi	-	-	-	-	1	1	1
	Margay	1	1	1	1	7	1	9
	Nine-banded armadillo	-	-	2	1	2	1	4
	Northern tamandua	-	-	-	-	1	1	1
	Ocelot	4	1	1	1	6	1	11
	Opossum	-	-	3	1	5	1	8
	Paca	-	-	9	1	7	1	16
	Puma	-	-	10	1	6	1	16
	Raccoon	-	-	2	1	-	-	2
	Red-Brocket Deer	5	1	-	-	3	1	8
	Skunk	-	-	-	-	1	1	1
	Squirrel	-	-	3	1	16	1	19
	Tapir	1	1	1	1	29	1	31
	Tayra	-	-	2	1	3	1	5
	White-lipped peccary	19	6.33	-	-	2	2	21
Total		48		75		177		300
Species Richness		11		19		25		27

The traps captured a minimum of 300 individuals – we counted five bird species and at least 20 mammal species excluding bats (Table 13). The table counts the number of passes of individuals and does not include possible repetitions – pictures taken by the camera on the other side, or repeated pictures of the same individual. The herd size indicates a minimum average of individuals passing at one single pass. GSCP was the area where most individuals and species were captured. In addition, species richness was highest in GSCP; most species found in GSCP are suspected to be present in BNR, but the number of trapping nights in BNR might have been insufficient to capture them.

Given the difference between the amounts of camera trap stations deployed in each protected area, the results are not comparable. In order to be able to compare the results, a factor based on the number of trapping nights on each area has been used (see Figure 20).

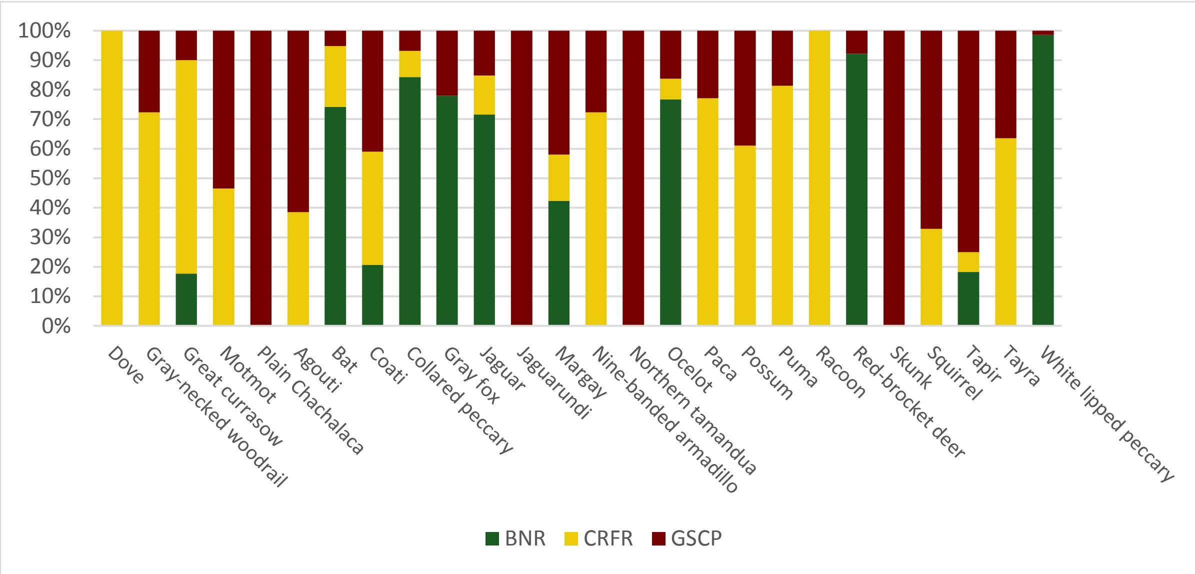


Figure 20. Percentages of individual capture using the normalising factor

When looking at data normalised by the trapping time factor, GSCP accounts for a lower percentage of individuals trapped, followed by CRFR and BNR, consecutively. White-lipped peccaries were recorded mostly in BNR, but two individuals were recorded in GSCP near the foothills. Additionally, some of the mammals on our indicator list that are rarely reported during transects were recorded by camera traps; in GSCP, a Jaguarundi was photographed, a disturbance indicator, the Coatimundi, a not-assigned indicator, was reported in all locations. Forest quality indicators like Margays, were also reported in all protected areas. Finally, a Northern Tamandua, a species rare to see, was photographed by one of the cameras in GSCP.

Figure 21. Camera trap in GSCP captured a Margay carrying its prey (left) and made a close shot of a jaguar (right).

Bats

During 2014, the bat recording unit (Anabat) was deployed 24 times, which, despite the equipment breaking down in September, increases survey efforts since last year. Due to equipment failure, 9 out of these 24 deployments did not record any data. Hence, for analysis purposes, this report will only take into account the 15 nights where the detector was functional.

Our surveys resulted in nearly 135 hours of recordings over 15 nights in 13 different locations. The Anabat recorded data in all forest and savannah transects except GSCP1. BNR transects were the locations where the Anabat was deployed the most (see Table 14).

Table 14. Bat monitoring effort in 2014

	Nights	Hours	Locations
BNR2	4	43.1	3
BNR3	3	19.6	2
Total BNR	7	62.7	5
CRFR1	1	11	1
CRFR2	2	22.6	2
CRFR3	1	10.6	1
CRFR4	1	10.5	1
Total CRFR	5	54.7	5
GSCP2	2	6.3	2
GSCP9	1	11.1	1
Total GSCP	3	17.4	3
Grand Total	**15**	**134.8**	**13**

To be conservative, unidentified bat calls (or call fragments) are not included neither in the species richness count.

Table 15 shows the level of activity each species of bat was recorded. A total of 16 species of bats were identified, representing 11 genera in 4 different families; Free-tailed bats (Molossidae), Vesper bats (Vespertilionidae), Sac-winged bats (Emballonuridae) and leaf-chinned bats (Mormoopidae). In addition, a nose-leaf bat (Phyllostomidae family) was recorded in CRFR3; bats belonging to this family are rarely recorded in recorders due to their low intensity echolocation. For that reason, methods other than recorders are used to monitor this family and therefore they are not counted in the species richness in this report. To be conservative, unidentified bat calls (or call fragments) are not included neither in the species richness count.

Table 15. Bat diversity and activity in the MGL. AI% was calculated dividing the amount of one minute blocks one particular species was present with the total amount of minutes the detector was recording.

Fam	**AI%**	**BNR2**	**BNR3**	**CRFR1**	**CRFR2**	**CRFR3**	**CRFR4**	**GSCP2**	**GSCP9**
Emballonuridae	Greater dog-like bat	0.39							
	Greater white-lined bat	0.08	0.51	0.15	0.37				0.3
	Lesser dog-like bat	0.27	0.09						
	Lesser white-lined bat		0.08						0.15
	Proboscis bat	0.04							
	Thomas's sac-winged bat	0.04							
Molossidae	Thomas's shaggy bat				0.22				
	Mexican dog-faced bat				0.37				
	Molossid species (unidentified)	0.12	0.51						
Mormoopidae	Big naked-backed bat		0.26						
	Common mustached bat	14.15	0.85	14.7	14.01	5.97	6.35	10.84	6.76
	Davy's naked-backed bat	0.08	1.02						
	Ghost-faced bat								
Vespertilionidae	Argentine brown bat	0.04							
	Elegant myotis	0.04	0.09						
	Hairy legged myotis			0.9	0.15				
	Yucatan yellow bat				0.07				
	Unidentified	1.74	0.85	0.6	1.03	0.63			
	Species Richness	10	8	3	6	1	1	1	3
	Overall AI%	17.09	4.25	16.36	16.22	6.76	6.35	10.84	7.21

The common moustached bat was by far the most recorded species across the MGL. Activity levels of this species was particularly high in BNR2, CRFR1 and CRFR2. This, is indeed the most common species found in Mesoamerica due to its opportunistic biology; it is abundant in all types of lowland forests and generally uses forest trails to commute, where our Anabat is deployed.

Among CRFR transects, the highest bat diversity was recorded in CRFR2, with a bat species richness of six. However, the Anabat unit was deployed twice (more than 22 hours recording) in this site, while in the other transects the unit was only deployed twice (a maximum of 11 hours recording). In this transect, the detector recorded high-flying bats (Mexican dog-faced bats), indicating that the detector was deployed under an opening of the canopy, thus recording a higher diversity of bats. In Golden Stream, the detector recorded a higher diversity in GSCP9 than in GSCP2, with a species richness of 1 in GSCP2 versus a species richness of 3 in GSCP9. This again could be due to the fact that the Anabat was functional for longer hours in GSCP9 (see Table 14).

Unlike previous years, BNR2 transect recorded the highest diversity of bats. In addition, activity of Thomas's sac-winged bat (Balantiopteryx io) was recorded here – a species listed as vulnerable in the IUCN red list. However, this transect had 32% of the total hours of recordings in the whole MGL, possibly increasing bat diversity and activity levels. The savannah transect (BNR3) also recorded a high diversity, but activity levels were lower than other years.

In last year's report, we explained that habitats with increased clutter (vegetation) buffer sounds affecting bat detectability (for example, detectors deployed under canopy are unable to detect high-flying bats). In addition, studies have shown that bat acoustic survey are biased towards the detection of species with higher intensity calls which tend to be fast-flying bats characteristic of open landscapes (Duffy et al., 2000; Broders et al., 2004).

Among forest transects, there does not seem to be a correlation between forest quality and bat diversity. As we will explain in the conclusions and recommendations sections later on, this is mostly due to the lack of standardization of the methodology used; in some sites the detector is by chance deployed under a small forest opening, detecting higher diversity of bats, and some other times the detector is deployed in a closed trail where only moustached bats can be recorded.

Wildlife observations

As mentioned in the methodology section, the purpose of recording unusual sightings during daily ranger is to complement our transect data, rather than including them in any form of analysis of general biodiversity. Table 16 collects the sightings recorded in both BNR and GSCP. As explained earlier, sightings in CRFR fall under BNR section in this table.

Despite daily patrols are done in both areas, the difference in number of observations between BNR and GSCP is considerable. As in the previous two years, a sighting of a Harpy eagle was recorded in BNR. The Harpy eagle sighting fits in with the sightings that were reported jointly by Ya'axché and BFREE (BFREE/Ya'axché Conservation Trust, 2013).

Table 16. Species sighted in 2014 during patrolling activities

		BNR		GSCP	
	Species	# of obs	Avg. group size	# of obs	Avg. group size
Birds	Agami heron	5	1	-	-
	Crested guan	26	2.3	1	3
	Great curassow	33	1.5	3	1.7
	Great tinamou	25	1.1	7	1.2
	Harpy eagle	1	1	-	-
	Scarlet macaw	2	2	-	-
	Solitary eagle	1	1	-	-
Mammals	Agouti	3	1	7	1
	Collared peccary	6	2.2	3	2.2
	Howler monkey	19	3.3	3	2.2
	Jaguar	2	1	-	-
	Neotropical river otter	1	1	2	1
	Nine-banded armadillo	1	1	-	-
	Red brocket deer	5	1.4	1	1
	Spider monkey	61	5	1	1
	Tapir	1	1	2	1.5
	White-lipped peccary*	9	-	-	-
	White-tailed deer	2	2	-	-
	Total # of obs.	**203**		**30**	
	Species richness	**18**		**10**	

**=only herds are recorded, without an estimate of actual number of animals*

In addition, Ya'axché rangers have continued recording Howler monkeys in GSCP. Last year the first observations of howler monkeys were recorded after Hurricane Iris in 2001, which proves the importance of enforcing conservation and tracking wildlife recovery after disturbances (Hofman, 2014).

Highway crossings

As in 2012 and 2011, Ya'axché's field staff has yielded reports of wildlife road crossings and casualties in the Southern highway intersecting the Maya Golden Landscape (Figure 22). The larger number of observations in the Indian Creek – Golden Stream – Tambran area is most likely due to the combined effect of the higher visit frequency in the area and the function of the Golden Stream Corridor Preserve as a wildlife corridor.

There were records of some species that are very infrequently seen in the area, for example the long tailed weasel and the Greater Grison. The sighting of a Crested guan passing through Golden Stream village is also an unusual observation. These game birds are not known to regularly migrate through human influenced landscape and usually prefer the deeper forest.

Big Falls	Indian Creek	Golden Stream/GSCP	Tambran	Deep river	Medina Bank
	2 Coatimundi (→↓)	1 Crested Guan (↗)		Grison (↗)	1 Pigmy owl
	1 Green vine snake (←)	4 Gray fox (All directions)			1 Jaguar
	1 Jaguar (←)	1 Long tailed weasel (←)			1 Gray Fox (↑)
	1 Jaguarundi (←)	1 Tayra (↘)			
	1 Tayra (←)	1 Black vulture (†)			
	Grey necked woodrail (†)	1 Cloudy snail sucker (†)			
		1 Gray fox (†)			
		1 Noseleaf bat (†)			

Figure 22. Recordings of road crossings and casualties along a schematic representation of the Southern Highway between Big Falls and Medina Bank villages. Darker shades represent sections of the highway that were more frequently visited; arrows indicate the direction of movement (↓ = south; ↑ = north; † = road kill).

Road traffic

In 8 hours of monitoring, a total of 198 vehicles were recorded. The most recorded vehicles were cars and pick-ups (nearly half of the passes, see Table 17). Freight trucks, vans and buses followed with similar passes, and lorries ranked last. No oil trucks were seen while we conducted our traffic monitoring survey.

Table 17. Number of vehicles passing by the Ya'axché's field center in Golden Stream. (Vehicle classes listed in the methodology section on p18.)

No. of passes	Hours monitored	Motorbike	Car/Pick-ups	Van	Truck	Bus	Lorry	Oil truck
Monday	1.5	3	16	8	3	6	1	0
Tuesday	1.5	4	25	5	12	10	1	0
Wednesday	0.5	0	2	3	1	0	0	0
Thursday	0.5	0	7	2	3	1	0	0
Friday	1	2	14	1	7	1	0	0
Saturday	1.5	5	18	9	4	5	0	0
Sunday	1.5	0	10	2	1	5	1	0
Total	8	14	92	30	31	28	3	0
Percentage		7%	46%	15%	16%	14%	2%	0%

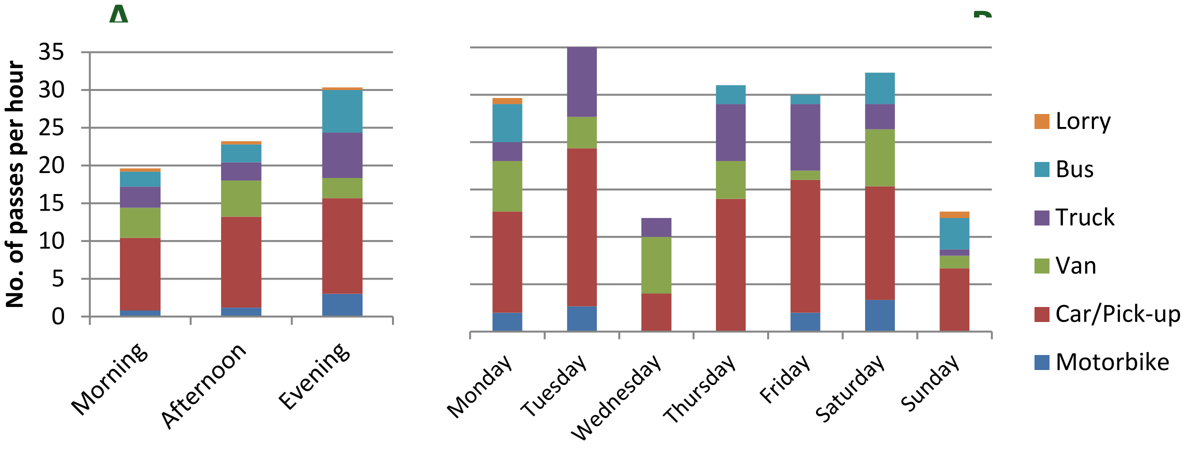


Figure 23. Average number of vehicles passing per hour, grouped per part of day (A), and day of the week (B)

Traffic density (vehicles per hour) was measured at two scales: daily and weekly (Figure 23 A&B). Througout the day, an increase on passes can be noted, with an increase of all type of vehicles except of lorries and vans, which are maintained and decreased, respectively. On a weekly basis, similar traffic densities were recorded througout the week, with the greatest peak noted on Tuesday, and the lowest densities on Wednesdays and Sundays. Trucks were more active during weekdays, while lorries were only seen on Mondays and Sundays. As a whole, the total traffic density while our survey lasted was 23.67 vehicles per hour on average, ranging between 12 and 38 passes.

Vegetation

In the four plots established by Dr. Steven Brewer and Ya'axché's former Botanist Gail Stott (see Figure 24 for plot locations), nearly 5,000 trees were counted from which 227 species were identified belonging to 65 plant families (Brewer, 2014). The most important families in species richness were the Fabaceae, Rubiaceae, Sapotaceae, Lauraceae, Meliaceae, Apocynaceae and Moraceae. In the slope and ridge plots, the Myrtaceae was the most important family. Additionally, the ridge plot was the plot with lowest family diversity.

Species richness was highest on the Alluvium 1 plot, followed by the Ridge, Alluvium 2 and Slope plots. To measure actual diversity, as in our bird and mammal transects, diversity profiles using Hill's series of diversity indices are used to examine the effect of species evenness and richness of species. Figure 25 shows that the slope plot is significantly more diverse than the ridge plot by all indices of diversity.

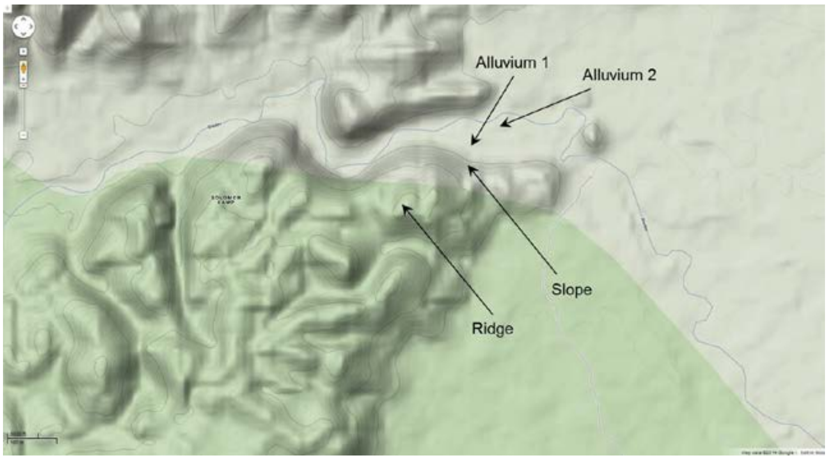


Figure 24. Vegetation Plot locations in Bladen Nature Reserve

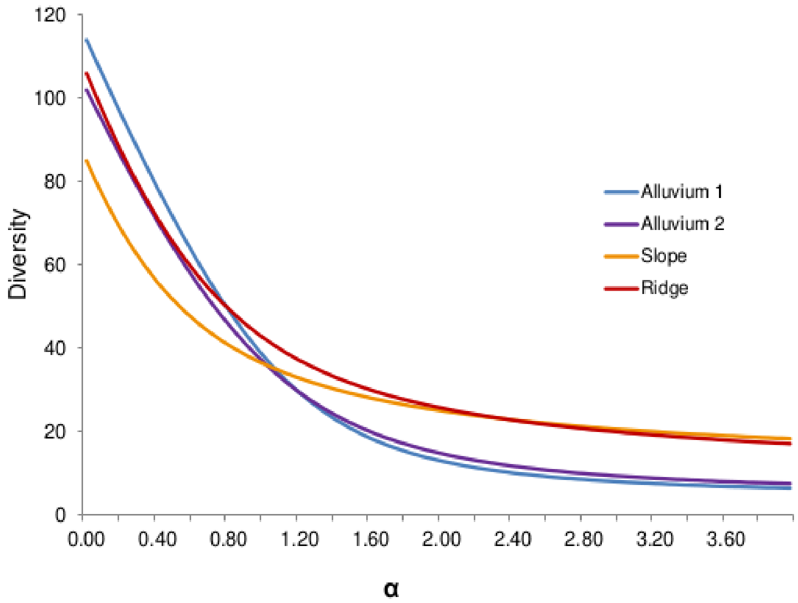


Figure 25. Diversity profiles plotting species diversity in the vegetation plots. Three common measures of diversity are used: Species richness or total number of species (**α** = 0), Shannon's entropy (**α** =1) and Simpson's dominance index (**α** = 2) (extracted from Brewer, 2014)

Regarding the species composition, the ridge plot was the most unique plot, sharing only 20% of species with the slope and 9-11% of species with the alluvium plots, which was expected due to its topographic location. The slope plot was intermediate in similarity to the plots on its neighbouring topographic positions, the alluvium plots.

Of the 227 species identified among all of the plots, 72 (approximately 32%) are restricted to northern Mesoamerica. Among these species with restricted distributions, 43% were confined to the ridge plot and 15% were found only in the slope and alluvium plots.

Weather

Weather data in 2014 was the most complete and the highest quality recorded in Ya'axché's accounts. Bladen ranger base and Golden Stream Field Centre had a yearly data coverage of 99.18% and 98.9% respectively. This demonstrates the possitive outcomes of Ya'axché's efforts to train our rangers on data entry. Raw weather data is available upon request.

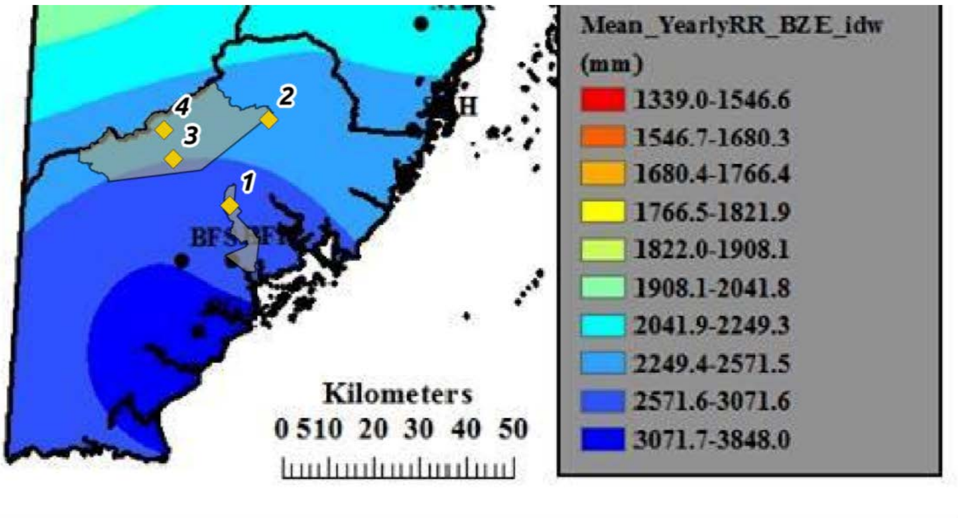
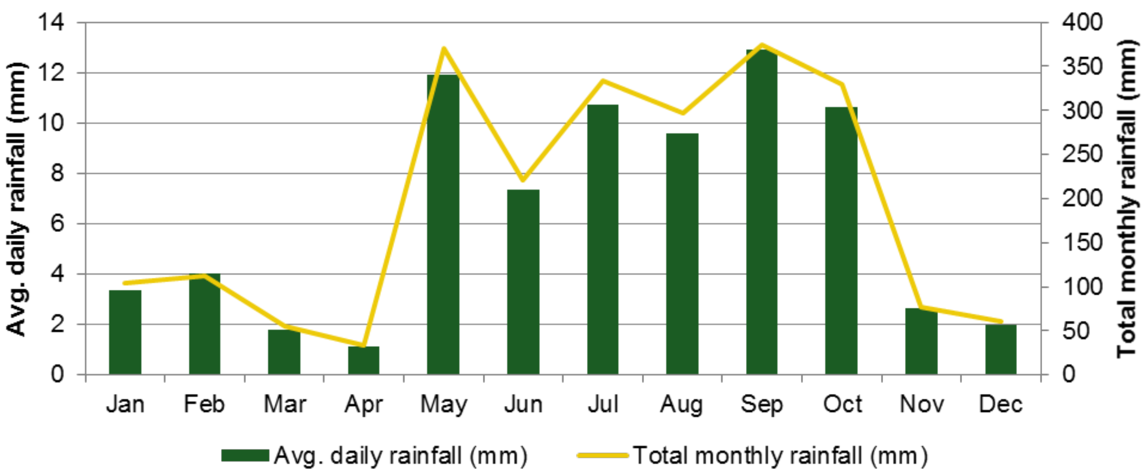


Figure 26. Detail of the mean rainfall map presented in the methodology section (Figure 4 on p22)

Bladen Nature Reserve ranger base

In 2014, there were only three days of missing data in Bladen ranger base, making a total of 362 days (99.17% of the year) of weather data registered. This, yielded an annual rainfall of 2368mm, which falls within the expected values for that area (see Figure 27A&B), indicating that there is validity to the data collected. Data collected showed a very rainy wet season and a dry season with a mild drought.

A



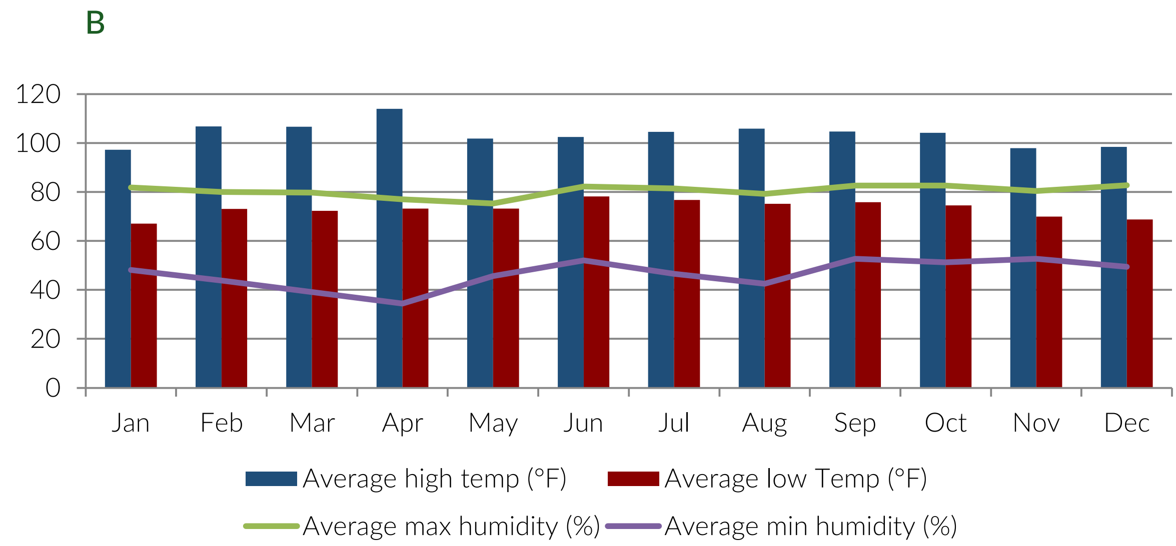
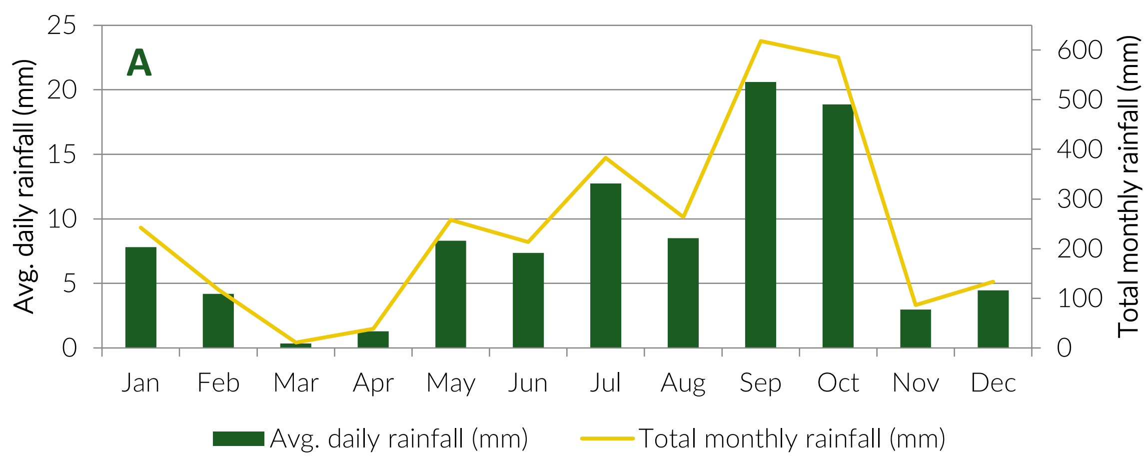


Figure 27. BNR ranger base rainfall (A) average daily and total monthly (B) patterns throughout 2014

Golden Stream Corridor Preserve field centre

A total of 2949.63mm of rain was registered at the Golden Stream Field Centre in 2014. There were only four days of data missing, which gives us a very reliable data with 98.9% of the year covered. The total amount of rainfall registered follows the expected trend registered in the last 60 years.

As in BNR ranger base weather station, the monthly rainfall pattern roughly follows the expected dry-wet seasons trend (Figure 28A&B). However, when comparing Golden Stream Field Station with Bladen ranger base, the first recorded a more significant drought during the dry season and a more erratic rainfal pattern during the wet season. Additionally, Golden Stream recorded a higher annual rainfal than Bladen, which is expected due to the more southward location of GSCP



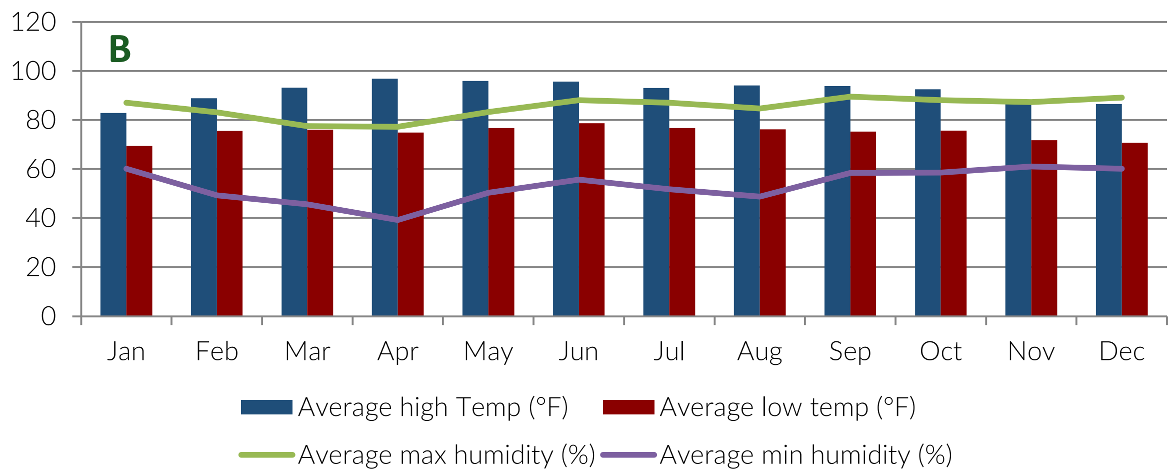


Figure 28. Golden Stream field centre rainfall (A) and temperature and humidity (B) patterns throughout 2014

Land-use change

The satellite pictures obtained throughout 2014 detected a total of 670 clearings in the new Maya Golden Landscape covering a total area of 3,389.21 acres, and an average size of 5.05 acres (SD 7.69) (Figure 29). Of the total ammount of clearings, 510 of them (1,779.2 acres) were done within the agricultural matrix and 385 of them (1,610 acres) were done outside the matrix, in previously forested areas. The attentive reader will note that the sum of the total ammount of clearings in the MGL is higher than the sum of clearings inside and outside the matrix – this is due to the fact that some clearings had a part inside and a part outside the agricultural matrix. Clearings outside protected areas were done in community lands all over the MGL.

In protected areas, 107 patches of 227,9 ares were cleared in 2014. Most clearings in protected areas were found in Maya Mountain North Forest Reserve and Deep River Forest Reserve.

When comparing these resuts whith last years', we found that in 2014 no significant escaped fires happened and clearings were, in general, smaller. This is due to a milder drought during the dry season and therefore a less favourable conditions for fire.

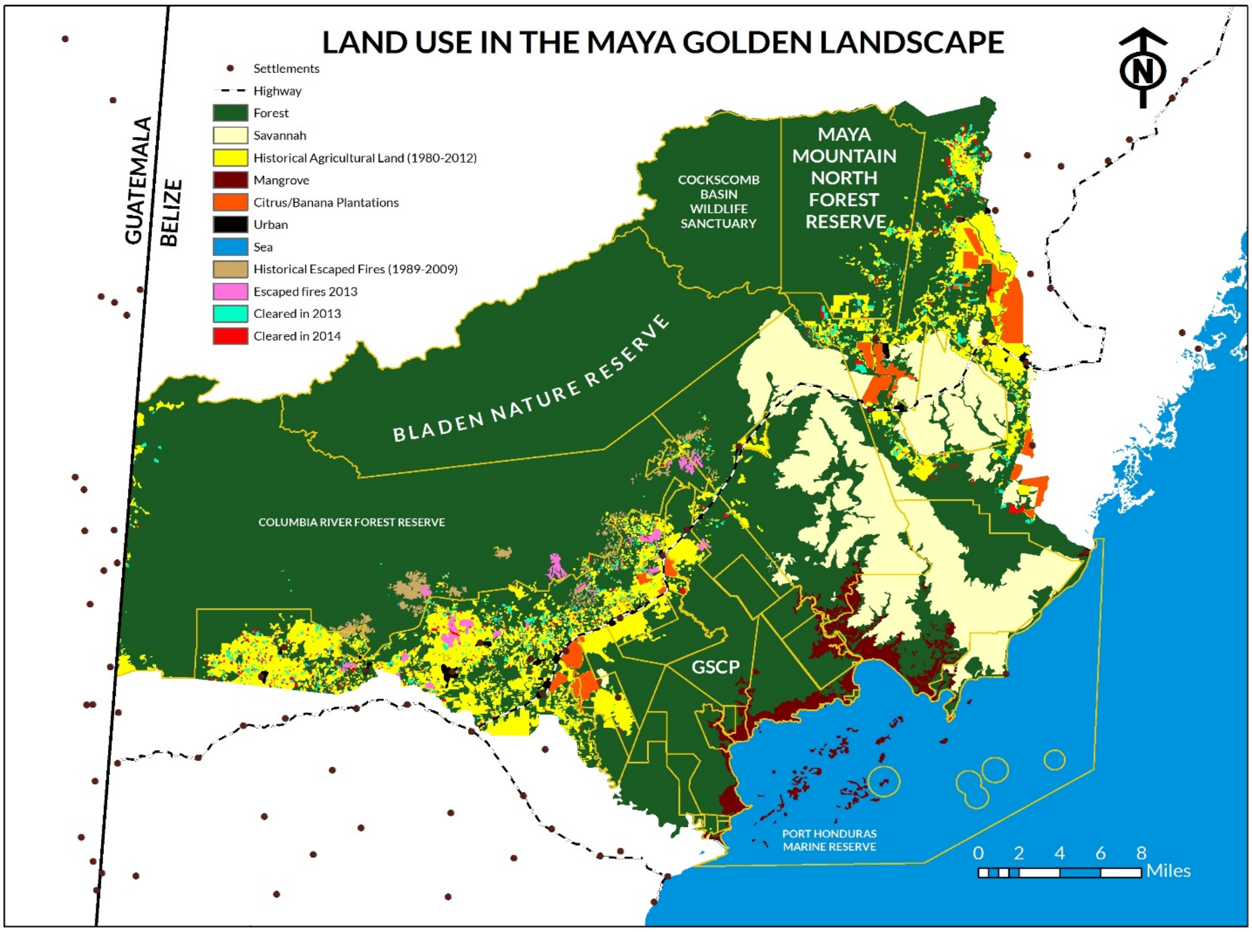


Figure 29. Location and size of agricultural clearings in the new MGL during 2014

Conclusions

Over the last five years, we have made efforts to increase the quality of data gathered in our monitoring activities, efforts that are proven successful year after year. This year again, we have maintained the trend of increasing efforts in biodiversity monitoring. We completed just over the amount of transects that were done last year, and most additional components added to our monitoring programme are being maintained. Our bat monitoring equipment broke in mid-year, but even so bat monitorings nights have been increased. Vegetation plots have been fully analised and plots will be re-measured in 2017. Ranger data-entry skills have ben greatly inproved, and mistakes in our databases are virtually zero.

Throughout the years, we have seen many successes and failures, but Ya'axché is still working to improve our monitoring scheme with further training and adquiring new equipment.

Birds – As in previous years, we observed that the savannah transect (BNR2) was the most target species rich, followed by CRFR2, CRFR3 and CRFR4. We understand that high diversity in the savannah can be due to an increased etectability due to the openness of this habitat, which can bias our results. When weighing species dominance, BNR3 was heavily affected, indicating less eveness and therefore less biodiversity. The transects less affected by species dominance were CRFR4, GSCP9 and GSCP2.

When looking at indicator species, CRFR2 recorded most forest health indicators, and BNR2 most game species. When compared with other transects, there was a substantial decrease of forest health indicators in GSCP and Village lands transects, and an increase of disturbance indicators. We also observed a marked trend of game species across our transects; no bird game species were recorded in village lands nor in most disturbed forests (GSCP). However, Crested Guans, Great Curassows and Great Tinamus were recorded across GSCP by our rangers during their daily patrols, and camera traps deployed in GSCP also took pictures of Great Curasows.

Additionally, we observed the expected trend we see every year of migratory species peaks.

Large mammals – This year's data showed an improvement on our sampling effort with an increase in the number of visits and the observations of mammals. There was more consistency with the data collection and reporting. Detectability within BNR3 is perhaps a contributing factor for the large number of reported target species documented in the savannah. The forest habitat however did show a greatest number of observations and the higher diversity. The village lands have low diversity and mostly comprising of medium size game species. Some of the larger species may be sensitive to the level of disturbance as shown by the absence of tapirs in village lands. Nine-banded armadillo seems to have an even distribution across all habitats. Pacas appear to be more common within village lands than they are in the forest or savannah. This could be related to a higher abundance of food from farms. This is a direct contradiction to what was recorded last year where pacas were scarce in village lands. GSCP2 and BNR3 were the transects with the highest species richness followed by BNR2.

Bats – This year's results show the great variablity between transects and over the years. Unlike other years, BNR2 was the area with the highest species richness, but this is probably due to the large ammount of recording hours done in that transect. Outside Bladen, CRFR2 showed a notably high diversity, including high flying bats. This can be owing to an opening in the canopy, allowing the Anabat to detect more species.

A total of 16 species were identified, belonging to four families. A Thomas' sac-winged bat was also recorded, a species listed as vulnerable in the IUCN red list. In addition, a call from a nose leaf bat (Phyllostomidae family) was recorded, but the species could not be identified due to the Anabat system's disadvantage of not being able to promptly record species belonging to this family.

Overall, we are unable to see any link between forest quality and bat diversity, mostly due to the lack of an standardised methodology on our bat monitoring approach.

Vegetation – The results obtained after analysis showed that Bladen has a particularly high tree species richness for northern Central America. Among the plots measured, the ridge plot showed a high uniqueness of species due to its topographic position. This plot was also one of the most species rich. However, when comparing Biodiversity Indices, the slope plot showed a higher diversity than the ridge plot (or more eveness of species).

Weather – With continued training efforts at Ya'axché, we have obtained the most complete results of our accounts. This leads to a more reliable data set. The most important finding was the mild drought during the rainy season. We also noted that during the dry season, Bladen acounted for more rains than Golden Stream.

Land-use change – The results obtained this year are less alarming than the ones last year. A milder drought during the dry season lead to a decrease on escaped fires due to agricultural practices througout the MGL. However, deforestation rates are still on the rise; there were a considerabe amount of clearings done outside the agricultural matrix, in previously forested areas. Maya Mountain North Forest Reserve and Deep River Forest Reserve were the Protected areas with most new clearings in the MGL.

Overall, we have noticed that the patterns on wildlife data follow the same outline every year, an outline we can expect. This indicates that our monitoring approach is not being affected by inaccuracies and our field staff is suitably trained. In the long run, this approach should enable us to detect the impacts of future possible changes on the environment of the Maya Golden Landscape. However, at Ya'axché we are aware that there are areas that need examination for increased data improvement. Therefore, we are still working with other National Institutions to design a Monitoring Programme that can be adapted to other areas in the country.

Recommendations

This section includes suggestions to improve data collection and analysis in the biodiversity monitoring programme. Priority species or taxa for conservation, field methods or financial resources are subject to continuous change, and as a result so are our monitoring activities. However, at Ya'axché we have the determination and commitment to obtain long-term biodiversity data of the best quality, and so we keep learning and adapting from the challenges we face in the field.

The most important challenge Ya'axché will face in the comming years is the great task of revising and updating the Biodiversity Research, Inventory and Monitoring Programme. Given the ammount of work this will suppose, it is recommended to be done aiming different chapters (f.e. bird indicator list, mammals, bats or freshwater invertebrates) when we have access to skills from national and international specialists.

Birds and large mammals – This year transect visits have been more consistent througout the year. In addition, data-entry mistakes have been visually removed, indicating that our training efforts have been fruitful. However, to keep consistency refresher training sessions need to be continued, and a specialized monitoring team among the rangers need to be targeted.

To obtain the most from the data obtained in the last years, additional statistical analysis should be conducted. For example, Generalised Linear Models would examine how different factors affect biodiversity data. An analysis of trends of encounter rates could also provide an approximate proxy of population estimates.

Finally, efforts to maintain our relationship with Panthera and ERI-UB needs to be done. Continuing our camera trap surveys alonside Panthera should establish a minimum Jaguar population estimate in the MGL.

Bats – The strong variation in species richness and activity levels over sites and years indicate the lack of stardadisation of our monitoring approach. With new equipment, a new monitoring approach will need to be established to monitor bats – to understand the differences of bat populations in different sites we will need to survey similar habitats in different areas, for example, rivers, forest openings, under cannopy, etc. This will allow us to compare pristine habitats with disturbed ones. In addition, we should aim to increase survey nights (from one to at least three) to respond to nights with bad weather conditions.

Additionally, to get records of species that are not readily detected by the Anabat system (Phyllostomids), different methodologies like harp-trapping and mist netting should be used sporadically.

Highway crossings – To obtain more consistent and complete data, it is recommended to create a boad to be hung at the field station. To avoid data being lost, Ya'axché staff should be able to immediately report any wildlife sighting in the road immediately after it occurs.

Vegetation – The surveys have helped us to establish a baseline for long-term monitoring. The plots will need to be re-visited every 5 years, so in 2017, all stems will be re-measured and new recruits (stems that are ≥5cm DBH) will be tagged and measured. The value of vegetation diversity of Bladen's forests are undiscutible.

To add on to these vegetation surveys, plots in Golden Stream Corridor Preserve should be established and measured, to track the recovery of vegetation after the devastating effects in this area of Hurricane Iris (2001). Gathering information of forest recovery in this area would help us to further understand vegetation recovery processes after full destruction and therefore help to improve the management of forests in Belize.

Weather – Due to increased training efforts, weather data is notably improving year after year. To make sure data entry does not deteriorate with the future recruitment of new staff, additional refresher trainings will need to be conducted. The weather station needs to be fixed and redeployed in an area safer from floods, or installing it on a higher pole.

In addition, rainfall data should be used to obtain more information in the MGL, for example, integrating rainfall data with agricultural yield data.

Land-use change - Continuing quantifying the development of agricultural coverage and deforestation in the MGL should be a priority at Ya'axché. Additionally, examining clearings in protected areas can help to understand the needs of different communitites for land. This should have a promt response in the form of amplified enforcement in the protected area and increasing sustainable livelihood programes in the community.

In the following years, we will aim to include freshwater invertebrate monitoring in the MGL using tools developed by our freshwater ecologist, Dr Rachael Carrie. In addition, increased internal research to understand bat populations is being carried out by Ya'axché's science branch. Both freshwater invertebrates and bats have been classified as high priority in the National Biodiversity Monitoring Program.

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