Biodiversity Synthesis Report

2017

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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
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
MMNFR	Maya Mountain North Forest Reserve
NGO	Non-Governmental Organization
PSP	Permanent Sample Plot
SP	Species Richness
Ya'axché	Ya'axché Conservation Trust

Summary

Ya’axché Conservation Trust is a Belizean community-based NGO that works to protect and promote the sustainable use of the natural resources of the Maya Golden Landscape (MGL), a 770,000-acre mosaic of public and private protected lands, and communities. Ya’axché manages the Golden Stream Corridor Preserve (GSCP, 15,441 acres, private) and co-manages the Bladen Nature Reserve (BNR, 99,796 acres) and the Maya Mountain North Forest Reserve (MMNFR, 36,000 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 on these and other protected areas not co-managed by Ya’axché. The intention of this monitoring is to inform our conservation actions. Initially, the Science Program at Ya’axche only included monitoring along bird and mammal transects, but over the years we have added other taxa and methods such as freshwater macro-invertebrates, bats, vegetation, weather monitoring, road traffic density and road crossings, and finally, land-use change monitoring. Not all monitoring targets are reported on regularly due to whether or not resources are available in a specific year. This report presents the methods and results of weather monitoring, bird point counts, and mammal track censuses along transects across the Maya Golden Landscape.

In 2017, the transect monitoring effort by the Science Program was strategic; the overall frequency of visits was more even across transects than in previous years. The lowest number of visits at any transect was 7, a significant increase from the varying effort of previous years. Transect GSCP1, located in secondary forest recovering from hurricane damage in 2001, recorded higher species richness when compared to the other transects and to that of 2016. Both mammal and bird target species are comparable to that of the forested transect in the Bladen Nature Reserve, which is considered the most adequate habitat for high diversity. On the opposite end of the gradient, village lands, which are considered the least adequate, turned up to have a higher richness in bird target species than some of the other forested transects. However, fewer mammals are recorded on this transect, an anticipated sign of disturbance in the area. Overall the forest transects in Bladen Nature Reserve, Columbia River Forest Reserve, and Maya Mountain North Forest Reserve account for the highest target species richness across a disturbance gradient.

Rain patterns differ between the Golden Stream Corridor Preserve and the Bladen Nature Reserve. While rain is abundant year round there is a slowing down of heavy rains around August that is evident at BNR and not GSCP. GSCP appears to be on the same rain gradient as Belize’s southernmost town Punta Gorda. It observes a rainy August, and in general, a wetter climate throughout the year than the Bladen Nature Reserve. However, the total annual rainfall is higher in BNR than GSCP. BNR records roughly 100 mm more rain than its location predicted, and GSCP records roughly 100 mm less rain than predicted. From month to month, BNR has consistently wider daily temperature ranges and lower relative humidity than GSCP.

Ya'axché continuously strives to improve its efforts at data collection in order to provide the conservation community and the general public with reliable, accurate, and high quality information. It is not always possible to conduct data collection considering limitations beyond our control and the number of tasks carried out by the Ya'axché ranger team. However, the quality of work conducted by the team is of the highest standards and Ya'axché aims to keep improving its monitoring program through constant capacity building and targeted approaches. The next iteration of the Biodiversity Synthesis Report will feature a wider array of information ranging from camera trap surveys to vegetation work.

Introduction

Ya'axché Conservation Trust (Ya'axché) is a Belizean organization which aims to maintain a healthy environment with empowered communities by fostering sustainable livelihoods, protected area management, biodiversity conservation, and environmental education within the Maya Golden Landscape. The organization's geographical focus is the Maya Golden Landscape (MGL), which encompasses twelve protected areas in Toledo, as well as the buffer communities around them (see Figure 1). Three of these protected areas are managed by Ya'axché. The Golden Stream Corridor Preserve (GSCP) is a 15,441-acre preserve owned and managed by Ya'axché that forms part of the link between the Maya Mountain Massif and the coastal ecosystems of southern Belize. The Bladen Nature Reserve (BNR) is a 99,796 acre strictly protected nature reserve (IUCN Category 1a), owned by the Government of Belize and co-managed by Ya'axché since 2008. The Maya Mountain North Forest Reserve (MMNFR), a key biodiversity area, is a 36,000-acre forest reserve that serves as a model for sustainable use and extraction of natural resources within Belize's protected areas system.

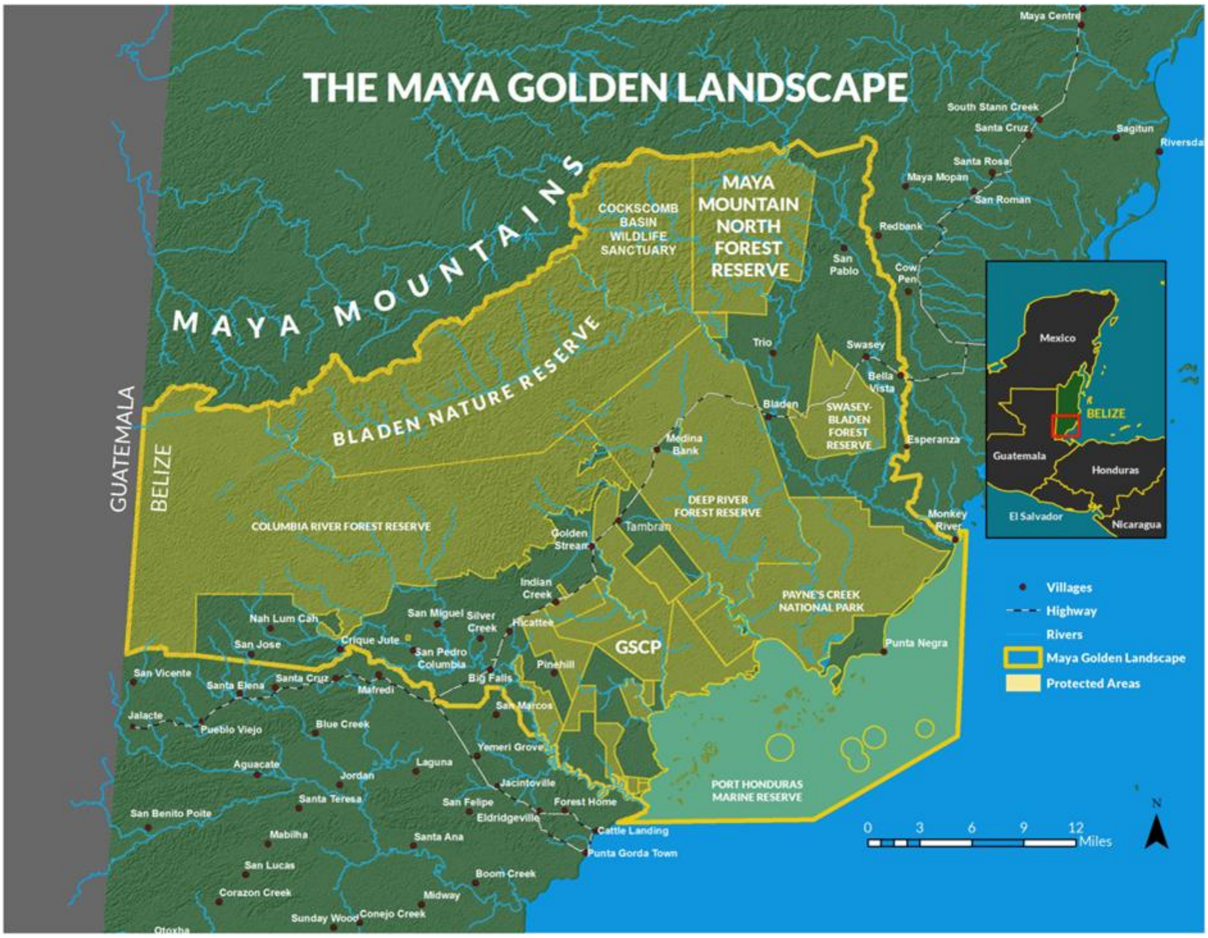


Figure 1. The MGL and its communities surrounding the protected areas in southern Belize.

Over the past 9 years, Ya'axché has implemented a biodiversity monitoring system to observe possible changes occurring in the natural environment that could indicate unsustainable human activities and inform management practices. When Ya'axché accepted co-management of the Bladen Nature Reserve in 2008, a Biodiversity Research, Inventory and Monitoring (BRIM) strategy 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 Ya'axché faces when managing and co-managing protected areas and recommends a number of target groups (e.g. birds and mammals, freshwater invertebrates, vegetation) to be monitored in order to answer these questions. The BRIM strategy provides short outlines of the methodology to be used and general guidelines for the analysis of the data gathered. It also prescribes the annual analysis of the data to facilitate comparison among years and provide information to guide management decisions.

Ya'axché has collected data on birds and large mammals using transect monitoring throughout the Maya Golden Landscape since 2006. A formal structure was put in place in 2009, and since that time, the ranger team has been trained in freshwater macro-invertebrate sampling and freshwater physiochemical monitoring by freshwater ecologist, Dr. Rachael Carrie. Dr. Carrie also initiated the weather monitoring activities. In 2011, bats were added to the monitoring program. Bat data collection and sampling was improved between 2013 and 2015 by Ya'axché's Research Coordinator OlatzGartzia and Consultant Thomas Foxley, both experienced bat researchers. In 2012, Ya'axché's Botanist, Gail Stott, in collaboration with Plant Ecology Consultant Dr. Steven Brewer, added vegetation monitoring to the existing program by establishing two one-hectare Permanent Sample Plots (PSPs) according to international standards. In 2013, a collaboration between Ya'axché and The Global Trees Campaign established phenology monitoring for 19 species of rare, data deficient and threatened trees.

Finally, GIS Specialist JaumeRuscalleda continued improving Ya'axché's capacity to use remote sensing utilizing satellite imagery to monitor land use and land cover change. The main targets of this monitoring include the conversion of forested areas into farmlands, as well as forest burned by escape fires and its potential impacts to biodiversity. Fire plays an important role in the lives of people in southern Belize, who regard the use of fire as a necessity for successful farming and use it as a hunting technique and to clear vegetation from roadsides. However, many people are ill-equipped and lack the fire management knowledge to control the fire once started. Escaped fires are therefore one of the main threats to forests and biodiversity conservation in the area. By combining land-use change monitoring and other abiotic parameter monitoring, Ya'axché has been implementing an inclusive landscape-scale approach to conservation in the MGL.

As a result, the Biodiversity Research, Inventory and Monitoring program 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. This report continues the efforts made throughout the past 8 years to ensure the fulfilment of the BRIM requirement to annually report findings. This year, we report on bird diversity and mammal diversity, as well as a comprehensive look at weather data from 2009 to 2017. Camera trap data from agroforestry farms will be a feature of the 2018 Biodiversity Synthesis Report. Other areas of interest will be reported on based on the availability of data and feasibility of monitoring efforts.

This report has seven important sections including this Introduction and the Summary. The following section, Methodology, consists of an in-depth description of the methodologies used to collect data and the statistical tools used for analysis, which is then presented in the fourth section titled Results. This is followed by a set of Conclusions and Recommendations to improve data collection and analysis for the coming years and how to overcome identified shortcomings. Finally, a section is included to acknowledge the people and organizations that helped in the fulfilment of this report.

Methodology

Birds and Large Mammals

Transect monitoring in 2017, as in previous years, involved birds and large mammals as key taxa. Transects are located in and around some of the protected areas in the Maya Golden Landscape (see Figure 2). These are point count 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, tracks, and an array of different signs such as scat, smell, sounds, and scratch marks. For both focal taxa a previously generated list of indicator species was used, and the recorded observations were limited to those selected species (see Table 3 for birds and Table 4 for mammals). These species lists were adapted from Ya'axché's BRIM strategy.

Our target species were classified into six indicator groups (see Table 1) and each species in the list indicates a different factor based on their habitat preferences and ecology. This classification was taken into account when analyzing bird and mammal data and was used to facilitate interpretation of the monitoring results. For example, an increase of 'disturbed forest indicators' could indicate habitat degradation, whereas decreased 'game species' richness could indicate a high level of hunting pressure and/or habitat degradation.

Table 1.Description of indicator groups for both mammal and bird target species

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

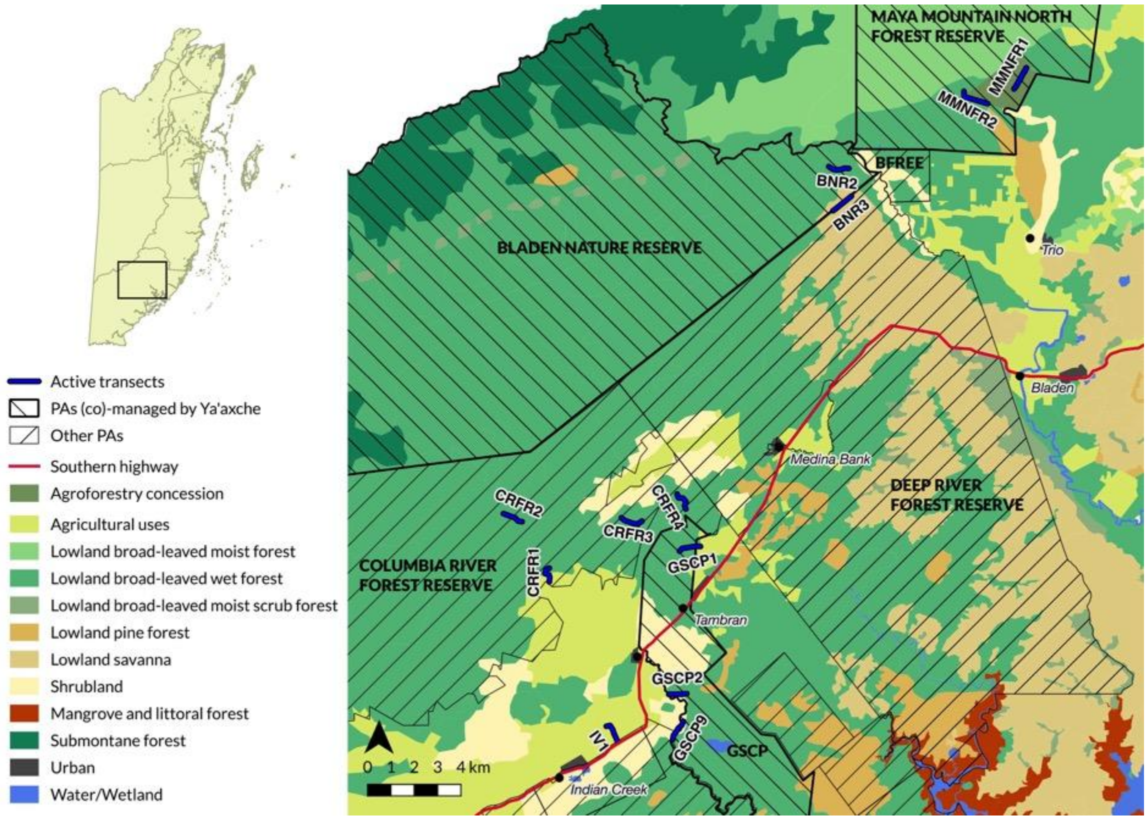


Figure2.Location of 2017 biodiversity monitoring transects within the MGL

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 ranger team.

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 savanna). Therefore, we assigned all mammals to either forest health, game species or wetland indicator groups, and only a small number of species were not assigned to any group due to their "generalist" habitat nature (see Table 2). Tables 3and 4 present a more detailed species list and their corresponding indicator group.

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

		D	F	G	M	P	W	N/A
Birds	# species	4	10	3	7	3	3	0
	% species	13.3%	33.3%	10.0%	23.3%	10.0%	10.0%	0.0%
Mammals	# species	1	7	6	0	0	2	3
	% species	5.3%	36.8%	31.58%	0.0%	0.0%	10.53%	15.79%

Table 3. Selected target 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	F
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

Table 4. Selected target mammal indicator species (n=19)

Common Name	Class
Agouti	G
Baird's Tapir	W
Brown Brocket Deer	NA
Coatimundi	NA
Collared Peccary	G
Howler Monkey	F
Jaguar	F
Jaguarundi	D
Margay	F
Naked-tail Armadillo	NA
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

Data collection

Transect location and habitat

The core data collected in transects was the number of species observed and the number of individuals observed per species. In 2016, two new transects were established in Maya Mountain North Forest Reserve, bringing the total number of transects monitored in the MGL to 12. Besides these two transects in MMNFR (MMNFR 1 and 2), four transects were monitored 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 (GSCP 1, 2 and 9) and two in Bladen Nature Reserve's forest (BNR2) and savanna (BNR3). The diversity of habitats across the transects makes our monitoring program a landscape scale approach. Table 5 contains information about each transect, and a map showing the location of the transects is depicted in Figure 2.

Table 5. Description of the currently active transects, their locations, levels of human disturbance and general ecosystem types through which the transects run.

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
MMNFR1	1000	Maya Mountain North	Forest Reserve	30-60% canopy cover within shade grown cacao plots	Cacao agroforest within primary forest on karst hills
MMNFR2	1000	Maya Mountain North	Forest Reserve	Minimal	Primary forest on karst hills

Disturbance gradient

Among the transects that occur in forest habitats, a gradient of natural and human disturbances can be observed. The transects in Bladen Nature Reserve are the least disturbed and the ones in Golden Stream Corridor Preserve are the 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.

Transect visit schedule

Transects were visited according to a pre-set monthly schedule (see Table 6). Exact visit dates were kept flexible to allow for uncertainty such as seasonal bad weather and/or interference of other ranger tasks (e.g. expeditions or deep patrols).

For bird monitoring, the transects occurred twice daily: early morning and late afternoon. Some distant transects could only be reached after a day of hiking; for these, the afternoon visit was 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 visits in 2017; shaded areas indicate periods of inaccessibility

	Month	BNR2	BNR3	CRFR1	CRFR2	CRFR3	CRFR4	GSCP1	GSCP2	GSCP9	IV1	MMNFR1	MMNFR2	Total
	Jan	1	1	1	1			1		1	1			**7**
	Feb	1	1	1	1	1	1	1	1	1	1	1	1	**12**
	Mar	1	1	1	1	1	1	1	1	1	1	1	1	**12**
Dry Season	Apr	1	1	1	1	1	1	1	1	1	1	1	1	**12**
	May	1	1	1	1	1			1	1	1	1	1	**10**
	Jun	1	1	1	1	1	1	1	1	1	1	1	1	**12**
	Jul	1		1	1	1	1	1	1	1	1		1	**10**
	Aug	1	1	1	1			1			1		1	**7**
	Sep	1	1			1	1		1	1		1	1	**8**
Wet Season	Oct	1	1	1	1	1	1		1		1	1	1	**10**
	Nov							1	1	1	1			**4**
	Dec	1	1					1	1					**4**
Total		**11**	**10**	**9**	**9**	**8**	**7**	**9**	**10**	**9**	**10**	**7**	**9**	**108**

Data quality

Ya'axché field staff is constantly facing challenges with data collection both for enforcement and compliance and for biodiversity monitoring. While data collection, database management, and quality of the data have significantly improved since the first Biodiversity Synthesis Report, logistical limitations can often hinder the amount and quality of data collected. Transect visit schedules are flexible and prioritized when possible over other activities, allowing for an increase in our monitoring effort. 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'. Ya'axché's monitoring program is expected to expand, encompassing the farming landscape of the MGL after 2018. This will require a proactive restructuring of the team and of our current databases.

Data analysis

Data analysis used the instructions in the BRIM strategy as a starting point but was largely built on the progress accomplished in previous Biodiversity Synthesis Reports. In 2017, 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 (savanna, forests and village lands), as we did in the last four biodiversity reports (Gutierrez & Dorgay 2017; Gutierrez 2016; Gartzia and Gutierrez 2015; Gartzia, 2014; Hofman et. al, 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 was 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 previous years' reports, 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):

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

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

The higher the profile, 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 PAST v3.12 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 used rarefaction curves (Gotelli& Colwell 2001; Magurran 2004)that allow comparison of 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 PAST v3.12 software (Hammer et al. 2001).

Indicator Groups

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

Weather

Belize's weather is characterized by a rainfall gradient that increases roughly from north to south (see Figure 3). 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 enables a more localized picture of specific circumstances that could, among other things, inform us about farming success or failure in certain years. Therefore, we gather rainfall, temperature, and relative humidity data at the two Ya'axché ranger bases located at Golden Stream Corridor Preserve (W088°47'13.90" N16°22'23.41" [WGS 84]) and Bladen Nature Reserve (W088°42'44.79" N16°32'07.61" [WGS 84]). Both weather stations are composed of an electronic temperature and humidity device (Digital Hygro-Thermometer, Forestry Suppliers Inc.), and a manually operated rain gauge. Data were recorded manually and entered in a digital spreadsheet.

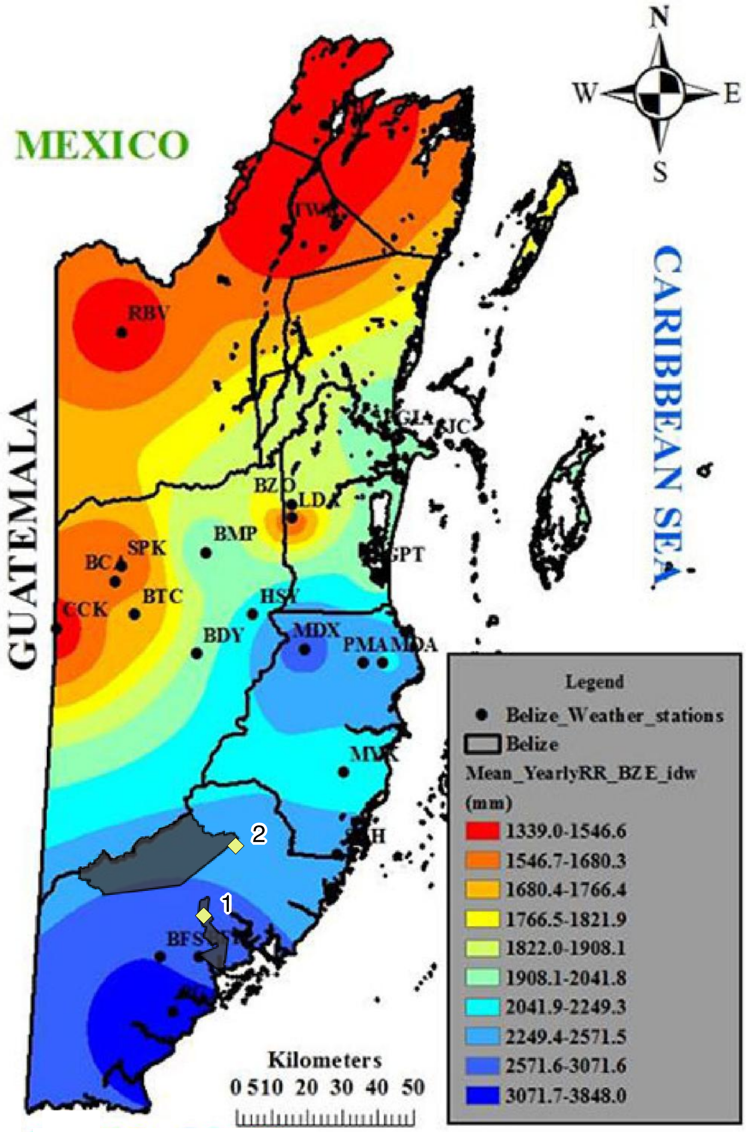


Figure 3.Mean annual rainfall across Belize since 1951, with varying number of year's data availability per weather station. Bladen Nature Reserve and the Golden Stream Corridor Preserve are indicated by transparent polygons. The two Ya'axché weather stations are Golden Stream field station (1) and BNR ranger base (2). 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 analyzed 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 analyzed and presented in an equally straightforward manner.

Birds

Each transect was visited between 11 and 18 times over the course of the year, resulting in a total of 137 km of transects completed and an average of 9.5 visits per transect (see Table 7). This was a decrease from the previous year's sampling effort, that averaged 11.7 visits per transect. However, the number of visits per transect was more evenly distributed than in the previous 4 years.

Table 7.Bird monitoring effort per transect in 2017, BNR=Bladen Nature Reserve, CRFR=Columbia River Forest Reserve, GSCP=Golden Stream Corridor Preserve, IV=Indian Creek Village

Transect ID	# of visits	# of m transect	# of obs./1000m
BNR2	18	18000	10.6
BNR3	18	18000	8.3
CRFR1	14	14000	4.4
CRFR2	15	15000	5.9
CRFR3	11	11000	8.9
CRFR4	12	12000	7.6
GSCP1	17	17000	11.0
GSCP2	16	16000	9.9
GSCP9	13	13000	11.8
IV1	14	14000	13.1
MMNFR1	14	14000	11.6
MMNFR2	12	12000	10.8
Total	174	174000	9.5

Of the 30 bird target species, a total of 25 species were detected, with a total of 1,922 observations recorded, resulting in an average of 9.5 observations per km of completed transect. There was no significant positive correlation between the number of visits and the number of observations per transect (Spearman's ρ=0.494; p> 0.05). Similarly, there was no correlation between the number of visits and average number of observations per 1000m (Spearman's ρ=-0.042; p> 0.05). No obvious link was seen between the number of visits and the number of individual birds recorded (Spearman's ρ= 0.461; p > 0.05). Compared to previous years, a high number of visits per transect did not necessarily translate to more records of individual birds.

Consistent with previous years, BNR2 had the highest record in number of observations over all the others. IV1 (the village transect) had the highest average observations per 1000m. We will see later in this section that having a higher number of observations per 1000m does not necessarily indicate the presence of more target birds or more target species diversity but potentially the influence of dominant species.

In 2017, between 6 and 24 transect visits were conducted per month (see Figure 4). July consistently has the lowest number of transect visits, and that trend continued in 2017 with only 6 visits recorded that month. March and April had the greatest number of visits at 24 each. The average transect effort overall was 14.7 visits per month, so generally transect visits were less evenly spread most of the year.

As noted in Figure 4,the number of visits per transect was less even between June and August and between November and December. Changes in ranger tasks influence this fluctuation. Peaks in transect visits coincide with the bird migration peaks. June and August typically record fewer target species. In 2017, July had the lowest species richness, which was mostly influenced by the absence of migrant species which make up the bulk of the targets. More detail on migrants can be found later on in this section.

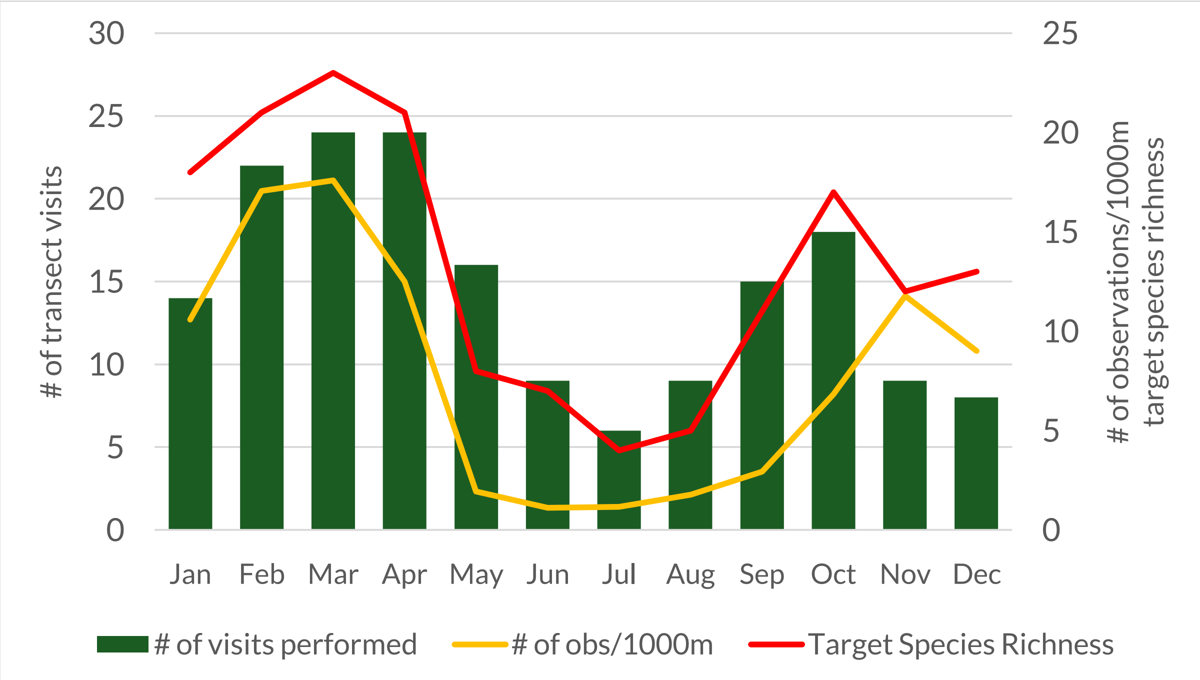


Figure 4. Bird monitoring effort in 2017

Target Species Richness

As explained in the methodology section, our list of target bird species is biased towards forest species, but it does contain disturbance indicators and savanna species. Therefore, we are able to compare the results of the three different habitats by assembling the transects conducted in each landscape type. However, there is one important factor to consider when making comparisons: there is a larger proportion of forest transects relative to that of the other transect types. We therefore compare the average target species richness in 10 forest transects with a single savanna and a single village land transect; using an average value can result in a coarse reflection of the total forest target species richness because the arithmetic average is sensitive to outlying values. On the other hand, given the openness of the savanna and village habitats, we would expect that visibility increases and sound travels farther than in forested environments, which inflates species richness estimates in these cases.

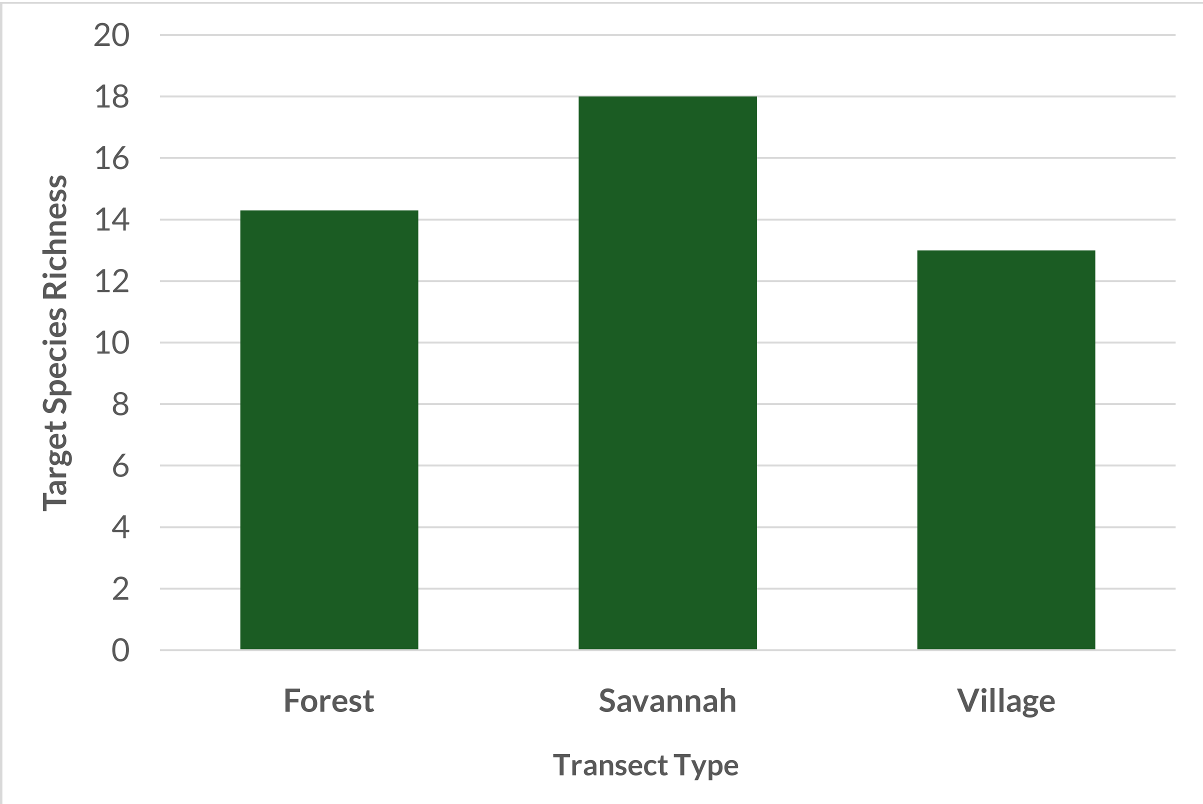


Figure 5. Total target bird species richness per habitat

Figure 5 shows an average of 14.3 target bird species detected on forest transects, compared with 18 target species detected in the savanna and 13 in village lands. All forest transects yielded a total of 23 target species, including all species found in the other two habitats, except three that are restricted to the pine savanna (Grace's warbler and yellow-headed parrot). With this in mind we can only interpret Figure 5 as indicating a similar number of species found within all three transect types but that the species composition differs from habitat to habitat. Composition by indicator class is explored later in this section.

Sample-based species rarefaction curves

For a fair comparison, each transect should have an equal number of visits. However, logistical limitations prevent even sampling at any given point in time, so it is not realistic to consider an even number of transect visits per transect. Therefore, we compare all the transects' expected target species accumulation at the point where the minimum sample size lays (in this case, the minimum amount of samples, or visits, was 11 for CRFR3). The rarefaction analysis (explained in the methods section) results in rarefaction curves or species accumulation curves as seen in Figure 6.

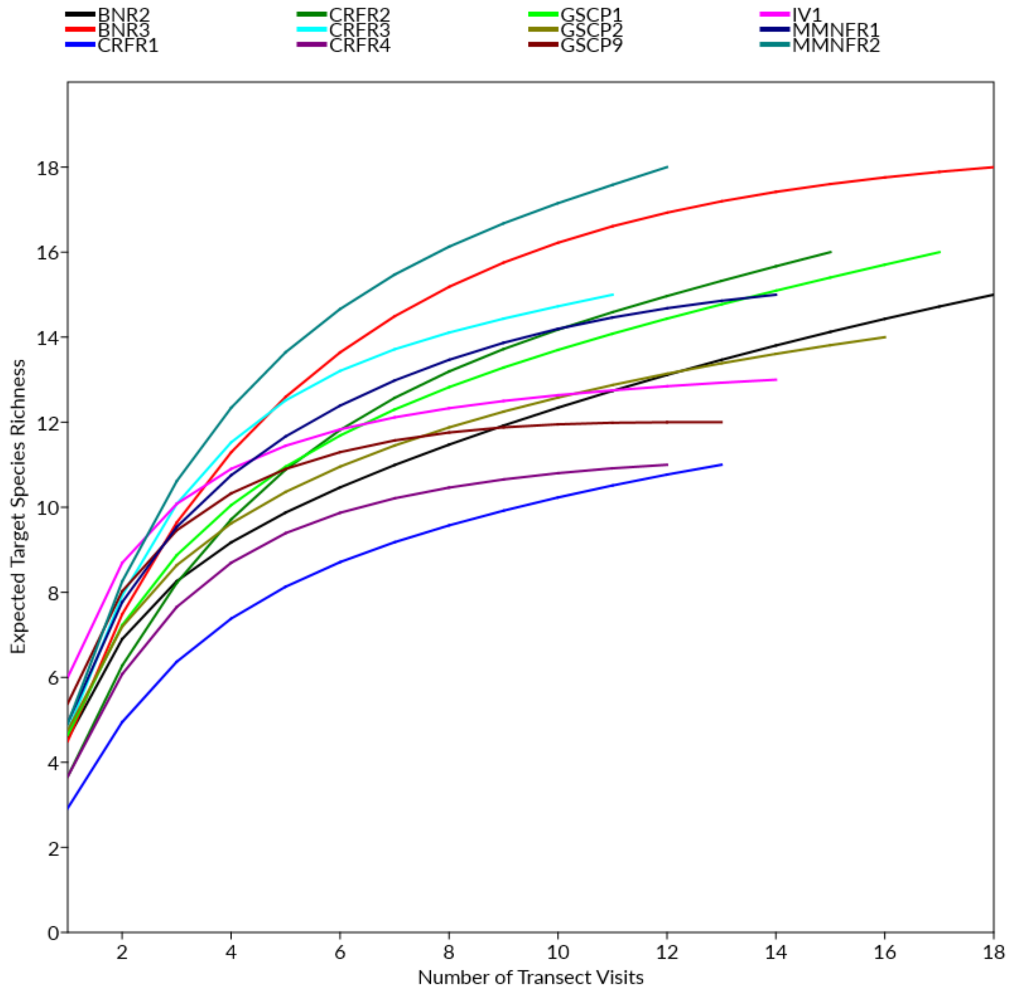


Figure 6. Sample-based rarefaction curves for all transects

Ranking	Transect
1	MMNFR2
2	BNR3
3	CRFR3
4	CRFR2
5	MMNFR1
6	GSCP1
7	GSCP2
8	IV1
9	BNR2
10	GSCP9
11	CRFR4
12	CRFR1

Table 8. Transect ranking according to expected bird target species richness after 11 transect visits

Table 8 shows ranking in expected species richness of the transects at 11 transect visits. Transects MMNFR2 and BNR3 accumulated most species at 7 visits (17.6 and 16.6 respectively) followed by CRFR3 (15) in descending order of rank. In general, all transects accumulate most species within 11 visits. Unlike previous years there was no pattern of cluttering by transects from any particular protected area. We consider this to be the result of an increase in transect visits across all transects with a more even distribution. A similar effort in 2018 should be compared to 2017's effort.

Diversity Profiles

Both MMNFR2 and BNR3 recorded the highest diversity but have a notable effect of dominance caused by magnolia warbler and yellow-headed parrot respectively (see Figure 7). The steeper the curves are the higher the effect of dominance. Dominance by one or more species is apparent in all transects except CRFR4 and to a lesser extent CRFR1. The number of individuals per species along those two transects was more evenly distributed compared to all other transects.

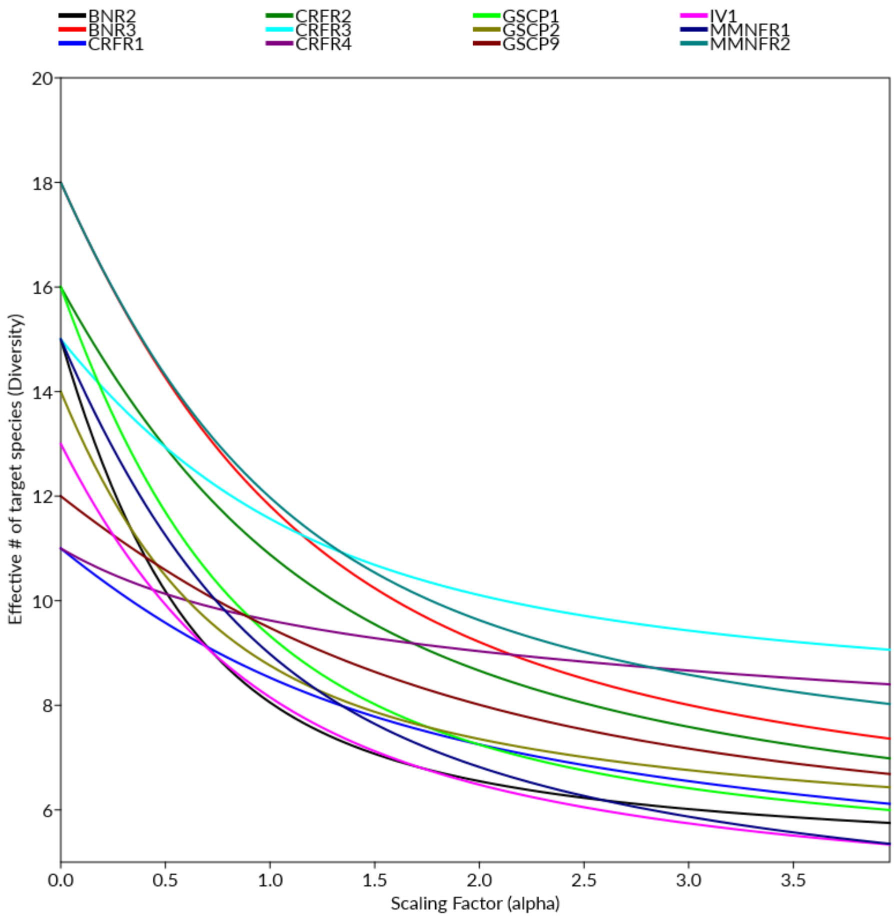


Figure 7.Bird diversity profiles

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. There was no statistically significant correlation between the number of individuals per 1000m and the number of transect visits per month (Spearman's ρ = 0.55; p = 0.61), which enables us to compare between months without controlling for the number of visits conducted in these months.

The pattern of migration can be clearly seen as the peak of the season is marked from October to April (see Figure 8). Like previous years, species richness follows a similar pattern with encounter rates plummeting to low numbers or none at all in the summer months. Species richness was highest in January 2017 and species richness was lowest in June 2017. Consistent with previous years, the American redstart was the migrant species that was present for the greatest number of months throughout the year.

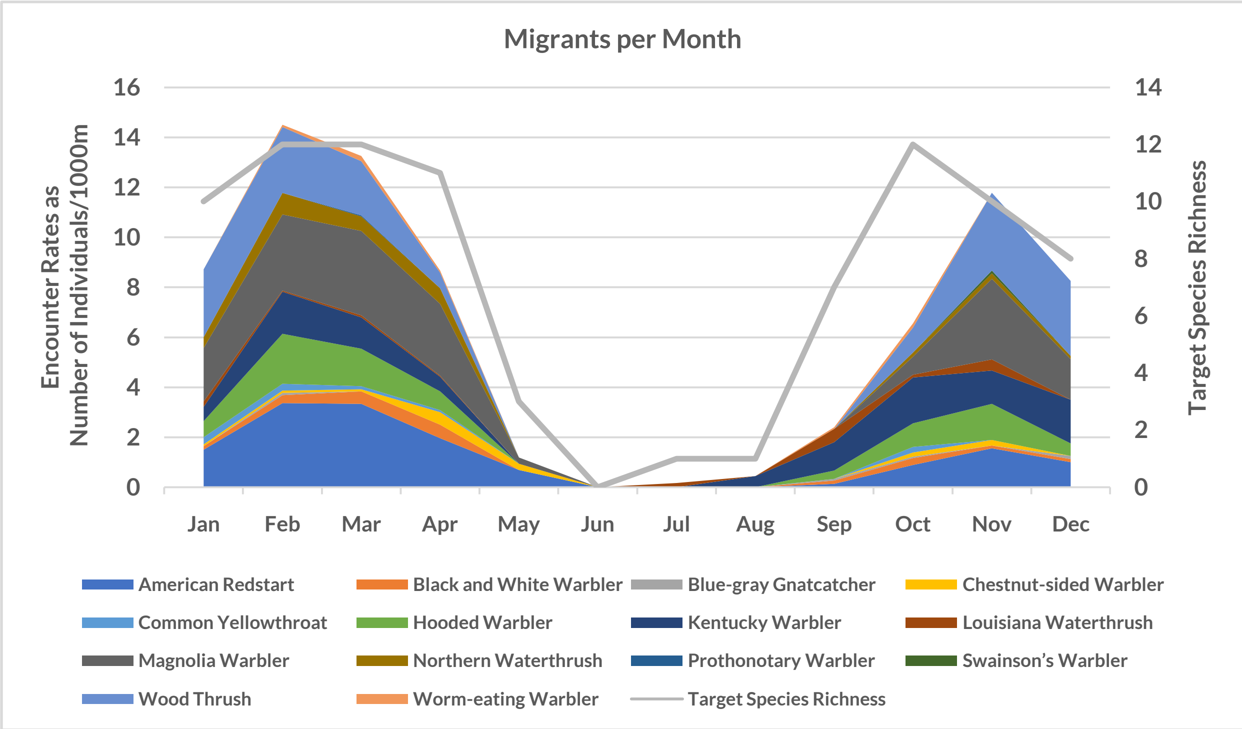


Figure 8.Migrant encounter rate and species richness throughout the year

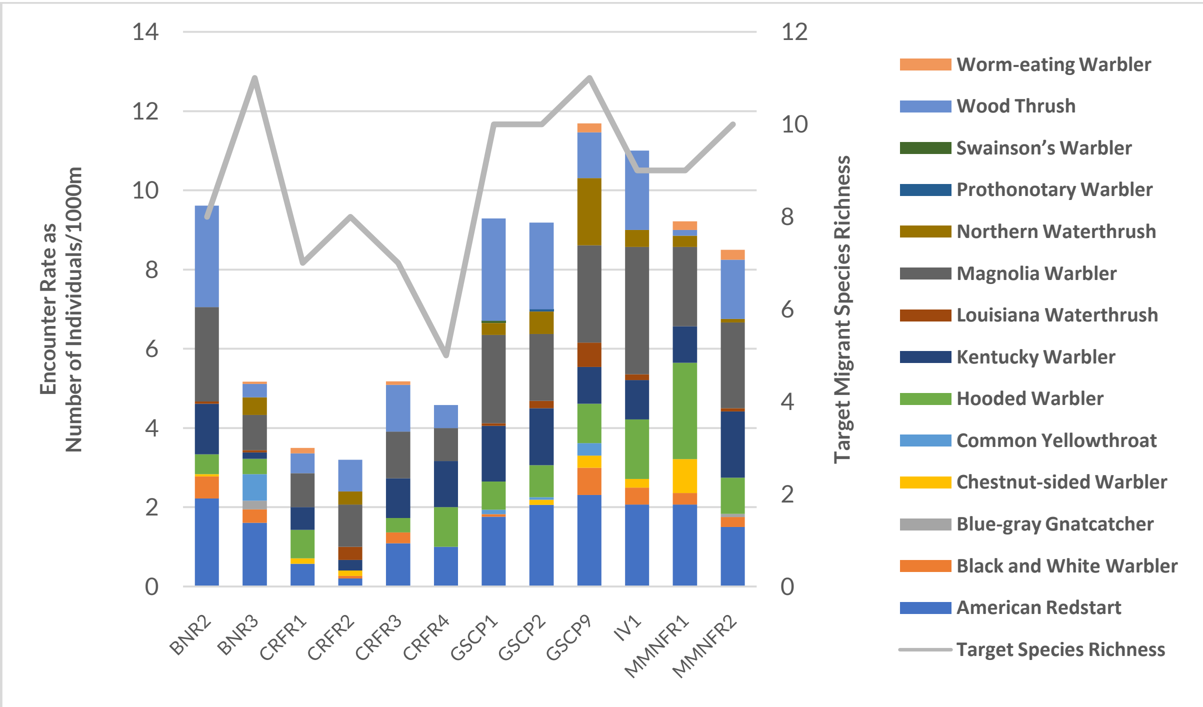


Figure 9.Encounter rate and species richness of migrants per transect

Migrant species richness fluctuated across transects, but there was a notable dip in richness for CRFR4 (Figure 9) and peak in richness for BNR3. The lowest encounter rate can be seen for CRFR2. The transects with the highest encounter rates were GSCP9 and IV1, indicating that migrants are widespread across gradients. Wood thrush, magnolia warbler and American redstart are clearly the dominant migrants across transects.

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. There were 142 transect visits in forest habitats but only 18 visits in the savanna and 14 in village lands. The higher sample size of forest transect visits explains why more individuals and species were observed there than on the transects in the savanna 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 = the number of individuals per 1000m), to avoid the difference in observed number of species affecting the summed encounter rates per indicator group. In Figure 10, the total number of individuals encountered in each habitat is shown in brackets.

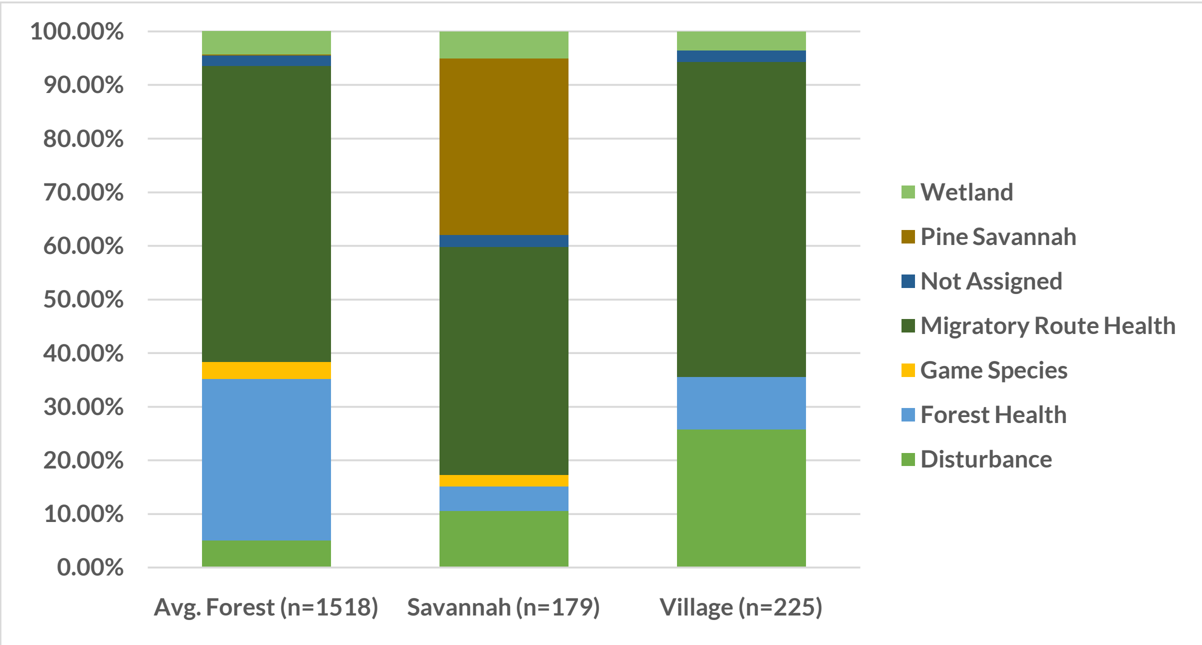


Figure 10.Distribution of individuals among Indicator Groups

Migratory route health indicators made up 55.2% of the individuals recorded in all forest transects combined. Forest health indicators made up 30% of the individuals recorded in all forest transects combined. Disturbance indicators, notably one species (plain chachalaca), made up 5% of the total number of individuals while game species made up 3.2% of the total number of individuals in forest transects (see Figure 10).

In the savanna, a third (32.9%) of all individuals detected were pine savanna indicators. As in the previous year's data, a large percentage (42.5%) of the individuals were migratory route health indicators. In addition, disturbance indicators are greater in the savanna than expected with 10.6%.

In village lands, considerably fewer forest health, game, and pine savanna indicator species were detected. Indicators of disturbance represented 25.7% of individuals, much higher than that seen in the other two habitats. Migratory route health indicators made up the bulk of individuals here, representing 58.7% of the individuals in the village.

To compare the distribution of indicator groups across transects, we arranged the transects along a roughly defined disturbance gradient for forest transects originally defined by Hofman et. al. (2013). Figure 11 presents the proportions of individuals belonging to each indicator group for all forest transects and compares them side by side with the village transect and savanna transects. As this is a coarse gradient of disturbance, it should be taken conservatively considering that there may be other factors affecting any patterns in the indicator groups (weather, monitoring effort, population fluctuations, etc.).

The most notable trend is a decrease of forest indicators as the disturbance gradient increases. On the other hand, disturbance indicators increase as the disturbance increases. Migrants remain relatively even throughout, even in disturbed habitats. The number of individuals detected in the different transects is shown in brackets.

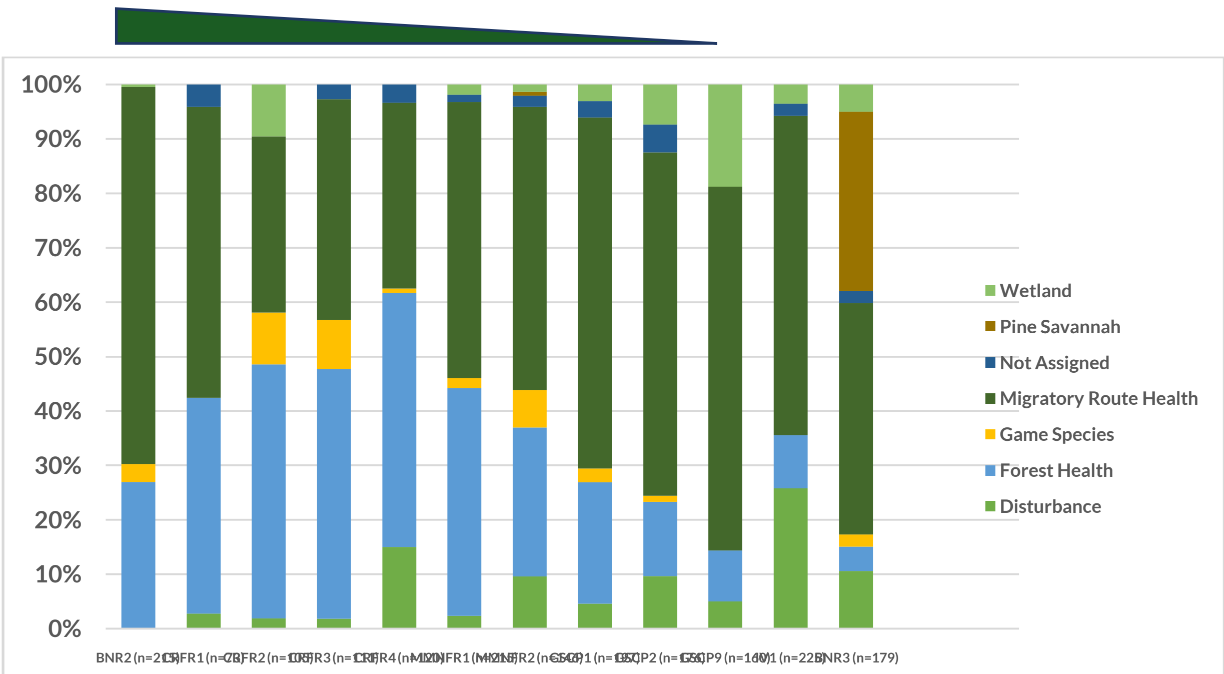


Figure 11. From the left, the first 10 transects indicate a habitat disturbance gradient in the forest from least to most disturbed. The second bar from the right is the village lands transect (IV1) and at the far right the savanna transect (BNR3).

Large Mammals

The total number of mammal transect visits was approximately half that of birds. For 2017, 108 mammal transects were carried out, covering a total of 108km (see Table 9). This was an increase from 63km in 2016. The number of transect visits per general location (e.g. all transects in Bladen) was more consistent than in previous years with a minimum of 7 visits, a maximum of 11 visits, and an average of 5.3 observations per 1000m transect in the MGL.

Table 9. Mammal monitoring effort per transect in 2017, BNR=Bladen Nature Reserve, CRFR=Columbia River Forest Reserve, GSCP=Golden Stream Corridor Preserve, IV=Indian Creek Village

Transect ID	# of visits	# of m transects	Avg. # of obs/1000m
BNR2	11	11000	5.18
BNR3	10	10000	7.90
CRFR1	9	9000	2.22
CRFR2	9	9000	4.67
CRFR3	8	8000	4.00
CRFR4	7	7000	2.86
GSCP1	9	9000	9.11
GSCP2	10	10000	6.30
GSCP9	9	9000	4.56
IV1	10	10000	6.50
MMNFR1	7	7000	4.43
MMNFR2	9	9000	5.56
MGL	**108**	**108000**	**5.3**

Fifteen of the 19 target species of mammals were recorded in 2017, from a total of 582 observations made and 700 individuals counted. The neo-tropical river otter, brown brocket deer, jaguarundi and white-nosed coati were not recorded over the course of the year. The largest number of mammal observations per km was recorded for GSCP1 and BNR3. BNR3 and GSCP1 have consistently been on the top of the list for number of observations per km as reported in Gutierrez & Dorgay 2017, Gutierrez 2016, Gartzia and Gutierrez 2015 and Gartzia 2014. This is largely due to dominant species within these transects (e.g. armadillos in BNR3 and agoutis in GSCP1). Transects with the least number of mammal observations per km were CRFR1 and CRFR4.

A strong positive correlation between the number of transect visits and the number of observations was seen in the data (Spearman's, ρ= 0.71; p = 0.009) indicating that a larger number of observations could have resulted from additional transect visits. There was also a significant positive correlation between the number of visits and the number of individuals recorded (Spearman's, ρ= 0.79; p = 0.002) partly owing to the high number of game species recorded in some transects. There was a significant relationship between the number of visits and the average number of individuals per 1000m (Spearman's, ρ= 0.72; p = 0.007).

Transect visits were less variable than in previous years, with a minimum of 4 visits per month and maximum of 12 visits per month. February, March, April and June had the most transect visits at 12 each, and November and December had the least transect visits at 4 each (see Figure 12). Under normal conditions the dry season does not offer very favorable conditions for recording tracks. However, tracks were recorded throughout the year although in lower numbers in May and June.

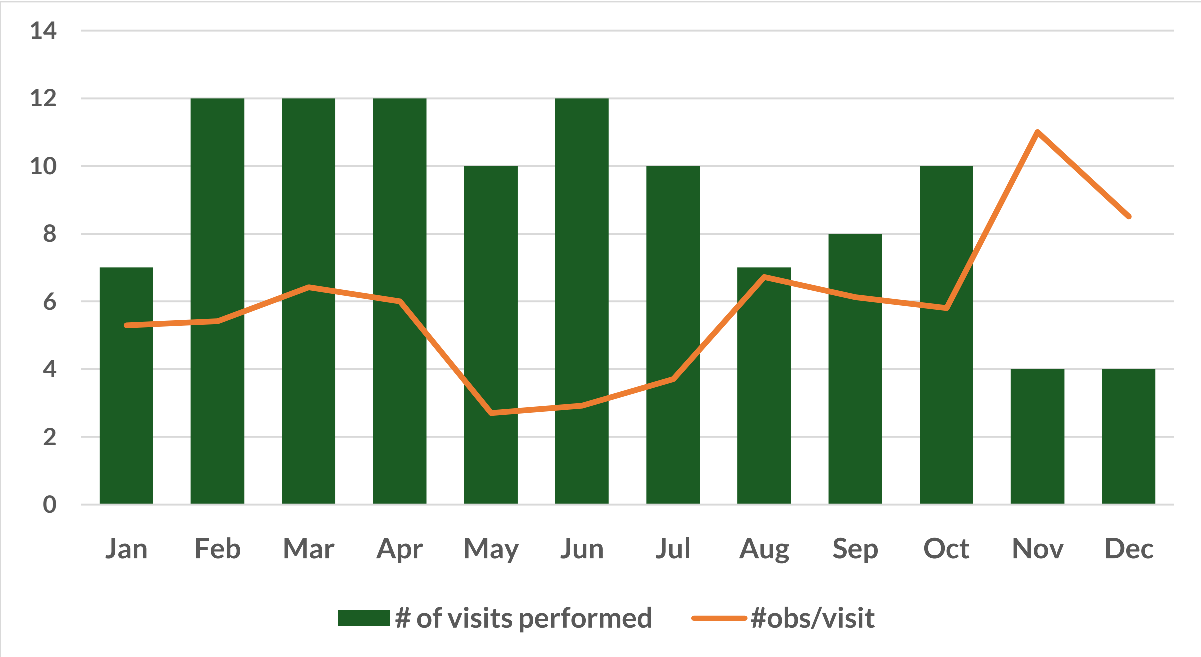


Figure 12. Mammal monitoring effort in 2017.

Target Species Richness

There are three broad habitats that we can compare from the data collected under the monitoring program. Forest habitat is represented in far more transects than the savanna and village lands transects. The latter two are represented in only one transect each. Due to the differing numbers of transects per habitat, the forest transects were pooled and the averages used for comparisons with the other two habitats. Although there was a total of 15 target species recorded within forest transects, the average target species richness within forest habitats was comparatively similar to the target species richness in the other two habitats (see Figure 13). The savanna and village transects recorded 10 and 7 target species respectively. BNR2 and GSCP1 recorded the highest richness at 13 and 14 species respectively.

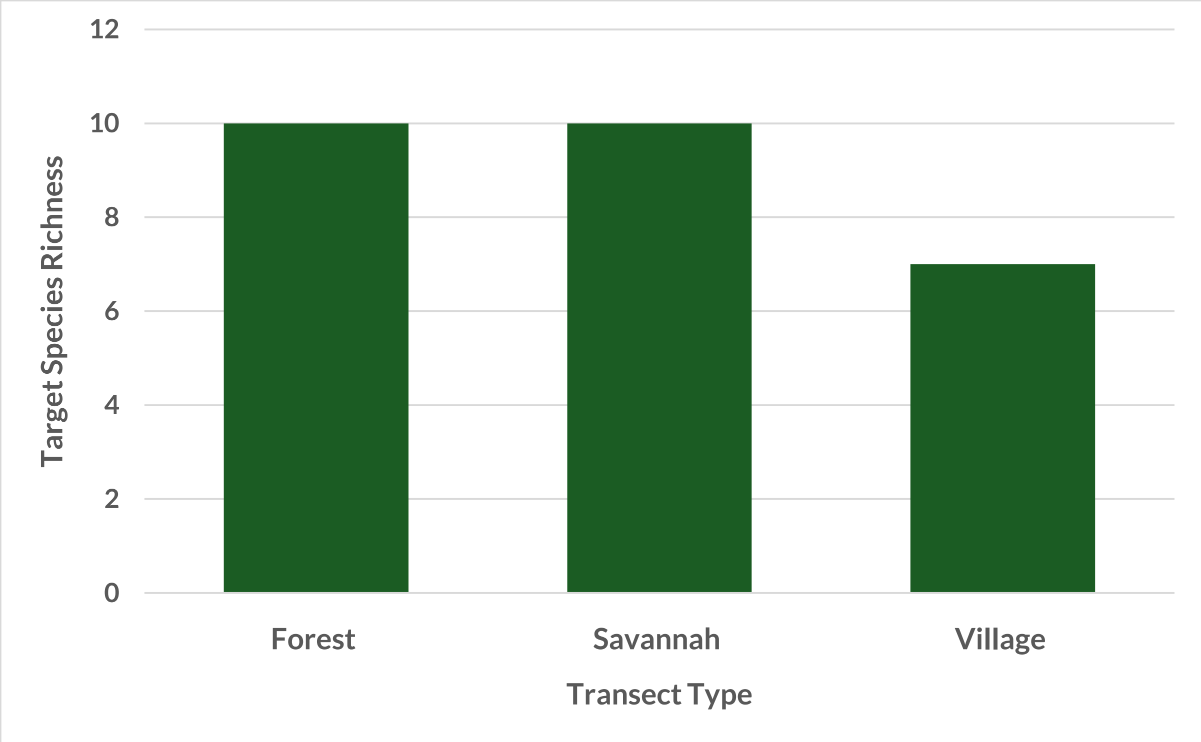


Figure 13. Target mammal species richness per habitat type. “Forest” shows the average target species richness for that particular habitat.

Species Accumulation Curves

We calculated the expected species richness for each transect and produced rarefaction curves (see 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 7 to a maximum of 11.

Table 10 shows the ranking of transects based on their expected species richness after the minimum number of visits. GSCP1, BNR2 and GSCP2 recorded between 9 and 13 species after 7 transect visits. The village transect IV1 represent the lowest target species richness at 6.1.

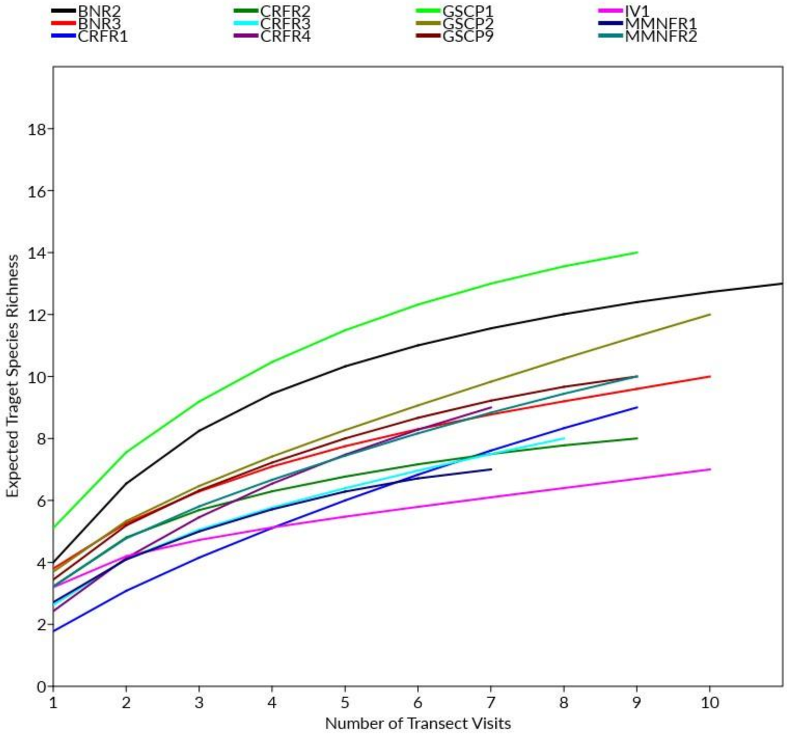


Figure 14.Sample-based rarefaction curves for large mammals

Table 10.Transect ranking according to expected mammal target species richness after 7 transect visits

Ranking	Transect
1	GSCP1
2	BNR2
3	GSCP2
4	GSCP9
5	CRFR4
6	MMNFR2
7	BNR3
8	CRFR1
9	CRFR2
10	CRFR3
11	MMNFR1
12	IV1

Diversity Profiles

Dominant species in some of the transects can create an “uneven” distribution of relative abundance. Most transects have at least one species that has this effect of dominance (see Figure 15). This pattern can vary from year to year or transect to transect; this has always been due to one species that seems to dominate in certain areas at different times of the year. In previous years, white-lipped peccaries were responsible for the large dominance effect on at least transect BNR2. This year there was a drastic decrease in the numbers of white-lipped peccaries recorded. However, this transect still remains the most diverse year after year. GSCP1 recorded the second highest for target species richness although it was influenced by two dominant species (armadillos and pacas).

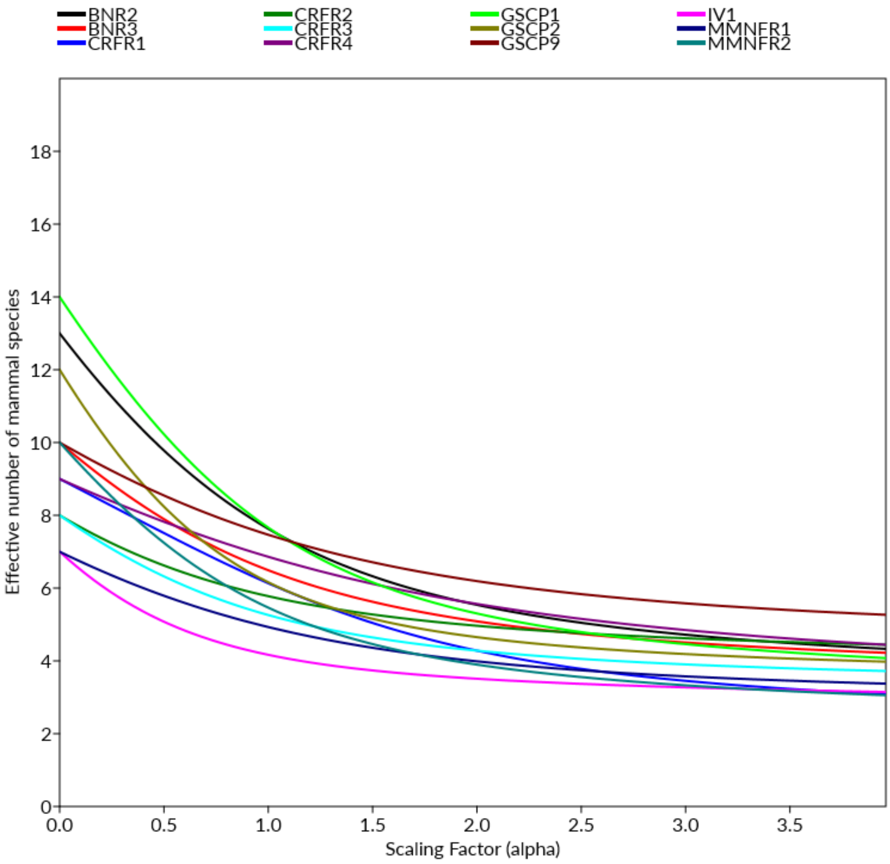


Figure 15.Mammal diversity profiles 2017

Indicator Groups

The uneven number of forest transects forces us to use an average for a crude comparison across the landscape (Figure 16). Game species were the most abundant indicators across landscape types. Within the village landscape, numbers of game species spike to encompass the majority of the species present. A few forest species make a presence in the area but generally avoid the open areas. The average number of species per indicator group within forest transects were similar to that of the savanna and the village transect as compared to 2016 (Table 11). In recent years, Baird's tapirs have been recorded within village areas, but they remain uncommon in that habitat.

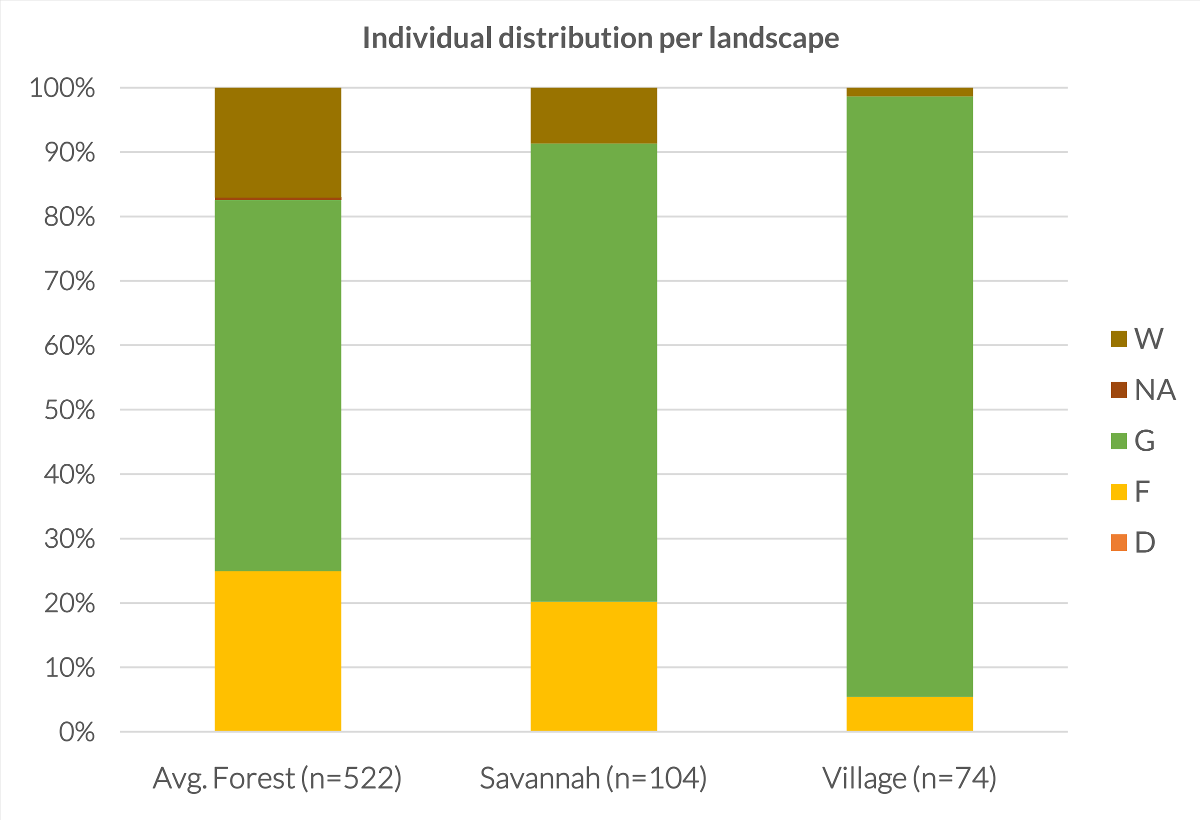


Figure 16.Distribution of individuals among Indicator Groups

Table 11. Average number of species per transect type

Indicator Group	Average Forest (n=10)	Savannah (n=1)	Village (n=1)
D	0	0	0
F	4.4	4	1
G	4.5	5	5
NA	0.1	0	0
W	1	1	1

To get a clearer understanding of species composition, we assessed the encounter rate of individual forest indicator species per 1000m (see Figure 17). The composition of forest species between forest transects and the savanna transect were less similar than in 2016 with only 4 forest species recorded in the savanna compared to 7 in the forest transects combined. The village transect recorded only jaguars as forest indicator species but not as often as in the forest transects. As the agricultural landscape grows, the chances of a jaguar coming in contact with farms and open fields increases drastically.

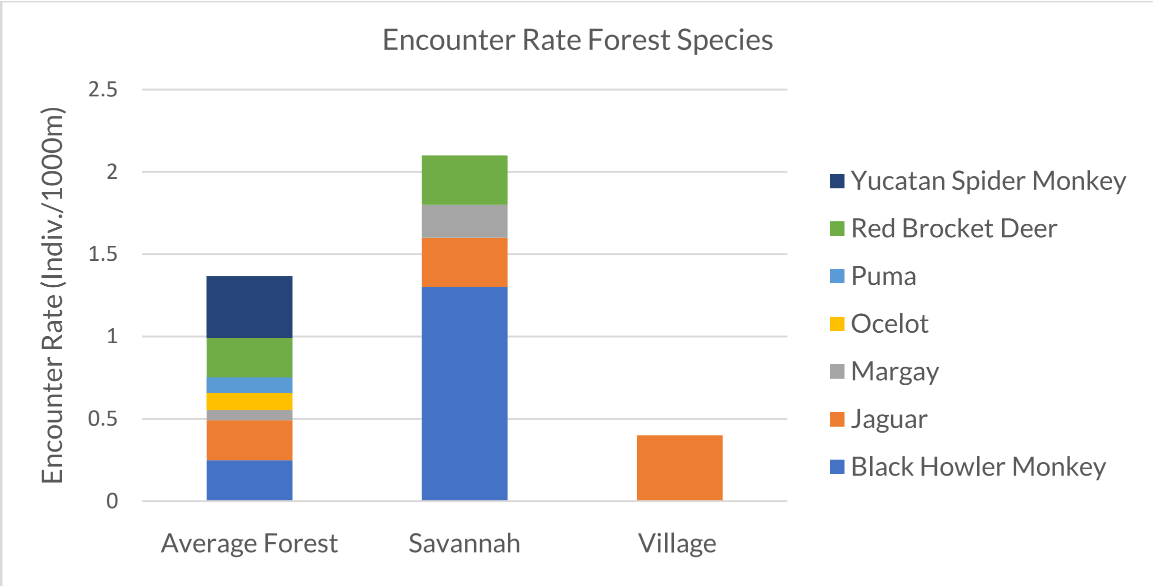


Figure 17. Encounter rate of all forest health indicator species

The encounter rate for game species was assessed in a similar manner (Figure 18). The village transect shows a higher encounter rate for agoutis than the average forest encounter rate and the savanna. Armadillos seem to be encountered in similar numbers within the village transect and savanna and less so in the forest transects. White tailed deer that are generally recorded in the savanna habitats were recorded at a similar rate to that of 2016. Pacas were increasingly common within the village transect and less so within the savanna and forest transect. Combined, pacas, agoutis and nine-banded armadillos make the bulk of individuals that are more likely to be found within the village areas indicating a potential decline in hunting pressures in the vicinity of the transect and/or regeneration of lands left in fallow.

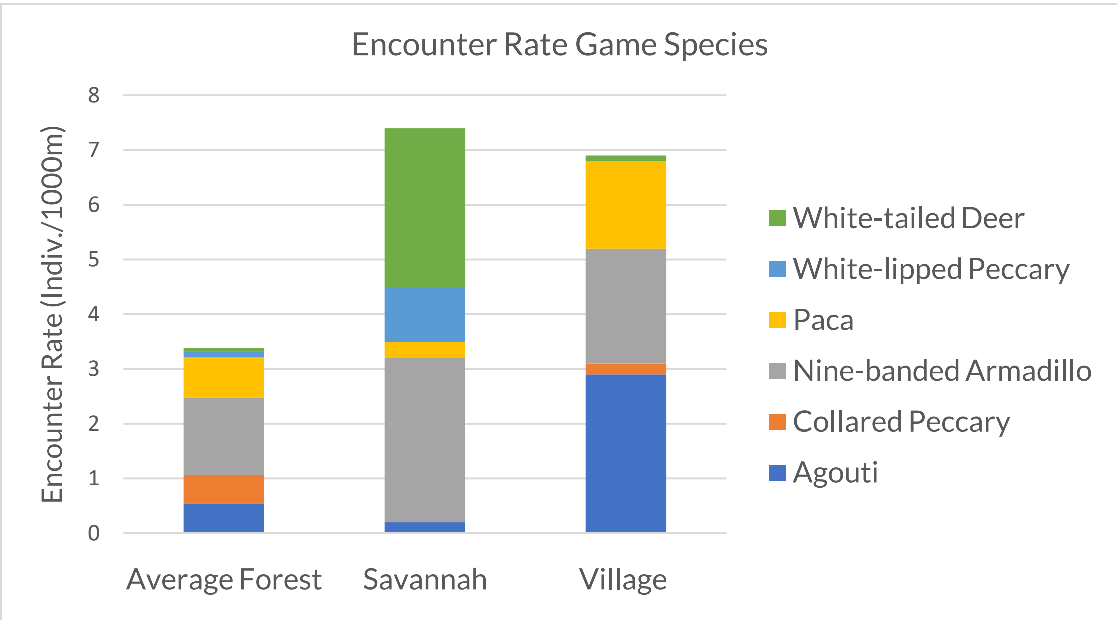


Figure 18.Encounter rate of all game indicators species

Weather

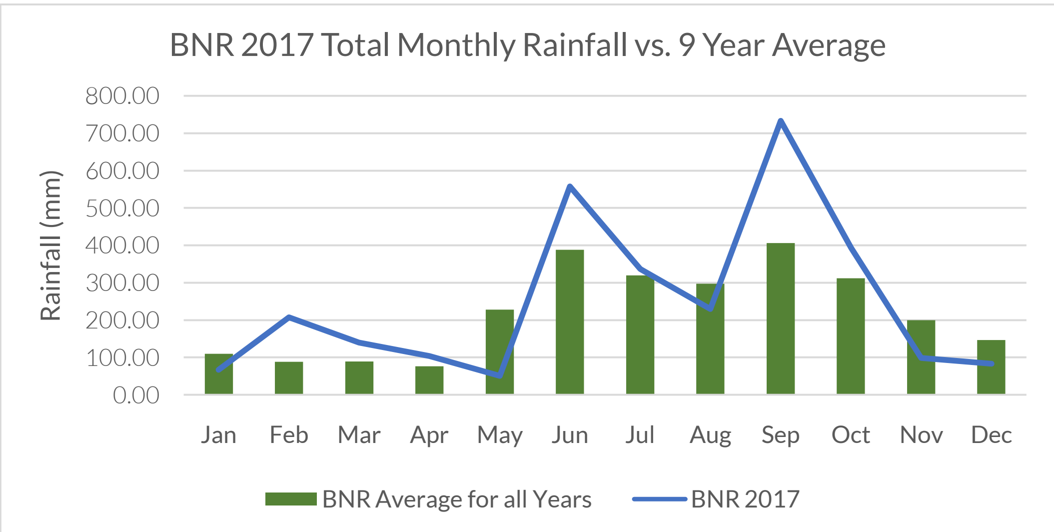
Weather data coverage for 2017 varied between stations. The ranger base in the Bladen Nature Reserve recorded rainfall, humidity, and temperature for all but 32 days of the year, resulting in 91.23% cover. At the Golden Stream Corridor Preserve field station, 24 days had missing data giving 93.42% cover for the year. Data coverage information for years 2009-2016 can be found in the Ya'axché Biodiversity Synthesis Reports for each respective year. Raw data from all years are available upon request.

Monthly/Seasonal Rainfall

Both weather stations experienced a wetter dry season in 2017 than the average for all previous years (Figure 19, A and B). The rainy season traditionally begins in early May in the Toledo District, which is nearly a month earlier than in the northernmost Corozal District ("Climate Summary," n.d.). The nine-year rainfall averages at each station are consistent with expectations for the Toledo District. However, May 2017 followed the trend of the past two years and was drier than usual (Gutierrez, 2016; Gutierrez & Dorgay, 2017). The beginning of the 2017 rainy season is indicated by the sudden increase in rainfall in June in the figure below. The Bladen station recorded more rain than average during most of the 2017 rainy season months.

According to the nine-year averages, the month of August brings nearly 100 mm more rain to Golden Stream than to Bladen. The Golden Stream rainfall distribution (Figure 19 B) follows more closely to the rainfall pattern captured by the Hydromet weather station in Punta Gorda, which is the wettest in the country ("Climate Summary," n.d.). Outside of the Toledo District, the rest of Belize experiences a "mauga" effect in August, where rainfall sharply decreases before picking up again in September. The Bladen station observes this mauga pattern (Figure 19 A).

A.



B.

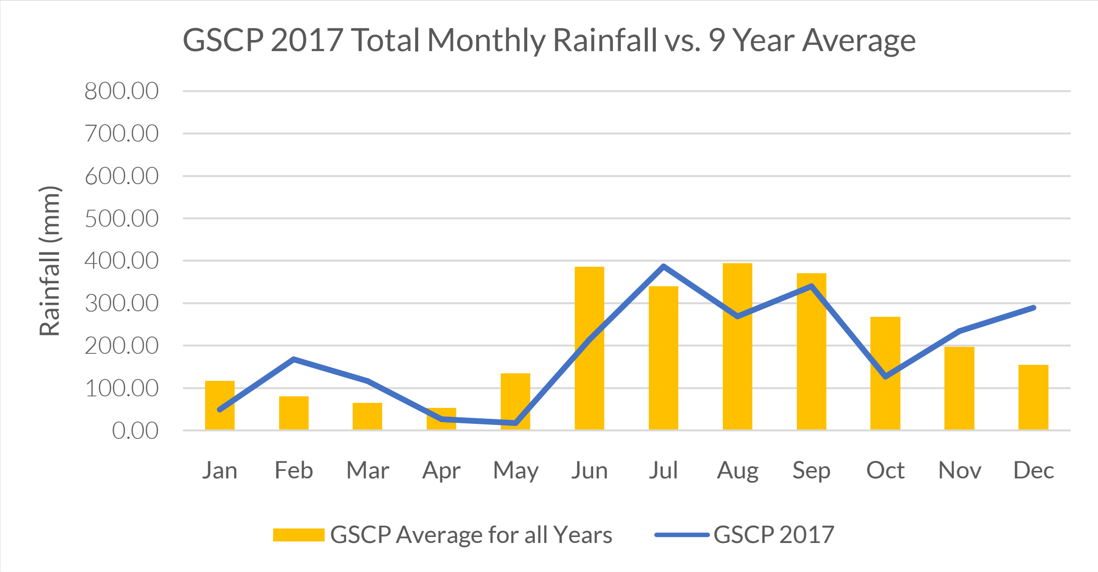


Figure 19.Monthly rainfall in 2017 as compared to the average monthly rainfall between 2009-2017 for A. the Bladen Nature Reserve weather station and B. the Golden Stream Corridor Preserve weather station.

Yearly Trends in Rainfall

Trends in total yearly rainfall show that the Bladen station averages slightly more rainfall than the Golden Stream station (see trend lines in Figure 20). In addition, while rainfall amounts have varied yearly, trends for both stations show increasing rainfall recorded over time.

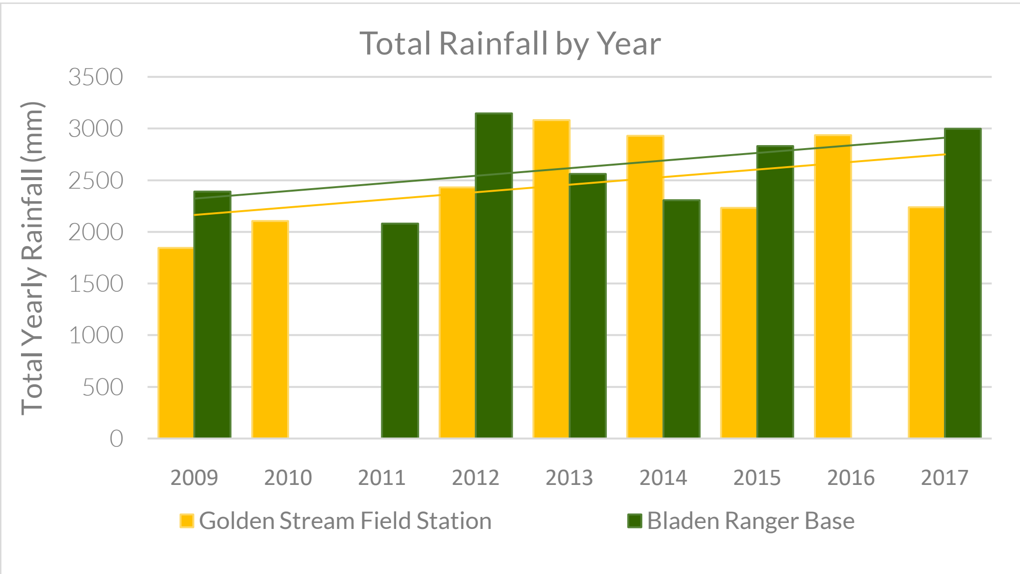


Figure 20.Total rainfall received each year between 2009 and 2017 for each weather station. The trend lines indicate that Bladen is rainier than Golden Stream (not significant) and that rainfall is increasing at both stations. The Bladen station 2010 and

2016 data and the Golden Stream 2011 data were excluded from the analysis due to low data coverage during 4 or more months in those years.

Between 2009 and 2017, the Bladen weather station averaged 2616.82 mm of total rainfall each year, while the Golden Stream station averaged 2475.15 mm. This higher rainfall total for Bladen than for Golden Stream deviates from the pattern predicted by the Hydromet model for the region (see Figure 21). According to the model, the Bladen station falls within a lesser rainfall gradient than Golden Stream. In actuality, the Bladen station records an average amount of rainfall that places it into the predicted band of rainfall for the more southerly located Golden Stream station, and vice versa. The results indicate that rainfall patterns are more nuanced on a regional level than captured in the national rainfall map, and gaps in the Hydromet model do not tell the complete picture of rainfall on the ground.

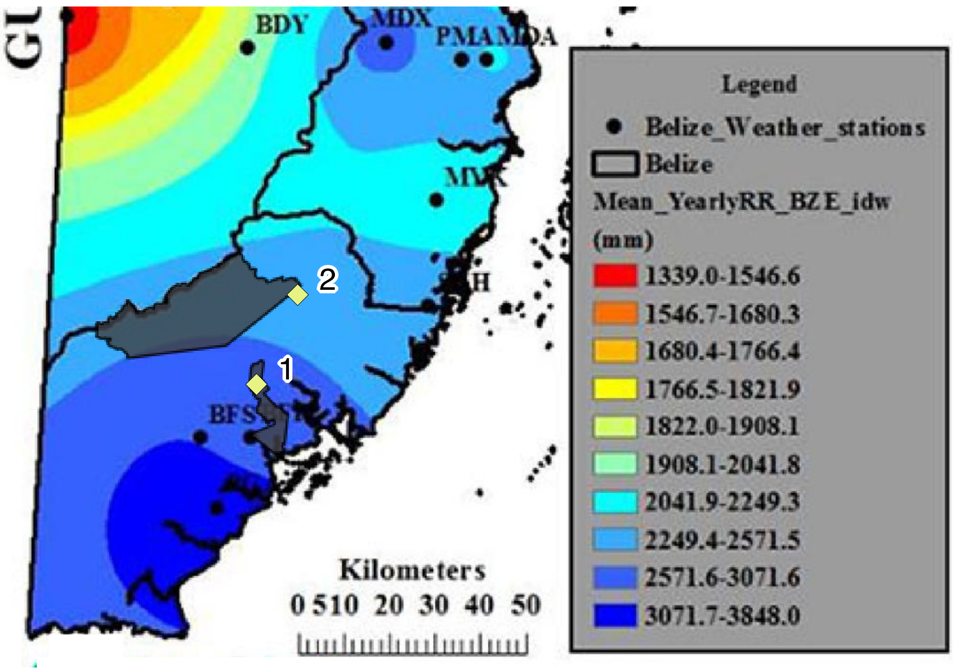


Figure 21. Detail from Figure 3 on page 19, Belize's annual rainfall map (Frutos, 2013) showing locations of the Golden Stream Corridor Preserve weather station (1) and Bladen Nature Reserve weather station (2). The legend shows the average expected annual rainfall for each station, which is extrapolated from a limited set of Hydromet stations in the south.

Monthly/Seasonal Temperature and Humidity

Since Ya'axché rangers began collecting data on temperature and humidity, the Bladen weather station has reported high temperatures that are roughly 6-14 degrees hotter and low temperatures that are 0-4 degrees cooler than the Golden Stream station from month to month (Figure 22, A and B). Average daily high temperatures in Bladen span from 93.79 °F in the coolest month of November to 105.86 °F in April at the peak of the dry season. In April, Golden Stream temperatures reach an average high around 96.97 °F. While the Bladen station has consistently higher high temperatures and lower low temperatures than Golden Stream, the daily relative humidity at Bladen averages between 6-16% lower than in Golden Stream.

A. Bladen Ranger Base

	Average High Temp (°F)	Average Low Temp (°F)	Average Max Percent Humidity	Average Min Percent Humidity
Jan	98.61	68.79	78.96	44.97
Feb	102.25	67.86	76.66	38.05
Mar	102.59	70.56	75.52	35.48
Apr	105.86	74.03	73.98	33.92
May	103.46	73.02	72.90	36.45
Jun	99.74	74.81	77.79	44.07
Jul	103.29	74.78	76.87	40.61
Aug	104.57	75.24	75.51	38.86
Sep	104.81	75.45	76.18	43.23
Oct	100.93	74.05	78.19	45.42
Nov	93.79	69.87	77.18	46.60
Dec	94.43	67.90	77.84	45.17

B. Golden Stream Field Station

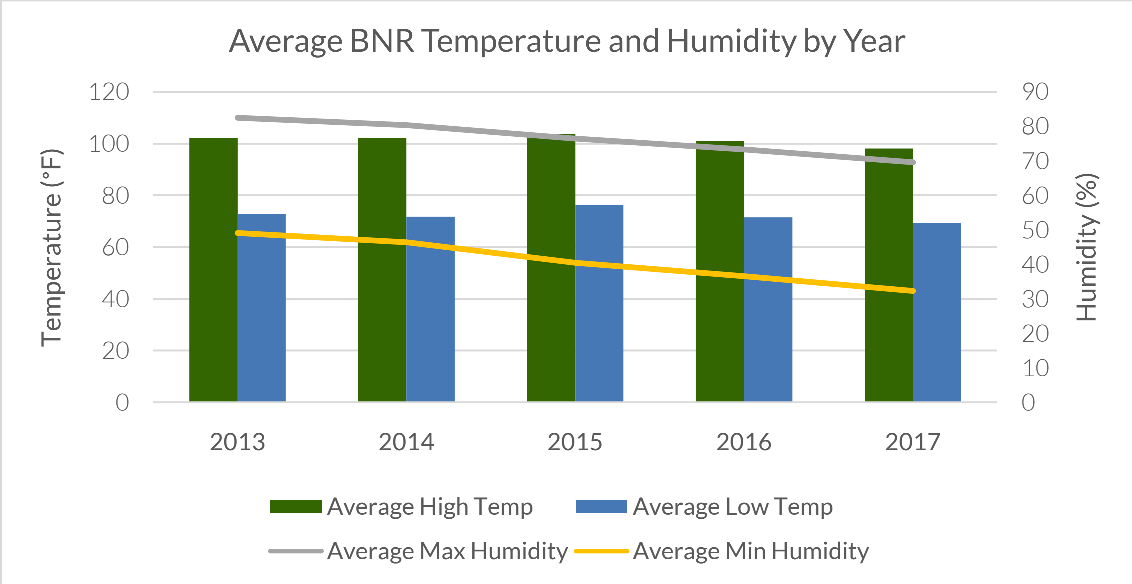
	Average High Temp (°F)	Average Low Temp (°F)	Average Max Percent Humidity	Average Min Percent Humidity
Jan	87.49	70.03	87.55	57.77
Feb	88.24	70.23	90.28	51.77
Mar	93.20	71.86	83.95	45.69
Apr	96.97	74.02	80.59	41.10
May	95.04	76.66	81.13	44.99
Jun	93.58	77.01	87.99	53.14
Jul	92.38	75.70	88.57	53.24
Aug	91.91	75.29	83.35	48.24
Sep	94.03	77.27	88.04	53.98
Oct	93.10	78.16	87.11	58.27
Nov	86.91	72.69	89.36	57.64
Dec	85.61	70.17	89.38	61.63

Figure 22. Monthly average temperature and humidity data for A. BNR from 2013-2017 and B. Golden Stream from 2009-2017 (temperature) and 2011-2017 (humidity)

Yearly Trends in Temperature and Humidity

Both weather stations have experienced relatively stable temperatures since Ya'axché began recording temperature data (Figure 23, A and B). The hottest year recorded thus far in Bladen was 2015, in which the average high temperature across all months was 103.76 °F and the average low temperature was 76.30 °F. Temperatures in Golden Stream were highest in 2016, where all months for the year averaged high temperatures of 95.79 °F and low temperatures of 75.41 °F. Relative humidity at the Bladen station has decreased each year since 2013, though this pattern is not as evident at the Golden Stream station.

A.



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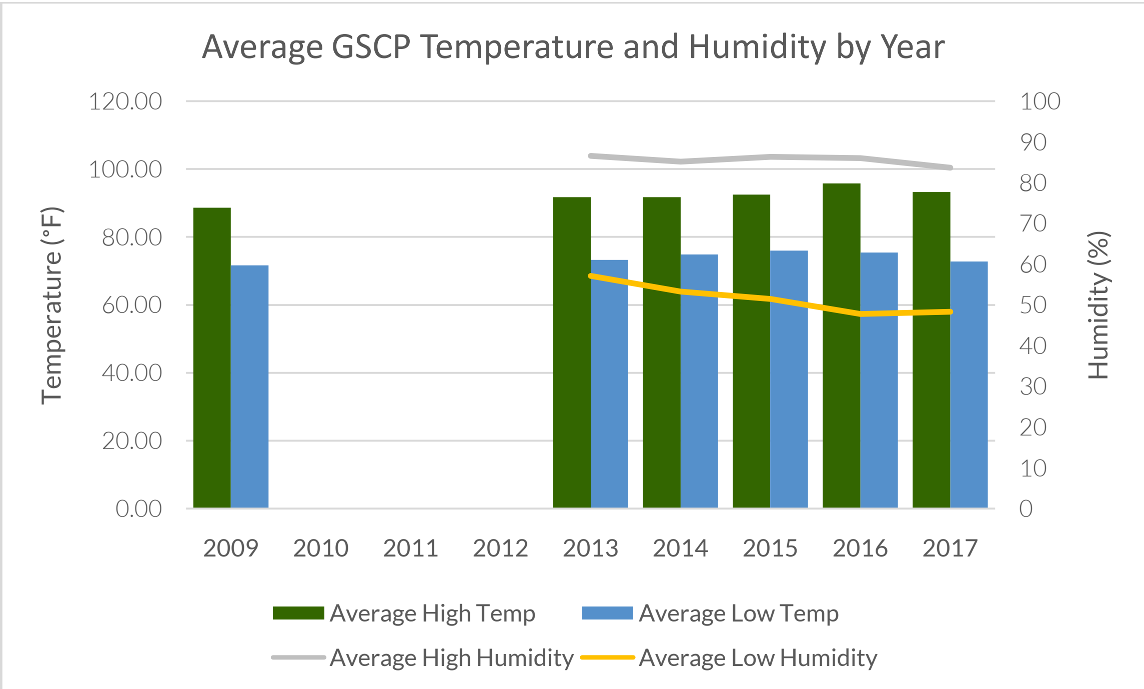

Figure 23A.Yearly high and low temperature and relative humidity averages in BNR since 2013; B. Yearly high and low temperature in GSCP since 2009, and high and low relative humidity since 2013. 2010, 2011 and 2012 GSCP temperatures were excluded from the analysis due to incomplete data coverage for more than 4 months of those years.

Conclusions

While Ya'axché continues to expand its monitoring efforts in the Maya Golden Landscape, this report only covers the data collected from its established biodiversity transects. It is intended to provide us with a landscape-wide view of the status of target indicator species and the status of their environments. Featured in the report were birds, mammals and a multi-year analysis of our weather data. Other sections to the report such as camera traps and vegetation are all in the process of expansion and development and will be featured in the 2018 Biodiversity Synthesis Report. As has been the case for the past 8 years, Bladen Nature Reserve provides the highest diversity of species but is edged closely by Columbia River Forest Reserve. With limited sampling from village areas we will see more information in our agroforestry section in the 2018 report.

Birds

BNR3 and MMNFR2 recorded the highest target species richness for birds at 18 species followed closely by CRFR2 and GSCP1 with 16 species. This is in contrast to 2016 when GSCP1 had the lowest richness. It is after all, a reflection of the increased transect visits to this transect as the previous year it was recorded as the transect with the lowest number of visits. The open space of the savanna transect and its proximity to broadleaf forest, ensures that the target species richness includes a higher number of forest species and edge dependent species. The diversity of the species in the transects is affected by the dominance of one or more species. BNR2 is generally well dominated by the abundance of some migrants including the American redstart, magnolia warbler and wood thrush. The village transect with its open spaces and proximity to patches of forests and fallow land attracts an abundance of plain chachalacas and to a lesser extent magnolia warblers and wood thrushes. Transect MMNFR1, which is within an agroforestry concession in a forest reserve, seemed to attract a high number of keel-billed toucans. Perhaps it is a result of agroforest management activities, in which the forest was thinned and many fruit trees kept for shade for the production of cacao. As has been the case in previous years, it is increasingly unlikely to expect game bird species within the village lands.

Mammals

GSCP1 recorded the highest species richness for target mammal species followed by BNR2 which recorded the highest richness the previous year. The white-lipped peccary has been a dominant species within this transect and is of great importance as an indicator of forest health due to its requirement of large areas of forested land for survival. White-lipped peccaries were largely absent across the landscape and only a few were recorded in the savanna transect. The species is in trouble across the region and the absence of it may signal increased hunting pressures or habitat conversion. In the case of BNR it is not likely that the latter is an issue. The village and the MMNFR1 transects had the lowest species richness at 7 species than the other transects with abundances leaning towards the smaller game species like agoutis and armadillos that appear to thrive in areas adjacent to farms from the communities and where habitat degradation is evident. The MMNFR1 transect is in the middle of a cacao agroforestry concession under development. When compared to the MMNFR2 transect, which is within a forested area of the concession, the difference in richness is obvious (10 species). The larger game species seem to avoid these areas or are likely hunted to exhaustion in community lands. Tapirs were present across the landscape with low abundances within the village transect. Jaguars appear to be present across the landscape with similar frequency of observations across habitat types although more observations were made in the forest transects. As in previous years armadillos have been recorded across the landscape and in similar abundances.

Weather

Though both the Golden Stream and Bladen weather stations are located in the Toledo District, roughly 22 km apart, much variation exists in the amount of rainfall, temperature, and relative humidity captured by Ya'axché rangers at each station. Analyses of daily weather data collected since 2009 show the following:

- A "mauga" rainfall patterning (decrease in rain in the month of August) is evident at BNR and not GSCP, separating the two stations along a line that divides the country. GSCP, like Punta Gorda, observes a rainy August, while BNR and the rest of Belize experience a brief reprieve in rain during that month.
- Total annual rainfall is higher in BNR than GSCP, which is not expected for the more northerly location of the station. Predictions of countrywide annual rainfall by the National Meteorological Service of Belize show a general gradient that decreases from south to north. BNR records roughly 100 mm more rain than its location predicted, and GSCP records roughly 100 mm less rain than predicted.
- From month to month, BNR has consistently wider daily temperature ranges and lower relative humidity than GSCP.

Topographic features and tree cover differences at each station likely produce the variations in rainfall, temperature and relative humidity that we see between stations. The Bladen station is located at the boundary of the reserve, squarely in the middle of the Deep River Forest Reserve pine savanna just before it meets the foothills of the Maya Mountains. The station's greater than expected annual rainfall for its latitude could be a result of orographic rain, produced when moist air from the lowlands is forced to rise over the hills, causing it to cool and release moisture. Wider variations in daily temperature and lower humidity experienced at the Bladen station than the Golden Stream station are likely due to the relative lack of tree cover in the savanna. In comparison, Golden Stream's weather station is at the Ya'axché field station compound, surrounded by the forested Golden Stream Corridor Preserve, where tree cover serves to stabilize the daily temperature swings and increase humidity.

Recommendations

Birds

Target species richness within forest types has remained relatively consistent over the last few years. As such, there is now a large data set that can be used to assess the variation in abundances and richness between and among transects within the Maya Golden Landscape. The data set is beyond a baseline dataset and the monitoring efforts can be transitioned to more robust methodologies that look at assessing overall species richness, abundances, and other relevant metrics. In the next year, consideration should be given to the inclusion of a more robust point count methodology that recognizes the importance of indicators species. This will allow for comparison of data across years. With the transition of the science work to a full time established program, it will become possible to conduct adequate sampling of bird populations in the MGL. Care should be placed in adhering to Ya'axché's needs while ensuring that methodologies are aligned with national plans and programs.

Mammals

Similarly, to the bird data, there is a significant amount of data that requires an in depth analysis of the mammal assemblages across the landscape. Over the years it has become apparent that the track census method is inefficient at capturing adequate data for analysis. As the science work at Ya'axché continues to develop, emphasis should be placed on the expansion and adoption of newer methodologies including the adoption of camera trapping surveys that align with the national monitoring program. In the next year, a gradual move to camera trapping should ensure that a larger dataset is built with increased reliability and accuracy.

Weather

2019 will make the 10th year that Ya'axché rangers have collected weather data. Data quality and coverage have improved over time through training workshops and the procurement of new equipment. Weather-worn rain gauges should be replaced in 2019, and multi-year analyses of the data should continue for future years. Long-term weather station monitoring is important in the Maya Mountains, where our data show that rainfall patterns on the ground do not match the predicted patterns created from national models. Ya'axché should install automated weather stations in more difficult to reach locations along the Main Divide and make an investment in the establishment of additional weather stations across the MGL. The nearby Maya Mountain North Forest Reserve, where a cacao agroforestry concession is located, would be an ideal site for a new station. The data could benefit the implementation of our sustainable agroforestry and other alternative, environmentally friendly agricultural practices by providing accurate localized weather information for planned development.

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