Technical report for defra project 'Developing Integrated assessment of Biodiversity in Belize'

Lindsay Maskell, Ivis Chan, Emerson Garcia, Zoe Goodwin, Adam Lloyd, Normando Mora, Simon Smart, Rick Stuart, Paul Walker.

Wildtracks

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Chapter 1: Introduction

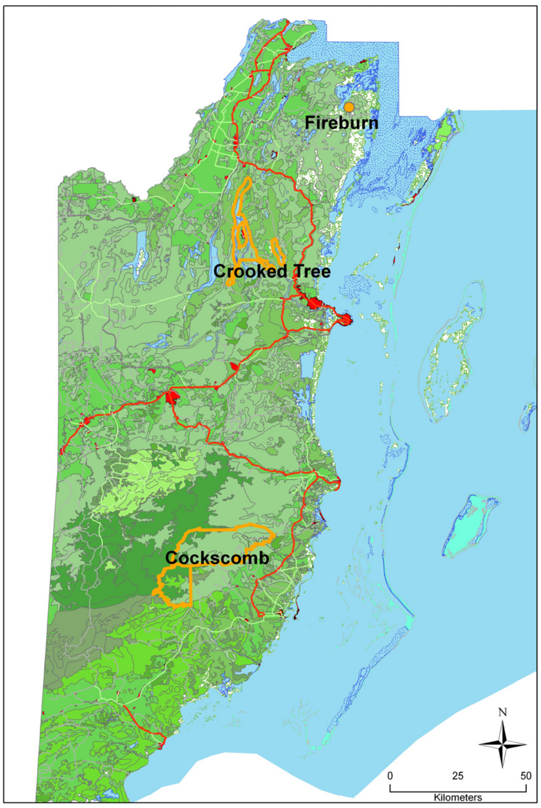
This project arose from a need to coordinate and collate information at larger geographic scales and to take an ecosystem level approach to understand the functioning of communities. It was developed in response to the recognition of absence of data on the relative biodiversity value of previously impacted forests, and their role and contribution within the national protected areas system of Belize. Predicting the impacts of human intervention on biodiversity and understanding present forest characteristics (Thompson, Brokaw et al. 2002) is important for conservation efforts in tropical forests (Schulze, Waltert et al. 2004).

There are a number of objectives for this study;

1. To determine the biodiversity value of secondary forest tracts within and surrounding three protected areas, that are regenerating from past natural and anthropogenic impacts.
2. To relate past and present landuse to biodiversity and attempt to identify indicator species that could be used to demonstrate conservation status. It is hoped that indicator taxa may be selected as proxies for habitat biodiversity which will enable rapid habitat assessment .
3. To build capacity of partner organisations in Belize, establish facilities, set up database structures, GIS and provide training
4. To compare forest regeneration in naturally regenerated forests (e.g. post-hurricane) with that from anthropogenic landuse specifically post-agricultural

Three study sites across Belize were chosen (Fig 1). These were Fireburn Reserve in the North-east of Belize (on Shipstern Lagoon), Crooked Tree Wildlife Sanctuary in the centre of the country and Cockscomb Basin Wildlife Sanctuary both managed by the Belize Audubon Society.

Figure 1. Map of Belize showing 3 study sites



Fireburn Reserve
A private protected area, the Fireburn Reserve is located in the North East of Belize in the Corozal District It is found on the southern edge of Shipstern Lagoon, well known for its wildlife, part of which has protected status as Shipstern Nature Reserve owned by the International Tropical Conservation Foundation. The Fireburn lands adjoin the southern edge of Shipstern Reserve. To the South and East of Fireburn is a large area of forest and mangrove swamp that at present is undeveloped.

The Fireburn Lands include the 1,818 acres of the Fireburn Reserve (managed in a partnership between Wildtracks and the Fireburn Community) and 187 acres of Community lands retained for farming. The Fireburn Reserve forms a part of the proposed NE Biological Corridor of Belize, identified under the Mesoamerican Biological Corridors Project, to provide biological connectivity between Shipstern Nature Reserve to the north, and Freshwater Creek Forest Reserve to the south.

History
The Fireburn Community has been living in and managing the area for 125 years. Areas have been used for agriculture in shifting cycles allowing the land to regenerate. The amount of time that the land has been out of cultivation is obviously important in understanding patterns of vegetation development; this will be discussed later. There has been logging of the reserve for species such as Mahogany (*Swietenia macrophylla*) and Ciricote (*Cordia dodecandra*) as well as Chicle (*Manilkara sapote*) harvesting. This has resulted in the removal of some of the larger diameter trees. The area was also greatly affected by Hurricane Janet in 1955 when large areas of forest were destroyed. Most of the forest in Fireburn dates from that time so it is all no more than 54 years old.

Climate
Rainfall in Belize increases as from the North to the South. The northern part of the country is quite dry as shown by measurement of the rainfall at Shipstern Nature Reserve. The rainfall was measured over 4 years (Bijleveld 1998) and the mean amount was 1260mm a year; the minimum was 1029 mm/yr. The dry season begins in mid January and ends in May. In terms of the amount of rainfall and the impact that this has on vegetation type Shipstern is thought to be in transition between subtropical moist forest, subtropical dry forest and tropical dry forest (Bijleveld 1998). The Fireburn Reserve lies within the next rainfall isohyet – receiving up to 500mm more rainfall per annum than Shipstern, as reflected in its markedly more humid vegetation.

Cockscomb Basin Wildlife Sanctuary

Cockscomb Basin Wildlife Sanctuary, lying in the Stann Creek District of southern Belize, is the pre-eminent reserve of Belize, and now encompasses approximately 127,000 of humid tropical forests ranging from 50m elevation to over 1,100m – in the south-eastern portion of the Maya Mountains Massif, one of the largest and most intact forest tracts in Central America. Under a co-management agreement with the Forest Department of the Government of Belize, the Sanctuary is managed by the Belize Audubon Society.

History.
First given protection as a Forest Reserve (1984), a 4,000 acre tract was upgraded to Wildlife Sanctuary status in 1986. Subsequent extensions of the Sanctuary (and including the Victoria Peak Natural Monument) have increased the area to 127,000 acres. Both the East Basin and the more remote West Basin of Cockscomb were logged extensively up to Hurricane Hattie in 1961, with only a few of the more remote valleys in the West Basin remaining 'primary' forest. Subsequent to 1961, logging resumed in East Basin, but didn't reach West Basin. In the early 1980's a small community of sawmill and logging crew became established at Quam Bank, developing small slash-and-burn milpa farms close to the centre of the sawmill operations. By the mid-80's, the inhabitants of Quam Bank were relocated to Maya Centre, and the abandoned farms allowed to regenerate.

Climate.
Much of Cockscomb receives in excess of 4,000mm of rainfall a year, with a shorter and less pronounced dry season than that of northern Belize. The Sanctuary supports a variety of forest types, mostly falling within the tropical moist category, across a broad elevational range – with tall lowland forest in the two Basins and cooler upper elevation temperatures supporting cloud forest on Outlier and Victoria Peaks.

Crooked Tree Wildlife Sanctuary

Lying in the central northern coastal plain of Belize, Crooked Tree Wildlife Sanctuary protects the wetland system of Crooked Tree Lagoon, Belize's only RAMSAR site. The Sanctuary boundaries incorporate approximately 300 feet of ground above the high water mark of the Lagoon: to the east this is primarily swamp forest and pine savanna, to the west it includes a tract of broadleaf lowland forest.

History
Established in 1984 to protect the bird fauna of the Crooked Tree Lagoon wetlands, the Sanctuary encompasses approximately 36,500 acres of lagoon, creeks, marsh, broadleaf forest and pine savanna. Surrounding the island community of Crooked Tree Village, the boundaries have never been delineated on the ground, and significant agricultural incursions have occurred within the broadleaf forest on the western bank of Western Lagoon. Under a co-management agreement with the Forest Department of the Government of Belize, the Sanctuary is managed by the Belize Audubon Society.

Climate
Much of the Crooked Tree Wildlife Sanctuary lies within the same rainfall isohyet as the Fireburn Reserve, receiving 1,500 to 1,750mm of rainfall per annum, and supporting a similar tropical seasonal regime as Fireburn – with a pronounced dry season from mid-January through May. On the poor sandy soils of the easternmost portion of the Sanctuary this supports a pine savanna habitat, whereas on the richer loamy soils of western Crooked Tree it supports a seasonal broadleaf forest.

Chapter 2: Training

A number of training activities were planned to exchange the skills required for the project and to build capacity within Belize. Most of the CEH staff had not worked in the tropics previously so it was a mutual exchange of skills identifying which techniques available for studying temperate systems would transfer to the tropics.
The staff from CEH were experienced in large scale data collection and management, temperate botanical identification, GIS, experimental design, statistical and spatial analysis, presentation of research findings and publication in scientific journals all skills which it was thought would be transferrable. The Belize team had good field identification skills for some species groups- herps, mammals, birds, and the ability to carry out fieldwork under testing conditions. There was a gap in botanical identification skills, the key researcher employed by the project in Belize had spatial and data management experience but was not a botanist so a botanist from the UK was brought into the project team. The lead organisation in Belize plays a key role in national conservation planning and has good links to many conservation organisations in Belize, they also had project management and project coordination experience. It was planned to extend the training activities outside of the core project team.

GIS WORKSHOP

In November 2005 a workshop took place taught by CEH staff entitled 'basic training in ecological field mapping, data entry and management, and introduction to use and analysis of data'.The training week was intended to provide a basic introduction to ecological field mapping, and data management and manipulation. Informal and formal workshops were held, during which the whole process from collection of spatial data in the field, to use of this data in interaction with other data sets was addressed. This required a 'hands on' approach from participants where they carried out all of the processes themselves, including creating maps, digitising spatial data and basic analyses. It was not intended as a workshop for GIS or database experts. A mixed level of experience was anticipated and the course aimed to be as flexible as possible.

The workshop began with an introduction to the considerations and challenges in collecting spatial data in the field. Raw data were collected by the participants, techniques for inputting data into a GIS system were demonstrated and the raw data collected were entered by participants. Simple techniques for manipulating the data within the software package ArcGIS 9 were shown, incorporating techniques for spatial analysis such as overlaying and spatial querying. Input of other types of data was discussed, along with the appropriate software which included Microsoft Excel and Microsoft Access. Simple and more complex forms for data input were discussed. Basic principles for best practice in the construction of a database were presented and participants were supported in developing their own example database. Use of data and subsequent analyses was discussed. Throughout the week, participants were encouraged to think in terms of a process, beginning with raw data collection and finishing with output of processed data, whilst developing a better understanding of spatial data.

There were ten attendees, some from the core Darwin project team as well as Forest Department staff and protected area managers.

The workshops were held at Wildtracks, Sarteneja, Corozal, Belize.

Topics covered during the course included

- experimental design and strategic data planning
- an introduction to GIS and the software package ArcGIS: viewing data, creating maps, customising maps, creating GIS data, editing data, map symbology and appearance, attribute management , digitising, editing points, lines, polygons and shapefiles and geodatabase feature classes.
- an introduction to Database concepts, data entry, data querying, combining and analysing data. Using MS Excel and Access. Designing a database, conceptual, logical and technical design, populating with data, documentation,
- field mapping including a practical exercise in field mapping around Sarteneja,
- basic compass and map use for mapping, navigation and field recording. A session was spent instructing students on the basics of map and compass work in the grounds of Wildtracks.
- GIS Analysis Overlaying GIS datasets, Buffering, Geoprocessing: Vector/raster conversion

The workshop was successful according to feedback from participants. Some of the skills were then used by members of the project team throughout the project.

FIELD SKILLS WORKSHOP AND PILOT SURVEY
This workshop took place in April 2006 and comprised a team from CEH Lancaster and the core project team in Belize.

The aims of this workshop were to;

- Develop/finalise protocols for botanical sampling
- To provide training in sampling design
- Teach basic fieldwork techniques and skills
- Field visit to employ techniques

The aim was to scope and test options for recording botanical species composition and forest structure in readiness for biological recording on the three sites.

Summary of pilot results

Three days of field method testing were undertaken at two forest sites near Sarteneja. Two plot sizes were trialled; 4x10m and 10x10m. Botanical data were collected from nested quadrats of varying size within each plot with the intention that these plots would be arranged contiguously to form a transect or placed at random locations within a pre-defined forest patch. Field recording concentrated on answering a series of questions that would help determine the optimal plot size and set of attributes to record. Of particular interest was the size of individual sub-plots relative to the species accumulation curves (SPACs) for forest patches. The objective was to select a plot size that would maximise the number of species encountered per area censused.

A number of questions were identified to be tested and answered:

1. Which plot sizes accumulated species quicker?
   Did the Species Accumulation Curves flatten off?
   Did results differ between species groups – field layer herbs, shrubs & saplings, canopy trees.

<u>Results</u>:

- 10x10m nested plots accumulated more species per incremental increase in area than 4x10m nested plots. This applied to canopy trees and to all groups combined (Figures 1 and 3).
- Different SPACs clearly can apply to different plant species groups and this inevitably reflects differences in the richness of each pool as well as differences in plant size (Figure 2).

Figure 1. SPAC for all species in two sites and at two plot sizes.

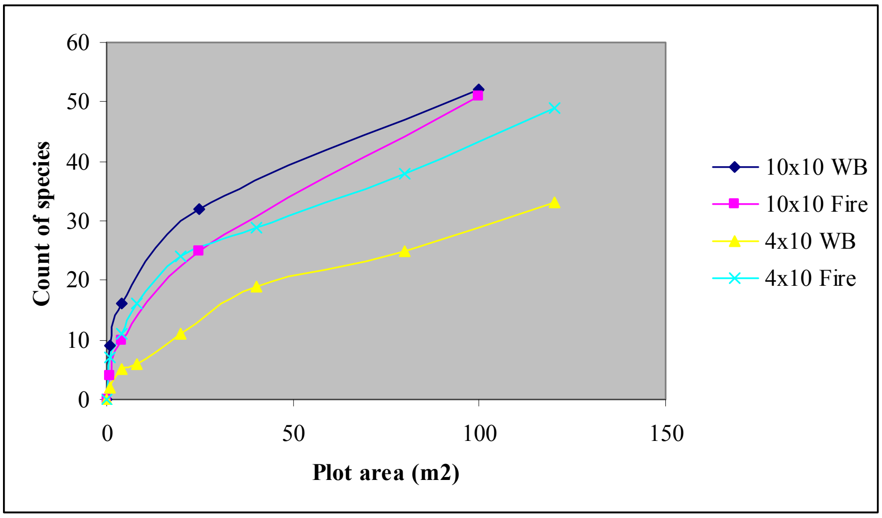


Figure 2. SPAC by plant group – Waree Bight 10x10m nested plot. F=forbs, JT =juvenile trees, L=lianas, S=shubs, T=trees.

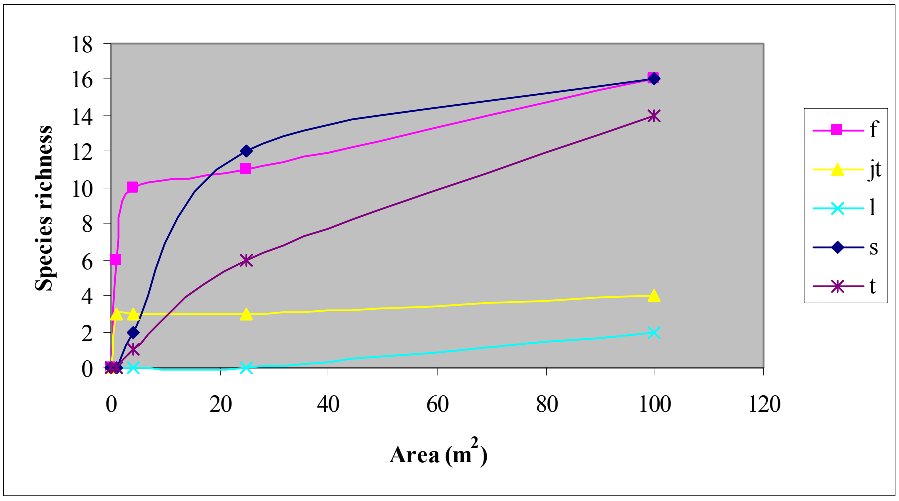
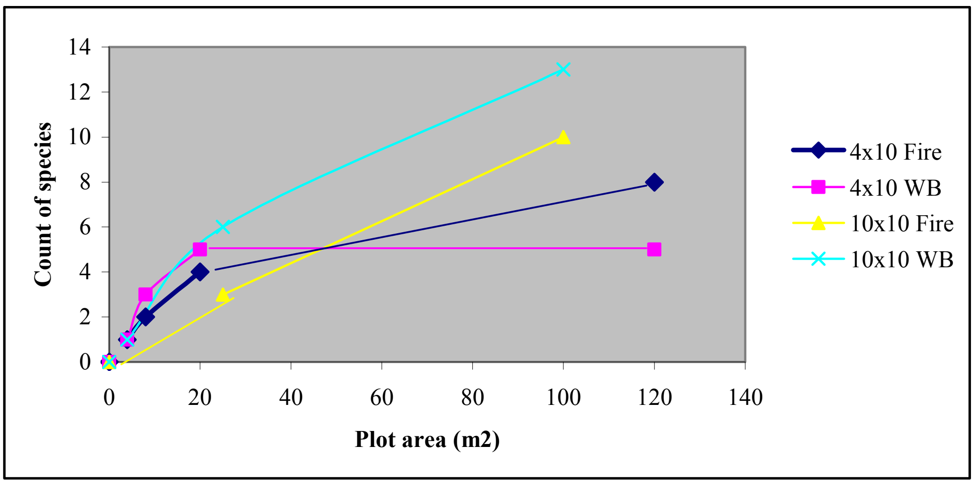


Figure 3. SPAC for canopy tree species only at two sites and two plot sizes.



2. How repeatable were DBH measurements ie. was there much variation between recorders?

Results:

- Consistency between the two teams on the two sites was very high (Figures 4 and 5).

Figure 4. DBH data recorded independently by two teams in the same plot and on the same day at Fireburn.

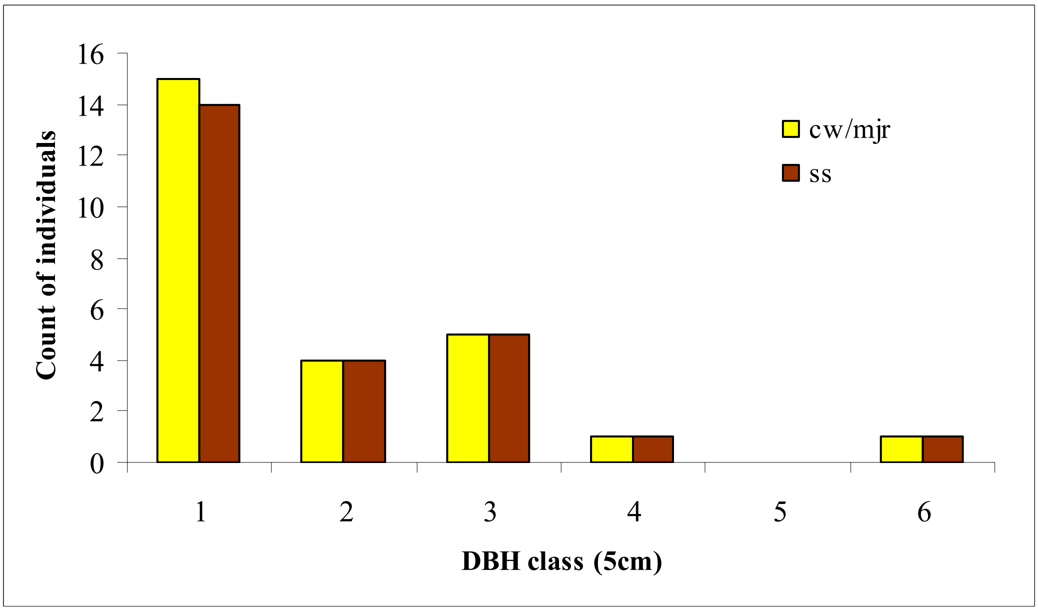
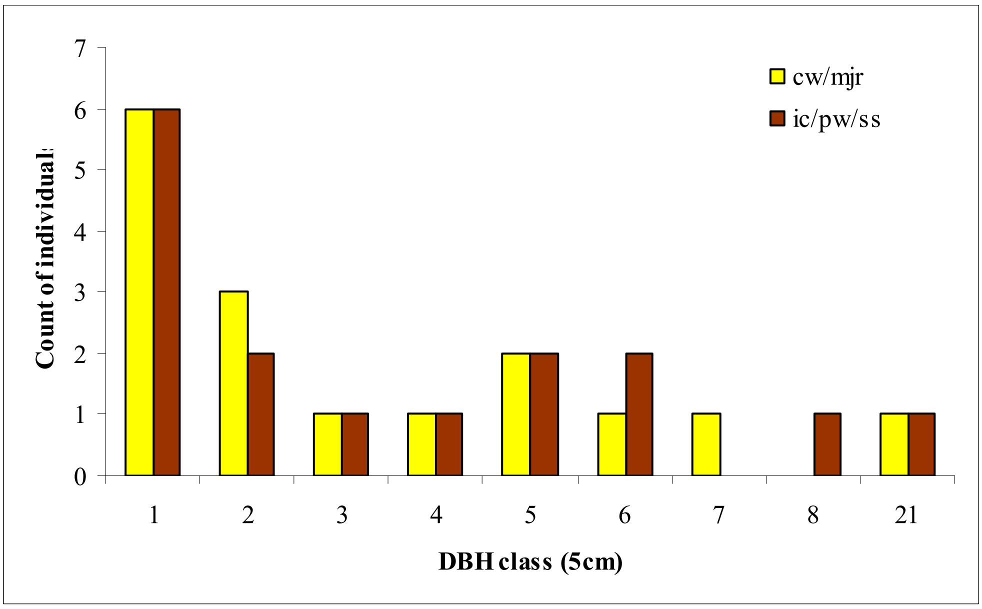


Figure 5. DBH data recorded independently by two teams in the same plot and on the same day at Warree Bight.



Conclusions to workshop

- Participants were introduced to basic fieldwork skills, use of equipment e.g. relascope, clinometer, soil sampling, GPS, recording DbH, plot location and methodology.
- Training in sampling design was given and discussed in the context of the project objectives. i.e. sampling areas subject to different types of Landuse.
- Statistical considerations suggest that the level of replication is at the patch level. This emphasises the need to consider and describe how many patches are present on each site and how they are crossed and replicated in terms of disturbance type, forest type and soil conditions.
- Plot location is dependent on the initial exercise of land use mapping.
- It was decided to focus on canopy trees within the vegetation plots in terms of identification and collection of specimens, but non-canopy species would also be recorded where possible. Focusing on canopy species enables indicators to be drawn from correlations between forest structure data versus birds, herps, bat records and crucially, botanical records of canopy tree species (defined as >=1.3m and >=5cm DBH). There is no reason why indicators from these groups cannot be determined even if many other plants remain unidentified.

<u>Plot location/relocation issues</u>

- GPS satellite acquisition can be slow under a tall and dense canopy. Given the long-term nature of the recording campaign necessary to do a complete botanical inventory of each transect, permanent plot marking would also be useful.

MULTIVARIATE ANALYSIS WORKSHOP

The purpose of this workshop was to train project personnel in;

- spatial datasets and analysis.
- multivariate analysis of species compositional data
    - Why multivariate analysis should be used.
    - Hypothesising explanatory variables
    - Developing hypotheses
    - Introduction to techniques
    - Assembling and manipulating data
    - Statistical testing using project data
    - Interpretation
    - Identifying indicator species

This workshop included the core project team although unfortunately without the researcher and used data collected in the project to carry out basic analyses. It was extremely useful for all participants and began the process of data analysis.

HERPETOLOGICAL TRAINING

Training of Belizean students took place at Wildtracks, Fireburn, Cockscomb, and in the Peccary Hills Reserve. It was implemented at two levels – extended, extensive training of two University of Belize students (Emerson Garcia and Marvin Vasquez) and of a Belizean Wildtracks team member (Norman Mora), along with Protected Area staff; and in an intensive one-day training of a large class of UB undergraduates.

The extended training included identification skills, use of identification keys and guides, safe handling of amphibians and reptiles, survey techniques (diurnal and nocturnal transects), leaf litter searches, data collection and analysis. The UB training course covered all these areas (except for the implementation of a nocturnal transect), dwelt more on use of key features in identification, and also included swabbing of amphibians to test for chytrid infection.

The outputs of the training exercises in field herpetology are measured by the cadre of students and protected area staff who now have the skills and experience to conduct amphibian assessments across a number of forested habitats, and implement PA monitoring activities in this regard

BAT TRAINING

In a partnership with Dr. Bruce Miller (then of the Wildlife Conservation Society), training in the use of Anabat acoustic monitoring equipment, in the assessment of bat populations, was given to several protected areas staff members and University of Belize students. The overnight training course was held at Crooked Tree Wildlife Sanctuary, and included a classroom overview of the reasons to assess and monitor bats, the various techniques available, their individual biases, and the benefits of automated systems such as the Anabat. The training doubled also as the launching pad of a national bat monitoring feasibility study, conducted by Bruce Miller.

One University of Belize student (Emerson Garcia) took on a bat survey project, under the Darwin Initiative, for his final year dissertation. Protected area staff in Fireburn, Crooked Tree and Cockscomb also continued participation in the national bat monitoring project through much of the first year of the Darwin Initiative project. Training continued on an 'as needed' basis throughout this period, as equipment failures and deployment errors meant that fine tuning of the use of the Anabat equipment continued throughout the project.

Chapter 3: Methods

LAND USE MAPPING

Within these sites transects and plots were recorded in areas subject to different types of Landuse. Historical Landuse was ascertained by reference to existing literature, interviews with local residents and local knowledge. Landuse types consisted of: agriculture (shifting cultivation), selective logging and natural forest subject to disturbance by hurricanes. It was extremely difficult to find control plots particularly from logging as most of the areas had been selectively logged and in some areas this was ongoing. The plots in West Basin at Cockscomb have been undisturbed for almost half a century, and are considered 'old growth' in the context of this project. Primary forest, never logged or farmed, exists in some of the most remote areas of West Basin, but occurs on different soils, in more rugged terrain – and would not therefore be well suited for control plots. It was easier to find plots that had been unfarmed at all sites as farming tends to be more focused on particular areas because they are close to settlements.

Figure 6; Plot locations at Cockscomb, Map shows areas that have been logged or farmed. Other information is available in the GIS.

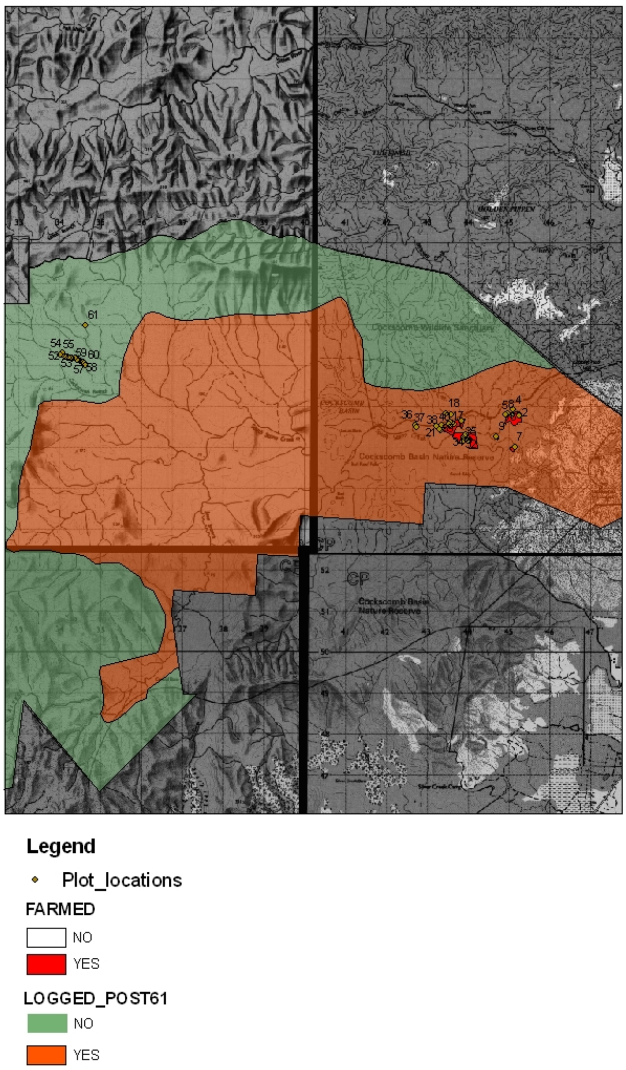


Figure 7: Plot locations at Cockscomb, Map shows areas that have been logged or farmed. Other information is available in the GIS.

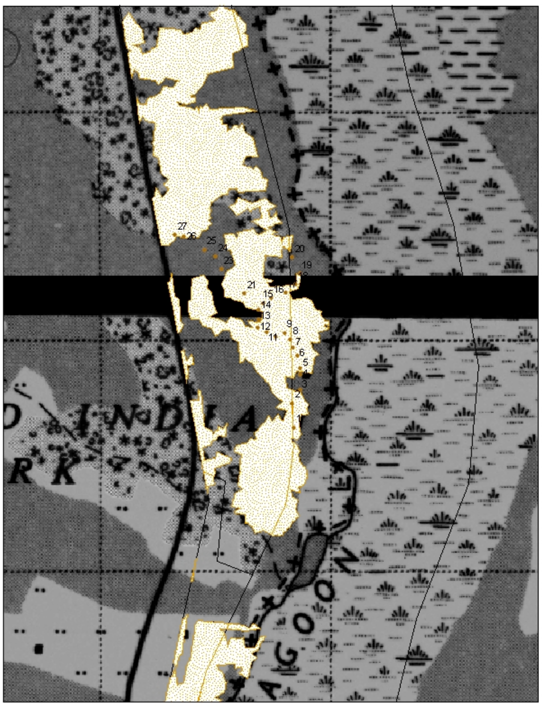
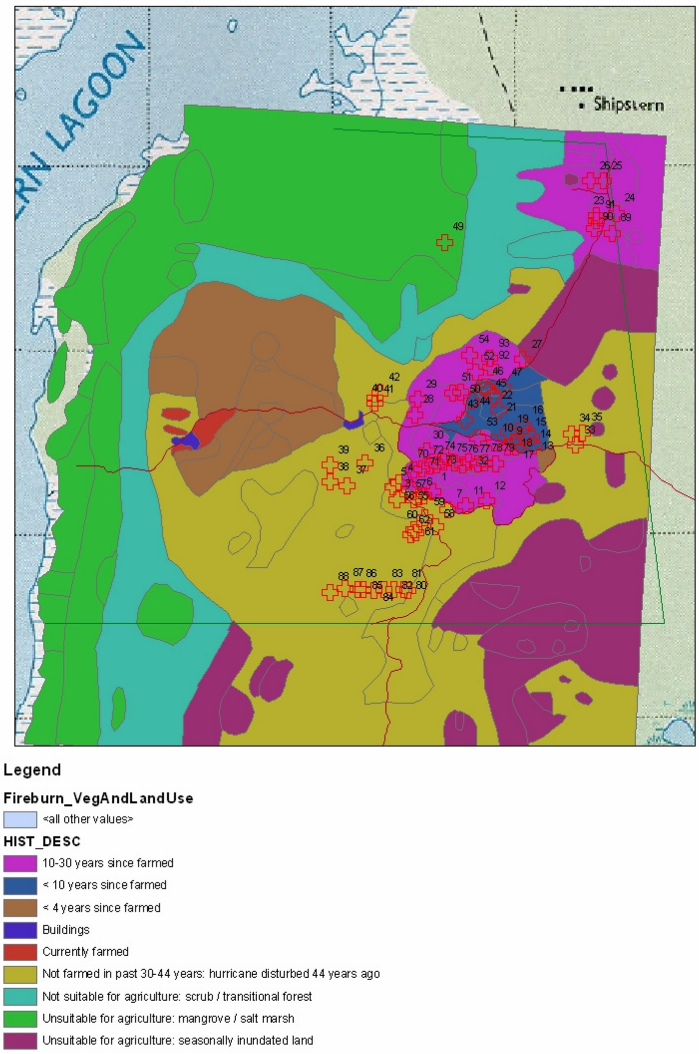


Fig 8; Plot locations at Fireburn reserve, Map shows areas that have been logged or farmed. Other information is available in the GIS.



BOTANICAL SAMPLING

Field testing indicated that 10m x 10m plots would be the most efficient for sampling vegetation, the advantage of small and many plots versus few and large is that the former is more cost effective when sampling variation (Gillison and Liswanti 2004) in addition the landuse types are not necessarily in large blocks and particularly with shifting cultivation may vary over smaller areas. Within each 10m x 10m plot all canopy trees were recorded and voucher specimens taken for identification and confirmation. The tree DBH was measured. Additional measurements within a plot included foliage density, light meter readings, soil depth, pH and soil moisture.
Vegetation analysis has begun using multi-variate techniques.

BOTANICAL IDENTIFICATION

One set of specimens was left in the herbarium in Belmopan, Belize. The other was shipped back to the UK and the project botanist spent time at the Natural History Museum in London and the Royal Botanic Garden, Edinburgh identifying and preparing the specimens. They now reside in the Royal Botanic Garden and information is available on them electronically.
http://elmer.rbge.org.uk/bgbase/vherb/bgbasevherb.php

AVIAN SAMPLING PROTOCOL

This avian sampling protocol was developed for the Darwin Initiative Integrated Assessment of Biodiversity in Secondary Forest in Belize to be used in conducting bird surveys in secondary-forest study plots in three separate protected areas. These surveys were conducted over two years to collect and compare data on avian use of regenerating forest lands that: (1) have been impacted by natural causes such as hurricanes and (2) have been impacted by man for agriculture and resource extraction. The data collected in these surveys can also be used in future years to assess changes in avian composition and diversity over time as these forests mature.

The quantitative sampling of the avian community in forests regenerating from natural and anthropogenic deforestation is intended to address the objective to determine the biodiversity value of secondary forest tracts, for one animal group that will be complementary to the botanical work and sampling of other species groups.

1. Protocol design

A number of avian sampling protocols are available, some better designed for sampling birds, forested environments, biodiversity, and species composition than others. Most protocols designed for these purposes are either based on line transects or point counts or a combination of the two. Point counts, however, are easier to incorporate into studies designed to sample specific habitat types in relatively small plots and in areas of rugged terrain or otherwise difficult access (Bibby et al. 1992). Point counts are ideal for sampling a variety of plots or habitat types, especially those of relatively small unit size. They are also generally considered to be better than line transects for sampling forested habitats because they allow more time than transects to detect and identify secretive and difficult species and those that vocalize less frequently. A further disadvantage of line transects is that selection of transect routes is seldom random or systematic because their placement is often restricted by such factors as difficult terrain, dense understory, lack of access trails or roads in many areas, and typically complex arrays of habitat types over relatively short distances (where habitat use is a critical component of the study design).

Also, it has been shown that point counts when conducted properly give an accurate reflection of true population densities in forested habitats in that the relative density estimates obtained with point counts and actual densities are linearly related across a wide variety of density levels (Toms et al. 2006). For these reasons, the protocol design adopted for this project is based on the standard point count sampling methodology.

2. Considerations

This point-count protocol is designed to quantitatively sample birds in forested habitats. It is not appropriate for sampling animals other than birds; open areas such as grasslands, savannas, wetlands, or open water; aerial species such as raptors, swallows, and swifts; and plots with multiple habitat types; and it may not be preferable to line transects for sampling large expanses of relatively uniform forested habitats.

Repeatability

Because the study is designed to compare avian diversity, relative abundance, and species composition between plots (variations in space) and to detect future changes (variations in time), it is paramount that the protocol be followed precisely in each of the study plots and during each temporal sampling period. Ideally, the same observer or observers should conduct all the surveys throughout the life of the project, thus eliminating biases resulting from differences in observer identification skills, in estimating distances, and in estimating numbers. But this may not be practical in studies that continue for many years; therefore, it is important that all observers possess excellent identification skills and that they be trained beforehand in accurately estimating distances and making accurate counts.

Plot Selection

Point count locations should be placed well within the habitat type(s) to be sampled to maximize the area covered and minimize the likelihood of recording species in other habitats. Ideally, each plot will be sufficiently large to accommodate a sampling area of 200 m in diameter (100 m radius). In plots of smaller area, the plot size should be adjusted downward accordingly, and the observer must take care in not counting birds detected beyond the boundaries of the habitat.

Normal Variation and Bias

All sampling protocols have inherent biases, some beyond the control of the observer and some within the observer's control. Potential normal variables and observer sampling biases should be identified at the outset, and steps should be taken to minimize or eliminate as many of these variables and biases as possible before the study begins.

Distinguishing Normal Variation from Bias

Normal variation may consist of habitat or structural variations between plots, plot size differences, exposure (e.g., south-facing vs. north-facing slopes, vs. flat terrain), differences in adjoining habitats that may influence avian populations within the sampled habitat, and differences in species composition and abundance between plots due to random fluctuation. Differences in weather, time of day, geography, and the season in which the surveys are conducted may also be considered part of the normal variation. Some of this variation, however, can be controlled, other variables cannot.

Sampling bias, on the other hand, results from differences in observer skills, deviations from protocol within and between surveys, and even the mere presence of the observer. Other biases may have little or nothing to do with the observer, for example, the differences in detectability of different species, decreasing detectability of most species with increasing distance, and undetected movements of birds during the sampling period that may result in double counting.

Minimizing Normal Variation

Weather conditions are constantly changing. Cloud cover, rain, wind, temperature, and humidity all affect bird behavior to some degree, including activity patterns and the tendency to vocalize – the key elements that increase detectability. The effect of these variables is reduced in direct proportion with the number of samples, i.e., the more point counts conducted at each location the less pronounced the effects of weather. To further reduce the effects of variable weather conditions counts should not be taken during or immediately after rain (rain-drip noide can substantially reduce one's ability to detect vocalizations) or in mid-day when temperature and humidity are typically higher and most terrestrial and arboreal bird activity is depressed. Mid-day may be better for raptors aloft, but this protocol is not designed for sampling raptors.

Other normal variables resulting in bias are the differences in detectability of birds at different distances, differences in behavior patterns that result in some birds being more detectable than others, and the fact that birds are highly motile and will invariably move around within the study area, often without observer awareness. To some extent, these variables can also be minimized.

By recording the approximate distance (or distance range) to each bird, the drop off in detectability with distance can be accounted for in the statistical analysis of the results. Because distances are difficult to estimate, especially for unseen vocalizing birds in dense forest, the simplest way to reduce this bias is to divide the study area into two or three distance ranges. In this study, two distance ranges are given: birds detected within 50 meters of the observer and those detected between 50 and 100 meters (in plots with dense forest cover, few species are detectable beyond 100 meters). The usefulness of these distance categories is directly related to the observer's ability to accurately estimate distances; however having only two distance parameters requires only that the observer accurately estimate two distances, 50 meters out and 100 meters out.

Little can be done to account for the differences in detectability of different species; however, differences in detectability for any given species should not vary from one plot to another, so comparative results on a species by species basis should not be affected. The number of highly vocal stub-tailed spadebills detected should never be compared directly with the number of relatively non-vocal eye-ringed flatbills, for example, as the true density of the former is more likely to be more closely approximated in the sample than the true density of the latter, which is almost certain to be consistently underestimated.

Double counting resulting from undetected movements of individual birds can be minimized by shortening the duration of the survey; however, by shortening the survey, a greater number of species may go unrecorded. An acceptable compromise adopted in this protocol is a survey duration of 20 minutes. Nevertheless, caution should be taken to avoid double counting as much as possible. For example, a black-headed trogon calling consistently about 70 meters to the east in the first five minutes followed by a few minutes of silence, then a trogon calling consistently about 90 meters to the southeast is likely to be the same individual.

Even the mere presence of the observer in the study plot will can affect the sample. Birds tend to move away from an observer as he or she enters their territory, and many will also stop vocalizing for a short period. Even after the observer has remained stationary for awhile, most species will remain at a certain minimum distance. Therefore, detections within 10 meters of the observer will be lower than detections farther away because of real differences, whereas detections of distant birds will be lower due to a drop-off in detectability, not a drop-off in numbers. By setting the close distance component as 50 meters, the effect on the sample of the observer's presence on bird density levels in the immediate vicinity is minimized. Another way to reduce the effect of observer presence is for the observer to remain relatively motionless at one spot for at least two minutes before beginning the survey to allow the nearby birds to accommodate to the observer's presence.

To minimize the effects of heat and humidity and a natural drop in activity in mid-day, all plots should be surveyed in the morning, with the first survey beginning about 10 minutes before sunrise, and the last ending no later than three hours after sunrise. For best results, the time of day each plot is surveyed should be varied so that all plots are sampled approximately the same number of times at dawn and later in the morning. This will negate the bias of one plot appearing to have more species because it was always surveyed at or shortly after dawn when bird activity is typically at its highest level.

Minimizing Observer Bias

An unskilled observer may recognize 20 percent of the species seen or heard, a moderately skilled birder may recognize 60 percent, and a truly skilled birder should be able to recognize close to 90 percent of all birds detected. Therefore, it is important that observers employed for avian sampling programs such as this be highly skilled for two reasons: the skilled observer is not likely to miss many of the species present, and if two observers are employed to conduct surveys, two highly skilled observers are likely to detect close to the same array of species. On the other hand, two lesser skilled observers may not only detect many fewer species, but the subset of species each is familiar with may differ significantly.

Ideally, the same observer should be used to conduct all surveys, but this is not always practical, especially in studies that may last several years. If two observers with similar skill levels are employed, they should alternate duties so that each observer samples each plot roughly the same number of times.

To reduce sampling error, it is important that the protocol be followed precisely. Some areas where less experienced observers have a tendency to depart from protocol are listed below.

- Count only those birds detected during the 20-minute counting period. A natural tendency is to count slightly beyond the end of the period in order to "pad the count" if a previously undetected species suddenly appears or vocalizes. This should never be done. Likewise, a point count should never begin earlier than planned to accommodate an interesting species that makes itself known moments before the official start time. If the start time is set for 09:06, it should begin at precisely 0906 and end precisely at 0926. It should never be back-adjusted to 09:05 to account for a species that is detected in the minute before the count but not during the 20-minute counting period. If an interesting species appears or vocalizes a few seconds before 0906, it should be recorded separately at the bottom of the data sheet but never as part of the official count. Birds noted beyond the plot perimeter and species other than birds may also be noted in the margins as well, as these are important observations even if they are not part of the official count.
- Record only those birds that are determined to be within the habitat sampled. A blue-black grassquit is not likely to be within a forested area and should not be included unless its presence in the study plot is confirmed. Likewise, a black hawk-eagle or even a flock of olive-throated parakeets heard flying above the forest should not be counted, as they are not utilizing the habitat.
- If the identification of the bird is in question, record it with a question mark or record the lowest taxonomic level to which it is identified. For example, a vocalization that cannot be ascribed to either plain xenops or olivaceous woodcreeper, or a "generic" warbler chip note should be recorded as "plain xenops/olivaceous woodcreeper" or "warbler sp.". Other common examples of birds not always identified to species are *Leptotila* sp. and hummingbird sp. Never guess.

Each participant should practice estimating distances before beginning the study: for the purposes of this study 50 meters and 100 meters. Study participants should practice estimating distances within this range and then check their accuracy by measuring or pacing off the actual distance. To learn the length of one's normal walking pace, it is a good idea to count the number of steps required to walk at a normal pace a known distance such as a 100-meter football field. If 118 steps is required to walk 100 meters, then each step is about 0.85 meters long.

Estimating the number of birds present is usually not a problem in forested habitats, since numbers are usually in the single digits. The bigger problem is over- or under-counting birds because of uncertainty in whether a bird heard 15 minutes into the sampling period is the same as one heard ten minutes earlier or a different individual. In these cases, each observer must use his or her best judgment.

3. Data Recording

The accompanying point count data form (Appendix) has space for recording two types of data: station data and species data. The rows at the top of the sheet are for entering data specific to the station where the survey is to be performed. The columns below these rows are for entering data on each species recorded during the survey. Below is an explanation for each entry.

Station Data

- *Station Name*: Each survey station should have a unique name, such as CB TF-L2, the second station in previously logged forest along the Tiger Fern Trail in the Cockscomb Basin Wildlife Sanctuary.
- *Date*: The date of the survey.
- *Start Time and End Time*: The 20-minute time period of the survey. A survey can begin at any time, preferably the beginning of a minute (09:07–10:07 is acceptable, but 09:07:20–10:07:20 is unnecessarily confusing). It is therefore assumed that each survey begins and ends at the beginning of a minute.
- *Observer*: The observer’s initials are adequate unless more than one observer has the same initials.
- *Temperature*: One temperature reading at about the mid-point of the survey period is adequate. Indicate whether the temperature recorded is in degrees Fahrenheit or Celsius.
- *Wind*: This can be a general indicator such as calm, light breeze, moderate breeze, or strong wind. Surveys should not be initiated if the wind is moderate to strong, but if the wind picks up during the survey period, the survey should continue and this change in conditions should be noted.
- *Noise*: If cicadas, wind, or leaf-drip following a rain interfere with the ability to hear birds, this should be indicated. Otherwise, write “normal”.
- *Additional Weather Comments*: Use this space to record pertinent information about the weather such as precipitation (mist, light rain, heavy rain, or fog), cloud cover, or a significant change in the weather during the survey.

Species Data

- *Time*: In the first column indicate the minute during which the bird was first detected, whether by sight or vocalization.
- *Species*: Record the name of the bird in this column. Abbreviations are acceptable as long as there is no confusion as to which species is being noted. For example GRKI could be either Great Kiskadee or Green Kingfisher. Likewise, beware when using initials for Green-breasted Mango and Gray-breasted Martin, Blue-black Grosbeak and Blue-black Grassquit, Gray-headed and Golden-hooded Tanager, and Ruby-throated and Rufous-tailed Hummingbird. NOTE: do not record birds seen or heard flying overhead unless they flushed from or landed in trees within the study plot.
- *Number*: Most detections will be of only one or two individuals. If two or more individuals of the same species are seen or heard within a short period, they should be included as separate entries unless they are part of a unit, i.e.,

in the same tree or same feeding flock. If either the distance or the direction to the birds differ significantly, then they should be entered separately.

- *Distance to Bird/s*: If the bird is estimated to be within 50 meters, record a “1” in this column; if it is between 50 and 100 meters, record a “2”; for birds beyond 100 meters, record a “3”. Even though birds recorded beyond 100 meters will not be included in the results, it is a good idea to note them anyway. CAUTION: Do not record birds in other habitats (pastures, citrus groves, overgrown fields).
- Comments: Notes on age, sex, and interesting behavior can be included here. It is also a good idea to note whether the bird was seen or heard in cases where the species may be confused with a similar species. For example, a plain xenops seen carries more assurance of correct identification than one that is heard only, because of the vocally very similar olivaceous woodcreeper. If there is some question about the bird’s identification, an explanation can be provided in this column.

HERPETOLOGICAL SAMPLING

Rain forests challenge investigators because of the dense under- and overstory, low light conditions, extreme rainfall and humidity, and a generally uncomfortable environment for the observer (Inger, 1980; Scott, 1994; Pearman et al., 1995).
Some standard methods are difficult to implement or are completely inappropriate for rain forest surveying.
Herpetofauna was sampled mainly via Visual Encounter Surveys (transects)- the most effective sampling technique for maximised species acquisition within humid tropical forests. These transects were supplemented by opportunistic observations whilst implementing the botanical plots.

ANALYSIS

Simple statistical comparisons have been used to compare mean species number, canopy height and DbH. Multi-variate techniques using the program Canoco (ter Braak & Smilauer 2002) have been used on the vegetation data. Detrended (DCA) and constrained (CCA) Canonical analysis have been used to look at patterns in the botanical species composition to relate them to explanatory variables including Landuse (farmed, logged, hurricane-impacted) and physical parameters such as light levels. As well as using each variable individually a 'disturbance' score was created which subsumed all disturbance agents by coding farmed as 10, logged as 2 and not logged as 1 hence farmed is 5 times the impact of logging which is 2 times the controls yet these are coded as 1 because of the possibility they were logged in past.

The initial gradient lengths were determined from the DCA and the appropriate model selected. Then a constrained analysis was run and each disturbance factor tested for impact using 499 Monte Carlo permutations. Constrained axes scores were extracted and species variance fitted and used to sort to give positive and negative indicators plus the importance of the factor in explaining the species' overall variance across the sampled plots. Both techniques were carried out on the raw species data with no transformation and also on species data weighted by DBH. Using the species data alone does tell you which species are associated with which disturbance factor, however, these could be juvenile species that have recently invaded and so this method is not such a powerful discriminator of time since disturbance. We developed an analysis which we called 'pseudospecies analysis'. Species were assigned a DBH class (1=<10cm , 2=10-<20cm , 3=20-<30cm, 4=30-<40cm, 5=>40cm) and this was combined with the species identity in the analysis to give an indication of how different land management affected the size and age class of species. The indicator species were then selected and discussed amongst the project team.

One way ANOVA's were carried out across all three sites with simplified Landuse variables. The response variable was species number or mean DBH and the explanatory variables recently logged, not logged, recently farmed and not farmed.

Chapter 4: Results

Vegetation

Vegetation was recorded in 62 plots at Cockscomb, 86 at Fireburn and 27 at Crooked tree. Botanical specimens were sent to the UK for identification at the Natural History Museum, London and have now been deposited in the Royal Botanic Gardens, Edinburgh. One set of duplicates was deposited at the Forest Department Herbarium in Belize. 382 different canopy species were identified across all three sites, of these 298 were identified to the species level. At Cockscomb there were 232 (184 identified to species), Fireburn 141 (111 to species), and Crooked Tree 105 (82 to species). Mean DBH varied between sites. It was highest at Cockscomb, then Fireburn and Crooked Tree was the smallest. Mean number of canopy species per plot also varied, it was highest at Fireburn, then Crooked Tree and Cockscomb. The lower number at Cockscomb when overall there were many more species recorded is likely to be due to the larger DBH so in relatively small plots there would be fewer large canopy species.

Table 1:Mean DbH (cm)

	Mean DbH (cm)	Mean species number
Cockscomb	20.12	3.7
Crooked Tree	10.10	4.2
Fireburn	16.26	5.4

<u>Cockscomb Basin Wildlife Sanctuary</u>

The flora of Cockscomb Basin Wildlife Sanctuary has been remarkably under-collected, with the collections of this project adding enormously to the Reserve checklist. Although there were no big surprises within the plants collected in the plots, supplementary collections (within other habitats) recorded some upper elevation species that were new records for Belize. Extensive colonial logging covered most of Cockscomb, though the sampled area in West Basin has remained untouched now for almost half a century. The only truly primary forest is in rugged sheltered valleys on the southern slopes of Victoria Peak: on different soils, topography, slope, aspect and hydrology than the East Basin plots, and therefore not used here as controls.

We have one specimen (R. Akers 9) (plus subsequent observations), which we convincingly keyed out and matched to *Jacaratia mexicana* A.DC., however there is an element of doubt as this would be a new record to Belize and we need to make thoroughly sure that it is not the very similar *Jacaratia dolichaula* (Donn. Sm.) Woodson first.

<u>Crooked Tree Wildlife Sanctuary</u>

A noteable record for Crooked Tree wildlife reserve was *Blomia prisca* (Standl.) Lundell, Z.A.Goodwin 628 which is a tree known to Belize but apparently confined only to the Orange Walk District within Belize (it is also known from the Peten, Guatemala and Southern Mexico) (Tropicos 2009).

The area surveyed at Crooked Tree was a thin strip of disturbed forest between Western Lagoon and cultivated land. Periodically the plots were conducted in swampy forest (dominated by *Zygia conzattii* (Standl.) Britton & Rose and *Bactris* sp).

Fireburn Reserve

Species of particular interest that were found in the survey included *Acacia cedilloi* L. Rico, Z.A.Goodwin 163 & E.Kay 303 . Previous to this it was only known from one reserve in Quintana Roo (Rico-Arce 2007), until two specimens from Fireburn were identified by L.Rico-Arce as also being *A. cedilloi*. She said that they had searched but not found this species anywhere in Quintana Roo except in the reserve where *A. cedilloi* was first discovered, so not only is this a new record for Belize but also a nice range extension for the species.
Loose leaflets from both these samples (and the other Acacias collected) have been sent to a PhD student at the Universidad Nacional Autónoma de México for her research into the evolution of ant-associations in the Acacias.

It was assumed that Fireburn has a basic soil chemistry because of the limestone Yucatan bedrock, however the most conspicuous elements of much of the forest at Fireburn are classic acid indicator species (S.Brewer pers.com.).

- Cassipourea guianensis Aubl. [small tree]
- Matayba apetala Radlk. [tree]
- Mosannona depressa (Baill.) Chatrou [shrub]

In addition to the appearance of acid-loving plants Fireburn also has mixture of classic Yucatan dry forest plants (primarily Yucatan/Quintana Roo and into Peten) such as *Caesalpinia gaumeri* Greenm., *Exothea diphylla* (Standl.) Lundell and *Diospyros tetrasperma* Sw. and widespread lowland generalists such as *Attalea cohune* Mart., *Dendropanax arboreum* (L.) Decne. & Planch. and *Cupania belizensis* Standl.. The latter are not found in the drier Yucatan forest as seen around Sarteneja.

Other outputs
Two botanical guides were created by the project botanist Zoe Goodwin, these can be seen in Appendix 1.

Multi-variate analysis was carried out separately at the three sites in the first instance because they all varied in the nature and type of disturbance.

Cockscomb
Species only
CCA of the raw species data at Cockscomb showed that logging (post 1961) and farming both had a significant effect on the species composition ($p<0.05$) (Fig. 9).

Figure 9. CCA of raw species data at Cockscomb showing significant variables.

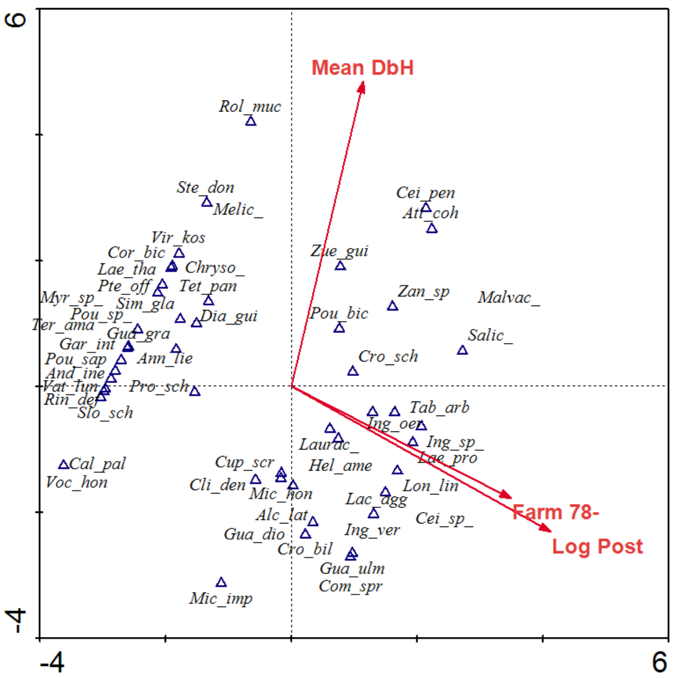


Table 2; results of testing of variables individually (i.e. not stepwise regression) in raw species data at Cockscomb.

Variable	p	F
Farmed	<0.05	1.3
Disturbance	<0.01	1.3
Logged	<0.01	1.52

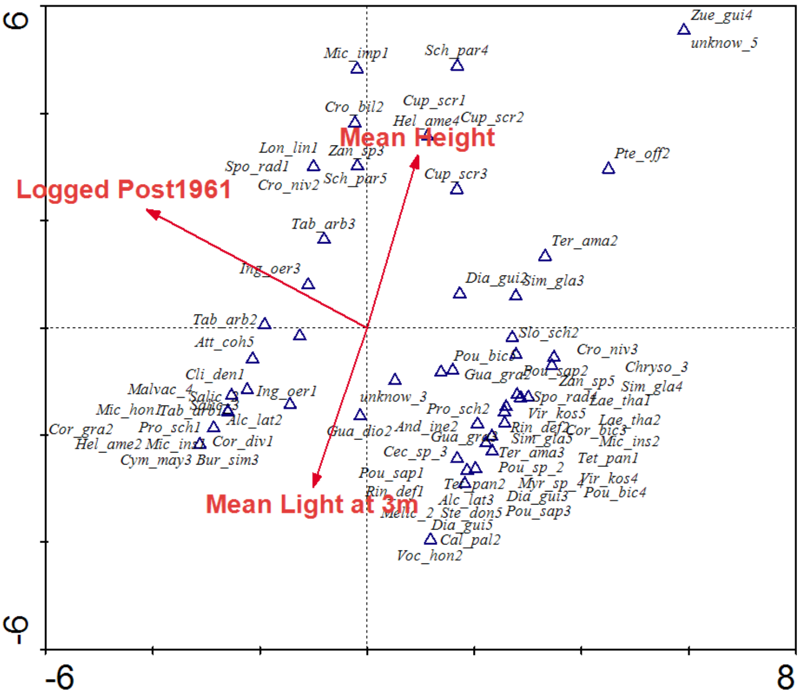
The results from the constrained analysis between individual variables to determine indicator species can be seen in Table 2. Farming, disturbance and logging were all significant when tested individually.

The raw species data showed that some species *Tabaernaemontanum arborea* , *Inga oerstediana, Attalea cohune, Laetia procera*, *Heliocarpus americanus, Miconia hondurensis, Schizolobium parahyba* showed a positive association with logging (Table 4, Appendix 2) . Similar species were associated with farming with the addition of *Lonchocarpus lineatus, Ceiba* sp. and *Lacistema aggregatum*. Others e.g. *Pouteria sapota, Guarea grandifolia*, *Andira inermis, Terminalia amazonia* and *Rinorea deflexiflora* showed a negative association with logging. These were similar to those in areas that had not been farmed, also *Dialium guianense* and *Croton niveus.*

Pseudospecies

CCA of the pseudospecies data using forward selection showed that logging ($p<0.001$), mean height and light level had a significant impact on species composition ($p<0.05$) (Figure 10).

Figure 10. CCA of pseudo-species data at Cockscomb showing significant variables.



When the Landuse variables were tested individually, farming, disturbance and logging were again significant (Table 5).

Table 5; results of testing of variables individually (i.e. not stepwise regression) in pseudo-species data at Cockscomb.

Variable	p	F
Farmed	0.028	1.2
Disturbance	0.016	1.2
Logged	0.002	1.3

Logging significantly influenced species composition when species were classified by DBH class (Table 6, Appendix 2). Species positively associated with logging with a larger DBH using the DBH class analysis include *Inga oerstediana, Pouroma bicolour,Croton schiedeanus Zanthoxylum sp., Tabaernaemontanum arborea* and *Attalea cohune*. There was a difference between the identity of the larger species in logged areas and the smaller, species identified with logging included *Croton bilbergianus, Miconia hondurensis, Tabebuia guayacan* and *Clidemia dentata.*

Other large species associated with disturbance included *Ceiba sp., Schizolobium parahyba, Heliocarpus amricanus* and *Zeulania guidonia*. Smaller species included *Guatteria diospyroides* and *Lacistema aggregatum*.

Species positively associated with farming (Table 7, Appendix 2) were similar to those associated with logging and disturbance, larger species include *Croton schiedeanus, Ceiba sp., Schizolobium parahybum, Heliocarpus americanus, Attalea cohune, Zuelania guidonia, Inga oerstediana, Tabernaemontana arborea*. Smaller species include *Miconia hondurensis, Alchornia latifolia, Lacistema aggregatum, Lonchocarpus lineatus, Tabernaemontana arborea, Guatteria diospyroides, Laetia procera, Protium schippii* and *Sloanea tuerckheimii*.

Species negatively associated with logging with a larger DBH included *Dialium guianense, Pourouma bicolor, Simarouba glauca* and *Stemmadenia donnell-smithii..*

Species negatively associated with farming and more likely to be in undisturbed areas include *Cupania scrobiculata, Heliocarpus americanus, Zanthoxylum sp., Guarea grandifolia*.

Species negatively associated with disturbance with a larger DbH include *Stemmadenia donnell-smithii,Pouroma bicolour, Cupania scrobiculata, Dialium guianense, Zanthoxylum* sp., *Guarea grandifolia, Simarouba glauca* and *Spondias radlkoferi*. Species with a smaller DbH included *Protium schippii, Guarea grandifolia Pouteria sapota, Andira inermis, Rinorea deflexiflora, Tetragastris panamensis, Dialium guianense* and *Calypthranthes pallens.*

Two species *Simarouba glauca* and *Spondias radlkoferi* were surprising as species not associated with disturbance as they are known to be early successional species, however, although there has been no anthropogenic disturbance (post 1961) within these plots they may have been subject to natural disturbance (Hurricane Hattie had a great impact on these sites in 1961). Similarly, they are likely to be old specimens (larger size class), indicative of the selective logging in that area that took place up to 1961.

Crooked Tree Wildlife Sanctuary

Species only

All plots at Crooked Tree had been subject to logging and hurricane disturbance so the only explanatory disturbance variable which could be used was farming. In a CCA with other variables such as mean light level, mean DbH and mean height included farming was not significant ($F=0.8$, $p=0.8$). Mean DbH was the only variable significantly related to species composition. ($F=1.65$, $p<0.01$).

Pseudospecies

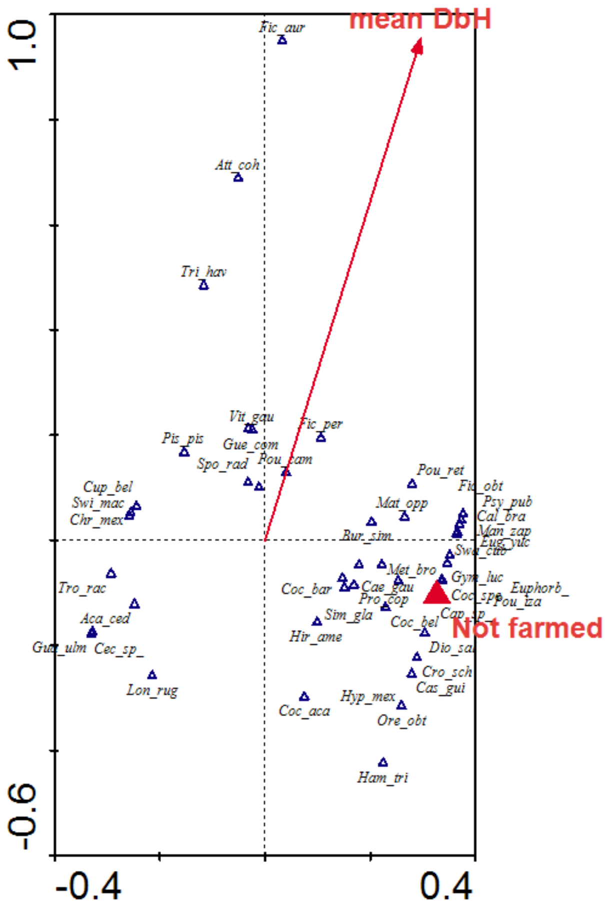
Similar to above there was no significant effect from farming. ($F=0.86$, $P=0.68$)

Fireburn Reserve

Species only

It was not possible to use logging as a variable at this site as it is likely that all plots were selectively logged at some point. When all variables were tested individually many of them were significant. However when all variables were included and forward selection used only plots which had not been farmed (p<0.01, F=5.03) and mean DbH (p<0.01, F=2.21) showed significant associations with species composition (Figure 11). This is likely to be because these plots are very different to those that had been farmed or logged.

Figure 11. CCA of raw species data at Fireburn showing significant variables



When tested individually plots that were farmed recently or farmed more than 17 years ago were also significant (Table 8).

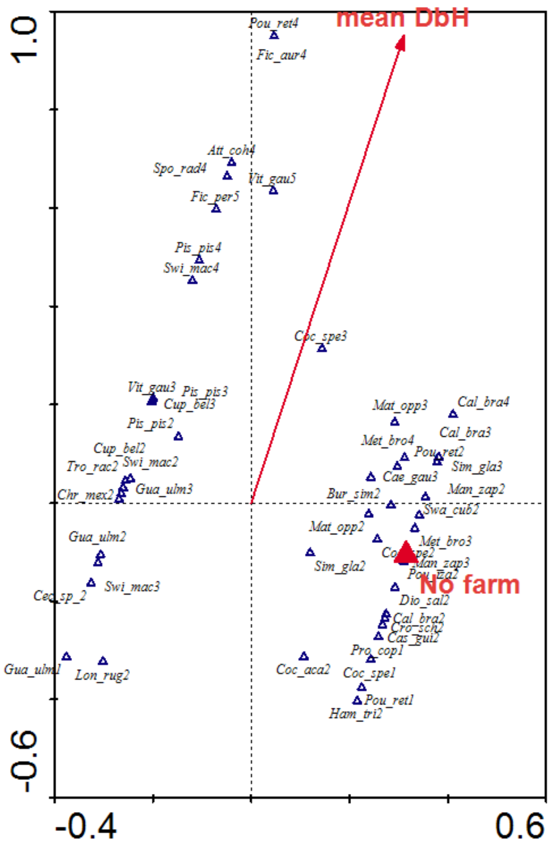
Table 8; results of testing of variables individually (i.e. not stepwise regression) in raw data at Fireburn.

Variable	p	F
Not farmed	<0.01	5.1
Farmed recently	<0.01	2.7
Farmed >17 years ago	<0.01	1.72

Potential indicator species associated with areas that had been farmed recently included *Cupania belizensis,Guazuma ulmifolia, Chrysophyllum mexicanum, Cecropia sp., Dendropanax arborea, Swietenia macrohpylla* and *Spondias radlkoferi* (Table 9, Appendix 2).
Species associated with areas farmed more than 17 years ago included *Lonchocarpus rugosa, Piscidia piscipula, Attalea cohune, Swietenia macrophylla, Acacia cedilloi, Trophis racemosa, Vitex gaumeri* and *Cupania belizensis.*
Areas that had not been farmed contained species such as *Coccoloba* sp., *Matayba oppositifolia, Croton schippii, Metopium browneii, Manilkara zapote, Bursera simarouba, Pouteria izabalensis, Calophyllum brasiliense, Simarouba glauca* and *Caesalpinia gaumeri*. Some of these such as *Metopium browneii, Simarouba glauca* and Bursera simarouba are surprising as species associated with undisturbed areas as they tend to be regarded as gap colonists and pioneer species.

Pseudospecies
As above when all variables were tested together only not farmed and Mean DbH were significant (Figure 12). Although the other variables were significant individually areas that had never been farmed were significantly more different**.**

Figure 12. CCA of pseduo-species data at Fireburn showing significant variables



We were concerned that there might be something different about plots that hadn't been farmed i.e. they were not suitable for farming (there is some swamp forest in this reserve which wouldn't be able to be farmed) so we carried out an additional analysis including an explanatory variable 'control farm' where areas were identified that could have been farmed but weren't and the plots within them coded. Plots that had not been farmed were still significantly different in species composition from those that had been, however the areas which would definitely have been suitable for farming were also significantly different to other areas (Figure 13).

Figure 13. CCA of raw species data at Fireburn with control farm as an explanatory variable

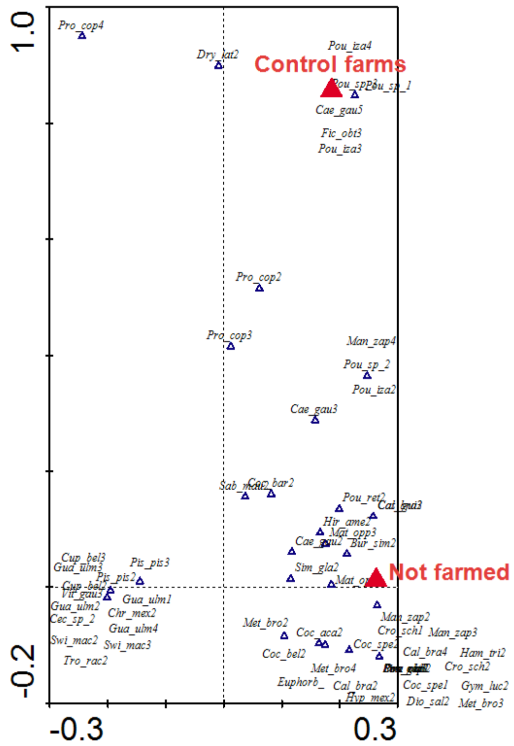


Table 10; results of testing of variables individually (i.e. not stepwise regression) in pseudo-species data at Fireburn.

Variable	p	F
Not farmed	0.002	3.404
Farmed recently	0.002	2.002
Farmed >17 years ago	0.002	1.548

Species associated with areas that had been recently farmed with a larger DbH (Table 11, Appendix 2) include *Guazuma ulmifolia, Chrysophyllum mexicana, Cecropia sp., Cupania beliziensis, Vitex gaumeri, Spondias radlkoferi, Dendroponax arboreus, Swietenia macrophylla, Piscidia piscipula* and *Sabal mauritiformis*

Unlike Cockscomb the smaller species associated with recent farming were very similar to those with a larger DbH so there is not a significant difference between those species that have been established for a while and those that have colonised more recently.

Where farming had been abandoned more than 17 years ago the associated species with a larger DbH included *Attalea cohune, Guazuma ulmifolia, Vitex gaumeri Swietenia macrophylla, Ficus pertusa, Acacia cedilloi, Bursera simarouba, Ficus aurea, Pouteria reticulate, Protium copal* and *Piscidia piscipula*.
Smaller species were different in this case suggesting a more established canopy. Associated species with a smaller DbH *included Lonchocarpus rugosus, Piscida piscipula, Cupania beliziensis, Acacia cedilloi, Guazuma ulmifolia, Spondias radlkoferi, Trophis racemosa, Guettarda combsii* and *Cecropia* sp.
Species in areas which hadn't been farmed with a larger DbH included *Metopium browneii, Calophyllum brasiliense, Matayba oppositifolia, Manilkara zapote, Caesium gaumerii, Simarouba glauca, Ficus obtusifolius* and *Pouteria izabalensis*.
Smaller species included *Bursera simarouba, Croton schiedeanus, Matayba oppositifolia, Protium copal, Manilkara zapote, Pouteria izabalensis, Diospyros salicifolia, Pouteria reticulata* and *Swartzia cubensis*.

When we analysed separately plots that we thought would be suitable for farming but hadn't been farmed (Table 12) the indicators associated with unfarmed were similar (*Ficus obtusifolius, Caesium gaumeri, Pouteria izabalensis, Manilkara zapote, Protium copal, Calophyllum brasiliense, Matayba oppositifolia* and *Pouteria campechiana*) but didn't include species such as *Simarouba glauca* and *Metopium brownei* which are early successional species associated with thinner soils.

Analysis across all three sites

Species number
Plots that had been recently logged or farmed contained fewer species (Table 13). Plots that had not been farmed showed a higher species number. There was no significant effect on species number from logging (over a longer time period).

Table 13: Results of testing LandUse variables against Species number (ANOVA) across three sites.

	F	P	Direction
Recent logging	7.6	< 0.01	↓
Not logged	0.005	0.95	n.s.
Recently farmed	5.6	<0.05	↓
Not farmed	8.04	<0.01	↑

Mean DbH
There were similar relationships with DbH, (Table 14) i.e. a larger DbH was associated with plots where there has been no logging or farming. Plots that had been recently farmed or logged had a lower DbH. Interestingly although there was no significant effect on species number in plots that had been logged and those that hadn't there was an effect on DbH

Table 14: Results of testing LandUse variables against DbH across three sites.

	F	P	Direction
Recent logging	4.2	<0.05	↓
Not logged	17.6	<0.001	↑
Recently farmed	11.2	<0.001	↓
Not farmed	9.1	<0.01	↑

Birds

<u>Cockscomb Basin Wildlife Sanctuary</u>

There were more species and individuals recorded from areas that were farmed at Cockscomb compared to areas that were logged (Table 15) – because of the number of edge species that persist.

Table 15: Mean species number and mean number of individuals from Cockscomb

	Farmed	Logged
No. of species	19.4	15.3
No. of individuals	30.8	21.7

Table 16: Bird species recorded at Cockscomb

Species only found in farmed areas	**Species only found in logged areas**
Black-faced Grosbeak	Blue-crowned Motmot
Black-headed Saltator	Collared Aracari
Black-throated Green Warbler	Montezuma Oropendola
Buff-throated Saltator	Orange-billed Sparrow
Chestnut-colored Woodpecker	Ovenbird
Dusky Antbird	Phaethornis sp.
Greenish Elaenia	Polioptila sp.
Hooded Warbler	Squirrel Cuckoo
Red-legged Honeycreeper	Stub-tailed Spadebill
Rufous-tailed Jacamar	Sulphur-rumped Flycatcher
Slate-headed Tody-Flycatcher	Tawny-crowned Greenlet
small woodpecker sp.	White-throated Robin
Wood Thrush	Wood Thrush
Yellow-bellied Tyrannulet	Yellow-throated Euphonia
Yellow-olive Flycatcher	
Most abundant species in farmed	**Most abundant species in logged**
Red-throated Ant-Tanager	Black-faced Antthrush
Rufous-tailed Hummingbird	Dot-winged Antwren
Black-faced Grosbeak	Tawny-crowned Greenlet
Spot-breasted Wren	Kentucky Warbler
Gray Catbird	Amazilia sp.
Kentucky Warbler	Spot-breasted Wren
Thrush-like Schiffornis	Stub-tailed Spadebill
Dot-winged Antwren	Thrush-like Schiffornis
Long-billed Hermit	White-breasted Wood-Wren
Stripe-throated Hermit	Northern Bentbill
Wood Thrush	Olivaceous Woodcreeper
White-breasted Wood-Wren	Ovenbird
Amazilia sp.	Pale-billed Woodpecker

Northern Bentbill Rufous-tailed Jacamar Yellow-olive Flycatcher Dusky Antbird Olivaceous Woodcreeper Black-faced Antthrush Buff-throated Saltator Lesser Greenlet Long-billed Gnatwren Plain Xenops Red-crowned Ant-Tanager Smoky-brown Woodpecker warbler sp. Yellow-bellied Tyrannulet	Red-crowned Ant-Tanager Red-throated Ant-Tanager Buff-throated Foliage-gleaner Gray Catbird Long-billed Gnatwren Olive-backed Euphonia Stripe-throated Hermit warbler sp.

Several of these are potentially strong indicators of past anthropogenic impacts: the black-headed saltator being a prime example. It should be noted though that the limited extent (both geographic and temporal) has resulted in apparent land-use associations that are in fact false: collared aracaris for instance are probably more abundant in previously farmed areas than in previously logged ones, but also occur throughout undisturbed forests.

Crooked Tree Wildlife Sanctuary

Similarly to Cockscomb, there were more species in areas that had been farmed than those that had not (Table 17) .

Table 17: Mean species number and mean number of individuals from Crooked Tree

	Farmed	Unfarmed
No. of species	24	13
No. of individuals	65	18.5

Table 18: Species associated with different landuses,

Farmed	Unfarmed
Black Vulture Common Yellowthroat Golden-fronted woodpecker Grayish Saltator Great Kiskadee Great-tailed Grackle ground dove Killdeer Least Flycatcher Long-billed Hermit Mangrove Swallow Melodious blackbird Northern Beardless-Tyrannulet Northern Catbird Northern Jacana Northern Waterthrush Pale-vented Pigeon Red-lored Parrot Red-winged Blackbird Ruddy ground-dove	Black-faced Antthrush Blue Ground-Dove Boat-billed Flycatcher Ivory-billed Woodcreeper Long-billed Gnatwren Montezuma Oropendola Northern Bentbill Red-throated Ant-Tanager Ringed Kingfisher Stub-tailed Spadebill White-collared Manakin Yellow-olive Flycatcher Yellow-throated Euphonia

Social Flycatcher Tropical Mockingbird Turkey Vulture Vermillion flycatcher White-collared Seedeater Wood Stork Yellow Warbler Yellow-bellied Elaenia Yellow-breasted Chat Yellow-rumped Warbler Yellow-tailed Oriole	
Most abundant in farmed	**Most abundant in unfarmed**
White-fronted Parrot Red-winged Blackbird Northern Jacana Great Kiskadee Melodious blackbird Killdeer Vermillion flycatcher Social Flycatcher Great-tailed Grackle Yellow-rumped Warbler Yellow-bellied Elaenia Yellow Warbler White-collared Seedeater Northern Waterthrush Northern Catbird Mangrove Swallow Tropical Mockingbird Summer tanager Ruddy ground-dove Red-lored Parrot Long-billed Hermit Grayish Saltator Golden-fronted woodpecker Brown Jay	White-fronted Parrot Brown Jay Dusky-capped Flycatcher Montezuma Oropendola Red-throated Ant-Tanager Rufous-tailed Hummingbird White-tipped dove White-collared Manakin

Fireburn Reserve

Table 19: Mean species number and mean number of individuals from Fireburn

	Recently farmed	**Farmed >17 years ago**	**Unfarmed**
No. of species	12.7	10.5	15.3
No. of individuals	17.7	11.8	20g

Table 20: Species associated with different landuses, species found in all disturbance types and species found in recently farmed and unfarmed simultaneously have been removed as unhelpful indicators

Recently farmed	**Farmed >17 years ago**	**Unfarmed**
Black and White Warbler Boat-billed Flycatcher Gray-throated Chat Kentucky Warbler Lesser Greenlet Scaled Pigeon Summer tanager White-bellied Wren White-eyed Vireo Yellow-bellied Flycatcher Yucatan Flycatcher	American Red-start Black and White Warbler Black-headed Trogon Blue-crowned Motmot Bright-Rumped Attila Hooded Warbler Keel-billed Toucan Kentucky Warbler Lesser Greenlet Long-billed Gnatwren Mottled Owl northern barred-woodcreeper Ruddy Woodcreeper Scaled Pigeon Social Flycatcher Violaceous Trogon warbler sp. White-breasted Wood-Wren White-eyed Vireo Wood Thrush Worm-eating Warbler Yellow-olive Flycatcher	American Red-start Black-headed Trogon Black-throated Green Warbler Blue-crowned Motmot Bright-Rumped Attila Collared Aracari Hooded Warbler Keel-billed Toucan Kentucky Warbler Mottled Owl northern barred-woodcreeper Ovenbird Plain Xenops Red-capped Manakin Smoky-brown Woodpecker Squirrel Cuckoo Stripe-throated Hermit Tawny-crowned Greenlet Violaceous Trogon warbler sp. Wood Thrush Yellow-bellied Flycatcher Yellow-lored Parrot Yellow-olive Flycatcher
Most abundant species in recently farmed	**Most abundant species in farmed >17 years ago**	**Most abundant species in unfarmed**
Lesser Greenlet Red-throated Ant-Tanager Yellow-throated Euphonia Brown Jay	Magnolia Warbler Northern Bentbill Spot-breasted Wren Lesser Greenlet Mangrove Vireo Red-throated Ant-Tanager Yellow-olive Flycatcher	Wood Thrush Hooded Warbler Magnolia Warbler Thrush-like Schiffornis Collared Aracari Tawny-winged Woodcreeper Keel-billed Toucan Northern Bentbill warbler sp. Yellow-lored Parrot Bright-Rumped Attila Gray Catbird Greenish Elaenia Kentucky Warbler Mangrove Vireo Ovenbird Pale-billed Woodpecker Red-capped Manakin Rufous-tailed Hummingbird Yellow-bellied Flycatcher

The data resulting from this project is now being assessed by collaborating ornithologists, to determine whether the potential avian indicators for the specific *types* of past impact are meaningful, or whether they are an artifact of methodology or sample size. The avian data also provides the opportunity to explore patch size and occupancy - whether even small areas of disturbed vegetation within larger tracts of 'old growth' forest are used by disturbance species, by virtue of their mobility and dispersal strategies. Similarly, using existing background information, the strength of habitat association will be examined across the species recorded in the project, in order to support the identification of most reliable indicators for (a) old growth forest, (b) disturbed secondary growth, (c) past logging impacts and (d) past farming impacts.

Herpetological sampling

A number of key observations were made during the early phases of the project, supported by a more extensive concurrent herpetological study (Walker, P., et. al., in prep) demonstrating significant issues of scale that would limit the ability of the project to identify amphibian indicators of past impacts, particularly within the coastal plain (Fireburn Reserve and Crooked Tree Wildlife Sanctuary):

- Because of often very low population densities, many amphibian surveys are focused on breeding populations, and breeding aggregations
- Within the coastal plain of Belize, most amphibian species are pool-breeders, a few are stream / river breeders
- Availability of suitable ephemeral breeding pools is often a limiting factor to amphibian abundance and distribution
- For the ubiquitous amphibian fauna of the coastal plain of Belize, most species appear tolerant of significant habitat degradation – as long as access to suitable breeding sites is maintained
- The distance travelled by individual amphibian species to access suitable breeding sites is unknown, but is potentially multiple kilometres
- Patch size of past impacts within the three study sites is such that a mosaic of different age classes (of habitat) has been created, within the likely range of individual amphibians
- Heterogeneity of habitat, specifically the distribution of suitable water bodies for breeding amphibians, across the landscape means that it was not possible to design an adequate grid of survey plots, with controls, to determine the impacts of past farming, logging, or even hurricanes – within the two coastal plain study sites
- The greatest impact of past farming and logging, on amphibian habitat, appears to be physical change to the availability of suitable breeding sites for pool-breeding species: heavy logging equipment creates deep wheel ruts that persist for many years, whilst farming tends to dry surface and subsurface soils – limiting availability of breeding pools for multiple years beyond the cessation of farming activities
- Assessment of amphibian population use of non-breeding habitat (within and across the available age-class patches) would have required considerably more effort than available within this project

With these findings and observations, it became evident that the amphibian fauna of the coastal plain of Belize is not well suited to indicate impacts from past small-scale (small patch size) farming or logging activities – habitat heterogeneity and unknown range size of individual animals preclude rigorous interpretation of data at the scale of this project. The focus of the herpetological component of the project was therefore shifted largely to capacity-building: training University of Belize undergraduates, high school students, and community participants in the techniques to survey amphibians and reptiles.

The situation within Cockscomb Basin Wildlife Sanctuary, within the Maya Mountains of Belize, is rather different. The amphibian fauna of the Maya Mountains is distinct from that of the coastal plain, and includes all of Belize's threatened amphibians (critically endangered, endangered and vulnerable). Many of these species are very different from those of the coastal plain, with terrestrial-breeding Eleutherodactylid anurans being a major component of the Maya Mountain amphibian fauna (and largely absent from the coastal plain). The project did indicate that two of these species (*Craugastor sabrinus* and *Craugastor sandersoni*) may be good indicators of habitat quality. Neither species is known to occur within young secondary forest habitat, *Craugastor sabrinus* was observed within CBWS forest patches that had been farmed up to 1984, *C. sandersoni* was not. Insufficient data resulted from the project to statistically support this observation – but it is considered sufficiently important for a follow-up study to have been organized for a UK masters student to conduct later this summer. In a similar vein, the toad *Ollotis campbelli* is known only from old growth forest (including the control plots in West Basin), whereas *O. valliceps* occurs primarily within seconday forest.

Bat sampling

Regrettably a combination of factors, including equipment failures and human error, severely limited the data capture / storage process of Anabat use – such that very significant data-sets were irretrievably lost. The national bat monitoring feasibility study was aborted after several months, but bat assessment and monitoring in the three protected areas covered by the Darwin Initiative project was continued. The combined obstacles to effective bat assessment and data capture / storage persisted throughout the project, raising serious doubts about the value of sophisticated automated equipment such as Anabat in such projects. A more hands-on approach, using mist-nets and harp traps would have been more easily assessed for effectiveness, with data capture / storage being manual rather than electronic – and therefore less vulnerable to equipment failures.

Chapter 5: Discussion

This work is preliminary in identifying indicators associated with different types of disturbance. In Cockscomb some species stand out as indicators of disturbance *Tabernaemontana arborea, Attalea cohune, Croton schiedeanus* and *Inga oerstediana*. These are all species which have become well established since farming finished (larger DbH), some species such as *Miconia honudrensis* are present as smaller species. Particularly associated with areas that were farmed are *Schizolobium parahyba* and *Zuelania guidonia* with *Lacistema aggregatum, Guatteri combsiia* and *Protium schippii* smaller. Species associated with less disturbed areas are *Pouteria sapota, Andira inermis* and *Dialium guianense*. The farming at Cockscomb was not as recent as the farming at Fireburn so is better established. Fireburn is a very interesting site for studying the effects of disturbance as it has areas at different stages of recovery, although was also heavily impacted by a hurricane in 1955 (and has been again in 2007). More recent farming (10 years) species such as *Guazuma ulmifolia, Cupania beliziensis, Vitex gaumeri , Cecropia* sp. and *Swietenia macrophyllum* are present, *Attalea cohune* seems to come in a bit later on in the succession but can establish dense stands, *Protium copal* and *Bursera simarouba* were also found in mid term succession from farming. Species that were associated with less disturbed areas seemed to be *Calophyllum brasiliense, Matayba oppositifolia, Manilkara zapote, Caesium gaumeri* and *Pouteria izabalensis* with *Hampea trilobata, Swartzi cubensis* and *Cassipourea guianensis* found as smaller species.

Some species were found in areas where anthropogenic disturbance had not been significant and hence described as undisturbed areas which were unexpected/unlikely. These were species generally regarded as gap colonists or pioneers such as *Bursera simarouba, Protium schippii, Simarouba glauca* and *Metopium browneii*.. There are several possible reasons for this. 1. these areas had been disturbed by natural disturbance factors such as hurricanes 2. the soils are thin and infertile which influenced the type of species to establish.

At Cockscomb these pioneer species in undisturbed areas have a large DbH so there incursion has not been recent and it may be that past disturbance such as hurricane Hattie in 1961 enabled establishment and they have remained in place. At Fireburn the analysis comparing areas which were suitable for farming but had not been farmed with all other areas didn't have these pioneer species as indicators suggesting that they are found where the soil is thinner (i.e. not suitable for farming). This analysis will be confirmed with the soil analyses.

This work is a good starting point for looking for indicators of disturbance, a few things have become apparent from this study

1. It is difficult to generalise across sites, geology, climate, soils and exact nature of the disturbance influence the vegetation to such a great extent, Fireburn and Cockscomb are very different in species composition and forest type. *Attalea cohune* is found in both and known to be a species associated with recovery from disturbance particularly occurring on soils suitable for farming. Indeed there appears to be a different species response to past impacts, depending (possibly) on soil pH – something that will be examined as the soil analysis results are available.

2. Within a site there can be a great deal of variation, changes in micro-topography, soils and drainage and a more thorough study of all of these factors would be beneficial.
3. It would be extremely interesting to validate these groupings of species. By going to an area where you have identified previous land use, predicted the species composition and recording actual species then comparing predicted with observed.
4. The database resulting from this work is an extremely valuable resource to continue research.

It is still relatively early days in terms of analysis of the relatively large volume of data collected during the project, with a significant focus to date having been placed on the identification of indicators of past impacts - so that the identified indicator species can be used to readily identify areas regenerating from the predominant past anthropogenic impacts. With the progress to date in this direction, greater focus will now be placed on the assessment of alpha diversity across the range of past impacts, within each of the three protected areas (recognizing the gradual decline of invasive 'weed' species), to strengthen the prioritization of effective zoning of enforcement activities: placing greatest focus on areas with greatest diversity, whilst previously impacted areas continue the regeneration processes. This will take on greater importance in the refining of the Core Protection Zone of the Maya Mountains Massif of Belize (Walker, P.,Walker, Z.; Awe, J. & Catzim, N., 2008) and the assessment of Key Biodiversity Areas (Meerman, J.C., 2008), applying the knowledge acquired through the Darwin Initiative project to validate system-level protected area zonation through the inclusion of quantified alpha, beta and gamma diversity data in the assessment.

In a similar vein, data collected during the process will be applied in a current 'Assessment of the Status of the Protected Areas in 2009' - a project supported by the Association of Protected Area Management Organizations (APAMO) and The Nature Conservancy (TNC), and conducted by Wildtracks. The project aims to assess the effectiveness of Belize's protected areas and protected area system in biodiversity conservation, assess overall management effectiveness, identify gaps, and develop strategies to enhance management of the individual protected areas and of the system as a whole, in the primary mandate of biodiversity conservation. Knowledge gained from the Darwin Initiative project, relating to the assessment of biodiversity of extensive tracts of secondary forest within the protected area system, will be of significant value in this national assessment - which will form the baseline for future system-level monitoring.

The capacity building components of the project are already being implemented in biodiversity conservation in Belize, with the two primary University of Belize interns having graduated and used their acquired additional skills in securing positions at the University of Belize and in the Department of the Environment. With a core group of trained personnel now available, rapid ecological assessments of identified priority areas is now significantly more feasible than prior to the project - which will facilitate governmental and non-governmental initiatives to continue refining management of the protected areas for more effective biodiversity conservation. The use of indicator species identified within the project will further facilitate such assessments.

Future work
Areas for future research were identified:

1. The fixed plot series recorded in this project provides a baseline for future site surveillance and assessment of recovery from disturbance. However, the baseline could also be readily used in combination with habitat mapping using remotely sensed data and low-level aerial photography to test the feasibility for a statistically robust, sampled based program for ecological surveillance across Belizean ecosystems. This feasibility would be timely since an assessment of ecological monitoring priorities in and outside protected sites is underway and methods are sought for efficient ways of estimating extent, changes in extent and species-based changes in ecological condition within terrestrial ecosystems. Initial discussions with DARWIN project partners suggested a model based on current GB Countryside Survey best practice combined with the DARWIN-funded baseline plots would be a cost-effective starting point.
2. Prediction of canopy composition of forest areas dependent on disturbance/land use history combined with some soils/geological knowledge then validation by visiting areas and recording existing species.
3. Determination of the species composition of the fixed plots involved a census of canopy individuals within a fixed plot area. These data are therefore eminently suitable for testing biodiversity census methods. The aim here would be to tests a variety of Species Area Curve fitting techniques, plus individual-based and sample-based accumulation curves to estimate total gamma diversity of canopy tree species in each reserve and reserve-sub region where appropriate. During the last visit, the CEH team conducted an initial and promising test of some of these techniques on the amphibian data gathered in sub-regions at Cockscomb. Further analysis would utilise the data already collected and is planned for the medium-term to produce a second paper from the project.

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Acknowledgements

We would like to thank Martin Rossall, Paul Scholefield, Les Firbank and Claire Wood for support and technical assistance on visits to Belize. We would also like to thank Paul Edgar and Zoe Walker for support and assistance in Belize.
Thanks to Rebecca Pinder for financial assistance.
Thank you most of all to the Darwin initiative for funding this work.

Table 4: Indicator species identified from results of CCA with sole explanatory variables-Raw Species only at Cockscomb

Logged	**Disturbed**	**Farmed**	**Unlogged**	**Undisturbed**	**Unfarmed**
Tabernaemontana arborea	Laetia procera	Laetia procera	Pouteria sapota	Guaria grandifolia	Guaria grandifolia
Inga oerstediana	Inga oerstediana	Inga oerstediana	Guaria grandifolia	*Simarouba glauca	*Simarouba glauca
Attalea cohune	Tabernaemontana arborea	Miconia hondurensis	*Simarouba glauca	Pouteria sapota	*Protium schippi
Heliocarpus americanus	Miconia hondurensis	Tabernaemontana arborea	Andira inermis	Protium schippi	Pouteria sapota
Laetia procera	Lonchocarpus lineatus	Lonchocarpus lineatus	Terminalia amazonia	Dialium guianense	Dialium guianense
Croton bilbergianus	Ceiba sp.	Ceiba sp.	Rinorea deflexiflora	Andira inermis	Croton niveus
Clidemia dentata	Lacistema aggregatum	Lacistema aggregatum	Protium schippii	Terminalia amazonia	*Miconia insularis
Miconia hondurensis	Croton schippii	Croton schiedeanus	Chrysophyllum sp.	Rinorea deflexiflora	Andira inermis
Zanthoxylum sp.	Inga sp.	Guatteria diospyroides	Sloanea schippii	Croton niveus	Terminalia amazonia
Schizolobium parahyba	Guatteria diospyroides	Inga sp.	Myriocarpa sp.	Miconia insularis	Rinorea deflexiflora

* slightly surprising species to have as an indicator, gap coloniser, early successional

Table 6: Indicator species identified from results of CCA with sole explanatory variables (logged or disturbed)-Pseudo-species at Cockscomb.

Logged		**disturbed**		**undisturbed**	
Larger trees	**Smaller trees**	**Larger trees**	**Smaller trees**	**Larger trees**	**Smaller trees**
Attalea cohune	Tabernaemontana arborea	Croton schiedeanus	Miconia hondurensis	*Simarouba glauca	Protium schippii
Inga oerstediana	Croton bilbergianus	Ceiba sp.	Lacistema aggregatum	*Spondias radlkoferi	Guarea grandifolia
Pouroma bicolor	Miconia hondurensis	Schizolobium parahyba	Lonchocarpus lineatus	Stemmadenia donnell-smithii	Pouteria sapota
Croton schiedeanus	Tabebuia guayacan	Tabernaemontana Arborea	Alchornia latifolia	Pouroma bicolor	Andira inermis
Tabernaemontana arborea	Clidemia dentata	Heliocarpus americanus	Tabernaemontana arborea	Cupania scrobiculata	Rinorea deflexiflora
Zanthoxylum sp.	Cecropia sp.	Inga oerstediana	Guatteria diospyroides	Dialium guianense	Tetragastris panamensis
	Croton niveus	Zeulania guidonia	Laetia procera	Zanthoxylum sp.	Dialium guianense
	Spondias radlkoferi	Attalea cohune	Croton schiedeanus	Guarea grandifolia	Calypthranthes pallens
			Inga sp.		*Vochsia hondurensis
			Inga oerstediana		

* slightly surprising species to have as an indicator, gap coloniser, early successional

Table 7: Indicator species identified from results of CCA with sole explanatory variable (farmed) -pseudospecies at Cockscomb

farmed		**unfarmed**	
Larger trees	**Smaller trees**	**Larger trees**	**Smaller trees**
Croton schiedeanus	Miconia hondurensis	*Simarouba glauca	*Protium schippii
Ceiba sp.	Alchornia latifolia	*Spondias radlkoferi	Guarea grandifolia
Schizolobium parahybum	Lacistema aggregatum	Cupania scrobiculata	Pouteria sapota
Heliocarpus americanus	Lonchocarpus lineatus	Heliocarpus americanus	Andira inermis
Attalea cohune	Tabernaemontana arborea	Zanthoxylum sp.	Dialium guianense
Zuelania guidonia	Guatteria diospyroides	Guarea grandifolia	Rinorea deflexiflora
Inga oerstediana	Laetia procera		Tetragastris panamensis
Tabernaemontana arborea	Protium schippii		Tabebuia guayacan
	Sloanea tuerckheimii		Clidemia dentata
			Calyptranthes pallens

* slightly surprising species to have as an indicator, gap coloniser, early successional

Table 9: Indicator species identified from results of CCA with sole explanatory variables (farmed recently, <17 years ago and unfarmed) –raw species at Fireburn

Recently farmed	**Farmed >17 years ago**	**Unfarmed**
Cupania belizensis	Lonchocarpus rugosa	Coccoloba sp.
Guazuma ulmifolia	Piscidia piscipula	Matayba oppositifolia
Chrysophyllum mexicanum	Attalea cohune	Croton schippii
Cecropia sp.	Swietenia macrophylla	*Metopium browneii
Dendropanax arborea	Acacia cedilloi	Manilkara zapote
Swietenia macrohpylla	*Trophis racemosa	*Bursera simarouba
Spondias radlkoferi	Vitex gaumeri	Pouteria izabalensis
*Trophis racemos	Cupania belizensis	Calophyllum brasiliense
*Piscidia piscipula	Eugenia aeruginea	*Simarouba glauca
	Trichilia havanensis	Caesalpinia gaumeri

* slightly surprising species to have as an indicator, gap coloniser, early successional

Table 11: Indicator species identified from results of CCA with sole explanatory variables (farmed recently, <17 years ago and unfarmed) – pseudospecies at Fireburn

Recently farmed		**Farmed >17 years ago**		**unfarmed**	
Larger	**Smaller**	**Larger**	**Smaller**	**Larger**	**Smaller**
Guazuma ulmifolia	Guazuma ulmifolia	Attalea cohune	Lonchocarpus rugosus	*Metopium browneii	*Bursera simarouba
Chrysophyllum mexicana	Cupania beliziensis	Guazuma ulmifolia	Piscida piscipula	Calophyllum brasiliense	Croton schiedeanus
Cecropia sp.	Cecropia sp.	Vitex gaumeri	Cupania beliziensis	Matayba oppositifolia	Matayba oppositifolia
Cupania beliziensis	Piscdia piscipula	Swietenia macrophylla	Acacia cedilloi	Manilkara zapote	*Protium copal
*Vitex gaumeri	Dendroponax arboreus	Ficus pertusa	Guazuma ulmifolia	Caesium gaumerii	Manilkara zapote
Spondias radlkoferi	Swietenia macrophylla	Acacia cedilloi	Spondias radlkoferi	*Simarouba glauca	Pouteria izabalensis
Dendroponax arboreus	*Trophis racemosa	Bursera simarouba	*Trophis racemosa	Ficus obtusifolius	Diospyros salicifolia
Swietenia macrophylla	Pouteria campechiana	Ficus aurea	Guettarda combsii	Pouteria izabalensis	*Pouteria reticulata
*Piscidia piscipula	Spondias radlkoferi	Pouteria reticulata	Eugenia aeruginea	Coccoloba barbadensis	Swartzia cubensis
*Sabal mauritiformis		Protium copal	Cecropia sp.	Exothea diphylla	Hampea trilobata
		Piscidia piscipula	Coccoloba acapulcensis	Lonchocarpus rugosus	Cassipourea guianensis

* slightly surprising species to have as an indicator, gap coloniser, early successional

Table 12: Indicator species identified from results of CCA with sole explanatory variables (unfarmed but suitable for farming‘control’ farm) – pseudospecies at Fireburn

Unfarmed but suitable for farming	
Larger species	**Smaller species**
Ficus obtusifilius	*Protium copal
Caesium gaumeri	Pouteria izabalensis
Pouteria izabalensis	Drypetes lateriflora
Manilkara zapote	Coccoloba barbadensis
*Protium copal	Pouteria reticulata
Calophyllum brasiliense	*Bursera simarouba
Matayba oppositifolia	Hirtella americana
Pouteria campechiana	Caesium gaumeri
	Cassipourea guianensis

* slightly surprising species to have as an indicator, gap coloniser, early successional

Appendix 1: Rubiaceae of CBWS

Psychotria poeppigiana
ZAG214





ZAG248




Psychotria capitata
ZAG252





Psychotria deflexa.
ZAG254





Appendix 1: Rubiaceae of CBWS

Psychotria sp.
ZAG255

Sabicea panamensis.
ZAG256

Psychotria chiapensis.
ZAG266

ZAG277

Appendix 1: Rubiaceae of CBWS

Psychotria glomerulata
ZAG349

Psychotria sp
ZAG350

Posoqueria latifolia
ZAG354

Psychotria elata
ZAG366
Purple/white inflorescence on long peduncle.

Appendix 1: Rubiaceae of CBWS

Psychotria officinalis
ZAG367





Bertiera guianensis?
ZAG378




Psychotria sp
ZAG383


Psychotria sp
ZAG385




Melastomataceae of Cockscomb Basin Wildlife Sanctuary

1 Herbs (non-woody)

1

Acisanthera quadrata (245)
(photos 3-5)
Habitat: Open, wet ground.
Habit: Delicate herb.
Height: <30cm
ID tip: Tiny herb, square stem, large scythe-shape anther connectives.

2

3 *A. quadrata* (habit)

4 *A. quadrata* (habit)

5 *A. quadrata* (flowers)

Arthrostemma ciliatum (237)
(photos 7-10)
Habitat: Open, disturbed vegetation.
Habit: low, scrambling herb.
Height <1m
ID tip: Square stem, often glandular hairs.

6

7 *A. ciliatum* (habit)

8 *A. ciliatum* (upper lf. surface)

9 *A. ciliatum* (lower lf. surface)

10 *A. ciliatum* (flower/fruits)

2 Shrubs or Trees (woody)

2A Leaves not green underneath.

11

Miconia oinochrophylla (219)
(photos 13-15)
Habitat: Forest.
Habit: Understory shrub/tree.
Height <5m
ID tip: Unique purple leaf undersurface.

12

13 *M. oinochrophylla* (upper lf. surface)

14

15 *M. oinochrophylla* (lower lf. surface)

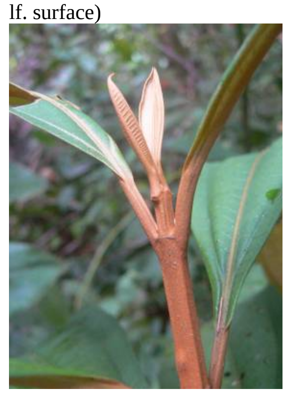
Miconia chrysophylla (217)
(photos 17-20)
Habitat: Forest.
Habit: Understory shrub.
Height <5m
ID tip: Pale leaf undersurface, reddish young twigs.

16

17 *M. chrysophylla* (upper lf. surface)

18

19 *M. chrysophylla* (lower lf. surface)



20 *M. chrysophylla* (bud & stem)

Melastomataceae of Cockscomb Basin Wildlife Sanctuary

Miconia? ZAG 280
(photos 22-25)
Habitat: Forest.
Habit: Small tree/shrub.
Height <10m
ID tip: Long reddish petioles, wider than *M. chrysophylla*.

21

22 *U. Zag280* (upper lf. surface)

23 *U. Zag280* (lower lf. surface)

24 *U. Zag280* (other)

25 *U. Zag280* (other)

2 Shrubs or Trees (woody)

2B Large leaves.

26

Bellucia costaricensis? (242)
(photos 28-30)
Habitat: Forest.
Habit: Small tree.
Height <8m
ID tip: umm.

27

28 *B. costaricensis* (lf.)

29 *B. costaricensis* (fruit)

30 *B. costaricensis* (flower)

Miconia amplexans? (224)
(photos 32-35)
Habitat: Forest.
Habit: Tree/shrub.
Height <8m
ID tip: Large leaves (60x30cm), with unique shape & venation.

31

32 *M. amplexans* (upper lf. surface)

33 *M. amplexans* (lower lf. surface)

34 *M. amplexans* (lf. base)

35 *M. amplexans* (habit)

Unknown ZAG229
(photos 37-40)
Habitat: Forest.
Habit: Tree/shrub.
Height: <8m
ID tip: Large leaves (70x30cm), with unusual venation.

36

37 *U. zag 229* (upper lf. surface)

38

39 *U. zag 229* (lower lf. surface)

40

Melastomataceae of Cockscomb Basin Wildlife Sanctuary

2 Shrubs or Trees (woody)

2C Swellings at base of leaf.

41

Tococa guianensis (328)

(photos 43-45)

Habitat: Forest.
Habit: Shrub.
Height <3m
ID tip: Swellings (domatia, usually associated with ants) at base of some leaves, leaves often unequal in size.

42

43 *T. guianensis* (upper lf. surface)

44 *T. guianensis* (lower lf. surface)

45 *T. guianensis* (detail)

2 Shrubs or Trees (woody)

2D Miscellaneous.

46

Clidemia dentata (238)

(photos 48-50)

Habitat: Open, disturbed vegetation.
Habit: Small shrub.
Height <1m
ID tip: Terminal infloresence.

47

48 *C. dentata* (upper lf. surface)

49 *C. dentata* (lower lf. surface)

50 *C. dentata* (flowers)

Clidemia hirta (234)

(photos 52-55)

Habitat: Open, disturbed vegetation.
Habit: Small shrub.
Height <1m
ID tip: Axile inflorescence, pink stem.

51

52 *C. hirta* (habit)

53 *C. hirta* (upper lf. surface)

54 *C. hirta* (lower lf. surface)

55 *C. hirta* (flowers/fruits)

Clidemia capitulata (233)

(photos 57-60)

Habitat: Open, disturbed vegetation.
Habit: Small shrub.
Height <1.5m
ID tip: Axile inflorescence, white flowers.

56

57 *C. capitulata* (habit)

58 *C. capitulata* (upper lf. surface)

59 *C. capitulata* (lower lf. surface)

60 *C. capitulata* (flowers)

Melastomataceae of Cockscomb Basin Wildlife Sanctuary

Leandra mexicana (232)
(photos 62-65)
Habitat: Open, disturbed vegetation.
Habit: Small shrub.
Height <2m
ID tip: Terminal infloresence.

61

62 *L. mexicana* (habit)

63 *L. mexicana* (upper lf. surface)

64 *L. mexicana* (lower lf. surface)

65 *L. mexicana* (flower/fruits)

Miconia hyperprasina? (213)
(photos 67-70)
Habitat: Forest, shade.
Habit: Small shrub.
Height: <5m
ID tip: Glossy dark green leaves.

66

67 *M. hyperprasina* (upper lf. surface)

68 *M. hyperprasina* (lower lf. surface)

69 *M. hyperprasina* (other)

70 *M. hyperprasina* (other)

Miconia? ZAG 239
(photos 72-75)
Habitat: Open, disturbed vegetation.
Habit: Small shrub.
Height: <50cm
ID tip: dunno.

71

72 *U. Zag 239* (habit)

73 *U. Zag 239* (upper lf. surface)

74 *U. Zag 239* (lower lf. surface)

75 *U. Zag 239* (flowers)

Miconia lacera (244)
(photos 77-80)
Habitat: Open, disturbed vegetation.
Habit: Small shrub.
Height: <2m
ID tip: Long (>1cm) red hairs on stem.

76

77 *M. lacera* (habit)

78 *M. lacera* (upper lf. surface)

79 *M. lacera* (lower lf. surface)

80 *M. lacera* (flowers)

Melastomataceae of Cockscomb Basin Wildlife Sanctuary

Miconia nervosa (257)
(photos 82-85)
Habitat: Gaps in forest canopy.
Habit: Shrub.
Height: <5m
ID tip: Venation, pink-tinged terminal infloresences.



81

82 *M. nervosa* (habit)

83 *M. nervosa* (upper lf. surface)

84 *M. nervosa* (lower lf. surface)

85 *M. nervosa* (flowers)

Miconia matthaei (265)
(photos 87-90)
Habitat: Forest.
Habit: Shrub.
Height <Xm
ID tip: Dense pale brown hairs on stems and veins underneath leaves.



Appendix 2: Indicators for disturbance

COCKSCOMB
SPECIES ONLY ANALYSIS

Variable	p	F
Farmed	<0.05	1.3
Disturbance	<0.01	1.3
Logged	<0.01	1.52

Indicator species for **logged** plots

spp	ax1	%expl	
Tab_ arb	-0.7354	6.87	Logged
Ing_ oer	-0.5608	5.24	Logged
Att_ coh	-0.4361	4.81	Logged
Hel_ ame	-0.7354	3.63	Logged
Lae_ pro	-0.7354	2.74	Logged
Cro_ bil	-0.7354	2.28	Logged
Cli_ den	-0.7354	2.09	Logged
Mic_ hon	-0.7354	1.96	Logged
Zan_ sp	-0.3862	1.92	Logged
Sch_ par	-0.7354	1.84	Logged
Laur ac_	-0.3163	1.82	Logged
Lon_ lin	-0.7354	1.57	Logged
Cal_ bra	-0.7354	1.55	Logged
Tab_ gua	-0.7354	1.55	Logged
Cei_ sp_	-0.7354	1.36	Logged
Lac_ agg	-0.7354	1.36	Logged
Ing_ sp_	-0.7354	1.03	Logged
Malv ac_	-0.7354	1.03	Logged
Sali c_	-0.7354	1.03	Logged
Bur_ sim	-0.7354	1	Logged
Cor_ div	-0.7354	1	Logged
Cor_ gra	-0.7354	1	Logged
Gua_ ulm	-0.7354	0.9	Logged
Ing_ ver	-0.7354	0.81	Logged
Cei_ pen	-0.7354	0.8	Logged
Cup_ scr	-0.5259	0.79	Logged
Slo_ tue	-0.3163	0.78	Logged
Mic_ imp	-0.7354	0.7	Logged
Cas_ syl	-0.7354	0.67	Logged
Cro_ sch	-0.2116	0.63	Logged
Ery_ fol	-0.7354	0.63	Logged
Mic_ sp_	-0.7354	0.63	Logged
Sym_ glo	-0.7354	0.63	Logged
Tab_ alb	-0.7354	0.63	Logged
Vis_ mac	-0.7354	0.63	Logged
Com_ spr	-0.7354	0.59	Logged
Cym_ may	-0.7354	0.56	Logged
Gua_ dio	-0.3862	0.54	Logged

Cec_ sp_	-0.3163	0.5	Logged
Coc_ bel	-0.7354	0.37	Logged
Bro_ gui	-0.7354	0.27	Logged
Pou_ bic	-0.1068	0.2	Logged
Alc_ lat	-0.1368	0.1	Logged

Indicator species for Unlogged plots

spp	ax1	%expl	
Pou_ sap	1.3598	17.38	unlogged
Gua_ gra	0.8942	15.88	unlogged
Sim_ gla	1.0106	11.93	unlogged
And_ ine	1.3598	8.24	unlogged
Ter_ ama	1.3598	8.14	unlogged
Rin_ def	1.3598	7.99	unlogged
Pro_ sch	0.5979	6.91	unlogged
Chry so_	1.3598	6.51	unlogged
Slo_ sch	1.3598	6.05	unlogged
Myr_ sp_	1.3598	4.94	unlogged
Pou_ sp_	1.3598	4.94	unlogged
Vir_ kos	1.3598	4.92	unlogged
Cal_ pal	1.3598	4.78	unlogged
Voc_ hon	1.3598	4.78	unlogged
Dia_ gui	0.836	4.52	unlogged
Cor_ bic	1.3598	3.53	unlogged
Pte_ off	1.3598	2.92	unlogged
Meli c_	1.3598	2.86	unlogged
Ste_ don	1.3598	2.86	unlogged
Tet_ pan	0.836	2.57	unlogged
Vat_ lun	1.3598	2.45	unlogged
Ann_ lie	1.3598	1.94	unlogged
Lae_ tha	1.3598	1.85	unlogged
Spo_ rad	0.1958	1.62	unlogged
Rol_ muc	1.3598	1.59	unlogged
Pos_ lat	1.3598	1.08	unlogged
Cro_ niv	0.3122	0.46	unlogged
Mic_ ins	0.3122	0.45	unlogged
Mic_ ela	0.3122	0.38	unlogged
Faba ce_	0.3122	0.33	unlogged
Zue_ gui	0.3122	0.17	unlogged

Indicator species for farmed plots

spp	ax1	%expl	Ind direction
Lae_ pro	1.3071	8.64	Farmed
Ing_ oer	0.6164	6.33	Farmed
Mic_ hon	1.3071	6.19	Farmed

Tab_ arb	0.6855	5.97	Farmed
Lon_ lin	1.3071	4.95	Farmed
Cei_ sp_	1.3071	4.3	Farmed
Lac_ agg	1.3071	4.3	Farmed
Laur ac_	0.4783	4.16	Farmed
Cro_ sch	0.5301	3.93	Farmed
Gua_ dio	0.9618	3.38	Farmed
Ing_ sp_	1.3071	3.26	Farmed
Malv ac_	1.3071	3.26	Farmed
Sali c_	1.3071	3.26	Farmed
Gua_ ulm	1.3071	2.84	Farmed
Alc_ lat	0.7151	2.82	Farmed
Ing_ ver	1.3071	2.57	Farmed
Ery_ fol	1.3071	2	Farmed
Tab_ alb	1.3071	2	Farmed
Vis_ mac	1.3071	2	Farmed
Com_ spr	1.3071	1.86	Farmed
Slo_ tue	0.4783	1.78	Farmed
Zan_ sp	0.271	0.95	Farmed
Att_ coh	0.123	0.38	Farmed
Cro_ bil	0.271	0.31	Farmed
Mic_ ela	0.271	0.29	Farmed
Sch_ par	0.271	0.25	Farmed
Zue_ gui	0.271	0.13	Farmed
Pou_ bic	0.0638	0.07	Farmed

Indicator species for unfarmed plots

spp	ax1	%expl	Ind direction
Gua_ gra	-0.765	11.63	unfarmed
Sim_ gla	-0.765	6.84	unfarmed
Pro_ sch	-0.5767	6.42	unfarmed
Pou_ sap	-0.765	5.5	unfarmed
Dia_ gui	-0.765	3.78	unfarmed
Cro_ niv	-0.765	2.75	unfarmed
Mic_ ins	-0.765	2.67	unfarmed
And_ ine	-0.765	2.61	unfarmed
Ter_ ama	-0.765	2.58	unfarmed
Rin_ def	-0.765	2.53	unfarmed
Cli_ den	-0.765	2.26	unfarmed
Tet_ pan	-0.765	2.15	unfarmed
Chry so_	-0.765	2.06	unfarmed
Faba ce_	-0.765	2	unfarmed
Slo_ sch	-0.765	1.91	unfarmed
Cal_ bra	-0.765	1.68	unfarmed
Tab_ gua	-0.765	1.68	unfarmed
Cup_ scr	-0.765	1.66	unfarmed
Myr_ sp_	-0.765	1.56	unfarmed
Pou_ sp_	-0.765	1.56	unfarmed
Vir_ kos	-0.765	1.56	unfarmed
Cal_ pal	-0.765	1.51	unfarmed
Voc_ hon	-0.765	1.51	unfarmed

Cor_ bic	-0.765	1.12	unfarmed
Bur_ sim	-0.765	1.08	unfarmed
Cor_ div	-0.765	1.08	unfarmed
Cor_ gra	-0.765	1.08	unfarmed
Pte_ off	-0.765	0.93	unfarmed
Meli c_	-0.765	0.9	unfarmed
Ste_ don	-0.765	0.9	unfarmed
Cei_ pen	-0.765	0.87	unfarmed
Vat_ lun	-0.765	0.78	unfarmed
Mic_ imp	-0.765	0.76	unfarmed
Cas_ syl	-0.765	0.72	unfarmed
Mic_ sp_	-0.765	0.69	unfarmed
Sym_ glo	-0.765	0.69	unfarmed
Cec_ sp_	-0.3506	0.61	unfarmed
Ann_ lie	-0.765	0.61	unfarmed
Cym_ may	-0.765	0.6	unfarmed
Lae_ tha	-0.765	0.58	unfarmed
Rol_ muc	-0.765	0.5	unfarmed
Coc_ bel	-0.765	0.4	unfarmed
Pos_ lat	-0.765	0.34	unfarmed
Bro_ gui	-0.765	0.29	unfarmed
Spo_ rad	-0.0743	0.23	unfarmed
Hel_ ame	-0.0743	0.04	unfarmed

Indicator species for Disturbed plots

spp	Ax1	%expl	
Lae_ pro	1.3012	8.56	Disturbed
Ing_ oer	0.6382	6.79	Disturbed
Tab_ arb	0.7226	6.64	Disturbed
Mic_ hon	1.3012	6.13	Disturbed
Lon_ lin	1.3012	4.91	Disturbed
Cei_ sp_	1.3012	4.26	Disturbed
Lac_ agg	1.3012	4.26	Disturbed
Laur ac_	0.4815	4.22	Disturbed
Cro_ sch	0.5177	3.75	Disturbed
Ing_ sp_	1.3012	3.23	Disturbed
Malv ac_	1.3012	3.23	Disturbed
Sali c_	1.3012	3.23	Disturbed
Gua_ dio	0.9396	3.22	Disturbed
Gua_ ulm	1.3012	2.81	Disturbed
Alc_ lat	0.6813	2.56	Disturbed
Ing_ ver	1.3012	2.54	Disturbed
Ery_ fol	1.3012	1.98	Disturbed
Tab_ alb	1.3012	1.98	Disturbed
Vis_ mac	1.3012	1.98	Disturbed
Com_ spr	1.3012	1.84	Disturbed
Slo_ tue	0.4815	1.8	Disturbed
Zan_ sp	0.2967	1.13	Disturbed
Att_ coh	0.1647	0.69	Disturbed
Cro_ bil	0.3369	0.48	Disturbed
Sch_ par	0.3369	0.39	Disturbed

Mic_ ela	0.2163	0.18	Disturbed
Pou_ bic	0.0717	0.09	Disturbed
Zue_ gui	0.2163	0.08	Disturbed

Indicator species for undisturbed plots

spp	Ax1	%expl	
Gua_ gra	-0.8149	13.19	Undisturbed
Sim_ gla	-0.8283	8.02	Undisturbed
Pou_ sap	-0.8685	7.09	Undisturbed
Pro_ sch	-0.6055	7.08	Undisturbed
Dia_ gui	-0.8082	4.22	Undisturbed
And_ ine	-0.8685	3.36	Undisturbed
Ter_ ama	-0.8685	3.32	Undisturbed
Rin_ def	-0.8685	3.26	Undisturbed
Chry so_	-0.8685	2.66	Undisturbed
Cro_ niv	-0.748	2.63	Undisturbed
Mic_ ins	-0.748	2.56	Undisturbed
Slo_ sch	-0.8685	2.47	Undisturbed
Tet_ pan	-0.8082	2.4	Undisturbed
Myr_ sp_	-0.8685	2.01	Undisturbed
Pou_ sp_	-0.8685	2.01	Undisturbed
Vir_ kos	-0.8685	2.01	Undisturbed
Cal_ pal	-0.8685	1.95	Undisturbed
Voc_ hon	-0.8685	1.95	Undisturbed
Faba ce_	-0.748	1.91	Undisturbed
Cli_ den	-0.6274	1.52	Undisturbed
Cor_ bic	-0.8685	1.44	Undisturbed
Cup_ scr	-0.6515	1.21	Undisturbed
Pte_ off	-0.8685	1.19	Undisturbed
Meli c_	-0.8685	1.17	Undisturbed
Ste_ don	-0.8685	1.17	Undisturbed
Cal_ bra	-0.6274	1.13	Undisturbed
Tab_ gua	-0.6274	1.13	Undisturbed
Vat_ lun	-0.8685	1	Undisturbed
Ann_ lie	-0.8685	0.79	Undisturbed
Lae_ tha	-0.8685	0.75	Undisturbed
Bur_ sim	-0.6274	0.72	Undisturbed
Cor_ div	-0.6274	0.72	Undisturbed
Cor_ gra	-0.6274	0.72	Undisturbed
Rol_ muc	-0.8685	0.65	Undisturbed
Cei_ pen	-0.6274	0.58	Undisturbed
Mic_ imp	-0.6274	0.51	Undisturbed
Cas_ syl	-0.6274	0.49	Undisturbed
Mic_ sp_	-0.6274	0.46	Undisturbed
Sym_ glo	-0.6274	0.46	Undisturbed
Pos_ lat	-0.8685	0.44	Undisturbed
Cec_ sp_	-0.2899	0.42	Undisturbed
Cym_ may	-0.6274	0.41	Undisturbed
Spo_ rad	-0.0917	0.36	Undisturbed
Coc_ bel	-0.6274	0.27	Undisturbed
Bro_ gui	-0.6274	0.2	Undisturbed

PSEUDOSPECIES ANALYSIS

Variable	p	F
Farmed	0.028	1.2
Disturbance	0.016	1.2
Logged	0.002	1.3

Indicator species for Logged; top indicators for **logged** plots

% species data explained by axis 1 constrained by Logging post-61=2.3

NAME	AX1	% EXPL	Indicator direction
Ing_ oer3	-0.7324	5.7	logged
Att_ coh5	-0.4993	5.26	logged
Tab_ arb2	-0.7324	3.32	logged
Tab_ arb3	-0.7324	2.9	logged
Cro_ bil2	-0.7324	2.61	logged
Laur ac_1	-0.7324	2.56	logged
Laur ac_2	-0.4327	2.17	logged
Mic_ hon1	-0.7324	2.17	logged
Tab_ gua2	-0.7324	2.13	logged
Cli_ den1	-0.7324	2.1	logged
Cro_ sch3	-0.7324	2.06	logged
Cec_ sp_2	-0.7324	1.98	logged
Cli_ den2	-0.7324	1.65	logged
Zan_ sp4	-0.7324	1.65	logged
Cro_ niv2	-0.7324	1.55	logged
Malv ac_4	-0.7324	1.55	logged
Sali c_2	-0.7324	1.55	logged
Sali c_3	-0.7324	1.55	logged
Spo_ rad1	-0.7324	1.55	logged
Pou_ bic3	-0.3828	1.51	logged

Indicator species for Dist_1; top indicators for **undisturbed** plots

% species data explained by axis 1 constrained by Dist_1 (disturbance over all factors as ordinal scale) = 2.1

NAME	AX1	% EXPL	Indicator direction
Pro_ sch2	-0.7831	11.65	undisturbed
Gua_ gra2	-0.7866	11.3	undisturbed
Pou_ sap2	-0.8559	5.45	undisturbed
And_ ine2	-0.8559	4.88	undisturbed
Sim_ gla5	-0.8559	4.31	undisturbed
Spo_ rad4	-0.8559	4.14	undisturbed
Rin_ def2	-0.8559	3.61	undisturbed
Tet_ pan2	-0.8559	3.26	undisturbed

Dia_ gui2	-0.7345	3.24	undisturbed
unkn ow_3	-0.4918	3.13	undisturbed
Chry so_3	-0.8559	2.58	undisturbed
Sim_ gla4	-0.8559	2.58	undisturbed
Zan_ sp5	-0.8559	2.58	undisturbed
Cal_ pal2	-0.8559	2.42	undisturbed
Voc_ hon2	-0.8559	2.42	undisturbed
Cup_ scr3	-0.6941	2.34	undisturbed
Dia_ gui3	-0.8559	2.26	undisturbed
Myr_ sp_4	-0.8559	2.26	undisturbed
Pou_ sp_2	-0.8559	2.26	undisturbed
Gua_ gra3	-0.8559	2.17	undisturbed
Faba ce_3	-0.7345	2.13	undisturbed
Slo_ sch2	-0.8559	2.06	undisturbed
Ter_ ama2	-0.8559	2.05	undisturbed
Mic_ ins2	-0.8559	1.95	undisturbed
Dia_ gui5	-0.8559	1.65	undisturbed
Meli c_2	-0.8559	1.65	undisturbed
Ste_ don5	-0.8559	1.65	undisturbed
Sim_ gla3	-0.8559	1.62	undisturbed
Cro_ niv3	-0.8559	1.5	undisturbed
Pou_ bic5	-0.8559	1.5	undisturbed

Indicator species for Dist_1; top indicators for **disturbed** plots

NAME	AX1	% EXPL	Indicator direction
Mic_ hon1	1.3289	7.13	disturbed
Cro_ sch3	1.3289	6.79	disturbed
Malv ac_4	1.3289	5.09	disturbed
Sali c_2	1.3289	5.09	disturbed
Sali c_3	1.3289	5.09	disturbed
Cei_ sp_5	1.3289	4.71	disturbed
Lac_ agg1	1.3289	4.71	disturbed
Lon_ lin1	1.3289	4.71	disturbed
Sch_ par5	1.3289	4.71	disturbed
Zan_ sp3	1.3289	4.71	disturbed
Alc_ lat2	0.8919	4.67	disturbed
Tab_ arb1	1.3289	4.56	disturbed
Tab_ arb2	0.8434	4.4	disturbed
Gua_ dio1	1.3289	4.32	disturbed
Lae_ pro1	1.3289	4.32	disturbed
Zan_ sp2	1.3289	4.32	disturbed
Gua_ ulm2	1.3289	4.2	disturbed
Cro_ sch1	1.3289	3.96	disturbed
Ing_ sp_1	1.3289	3.96	disturbed
Ing_ sp_2	1.3289	3.96	disturbed
Ing_ oer1	1.3289	3.4	disturbed
Pro_ sch1	1.3289	3.4	disturbed
Slo_ tue1	1.3289	3.25	disturbed
Hel_ ame3	1.3289	3.24	disturbed
Ing_ oer3	0.5521	3.24	disturbed

Lae_ pro2	1.3289	3.24	disturbed
Zue_ gui3	1.3289	3.24	disturbed
Ing_ oer2	1.3289	3.23	disturbed
Com_ spr1	1.3289	2.8	disturbed
Com_ spr2	1.3289	2.8	disturbed
Ing_ ver2	1.3289	2.75	disturbed
Alc_ lat1	1.3289	2.5	disturbed
unkn own2	1.3289	2.5	disturbed
unkn own3	1.3289	2.5	disturbed
Laur ac_2	0.4619	2.48	disturbed
Laur ac_1	0.6816	2.21	disturbed
Ery_ fol1	1.3289	2.14	disturbed
Tab_ alb2	1.3289	2.14	disturbed
Vis_ mac2	1.3289	2.14	disturbed
Tab_ arb4	1.3289	1.79	disturbed
Laur ac_	1.3289	1.63	disturbed
Att_ coh4	0.6006	1.6	disturbed

Indicator species for **unfarmed** plots

% species data explained by axis 1 constrained by Farmed=2.0

NAME	AX1	% EXPL	Indicator direction
Pro_ sch2	-0.749	10.66	unfarmed
Gua_ gra2	-0.749	10.24	unfarmed
Pou_ sap2	-0.749	4.17	unfarmed
And_ ine2	-0.749	3.74	unfarmed
Dia_ gui2	-0.749	3.37	unfarmed
Sim_ gla5	-0.749	3.3	unfarmed
Spo_ rad4	-0.749	3.17	unfarmed
unkn ow_3	-0.4885	3.09	unfarmed
Rin_ def2	-0.749	2.76	unfarmed
Cup_ scr3	-0.749	2.72	unfarmed
Tet_ pan2	-0.749	2.5	unfarmed
Faba ce_3	-0.749	2.22	unfarmed
Tab_ gua2	-0.749	2.22	unfarmed
Cli_ den1	-0.749	2.2	unfarmed
Chry so_3	-0.749	1.98	unfarmed
Sim_ gla4	-0.749	1.98	unfarmed
Zan_ sp5	-0.749	1.98	unfarmed
Cal_ pal2	-0.749	1.85	unfarmed
Voc_ hon2	-0.749	1.85	unfarmed
Cli_ den2	-0.749	1.73	unfarmed
Dia_ gui3	-0.749	1.73	unfarmed
Myr_ sp_4	-0.749	1.73	unfarmed
Pou_ sp_2	-0.749	1.73	unfarmed
Gua_ gra3	-0.749	1.66	unfarmed
Cro_ niv2	-0.749	1.62	unfarmed
Spo_ rad1	-0.749	1.62	unfarmed
Slo_ sch2	-0.749	1.58	unfarmed
Ter_ ama2	-0.749	1.57	unfarmed

Cup_ scr1	-0.749	1.55	unfarmed
Cup_ scr2	-0.749	1.55	unfarmed
Hel_ ame4	-0.749	1.55	unfarmed
Mic_ ins2	-0.749	1.5	unfarmed

Indicator species for **farmed** plots

NAME	AX1	% EXPL	Indicator direction
Mic_ hon1	1.3352	7.2	farmed
Cro_ sch3	1.3352	6.85	farmed
Malv ac_4	1.3352	5.14	farmed
Sali c_2	1.3352	5.14	farmed
Sali c_3	1.3352	5.14	farmed
Alc_ lat2	0.9183	4.95	farmed
Cei_ sp_5	1.3352	4.75	farmed
Lac_ agg1	1.3352	4.75	farmed
Lon_ lin1	1.3352	4.75	farmed
Sch_ par5	1.3352	4.75	farmed
Zan_ sp3	1.3352	4.75	farmed
Tab_ arb1	1.3352	4.61	farmed
Gua_ dio1	1.3352	4.36	farmed
Lae_ pro1	1.3352	4.36	farmed
Zan_ sp2	1.3352	4.36	farmed
Gua_ ulm2	1.3352	4.24	farmed
Tab_ arb2	0.8141	4.1	farmed
Cro_ sch1	1.3352	3.99	farmed
Ing_ sp_1	1.3352	3.99	farmed
Ing_ sp_2	1.3352	3.99	farmed
Ing_ oer1	1.3352	3.43	farmed
Pro_ sch1	1.3352	3.43	farmed
Slo_ tue1	1.3352	3.28	farmed
Hel_ ame3	1.3352	3.27	farmed
Lae_ pro2	1.3352	3.27	farmed
Zue_ gui3	1.3352	3.27	farmed
Ing_ oer2	1.3352	3.26	farmed
Com_ spr1	1.3352	2.83	farmed
Com_ spr2	1.3352	2.83	farmed
Ing_ ver2	1.3352	2.78	farmed
Ing_ oer3	0.5015	2.67	farmed
Alc_ lat1	1.3352	2.53	farmed
Laur ac_2	0.442	2.27	farmed
Ery_ fol1	1.3352	2.16	farmed
Tab_ alb2	1.3352	2.16	farmed
Vis_ mac2	1.3352	2.16	farmed
Laur ac_1	0.6405	1.96	farmed
Att_ coh4	0.6405	1.82	farmed
Tab_ arb4	1.3352	1.8	farmed
Laur ac_	1.3352	1.64	farmed

FIREBURN
SPECIES ONLY

Variable	**p**	**F**
No farm	<0.01	5.1
Farmrec	<0.01	2.7
Farmold	<0.01	1.72

Indicator species for **recently farmed** plots

spp	ax1	%expl	
Cup_ bel	0.689	18.83	recently farmed
Gua_ ulm	0.7911	13.81	recently farmed
Chr_ mex	0.8127	8.17	recently farmed
Cec_ sp_	1.1141	6.73	recently farmed
Cri_ sp_	1.9952	2.97	recently farmed
Den_ arb	1.1631	1.82	recently farmed
Swi_ mac	0.331	1.12	recently farmed
Spo_ rad	0.1596	0.48	recently farmed
Tro_ rac	0.2121	0.3	recently farmed
Pis_ pis	0.1389	0.29	recently farmed

Indicator species for plots farmed >17 years ago

spp	ax1	%expl	
Lon_ rug	0.8921	5.74	old farm
Pis_ pis	0.6057	5.59	old farm
Att_ coh	1.3574	5.01	old farm
Swi_ mac	0.6594	4.45	old farm
Aca_ ced	1.148	4.15	old farm
Tro_ rac	0.7591	3.84	old farm
Vit_ gau	0.3851	2.34	old farm
Cup_ bel	0.2373	2.23	old farm
Eug_ aer	1.2265	2.05	old farm
Tri_ hav	1.3574	1.85	old farm
Laur ace_	0.8339	1.72	old farm
Gua_ ulm	0.2734	1.65	old farm
Zue_ gui	0.6594	1.4	old farm
Pim_ dio	0.8339	1.29	old farm
Fic_ aur	1.3574	1.25	old farm
Gue_ com	0.4055	1.12	old farm
Chr_ mex	0.2552	0.81	old farm
Bei_ hon	0.6594	0.63	old farm
Fic_ per	0.3104	0.37	old farm
Alb_ tom	1.3574	0.31	old farm
Dry_ lat	0.3104	0.17	old farm
Sab_ mau	0.0827	0.13	old farm
Spo_ rad	0.064	0.08	old farm

Indicator species for **unfarmed** plots

spp	Ax1	%expl	
Coc_ spe	0.8872	22.03	unfarmed
Mat_ opp	0.8024	17.88	unfarmed
Cro_ sch	1.1506	17.34	unfarmed
Met_ bro	0.7554	16.27	unfarmed
Man_ zap	1.1506	15.58	unfarmed
Bur_ sim	0.612	14.51	unfarmed
Pou_ iza	1.1506	10.42	unfarmed
Cal_ bra	1.1506	10.07	unfarmed
Sim_ gla	0.5735	8.93	unfarmed
Cae_ gau	0.6191	7.98	unfarmed
Dio_ sal	1.1506	7.44	unfarmed
Pro_ cop	0.627	6.09	unfarmed
Swa_ cub	1.1506	5.43	unfarmed
Euph orb_	1.1506	4.95	unfarmed
Pou_ ret	0.7834	4.8	unfarmed
Cas_ gui	1.1506	4.47	unfarmed
Ham_ tri	1.1506	4.16	unfarmed
Coc_ bar	0.5447	3.01	unfarmed
Gym_ luc	1.1506	2.91	unfarmed
Coc_ bel	0.8621	2.85	unfarmed
Hyp_ mex	1.1506	2.66	unfarmed
Ore_ obt	1.1506	2.66	unfarmed
Fic_ obt	1.1506	2.39	unfarmed
Coc_ aca	0.5447	2.17	unfarmed
Cap_ sp_	1.1506	2.12	unfarmed
Psy_ pub	1.1506	2.09	unfarmed
Eug_ yuc	1.1506	1.95	unfarmed
Exo_ dip	1.1506	1.95	unfarmed
Lae_ tha	1.1506	1.95	unfarmed
Coc_ coz	1.1506	1.75	unfarmed
Pou_ sp_	1.1506	1.62	unfarmed
Hir_ ame	0.4774	1.52	unfarmed
Fic_ per	0.1407	0.08	unfarmed
Dry_ lat	0.1407	0.03	unfarmed

PSEUDOSPECIES

Variable	**p**	**F**
No farm	0.002	3.404
Farmrec	0.002	2.002
Farmold	0.002	1.548

Indicator species for **recently farmed** plots

NAME	**AX1**	**% EXPL**	
Gua_ ulm2	1.2219	26.26	Recently farmed
Cup_ bel2	0.614	14.71	Recently farmed
Cup_ bel3	1.3905	9.04	Recently farmed
Gua_ ulm4	1.181	7.88	Recently farmed
Cec_ sp_2	1.1211	6.93	Recently farmed
Cec_ sp_3	2.0191	6.55	Recently farmed
Chr_ mex3	2.0191	6.38	Recently farmed
Cup_ bel1	1.3905	5.43	Recently farmed
Chr_ mex2	0.6781	5.39	Recently farmed
Cup_ bel4	2.0191	5.04	Recently farmed
unkn ow_5	2.0191	4.42	Recently farmed
Pis_ pis1	1.181	3.72	Recently farmed
Vit_ gau3	0.7619	3.57	Recently farmed
Den_ arb2	2.0191	3.28	Recently farmed
Cri_ sp_1	2.0191	2.94	Recently farmed
Cri_ sp_2	2.0191	2.94	Recently farmed
Swi_ mac2	0.6223	2.66	Recently farmed
Tro_ rac2	0.5105	2.14	Recently farmed
Gua_ ulm1	0.4191	1.91	Recently farmed
Spo_ rad4	1.181	1.64	Recently farmed
Pou_ cam1	0.5823	1.01	Recently farmed
Chr_ mex1	0.7619	0.89	Recently farmed
Pis_ pis4	0.3429	0.29	Recently farmed
Spo_ rad3	0.1333	0.23	Recently farmed
Den_ arb3	0.3429	0.11	Recently farmed
Gua_ ulm3	0.1333	0.11	Recently farmed
Spo_ rad2	0.085	0.07	Recently farmed
Swi_ mac3	0.1333	0.07	Recently farmed
Vit_ gau4	0.1333	0.07	Recently farmed
Pis_ pis3	0.0635	0.03	Recently farmed
Pis_ pis2	0.0286	0.01	Recently farmed
Sab_ mau3	0.0076	0	Recently farmed

Indicator species for plots **farmed >17 yrs ago**

% species data explained by axis 1 constrained by farmed>17yrs ago =1.9

NAME	AX1	% EXPL	
Lon_ rug2	1.0669	7.03	Old farm
Pis_ pis2	0.6335	5.77	Old farm
Cup_ bel2	0.3785	5.59	Old farm
Pis_ pis3	0.8647	5.1	Old farm
Att_ coh4	1.327	5.06	Old farm
Aca_ ced2	1.0669	4.19	Old farm
Gua_ ulm3	0.8069	4.17	Old farm
Vit_ gau5	0.9803	3.99	Old farm
Swi_ mac4	1.327	3.98	Old farm
Gua_ ulm1	0.5704	3.54	Old farm
Spo_ rad1	1.327	2.79	Old farm
Tro_ rac1	1.327	2.79	Old farm
Swi_ mac3	0.8069	2.59	Old farm
Gue_ com2	0.6335	2.56	Old farm
Eug_ aer2	1.119	2.55	Old farm
unkn ow_2	0.2867	2.55	Old farm
Cec_ sp_1	1.327	2.43	Old farm
Fic_ per5	1.327	2.43	Old farm
Coc_ aca1	1.327	2.14	Old farm
Pim_ dio3	1.327	2.14	Old farm
unkn ow_4	1.327	2.12	Old farm
Bei_ hon2	1.327	2.07	Old farm
Bei_ hon3	1.327	2.07	Old farm
Tro_ rac2	0.4948	2.01	Old farm
Hir_ ame1	1.327	1.99	Old farm
Met_ bro1	1.327	1.99	Old farm
Aca_ ced1	1.327	1.97	Old farm
Aca_ ced4	1.327	1.94	Old farm
Eug_ aer1	1.327	1.9	Old farm
Tri_ hav2	1.327	1.85	Old farm
Laur ace_	1.327	1.68	Old farm
Bur_ sim3	0.3813	1.61	Old farm
unkn ow_1	1.327	1.53	Old farm
Chr_ mex2	0.3561	1.49	Old farm
Zue_ gui2	0.6335	1.32	Old farm
Swi_ mac2	0.4023	1.11	Old farm
Laur ace_	0.6335	1.06	Old farm
Fic_ aur4	1.327	1	Old farm
Pou_ ret4	1.327	1	Old farm
Pro_ cop4	1.327	1	Old farm
Pis_ pis4	0.6335	0.98	Old farm
Pim_ dio2	0.6335	0.94	Old farm
Pou_ cam3	0.6335	0.77	Old farm
Bur_ sim1	0.6335	0.65	Old farm
Sab_ mau3	0.4948	0.59	Old farm
Vit_ gau3	0.2867	0.5	Old farm

Spo_ rad2	0.2067	0.41	Old farm
Vit_ gau4	0.2867	0.34	Old farm
Coc_ spe3	0.2867	0.32	Old farm
Alb_ tom3	1.327	0.3	Old farm
Bur_ sim4	0.2867	0.29	Old farm
Fic_ per3	0.2867	0.27	Old farm
unkn ow_3	0.2867	0.25	Old farm
Pro_ cop3	0.2867	0.14	Old farm
Chr_ mex1	0.2867	0.13	Old farm
Dry_ lat2	0.2867	0.12	Old farm
Vit_ gau2	0.1133	0.1	Old farm
Pou_ cam1	0.1381	0.06	Old farm
Alb_ tom2	1.327	0.05	Old farm
Pro_ cop2	0.0467	0.02	Old farm
Coc_ bar2	0.0267	0.01	Old farm

Indicator species for **unfarmed** plots

NAME	**AX1**	**% EXPL**	
Coc_ spe2	0.9024	24.35	unfarmed
Bur_ sim2	0.9179	19.97	unfarmed
Cro_ sch2	1.1262	18.93	unfarmed
Met_ bro3	1.1262	16.01	unfarmed
Mat_ opp2	0.7905	13.83	unfarmed
Pro_ cop1	1.1262	12.48	unfarmed
Man_ zap2	1.1262	11.93	unfarmed
Coc_ spe1	1.1262	11.21	unfarmed
Pou_ iza2	1.1262	9.83	unfarmed
Sim_ gla2	0.5667	8.34	unfarmed
Met_ bro4	0.9024	7.86	unfarmed
Cal_ bra3	1.1262	7.58	unfarmed
Dio_ sal2	1.1262	7.5	unfarmed
Pou_ ret2	0.8745	7.09	unfarmed
Mat_ opp3	0.76	6.01	unfarmed
Swa_ cub2	1.1262	5.36	unfarmed
Ham_ tri2	1.1262	5.32	unfarmed
Man_ zap3	1.1262	4.96	unfarmed
Cae_ gau3	0.7234	4.61	unfarmed
Cro_ sch1	1.1262	4.57	unfarmed
Sim_ gla3	1.1262	4.57	unfarmed
Cas_ gui2	1.1262	4.54	unfarmed
Man_ zap4	1.1262	4.45	unfarmed
Cal_ bra2	1.1262	4.34	unfarmed
Cae_ gau2	0.5065	4.16	unfarmed
Coc_ aca2	0.6786	3.97	unfarmed
Hir_ ame2	0.7234	3.9	unfarmed
Coc_ bel2	0.7234	3.66	unfarmed
Euph orb_	1.1262	3.35	unfarmed
Cal_ bra4	1.1262	3.11	unfarmed

Met_ bro2	0.4213	3	unfarmed
Pou_ ret1	1.1262	2.99	unfarmed
Gym_ luc2	1.1262	2.84	unfarmed
Hyp_ mex2	1.1262	2.58	unfarmed
Ore_ obt2	1.1262	2.58	unfarmed
Fic_ obt3	1.1262	2.51	unfarmed
Coc_ bar1	1.1262	2.31	unfarmed
Ham_ tri1	1.1262	2.31	unfarmed
Pou_ sp_5	1.1262	2.24	unfarmed
Cap_ sp_1	1.1262	2.1	unfarmed
Cap_ sp_2	1.1262	2.1	unfarmed
Met_ bro5	1.1262	2.1	unfarmed
Pou_ ret3	1.1262	2.06	unfarmed
Psy_ pub1	1.1262	2.06	unfarmed
Psy_ pub2	1.1262	2.06	unfarmed
Exo_ dip3	1.1262	2.04	unfarmed
Lae_ tha1	1.1262	2.04	unfarmed
Eug_ yuc2	1.1262	2	unfarmed
Euph orb_	1.1262	2	unfarmed
Coc_ coz2	1.1262	1.84	unfarmed
Fic_ per2	1.1262	1.74	unfarmed
Pou_ iza1	1.1262	1.74	unfarmed
Pou_ sp_2	1.1262	1.65	unfarmed
Coc_ bar2	0.3709	1.33	unfarmed
Cae_ gau5	1.1262	1.26	unfarmed
Pou_ iza3	1.1262	1.26	unfarmed
Coc_ bar4	1.1262	1.17	unfarmed
Man_ zap1	1.1262	1.17	unfarmed
Pou_ iza4	1.1262	1.16	unfarmed
Coc_ bel3	1.1262	1.11	unfarmed
Pou_ cam2	0.4548	1.1	unfarmed
Pro_ cop2	0.3516	1.08	unfarmed
Pou_ sp_1	1.1262	0.62	unfarmed
Pou_ sp_3	1.1262	0.62	unfarmed
Lon_ rug3	1.1262	0.6	unfarmed
Pou_ cam4	1.1262	0.6	unfarmed
Sab_ mau2	0.1784	0.53	unfarmed
Vit_ gau2	0.1192	0.11	unfarmed
Coc_ spe3	0.1192	0.06	unfarmed
Bur_ sim4	0.1192	0.05	unfarmed
Fic_ per3	0.1192	0.05	unfarmed
unkn ow_3	0.1192	0.04	unfarmed
Dry_ lat2	0.1192	0.02	unfarmed
Pro_ cop3	0.1192	0.02	unfarmed
Bur_ sim3	0.0276	0.01	unfarmed

Indicator species for control famrs i.e. plots that could have been farmed but weren't, unfarmed controls

spp	Ax1	%expl	
Pro_ cop2	2.2392	43.54	unfarmed
Fic_ obt3	3.8031	28.26	unfarmed

Pou_ iza2	1.7701	24.01	unfarmed
Dry_ lat2	3.8031	20.63	unfarmed
Cae_ gau3	1.3635	16.05	unfarmed
Cae_ gau5	3.8031	14.11	unfarmed
Pou_ iza3	3.8031	14.11	unfarmed
Pou_ iza4	3.8031	13.48	unfarmed
Man_ zap4	1.7701	10.83	unfarmed
Pro_ cop4	3.8031	8.04	unfarmed
Sab_ mau2	0.6938	7.9	unfarmed
Pou_ sp_1	3.8031	6.89	unfarmed
Pou_ sp_3	3.8031	6.89	unfarmed
Coc_ bar2	0.7536	5.4	unfarmed
Pou_ ret2	0.7536	5.17	unfarmed
Pro_ cop3	1.7701	5.16	unfarmed
Bur_ sim2	0.4381	4.5	unfarmed
Pou_ sp_2	1.7701	3.99	unfarmed
Cal_ bra3	0.7536	3.33	unfarmed
Mat_ opp3	0.4763	2.34	unfarmed
Hir_ ame2	0.5503	2.21	unfarmed
Cae_ gau2	0.3626	2.1	unfarmed
Cas_ gui2	0.7536	2	unfarmed
Pou_ cam3	0.7536	1.63	unfarmed
Mat_ opp2	0.1888	0.77	unfarmed
Sim_ gla2	0.1651	0.67	unfarmed
Aca_ ced2	0.2453	0.22	unfarmed
Man_ zap2	0.1067	0.11	unfarmed
Gue_ com2	0.1067	0.08	unfarmed
Spo_ rad2	0.0498	0.02	unfarmed

<u>Associated with farming or plots that weren't suitable for farming.</u>

spp	Ax1	%expl	
Coc_ spe2	-0.2629	2.04	farmed or unsuitable
Cup_ bel2	-0.2057	1.69	farmed or unsuitable
Gua_ ulm2	-0.2629	1.19	farmed or unsuitable
Met_ bro2	-0.2629	1.15	farmed or unsuitable
Cro_ sch2	-0.2629	1.01	farmed or unsuitable
Spo_ rad3	-0.2629	0.89	farmed or unsuitable
Met_ bro3	-0.2629	0.86	farmed or unsuitable
Chr_ mex2	-0.2629	0.8	farmed or unsuitable
Bur_ sim3	-0.2629	0.76	farmed or unsuitable
Gua_ ulm1	-0.2629	0.72	farmed or unsuitable
Pro_ cop1	-0.2629	0.67	farmed or unsuitable
Met_ bro4	-0.2629	0.66	farmed or unsuitable
Coc_ spe1	-0.2629	0.6	farmed or unsuitable
Coc_ aca2	-0.2629	0.58	farmed or unsuitable
Tro_ rac2	-0.2629	0.57	farmed or unsuitable
Vit_ gau2	-0.2629	0.52	farmed or unsuitable
Coc_ bel2	-0.2629	0.48	farmed or unsuitable
Pis_ pis3	-0.2629	0.47	farmed or unsuitable
Swi_ mac2	-0.2629	0.47	farmed or unsuitable
Gua_ ulm3	-0.2629	0.43	farmed or unsuitable

Lon_ rug2	-0.2629	0.41	farmed or unsuitable
Vit_ gau3	-0.2629	0.41	farmed or unsuitable
Dio_ sal2	-0.2629	0.4	farmed or unsuitable
Cec_ sp_2	-0.2629	0.38	farmed or unsuitable
Gua_ ulm4	-0.2629	0.38	farmed or unsuitable
Pou_ cam2	-0.2629	0.36	farmed or unsuitable
Cup_ bel3	-0.2629	0.35	farmed or unsuitable
Swa_ cub2	-0.2629	0.29	farmed or unsuitable
Ham_ tri2	-0.2629	0.28	farmed or unsuitable
Vit_ gau4	-0.2629	0.28	farmed or unsuitable
Vit_ gau5	-0.2629	0.28	farmed or unsuitable
Swi_ mac3	-0.2629	0.27	farmed or unsuitable
Coc_ spe3	-0.2629	0.26	farmed or unsuitable
Man_ zap3	-0.2629	0.26	farmed or unsuitable
Sim_ gla3	-0.2629	0.25	farmed or unsuitable
Bur_ sim4	-0.2629	0.24	farmed or unsuitable
Cro_ sch1	-0.2629	0.24	farmed or unsuitable
Sab_ mau3	-0.2629	0.24	farmed or unsuitable
Cal_ bra2	-0.2629	0.23	farmed or unsuitable
Fic_ per3	-0.2629	0.23	farmed or unsuitable
Zue_ gui2	-0.2629	0.22	farmed or unsuitable
Pou_ cam1	-0.2629	0.2	farmed or unsuitable
Att_ coh4	-0.2629	0.19	farmed or unsuitable
Cup_ bel1	-0.2629	0.19	farmed or unsuitable
Euph orb_	-0.2629	0.18	farmed or unsuitable
Euph orb_	-0.2629	0.18	farmed or unsuitable
Laur ace_	-0.2629	0.18	farmed or unsuitable
Laur ace_	-0.2629	0.18	farmed or unsuitable
Pis_ pis1	-0.2629	0.18	farmed or unsuitable
Cal_ bra4	-0.2629	0.17	farmed or unsuitable
Pis_ pis4	-0.2629	0.17	farmed or unsuitable
Pim_ dio2	-0.2629	0.16	farmed or unsuitable
Pou_ ret1	-0.2629	0.16	farmed or unsuitable
Gym_ luc2	-0.2629	0.15	farmed or unsuitable
Swi_ mac4	-0.2629	0.15	farmed or unsuitable
Eug_ aer2	-0.2629	0.14	farmed or unsuitable
Hyp_ mex2	-0.2629	0.14	farmed or unsuitable
Ore_ obt2	-0.2629	0.14	farmed or unsuitable
Spo_ rad4	-0.2629	0.13	farmed or unsuitable
Pis_ pis2	-0.0935	0.12	farmed or unsuitable
Coc_ bar1	-0.2629	0.12	farmed or unsuitable
Ham_ tri1	-0.2629	0.12	farmed or unsuitable
Pou_ sp_5	-0.2629	0.12	farmed or unsuitable
Bur_ sim1	-0.2629	0.11	farmed or unsuitable
Cap_ sp_1	-0.2629	0.11	farmed or unsuitable
Cap_ sp_2	-0.2629	0.11	farmed or unsuitable
Cec_ sp_3	-0.2629	0.11	farmed or unsuitable
Chr_ mex3	-0.2629	0.11	farmed or unsuitable
Eug_ yuc2	-0.2629	0.11	farmed or unsuitable
Euph orb_	-0.2629	0.11	farmed or unsuitable
Euph orb_	-0.2629	0.11	farmed or unsuitable
Exo_ dip3	-0.2629	0.11	farmed or unsuitable

Lae_ tha1	-0.2629	0.11	farmed or unsuitable
Met_ bro5	-0.2629	0.11	farmed or unsuitable
Pou_ ret3	-0.2629	0.11	farmed or unsuitable
Psy_ pub1	-0.2629	0.11	farmed or unsuitable
Psy_ pub2	-0.2629	0.11	farmed or unsuitable
Spo_ rad1	-0.2629	0.11	farmed or unsuitable
Tro_ rac1	-0.2629	0.11	farmed or unsuitable
Chr_ mex1	-0.2629	0.1	farmed or unsuitable
Coc_ coz2	-0.2629	0.1	farmed or unsuitable
Bei_ hon2	-0.2629	0.09	farmed or unsuitable
Cec_ sp_1	-0.2629	0.09	farmed or unsuitable
Fic_ per2	-0.2629	0.09	farmed or unsuitable
Fic_ per5	-0.2629	0.09	farmed or unsuitable
Pou_ iza1	-0.2629	0.09	farmed or unsuitable
Aca_ ced1	-0.2629	0.08	farmed or unsuitable
Aca_ ced4	-0.2629	0.08	farmed or unsuitable
Bei_ hon3	-0.2629	0.08	farmed or unsuitable
Coc_ aca1	-0.2629	0.08	farmed or unsuitable
Cup_ bel4	-0.2629	0.08	farmed or unsuitable
Eug_ aer1	-0.2629	0.08	farmed or unsuitable
Hir_ ame1	-0.2629	0.08	farmed or unsuitable
Met_ bro1	-0.2629	0.08	farmed or unsuitable
Pim_ dio3	-0.2629	0.08	farmed or unsuitable
unkn ow_4	-0.2629	0.08	farmed or unsuitable

Crooked Tree

Farming not significant variable

NAME	AX1	% EXPL
Blo_ pri	0.3239	32.39
Coc_ bar	0.2119	21.19
Tab_ ros	0.2119	21.19
Spo_ rad	0.1173	11.73
Tro_ rac	0.1051	10.51
Cec_ sp_	0.0917	9.17
Den_ arb	0.0414	4.14
Fic_ max	0.0411	4.11
Roy_ reg	0.0411	4.11
Faba ce_	0.0325	3.25
Euph orb_	0.031	3.1
Coc_ bel	0.0301	3.01
Bau_ div	0.0247	2.47
Alb_ tom	0.0219	2.19
Pis_ pis	0.0207	2.07
Swa_ cub	0.0207	2.07
Phy_ acu	0.0198	1.98
Gua_ ulm	0.0135	1.35
Tab_ alb	0.012	1.2

Lon_ rug	0.0084	0.84
Zue_ gui	0.0084	0.84
Pit_ lan	0.0081	0.81
Coc_ vit	0.0071	0.71
Eug_ sp_	0.0063	0.63
Seb_ tue	0.0063	0.63
Ran_ acu	0.0052	0.52
Ran_ arm	0.0052	0.52
All_ psi	0.0042	0.42
Cas_ tre	0.0042	0.42
Cra_ tap	0.0034	0.34
Zyg_ con	0.0034	0.34
Att_ coh	0.0022	0.22
unkn ow_	0.0012	0.12
Lon_ sp_	0.0008	0.08
Cup_ bel	0.0002	0.02

Appendix 3: Plant Species Lists
Cockscomb Wildlife Basin Sanctuary

Family	Genus	Species
Euphorbiaceae	Acalypha	macrostachya
Adiantaceae	Adiantum	pulverulentum
Fabaceae - Mimosoideae	Albizia	tomentosa
Euphorbiaceae	Alchornea	latifolia
Bignoniaceae	Amphilophium	paniculatum
Fabaceae - Faboideae	Andira	inermis
Annonaceae	Annona	liebmanniana
Araceae	Anthurium	pentaphyllum
Myrsinaceae	Ardisia	nigropunctata
Apocynaceae	Aspidosperma	megalocarpon
Cyclanthaceae	Asplundia	? sp
Cyclanthaceae	Asplundia	chiapensis
Arecaceae	Astrocaryum	mexicanum
Arecaceae	Attalea	cohune
Arecaceae	Bactris	mexicana
Melastomataceae	Bellucia	grossularioides
Rubiaceae	Bertiera	guianensis
Bromeliaceae	Bromelia	pinguin
Moraceae	Brosimum	guianense
Burseraceae	Bursera	simaruba
Marantaceae	Calathea	? sp
Marantaceae	Calathea	crotalifera
Marantaceae	Calathea	micans
Bignoniaceae	Callichlamys	latifolia
Clusiaceae	Calophyllum	brasiliense
Myrtaceae	Calyptranthes	pallens
Polypodiaceae	Campyloneurum	repens
Capparaceae	Capparis	quiriguensis
Salicaceae	Casearia	? sp
Salicaceae	Casearia	sylvestris
Salicaceae	Casearia	tremula
Rhizophoraceae	Cassipourea	guianensis
Moraceae	Castilla	elastica
Cecropiaceae	Cecropia	? sp
Malvaceae - Bombacoideae	Ceiba	? sp
Malvaceae - Bombacoideae	Ceiba	pentandra

Solanaceae	Cestrum	megalophyllum
Arecaceae	Chamaedorea	? sp
Arecaceae	Chamaedorea	ernesti-augustii
Arecaceae	Chamaedorea	neurochlamys Burret
Arecaceae	Chamaedorea	tepejilote
Celastraceae	Cheiloclinium	belizense
Sapotaceae	Chrysophyllum	mexicanum
Melastomataceae	Clidemia	capitellata
Melastomataceae	Clidemia	dentata
Melastomataceae	Clidemia	hirta
Melastomataceae	Clidemia	petiolaris
Melastomataceae	Clidemia	septuplinervia
Clusiaceae	Clusia	? sp
Fabaceae - Mimosoideae	Cojoba	graciliflora
Commelinaceae	Commelina	rufipes
Myristicaceae	Compsoneura	sprucei
Boraginaceae	Cordia	bicolor
Boraginaceae	Cordia	diversifolia
Verbenaceae	Cornutia	grandifolia
Costaceae	Costus	pulverulentus
Euphorbiaceae	Croton	billbergianus
Euphorbiaceae	Croton	niveus
Euphorbiaceae	Croton	schiedeanus
Sapindaceae	Cupania	scrobiculata
Cyclanthaceae	Cyclanthus	? sp
Annonaceae	Cymbopetalum	mayanum
Dilleniaceae	Davilla	nitida
Arecaceae	Desmoncus	orthacanthos
Fabaceae - Caesalpinioideae	Dialium	guianense
Dilleniaceae	Doliocarpus	multiflorus
Fabaceae - Faboideae	Erythrina	folkersii
Arecaceae	Euterpe	precatoria Mart.
Rubiaceae	Faramea	brachysiphon
Clusiaceae	Garcinia	intermedia
Arecaceae	Geonoma	? sp
Arecaceae	Geonoma	deversa
Arecaceae	Geonoma	interrupta (Ruiz & Pav.) Mart.
Rubiaceae	Geophila	repens
Apocynaceae	Gonolobus	leianthus

Rhamnaceae	Gouania	? sp
Meliaceae	Guarea	glabra
Meliaceae	Guarea	grandifolia
Annonaceae	Guatteria	diospyroides
Malvaceae - Sterculioideae	Guazuma	ulmifolia
Heliconiaceae	Heliconia	latispatha
Heliconiaceae	Heliconia	vaginalis
Malvaceae - Tilioideae	Heliocarpus	americanus
Fabaceae - Mimosoideae	Inga	? sp
Fabaceae - Mimosoideae	Inga	oerstediana
Fabaceae - Mimosoideae	Inga	vera
Lacistemataceae	Lacistema	aggregatum
Salicaceae	Laetia	procera
Salicaceae	Laetia	thamnia
Melastomataceae	Leandra	mexicana
Chrysobalanaceae	Licania	hypoleuca
Chrysobalanaceae	Licania	sparsipilis
Fabaceae - Faboideae	Lonchocarpus	lineatus
Acanthaceae	Louteridium	chartaceum
Schizaeaceae	Lygodium	heterodoxum
Schizaeaceae	Lygodium	venustum
Fabaceae - Faboideae	Machaerium	floribundum
Bignoniaceae	Mansoa	kerere
Marcgraviaceae	Marcgravia	nepenthoides
Clusiaceae	Marila	laxiflora
Apocynaceae	Matelea	gentlei
Melastomataceae	Miconia	? sp
Melastomataceae	Miconia	ampla
Melastomataceae	Miconia	chrysophylla
Melastomataceae	Miconia	elata
Melastomataceae	Miconia	hondurensis
Melastomataceae	Miconia	impetiolaris
Melastomataceae	Miconia	insularis
Melastomataceae	Miconia	lacera
Melastomataceae	Miconia	matthaei
Melastomataceae	Miconia	nervosa
Melastomataceae	Miconia	oinochrophylla
Melastomataceae	Miconia	tomentosa
Asteraceae	Mikania	pyramidata

Asteraceae	Mikania	species 1
Asteraceae	Mikania	species 2
Asteraceae	Mikania	species 3
Monimiaceae	Mollinedia	guatemalensis
Araceae	Monstera	acuminata
Melastomataceae	Mouriri	exilis
Melastomataceae	Mouriri	myrtilloides
Fabaceae - Faboideae	Mucuna	? sp
Urticaceae	Myriocarpa	? sp
Nyctaginaceae	Neea	psychotrioides
Davalliaceae	Nephrolepis	biserrata
Rubiaceae	Palicourea	guianensis
Bignoniaceae	Paragonia	pyramidata
Passifloraceae	Passiflora	? sp
Passifloraceae	Passiflora	biflora
Piperaceae	Peperomia	? sp
Piperaceae	Peperomia	macrostachya
Piperaceae	Peperomia	rotundifolia
Araceae	Philodendron	? sp
Araceae	Philodendron	aurantiifolium
Araceae	Philodendron	radiatum
Araceae	Philodendron	sagittifolium
Piperaceae	Piper	? sp
Piperaceae	Piper	hispidum
Piperaceae	Piper	jacquemontianum
Piperaceae	Piper	sanctum
Piperaceae	Piper	schiedeanum
Asteraceae	Piptocarpha	poeppigiana
Nyctaginaceae	Pisonia	? sp
Myrtaceae	Plinia	peroblata
Aspleniaceae	Polybotrya	caudata
Rubiaceae	Posoqueria	latifolia
Cecropiaceae	Pourouma	bicolor
Sapotaceae	Pouteria	campechiana
Sapotaceae	Pouteria	durlandii
Sapotaceae	Pouteria	sapota
Burseraceae	Protium	? sp
Burseraceae	Protium	schippii
Rubiaceae	Psychotria	? sp

Rubiaceae	Psychotria	acuminata
Rubiaceae	Psychotria	brachiata
Rubiaceae	Psychotria	capitata
Rubiaceae	Psychotria	chiapensis
Rubiaceae	Psychotria	deflexa
Rubiaceae	Psychotria	elata
Rubiaceae	Psychotria	glomerulata
Rubiaceae	Psychotria	marginata
Rubiaceae	Psychotria	officinalis
Rubiaceae	Psychotria	poeppigiana
Rubiaceae	Psychotria	racemosa
Adiantaceae	Pteris	altissima
Fabaceae - Faboideae	Pterocarpus	officinalis
Quiinaceae	Quiina	schippii
Violaceae	Rinorea	deflexiflora
Annonaceae	Rollinia	mucosa
Rubiaceae	Sabicea	panamensis
Fabaceae - Caesalpinioideae	Schizolobium	parahyba
Selaginellaceae	Selaginella	hoffmannii
Sapindaceae	Serjania	atrolineata
Sapindaceae	Serjania	cardiospermoides
Simaroubaceae	Simarouba	glauca
Monimiaceae	Siparuna	thecaphora
Elaeocarpaceae	Sloanea	meianthera
Elaeocarpaceae	Sloanea	schippii
Elaeocarpaceae	Sloanea	tuerckheimii
Cyatheaceae	Sphaeropteris	myosuroides
Anacardiaceae	Spondias	radlkoferi
Apocynaceae	Stemmadenia	donnell-smithii
Malpighiaceae	Stigmaphyllon	retusum
Loganiaceae	Strychnos	panamensis
Loganiaceae	Strychnos	peckii
Meliaceae	Swietenia	macrophylla
Clusiaceae	Symphonia	globulifera
Arecaceae	Synechanthus	fibrosus
Araceae	Syngonium	podophyllum
Bignoniaceae	Tabebuia	guayacan
Apocynaceae	Tabernaemontana	alba
Apocynaceae	Tabernaemontana	arborea

Aspleniaceae	Tectaria	incisa
Combretaceae	Terminalia	amazonia
Burseraceae	Tetragastris	panamensis
Celastraceae	Tontelea	hondurensis
Hymenophyllaceae	Trichomanes	collariatum
Poaceae	Tripsacum	latifolium
Bignoniaceae	Tynanthus	guatemalensis
Rubiaceae	Uncaria	tomentosa
Orchidaceae	Vanilla	? sp
Fabaceae - Faboideae	Vatairea	lundellii
Myristicaceae	Virola	koschnyi
Clusiaceae	Vismia	macrophylla
Vitaceae	Vitis	? sp
Vochysiaceae	Vochysia	hondurensis
Gentianaceae	Voyria	parasitica
Annonaceae	Xylopia	frutescens
Rutaceae	Zanthoxylum	? sp
Salicaceae	Zuelania	guidonia

Crooked Tree Wildlife Sanctuary

Family	Genus	Species
Fabaceae - Mimosoideae	Acacia	gentlei
Fabaceae - Mimosoideae	Albizia	tomentosa
Rubiaceae	Alibertia	edulis
Sapindaceae	Allophylus	psilospermus
Fabaceae - Faboideae	Andira	inermis
Arecaceae	Attalea	cohune
Arecaceae	Bactris	major Jacq.
Poaceae	Bambusa	vulgaris
Fabaceae - Caesalpinioideae	Bauhinia	divaricata
Fabaceae - Caesalpinioideae	Bauhinia	herrerae
Lauraceae	Beilschmiedia	hondurensis
Sapindaceae	Blomia	prisca
Malvaceae - Sterculioideae	Byttneria	aculeata
Marantaceae	Calathea	lutea
Clusiaceae	Calophyllum	brasiliense
Salicaceae	Casearia	tremula
Asteraceae	Chromolaena	odorata
Sapotaceae	Chrysophyllum	mexicanum
Melastomataceae	Clidemia	petiolaris
Polygonaceae	Coccoloba	barbadensis
Polygonaceae	Coccoloba	belizensis
Bixaceae	Cochlospermum	vitifolium
Fabaceae - Mimosoideae	Cojoba	graciliflora
Capparaceae	Crateva	tapia
Arecaceae	Cryosophila	stauracantha
Sapindaceae	Cupania	belizensis
Bignoniaceae	Cydista	diversifolia
Araliaceae	Dendropanax	arboreus
Arecaceae	Desmoncus	orthacanthos
Myrtaceae	Eugenia	acapulcensis
Myrtaceae	Eugenia	yucatanensis
Moraceae	Ficus	maxima
Apocynaceae	Gonolobus	salvinii
Rhamnaceae	Gouania	polygama
Malvaceae - Sterculioideae	Guazuma	ulmifolia
Rubiaceae	Hamelia	patens
Chrysobalanaceae	Hirtella	americana
Fabaceae - Faboideae	Lonchocarpus	rugosus
Schizaeaceae	Lygodium	venustum
Malpighiaceae	Malpighia	glabra
Cucurbitaceae	Melothria	trilobata
Melastomataceae	Mouriri	myrtilloides
Davalliaceae	Nephrolepis	biserrata
Passifloraceae	Passiflora	biflora
Passifloraceae	Passiflora	coriaceae
Sapindaceae	Paullinia	costaricensis
Verbenaceae	Petrea	volubilis
Araceae	Philodendron	radiatum
Euphorbiaceae	Phyllanthus	acuminatus
Piperaceae	Piper	amalago
Piperaceae	Piper	jacquemontianum

Fabaceae - Faboideae	Piscidia	piscipula
Fabaceae - Mimosoideae	Pithecellobium	lanceolatum
Fabaceae - Mimosoideae	Pithecellobium	macrandrium
Sapotaceae	Pouteria	izabalensis
Bignoniaceae	Pseudocatalpa	caudiculata
Rubiaceae	Psychotria	mexiae
Rubiaceae	Psychotria	pubescens
Rubiaceae	Psychotria	quinqueradiata
Rubiaceae	Randia	aculeata
Rubiaceae	Randia	armata
Zingiberaceae	Renealmia	aromatica
Connaraceae	Rourea	glabra
Arecaceae	Roystonea	regia
Arecaceae	Sabal	mauritiiformis
Euphorbiaceae	Sebastiania	tuerckheimiana
Fabaceae - Caesalpinioideae	Senna	pallida
Fabaceae - Caesalpinioideae	Senna	peralteana
Elaeocarpaceae	Sloanea	petenensis
Smilacaceae	Smilax	spinosa
Anacardiaceae	Spondias	radlkoferi
Bignoniaceae	Stizophyllum	riparium
Fabaceae - Faboideae	Swartzia	cubensis
Bignoniaceae	Tabebuia	rosea
Apocynaceae	Tabernaemontana	alba
Dilleniaceae	Tetracera	volubilis
Meliaceae	Trichilia	havanensis
Malvaceae - Tilioideae	Triumfetta	semitriloba
Moraceae	Trophis	racemosa
Vitaceae	Vitis	tiliifolia
Salicaceae	Zuelania	guidonia
Fabaceae - Mimosoideae	Zygia	conzattii

Fireburn Reserve

Family	Genus	Species
Fabaceae - Mimosoideae	Acacia	cedilloi
Fabaceae - Mimosoideae	Albizia	tomentosa
Sapindaceae	Allophylus	psilospermus
Arecaceae	Attalea	cohune
Fabaceae - Caesalpinioideae	Bauhinia	divaricata
Fabaceae - Caesalpinioideae	Bauhinia	jenningsii
Lauraceae	Beilschmiedia	hondurensis
Moraceae	Brosimum	alicastrum
Burseraceae	Bursera	simaruba
Fabaceae - Caesalpinioideae	Caesalpinia	gaumeri
Clusiaceae	Calophyllum	brasiliense
Rhizophoraceae	Cassipourea	guianensis
Arecaceae	Chamaedorea	elegans
Sapotaceae	Chrysophyllum	mexicanum
Euphorbiaceae	Cnidoscolus	aconitifolius
Polygonaceae	Coccoloba	acapulcensis
Polygonaceae	Coccoloba	barbadensis
Polygonaceae	Coccoloba	belizensis
Polygonaceae	Coccoloba	cozumelensis
Fabaceae - Mimosoideae	Cojoba	graciliflora
Euphorbiaceae	Croton	schiedeanus
Arecaceae	Cryosophila	stauracantha
Sapindaceae	Cupania	belizensis
Bignoniaceae	Cydista	heterophylla
Bignoniaceae	Cydista	potosina
Euphorbiaceae	Dalechampia	scandens
Dilleniaceae	Davilla	nitida
Araliaceae	Dendropanax	arboreus
Arecaceae	Desmoncus	orthacanthos
Ebenaceae	Diospyros	salicifolia
Erythroxylaceae	Erythroxylum	guatemalense
Myrtaceae	Eugenia	aeruginea
Myrtaceae	Eugenia	yucatanensis
Sapindaceae	Exothea	diphylla
Moraceae	Ficus	maxima
Moraceae	Ficus	pertusa
Rubiaceae	Geophila	repens
Apocynaceae	Gonolobus	leianthus
Malvaceae - Sterculioideae	Guazuma	ulmifolia
Rubiaceae	Guettarda	combsii
Rubiaceae	Guettarda	gaumeri
Euphorbiaceae	Gymnanthes	lucida
Malvaceae - Malvoideae	Hampea	trilobata
Celastraceae	Hippocratea	volubilis
Malpighiaceae	Hiraea	reclinata
Chrysobalanaceae	Hirtella	americana
Menispermaceae	Hyperbaena	mexicana
Theophrastaceae	Jacquinia	albiflora
Lacistemataceae	Lacistema	aggregatum
Salicaceae	Laetia	thamnia
Fabaceae - Faboideae	Lonchocarpus	rugosus

Fabaceae - Faboideae	Lonchocarpus	xuul
Schizaeaceae	Lygodium	venustum
Rubiaceae	Machaonia	lindeniana
Annonaceae	Malmea	depressa
Sapotaceae	Manilkara	zapota
Sapindaceae	Matayba	oppositifolia
Cucurbitaceae	Melothria	pendula
Anacardiaceae	Metopium	brownei
Melastomataceae	Mouriri	myrtilloides
Araliaceae	Oreopanax	obtusifolius
Ochnaceae	Ouratea	lucens
Fabaceae - Faboideae	Pachyrhizus	erosus
Passifloraceae	Passiflora	biflora
Passifloraceae	Passiflora	coriaceae
Sapindaceae	Paullinia	costaricensis
Verbenaceae	Petrea	volubilis
Simaroubaceae	Picramnia	antidesma
Rutaceae	Pilocarpus	racemosus
Myrtaceae	Pimenta	dioica
Piperaceae	Piper	amalago
Piperaceae	Piper	jacquemontianum
Piperaceae	Piper	psilorhachis
Fabaceae - Faboideae	Piscidia	piscipula
Nyctaginaceae	Pisonia	aculeata
Fabaceae - Mimosoideae	Pithecellobium	lanceolatum
Fabaceae - Mimosoideae	Pithecellobium	macrandrium
Sapotaceae	Pouteria	campechiana
Sapotaceae	Pouteria	izabalensis
Sapotaceae	Pouteria	reticulata
Burseraceae	Protium	copal
Moraceae	Pseudolmedia	glabrata
Rubiaceae	Psychotria	costivenia
Rubiaceae	Psychotria	fruticetorum
Rubiaceae	Psychotria	pubescens
Rubiaceae	Randia	aculeata
Connaraceae	Rourea	glabra
Arecaceae	Sabal	mauritiiformis
Fabaceae - Caesalpinioideae	Senna	peralteana
Sapindaceae	Serjania	yucatanensis
Simaroubaceae	Simarouba	glauca
Rubiaceae	Simira	salvadorensis
Elaeocarpaceae	Sloanea	meianthera
Smilacaceae	Smilax	spinosa
Anacardiaceae	Spondias	radlkoferi
Bignoniaceae	Stizophyllum	riparium
Loganiaceae	Strychnos	brachistantha
Fabaceae - Faboideae	Swartzia	cubensis
Meliaceae	Swietenia	macrophylla
Apocynaceae	Tabernaemontana	alba
Dilleniaceae	Tetracera	volubilis
Apocynaceae	Thevetia	gaumeri
Arecaceae	Thrinax	radiata
Meliaceae	Trichilia	havanensis
Moraceae	Trophis	racemosa

Verbenaceae	Vitex	gaumeri
Vitaceae	Vitis	tiliifolia
Gentianaceae	Voyria	parasitica
Salicaceae	Zuelania	guidonia
Fabaceae - Mimosoideae	Zygia	conzattii
Fabaceae - Mimosoideae	Zygia	peckii