Birds in Cerrado and Eucalyptus plantations

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Tropical Forestry
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‘The influence of Eucalyptus plantations on cerrado bird species’

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Abstract

This research was carried out on behalf of Para la Tierra at Reserva Natural Laguna Blanca, San Pedro, Paraguay.
The fast disappearing cerrado habitat, through cattle ranch expansion and agricultural practices, is a major threat to all flora and fauna species that are dependent upon it. Fragmentation is one of the biggest threats to this habitat, acting as a major barrier to the movement of flora and fauna across the landscape.
Next to Reserva Natural Laguna Blanca, which partly consists of cerrado habitat, *Eucalyptus grandis* plantations have been created, with plots of differently aged trees scattered amongst several patches of cerrado. To determine whether the conversion of cerrado habitat to Eucalyptus plantations is affecting local wildlife diversity, birds were chosen as indicator.

This research shows results of surveys done in Eucalyptus plantations and the cerrado, focussing on bird species that live in either habitat. The ways in which the birds use each habitat and the differences between each habitat will be studied.

The research was carried out at 8 different study sites, 4 in the Eucalyptus plantations (1, 3, 5 and 7 years old) and 4 in the cerrado ecotypes (Campo Limpio, Campo Sucio, Sensu Strictu and Cerradon). Each study site was visited 4 times, twice in the early morning (between 6 and 9am) and twice in the afternoon (between 3 and 6pm). Each survey lasted 2 hours, resulting in a total of 8 survey hours per site and 32 hours per habitat type.
The birds were surveyed using the McKinnon method and backed up with the Time Schedule Count. In addition to both methods, the number of individuals per species and their behaviour was recorded. The vegetation cover of all study sites was measured in accordance with the National Vegetation Classification of the UK. Undergrowth to 3m in height was measured with 4m x 4m plots at 6 randomly selected points at each study site, providing an estimate of the undergrowth density at the site.

The results showed that the number of bird species in the cerrado was significantly higher (t-test) than in the plantations, $t(6) = -2.95$, $p = 0.026$. The cerrado recorded 44 species (556 individuals) while 24 species (116 individuals) were present in the plantations.
In both areas, species richness depended on the amount of undergrowth, with greater undergrowth coverage supporting a higher number of species, as shown in a Pearson's correlation, $r(6) = .75$, $p = 0.03$. The height and the density of the undergrowth itself shown to be influenced by the canopy cover.
The taller Eucalyptus trees were used by several species as night roosts, because they provide shelter from nocturnal predators. The most bird activity within the plantations occurred in the 10 meter edge within the plantations, probably because the undergrowth coverage along the edges is denser and higher than in the middle of the plantations.

This research showed that the number of bird species in the cerrado was significantly higher than in the Eucalyptus plantations, predominately because the undergrowth coverage is low in all plantations. Many birds depend on dense understory vegetation for cover, and particularly small species tended to avoid the plantations.
A possible solution to this problem is the creation of vegetation corridors between plantations which would allow birds to move to other areas.

Preface

This research report forms a part of my thesis project for my study Tropical Forestry and Nature Management at the University of Applied Sciences vanHall-Larenstein in Velp (NL).
The data contained within has been collected at Reserva Natural Laguna Blanca in Paraguay. I owe many thanks to Para la Tierra for their hospitality and support during my three months fieldwork. Special thanks go to Karina Atkinson and Joseph Sarvary of Para la Tierra, who helped me with designing the project, and Kevin Guest, who was always prepared to drive me to my study sites, and assist with identifying birds and collecting data. I'm also indebted Paul Smith, for providing background information for this study.
Volunteers at Para la Tierra are thanked for their support and help during my three month stay.
A word of thanks goes also to Jaap de Vletter as supervisor and Judith Jobse from the University of Applied Sciences for supporting and designing the project.

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1. Introduction

When people talk about a diminishing habitat and refer to an example, they mostly mention the Amazon rainforest in Brazil; but there is a habitat type which is disappearing much faster than the Amazon - the cerrado (Machado R, 2008).
The original cerrado habitat covered 2,031,990 km^2, though only 438,910 km^2 remains today. Between 2002 and 2008, 21,000 km^2 of cerrado was destroyed annually, twice the rate at which the Amazon disappeared during the same period (Conservation International, 2012).
The cerrado is characterised by the typical savannah appearance of dry grass and woodland which appears on nutrient poor soils (Eiten 1972). This unique habitat, which is considered one of the 25 most important terrestrial hotspots in the world, is home to an estimated 160,000 species of plants, animals and fungi, almost 4,500 of which are endemic.
The cerrado covers nearly 21% of Brazil's land surface with extensions into Bolivia and Paraguay. The greatest threats to the cerrado are cattle farms and agricultural use of the cerrado land. Until recent years land owners considered the cerrado to be useless dry savannah, but recent new studies have shown that the land can be optimised by adding phosphorus and lime to the soil, improving the yield of cash crops like soya (Oliveira P. S., 2002). The interest in the cerrado land is rapidly growing, leading to major destruction of the native vegetation.

1.1 Problem indication

Fragmentation of landscapes or habitats is a worldwide problem for flora and fauna. Many habitat fragments are so isolated as a result of human activities, for example infrastructure and agricultural extensions, that species inhabiting them are unable to persist or move to other areas, and this can lead to extinctions. In South America, approximately 5.5% of the cerrado is made up of fragments of protected areas scattered across Brazil, Bolivia and Paraguay, while the remainder is located within private properties, making protection and conservation extremely difficult.
In Paraguay private owners mostly convert their cerrado land to cattle farms or modify it for agricultural purposes such as the growing of plantations. Setting up a plantation in Paraguay has become more interesting since the government has set up a reforestation law (ley no. 536 de 1995) declaring that 75% of the establishment and maintenance costs of reforestation projects, including plantations, will be subsidised for up to 3 years (National Forest Institute, 2010; Global Forest Coalition, 2012). This law was introduced despite a major forest loss of 178,900 hectare annually, between 1990 and 2005 (Buthler R., 2009), and it has led to further destruction of the cerrado (Catterson T. M., 2004). Plantations give more yield than the native cerrado through the selling of the wood and the income of the subsidies. In 2005, an estimated 1,400,000 hectares of plantations existed in Paraguay, much of which was growing on former cerrado land (Buthler R., 2009). These plantations, in most cases, consist of exotic trees such as Eucalyptus *(Eucalyptus spp.)* and Pine *(Pinus spp.)* (Zurita G., 2006).

1.2 Problem description

The loss or fragmentation of an endangered habitat, such as the cerrado, is a serious threat to all species of flora and fauna that are adapted to it. This research is focusing on the influence of Eucalyptus plantations on the bird diversity of the native cerrado habitat, which is carried out at Reserva Natural Laguna Blanca, San Pedro, Paraguay. Reserva Natural Laguna Blanca consists of a

large area of cerrado. Scattered amongst the cerrado are Eucalyptus plantations of various ages. The effect of these plantations can be seen in the landscape as wide firebreaks and tall Eucalyptus trees separating different parts of the shorter cerrado.
No research has yet examined the influence of Eucalyptus plantations on the cerrado and its wildlife in Paraguay.
In this research birds are taken as indicator, because birds are quite specific in their habitat choice which makes it a reliable indicator for the quality of an area, and they are easy to observe.

1.3 Research questions

Main question:

- Do *Eucalyptus grandis* plantations affect cerrado birds in Reserva Natural Laguna Blanca in 2013, and in what way?

Sub-questions:

- Which bird species are associated with which habitat type?
- What are the differences in living conditions for bird species between the Eucalyptus plantations and cerrado?
- How do the birds use each area?
- Is there a relationship between the number of birds observed and vegetation growth?

1. 4 Scope

This research focuses only on bird species and numbers observed during the scheduled visits to the study sites within a three month period from April till June 2013. The study area incorporates only the cerrado (four ecotypes) within the Reserva Natural Laguna Blanca and the adjacent Eucalyptus plantations (four age classes). Vegetation measurements of the cerrado and plantations were conducted within the same areas.

1.5 Thesis outline

First, a description of the study sites and the methodology is given in Chapter 2, providing information about the selected habitats and their importance.
The results are presented in Chapters 3 to 6.
A discussion of the results is given in Chapter 7, followed by the conclusion of this research in Chapter 8.
Finally, the recommendations concerning this research are mentioned in Chapter 9.

2. Study area and methodology

2.1 Study area

This research was carried out in the province of San Pedro in the northeast of Paraguay (Figure 1). The study area was located in the northeast of San Pedro at Reserva Natural Laguna Blanca (Figure 2), which is a private property used for research purposes by Para la Tierra, an ecological research station which is based at Reserva Natural Laguna Blanca since April 2010. A small part of the reserve is also used by recreationists.

Figure 1: Overview of Paraguay and the province of San Pedro (Google Earth, 2007)

Figure 2: The province of San Pedro and the location of the Laguna Blanca nature reserve (Google Earth, 2007)

Reserva Natural Laguna Blanca is a small reserve, incorporating several different habitat types and covering an area of 815 ha. One of the habitats within this reserve is cerrado, which comprises an estimated 400 ha (Smith P., 2012). The four main cerrado ecotypes, campo limpio, campo sucio, cerradon and sensu strictu, can be found in the reserve. These all occur in areas of similar rainfall and soil type, but differ in vegetation structure and composition (Figure 3).
A brief overview of the four cerrado ecotypes (Mares M. E., 1989):

Campo Limpio: open grassland with variable densities of grasses, sedges and small shrubs. No woody vegetation extending above the grass.
Campo Sucio: grassland with scattered woody shrubs or palm-like species appearing above the grass.
Sensu Strictu: semi-deciduous tree/shrub woodland with an open canopy and ground cover of forbs and grasses. Ground cover ranging from 10% - 60%.
Cerradon: moderately tall trees, up to 9 metres, with a closed to semi-closed canopy.

Reserva Natural Laguna Blanca was declared an important Bird Area by BirdLife International in 2010, which means that it has an official protected status (Guyra Paraguay, 2008).

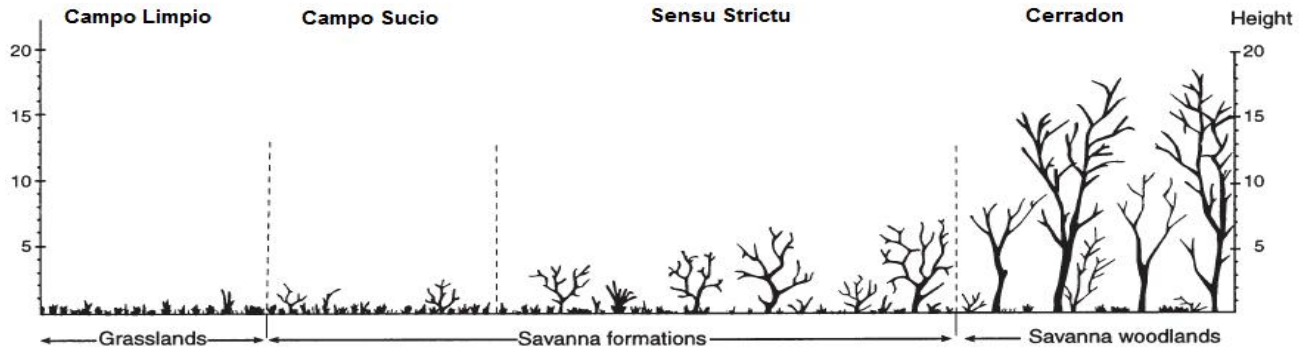

Figure 3: Vegetation structure at the four different study sites in the cerrado habitat. Height is in metres (Schmidt N., 2009)

The study also examined vegetation structure in Eucalyptus plantations, which border the reserve. The plantations are owned and managed by AgroForestal Rio Verde and were set up on former cerrado land approximately 10 years ago. They consist of *Eucalyptus grandis* trees aged 1, 3, 5 or 7 years, and scattered throughout the area covering approximately 750 ha (Figure 4). The plantations are homogeneous with little undergrowth.

Figure 4: Locations of the eight study sites. The yellow locations are cerrado and the red locations are plantations (Google Earth, 2007)

2.2 Methodology

2.2.1 Area selection

The influence of Eucalyptus plantations on cerrado bird species can be measured by comparing inventories obtained from each of these broad habitat types.

To account for variation within the habitat types, four different ecotypes were chosen to represent each of the Eucalyptus and cerrado. The cerrado habitat types were the campo limpio, campo sucio, sensu strictu and cerradon, while the plantations included four different age classes: 1, 3, 5 and 7 year.

The cerrado ecotype sites were selected from a contiguous area of the ecotype, to avoid any influence from different vegetation in the adjoining areas.

The plantations were selected by examining an existing map on Google Earth, provided by Para la Tierra, which showed the size and the cultivation age of all plantations in the area. Plantations were cultivated in squares per age, so all trees of the same age were found next to each other. The survey sites within plantations of the same age were not adjacent to each other to minimise the chance of counting the same birds during one survey.

2.2.2 Survey methods

The survey methods used were the McKinnon method and the Time Schedule Count (Bibby C. J., 2000), with the second being conducted in case of a possible failure with the first.
The McKinnon method is often used by researchers who are not familiar with the local avifauna. This method provides data on the relative abundance of bird species per study site. The purpose of the McKinnon method is to create a bird list containing five species, beginning a new list when each is completed, until five lists have been accumulated. This process is repeated once per visit to each study site. It is possible to record the same species on each list, but one species is never recorded twice on one list. All birds are recorded, including those that were are flying over if they are considered to be using the area (circling, hovering etc.).
The McKinnon method is one of the few that do not impose a time restriction, allowing the inexperienced observer a chance to determine the bird species recorded (Sutherland W. J., 2004).

The second method, the Time Schedule Count (TSC), indicates which species are the most common at each study site. During a period of one hour, all bird species are written down once, at the time they were seen. After one hour, all species recorded within the hour are allocated points based on the time they were detected. Species seen in the first ten minutes of a survey hour receive six points, species seen between ten and twenty minutes are awarded 5 points, and so forth until the end of the hour. After all surveys were completed at a site, the number of points per species were summed and divided by the number of survey hours. A higher average for a certain species indicates that it is more likely to be seen at the study site.
In addition to both of the above methods, all individual birds per species were recorded to enable the calculation of species richness and abundance per site. The abundance of a species at a site was considered to indicate how dependent the species was on the habitat at that location.

During each survey, the number of bird species, number of individuals and their behaviour was recorded. For the species seen in the plantations, their location was recorded as either being within ten metres of the edge, or in the middle of the plantation.

2.2.3 Time span

During April 2013, each study site was visited four times, twice in the early morning and twice in the late afternoon, because these are the periods when bird activity is the highest. The early morning surveys were conducted between 6 and 9 am and the late afternoon surveys occurred between 3 and 6 pm. A study site was visited no more than once every five days to minimise double counting's of individuals. With two hours allowed for observers to cover the target area on each visit, a total of eight hours was spent at each study site.

2.2.4 Vegetation measurements

Habitat requirements vary greatly among bird species, depending on their ecology. Vegetation measurements were taken to indicate whether there are differences in habitat that could affect the number of species found at a study site. These vegetation measurements focused on the undergrowth cover, the height of the undergrowth and the canopy cover (Suddjian D. L., 2004) .
Vegetation measurements were taken according to the National Vegetation Classification of the UK (Rodwell J. S., 2006), which describes how to take measurements in random plots.
At each study site, six randomly positioned plots of 4x4m were used to measure the percentage cover of vegetation up to 3m tall (Rodwell J. S., 2006). The randomly selected plots were established on every $1/6^{th}$ of the track, this was pointed out on a map of each area.

Coverage measurements of herbaceous plants from 0 – 30cm were taken using a 2x2m square, positioned within each 4x4m plot, so that a total of six measurements were obtained. To estimate the undergrowth height at each study site, the tallest growing twig or grass was measured within each 4x4m plot.
The canopy cover was measured by standing in the middle of each 4x4m square, pointing a camera straight up, and taking a photo. A raster of 100 squares was placed over the photo, which made it possible to count the percentage canopy cover.
All six measurements of herbaceous vegetation cover, undergrowth height and canopy cover per study site were averaged to give a single value for each at the site.

2.2.5 Data analysis

All data was entered into Microsoft Access to obtain a complete overview of the number of species and vegetation characteristics per study site.
To examine whether the plantations had a direct influence on cerrado bird species, a t-test was used to compare the total number of species observed in the cerrado and plantations (Fowler J., 2009), with a confidence interval of 95%. The outcome showed if there was a statistical difference between the number of species in the Eucalyptus plantations and the cerrado.
A Pearson's correlation test was conducted online (Kahn J., 2010; Fowler J., 2009) to determine whether there was a relationship between the number of bird species and the density of undergrowth, with a confidence interval of 95%.

3. Results

3.1 Birds of the cerrado and plantations

After 32 hours of surveying four different cerrado ecotypes and further 32 hours in Eucalyptus plantations of four different ages, an overall bird species list could be compiled for the two main habitat types, as well as a list for every study site.

A total of 44 different bird species, consisting of 556 individuals, were found in the cerrado, while the plantations used 24 different bird species, incorporating 116 individuals (Table 1).

Table 1: Species recorded during the 2013 surveys in cerrado and Eucalyptus plantations (grey highlighting indicates red-list or endemic species)

	Cerrado	
No.	**Common Name**	**Scientific Name**
1	Tataupa Tinamou	*Crypturellus tataupa*
2	Red-winged Tinamou	*Rhynchotus rufescens*
3	Greater Rhea	*Rhea americana*
4	Turkey Vulture	*Cathartes aura*
5	Black Vulture	*Coragyps atratus*
6	Roadside Hawk	*Buteo magnirostris*
7	White-tailed Hawk	*Buteo albicaudatus*
8	American Kestrel	*Falco sparverius*
9	Aplomado Falcon	*Falco femoralis*
10	Southern-Crested Caracara	*Caracara plancus*
11	Eared Dove	*Zenaida auriculata*
12	Picazuro Pigeon	*Patagioenas picazuro*
13	Blue-fronted Amazon	*Amazona aestiva*
14	Guira Cuckoo	*Guira guira*
15	Burrowing Owl	*Athene cunicularia*
16	Nacunda Nighthawk	*Podager nacunda*
17	Pauraque	*Nyctidromus albicollis*
18	Blue-tufted Starthroat	*Heliomaster furcifer*
19	Glittering-bellied Emerald	*Chlorostilbon lucidus*
20	Spot-backed Puffbird	*Nystalus maculatus*
21	Toco Toucan	*Ramphastos toco*
22	Campo Flicker	*Colaptes campestris*
23	Pale-breasted Spinetail	*Synallaxis albescens*
24	Narrow-billed Woodcreeper	*Lepidocolaptes angustirostris*
25	Grey Elaenia	*Myiopagis caniceps*
26	Pearly-vented Tody Tyrant	*Hemitriccus margaritaceiventer*
27	Vermilion Flycatcher	*Pyrocephalus rubinus*
28	Great Kiskadee	*Pitangus sulphuratus*
29	Brown-crested Flycatcher	*Myiarchus tyrannulus*
30	Rufous Casiornis	*Casiornis rufus*
31	White-rumped Monjita	*Xolmis velatus*
32	Purplish Jay	*Cyanocorax cyanomelas*
33	Curl-crested Jay	*Cyanocorax cristatellus*
34	Plush-crested Jay	*Cyanocorax chrysops*
35	House Wren	*Troglodytes aedon*
36	Chalk-browed Mockingbird	*Mimus saturninus*
37	Grassland Sparrow	*Ammodramus humeralis*
38	Epaulet Oriole	*Icterus cayanensis*
39	White-rumped Tanager	*Cypsnagra hirundinacea*
40	White-banded Tanager	*Neothraupis fasciata*
41	Red-crested Finch	*Coryphospingus cucullatus*
42	Wedge-tailed Grassfinch	*Emberizoides herbicola*
43	Capped Seedeater	*Sporophila bouvreuil*
44	Black-throated Saltator	*Saltator atricollis*

Plantation	
Common Name	**Scientific name**
Red-winged Tinamou	*Rhynchotus rufescens*
Red-legged Seriema	*Cariama cristata*
Turkey Vulture	*Cathartes aura*
Black Vulture	*Coragyps atratus*
White-tailed Hawk	*Buteo albicaudatus*
American Kestrel	*Falco sparverius*
Eared Dove	*Zenaida auriculata*
Ruddy-ground Dove	*Columbina talpacoti*
White-tipped Dove	*Leptotila verreauxi*
Picazuro Pigeon	*Patagioenas picazuro*
Guira Cuckoo	*Guira guira*
Burrowing Owl	*Athene cunicularia*
Glittering-bellied Emerald	*Chlorostilbon lucidus*
Campo Flicker	*Colaptes campestris*
Flycatcher/Elaenia	
Great Kiskadee	*Pitangus sulphuratus*
Purplish Jay	*Cyanocorax cyanomelas*
Curl-crested Jay	*Cyanocorax cristatellus*
House Wren	*Troglodytes aedon*
Grassland Sparrow	*Ammodramus humeralis*
White-banded Tanager	*Neothraupis fasciata*
Black-throated Saltator	*Saltator atricollis*
Unidentified Spec. 1	
Unidentified Spec. 2	

In all cases, the cerrado study sites yielded a greater number of species than the Eucalyptus plantation sites (Figure 5), indicating that the avian diversity in the cerrado is higher than in the plantations. The most productive study site was the cerradon, which recorded 31 different bird species and 255 individual birds. A bird list for each study site, including the number of individuals observed, can be found Appendix I (cerrado) and Appendix II (plantations).

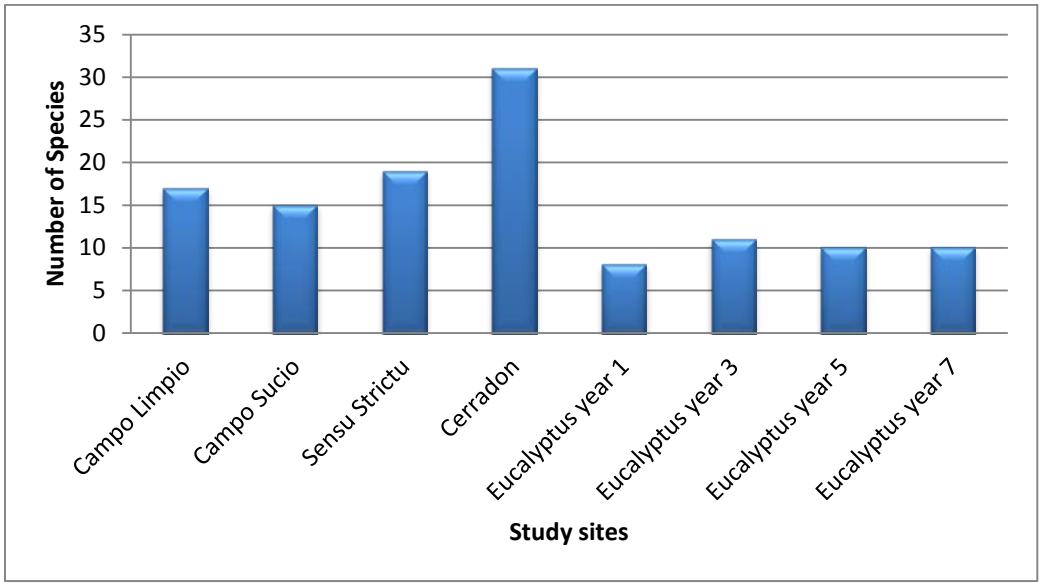

Figure 5: Number of bird species recorded per study site

3.2 Red list species

Three species, found at every study site within the cerrado, are listed as vulnerable on the Paraguayan red list (IUCN, 2012): the Curl-crested Jay *(Cyanocorax cristatellus*), White-rumped Tanager (*Cypsnagra hirundinacea*) and White-banded Tanager (*Neothraupis fasciata*). Of these, the Curl-crested Jay and White-banded Tanager, were also found in the plantations, but not at all study sites and in much lower numbers (Table 2). The cerrado is so unique in vegetation composition and structure that several bird species are endemic to it (da Silva, 1997). Two of these endemic species, the Curl-crested Jay and Black-throated Saltator (*Saltator atricollis)*, were found at every study site within the cerrado during the survey hours (Table 2).

Table 2: Numbers of red listed (●) and endemic (○) species recorded per study site. The highest number is the highest number of individuals of the selected species counted during a single survey.

Species	Study site	Highest number of individuals recorded
White-rumped Tanager ●	Campo Limpio	2
	Campo Sucio	4
	Sensu Strictu	2
	Cerradon	3
White-banded Tanager ●	Campo Limpio	2
	Campo Sucio	7
	Sensu Strictu	5
	Cerradon	6
	Eucalyptus year 1	2
Curl-crested Jay ●○	Campo Limpio	6
	Campo Sucio	8
	Sensu Strictu	6
	Cerradon	9
	Eucalyptus year 3	2
	Eucalyptus year 5	3
	Eucalyptus year 7	8
Black-throated Saltator ○	Campo Limpio	1
	Campo Sucio	3
	Sensu Strictu	2
	Cerradon	3
	Eucalyptus year 1	2

Curl-crested Jays were observed moving around in groups, using the Eucalyptus mostly as roosting sites in the late afternoon or early morning. The first year Eucalyptus was not used at all by this species because they were not tall or strong enough to roost in. The other three species are smaller birds that use shrubs as lookout posts. These birds were not seen in the older Eucalyptus plantations, because shrubs do not usually persist in plantations beyond the first year.

The species accumulation curves for both sites indicate that the 16 visits to each habitat was sufficient to record the majority of bird species in each area. (Figure 6).

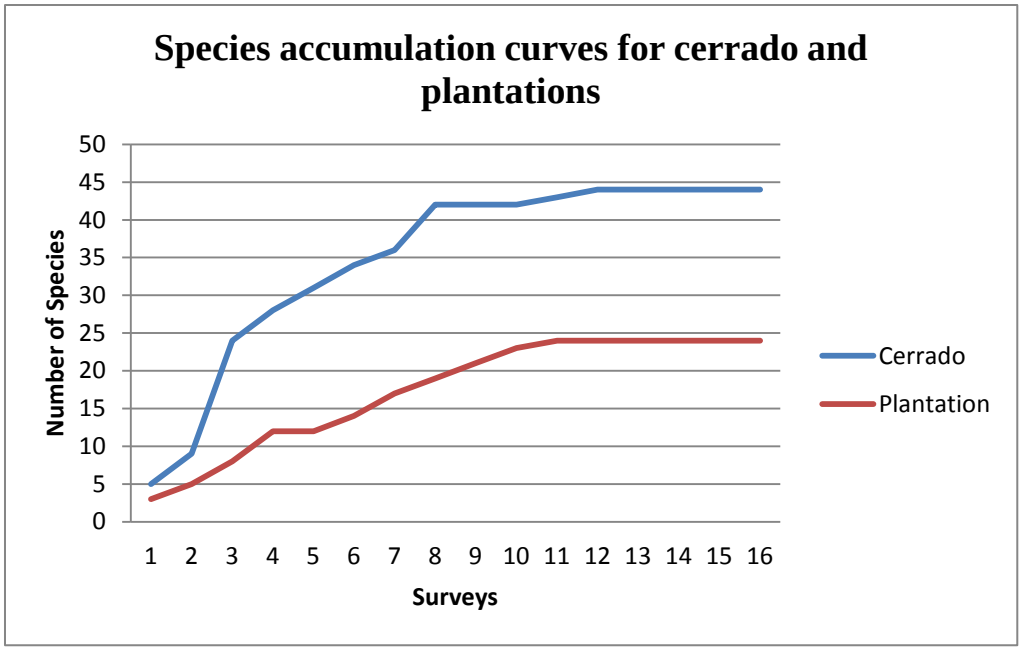

Figure 6: Species accumulation curves for the cerrado and plantation habitat

3.3 Difference in bird communities

The Eucalytpus plantation and cerrado habitats are home to a large range of bird species, some of which are adapted to particular conditions and some species will therefore be found in some areas but not in others.

As seen in the complete bird list, only three species were found in the plantations and not in the cerrado (Table 1). All species seen during the plantation surveys have generalist habitat preferences and are distributed widely low throughout Paraguay, apart from the red listed and endemic species. The birds seen only in the cerrado are not necessarily rare, but are adapted to the specific characteristics of this habitat. The chances of finding a particular bird species in a certain area depends on the ecology of the bird itself. Details on which bird species are attracted to which habitats, and how common the birds were in those habitats, can be found in Appendices I and II.

The total of 44 species recorded in the cerrado habitat was found to be significantly greater than the 24 recorded in the plantation habitat, ($t(6) = -2.95$, $p = 0.026$), with a confidence interval of 95%.

4. Characteristics of the cerrado and plantations

Despite all study sites being located close together, there were some differences between the characteristics of the habitats observed, and vegetation surveys were conducted to determine where the differences lay.

4.1 Eucalyptus plantations

The plantations are characterised as homogeneous stands of *E. grandis* trees between 16 and 18 metres tall, excluding the first year plantations which consisted of trees between 2.5 and 4 metres tall. The long rows of neatly ordered trees are distinct from the surrounding areas, and the long bare tree trunks make it possible to look from one side of the plantation to the other.
The undergrowth, comprising the herb and shrub layer, is minimal in all plantations (Table 3).
The three year plantation had almost no undergrowth except around the edges, most likely due to the use of herbicide and the shade produced by the dense canopy. The herbicide seems to be used only in third year plantations, with the undergrowth at plantation age 1 being manually removed by employees with hoes and shovels. The first manual pruning of branches occurs when the trees are two years of age.
Table 3 describes the cover and height of undergrowth below three metres and the canopy cover for the various plantation ages included in this study.

Table 3: Characteristics of the plantation study sites

Plantation characteristics			
Plantation age (year)	**Undergrowth cover (%)**	**Undergrowth height (cm)**	**Canopy cover (%)**
1	34	130	0
3	6	40	76
5	46	120	53
7	18	110	48

The undergrowth of the first year plantation includes branches of Eucalyptus trees which were not pruned, and entire trees shorter than 3 metres.
The density of the undergrowth within the fifth year plantation is extremely high compared to the other study sites. This is possibly a result of thinning operations, which are carried out in a plantations third or fourth year, reducing the canopy cover and allowing more light to reach the ground.

4.2 Cerrado

A great variety of habitat characteristics exist within the cerrado, with areas ranging from dense forest to open grassfields (Figure 3), supporting an equally diverse array of plants and animal species.
Trees found in the cerrado have thick, soft bark that feels like cork, and most have small leaves. These features are adaptations to the dry conditions and protects the plants from natural fires.
Smaller plant species also show drought tolerance, with most grass species being woody and shrubs having thick, leathery leaves.
Measurements of vegetation taken at all study sites defined the four ecotypes of the cerrado (Table 4). Three study sites did not have any canopy, which resulted in taller and denser undergrowth.

Table 4: Characteristics of the cerrado study sites

Cerrado characteristics			
Area	**Undergrowth cover (%)**	**Undergrowth length (cm)**	**Canopy cover (%)**
Campo Limpio	78	210	0
Campo Sucio	78	230	0
Sensu Strictu	87	230	0
Cerradon	75	170	37

5. Birds and vegetation growth

As previously discussed, the surveys recorded more bird species in the cerrado than in the plantations. Most bird species rely on dense vegetation which occurs in layers, including herb-, shrub- and tree layers. All of these layers can be found in the cerradon habitat, explaining the high diversity of bird species (31) seen at that study site.

To determine whether there was a relationship between the undergrowth density and the number of bird species, a Pearson's correlation was conducted.

The correlation showed that there was a positive correlation between undergrowth density at a site and the number of bird species recorded, ($r(6) = .75$, $p = 0.03$), indicating that a positive relationship exists between the number of bird species and the percentage cover of undergrowth (Figure 7).

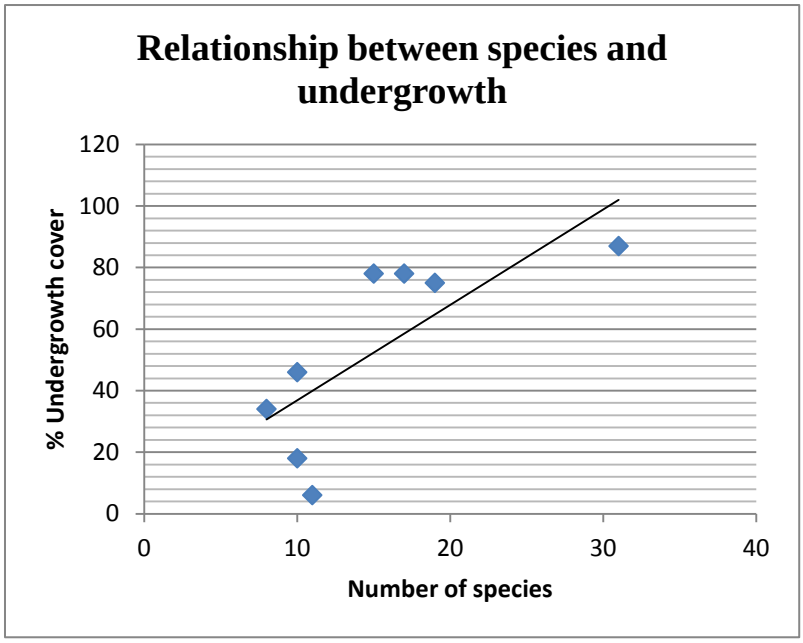

Figure 7: Relationship between the number of species and the percentage undergrowth cover

6. Habitat usage

There is a considerable difference in the number of individual birds seen in the two types of habitat, with 556 observed in the cerrado and 116 in the plantations. It is important to determine how these individuals are using each area (Table 5).

Table 5: Habitat use of individuals observed during the surveys

Cerrado	
Behaviour	**Individuals**
Calling	125
Resting	110
Foraging	108
Roosting	56
Alarming	43
Flushed	37
Circling	32
Feeding	20
Moving	16
Hunting	9

Plantations	
Behaviour	**Individuals**
Foraging	28
Calling	26
Roosting	18
Flushed	16
Resting	9
Moving	6
Circling	5
Flying	3
Alarming	2
Landing	2
Feeding	1

The roosting birds in the plantation were observed during the early morning and late afternoon, implying that they are using the high Eucalyptus trees as roosting sites. The tall straight trees without any lower branches, do not allow nocturnal, terrestrial predators to access the canopy, and are an ideal place to shelter.
The calling individuals recorded in the cerrado are birds that were heard but not seen during the surveys, due to the dense vegetation. The circumstances were similar in the plantations, where most calling birds were high in the dense canopy and couldn't be seen. The term moving refers to birds seen entering the study site during the survey, or moving from tree to tree, but not engaged to any of the other activities.
There were some slight differences in the behaviour of individuals between the study sites (Table 6).

Table 6: Total number of individuals displaying each behaviour per study site

Cerrado		
Study site	**Behaviour**	**Individuals**
Campo Limpio	Flushed	18
Campo Sucio	Calling	35
Sensu Strictu	Resting	25
Cerradon	Resting	58

Plantations		
Study site	**Behaviour**	**Individuals**
Age 1	Calling/Flushed	5
Age 3	Calling	13
Age 5	Foraging	15
Age 7	Roosting	17

The flushed individuals at the campo limpio study site were birds that occur in tall grass and will only fly up or move when they feel threatened. The sensu strictu and cerradon contain many open areas, where birds are easily observed resting on branches, or on top of bushes or trees.
The campo sucio and first year Eucalyptus plantations are dense areas where most birds are detected by their call before being seen, or flushed while foraging amongst the vegetation.

The calling birds recorded in third year plantations, and those seen roosting or foraging in the fifth and seventh year Eucalyptus, were all located in the dense canopy, with the lack of undergrowth appearing to discourage many species from spending time on the ground.

6.1 Plantation edge

Of the 116 individuals seen in the plantations, more were located in the 10 metre edge around the plantation than in the middle of the plantation (Table 7).

Table 7: Habitat usage of individuals recorded in the plantations

Area usage	
Area of activity	**Individuals**
Middle of plantation	46
Within 10m of edge	65
No use of specific area	5

The main reason for this difference in activity is the undergrowth being higher and denser around the edges, as a result of the increased light availability. In addition, the roads and roadside verges adjacent to all plantations provide foraging opportunities and shelter for some species, with individuals moving between the road and plantations as traffic passes by.
The 5 individuals defined as ‘no use of a specific area’ were birds that were circling or scanning the landscape showing no preference towards the middle or the edge of the plantation.

7. Discussion

The results of this study show a significant difference in the number of bird species occurring in the plantations and the cerrado. The most important factor appears to be the amount of vegetation cover below 3 metres. Woinarski (1979) also found that the diversity of bird species was slightly higher in natural areas compared to Eucalyptus plantations.

The importance of this data is that birds, which often experience difficulty in adapting to certain artificial habitats, are driven out of the cerrado when it is converted into a plantation. Species that are reliant upon shrubs and undergrowth, are unlikely to occur in the plantations. A similar situation has been observed in *E. grandis* plantations in South Africa, with Steyn (1977) finding that plantations had less diverse flora and fauna than indigenous forests.
The flora at the Paraguayan study sites was not identified to species level, however, this could be investigated in a future study comparing cerrado and Eucalyptus plantations.

The height of the undergrowth in combination with the density, is an important factor influencing the presence and number of species that occur in an area (MacArthur 1961; Orians 1969; Tubelius, 1997). The majority of bird species in this study were recorded in the cerradon, which was previously considered to be gallery forest rather than cerrado (Sick 1966), but is now considered an element of cerrado habitat. Because the occurrence of the same vegetation type and the use of the same soil circumstances as in other cerrado types, the cerradon considered to be a part of the cerrado.

According to Negret (1983), the campo limpio should have the lowest species richness in the cerrado, because of the simple vegetation structure, but this study showed the campo sucio to have the fewest species. Although the campo limpio has fewer individuals (86) than the campo sucio (126).
A possibility to this finding could be the visibility within the campo sucio, which was difficult through the shrubs. The results also showed that the most individuals within the campo sucio were observed calling and were not seen, so small birds that were moving around were not recorded during the surveys. The most birds in the campo limpio were flushed, if the surveys were done from an existing road the campo limpio would probably show the fewest species.

Eucalyptus stands tend to be used by birds mainly as foraging and roosting sites, but they are also reportedly used for nesting, particularly by raptors (Suddjian, 2004). At least 32 hours were spent surveying the plantations in Paraguay, and despite raptors were seen flying through the Eucalyptus, and roosting at the top of the trees, not a single nest was observed.

This research was focused only on birds and the lower vegetation, but other questions, such as the influence of tree density on bird populations, could be examined in the future. Different results may also be obtained if this survey was conducted at a different time of year, as many migratory species are absent during the months this study was conducted. It is also not known what influence monocultural plantations of native tree species have on cerrado bird communities.
In order to gain a better understanding of how Eucalyptus plantations affect cerrado dependent species, the responses of other floral and faunal groups also need to be studied. This information could assist in the development of a conservation plan to sustainably manage the existing cerrado habitat.

8. Conclusions

This study has shown that the bird diversity within Eucalyptus plantations is much lower than that of the native cerrado habitat. With 24 species recorded in the plantations, and 44 in the cerrado, it is evident that the latter is significantly more attractive to birds ($t(6) = -2.95$, $p = 0.026$). This notion is further supported by the fact that 556 individual birds were seen in the cerrado, while the plantations recorded only 116 individuals.
All bird species seen in the plantations, except for the red listed and endemic species, lack any specific habitat preferences and are found throughout the entire country. In contrast, most of the species only on the cerrado bird list (23) have special habitat requirements, making the conservation of cerrado important for these species.

The difference between the two habitats is the vegetation, which is much more complex in the cerrado. The results of this study show that the amount of undergrowth up to 3 metres is important in determining the number of birds using the habitat ($r(6) = .75$, $p = 0.03$), with more species expected in the undergrowth of higher density.
The amount of undergrowth is influenced by the canopy cover, with the dense canopy in the plantations resulting in minimal undergrowth. Undergrowth is particularly low in the third year plantations, but probably due to the use of herbicide, rather than increased canopy cover.
The monocultural Eucalyptus stands have very little stratification, consisting only of a canopy layer, and a small herb layer that is not attractive to birds.

The cerradon is attractive to largest variety of bird species due to the high diversity of plant species and the complex vegetation layering. The other cerrado study sites, while having lower species richness than the cerradon, support more species than plantation of any age, because they also have a considerable amount of undergrowth.
The species seen in the plantations were mostly located within 10 metres of the edge. This can be explained by the undergrowth height and density, which is much higher around the edges than in the centre of the plantation, probably due to the availability of sunlight.

Paraguayan red listed and endemic species were found in high numbers in the cerrado and in lower numbers in the plantations. The plantation sightings were incidental, except for the Curl-crested Jay, meaning the species were only seen once during the 16 surveys. This indicates that the red listed and endemic species likely rely on the cerrado for food and nesting.

This study found no difference in the usage of the cerrado or plantation by the birds present; calling, roosting and foraging were dominant behaviours recorded in both habitats. Roosting in the plantations was a behaviour shown only by the red listed Curl-crested Jays, which were present in the taller Eucalyptus trees during the early morning or late afternoon, and likely remained there during the night as this location was inaccessible to terrestrial predators.

9. Recommendations

It is highly recommended that the government modify the national forestry legislation (Ley No. 536 de 1995) by removing the incentive for land owners to replace valuable cerrado habitat with (exotic) plantations.

The construction of indigenous vegetation corridors, 20 – 30 metres wide, between plantations would reconnect the adjacent cerrado sites and allow the majority of flora and fauna species to move through the area. When establishing new plantations, developers should retain a strip of mature vegetation and ensure it is subjected to a minimum level of human disturbance (Brudvig L. A. 2009; Yale environment 360, 2011).

If weeds need to be removed from within plantations, it would be preferable to do this manually rather than by applying herbicides. Although chemical use was observed in the third year plantation, people were seen removing weeds from the first year plantation by hand, indication that it is possible to use this method instead. In fact, the canopy density in the third year plantation was so high that it appeared very few weeds were likely to germinate on the ground beneath the trees.

Future studies should investigate the use of Eucalyptus plantations by species other than birds. This information would improve our understanding of the influence plantations have on the natural landscape and biodiversity, and the effect of cerrado habitat loss. It could also be used to direct future research, and to assist land owners in managing their properties sustainably.

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Appendix I

Overview of all bird species recorded in the cerrado

Highest count = The highest number of individuals of the selected species recorded during a single survey
Total individuals = The total number of individuals counted after 4 surveys
Occurrence (TSC method) = The presence or abundance of a species according to the Time Schedule Count. The higher the number, the more likely the species will be observed in the selected area.

Campo Limpio					
No.	**Common Name**	**Scientific Name**	**Highest count**	**Total individuals**	**Occurrence (TSC method)**
1	Red-winged Tinamou	*Rhynchotus rufescens*	2	2	0.50
2	Turkey Vulture	*Cathartes aura*	2	5	1.25
3	Roadside Hawk	*Buteo magnirostris*	1	1	0.75
4	White-tailed Hawk	*Buteo albicaudatus*	1	1	0.13
5	American Kestrel	*Falco sparverius*	1	4	2.38
6	Aplomado Falcon	*Falco femoralis*	2	2	0.25
7	Southern-Crested Caracara	*Caracara plancus*	8	8	0.13
8	Eared Dove	*Zenaida auriculata*	2	3	1.75
9	Guira Cuckoo	*Guira guira*	7	7	0.75
10	Campo Flicker	*Colaptes campestris*	5	6	1.75
11	Pale-breasted Spinetail	*Synallaxis albescens*	1	1	0.25
12	Curl-crested Jay	*Cyanocorax cristatellus*	6	10	1.25
13	Grassland Sparrow	*Ammodramus humeralis*	7	24	4.75
14	White-rumped Tanager	*Cypsnagra hirundinacea*	2	2	0.25
15	White-banded Tanager	*Neothraupis fasciata*	2	2	0.63
16	Wedge-tailed Grassfinch	*Emberizoides herbicola*	2	4	1.63
17	Black-throated Saltator	*Saltator atricollis*	1	4	1.63

Campo Sucio					
No.	**Common Name**	**Scientific Name**	**Highest count**	**Total individuals**	**Occurrence (TSC method)**
1	Red-winged Tinamou	*Rhynchotus rufescens*	1	2	1.00
2	Greater Rhea	*Rhea americana*	2	2	0.38
3	Black Vulture	*Coragyps atratus*	15	15	0.38
4	Roadside Hawk	*Buteo magnirostris*	1	1	0.63
5	American Kestrel	*Falco sparverius*	1	1	0.50
6	Eared Dove	*Zenaida auriculata*	2	5	2.13
7	Burrowing Owl	*Athene cunicularia*	1	2	1.50
8	Campo Flicker	*Colaptes campestris*	3	6	0.88
9	Curl-crested Jay	*Cyanocorax cristatellus*	8	27	3.38
10	House Wren	*Troglodytes aedon*	2	4	0.75
11	Grassland Sparrow	*Ammodramus humeralis*	2	3	0.75
12	White-rumped Tanager	*Cypsnagra hirundinacea*	4	7	2.00
13	White-banded Tanager	*Neothraupis fasciata*	7	35	4.50
14	Red-crested Finch	*Coryphospingus cucullatus*	2	3	0.50
15	Black-throated Saltator	*Saltator atricollis*	3	13	3.38

Cerradon					
No.	**Common Name**	**Scientific Name**	**Highest count**	**Total individuals**	**Occurrence (TSC method)**
1	Tataupa Tinamou	*Crypturellus tataupa*	1	2	1.25
2	Roadside Hawk	*Buteo magnirostris*	1	4	1.75
3	American Kestrel	*Falco sparverius*	1	4	1.88
4	Aplomado Falcon	*Falco femoralis*	2	4	1.25
5	Southern-crested Caracara	*Caracara plancus*	2	3	1.00
6	Eared Dove	*Zenaida auriculata*	40	53	2.38
7	Picazuro Pigeon	*Patagioenas picazuro*	2	3	1.13
8	Blue-fronted Amazon	*Amazona aestiva*	2	2	0.75
9	Nacunda Nighthawk	*Podager nacunda*	1	1	0.13
10	Pauraque	*Nyctidromus albicollis*	1	1	0.63
11	Glittering-bellied Emerald	*Chlorostilbon lucidus*	1	7	3.38
12	Toco Toucan	*Ramphastos toco*	1	1	0.13
13	Campo Flicker	*Colaptes campestris*	3	12	2.50
14	Narrow-billed Woodcreeper	*Lepidocolaptes angustirostris*	3	10	4.13
15	Grey Elaenia	*Myiopagis caniceps*	1	5	2.50
16	Pearly-vented Tody Tyrant	*Hemitriccus margaritaceiventer*	1	3	1.75
17	Vermilion Flycatcher	*Pyrocephalus rubinus*	1	1	0.25
18	Great Kiskadee	*Pitangus sulphuratus*	1	1	0.63
19	Brown-crested Flycatcher	*Myiarchus tyrannulus*	2	7	3.38
20	Rufous Casiornis	*Casiornis rufus*	1	1	0.25
21	White-rumped Monjita	*Xolmis velatus*	2	6	2.88
22	Purplish Jay	*Cyanocorax cyanomelas*	5	6	1.25
23	Curl-crested Jay	*Cyanocorax cristatellus*	9	27	3.25
24	Plush-crested Jay	*Cyanocorax chrysops*	1	2	0.75
25	House Wren	*Troglodytes aedon*	1	4	1.88
26	Chalk-browed Mockingbird	*Mimus saturninus*	3	6	1.38

27	Grassland Sparrow	*Ammodramus humeralis*	1	3	0.75
28	White-rumped Tanager	*Cypsnagra hirundinacea*	3	7	2.38
29	White-banded Tanager	*Neothraupis fasciata*	6	17	2.63
30	Red-crested Finch	*Coryphospingus cucullatus*	4	30	4.88
31	Black-throated Saltator	*Saltator atricollis*	3	22	5.00

Sensu Strictu					
No.	**Common Name**	**Scientific Name**	**Highest count**	**Total individuals**	**Occurrence (TSC method)**
1	Tataupa Tinamou	*Crypturellus tataupa*	1	1	0.50
2	Turkey Vulture	*Cathartes aura*	1	1	0.63
3	Black Vulture	*Coragyps atratus*	2	2	0.25
4	American Kestrel	*Falco sparverius*	1	1	0.25
5	Eared Dove	*Zenaida auriculata*	3	5	1.88
6	Blue-tufted Starthroat	*Heliomaster furcifer*	1	1	0.38
7	Spot-backed Puffbird	*Nystalus maculatus*	1	1	0.50
8	Campo Flicker	*Colaptes campestris*	2	4	1.25
9	Pale-breasted Spinetail	*Synallaxis albescens*	1	1	0.50
10	Narrow-billed Woodcreeper	*Lepidocolaptes angustirostris*	1	1	0.75
11	Pearly-vented Tody Tyrant	*Hemitriccus margaritaceiventer*	1	2	1.00
12	Curl-crested Jay	*Cyanocorax cristatellus*	6	10	2.13
13	Grassland Sparrow	*Ammodramus humeralis*	3	7	2.13
14	Epaulet Oriole	*Icterus cayanensis*	1	1	0.75
15	White-rumped Tanager	*Cypsnagra hirundinacea*	2	7	2.88
16	White-banded Tanager	*Neothraupis fasciata*	5	20	2.88
17	Red-crested Finch	*Coryphospingus cucullatus*	4	13	3.00
18	Capped Seedeater	*Sporophila bouvreuil*	1	1	0.38
19	Black-throated Saltator	*Saltator atricollis*	2	10	3.25

Appendix II

Overview of all bird species recorded in the plantations

Highest count = The highest number of individuals of the selected species recorded during a single survey
Total individuals = The total number of individuals counted after 4 surveys
Occurrence (TSC method) = The presence or abundance of a species according to the Time Schedule Count. The higher the number, the more likely the species will be observed in the selected area.

Eucalyptus year 1					
No.	**Common Name**	**Scientific Name**	**Highest count**	**Total individuals**	**Occurrence (TSC method)**
1	Red-legged Seriema	*Cariama cristata*	2	3	1.00
2	American Kestrel	*Falco sparverius*	1	1	1.00
3	Eared Dove	*Zenaida auriculata*	2	4	1.50
4	Picazuro Pigeon	*Patagioenas picazuro*	1	1	0.63
5	Burrowing Owl	*Athene cunicularia*	1	1	0.75
6	Grassland Sparrow	*Ammodramus humeralis*	1	2	1.00
7	White-banded Tanager	*Neothraupis fasciata*	2	2	0.63
8	Black-throated Saltator	*Saltator atricollis*	2	3	1.50

Eucalyptus year 3					
No.	**Common Name**	**Scientific Name**	**Highest count**	**Total individuals**	**Occurrence (TSC method)**
1	American Kestrel	*Falco sparverius*	2	3	1.00
2	Eared Dove	*Zenaida auriculata*	1	1	0.88
3	Ruddy-ground Dove	*Columbina talpacoti*	2	3	1.50
4	Picazuro Pigeon	*Patagioenas picazuro*	1	4	1.00
5	Campo Flicker	*Colaptes campestris*	1	1	0.50
6	Great Kiskadee	*Pitangus sulphuratus*	1	3	1.38
7	Flycatcher/Elaenia		1	1	0.75
8	Curl-crested Jay	*Cyanocorax cristatellus*	2	2	0.25
9	House Wren	*Troglodytes aedon*	1	1	0.50
10	Unidentified Spec. 1		1	1	0.75
11	Unidentified Spec. 2		1	1	0.38

Eucalyptus year 5					
No.	**Common Name**	**Scientific Name**	**Highest count**	**Total individuals**	**Occurrence (TSC method)**
1	Red-winged Tinamou	*Rhynchotus rufescens*	1	2	0.88
2	Turkey Vulture	*Cathartes aura*	2	2	0.50
3	Black Vulture	*Coragyps atratus*	2	2	0.75
4	American Kestrel	*Falco sparverius*	2	5	2.50
5	Eared Dove	*Zenaida auriculata*	1	1	0.63
6	Picazuro Pigeon	*Patagioenas picazuro*	2	2	0.75
7	Guira Cuckoo	*Guira guira*	4	7	1.13
8	Glittering-bellied Emerald	*Chlorostilbon lucidus*	1	1	0.38
9	Campo Flicker	*Colaptes campestris*	3	8	2.75
10	Curl-crested Jay	*Cyanocorax cristatellus*	3	6	1.25

Eucalyptus year 7					
No.	**Common Name**	**Scientific Name**	**Highest count**	**Total individuals**	**Occurrence (TSC method)**
1	Red-winged Tinamou	*Rhynchotus rufescens*	1	1	0.50
2	White-tailed Hawk	*Buteo albicaudatus*	1	1	0.25
3	American Kestrel	*Falco sparverius*	2	4	1.38
4	Eared Dove	*Zenaida auriculata*	3	6	2.00
5	White-tipped Dove	*Leptotila verreauxi*	1	1	0.38
6	Picazuro Pigeon	*Patagioenas picazuro*	1	1	0.63
7	Campo Flicker	*Colaptes campestris*	3	5	1.75
8	Great Kiskadee	*Pitangus sulphuratus*	1	1	0.75
9	Purplish Jay	*Cyanocorax cyanomelas*	2	4	1.38
10	Curl-crested Jay	*Cyanocorax cristatellus*	8	18	1.88