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A biodiversity inventory and evaluation of forest and silvopastoral systems in Costa Rica

Can silvopastoralism support biodiversity in a degraded pasture landscape?

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Abstract

In agricultural landscapes silvopastoral systems have one of the highest biodiversity index for many animals including birds. I found that if properly managed silvopastoral systems might provide substantial opportunity for the conservation of avifauna utilizing these systems.

In the pastoral landscape of Esparza, Costa Rica, I inventoried vascular plants (≥10 cm DBH) and censused birds in forest, pasture with trees, live fences and degraded pastures to determine whether silvopastoral systems can support biodiversity conservation. I identified 45 species of woody vascular plants and 71 species of birds. Twenty of the 45 plant species and 55 of the 71 bird species were identified in the silvopastoral systems, while the other plant and bird species were identified in the forest habitats.

Although forest habitats were more diverse in both floral and avifaunal species, pasture with trees was highly similar in avian diversity. Pasture with trees harbored both native and migrant bird species as well as native and introduced species of woody plants. Although the forest habitats are likely the most important habitats, the inclusion of silvopastoral systems in the landscape appears to increase connectivity across the landscape and thereby facilitating bird movement.

Content

Introduction

Over the past years large-scale deforestation occurred in Central and Latin America for cattle ranching and other agricultural use (Kaimowitz, 1999). Cattle ranching started in Costa Rica with the arrival of the Spaniards who converted forest to pastures (Montenegro and Abarca, 1998), to capitalize on the increased foreign demand for beef and readily available financing from international development banks (Schelhas, 1991; Hall *et al*., 2000; Ibrahim *et al*., 2000). The development of open pasturelands with grass monocultures that are traditionally managed by burning, which is associated with the loss of soil cover and erosion, low productivity and loss of biodiversity (Serrão & Toledo, 1990; Szott *et al*., 2000), raised a great deal of biodiversity and environmental concerns. These systems may not be suitable as long-term habitats, but may be utilized by birds that can forage in them (Estrada *et al*., 2000; Daily *et al*., 2001). That is why institutions (e.g., CATIE, CIPAV, ICRAF, CIAT etc.) have been developing silvopastoral systems, which mimic forest ecosystems (Naranjo, 2000; Sanchez, 1999), to avoid further loss of biodiversity, degradation of pasturelands, and to accomplish improvement in people's livelihood.

A silvopastoral system is a form of agroforestry system consisting of trees (woody perennials) and pasture/animal components (Nair, 1993). Silvopastoralism involves the inclusion of trees, shrubs and other vegetation on degraded land, to improve social and ecological benefits. These benefits include reduction in climate change, improvement in water filtration, enhancement in soil retention, improvement in farmers' production and economic well-being, and the enhancement of biodiversity conservation (Crawford, 1998; Harvey and Haber, 1999; GEF, 2001; Ibrahim *et al*., 2000). Based on the functions and arrangement of trees the categories of silvopastoral systems classified are: 1) Live fences, 2) dispersed trees in pastures, 3) fodder banks, 4) grazing in forest and fruit plantations (Pezo and Ibrahim, 2000).

Recently, farmers have started to promote the incorporation of trees in their farming systems in order to increase their productivity and income and conservation of natural resources (Ibrahim and Schlönvoigt, 1999; Beer *et al*., 2000; Ibrahim *et al*., 2000). Studies conducted in the humid tropics showed that dairy cattle increased milk production by 20% when they had access to shade trees (Souza *et al*., 1999) and many other studies showed that trees (e.g., *Pithcellobium saman*, *Guazuma ulmifolia* and *Enterolobium cyclocarpum*) are important sources of feed for the cattle in the dry season (Cajas, 2001).

The isolated or dispersed trees within pastures may help to increase the connectivity within the agricultural landscape, by fostering seedling recruitment and regeneration (Estrada *et al*., 2000; Guevara *et al*., 1998; Harvey and Haber, 1999) hence the conservation of plant species. These trees may also help to maintain diversity of both resident and migratory birds, by providing food and habitat for nesting, roosting and perching (Estrada *et al*., 1993a; 1993b). This may depend on their fruiting status, as well as their distance from the nearest forest patch (Harvey, 1999), since these trees may serve as food resources when the forest patch is limited. In addition to conservation of biodiversity a high percentage of timber trees is already produced in pastures and it is foreseen that this trend would continue in the foreseeable future.

Other than isolated trees, some pastures have live fences, which may also serve as a stepping-stone for resident and migratory bird species, providing food and temporary cover from predators. It is suggested that these habitats may be unsuitable for prolonged residency for birds because of exposure to predators and extreme microclimatic conditions (Estrada *et al*., 2000). Many farmers are managing different configurations of trees on pastures, which include a combination of secondary forest, live fencing and trees in pastures that should promote a greater conservation of biodiversity (Restrepo, 2002).

Problem Description/Justification

Pasture expansion has been on the increase and has raised a great deal of concern about the loss of biodiversity in the humid and dry tropics. That is why there is growing interest to use silvopastoral systems to conserve biodiversity, because these systems are generally more diverse and complex in terms of their structure compared to traditional grass monocultures. But, available information on the benefits they represent in terms of biodiversity conservation is still scarce and most of the work has been done on forest patches. For example, there is limited information on the abundance and diversity of bird and vascular plant species in silvopastoral systems and how these systems can conserve the biodiversity of birds.

To determine whether the silvopastoral systems are effective for biodiversity conservation, I examined the bird and woody plant communities present in four different habitats (pasture with isolated trees, degraded pasturelands, live fences and forest patches). This information is important since it will help to clarify the contribution of silvopastoral systems (pasture with trees, live fence) to the conservation of biodiversity. Recently there has been considerable interest to study the importance of rural landscapes in the conservation of biodiversity and to determine how socio-economic situation and livelihoods of rural communities may affect conservation of biodiversity. In this respect, it is important to study the impacts of silvopastoral and other pasture systems on biodiversity, which represents more than 60% of agricultural use in some areas

(Restrepro, 2002; Szott *et al*., 2000), because of the importance these areas can play in the conservation of birds.

This investigation will serve as a pilot project for a larger GEF project: *Integrated Silvo-Pastoral Approaches to Ecosystem Management*. The objectives of this project are twofold; to demonstrate and measure the effects of the introduction of payment incentives for environmental services to farmers on their adoption of integrated silvopastoral farming systems in degraded pasture lands, and the improvements in ecosystem functions, global environmental benefits, and local socio-economic gains resulting from the provision of the said services. The results of this study may serve as a basis for long term monitoring and conservation of habitats, by tracking the impact of these new landscapes on local and regional avifaunas. This will be important since it is suggested that these habitats are critical for the maintenance of biodiversity within the region and also for the establishment of the Mesoamerican Biological Corridor.

Evaluation and inventory are often important means of acquiring the biological information needed to better manage wildlife populations. These temporal data can be used to evaluate the effects of management practices, thus providing critical feedback into the planning process. Biological inventories of selected subsets of the biota, in different habitats and in areas subject to different land-uses, provide baseline information for assessing biological diversity and environmental changes.

Objectives

The main objective of this research is to evaluate silvopastoral systems (pastures with trees) to determine whether they are effective for biodiversity conservation.

Specific objectives

- To characterize the bird communities associated with different pastures, silvopastoral and secondary forest systems (degraded pastures, pasture with trees, live fence and secondary forest)
- To characterize species richness, abundance and structural abundance of woody plants in degraded pastures, pasture with trees, live fence and secondary forest
- To explore the relationships between bird community and woody plant diversity and structure in degraded pastures, pasture with trees, live fence and secondary forest

- To develop recommendations on the value of these systems for conservation and provide baseline and guidelines for the payment of environmental services (specifically biodiversity conservation)

Hypotheses

- The abundance, species richness and diversity of bird communities are positively related to the structural and floristic diversity of degraded pastures, pasture with trees, live fence and secondary forest
- There are differences in the diversity and abundances of bird and tree species in the different habitats

Literature review

Land-use in Costa Rica

In the past, forest habitats in Latin America were cleared to promote extensive cattle production (Kaimowitz, 1996). Ibrahim *et al.*, (2000) and Naranjo, (2000) reported that in Costa Rica, cattle pastures are the main forms of land-use and occupy most of the national lands. Abarca and Montegenero (1998) determined this to be 46% of the total land. However, the cattle density is not at its maximum and could be increased to optimize production (Veldkamp and Fresco, 1997). The inclusion of trees within pastures has served to diversify cattle production areas (Pezo and Ibrahim, 1996. But farmers prefer to have trees in densities that do not negatively affect their production (Stokes, 2001).

The GEF project is encouraging farmers to improve/increase the environmental services within their farms (Francisco Casasola pers. comm.) by integrating silvopastoral systems in their management systems. The project has developed a land-use index, which incorporates services for carbon sequestration and biodiversity, and on the basis of the changes of land-use farmers will receive payments. It is expected that payments for environmental services will help to improve the biological diversity of plants and animals as well as soil and water protection and carbon fixation. In cattle farms, live fences (trees planted in lines to delimit pastures or properties) are the most common forms of silvopastoral systems (Ibrahim *et al.*, 2000, Restrepro, 2002). These trees serve multipurpose services, such as holding barbed wire, giving shade and fodder for cattle (Budowski, 1993; Harvey, 2000), and producing fire wood and lumber (Guevara *et al*., 1992; Harvey and Haber, 1999). In the dry pacific coast of Cañas Restrepro found that more than 75% of the farmers had live fences separating pastures.

Importance of trees within silvopastoral systems for biodiversity conservation

In Monteverde, 25% of the estimated 400 species of birds have been found within windshields placed in pastures of dairy farms, and 94% of the tree species found in pastures, provide fruits for birds, bats and other animals (Harvey and Haber, 1999). According to Harvey & Haber, silvopastoral systems provide significant support to the conservation of forest plants and wildlife within agricultural landscape. Food availability for wild birds is higher in these systems, and the complex structure of the vegetation provides more adequate nesting substrate and better protection against predators than other agro-ecosystems.

It has been pointed out that isolated trees within pastures and forest fragments play an important role in conservation of biodiversity, serving as stepping stones for animal movement and as foci for seed recruitment and regeneration (Guevara *et al*., 1992, 1998; Guevara and Laborde, 1993; Harvey and Haber, 1999; Haber, 2000). These trees also provide food, when its limited within protected areas (Guindon, 1997), and habitat for nesting, roosting and perching for many animals (Saab and Petit, 1992; Estrada *et al*., 1993a; 1993b; Harvey and Haber, 1999).

At the regional level, silvopastoral systems may play an important role in the establishment of the Mesoamerican Biological Corridor, providing habitat for wildlife and facilitating seed dispersal and regeneration of native trees (Saunders & Hobbs, 1991).

Biodiversity

Biological diversity according to the Convention on Biological Diversity (1992) "is the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and ecosystems". "Biodiversity is also the total number of species and distribution of a particular species calculated using formulae to index different attributes of diversity in a specific ecosystem" (Odum, 1975).

Biodiversity is constituted by three primary attributes: structure, function and composition (Noss, 1990). Each of these plays a role at various hierarchical levels, namely landscape, ecosystem, species and gene. They also share an interrelationship among themselves; for this reason biodiversity monitoring should not be limited only to one level but should be performed at various levels (Noss, 1990).

Biological monitoring and identification

Biological monitoring and identification are useful tools for conservation of biological diversity. Monitoring uses the response of sensitive species to assess changes in the environment (Noss, 1990). According to Synge (1995) monitoring means measuring a situation at regular intervals of time, a phenomenon that is lacking in most conservation databases. Several criteria are applied in the selection of an appropriate indicator for monitoring ecosystem changes and the biodiversity, e.g. the species richness within an ecosystem may be used as an indicator of ecological diversity.

Birds are among the most commonly used biological monitors of habitat modification (Wilson, 1991), because they are ecologically versatile, react very rapidly to changes in their habitat (Fuller *et al.*, 1995) and can be monitored relatively inexpensively. Conservationists and ornithologists have used changes in bird populations and communities, behavior and reproductive ability to monitor habitat fragmentation, water quality, environment pollutants and health of marine fishery stock (National Audubon Society, 1999; Wilson, 1991).

Methodology

Description of study area

The study was conducted in the Esparza area, located in the Central Pacific region of Costa Rica (Figure 1) from March to July 2003.

Figure 1. Map of the study area in the province of Puntarenas, Costa Rica, Central America.

The region is undulating with slopes ranging from 10 to 65 percent, with fragile ecosystems and evident land degradation. The Esparza region is classified as a tropical sub-humid forest with a seasonal rainfall pattern. The mean annual rainfall is 2040 mm, which is concentrated between the months of May and

December and a mean annual daily temperature of 26°C. The soils of Esparza are classified as moderately shallow (< 60 cm) and severely eroded. The project area is about 2870 km² (GEF Project Appraisal, 2002).

In Esparza, beef and dual-purpose cattle production systems are the main land-use systems. The main source of feed for animals is pasture mainly (*Hyparrenhia rufa*) and mineral supplements. The pastures are grazed extensively, and in some areas they are burnt to promote regeneration of young shoots, a habit that exposes the soil to erosion during the wet season, with subsequent degradation (GEF, 2002).

Physical description

The project area (2870 km²); consists of about 100 farms, dedicated to dual-purpose cattle farming. I selected three farms within the project area and one outside of the project area. All of them are privately owned and managed by local farmers. These farms were selected based on physical survey, and because they were the same farms sampled for testing carbon fixation. Farms within the project area range from 7 ha to 942.3 ha. The farms surveyed varied in size, farm 1-covered 29 ha, farm 2 was 42.35 ha, farm 3 was 16.15 ha, and farm 4 was 10.5 ha (GEF, 2001).

All the farms visited were demarcated with live fences, mainly of "Indio desnudo" (*Bursera simaruba*. Most of the farmers have introduced high yielding varieties of *Brachiaria decumbens* and/or *B. brisantha*, in their pastures, replacing natural pastures of Jaragua (*Hyparrhenia rufa*). Farms with rivers or water bodies running through them have buffer strips on both sides (personal observation), which is in compliance with Costa Rican law.

Habitat Identification/Selection

The research comprised of 2 phases: the study site identification and biodiversity survey. The first phase consisted of identification of habitat types through the interpretation of aerial photographs and maps for the selection of the study sites.

Four farms were selected based on the management system and land-use. Those farms with at least one of the four types of land-use (cattle production with live fence, degraded pasture, pasture managed with trees and forest) in the study were selected. The farms were selected based on information acquired from the GEF silvopastoral project, of which the database included production systems, and land-use practices in the area, aerial maps, photographs, size in hectares and physical survey.

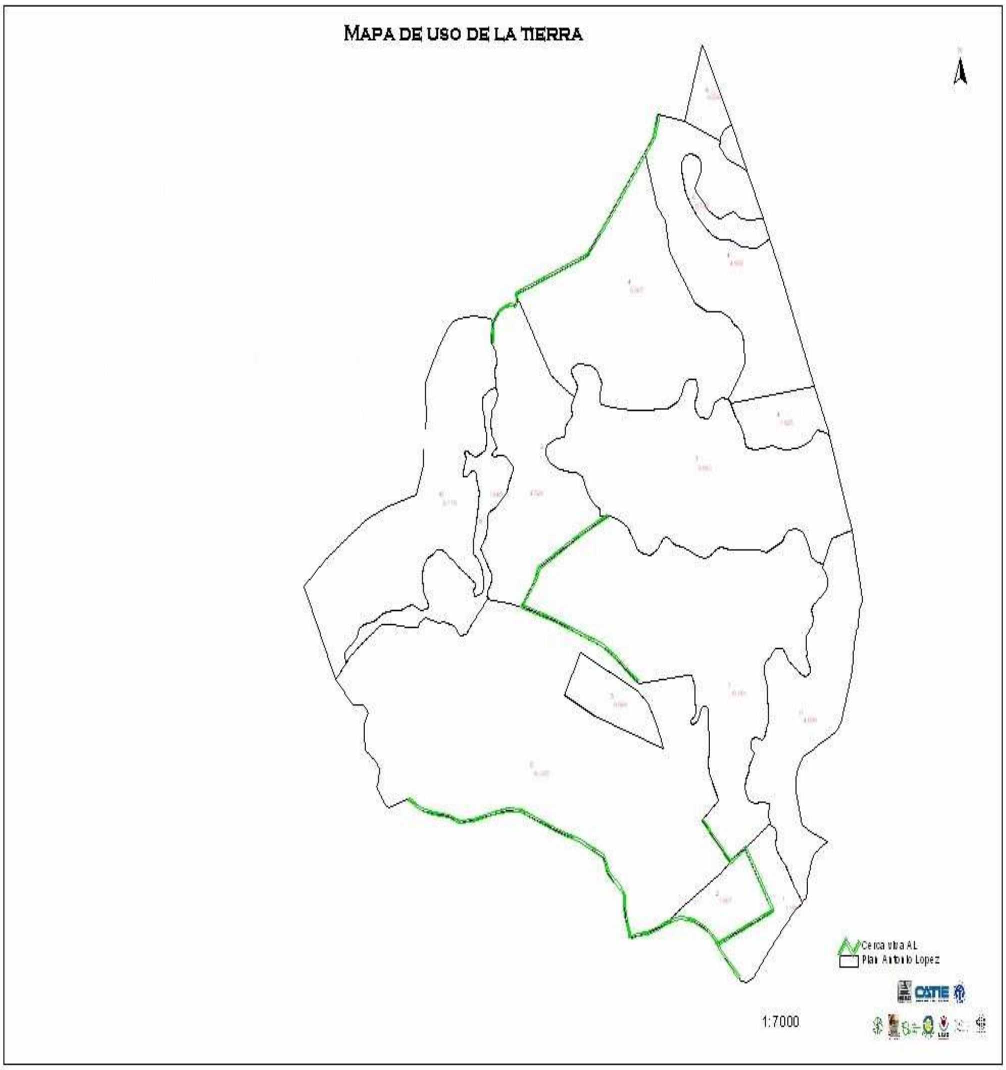


Figure 2. Map of farm 1 surveyed within the project area of Esparza, Costa Rica. (Cerca viva – live fence)

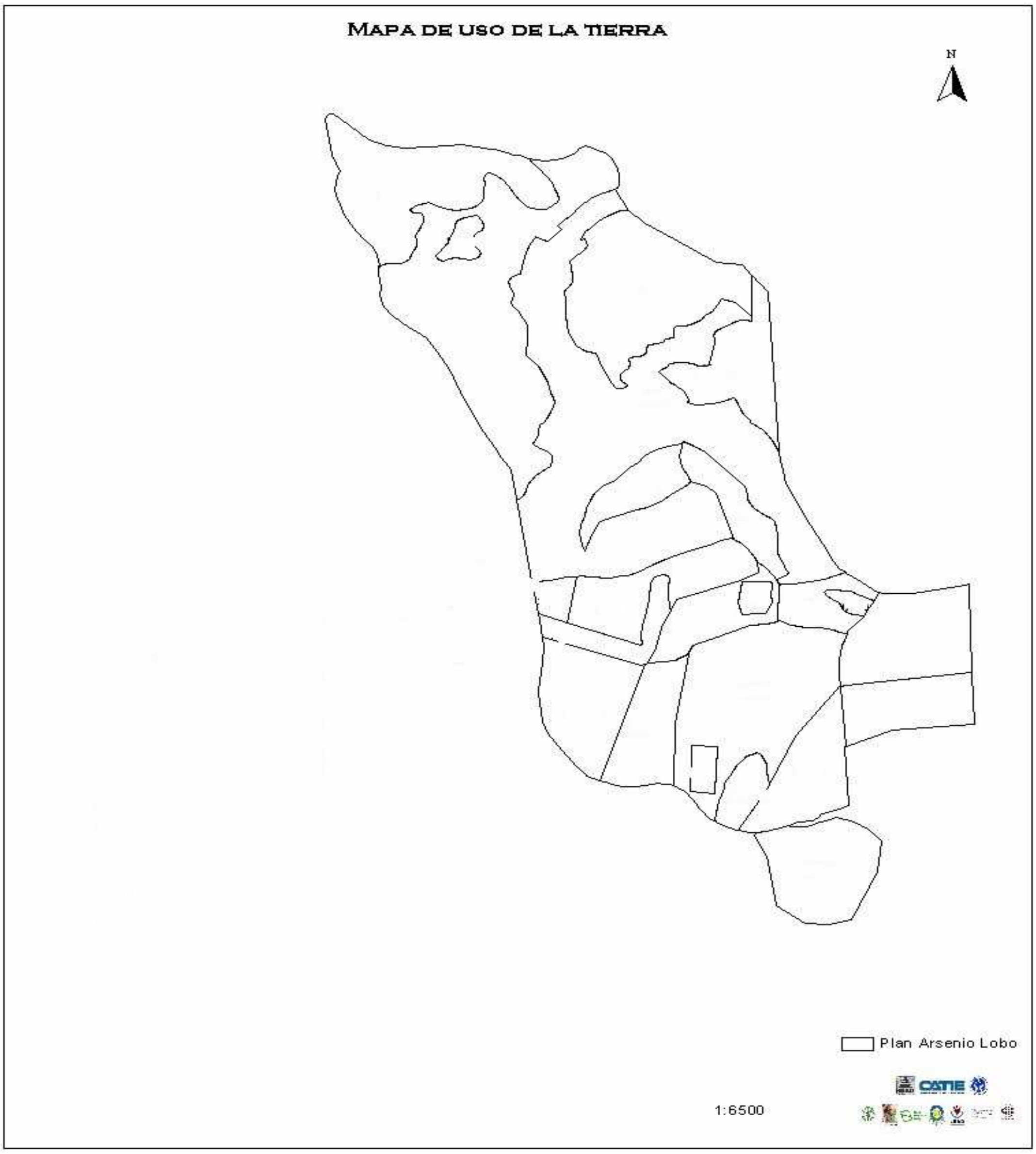


Figure 3. Map of farm 2 surveyed in the project area of Esparza, Costa Rica.

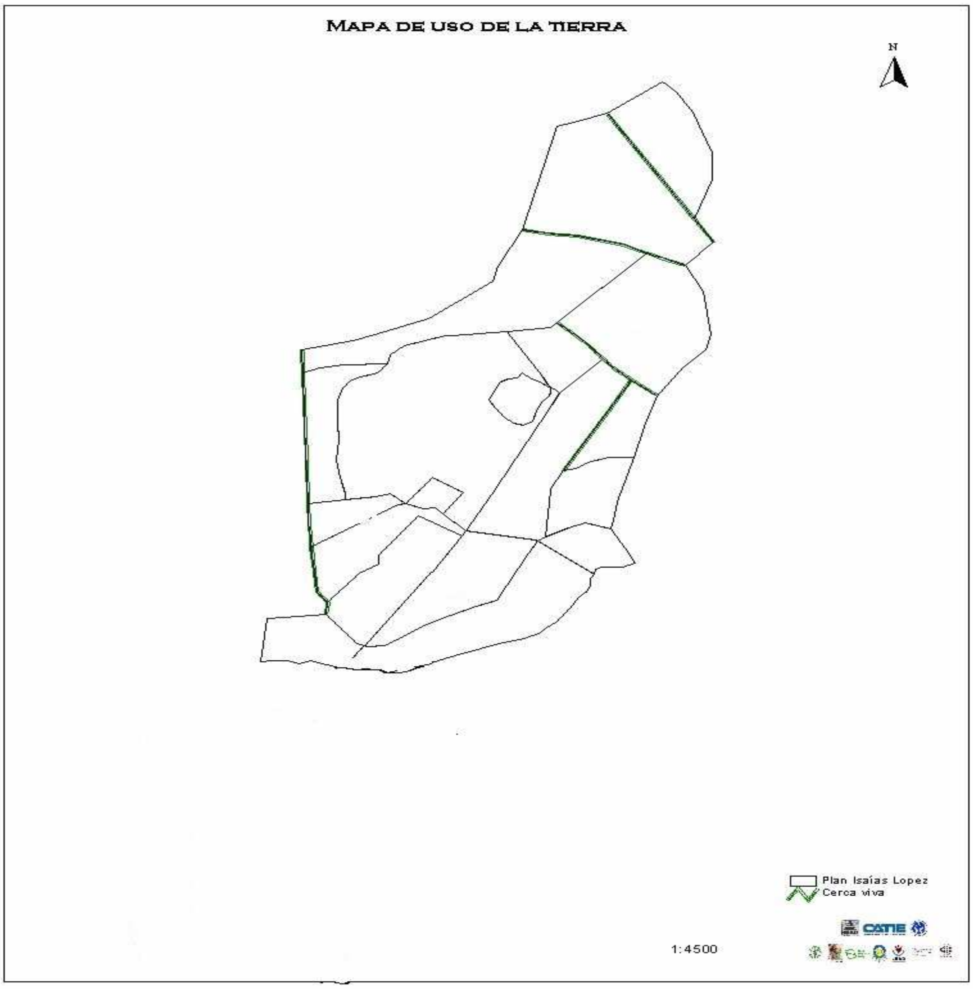


Figure 4. Farm 3 surveyed within the project area of Esparza, Costa Rica. (Cerca viva – live fence).

Treatments

Four types of land-use in cattle farms were studied. The types of use are those with major frequencies within the study area:

1) Secondary forest (SF) – these forests are about 25 years old and are managed for forest products.

2) Pasture with trees (PT) – these habitats were chosen depending on the tree density (≥15 adult trees/hectare).

3) Live fences (LF) – the points were selected in fences that delimit pasture with trees and degraded pastures.

4) Degraded pastures (DP) – these habitats were chosen based on the description provided by the GEF project classification of a degraded pasture.

Biodiversity inventory

The second stage of this research consisted of a bird survey and tree inventory within the established plots.

Tree inventory

To compare the plant diversity of habitat types sixteen 20 m x 20 m plots were randomly established within secondary forest, pasture with trees and degraded pastures (Figure 6). In live fences sixteen 20 m linear plots were established (Figure 5) in fences demarcating degraded pastures and pastures with trees. The plots were located within the areas where birds were sampled.

All trees with diameter at breast height (dbh) ≥10 cm within the selected plots were identified using Maas & Westra (1993), Poveda & Sanchez-Vindas (1999) and voucher specimens. The dbh and the common names were recorded. Trees were also assigned a category: 1) Native, 2) Introduced based on Poveda & Sanchez-Vindas, (1999), 3) Pioneer and 4) Forest based on Zamora *et al.* (2000).

○○○○○○○○○○○○←50 m - 80 m→ ○○○○○○○○○○○○

← 20 m →

Figure 5. Location and size of tree sample plots in live fence.

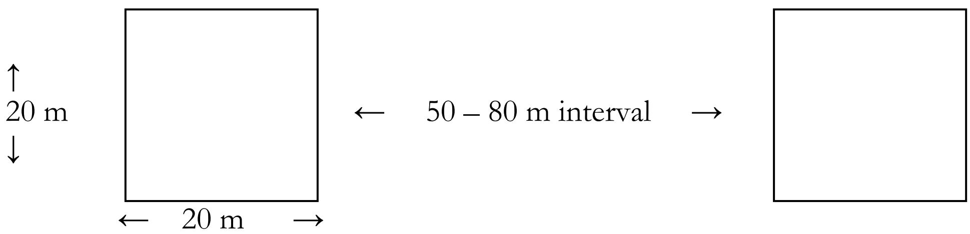


Figure 6. Location and size of plant sample plots in secondary forests, pastures with trees and degraded pastures.

Bird Survey

To census birds, 16 plots were manually placed within each land-use type. The central point for each of the plots was identified, numbered and marked with marking tape. The central points were established at 50–80 m intervals (Estrada *et al.*, 1997) (Appendix 1 and 2) and at least 25 m from the edge (Greenberg *et al.*, 1996). In each habitat there were 16 replicates and at each site the number of census points per site ranged from 1 to 4. The positions and altitudes of each central point were obtained and recorded using the GPS (Global Positioning System).

To compare the bird diversity of habitats, each central point was visited four (4) times at 15 minutes each visit to survey birds using the habitat (total 1hour) (Chipley *et al.*, 2003). The method of count used was the fixed-radius census point counts (Reynolds *et al.*, 1980) (Appendix 2) and in which all birds using the established plots were identified (Ralph *et al.*, 1996) and the following data were recorded: the species of the bird and number of individuals sighted. Counts were conducted between 6:00 h and 10:00 h (Chipley *et al.*, 2003) and between 15:00 h and 17:00 h (Johns, 1991) each day. The birds were identified using binoculars; taxonomic nomenclature was used according to Stiles & Skutch (1989).

Statistical Analysis

Tree data

For each habitat type, I calculated the total species richness (S), the total number of individuals (N), and the percentage composition of families. I calculated the relative frequency and abundance of species in each habitat as well as the distribution of individuals in diameter and height classes. I also calculated Shannon-Wiener diversity index to characterize species diversity in the different habitats, by the formula: $H' = \sum p_i \ln p_i$ where p_i is the proportion of individuals found in the *i*th species. The Evenness ($E = H' / \ln S$) of species was also calculated to determine how equally abundant the species are. To estimate the mean number of individuals in each habitat the analysis of variance (ANOVA) was used ($Y_{ij} = \mu + B_i + T_j + e_{ij}$). I characterized all plants on the basis of use (timber, medicinal, multipurpose, or non commercial) and category (forest, pioneer, native or introduced).

Bird data

I characterized the number of bird species and total number of individuals observed within each habitat. I also characterized all birds on the basis of their feeding guilds (frugivore, nectarivore, carnivore, omnivore, insectivore or granivore), status (resident, migrant or rare) and the most common species and their preferred habitat using Stiles & Skutch (1989). The Statistical Analysis System (SAS) program was used (with the assistance of Lopez Gustavo) to calculate the means for the total number of individuals and species in each habitat. I also calculated the percentage composition of families and feeding guilds. For each habitat the Shannon's diversity index and Evenness were calculated. The number of species and individuals within each guild was calculated as well.

In order to determine if there are any significant differences between habitats in bird species richness and abundance, I performed an analysis of variance (ANOVA) on the species and individuals for each plot in each habitat (forest, pasture with trees, degraded pastures and live fences). To determine the similarity of habitats in terms of species presences and absences the Jaccard measure was used (Magurran, 1988). $C_j = j/(a+b-j)$, where j = the number of species common to both sites, a = the number of species in site A, and b = the number of species in site B.

I used the SAS package, to perform all the statistical analyses. I analyzed the response variables (number of species, number of individuals, diversity) and treatments (forest, live fence, degraded pasture and pasture with trees) using Analysis of Variance (ANOVA) and Duncan's multiple range tests (SAS Institute, 1988).

To determine the response of birds in the various habitats, I explored the relationships between their species numbers and number of individuals and tree density and number of tree species using Pearson's correlation (r).

Results

General composition of trees

In general the study area in Esparza was not very rich in tree diversity. The total number of species registered was 45 representing 23 families (Appendix 3). The family with the highest number of species was Fabaceae (Papilionoideae) with 6 species followed by Anacardiaceae and Fabaceae (Mimosoideae) with 4 species and Bignoniaceae, Meliaceae and Rubiaceae with 3 species each (Appendix 3). These 6 families represented 52% of the species identified in the study area (Figure 7).

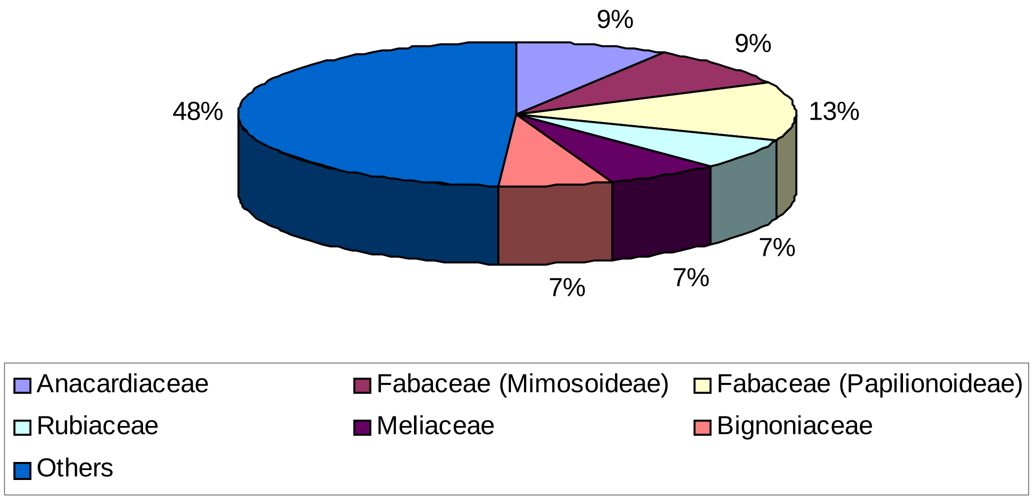


Figure 7. Distribution of families of the 45 species of trees observed in the study area. The number of families represented was 23.

Diversity of vegetation in the different habitats

Tree diversity in forest

The forest habitats contributed greatly to the tree diversity present in the landscape. I found 38 species of trees belonging to 23 families within forest habitats (Appendix 4). This represents 83% of the species and 48% of the individuals identified. The most abundant species was shared by Guayaquil (*Albizia guachapele*) and (Ecuador) Laurel (*Cordia alliodora*) with 35 individuals representing the total number of trees inventoried followed by Guarumo (*Cecropia peltata*) with 28 individuals and Guacimo (*Guazuma ulmifolia*) with 20 individuals. Caoba (*Swietenia macrophylla*) a species found only in forest habitats is said to be "in danger of genetic erosion" (Poveda Alvarez and Sanchez-Vindas, 1999).

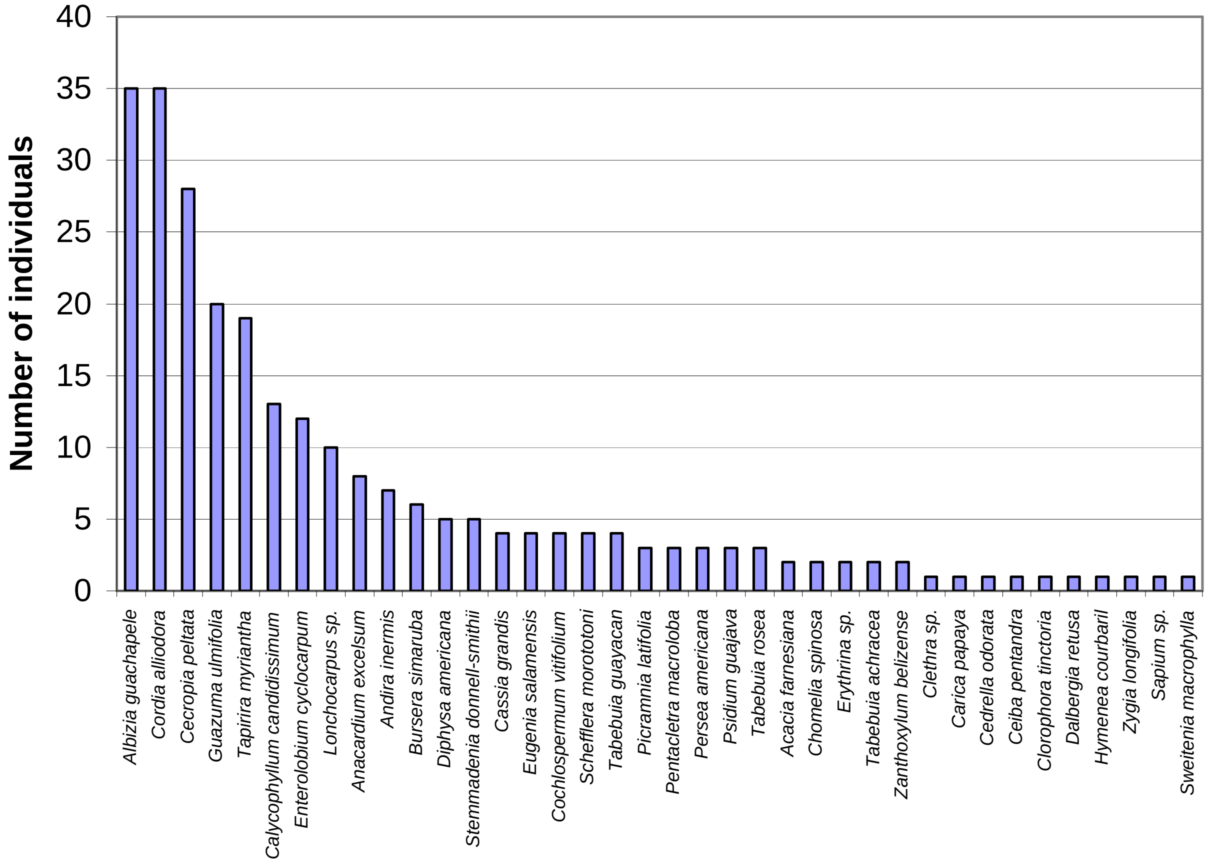


Figure 8. Rank-abundance of species of trees (n = 38) and individuals (n = 258) registered in forest habitats (6,400 m²).

Seven species were represented by >10 individuals, while 30 of the species identified in the forest habitat were represented by <10 individuals (Figure 8). The Shannon biodiversity index for forest habitats was 3.02 and Evenness 0.54.

Tree diversity in pasture with trees

I identified 79 individuals, 11 species and 9 families of trees within the pastures with trees (Appendix 4). Three species dominated the pasture with trees: *Cordia alliodora*, *Acrocomia aculeata* and *Diphysa americana* contributing 22, 15 and 11 individuals respectively. *Tabebuia rosea* and *Clethra sp*. followed closely behind with 9 individuals each (Figure 9). The Shannon biodiversity index for pasture with tree habitats was 2.02 with an Evenness of 0.46.

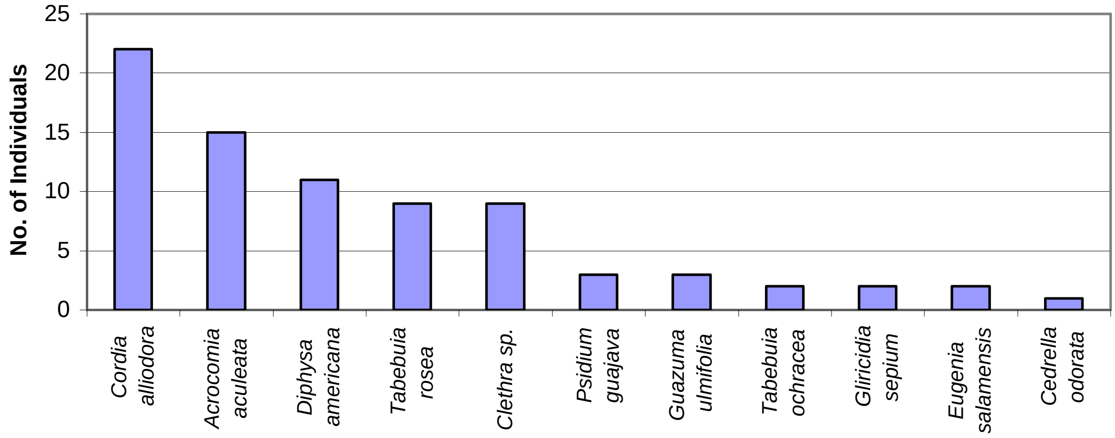


Figure 9. Rank-abundance for tree species (n = 11) and individuals (n = 79) registered in pasture with trees (6,400 m²).

Tree diversity in live fence

The live fence habitats did not contribute very much to the tree diversity present in the landscape, since it was predominated by *Bursera simaruba*. This species was represented by 150 individuals of the 188 individuals measured, followed by *Diphysa americana* 11 individuals and *Tabebuia rosea* with 6 (Figure 10). There were 15 species, belonging to 11 families identified in this habitat (Table 3). The Shannon diversity index for the live fence habitat was 0.92 and evenness 0.18.

Tree diversity in degraded pastures

I identified 17 individuals, 6 species and 6 families of trees within degraded pastures. Three of the species, *Acrocomia aculeata*, *Clethra sp.* and *C. alliodora* dominated the degraded pasture contributing 5, 4 and 4 individuals respectively (Figure 13). Most of the species in the habitat have multipurpose use and are forest species (Appendix 4). The Shannon-Wiener diversity index for degraded pastures was 1.63 and evenness was 0.58.

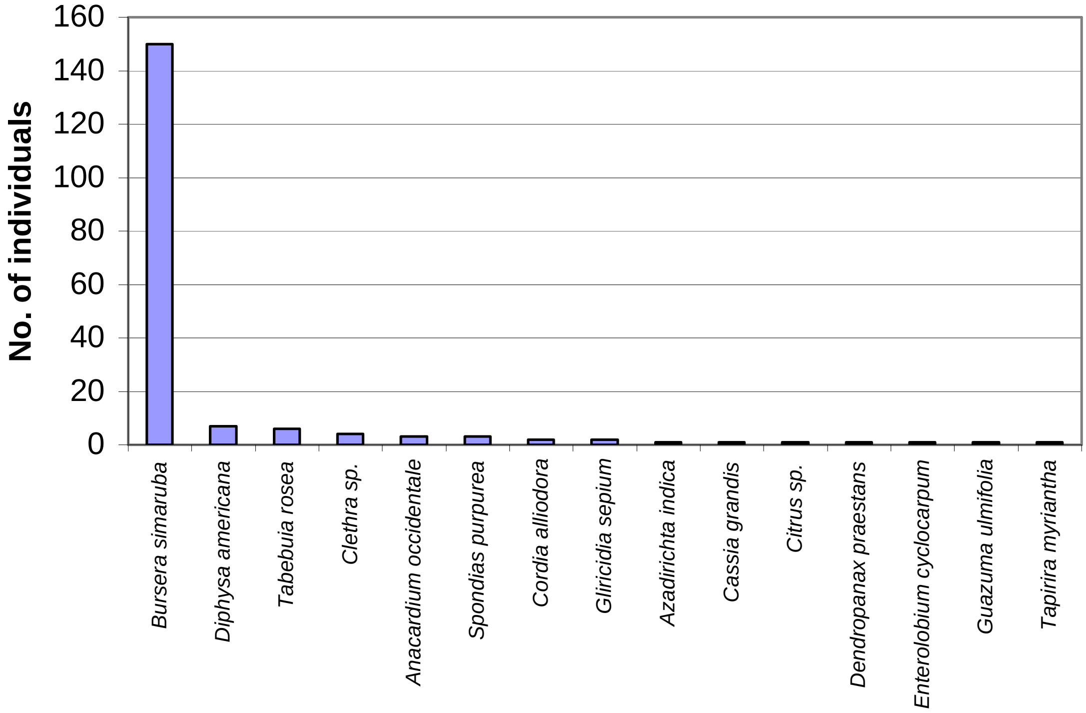


Figure 10. Rank-abundance for tree species (n=15) and individuals (n = 188) registered in live fence (320 m).

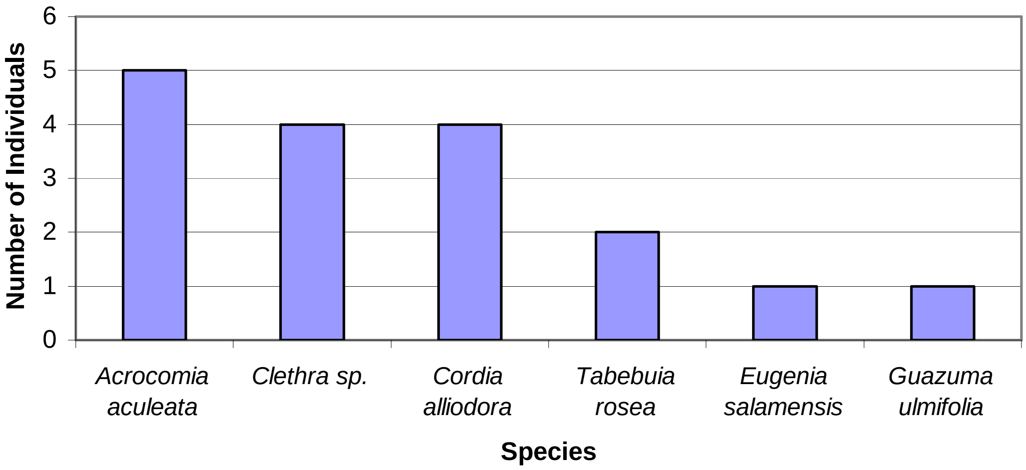


Figure 11. Rank-abundance of tree species (n=6) and individuals (n=17) registered in degraded pasture habitats (6,400 m²).

Comparison of the diversity of trees between habitats

The forests had a higher total number of tree species (38) than pasture with trees (11) and live fences (15). The forest habitat was also higher in number of individuals (Table 2).

Table 2. Summary of the tree inventories conducted on the different habitat types.

Habitat	Total # of Individuals	Total # of species	Families
Secondary forest	258	38	23
Pasture with trees	79	11	9
Live fence	188	15	11
Degraded pasture	17	6	6

The forest habitats had a greater diversity index compared to pastures with trees and degraded pastures with forest having 3.02, pastures with trees 2.02, degraded pastures 1.63 and live fences with 0.92 although the number of species in live fences was greater than pasture with trees and degraded pastures. The distribution of individuals among species or evenness in degraded pastures (0.58) was higher than in forests (0.54) and pastures with trees (0.46). The two most abundance species in the study area were *Bursera simaruba,* present in the live fence and forest habitats with 156 individuals followed by *Cordia alliodora* with 63 individuals (Table 3; Appendix 4). 29 species of trees were registered in only one habitat, of which 25 were represented in secondary forest and 4 in live fences (Appendix 4).

There were significant differences observed in the percentage of individuals registered in the different habitats. The forest category ranked highest with 48%, followed by live fence (34) pasture with trees (15),) and degraded pastures with 3 (Figure 12). There were some similarities in the abundance of species within habitats, pasture with trees and degraded pasture showed the highest similarity, while forest and degraded pasture had the least (Table 4).

Table 3. The most abundant species in the study area, the total number of individuals, and the habitat with the major number of individuals. (Abbreviations: LF-live fence, SF-secondary forest, PT-pastures with trees.)

Species	Total # of individuals	Habitat with major numbers
Bursera simaruba	156	LF
Cordia alliodora	63	SF
Albizia guachepele	35	SF
Cecropia peltata	28	SF
Guazuma ulmifolia	25	SF
Diphysa americana	23	PT

Acromia aculeata	20	PT
Tabebuia rosea	20	PT
Tapirira myriantha	20	SF
Clethra sp.	17	PT

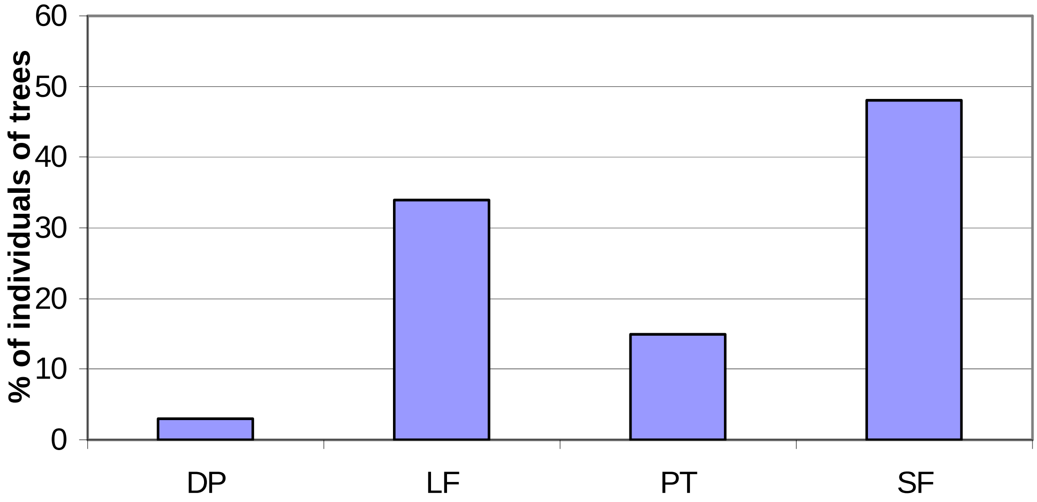


Figure 12. The percentage of individuals of trees in the different habitats.

Secondary forest was significantly (p=0.0002) higher in mean number of species compared to other habitats but there was no difference between degraded pasture (1.78), live fence (2.44) and pasture with trees (2.53) though live fence and pasture with trees was higher than degraded pasture (Figure 13).

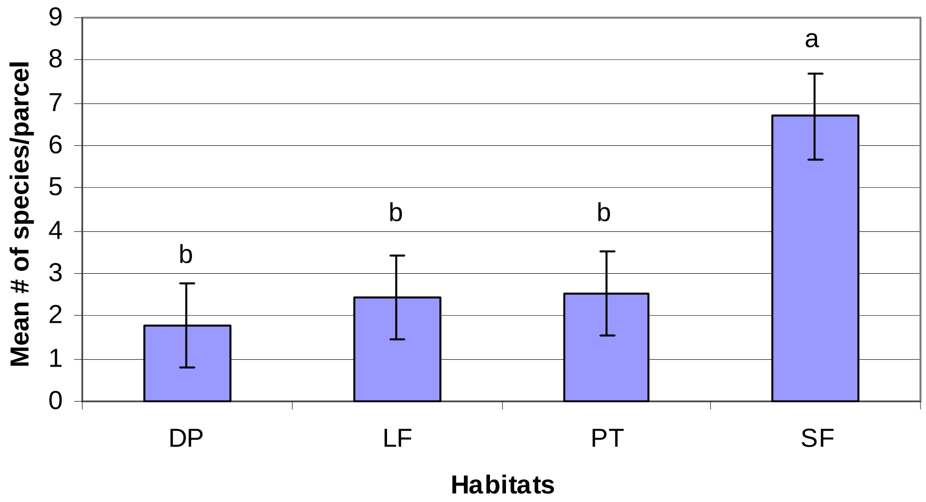


Figure 13. Mean number of species of trees in the different habitats and their standard error (Fx,y = 3, 37). The lower case letters indicate the significant differences. (P = 0.0002). Similar letters indicate no significant difference.

Table 4. The Jaccard similarity index of plant species abundance within the four habitat types.

	DP	LF	PT	SF
DP	–	0.23	0.42	0.13
LF	0.23	–	0.30	0.20
PT	0.42	0.30	–	0.19
SF	0.13	0.20	0.19	–

The range of tree diameters was similar in all habitats, within the (10–30 cm) diameter classes, however the major proportion of individuals represented in each habitat was in the smallest diameter class 10–19.9 cm with secondary forest having 34.9% of the individuals, live fence 27.3%, pasture with trees 2.4% and degraded pastures 2%(Figure 14). The classes with the smallest amount of individuals were 90–99.9 cm and > 100 cm, represented by a single individual each. The species with the highest dbh in degraded pastures was *Cordia alliodora* with a dbh of 43.94 cm, in live fence was *Enterolobium cyclocarpum* with a dbh of 119.37 cm, in pasture with trees was *Cordia alliodora* with a dbh of 60.48 cm and in secondary forest was *E. cyclocarpum* with a dbh of 98.04 cm (Figure 14).

The height class with the highest number of individuals of trees was the 5–9.9 m class with 40.5% of the individuals and secondary forest was represented by 18.8%. The class with the lowest number of individuals was 35–39.9 m with

0.4% of the individuals from secondary forest (Figure 15). The tallest species in degraded pasture was "Guacimo" (*Guazuma ulmifolia*) with a height of 26 m, in live fence *E. cyclocarpum* with 27 m, in pasture with trees "Corteza" (*Tabebuia ochracea*) with 21 m and in secondary forest "Guarumo" (*Cecropia peltata*) a pioneer species with 35 m.

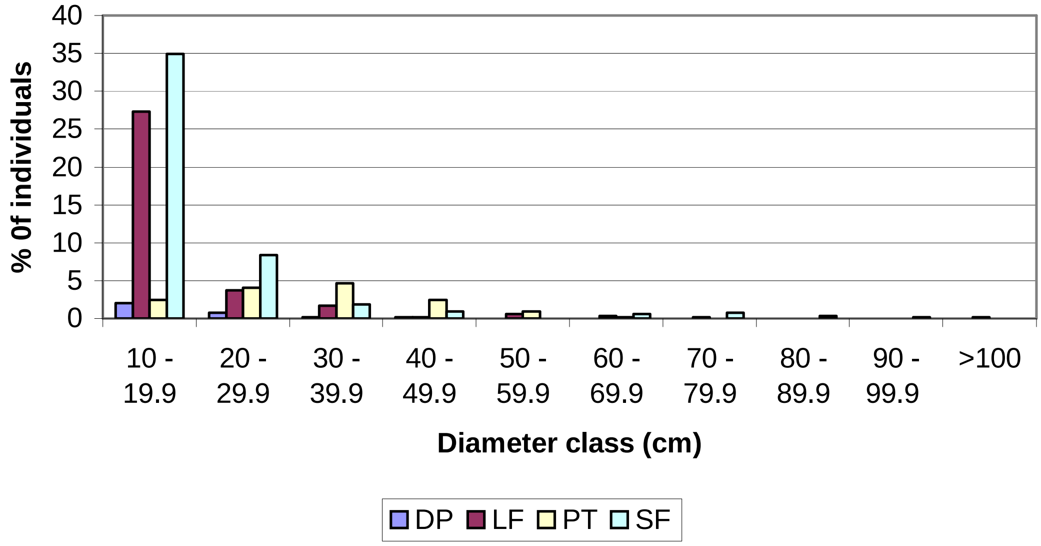


Figure 14. Distribution of tree diameter classes in all habitats inventoried (Secondary forest, pasture with trees, live fences, degraded pastures).

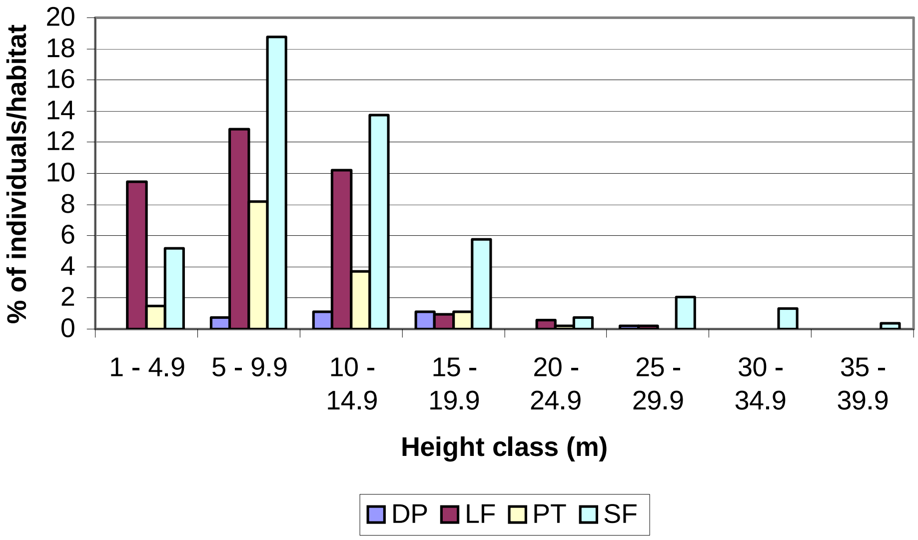
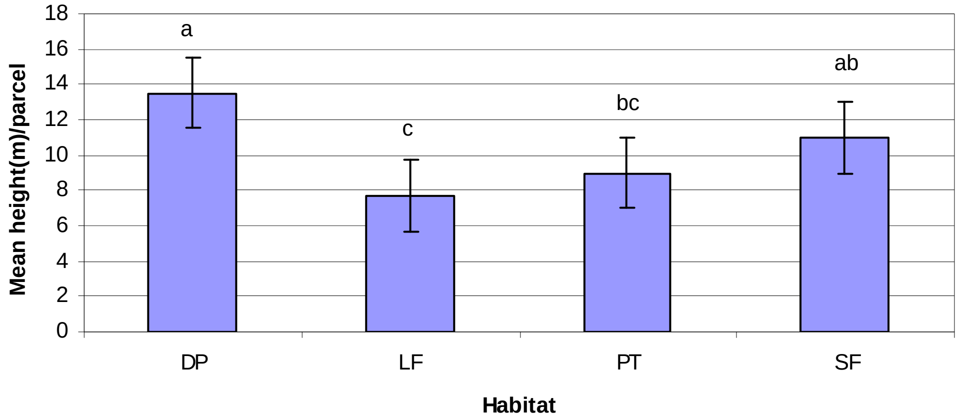


Figure 15. Distribution of height class of trees with diameter ≥10 cm in the different habitats.

There were significant differences in the mean diameter of trees identified in the plots. Pasture with trees was significantly different from the other habitats with (33.5 cm) followed by live fence (20.5 cm), forest (19.9 cm) and degraded pasture (18.3 cm) (Figure 16). Also there was some difference in the mean height among habitats. Degraded pasture (13.5 m) was significantly different from live fence (7.7 m) and pasture with trees (9.0 m), but there was no difference between degraded pasture and forest (11.0 m), but degraded pasture had a higher mean. Nor no significant differences between pasture with trees and live fence nor pasture with trees and forest (Figure 16).



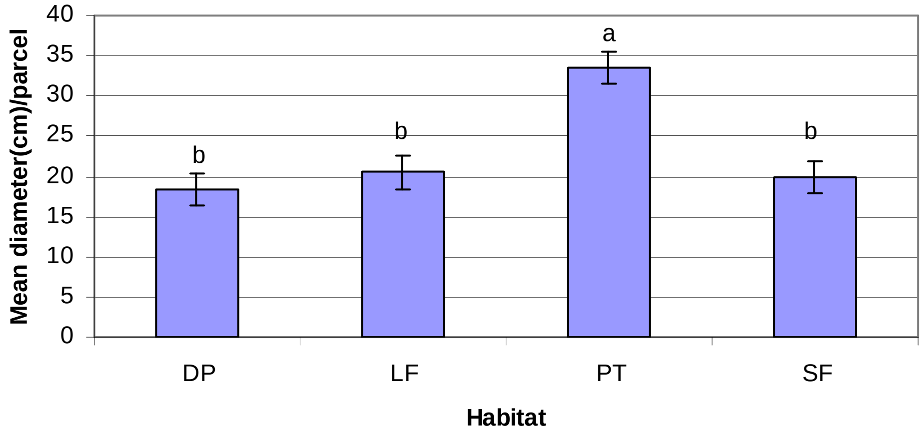


Figure 16. The mean height and diameter of trees identified in all habitats and the standard errors ($F_{x,y} = 3, 481$, $p = 0.0001$). Lower case letters indicate the significant difference. (DF, PT, SF = 20 m x 20 m and LF = 20 m). See fig. 15 for explanation.

4.3 General composition of avifauna

I observed a total of 28 families and 71 species of birds in the study area (Appendix 3). The family with the major number of species was Tyrannidae with 8 species which represented 11% of the species identified in the study area, followed by Emberizidae and Parulidae with 6 species each representing 8% of the species and Thraupidae with 5 species and 7% (Figure 17; Appendix 5). Six of the species identified in the study area were migrants, three of which are in the family Parulidae. None of the species identified are present in the list of species registered for Costa Rica in the IUCN (1992).

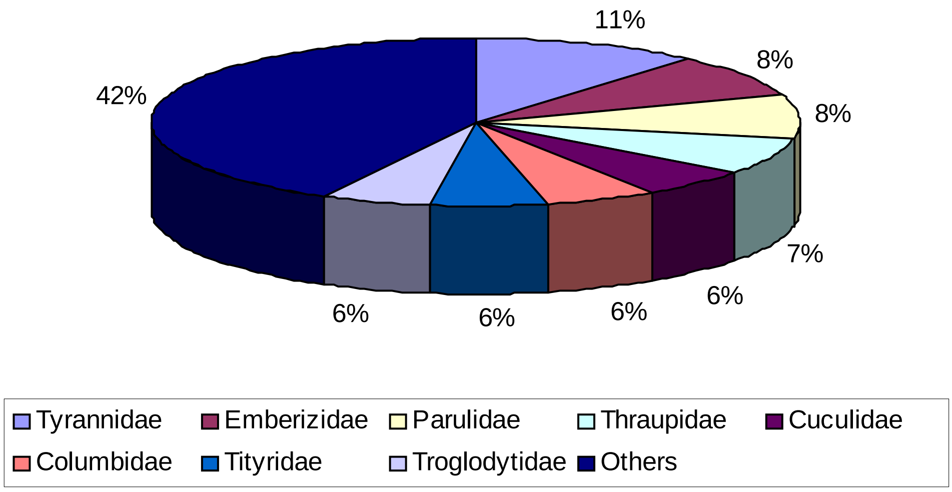


Figure 17. Distribution among families of the 71 bird species observed in the study area. The number of families represented was 28.

The feeding guild with the highest percentage of species was Insectivores with 40 % represented by 29 species of birds, followed by omnivores with 23 % (16 species) and frugivores with 14 % (10 species) (Figure 18; Appendix 6). The species with highest frequency in the guild of insectivores was the Nutting's flycatcher (*Myiarchus nuttingi*) followed by the Rufous-naped wren (*Campylorhynchus rufinucha*) (Table 9). In the guild of omnivores the most common species was the Groove-billed ani (*Crotophaga sulcirostris*) followed by the Lineated woodpecker (*Dryocopus lineatus*) and in the guild of frugivores the Long-tailed manakin (*Chiroxiphia linearis*) followed by the Orange-fronted parakeet (*Aratinga canicularis)* (Table 9). Carnivores were represented mainly by the "Turkey vulture" (*Catharthes aura*).

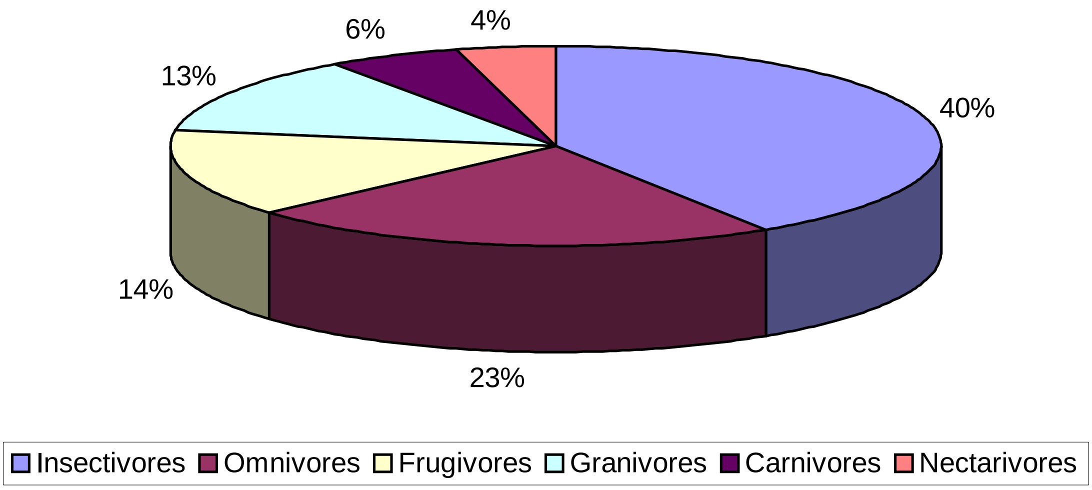


Figure 18. Distribution among feeding guilds of the bird species observed in the study area.

Seventy-one species of birds were identified in all habitats in the study area giving rise to a total of 1156 individuals, the most abundant species being *Myiarchus nuttingi* with 87 individuals followed by the *Campylorhynchus rufinucha* with 73 individuals, *Turdus grayi* and *Crotophaga sulcirostris* with 63 individuals each, Dusky-capped flycatcher (*Myiarchus tuberculifer*) with 57 individuals and the Hoffman's woodpecker (*Melanerpes hoffmannii*) with 53 individuals (Table 5;). Of the 71 species identified in the different habitats, 6 species registered more than 50 individuals, while 40 species registered less than 10 individuals (Appendix 5).

Twenty-three species of birds were identified in one habitat and in some cases only one individual was observed. All the habitats were represented with at least one species that was unique to that habitat. The forest habitat had the greatest number of unique species (16) with 3 of them being represented by a single individual followed by live fence, pasture with trees and degraded pastures with 4, 2 and 1 species respectively (Table 6).

Table 5. The most common species observed in the study area, areas of preference (from Stiles & Skutch, 1989), habitat observed, and feeding guild. The species are in alphabetical order.

Species	# of ind.	Preferred area	Habitat measured	Feeding guild
Campylorhynchus rufinucha	73	Open and closed	DP, LF, PT, SF	Insectivore
Chiroxiphia linearis	38	Open and closed	LF, SF	Frugivore
Columbina minuta	34	Open	DP, LF, PT, SF	Granivore
Crotophaga sulcirostris	63	Open	DP, LF, PT, SF	Omnivore
Melanerpes hoffmannii	53	Open and closed	DP, LF, PT, SF	Insectivore
Myiarchus nuttingi	87	Open and closed	DP, LF, PT, SF	Insectivore
Myiarchus tuberculifer	57	Open	DP, LF, PT, SF	Insectivore
Geothlypis poliocephala	32	Open	DP, PT, SF	Insectivore
Pintangus sulphuratus	43	Open	DP, LF, PT, SF	Insectivore
Turdus grayi	63	Open	DP, LF, PT, SF	Insectivore

Table 6. Species of birds observed in only one habitat (the species with the asterisk (*) indicates that one individual was observed).

Degraded pasture	Live fence	Pasture with trees	Secondary forest
Amazilia saucerrottei	*Columbina passerina* *Morococcyx erythropygius* *Pachyramphus polychopterus* *Thraupis episcopus*	*Buthraupis arcaei** *Sturnella magna*	*Amazilia tzacatl* *Arremonops conirostris* *Baryphthengus martii** *Basileuterus rufifrons** *Cyanocorax morio* *Dendroica petechia* *Herpetotheres cachinnans* *Lophostrix cristata* *Mniotilta varia* *Momotus momota* *Myiozetetes similis* *Oporornis philadelphia* *Pheucticus ludovicianus* *Saltator albicollis** *Thamnophilus doliatus* *Trogon violaceous*

Diversity of avifauna in the different habitats

Bird diversity in forests

Within the forest habitats, I identified a total of 383 individuals represented by 59 species in 27 families. This represented 33% of all individuals and 83% of all species identified. Sixteen of these species were exclusively forest dwelling birds, 18 preferred open areas and 25 preferred both open areas and forest. The majority (26) of the species identified within the forest habitats were insectivorous, 11 were omnivores, 8 were frugivores, 7 were granivores, 4 were carnivores and 2 were nectarivores. In this habitat the most abundant species were the *Chiroxiphia linearis* with 37 individuals, *Turdus grayi* with 18 individuals, and *Euphonia luteicapilla* and *Thryothorus pleurostictus* with 17 individuals each. There were also 8 species represented by only one individual (Appendix 5).

Bird diversity in pasture with trees

I identified 410 individuals represented by 43 species and 23 families within the pasture with trees habitats. The birds identified within this habitat represented 61% of the total number of species identified and 35% of the total number of individuals identified within the study area. Of the 43 species identified 10 were forest species, 17 open areas species and 16 generalists. The majority of the species were insectivores (18), 9 were omnivores, 6 frugivores and granivores, 3 carnivores and 1 nectarivore.

The most common species in this habitat were the *Myiarchus nuttingi* with 40 individuals, *M. tuberculifer* with 28 and *Crotophaga sulcirostris* and *Geothlypis poliocephala* with 27 individuals (Appendix 5).

Bird diversity in live fence

In live fence, I identified 217 individuals representing 37 species and 19 families. The birds identified within live fences represented 19% of the total number of individual identified and 52% of the total number of species. Most of the birds identified were commonly found in open areas (15), 10 were forest species and 12 found both in open and forest areas. The bird species represented 4 feeding guilds within the live fences, insectivores 17, omnivores 9, granivores 6 and frugivores 5. The majority of species identified had less than 10 individuals. The most abundant species were the *Myiarchus nuttingi*, *Campylorhynchus rufinucha* and *Turdus grayi*, with 22, 17 and 17 individuals respectively (Appendix 5).

Bird diversity in degraded pastures

In degraded pastures there were 146 individuals identified representing 30 species and 17 families, which represented 13% of the total number of individuals identified and 42% of the species. The majority of species observed in this habitat preferred open and forest areas (12), 10 were forest species and 8 were species that preferred open areas. The species were represented by 6 feeding guilds, with insectivores being the highest with 15 species, followed by granivores, frugivores and omnivores with 4 each, nectarivores with 2 and carnivore 1. The most abundant species were *Crotophaga sulcirostris*, *Myiarchus nuttingi*, *Campylorhynchus rufinucha* and *Columbina minuta* with 22, 16, 15, and 14 individuals respectively all the others were represented by <10 individuals (Appendix 5).

Comparison of bird composition in different habitats

There were differences in the number of individuals and the number of species identified in the different habitats. Pasture with trees had the highest number of individuals (410) while degraded pasture recorded the lowest (146). The highest number of species was recorded in forest (59) and the lowest in degraded pasture (30) (Table 7).

Table 7. The total number of families, species and individuals of birds identified in each habitat.

Treatments	# of families	# of species	# of ind.
Secondary forest	27	59	383
Pasture with trees	23	43	410
Live fence	19	37	217
Degraded pasture	17	30	146

There were significant differences in the mean number of bird individuals identified within the four habitats, except between pasture with trees and forest. Pasture with trees had the highest mean number of individuals (25.6) followed by forest (23.9), live fence (13.6) and degraded pasture (9.1) (Figure 19). Similarly there were significant differences in the mean number of species of birds between habitats, although forest and pasture with trees showed no significant difference. Forest recorded the highest mean number of species (11.6) followed by pasture with trees (11.2), live fence (6.9) and degraded pasture (4.8) (Figure 20).

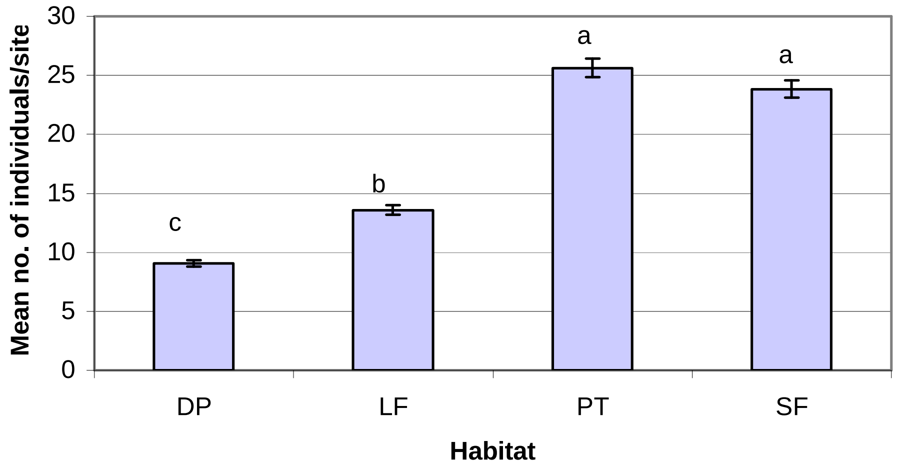


Figure 19. The mean number of individuals of birds in all habitats studied. The lower case letters indicate the significant differences ($F_{x,y}$ = 3, 45, p = 0.0001). See fig. 15 for explanation.

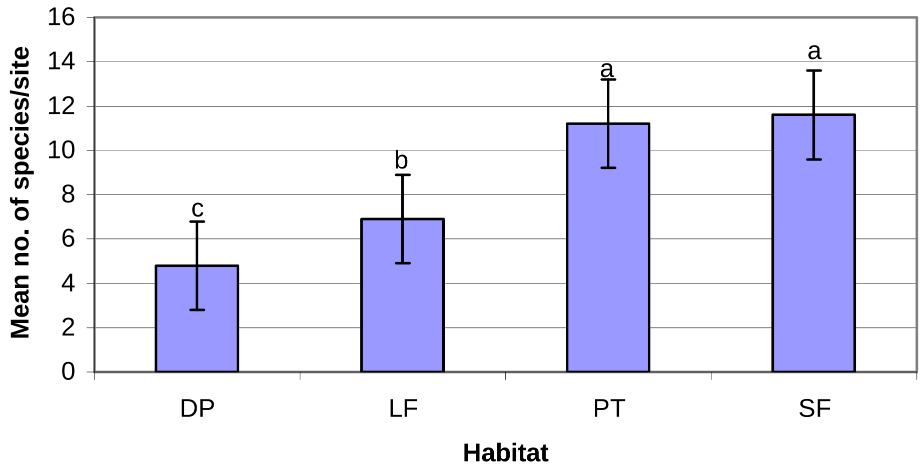


Figure 20. The mean number of species of birds in all habitats studied. Similar lower case letters indicate no significant difference ($F_{x,y}$ = 3, 60, $p < 0.05$). See fig. 15 for explanation.

The forest habitat had the greatest Shannon diversity index 3.72, followed by pasture with trees 3.29, live fence 3.20 and degraded pastures with 2.97. Forest also had the greatest distribution of individuals among species or evenness (E) between habitats (0.911) followed by live fence (0.888), pasture with trees (0.875) and degraded pastures (0.873).

There were significant similarities between the 4 habitats, the greatest similarity existed between pasture with trees and forest (0.59) followed by pasture with trees and live fence (0.57) then pasture with trees and degraded pasture (0.55) and the least similar were degraded pastures and live fence (0.37) (Table 8).

Table 8. The Jaccard similarity index for bird species abundances in the four habitats.

	DP	LF	PT	SF
DP	–	0.37	0.55	0.43
LF	0.37	–	0.57	0.39
PT	0.55	0.57	–	0.59
SF	0.43	0.39	0.59	–

There were close associations between the habitat type and feeding guilds and habitat preferences of the birds (Table 9 & 10). In all the habitats most of the species preferred open areas and were insectivores (26 species). The forest habitat recorded the highest number of species of forest specialists, generalists and those that prefer open habitats (Table 9). Interestingly, nectarivores and carnivores were found in all habitats except live fence (Table 10). The absence of nectarivores can have reciprocating effects since these species are important for pollination in plants.

Table 9. Habitat preference of bird species in the different habitats surveyed.

Habitat / Preference	DP	LF	PT	SF
Forest	10	10	10	16
Open areas	8	15	17	25
Open & Closed	12	12	16	18

Table 10. Percentage of individuals in each feeding guild recorded in the different habitats.

Feeding guild	DP	LF	PT	SF
Carnivore	2.05		2.19	3.92
Frugivore	8.90	12.90	10.00	24.54
Granivore	17.81	13.82	7.07	10.18
Insectivore	45.20	58.06	56.10	51.17
Nectarivore	4.11		0.73	2.09
Omnivore	21.92	15.21	23.90	7.05
Unknown				1.04

Correlation of birds and tree cover

According to the Pearson correlation coefficient there was neither any positive correlation between the diversity of bird and of tree species nor between the number of individual trees and birds (Table 11). This may be due to the short distance between the forest and the agricultural landscape. Birds may perceive these landscape elements at a larger scale and may not discriminate among habitats except for dietary requirements. As a result, bird species number and abundance did not differ between forest and pasture with trees, but the forest habitat had the greatest diversity in both plant (38) and avian (59) species (Figures 10 and 22). Forest also had a greater equitability of bird species while degraded pasture was least diverse and had the most inequitable distribution of individuals among species. The pasture with trees had a higher number of individuals and its equitability value was less than forest (0.911 vs. 0.875). Similarly there was no positive linear regression with species of birds and species of trees.

Table 11. The Pearson correlation coefficients, r and probability of relationship between variables.

		r	p
Bird species	Tree species	0.0420	0.2703
Bird species	Number of trees	0.2525	0.1541
Number of birds	Tree species	0.0606	0.2501
Number of birds	Number of trees	0.8393	0.0275

Discussion

Floristic Composition

The general richness of vegetation in the landscape was low with a total of 45 species of trees and palms within 23 families. The family with the highest number of species in the study area was Fabaceae, which included genera such as *Albizia*, *Enterolobium*, *Lonchocarpus* and *Gliricidia*. Farmers maintain these legumes within their farms because of their defense mechanism against cattle browsing as well as their ability to provide fodder for cattle during the dry season. These trees also produce fruits and seeds that are eaten by birds.

Farmers manage trees depending on the function of species and economic benefits. The most abundant species in the study area was the "Indio desnudo" (*Bursera simaruba*), registered primarily in the live fences, which is the most common form of silvopastoral system. This species is selected mainly for this purpose because of its fast growth and easy propagation and a live fence is cheaper compared to dead fence posts. Another species that was common was the Laurel, which had a very good distribution in the area. This species was present in all the habitats of the study area and is considered as an economically important species, since it has multipurpose uses (timber and firewood). Laurel also has a small crown, which makes it less competitive to fodder. In Costa Rica *Cordia alliodora* along with *Cedrella odorata* and *Tabebuia rosea* are very common in traditional silvopastoral systems because of their high regenerative ability (Camargo *et al*. 2001). Another species that was present in the majority of habitats was *Guazuma ulmifolia,* a species characteristic of the pacific region providing shade for livestock. Farmers also mentioned that this species is very important for conservation of birds because many species of birds use the fruits for food. *Acrocomia aculeata* was another species common in pastures; these palms are maintained within farms because they fruit during the dry season, and are a source of food for cattle.

Enterolobium cyclocarpum is a species that is avoided or maintained in low densities within pastures, because of its large crown cover and competition with fodder. Therefore it should be conserved in forest sites to avoid erosion and extinction of species.

Of the 45 species of trees identified, 15 were found exclusively in parcels of forest and live fence habitats. The habitat with major exclusivity of species was the secondary forest with 23 species. In live fence there was some amount of exclusiveness as well, with 4 species occurring only in this habitat (Table 7).

Differences in floristic composition between the different habitats

The secondary forest had the highest number and species of trees and was more diverse than the other habitats. According to the Shannon-Wiener (Magurran, 1988), the diversity index for forest was 3.02, followed by pasture with trees (2.02), degraded pasture (1.63) and live fence (0.92). Forests are rarely managed and sporadically grazed and therefore retain a high diversity of trees, while pastures are managed for cattle production and tree cover is limited due to competition with grass and the harvesting of trees by farmers. Degraded pastures' low diversity is due to elimination of tree species by the farmer. Tree diversity within pastures may be increased if there are changes in the management system. Having fallow periods to allow for regeneration of species without hindrances by livestock can probably do this but this will depend on soil conditions. In many cases degraded pastures are compacted with low fertility and natural regeneration on these sites are poor (Holl, 1998). However, degraded pastures had the highest Evenness (0.58) indicating that the individuals were more evenly distributed among the few species compared to the other habitats. Live fence had an evenness of 0.18, due to the dominance of one species *Bursera simaruba*.

There were differences in the floristic structure between habitats, but the majority of tree individuals were represented in the lower diameter (10–49.9

cm) and height (5–9.9 m) classes. The presence of individuals in these classes indicated that there was an occurrence of natural regeneration in these habitats. Natural regeneration of trees in pastures of good soil quality is successful when there are forest patches in the landscape, which are sources of propagules (Camargo *et al*., 2001). The majority of individuals in live fence were represented in the lower height and diameter class. This may be due to competition among trees for food since they are planted very close to each other and pruning, which can affect the growth rate. The tall trees in the silvopastoral systems were remnant trees of the original forest in the area, which function as foster parents, facilitating the establishment of tree species. These trees may also guide the movement of seed dispersers (birds and bats) depending on their spatial distribution within the landscape (Guevara *et al*., 1986, Mc Clanahan, 1993).

The flora in all four habitats had important similarities. The habitats with the greatest similarity in composition and abundance were pasture with trees and degraded pasture (0.42), while degraded pasture and forest were the most dissimilar (0.13) (Table 8). The presence of these trees within pastures may play an important role in the conservation of flora and fauna (Estrada *et al*., 2000; Guevara *et al*., 1998; Harvey & Haber, 1999), depending on the landscape structure (Turner, 1989).

In all the habitats the majority of tree species were forest species and had multipurpose uses. This can be very good because silvopastoral systems may be able to satisfy some of the needs for forest resources by farmers, and avoiding the direct use of the forest, allowing the expansion of forest in the landscape.

Composition of bird diversity

Birds play a very important role in the conservation of biodiversity, most importantly because they are seed dispersers, and to a lesser extent pollinators. They may also aid in the control of some insect pests. In the project area (2870 km^2) in Esparza, Puntarenas, 71 species of birds of 28 families were identified. Sixty-nine of these species were residents, one of which was a seasonal resident, one nomadic, one passage resident, 3 winter residents and 2 rare species at that location (Stiles & Skutch, 1989).

Of the 28 families of birds identified in the area, the families with greatest variation in species were Emberizidae, Parulidae, Thraupidae and Tyrannidae. The majority of species belonged to neotropical families. The Tyrannidae family was represented in all the habitats, as species in this family mainly prefer open habitats. The most common species of this family were *Myiarchus nuttingi, Myiarchus tuberculifer* and *Pintangus sulphuratus.*

The species of rare abundance were found mainly in the secondary forest. These species include *Baryphthengus martii*, *Basileuterus rufifrons*, *Dendroica petechia*, *Lophostrix cristata*, *Pheuticus ludovicianus*, *Saltator albicollis* and *Thamnophilus doliatus*. *Lophostrix cristata* is probably overlooked because this species is nocturnal (owl) and not normally observed during the day, while *Baryphthengus martii* is a species that is normally restricted to the Caribbean slope (Stiles & Skutch, 1989).

Comparison of avifauna diversity in different habitats

Each habitat type supports a somewhat different avifauna, but together they are complementary in their ability to protect avian diversity. Forest had the highest diversity of bird species (3.72) while degraded pasture was lowest with 2.97, but pasture with trees had the highest mean number of individuals (25.6) while degraded pasture had the lowest (9.1). Secondary forest also had the highest mean number of species (11.6) while degraded pasture was lowest with 4.8. The difference in bird diversity in secondary forest may be due to the greater variation in vegetation profile, with trees of varying heights above ground, some supporting ground dwellers, others shrub dwellers or canopy dwellers. Also some bird species are unable to utilize pasture with trees habitat, hence the greater number of species present in forest habitats. The lower number of species and individuals in live fence may be due to its drawbacks: thin linear habitat, frequently managed (reduces tree crown), low food availability, no cavity for nesting birds and high disturbance, making it unsuitable for species that are unable to forage in such habitats.
Enrichment planting could be used as a method to improve biodiversity within live fence habitats, by planting trees in more than one row and fencing them to avoid browsing by livestock.

There were important similarities between some habitats. Pasture with trees and forest were most similar in bird species composition (0.59), probably because the pasture trees were able to provide some of the services found in forests (Estrada *et al*., 1997; Harvey *et al*., 2000). The connectivity within the landscape may also be an influential factor, since forest bird species may use trees within pastures as stepping-stones for movement across the landscape.

It was surprising to see that forest specialist birds (19.7%) were represented in all habitats, probably because food resources can be found in the other habitats or because there is some degree of connectivity, which allows movement of the individuals using these habitats as stopover points. It also indicates that the native species have been able to adapt to the land conversion. But the species that live in both open and closed areas dominated all habitats. I found 19 forest species in the entire study area, only 4 of which were found exclusively in forest habitats. The presence of forest specialists in all habitats suggests that many bird species are able to utilize all the components of the fragmented landscape, irrespective of habitat type (Daily *et al*., 2001). These habitats may not be suitable for long-term inhabitation or breeding, but may be utilized as temporary food resources (Estrada *et al*., 2000; Daily *et al*., 2001).

Most of the species (39%) found in all habitats were insectivores. These habitats may provide suitable microclimates for insects, thereby providing food for insectivorous birds. Forest had the highest number of insectivorous species, while degraded pasture had the lowest, probably because insects are affected by the large variation in microclimate (Sabido, 2001) in the latter. The presence of frugivores in all habitats suggests that there is movement of seeds across the landscape creating some amount of connectivity between fragments.

Although there was no strong correlation between number and species of trees and number and species of birds, the forest habitat was more diverse in both tree flora (3.02) and avifauna (3.72), while degraded pasture had the lowest in both instances (Table 16). The relationship between tree cover and avifauna may vary depending on the connectivity within the landscape, since birds may not discriminate among habitats except for dietary requirements.

Table 16. The number of species, individuals and diversity indices of tree flora and avifauna identified in the different habitats.

	DP		LF		PT		SF	
	Tree	Bird	Tree	Bird	Tree	Bird	Tree	Bird
Number of species	6	30	15	37	11	43	38	59
Mean # of species	1.78	4.8	2.44	6.9	2.53	11.2	6.69	11.5
Number of individuals	17	146	188	217	79	410	258	383
Mean # of individuals	2.8	9.06	12.5	13.56	7.25	25.62	6.75	23.84
Diversity index (H')	1.63	2.97	0.92	3.21	2.02	3.29	3.02	3.72
Species Evenness (E)	0.58	0.873	0.18	0.89	0.46	0.875	0.54	0.91

Implications for conservation

It is important to recognize the role of the tree cover in the silvopastoral system for bird species in different landscapes with respect to what they provide for the birds: refuge, perching, nesting, and most importantly food. This will depend on the species of trees present in each habitat (Holl, 1998).

Pastures with trees habitats possess great potential to support substantial numbers of both flora and fauna (Table 16) within agricultural landscapes.

Therefore it is important to manage tree resources in farms for optimum conservation of biodiversity. Also essential is the composition and diversity of trees within fragmented landscapes because they may serve as foci for seed dispersal (Harvey, 2000). These pasture with trees are of fundamental importance when planning conservation actions. At the landscape level a variegated (landscape that includes a variety of man-made habitats and fragment) may be adequate as a conservation approach (Mc Intyre and Barret, 1992.) providing connectivity compared to a landscape devoid of intermediate stopover points.

Silvopastoral systems with a high density of trees were observed to contain a significant abundance of tree species in fragmented landscape compared to degraded pastures. These systems can provide conservation for a variety of species of organisms, depending on the distance and connectivity of the landscape (Harvey *et al.*, 2000). At the regional level, silvopastoral systems may play a pivotal role in the establishment of the Mesoamerican Biological Corridor. It is expected that these corridors will provide adequate habitat for wildlife while facilitating seed dispersal and the regeneration of native vegetation (Saunders & Hobbs, 1991).

Regional plans that incorporate means of protecting the larger ecosystem (including agriculture) are more likely to succeed, by promoting conservation of biodiversity and productivity within the region (Mc Neely, 1995).

Conclusions

Silvopastoral systems can be conceived as a complementary strategy for biodiversity conservation since these systems are more complex in structure and harbor species of varying types. I was able to determine that silvopastoral systems can support biodiversity conservation once a high density of trees is maintained. These trees provide refuge for birds that can disperse seeds, thereby enhancing regeneration of tree species and further colonization of forest in these habitats.

The forest habitats possess a significantly higher species richness and structural abundance of trees than the other habitats. Although silvopastoral systems did not possess the same species richness or structural abundance as secondary forest, they have shown to support similar species to the forest habitat. The trees in silvopastoral systems form a diverse resource system and the diameter and height distribution indicate natural regeneration, which can guarantee sustainability of these systems.

I have been able to demonstrate that many bird species utilize silvopastoral systems. The bird community within silvopastoral systems was of significant interest; most of the species observed in forest habitats were also present in pasture with trees or in live fences. These systems harbor both native and migratory bird species that can adapt to disturbance and require trees. With the increase of these habitats, the carrying capacity of migratory and resident bird should grow.

Although the tree diversity and abundance within the four habitats had no statistical significant effect on the bird community, forest habitats were more diverse in both plant and bird species.

Recommendations

Since this evaluation was done in a small sample of the project area and during one season, there is a need to increase sample size and sampling period for monitoring and identification of plant and animal species within these systems. The study of bird and plant diversity present within silvopastoral systems is important, since these systems are said to play a major role in the establishment of the Mesoamerican Biological Corridor (MBC).

The tree cover within the area may be an important field of study. The study of the tree species composition within primary forests is also important in order to determine if the diversity was eroded and whether the habitats present can conserve the existing biodiversity.

Planning for biodiversity conservation in silvopastoral systems should include the social and economic concerns of farmers, to obtain maximum effects of conservation within these systems. Farmers have a wealth of knowledge about which tree species will attract different species of animals and there is need for more in-depth studies to link farmers' knowledge for the design of systems, which will contribute to the conservation of biodiversity. The approach should be to combine all forms of diversity, cultural, biological, social and economic. Biologically, silvopastoral systems possess distinct habitats with different avian and floristic composition. Sociologically, these systems respond to economic forces operating at different levels, and culturally, ties between society and nature may support conservation, even when the perceived economic value is low.

The GEF project: *Integrated Silvo-Pastoral Approaches to Ecosystem Management,* would provide guidance on the definition of policy requirement for optimizing environmental services in livestock production. In order to promote conservation of biodiversity in silvopastoral systems a landscape approach should be taken into consideration, i.e. the conservation of fragmented areas, natural regeneration of degraded pastures and most importantly the connection of these areas with protected areas, since birds are highly mobile and require different habitat types during their annual cycle for food, shelter and nesting sites.

Silvopastoral systems should be promoted in alternative to monoculture systems, since they have one of the highest biodiversity indices except forest, for birds and many other animals within agricultural landscapes. These systems provide habitats for a wide variety of wild plants and animals, but not all species can survive in them. Therefore, they are not the perfect substitute to natural forests and will not solve all biodiversity problems. However, getting more wildlife into these systems is a step in the right direction.

For GEF, the payment of economic incentives should be based on changes in land-use system, providing both local and global environmental services by changing from monoculture to more complex systems. These systems may not be the most profitable for farmers; so to avoid abandonment of them will require suitable incentives.

Specific attention should be given to the use of native species within the silvopastoral systems, providing ecological services such as protection of soil and water quality, reduction in the risk of climate change and improving biodiversity.

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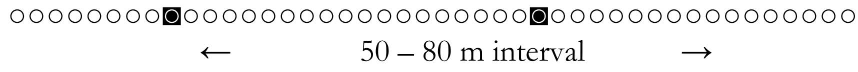
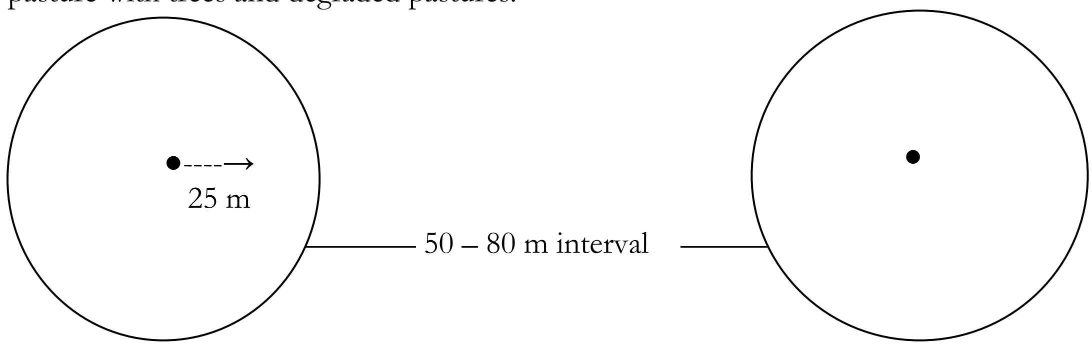
Appendixes

Appendix 1. Position of Central points for bird survey in the different habitats. Position of Central points (◙) and distance between points for bird survey in live fence.



Appendix 2. Position of fixed radius census points (25 meters) for bird survey in secondary forest, pasture with trees and degraded pastures.



Appendix 3. Species of trees identified within the different habitats in the study area. Families in alphabetical order, nomenclature of species Maas & Westra, (1993) and Poveda & Sanchez (1999).

Family	Species	Common name
Anacardiaceae	*Anacardium excelsum*	Espavel
	Anacardium occidentale	Marañon
	Spondias purpurea	Jocote
	Tapirira myriantha	Manteco
Apocynaceae	*Stemmadenia donnell-smithii*	Bijarro
Araliaceae	*Dendropanax praestans*	Mastate
	Schefflera morototoni	Pava macho
Arecaceae	*Acrocomia aculeata*	Coyol
Bignoniaceae	*Tabebuia ochracea*	Corteza
	Tabebuia guayacan	Guayacan
	Tabebuia rosea	Roble
Boraginaceae	*Cordia alliodora*	Laurel
Burseraceae	*Bursera simaruba*	Indio desnudo
Caricaceae	*Carica papaya*	Papayo
Cecropiaceae	*Cecropia peltata*	Guarumo
Clethraceae	*Clethra sp.*	Nance
Cochlospermaceae	*Cochlospermum vitifolium*	Poro poro
Euphorbiaceae	*Sapium sp.*	Yos
Fabaceae (Caesalpinioideae)	*Cassia grandis*	Carao

	Hymenea courbaril	Guapinol
Fabaceae (Mimosoideae)	*Acacia farnesiana*	Espino blanco
	Albizia guachapele	Guayaquil
	Enterolobium cyclocarpum	Guanacaste
	Pentaclethra macroloba	Gavilan
	Zygia longifolia	Canilla de mula
Fabaceae (Papilionoideae)	*Andira inermis*	Almendro
	Dalbergia retusa	Cocobola
	Diphysa americana	Guachipelin
	Erythrina sp.	Poro
	Gliricidia sepium	Madero negro
	Lonchocarpus sp.	Chaperno
Lauraceae	*Persea americana*	Aguacate
Malvaceae	*Guazuma ulmifolia*	Guacimo
	Ceiba pentandra	Ceiba
Meliaceae	*Azadirichta indica*	Neame
	Cedrella odorata	Cedro
	Swietenia macrophylla	Caoba
Moraceae	*Clorophora tinctoria*	Mora
Myrtaceae	*Eugenia salamensis*	Fruta pava
	Psidium guajava	Guayaba
Rubiaceae	*Calycophyllum candidissimum*	Madrono
	Chomelia spinosa	Mala chuite
	Citrus sp.	Limon
Rutaceae	*Zanthoxylum belizense*	Lagarto
Simaroubaceae	*Picramnia latifolia*	Coralillo

Appendix 4. Species, Economic importance, category and abundance of trees identified in the study area in Esparza. Nomenclature from Maas & Westra (1993) and Poveda & Sanchez (1999). Economic importance by Poveda & Sanchez (1999). Category by Poveda & Sanchez (1999) and Standley & Dahlgren (1937).

Species	Economic importance	Category	DP	LF	PT	SF
Bursera simaruba	Non commercial	Native		150		6
Cordia alliodora	Timber	Native	35	2	22	35
Albizia guachapele	Non commercial	Native				35
Diphysa americana	Multipurpose	Native		7	11	5
Cecropia peltata	Non commercial	Pioneer				28
Guazuma ulmifolia	Multipurpose	Native	1	1	3	20
Acrocomia aculeata	Non commercial	Native	5		15	
Tabebuia rosea	Multipurpose	Native	2	6	9	3
Tapirira myriantha	Timber	Forest		1		19
Clethra sp.	Multipurpose	Native	4	4	9	1

Calycophyllum candidissimum	Timber	Native				13
Enterolobium cyclocarpum	Multipurpose	Native		1		12
Lonchocarpus sp.	Non commercial	Forest				10
Anacardium excelsum	Timber	Forest				8
Andira inermis	Multipurpose	Forest				7
Eugenia salamensis	Non commercial	Native	1		2	4
Psidium guajava	Multipurpose	Native			3	3
Cassia grandis	Multipurpose	Native		1		4
Stemmadenia donnell-smithii	Medicinal, Cosmetics	Native				5
Cochlosperumum vitifolium	Timber	Forest				4
Gliricidia sepium	Timber	Native		2	2	
Schefflera morototoni	Multipurpose	Forest				4
Tabebuia ochracea	Multipurpose	Native			2	2
Tabebuia guayacan	Multipurpose	Forest				4
Anacardium occidentale	Timber	Introduced		3		
Picramnia latifolia	Ornamental	Forest				3
Pentacletra macroloba	Timber	Forest				3
Persea americana	Timber	Native				3
Spondias purpurea	Medicinal, Cosmetics	Native		3		
Acacia farnesiana	Non commercial	Native				2
Cedrella odorata	Timber	Forest			1	1
Chomelia spinosa	Medicinal	Native				2
Erythrina sp.	Ornamental	Forest				2
Zanthoxylum belizense	Non commercial	Forest				2
Azadirachta indica	Multipurpose	Introduced		1		
Carica papaya	Fruits	Introduced				1
Ceiba pentrandra	Timber	Forest				1
Citrus sp.	Commercial	Native		1		
Clorophora tinctoria	Multipurpose	Native				1
Dalbergia retusa	Timber	Native				1
Dendropanax praestans	Non commercial	Native		1		
Hymenea courbaril	Timber	Forest				1
Zygia longifolia	Multipurpose	Native				1
Sapium sp.	Timber	Native				1
Swietenia macrophylla	Multipurpose	Native				1

Appendix 5. Bird species identified within the study area in Esparza. Families are in alphabetical order, taxonomic nomenclature and status from Stiles & Skutch (1989).

Families & Species	English name	Status	SF	PT	LF	DP
Accipitridae						

Buteo nitidus	Gray hawk	Resident	4	2		
Caprimulgidae						
Nyctidromus albicollis	Common pauraque	Common resident	10	2	2	
Cathartidae						
Cathartes aura	Turkey vulture	Resident	4	5		3
Columbidae						
Columbina inca	Inca dove	Resident	3	8		6
Columbina minuta	Plain-breasted dove	Uncommon resident	3	8	9	14
Columbina passerina	Common ground dove	Resident			5	
Leptotila verreauxi	White-tipped dove	Common resident	6		2	
Corvidae						
Cyanocorax morio	Brown jay	Common resident	2			
Cuculidae						
Crotophaga sulcirostris	Grooved-billed Ani	Abundant resident	2	27	12	22
Morococcyx erythropygius	Lesser ground chuckoo	Common resident			2	
Piaya cayana	Squirrel chuckoo	Resident	2	2	1	
Tapera naevia	Striped chuckoo	Common resident			1	
Emberizidae						
Aimophila ruficauda	Striped-headed sparrow	Resident			3	3
Arremonops conirostris	Black-striped sparrow	Seasonal resident	6			
Guiraca caerulea	Blue grosbeak	Uncommon resident	4	1		3
Pheucticus ludovicianus	Rose-breasted grosbeak	Winter resident	1			
Saltator albicollis	Streaked saltator	Resident	1			
Volantinia jacarina	Blue-black grassquit	Common resident		3	1	
Falconidae						
Herpetotheres cachinnans	Laughing falcon	Common resident	4			
Micrastur ruficollis	Barred forest falcon	Uncommon resident	3	2		
Formicariidae						
Thamnophilus doliatus	Barred antshrike	Resident	1			
Fringillidae						
Carduelis psaltria	Lesser goldfinch	Nomadic resident	10	1	2	
Icteridae						
Sturnella magna	Eastern meadow lark	Common resident		4		
Momotidae						
Baryphthengus martii	Rufous motmot	Uncommon	1			
Eumomota superciliosa	Turquoise browed motmot	Common resident	10	4	1	1
Momotus momota	Blue crowned motmot	Resident	5			
Parulidae						
Basileuterus rufifrons	Rufous-capped warbler	Resident	1			
Dendroica caerulescens	Black-throated blue warbler	Rare migrant	15			1
Dendroica petechia	Yellow warbler	Winter resident	1			

Geothlypis poliocephala	Gray-crowned yellow throat	Common resident	7	27		2
Mniotilta varia	Black and white warbler	Uncommon resident	2			
Oporornis philadelphia	Morning warbler	Winter resident	14			
Passeridae						
Passer domesticus	House sparrow	Resident	7	8	13	
Passeriformes						
Glyphorhynchus spirurus	Wedge-billed woodcreeper	Common resident	1	4	2	1
Sittasomus griseicapillus	Olivaceous woodcreeper	Common resident	10	9	2	2
Picidae						
Dryocopus lineatus	Lineated woodpecker	Uncommon resident		17	5	
Melanerpes hoffmannii	Hoffman's woodpecker	Common resident	13	24	15	1
Pipridae						
Chiroxiphia linearis	Long-tailed manakin	Resident	37		1	
Psittacidae						
Aratinga canicularis	Orange fronted parakeet	Resident	13	2	14	4
Aratinga finschi	Crimson fronted parakeet	Common visitor	4	2		
Brotogeris jugularis	Orange chinned parakeet	Resident	3	7	4	
Ramphastidae						
Ramphastos sulfuratus	Keel billed toucan	Common resident	3	2	1	
Strigidae						
Lophostrix cristata	Crested owl	Fairly common	4			
Sylviidae						
Polioptila albiloris	White-lored gnatcatcher	Resident	6	4	8	4
Thraupidae						
Buthraupis arcaei	Blue and gold tanager	Resident		1		
Cyanerpes cyaneus	Red-legged honey creeper	Common resident	2	1	3	
Euphonia hirundinacea	Yellow throated euphonia	Common resident	7	21		1
Euphonia luteicapilla	Yellow crowned euphonia	Common resident	17	8		4
Thraupis episcopus	Blue gray tanager	Common resident			2	
Tityridae						
Pachyramphus algaiae	Rose-throated beccard	Uncommon resident	7	10	9	6
Pachyramphus polychopterus	White winged beccard	Uncommon resident			2	
Titrya semifasciata	Masked tityra	Common resident	1	15	2	3
Tityra inquisitor	Black-crowned tityra	Uncommon resident		6		
Trochilidae						
Amazilia rutila	Cinnamon hummingbird	Resident	4	3		1
Amazilia saucerrottei	Steely-vented hummingbird	Resident				5
Amazilia tzacatl	Rufous-tailed hummingbird	Resident	4			
Troglodytidae						
Campylorhynchus rufinucha	Rufous-naped wren	Resident	15	26	17	15
Thryothorus modestus	Plain wren	Resident	7		1	
Thryothorus pleurostictus	Banded wren	Abundant resident	17	2		2

Thryothorus rufalbus	Rufous white wren	Common resident	2			1
Trogonidae						
Trogon melanocephalus	Black headed trogon	Common resident	10	1	4	4
Trogon violaceus	Violaceous trogon	Resident	3			
Turdidae						
Turdus grayi	Clay-colored robin	Resident	18	22	17	6
Tyrannidae						
Contopus virens/ sordidulus	Wood pewee	Common transient	1	9	5	
Megarhynchus pitangua	Boat billed flycatcher	Common resident	1	3	3	
Myiarchus nuttingi	Nutting's flycatcher	Resident	9	40	22	16
Myiarchus tuberculifer	Dusky-capped flycatcher	Uncommon resident	13	28	9	7
Myiodynaster maculatus	Streaked flycatcher	Passage resident	5	11	12	1
Myiozetetes similis	Gray capped flycatcher	Common resident	3			
Pitangus sulphuratus	Great kiskadee	Common resident	8	26	3	6
Tyrannus verticalis	Western kingbird	Abundant resident	6	2		

Appendix 4. Species of birds, feeding guild and habitats. Taxonomic nomenclature and feeding guild from Stiles and Skutch (1989). Species are in alphabetical order (x denotes the habitats where the species were identified).

Species	Feeding guild	SF	PT	LF	DP
Aimophila ruficauda	Granivore			x	x
Amazilia rutila	Nectarivore	x	x		x
Amazilia saucerrottei	Nectarivore				x
Amazilia tzacatl	Nectarivore	x			
Aratinga canicularis	Frugivore	x	x	x	x
Aratinga finschi	Frugivore	x	x		
Arremonops conirostris	Granivore	x			
Baryphthengus martii	Omnivore	x			
Basileuterus rufifrons	Insectivore	x			
Brotogeris jugularis	Frugivore	x	x	x	
Bubulcus ibis	Insectivore				
Buteo nitidus	Carnivore	x	x		
Buthraupis arcaei	Omnivore		x		
Campylorhynchus rufinucha	Insectivore	x	x	x	x
Carduelis psaltria	Granivore	x	x	x	
Cathartes aura	Carnivore	x	x		x
Chiroxiphia linearis	Frugivore	x		x	
Columbina inca	Granivore	x	x		x
Columbina minuta	Granivore	x	x	x	x
Columbina passerina	Frugivore			x	
Contopus virens/ sordidulus	Insectivore	x	x	x	

Crotophaga sulcirostris	Omnivore	x	x	x	x
Cyanerpes cyaneus	Omnivore	x	x	x	
Cyanocorax morio	Omnivore	x			
Dendroica caerulescens	Insectivore	x			x
Dendroica petechia	Insectivore	x			
Dryocopus lineatus	Omnivore		x	x	
Eumomota superciliosa	Insectivore	x	x	x	x
Euphonia hirundinacea	Frugivore	x	x		x
Euphonia luteicapilla	Omnivore	x	x		x
Geothlypis poliocephala	Insectivore	x	x		x
Glyphorhynchus spirurus	Insectivore	x	x	x	x
Guiraca caerulea	Omnivore	x	x		x
Herpetotheres cachinnans	Carnivore	x			
Leptotila verreauxi	Granivore	x		x	
Lophostrix cristata	Little known	x			
Megarhynchus pitangua	Omnivore	x	x	x	
Melanerpes hoffmannii	Omnivore	x	x	x	x
Micrastur ruficollis	Carnivore	x	x		
Mniotilta varia	Insectivore	x			
Momotus momota	Omnivore	x			
Morococcyx erythropygius	Insectivore			x	
Myiarchus nuttingi	Insectivore	x	x	x	x
Myiarchus tuberculifer	Insectivore	x	x	x	x
Myiodynaster maculatus	Insectivore	x	x	x	x
Myiozetetes similis	Insectivore	x			
Nyctidromus albicollis	Insectivore	x	x	x	
Oporornis philadelphia	Insectivore	x			
Pachyramphus algaiae	Insectivore	x	x	x	x
Pachyramphus polychopterus	Omnivore			x	
Passer domesticus	Granivore	x	x	x	
Pheucticus ludovicianus	Omnivore	x			
Piaya cayana	Insectivore	x	x	x	
Pitangus sulphuratus	Omnivore	x	x	x	x
Polioptila albiloris	Insectivore	x	x	x	x
Psarocolius montezuma	Frugivore		x		
Ramphastos sulfuratus	Omnivore	x	x	x	
Saltator albicollis	Omnivore	x			
Sittasomus griseicapillus	Insectivore	x	x	x	x
Sturnella magna	Insectivore		x		
Tapera naevia	Insectivore			x	
Thamnophilus doliatus	Insectivore	x			
Thraupis episcopus	Omnivore			x	

Thryothorus modestus	Insectivore	x		x	
Thryothorus pleurostictus	Insectivore	x	x		x
Thryothorus rufalbus	Insectivore	x			x
Tigrisoma fasciatum	Carnivore				
Titrya semifasciata	Omnivore	x	x	x	x
Tityra inquisitor	Omnivore		x		x
Trogon melanocephalus	Frugivore	x	x	x	x
Trogon violaceus	Frugivore	x			
Turdus grayi	Insectivore	x	x	x	x
Tyrannus verticalis	Insectivore	x	x		
Volantinia jacarina	Granivore		x	x	