Habitat Conservation, Avian Diversity, and Coffee Agrosystems in Southern Costa Rica

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ABSTRACT

Coffee agrosystems can be an effective conservation tool if ecological processes are retained while the small farmer simultaneously receives socio-economic benefits. Traditionally coffee has been grown under a structurally diverse shade layer, yet has been transformed to a monoculture crop in many regions of Central America. The potential to increase shade in coffee farms in the southern Pacific region of Costa Rica was examined. The study combined socio-economic information and farmer preference from on-farm interviews with avian biodiversity information. Avian diversity was sampled with point counts in four coffee management systems varying in the main canopy species [Poró (*Erythrina poeppigiana), Musa* sp., *Eucalyptus deglupta,* and Amarillón (*Terminalia amazonia*)] and increasing in the amount of shade in the farm.

Of the four coffee management categories, *T. amazonia* had the highest avian diversity. Coffee farms with the heavily pruned Poró had low species richness and diversity, and were poor habitats for birds. The Eucalyptus farm had a surprisingly high biodiversity for a non-native tree species. From the interviews farmers stated an increase in fungal pests in the coffee as their main reservation to increasing shade, in addition to a decrease in yields and the cost of planting trees. Those that were interested in planting more trees stated a preference for timber species (including *T. amazonia*). Recommendations were made for strategies to increase the percent of shade in coffee farms and for future studies in the region.

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ABBREVIATIONS

ACPC	Association of Coffee Producing Countries
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza (Tropical Agronomic Centre for Research and Teaching)
CEC	Commission for Environmental Cooperation
CICAFE	Centro de Investigaciones en Café (Coffee Research Center)
COOPEAGRI	Cooperativa Agro-Industrial de Pérez Zeledón (Agro-Industrial Cooperative of Pérez Zeledón)
FES	Faculty of Environmental Studies, York University, Canada
ICAFE	Instituto Nacional de Café (National Coffee Institute of Costa Rica)
ICO	International Coffee Organization
IMN	Instituto Meteorologico Nacional (National Meteorological Institute)
INA	Instituto Nacional de Aprendizaje (National Institute of Apprencticeship)
MIDEPLAN	Minesterio de Planificacion Nacional y Política Económica (Ministry of National Planning and Economic Policy)
MINAE	Ministerio de Ambiente y Energía (Costa Rican Ministry of Environment and Energy)
MIRENEM	Ministerio de Recursos Naturales, Energía y Minas (Ministry of Natural Resources, Energy and Mines)
NAFTA	North American Free Trade Agreement
NGO	Non-governmental Organization
SINAC	Sistema Nacional de Areas de Conservación (National System of Conservation Areas)

SMBC	Smithsonian Migratory Bird Center
TSC	Tropical Science Center
USAID	US Agency for International Development
WWF	World Wildlife Fund

Unit Conversions:

1 *manzana* = 0.69 ha

1 hectare = 1.42 *manzanas*
= 10 km^2
= 2.47 acres

1 *fanega* = 258 kg of fresh coffee beans

1 acre = 0.405 ha

1 *quintal* = 46 kg bag

FOREWORD

I entered the Master's of Environmental Studies program at York University with a background in Zoology, a love for birds, and a strong desire to conserve the habitats about which I knew so much yet had so much more to learn. I began the program with a view that addressing issues of environmental destruction required more thanecological information - that the human component of all ecosystems lived with continual influence from and on surrounding natural habitats. I became interested with peoples' daily choices on natural resource use and the influences on their behavior. I sought in the program to integrate my previous skills and knowledge gained from the biological sciences with a different academic world from what I had experienced before – the social sciences. As humans are a critical part of all natural ecosystems, I wanted to learn how habitat conservation could be successful for both people and for nature.

My thesis research fulfills one of the requirements for my MES degree, focused on an interdisciplinary approach to habitat conservation. This research addresses all three learning components constructed at the start of my degree – 1) the use of ecological studies in habitat and biodiversity conservation, 2) understanding the context surrounding land-use, and 3) planning and management of conservation programs. The study combines ecological information, in terms of avian diversity, with socio-economic issues regarding coffee practices in Costa Rica, information obtained through informal interviews. Recommendations on how to encourage ecologically-beneficial coffee practices in the region, including the increase in amount of shade in coffee farms, were made by synthesizing the information gained throughout the research.

The opportunity to explore methods of combining ecological and socio-economic criteria to form successful conservation programs was provided in part by the donation of a 132-ha rainforest property to the Faculty of Environmental Studies (FES) at York University in 1998 by Dr. Woody Fisher. This property, now know as Las Nubes Biological Reserve, is located in the southern Pacific region of Costa Rica, 6km upstream from the Los Cusingos Neotropical Bird Sanctuary, the homestead of renowned tropical ornithologist Dr. Alexander F. Skutch. Los Cusingos is now owned by the Tropical Science Center (TSC) of Costa Rica, one of the first environmental organizations established in Central America, and now a leader in "the applied research and service concerning humankind, biological resources, and the physical environment" (TSC, 1993). In 1998, FES and TSC entered into a long-term partnership focusing on the biological protection of Las Nubes, Los Cusingos and the section of land connecting the two.

Directly to the northeast of Las Nubes lies Chirripó National Park, a 501-km^2 reserve that is part of the La Amistad Biosphere Reserve straddling the border with Panama. The opportunity to connect these highland regions with the foothills of Los Cusingos along the Peñas Blancas watershed could provide a passage for many altitudinal migrant animal species, as well as habitat for migratory bird species that breed in North America and spend the rest of the year in tropical regions. Encouraging sustainable practices in this region could provide a stretch of habitat suitable for the dispersal and migration of fauna.

My field experience in Costa Rica has taught me a variety of things, including a new language, what life is like in a rural tropical community, and the complexity involved in addressing habitat conservation issues. I brought back with me many fond memories, bonds of friendship that will last a lifetime, and a new way of looking at development and environmental issues in tropical countries. I only hope I have left as much behind.

CHAPTER 1: INTRODUCTION

1.1. Introduction

The field of conservation biology, by the very nature of the issues it seeks to resolve, must continually seek out alternative strategies in the quest for solutions to a prevalent worldwide problem. Specifically, the conversion of complex natural ecosystems to monospecific managed systems that lack the ability to function without external assistance and that are deficient in the character and value prevalent in diverse systems. The disappearance of biodiversity carries consequences affecting many aspects of human societies, and represents the loss of irreplaceable organisms developed over millennia of evolution. Most issues of habitat and biodiversity destruction are complex, location specific, and involve numerous and often conflicting groups of people, creating a challenge to biodiversity conservation that can only be met with a solid understanding of the true pressures and influences behind behavior patterns towards resource use.

The main approach to habitat conservation across the world has been the establishment of protected areas. Although the value of large intact sections of unused habitat is priceless for ensuring survival of biodiversity, this form of conservation has been burdened with complications. Protected areas in the past tended to neglect the human aspect of ecosystems and were often established without regard to socio-economic, cultural, and land tenure issues of the surrounding communities (Utting, 1994). Some parks were created through confiscation of land from people who had inhabited the region for centuries, and in various locations local communities were unaware that a park had even been created in their forest. Local people continued or increased their use of the resources protected in the reserve, either out of necessity or in anticipation of a loss of accessibility, increasing the conflict between the park and the people (Ryan, 1992). Other parks continue to exist solely on paper, with few enforcement staff and low budgets further hampering conservation efforts. More recently it has become apparent that the success of protected areas depends on the support and cooperation of local populations, and community participation has been incorporated into some park management decisions.

Protected areas alone however, cannot ensure the protection of all the Earth's biodiversity. Without tackling the influences behind environmentally destructive activities, parks do not necessarily attend to the reasons behind the need for protected habitat. They are also highly dependent on the state of the surrounding land use (Pimentel et al., 1992), often described as isolated in 'a sea' of devastation, and indeed deforestation outside of reserves remains high in many places in the world[1]. The amount of land in the world currently with protected status is estimated at 5% of the earth's land surface (Ryan, 1992), with the remainder shaped by human managed habitats. Hope for biodiversity lies in that fact that not all agricultural lands are biological deserts, and that some agrosystems, especially traditional structurally diverse systems, can support high levels of biodiversity. Putting a greater focus towards increasing the value of agrosystems for biodiversity may prove to be a more successful conservation strategy.

[1] A study of the Sarapiquí region of Costa Rica indicated that although deforestation within protected areas has decreased, between 1991 and 1995 there was a deforestation rate of 3.2% outside of reserves compared to 0.16% inside, along with a noticeable increase in the number of fragments (Sanchez-Azofeifa et al., 1999).

By incorporating ecologically sustainable practices into contemporary agriculture, that provide both benefits for the farmer and suitable habitat for biodiversity, the impacts of agriculture on biodiversity can be reduced. Although it should be possible to incorporate ecological practices into all types of agriculture, the strategy of restructuring agricultural landscapes for biodiversity protection is optimal in regions where traditional agriculture has previously operated with ecological practices, where agricultural land-use is adjacent to remaining stretches of intact habitat, and where biodiversity is high (Pimentel et al., 1992). Central America is a prime example of such a location, where there is a high concentration of the earth's biodiversity, indigenous cultures have been practicing sustainable agroforestry[2] for centuries, and smallholders tend to settle on the 'agricultural frontier' adjacent to remaining forest patches. Central America has also experienced high rates of deforestation in the past fifty years, as kilometres of forest have been replaced with pasture and commercial agriculture, making a search for alternative sustainable practices an even higher priority.

Agroforestry has been a significant part of livelihood in Central America since the pre-Columbian era, and continues today in the small farms seen throughout the region. Traditionally these systems have provided the majority of food, construction and medicinal products within a highly structurally diverse system. Farm practices have adapted to local conditions over generations and tend to share common management methods that promote ecological stability including low external inputs, intercropping,

[2] A system of land-use where trees are planted with the main agricultural crop, along with vegetables, medicinal plants, and animals, either sequentially or simultaneously (Nair, 1993).

diversification of crops, recycling of organic materials, minimum soil disturbance, and efficient use of local energy resources (Altieri, 1990). As the structure of these systems approaches that of natural ecosystems, the greater likelihood they will be sustainable by keeping complex ecological interactions intact while providing a livelihood for the farmer (Gliessman, 1998).

Coffee (*Coffea sp)* cultivation is an agroforestry system that has traditionally used ecologically beneficial practices, and that currently accounts for 7.4% of arable land and 44% of permanent cropland[3] in a region defined by Mexico, Central America, the Caribbean Islands and northern South America (Rice, 1993). Although not native to Central America[4], it has since become entwined with the people of the region and their cultures, and now provides a livelihood for over twenty million people (Ibid.). Initially coffee was grown in Central America under a dense shade canopy. It was also readily incorporated into indigenous agroforestry systems as the strategy for planting coffee was very similar to that used in indigenous shaded cacao systems cultivated beneath the forest canopy. The practice of keeping an intact canopy retained the associated epiphytes, lianas, moss and lichens on the native trees. As farmers incorporated useful and preferred tree species into the farm and removed those deemed unsuitable, the farm became a managed forest ecosystem that retained the structural diversity borrowed from the tropical forest.

[3] Other permanent crops (usually perennials as defined by the FAO) are bananas, oil palm and sugarcane.
[4] Coffee originated in the forest understory of Ethiopia and was not introduced to Central America until 1723.

Traditional coffee systems often attain a diversity of species and structure quite similar to the surrounding forests (Perfecto et al., 1996)[5]. The structural layers consist of coffee as the understory often interplanted with vegetable crops, nitrogen-fixing leguminous trees of the genus *Inga* or *Erythrina,* fruit trees and banana or plantains (*Musa* species) occupying the middle layer, and tall native hardwoods forming an open canopy. Products from the shade trees, such as fruit and timber, are used in the home or sold, supplementing the income gained from the annual coffee harvest and providing a well balanced diet (Lok, 1998). By retaining healthy ecological functions, few agrochemical inputs are required, as the natural system of pest control remains and the diverse canopy maintains nutrient cycling. The farm is also a good source of firewood, an essential fuel to rural dwellings.

Studies show that structurally diverse shaded coffee systems support a high biological diversity for a wide variety of taxa in Mexico, Guatemala and the Caribbean Islands, comparable to surrounding natural forest (Perfecto et al., 1996). Many have focused especially on birds and have shown that shaded coffee plantations could provide an important refuge for resident birds in a fragmented habitat. In Puerto Rico for example, where almost 99% of the forest cover had been removed by the early 1900s, only 11.6% of the island's native bird species became extinct, a phenomenon partly attributed to the findings that 46% of the island's resident land birds are commonly found in shaded coffee plantations (Brash, 1987). Studies have also shown that Nearctic-

[5] Farms in Mexico have been found to contain 90 to 120 species of trees and vegetation (Moguel and Toledo, 1999).

breeding migratory birds[6], whose declines in population can be attributed mainly to the fragmentation and loss of habitat in both wintering and breeding habitat (Askins et al., 1990), also benefit strongly from shaded systems (Greenberg et al., 1997a,b; Wunderle and Latta, 1996).

The practice of growing coffee with a stratified shade layer was transformed, however, in the mid 1900s across regions of Central America to increase yields in response to an increased world demand for coffee. This change was supported mainly by international agencies such as the World Bank and USAID (Rice, 1993). Traditional coffee tree varieties were replaced by those that were more sun tolerant, and the amount of shade in the canopy layer was reduced to almost zero (labeled as sun coffee). Although in the first year sun coffee plantations produce high yields, large amounts of chemical pesticides and fertilizers are required to retain the high output, killing soil microfauna, contaminating the local environment and adding health risks for farmers, as well as increasing the cost of production. Transformation to sun coffee gained justification in the 1970s when outbreaks of the coffee leaf rust (*Hemileia vastatrix*) began making its way up the isthmus from South America (Rice, 1993; Rice and Ward, 1996; Perfecto et al., 1996). This was a fungal disease, and it was believed that the humidity under a thick canopy would propagate the pest, so that the removal of shade was essential. Although the mayhem expected from this disease never occurred, transformation progressed anyway with removal of shade and was seen by some as a

[6] The term Nearctic-breeding migrant is used throughout this paper to represent those migrant bird species that breed in North America and winter in tropical regions. This is to distinguish these migrants from species that migrate from southerly tropical regions to northern tropical latitudes.

second wave of deforestation (Rice and Ward, 1996).

Coffee currently holds the position as the second largest export commodity in the world after petroleum, with a world value of US $14 billion (Rice and McClean, 1999). The crop is grown in over eighty countries on four continents, with Central America and the Caribbean accounting for 25 to 30% of production (Rice, 1993). The majority of coffee farms in Central America today are less than five hectares in size but together own less than half of all the land cultivated in coffee. The remainder of land is controlled by a small percentage of large landholders who have the capital to invest in the high production costs associated with sun coffee systems.

Small farmers in Central America are often locked in a cycle of agricultural credits and debt, and receive for their coffee only a fraction of the price consumers pay in North America (Rice and McClean, 1999). By focusing on one main income-generating crop, they are at the mercy of the fluctuating international price for coffee, and if all socio-economic needs are not met on the farm alone, farmers must seek alternative methods for obtaining them, at times from the surrounding tropical forests. Shaded coffee farms could meet some of these socio-economic needs through the additional trees and their products associated with coffee, and could assist biodiversity by both providing habitat and foraging niches and by alleviating pressure on intact forest patches. The magnitude of the coffee market and the influence of consumer demand on management practices in coffee producing countries indicates that ecologically beneficial coffee agrosystems could play a significant role in biodiversity protection.

1.2. Research issues and questions

In Costa Rica over 40% of coffee is currently considered technified, with an additional 50% at an intermediate level between traditional and sun coffee (Rice, 1993). The widespread practice of small amounts of shade associated with coffee presents a challenge for the attempt to encourage more sustainable practices in the region. Essentially six topics need to be investigated when looking at the possibilities to encourage the increase of shade in farms that have become technified (modified from Beer et al., 1998): (1) the priorities and preferences of farmers for home use and sale of additional shade tree products; (2) what tree species can grow at that location biophysically; (3) the benefits to biodiversity (e.g. tree species, specific to a location, that support high level of tropical forest diversity); (4) existence of markets for additional products and their profitability to farmers; (5) suitability of practices within environmental laws of the country; and (6) openness (or limitations) to change. The examination of socio-economic benefits derived from shade trees is essential because these variables, rather than biological ones, are used by farmers when making management decisions regarding their farms (Budowski, 1993).

The above issues must be investigated within the framework where land-use decisions are being made, incorporating "socio-economic, socio-cultural and socio-political aspects" into any proposed project design (Utting, 1994). To date few socio-economic studies have been conducted on coffee plantations in Central America or on the benefits and costs at the farm level (Beer et al., 1998; Budowski, 1993; Current et al., 1995; León, 1998).

In the following study I combine biodiversity data with social, cultural and economic information from local farmers, to investigate the possibility of increasing the amount of shade in coffee farms in two communities in southern Costa Rica, touching on the six previously mentioned topics. Three broad research questions were formed to investigate the current practice of coffee in the study region and how an increase in shade could be encouraged:

(1) What are the priorities of the farmer regarding the coffee farm and what are the concerns and attitudes of coffee farmers towards altering current practices by introducing more shade trees?

(2) What uses other than shade do different tree species cultivated with coffee provide for small farmers?

(3) How do different coffee management systems differing in the shade tree species compare in terms of avian diversity, and which tree species would be most beneficial to the conservation of this group?

Birds were used as a biodiversity indicator for a variety of reasons including the well-documented census methods for birds (Hutto et al., 1986; Bibby et al., 1992), the ability to discern birds both by sight and by sound, the general notion that birds are good indicators of environmental disturbances, and the wealth of research on tropical birds in the research location from the studies of Dr. Alexander Skutch (Stiles and Skutch, 1989; Skutch, 1987; 1983a,b; 1971; 1954). There is already evidence from observations that bird species are declining in and around Los Cusingos, especially as the land-use has rapidly changed from forest to a variety of agricultural practices, including coffee (Dr. Skutch, per. comm.). Additionally, there is considerable public interest in birds and study results can easily catch the attention of coffee consumers in North America.

From the research questions four main working objectives of the research were constructed as follows:

(1) To gather information and perspectives on the economic, social, and political factors affecting coffee land-use in Costa Rica, in order to set and understand the context in which current practices exist and in which land-use changes are occurring.

(2) To compare species diversity in four different coffee management practices, using avian diversity as a biological indicator.

(3) To gather information on the use and value of the different shade tree products to the people of the community from informal interviews and anecdotal information.

(4) To combine results from the previous objectives in order to recommend strategies to increase the amount of shade over coffee using management practices that are both ecologically sustainable and economically productive at the farm level for the region.

1.3. Organization of the research

The variety of coffee agrosystems in Central America is examined in more detail in Chapter 2, with emphasis on shaded coffee systems. To provide a framework and background for the research, Costa Rica and the significance of coffee in this country is examined in Chapter 3. Chapter 4 documents the research site, detailed research methods of both the informal interviews with community members, and the avian point counts in the four coffee management practices. Chapter 5 discusses the results of the research – a description of current coffee management practices, apparent themes from the interviews, and results and discussion of the data analysis from the avian point counts. Finally, Chapter 6 integrates and synthesizes the information attained during the study, providing suggestions on how to increase the use of shade over coffee in the region, and giving recommendations for future projects or research that would be beneficial for the study region.

CHAPTER 2: COFFEE MANAGEMENT SYSTEMS

2.1. Coffee

Coffee is a tropical plant that grows between the latitudes of 25° N and 25° S, which evolved under permanent shade within a four-layer forest complex in Ethiopia. It grows best in regions with precipitation of 1600 to 2000 mm per year, yet requires a distinctive dry season of three to four months to stimulate flowering of the plant and ripening of the fruit (Maestri and Santos Barros, 1977). Optimal altitudes for growth range between 900 and 1400 metres above sea level (Muschler, 1997), with growth restrictions mainly due to temperature as photosynthesis begins to slow above 24°C, becoming negligible at 34°C. According to a study by Muschler (1997) in Costa Rica, low elevations (below 900m), poor soils and high winds are all characteristics that favour the use of shade, whereas higher crop yields can be attained without shade at optimal elevations where the soil is rich in nutrients and there is no wind. Although this argument has been used to support the expansion of sun coffee in the Central Valley region in Costa Rica, this method of determining where shade should or should not be used is not always carried out in practice.

The timing and fruiting of the coffee plant depends on the elevation and on the variety of coffee used. After the white flowers have been pollinated, a green fruit or berry[7] develops, which becomes a deep red when ripe. The red berry is picked by hand

[7] There is varying terminology used in the literature to describe the stages of the coffee product from fruit to coffee cup. Throughout this paper I will be referring to the green and ripe fruit on the coffee plant as a 'berry' and the product after processing, which is traded on the market, as a 'bean'.

every harvest season. The berries consist of four layers: an outer layer of skin, a layer of pulp, a thin casing surrounding the seed, and the seed itself. It is the seed that, once roasted, becomes the familiar coffee bean that is ground for the beverage. There are two species of coffee sold on the international market differing in their taste quality. *C. robusta*, the majority of which is grown in Africa and Asia, has a coarser taste, is higher in caffeine, and is used mainly to produce instant coffees. *C. arabica*, 80% of which is grown in Latin America, has a smoother flavour but less caffeine, and is the origin of most gourmet coffees. A variety of other parameters affect the taste of the final product including elevation (berries ripen more slowly at higher elevations, producing a harder higher quality bean with more flavour), amount of shade [many consumers believe that coffee grown under shade has a richer flavour, Rice and Ward (1996) and CEC (1999)] and the way the fruit is processed (with either the wet or dry method).

Coffee produced with the wet versus the dry processing method is less bitter and has a richer flavour, and is the most common form of processing coffee in Costa Rica. The dry method involves drying the harvested red berry in the sun or a drier, and then removing the dried outer fruit before roasting the contained bean. The wet method involves subjecting the harvested berry to a variety of water treatments (occurring at *beneficios,* coffee processing plants) that decompose the surrounding fruit, isolating the contained seed (Alvarado Soto and Rojas Cubero, 1994). Dry processing is the traditional method and today is usually reserved for Robusta coffees. The isolated bean in its unroasted form (often called 'green' coffee) is the part that is traded on the international market, and is usually roasted and ground in the importing country.

2.2. Diversity of coffee systems

The main alterations to coffee management practices intended to increase yields throughout Central America (Table 1) involved replacing the actual variety of coffee plants cultivated, changing management methods in the farm, and reducing the amount of shade in the canopy. Older coffee varieties such as *tipica* and *bourbon*, which have a life span of more than thirty years and a height of up to five metres, were replaced with hybrid stunted varieties such as *caturra, catuai*, and *catimor,* and a new hybrid called CR95 that was supposedly resistant to leaf rust, all bred for their high production and low stature. As a result of high productivity and increased exposure to sun, the lifespan of a plant is between ten to twelve years instead of twenty-five or more for plants grown in traditional systems. Approximately 92% of Costa Rica's coffee sector is now made up of the newer short stature varieties of *catuai, caturra* and c*atimor* (Alvarado Soto and Rojas Cubero, 1994). Other improvements included recommendations for higher levels of fertilization and pesticide use, and strict pollarding[8] regimes for shade trees, increasing the amount of labour required in the farm compared to traditional systems. In Costa Rica, as a result of these technological changes, production of coffee increased 735% while the amount of land in coffee increased by only 125% between 1950 and 1990 (Zamora-Quirós, 1997). Yields increased from 10 *quintales*[9] per hectare to 32-35 *quintales* per hectare (Zamora-Quirós, 1997).

[8] An agroforestry term that describes the removal of branches from a tree to manage its growth and the amount of branching in the crown. It often involves the removal of all but a couple of branches attached to a trunk that is 2-4 m in height.
[9] A unit used to measure coffee – 1 *quintal* is equivalent to a 46 kg bag.

TABLE 1: Comparison of traditional and modern coffee management practices in Central America [modified from Perfecto et al., (1996)].

CHARACTERISTIC	**TRADITIONAL**	**MODERN**
Coffee variety	*tipica, bourbon*	*caturra, catuai, catimor*
Height of coffee plant	3-5m	2-3m
% shade cover	60 - 90%	0 - 50%
Height of shade trees	15-25m	5-8m
Species of shade used	mixed forest, fruit, bananas and legumes	legumes, often monoculture
Density of coffee plants	1,000-2,000 per hectare	3,000-10,000 per hectare
Years to first harvest	4-6 years	2-3 years
Plantation lifespan	30+ years	12-15 years
Agrochemical use	none to low	high
Soil erosion	low	high
Labour	low	high
Yield	low	high

The shade layer continuum from thick traditional shade coffee to sun coffee, as seen in coffee farms of Mexico, is illustrated in Fig. 1 (Moguel and Toledo, 1999). Rustic shade, consisting of coffee planted in the cleared tropical forest understory, and traditional polyculture, where selected trees are incorporated over the coffee, represent the traditional methods, with a canopy height of twenty to thirty metres. These systems are rare in Costa Rica. Commercial polyculture, with a canopy of around fifteen metres, and specialized shade represent coffee systems after modernization in the 1970s. The

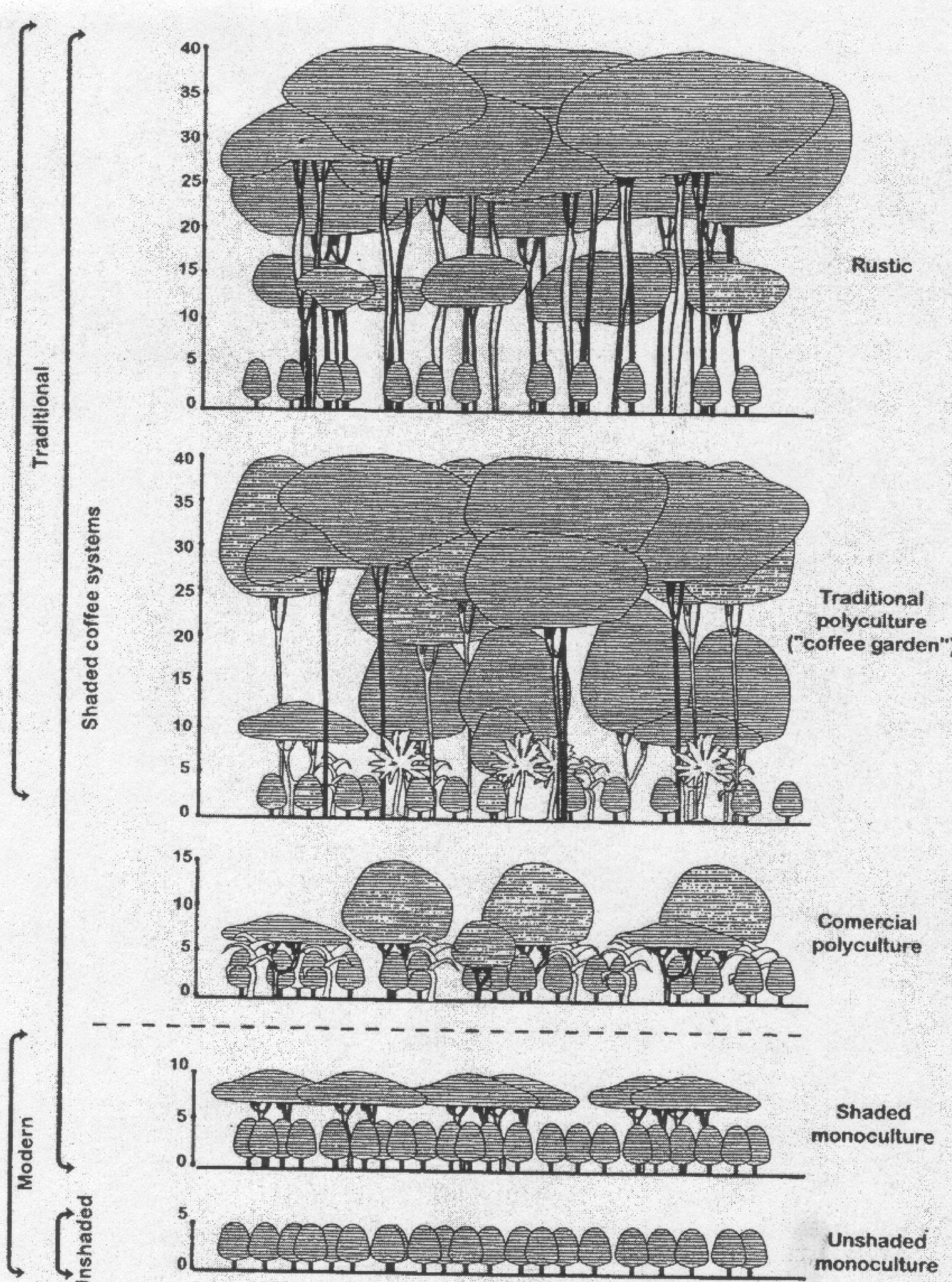

FIGURE 1: Illustration of five different shade regimes of coffee management systems in Mexico. [Source: Moguel and Toledo (1999)].

removal of shade reaches an extreme in sun coffee (unshaded monoculture), where tightly packed rows of coffee are fully exposed to sun. Sun coffee systems are concentrated in the Central Valley highlands in Costa Rica.

This variety of coffee systems in Central America makes providing a definition for 'shade coffee' extremely difficult. Shade coffee farms in countries such as Guatemala and El Salvador can be indistinguishable from forest by the untrained eye (Rice, 1993; various per. comm) due to the diversity of trees in coffee farms. In Costa Rica however, coffee grown with only one species, the leguminous Poró (*Erythrina poeppigiana*), cut to a height of three to four metres and widely distributed throughout the farm, is considered shade coffee by the National Costa Rican Institute of Coffee (ICAFE) because a tree species has been incorporated into the farm. A definition of 'shade coffee' is needed for marketing purposes, but this definition should be specific to the coffee producing country as shade coffee in countries such as Costa Rica may never reach levels of tree diversity seen in other countries, but can still be more beneficial to biodiversity than existing coffee systems.

2.3. Shade coffee as a refuge for biodiversity

The progressive alteration of traditional shaded coffee to high input monocultures in Central America during the past twenty years has spurred investigations comparing diversity between forest, shaded coffee and coffee monocultures across a wide variety of taxa in Central America (beetles: Nestel et al., 1993; ants: Perfecto and Vandermeer, 1996; Perfecto and Snelling, 1995; Roth et al., 1994; bats: Estrada et al., 1993; other mammals: Gallina et al., 1996 and Estrada et al., 1994). General results among these studies indicate a pattern of species diversity and species distribution evenness that is low in sun coffee, higher in shaded plantations, and highest in intact forest patches. Results indicate a removal of shade would reduce insect diversity, enhance the dominance of a few species (Nestel et al., 1993), and encourage the dominance of the tropical fire ant *Solenopsis geminata* (Perfecto and Vandermeer, 1996). Perfecto and Snelling (1995), looking specifically at the diversity of ground foraging ants with the change in vegetative structure from traditional to monocultue coffee, found a significant decrease of diversity through the gradient from shaded to zero shade plantations. There have been few studies done on insects in the canopy, but preliminary results with fogging techniques show a high diversity of ants in the canopy layer (qtd. in Perfecto and Snelling, 1995).

The majority of avian diversity studies in coffee have focused on Mexico, Guatemala and the Caribbean Islands (Wunderle and Latta, 1996; Greenberg et al., 1997a,b; Moguel and Toledo, 1999). These studies generally compared diversity between sun coffee, shaded coffee (usually with common leguminous trees such as *Inga or Gliricidia sepium)* and remnant forest sections in the region. Again, a higher avian diversity was found in structurally diverse coffee farms, comparable to surrounding intact forests.

Greenberg et al. (1997a) of the Smithsonian Migratory Bird Centre (SMBC), compared bird diversity in the Ocosingo Valley of Chiapas Mexico (using point counts and transects over time) between rustic coffee plantations (in the shade of semi-deciduous tropical broad leaved forest), farms dominated by planted *Inga,* and various surrounding natural habitats. There was no difference between the rustic and *Inga* coffee farms in terms of plantation size, average canopy height, coffee height or tree density. Results showed a higher species richness in the shaded plantations (104 species in *Inga* plantations, 107 species in rustic coffee) compared to other managed habitats sampled (pasture, milpa etc), with the exception of intact primary or lowland secondary growth forests. Although some of the more specialist forest species were not found in the coffee plantations, the study did show among the highest densities and diversity of Nearctic-breeding migrants. The authors concluded that "much of the value of shade coffee plantations for conserving bird diversity can be found in planted as well as rustic coffee, provided that the planted plantations are of comparable structure" (Greenberg et al., 1997a).

Following this study, research was conducted in Guatemala to examine the danger of adopting a dichotomous sun versus shade argument by looking at farms dominated by *Inga,* plantations dominated by *Gliricidia sepium* and sun coffee plantations with negligible canopy cover, and comparing these to forest remnant and surrounding natural habitat (Greenberg et al., 1997b). Both shaded plantations had a low canopy height of six to eight metres, with a 40% to 50% shade cover, and the *G. sepium* plantation had a lower vertical structural complexity than the *Inga* plantation. The avian diversity was highest in remnant forests (87-122 species) followed by farms with *Inga* (73 species), and the least amount of species was found in farms with *Gliricidia* (65 species), which had diversity levels closer to sun coffee. The study also found that the total number of birds per point was positively correlated with shade cover and the number of tree species. The higher diversity in *Inga* farms was most likely due to a strong attraction of hummingbird and icterid[10] species to *Inga* flowers, and possibly due to an increased insect food source on the Inga trees[11].

Comparing the study in Guatemala with the study in Chiapas, Greenberg et al. (1997b) observed a much lower species diversity overall in the Guatemalan coffee plantations than those in Mexico. The researchers attributed this to the heavy shade management practices in Guatemala (where trees are pollarded twice a year) and heavy pesticide use, to protect the farm against invasion from coffee fungal pests. In the farms studied in Chiapas, highly technified plantations with reduced shade were virtually absent, and most of the farms were of the rustic type. The overall message that can be taken from both of these studies is that heavy pruning of the shade layer affects biodiversity adversely, and that plantations should have "the greatest structural and floristic diversity possible and still allow economically viable returns from a coffee farm" (Greenberg et al, 1997b).

2.4. Biophysical benefits of shade trees to the farm

The Tropical Agronomic Centre for Research and Teaching (CATIE) was the first institution in Central America to initiate an agroforestry program and became a leading institution on the research of trees associated with coffee farms, investigating a variety of biophysical benefits of trees in coffee ecosystems (Beer, 1987; Beer et al., 1998). One

[10] American oriole and blackbird family.
[11] Ackerman et al. (1998) found a variety of insects attracted to Inga species including grasshopper and Lepidoptera species feeding on the leaves, leaf cutter ants, and wood boring insects as well as predators such as wasps, ants and spiders.

significant benefit of trees in agriculture is a reduction in soil erosion provided by the roots, and a large reduction in nitrogen leaching from the soil (Babbar and Zak, 1995). Exposure to full sun in sun coffee plantations causes overbearing of fruit, creating a great stress on the plant. Increasing the amount of shade removes this stress and increases the longevity of the plant. Shade was also found to decrease wind damage to coffee plants and to create a more optimal microclimate for ecological processes in the soil (Ibid).

Additional benefits of shade trees include the reduction in agrochemicals and labour required on the farm. The addition of nitrogen-fixing leguminous shade trees such as *Inga* species*, Erythrina* species *or G. sepium,* can provide levels of nitrogen equivalent to recommended levels of chemical fertilizers by using the leaves as mulch on the soil (Beer et al., 1998). A study of *E. poeppigiana* grown with coffee and zero fertilizer produced the same amount of fresh fruit and soil nitrogen level (224.75 m^3 of fruit and 74.2 kg per hectare of nitrogen) as a sun coffee plantation using 132 kg per hectare of fertilizer (Ramírez, 1993). Using the leaves as mulch in this manner also provides a protective layer to the soil, suppressing weed growth, and thereby reducing the labour and chemicals required. In addition, the higher diversity and density of arthropod predators and parasitoids, as well as foraging insectivorous mammals, can decrease the number of pests on coffee, and the amount of pesticides required (Perfecto et al., 1996).

2.5. Benefits of shade coffee to the small farmer

Cultivating other trees with coffee that provide additional products that can be sold (including timber, fruits, vegetables), reduces the dependency of coffee farmers on one crop (Beer et al., 1998). This is especially beneficial for a crop whose yield and prices vary substantially between years. A study conducted at CATIE (Beer et al., 1998) indicated that farms with *Cordia alliodora* (Laurel) planted at 100 trees per hectare produced an average of four to six cubic metres of wood per year, which would compensate for a reduction of coffee yield up to 17%. Smallholders also benefit through the reduction in agrochemical use in farms with more shade, by reduced costs and labour, and through the provision of a healthier environment for the smallholder and family.

Economic contributions of coffee agroforestry systems at the farm level have not yet been addressed and specific cost-benefit analyses are needed (Current et al., 1995; León, 1998). The economic studies that have been done usually do not include income from the sale of additional products from shade trees nor environmental externalities such as pesticide contamination, health risks, silting of rivers from erosion and others. Gobbi (2000) stated costs for five coffee farm types in El Salvador, and found that production costs, inputs and materials, and repair and maintenance were almost twice as high per hectare in sun coffee farms compared to other types. However further studies need to be conducted on the economic benefits to farmers, including all externalities and additional income that can be gained from a farm with an increased level of shade.

2.6. Market opportunities for shade coffee

Over 70% of the world coffee market deals in Arabica coffee, with the main terminal market in New York[12]. Three giant companies control most of the coffee market

[12] The second main terminal market is in London, dealing mainly with Robusta coffee from Brazil.

in the Western Hemisphere, Nestlé, Proctor and Gamble, and Phillip Morris, together accounting for 60% of the market share. Although the price of coffee has always fluctuated on the market, often in response to high or low harvests in Brazil, the demand for coffee is inelastic, remaining relatively stable as price varies[13]. This suggests that consumers would be willing to purchase ecologically friendly coffee, even if the price is higher.

There are currently three main types of certification programs available for coffee, varying in the focus of their certification criteria. The Fair Trade label requires improved treatment of coffee harvesters and better living conditions, while 'certified organic' requires agrochemical-free practices. Neither of these programs, however, requires the use of a shade layer with the coffee and therefore do not necessarily support high biodiversity levels.

The market for shade coffee has just begun in the last decade, and as yet there is no consensus on criteria or standards. Instead, a variety of organizations have promoted and marketed different labels of shade coffee, either through third party certification (e.g. ECO-O.K. label) or direct purchase from farms (Rice and McClean, 1999). The standards of each organization however share similarities in the number of tree species required in the canopy layer, the percent of shade and the regulation of agrochemical use. Some of the current programs include: Rainforest Alliance – ECO.O.K program in Guatemala and El Salvador; Conservation International – E-coffee in El Triunfo, Mexico;

[13] In 1995 the Association of Coffee Producing Countries (ACPC) formed to limit coffee exports in order to increase international prices. In May 2000 the ACPC raised the minimum price of coffee by 37 cents to ¢0.95 per pound, although this is not expected to have much impact on coffee consumers (Bertin, 2000).

World Wildlife Fund (WWF-Canada) Café Forestal in Arenal, Costa Rica; Smithsonian Migratory Bird Centre – Bird Friendly coffee seal.

The current demand for specialty coffee in North America may provide an indirect incentive for changing management practices to shade coffee through the higher monetary premiums farmers could obtain. Sales of specialty coffee in the United States, a country that accounts for half the global market for roasted gourmet coffee, increased from $1 billion in 1990 to $2.5 billion in 1995 (Rice and Ward, 1996). Shade coffee sales currently are valued at US$30 million, 1% of total gourmet coffee sales (Rice and McClean, 1999). The premiums from sale of coffee under the ECO-O.K. label are not decided, but could be sold for an extra $0.10 a pound or more (Ibid.). The adoption of shade certification criteria (planting trees, education in agrochemical use) was found to be feasible in five coffee farm types ranging from rustic to sun coffee in El Salvador (Gobbi, 2000). However incorporating these criteria into sun coffee showed the most profit, and a risk-free investment occurred only with adoption into traditional polyculture farms.

CHAPTER 3: SETTING THE CONTEXT FOR INVESTIGATION – COSTA RICA, CONSERVATION AND COFFEE

It is important to explore the social, economic and political conditions in which land use decisions are being made in order to gain a stronger understanding of the influences on farmers' decisions concerning coffee management practices. This chapter gives a concise background of Costa Rica, its conservation infrastructure, and the coffee industry in this country. These subjects are dealt with briefly, in order to set a context in which the research was conducted, and are accompanied by references that go into more depth cited throughout the discussion.

3.1. A brief description of Costa Rica

Costa Rica is located at the southern end of the Central American isthmus between 8° and 10° North of the equator, positioned between Panama to the south and Nicaragua to the northwest. It is the second smallest Central American country with a land area of 51,100 km^2. It supports a population near 3,841,000 (FAO, 1999), and has the highest GNP per capita in Central America ($6550 in terms of purchasing power parities), one of the highest literacy rates in the world (at 94%), and a life expectancy of 76 years (UNDP, 1999). The majority of the population is concentrated in the Central Valley highlands surrounding the capital city of San José (Fig. 2) and 56% of the population lived in rural areas in 1992 (Biesanz et al., 1999).

Agricultural production is the largest mainstay of the country, earning a combined two-thirds of the national revenue and occupying more than half of the arable land in the

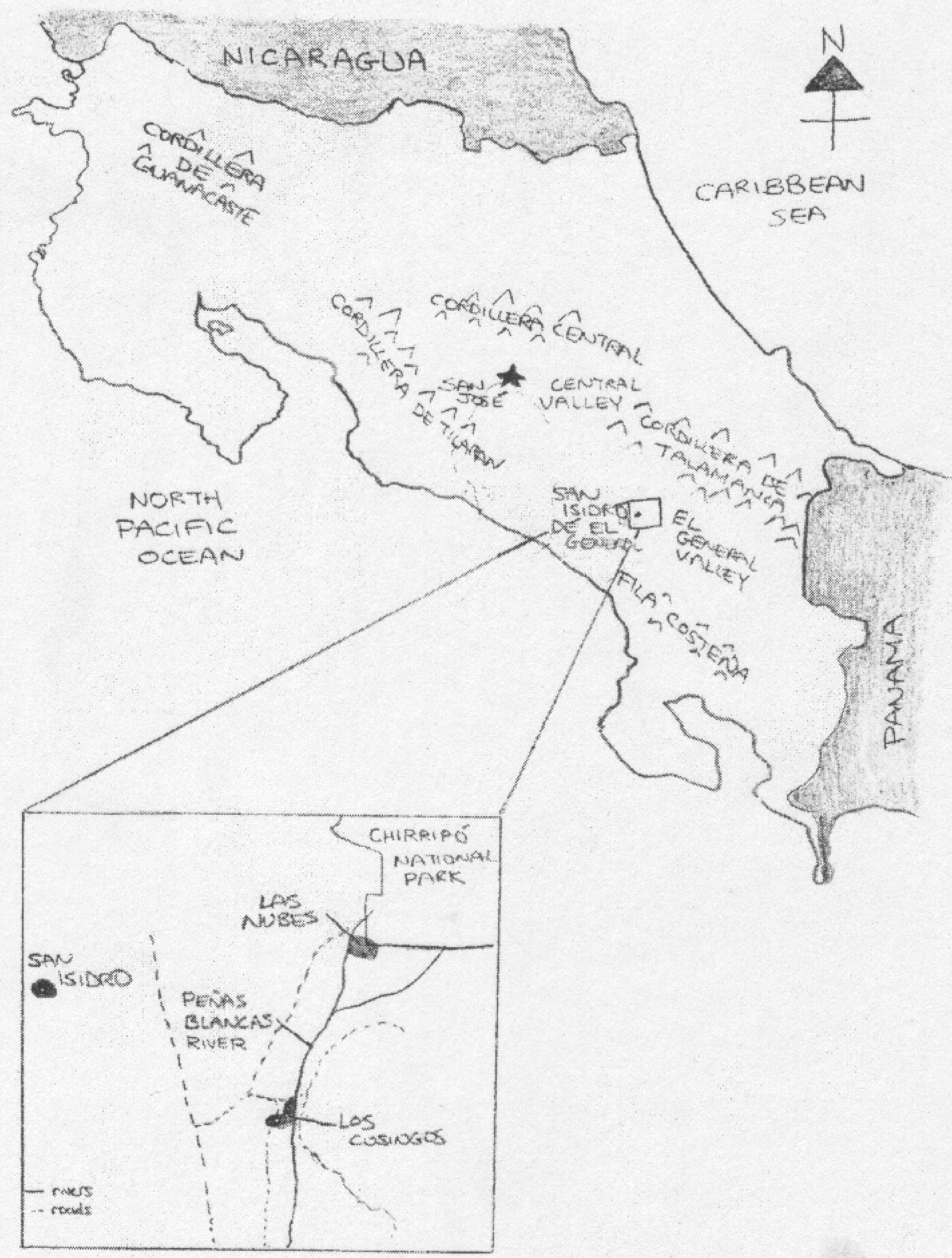

FIGURE 2: Map of Costa Rica situating the study region (inset).

country (Evans, 1999). Approximately 85% of these agricultural producers are small farmers with less than ten hectares while 3% are large estates owners who control 47% of the land in agriculture (Watson et al., 1998). The banana industry surpassed coffee as the number one revenue earner in the 1900s, yet both of these have been out competed by 'ecotourism' since 1992, which generated US$700 million in 1997 (Evans, 1999).

Five mountain chains divide the country and act as natural evolutionary barriers (Fig. 2), thereby supporting a high diversity of natural vegetation and fauna for such a small land area (Hall, 1985)[14]. Approximately 900 bird species have been documented in Costa Rica consisting of a complex mix of North American and South American families, a result of the geological formation of the Central American isthmus (Stiles and Skutch, 1989). Bird species in the southern Pacific region share a close affinity to those of South American origin. Of the total number of bird species noted in Costa Rica, over 200 are migratory, the majority Nearctic-breeding migrants. At least fifty to seventy-five species undertake altitudinal migrations, moving up-slope in the dry season to breed, and down-slope during the wet season to avoid the heaviest of rains, yet this is most likely an underestimate since movements of species are poorly known (Stiles, 1993). Despite the efforts at conservation in the country, the greatest threat to Costa Rica's avifauna is habitat loss (Stiles and Skutch, 1989), followed by hunting and the cage bird trade[15].

The culture of Costa Rica has a rich history as it was exposed to a European

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[14] These varied ecozones of Costa Rica are divided into twelve Life Zones by Dr. Leslie Holdridge of the Tropical Science Center, based on temperature, rainfall, evaporation, humidity and elevation (Holdridge, 1967).

[15] The practice of having at least one bird (e.g.Euphonias, Black-faced Solitaires (*jlgueros)*, Parakeets) in a cage is a common sight throughout rural Costa Rica (Stiles and Skutch, 1989; personal observation).

influence from the Spanish colonists which was intertwined with indigenous pre-Columbian cultures of the country. It is a common myth that there were few indigenous people when the Spanish settled, and that the independent subsistence colonists created a "rural classless democracy of peace-loving white farmers" (Biesanz et al., 1999). On the contrary, archaeological evidence indicates people had lived in Costa Rica for at least 11,000 years before conquest, and that the country was a bridge between cultures to the north and cultures from the south. An estimated 400,000 to 500,000 people lived in Costa Rica when Columbus arrived, distributed between some nineteen chiefdoms (Ibid). These populations practiced slash-and-burn agriculture and agroforestry with crops such as yuca, peppers, tomatoes, beans, corn, avocados, and pejibayes (Saenz Maroto, 1972), and had little negative effect on the existing forests.

When Spanish settlers arrived in 1521, many of these indigenous people were killed by foreign diseases, were shipped to other countries as slaves, or retreated into remote mountain regions. A mestizo culture emerged (the prevalent culture today) from the mixing of indigenous individuals with European colonists or the African slaves they brought with them. The lack of remaining large indigenous populations from which to draw a labour force eliminated the option to form large hacienda style plantations with conscription labour, seen in countries such as Guatemala (Williams, 1994; Winson, 1989). Instead the amount of land a farmer could use for agriculture was restricted by the size of the immediate family available to work it (Zamora-Quiros, 1997).

Costa Rica was the farthest, poorest and most neglected member of the Spanish Capitaincy General headquartered in Guatemala, the 'Cinderella' of the Spanish colony

(Biesanz et al., 1999). This positioning of Costa Rica however, allowed for more independent management decisions regarding land-use, and paved the way for the adoption of a large coffee industry (William, 1994; Winson, 1989). Added to this was a lack of rival products[16], few surviving indigenous communities to fight for land, and an ideal coffee habitat in the Central Valley in terms of elevation, temperature, rainfall and rich volcanic soils (Biesanz et al., 1999). During Braulio Caurillo's presidency from 1835 to 1842, coffee production was promoted by giving plants to the poor, and offering free land to anyone who cultivated coffee. In 1845 Costa Rica began to directly export coffee to London, opening a contact with Europe that would result in continual exchange of students, professors and ideas in the future (Evans, 1999).

Large landholdings of coffee became more prevalent at the end of the nineteenth century. When traditional dry processing (which could be conducted at the farm) was replaced by capital intensive wet processing, small farmers could not finance the processing, transport and shipping of their product. This opened the door for a wealthy elite coffee class that took over these activities, and soon purchased farms extending their property holdings (Biesanz et al, 1999). This coffee elite dominated country politics, "installing and removing presidents to suit their economic interests" (Wilson, 1998), and the period before 1880 was full of dictatorships, coups and military oustings.

In 1876 a railroad connecting the Central Valley to the Caribbean coast was built to provide an easier route to export coffee to Europe. The construction of this railroad contributed to making the Caribbean coastal region conducive for banana plantations, and

[16] The remainder of the Central American isthmus concentrated in the export of indigo or cochineal.

the expansion of this industry started a spiraling deforestation rate in the country. A total of 75,000 hectares was cleared for bananas between 1900 and 1965 (Watson et al., 1998), with most of these plantations owned by large foreign multinationals, such as United Fruit. An increase in foreign debt along with terms associated with rescheduling interest payments and providing an environment for future loans, led to an increased promotion of export crop production, including cattle. By the 1970s cattle ranching was expanding, converting one third of the country to pasture by 1980 (Evans, 1999) and two-thirds of the country by 1994 (Biesanz et al., 1999).

The rapid decline of forested regions of Costa Rica's land area was a phenomenon that did not truly intensify until the influence of development schemes involving increased production of export crop agriculture during the later half of the last century (Carrière, 1991). Forest cover dropped from 99% to 72% over the period from 1500 to 1950, yet fell to 39% by 1990 (Watson et al., 1998). The deforestation rate of 40,000 to 50,000 hectares per year (between 1950 and 1984) has been reduced in recent years (Watson et al., 1999), perhaps as a result of conservation efforts. This may also be due to the growing value of protected areas for ecotourism, whose increase has been attributed in part to the country's current lack of civil unrest and economic and political stability.

3.2. Conservation

Administration of natural reserves and historical sites in Costa Rica was united under the National Parks Department upon the passing of the Forestry Law in 1969, and became known as SINAC (National System of Conservation Areas) in the mid 1990s.

Under this system the country is divided into eleven conservation zones, each with its own regional environmental council. SINAC is administered by the Ministry of Environment and Energy (MINAE)[17], which is the governing body responsible for the enforcement of environmental laws, administration of protected areas, and the issueing of permits for the use of natural and state forests [for more detail on the history of the protected area system in Costa Rica see Evans (1999)].

The Forestry Law (No. 7575) was most recently amended in 1996. It regulates the use of forest and trees on both public and private lands, forbidding the change of land-use designated as forest under the system of geographic land-use capabilities[18]. Objectives of the law are to conserve, protect and administer natural forests, to ensure sustainable use of resources, and to increase the standard of living of the rural population (IJSA, 1997).

The Forestry Law dictates the use of permits to remove and transport individual or groups of native trees on private land, with MINAE responsible for the approval (by forest engineers) and issuing of the permits, including any tree that has grown naturally in a coffee farm. To obtain these permits for tree removal a *plan de manejo* or management plan for the property must be constructed clearly delineating the amount and timing of cuts, evaluating possible impacts, and detailing all protective measures that will be taken. Before the 1996 amendments to the forestry law, approval could be obtained solely through MINAE, yet with attempts to decentralize the conservation sector, authority was

[17] Formerly known as MIRENEM.
[18] This is a system that labels a piece of land by the most intensive form of land use it is able to sustain without degradation – for example clean-tilled crops, pasture, permanent crops, forestry and protected area.

passed to the regional environmental councils and/or municipalities to process permits of up to five trees per hectare per year on agricultural land. Many councils and municipalities, however, lack the capacity and resources to assess and grant these requests (Watson et al., 1998). As a result, landholders must travel to the closest MINAE office to begin the lengthy process, which at times is difficult and time consuming for smallholders living far from city centres, and trees are often removed without the required permits (personal observation). Under Article 28 of the Forestry law, agroforestry systems, tree plantations, or farms where individual trees are planted for the harvest of non-wood products, are the exception to this law and do not require permits to cut, transport or export the lumber, if the trees have been planted by hand (IJSA, 1997). Permits are still required, however, to remove native hardwood trees that have germinated without assistance in agroforestry designated farms.

In 1996 the amount of forest remaining in Costa Rica was 1,787,000 hectares, with 35% of this in protected areas or private land (Watson et al., 1998). However despite Costa Rica's worldwide reputation for its system of conservation areas, along with the reductions in the rate of deforestation, forests in the country are still threatened by the lack of effective enforcement of environmental laws, and the economic strain of small farmers causing them to encroach on existing forests (Watson et al., 1998; Biesanz et al., 1999). Overlap of duties and authority within government departments and uncertainty of park boundaries often leading to double ownership of land add to the inefficiency of the park system. In addition, many of the existing parks are located at high elevations unsuitable for agriculture, neglecting lowland habitats and especially the connections between the two (Skutch and Stiles, 1989).

3.3. Coffee in Costa Rica

Approximately 90% of coffee produced in Costa Rica is exported to over 50 countries, generating revenue of US$433.53 million in the 97/98 harvest (ICAFE, 1998), and contributing 2.8% of the world's total production by volume. The United States is the largest receiver of Costa Rican coffee (30.86%), followed by Germany and the United Kingdom (ICAFE, 1998), with a mere 2.67% exported to Canada. The remaining 10% of coffee produced is consumed nationally, roasted with sugar to add flavour to the usually inferior beans.

A total of 93,000 hectares of land are cultivated in coffee in Costa Rica, compared to 260,000 in Guatemala and 2,095,000 in Brazil (FAO, 1999). Around 92% of coffee farms are less than five hectares in size (Biesanz et al., 1999). Of the coffee planted in Costa Rica, only 30% is considered true sun coffee (Carlos Fonesca, ICAFE, per. comm.), the remainder qualifying as shade, regardless of the small percent cover seen in some farms. The contribution of coffee to total exports in Costa Rica decreased from 42% to 10% over the period from 1965 to 1993 (Rice, 1993).

The institutions involved in coffee production in Costa Rica take on a pyramidal shape, with a foundation of approximately one hundred thousand small producers, followed by approximately one hundred coffee *beneficios,* and topped off with a handful of major exporters. Small producers are required by law to sell their coffee to a *beneficio* who pays the producer first in agricultural credits, and then with the remaining income after the end of the harvest[19]. Producers therefore have little control over the price they receive for their coffee, or to which country it is sold after being handed over to the *beneficio,* and receive the lowest price for their product in the chain to the consumer. The minimum price *beneficios* must pay is set by the Institute of Coffee in Costa Rica (ICAFE), a self-governing body that regulates relations between the coffee producers, *beneficios,* and exporters, as dictated under the law No. 2762. ICAFE was established in 1932 to represent coffee producers around the Central Valley, and only opened an additional office in San Isidro de El General in 1998. ICAFE is also responsible for the research of management and technology regarding coffee production, which noticeably focuses on an increase in yields. Management recommendations include high amounts of fertilizers and pesticides and highly pruned shade, practices which are prevalent throughout the Central Valley. The organization controls the quality of exported coffee through workshops on harvesting technique, and also through the regulation of coffee plant varieties[20]. ICAFE approval is required before any national bank can issue customs or export permits for coffee and therefore any shade project executed in Costa Rica must be accepted by this organization.

[19] Before the establishment of *beneficios*, producers sold their coffee product directly to community general stores.

[20] Recent restrictions on the expansion of *veranero* coffee (summer coffee that is harvested in January or February in the Pacific dry season) were attributed to its inferior quality and higher prevalence of unripe beans in the harvest. Interestingly, the harvest of the *veranero* coffee coincides with the main harvest season in the Central Valley, where coffee harvesters from the southern Pacific region, both Nicaraguan immigrants and local workers, go to work after the Pacific harvest has finished.

CHAPTER 4: RESEARCH METHODS

4.1. Description of the study region

4.1.1. El General Valley

The communities in which the research was conducted are located within the canton[21] of Pérez Zeledón, in the El General Valley, nestled between the Talamanca mountain range to the northwest and northeast, and the Fila Costeña (coastal range) to the southwest and southeast (Fig 2). Pérez Zeledón receives less rainfall than the Atlantic coast, due to its position in the southern Pacific region of Costa Rica, which also has pronounced wet and dry seasons (Stiles and Skutch, 1989). The average rainfall in the canton varies especially with elevation, and is concentrated in the wet season (from May to December). Two records of annual rainfall from the National Meteorological Institute (IMN) in Pérez Zeledón indicate a yearly average of 2728.7 mm at the Instituto National de Aprendizaje (INA) in San Isidro at an elevation of 700 m, and an average of 4066.9 mm in the town of Cedral at an elevation of 1450 m. The dry season (*verano)* lasts from December to April, and is characterized by lengthy periods of sun with no appearance of clouds. The wet season (*invierno)* on the other hand makes up the remainder of the year and is marked by sun in the early hours and a generally predictable heavy rainfall throughout the afternoon and evening. During the field research seasons in 1999 and 2000 however, late January and early February were atypically wet, with days strongly resembling those of the wet season. The average daily temperature is 23.8° C

[21] A canton represents a region in Costa Rica that has its own municipal governing body. There are over 90 cantons in the country.

(MIDEPLAN, 1994), but has a wider diurnal than monthly variation.

The surrounding El General Valley was colonized as recently as the early 1900s (Skutch, 1971) by people from the Central Valley region. Pérez Zeledón had a population of 107,110 people in 1994 (MIDEPLAN, 1994). The age distribution was skewed towards youth and children, with 39.5% of the population less than 15 years of age, and only 3.1% over 65 years. Of the total population in the canton, 67.8% was dispersed in rural areas at the time of the study, with the remainder residing in the town of San Isidro and the immediate vicinity. The canton contains 12,000 hectares of land cultivated in coffee (out of 93,000 hectares in all of Costa Rica), contributing 10% to the national production levels, at an average of 26 *fanegas*[22] per hectare (Carlos Fonseca, per. comm.).

The exact location of the study region is in the 6-km stretch between Las Nubes Biological Reserve and Los Cusingos Neotropical Bird Sanctuary, northeast of the city of San Isidro de El General (Fig 2). The elevation in this section varies from 600 metres in the farms around Los Cusingos to an approximate elevation of 1500 metres near the peak of Las Nubes. Associated with the increasing elevation is a gradient of decreasing intensity of land use, spreading out from the concentrated urban center of San Isidro. Farms at the lower end of the 6-km section consist mainly of coffee and sugar cane plantations, while higher elevations (over approximately 900m) are composed of pastures greater than eighty hectares. The northern end of the 6-km stretch, above and surrounding Las Nubes, consists of intact forest continuing into Chirripó National Park

[22] One *fanega* is equivalent to 258kg of ripe coffee berries.

and the La Amistad Biosphere Reserve. Small forest remnants of a few hectares are scattered throughout the region, along with a few homesteads that protect significantly large sections of intact forest on their property. Soils throughout the 6-km stretch are generally acidic (ultisols) with the characteristic rusty color of iron-rich soils, yet there are nutrient rich dark soils adjacent to the banks of the Peñas Blancas and Peñas Blanquitas rivers. Three communities are present in the region, yet as coffee farms are concentrated at the lower elevations, interviews and avian surveys were conducted in the lower situated communities of Quizarrá and Santa Elena (Fig. 3).

4.1.2. Los Cusingos Neotropical Bird Sanctuary

Dr. Alexander Skutch bought the property currently known as Los Cusingos in 1941, and has since documented a wealth of information on the diversity and habits of the avifauna of Costa Rica. When the property was first purchased, only a little over a third could have been considered unspoiled forest (Skutch, 1971). Much of the remainder was pasture, extending directly to the banks of the river Peñas Blancas, which has since grown into a thick secondary growth forest. The property is currently 76 hectares in size, and half consists of primary forest.

The forest is rich in tree species, lianas, and epiphytes such as orchids and bromeliads, and has a canopy height of twenty-five to thirty metres. A total of 307 species of birds have been recorded at Los Cusingos alone, 171 of which have bred on his property and almost thirty of which are Nearctic-breeding migrants (TSC, 1993). Under

FIGURE 3: Map of study region with the location Los Cusingos (LC), Las Nubes (LN), and the six coffee farms examined for avian biodiversity. (P=Poró; B= *Musa* species; E= Eucalyptus; T=Amarillón). [Source: Instituto Geográfico Nacional, Costa Rica, 1980)].

the Holdridge Life Zone System (Holdridge, 1967) it is classified as Premontane Wet Forest. Dr. Skutch has personally witnessed the change in land use in the valley surrounding his property over the last 60 years, leaving Cusingos as a forested island amongst an agriculture landscape of sugar cane and coffee farms. Bird species that were found in Cusingos when he first arrived but have since disappeared include the Chestnut-mandibled Toucan (*Ramphastos swainsonii*), the Pale-billed Woodpecker (*Phloeoceastes guatemalensis*), the Rufous-tailed Jacamar (*Galbula ruficauda*), and mammals such as Tayras (*Tayra barbara*) and the Coatimundi (*Nasua narica*).

4.1.3. Las Nubes Biological Reserve

Las Nubes is located six km northeast (along the straightest possible route) from Los Cusingos at an elevation between 1200 and 1500 metres above sea level. The two properties are connected by the Peñas Blancas River that originates in the Talamanca mountain range and joins the El General River before making its way to the Pacific Ocean. Las Nubes is 124-hectares of Premontane Rain Forest merging into Lower Montane Rain Forest under the Holdridge Life Zone System (Holdridge, 1967)[23].

The northeastern section of Las Nubes lies within the boundaries of Chirripó National Park, and thus by the recent designation of Las Nubes as a protected area, it serves to widen the effective conservation zone of the larger park. Pastures of 80 to over 100 hectares lie along the southern and western borders of Las Nubes, while the farm to

[23] This differs from Premontane Wet Forest seen in Cusingos mainly by the amount of precipitation the region receives: wet forests are characterized by an average of 2000-4000mm of precipitation annually, whereas rain forests can have anywhere between 4000 and 8000mm per year of precipitation (Hall, 1985).

the northwest is half pasture and half forest. These pastures are owned by absentee landholders that live close to San Isidro. There has not yet been any in-depth scientific surveys on the flora and fauna in Las Nubes specifically, although local inhabitants attest to having seen Jaguars (*Panthera onca),* Collared Peccary (*Tayassu tajacu*), and *Jilgueros* or Black-faced Solitaires (*Myadestes melanops),* a species commonly taken in Pérez Zeledón for the national cage-bird trade (Dulude, 2000).

4.1.4. Quizarrá and Santa Elena

Dr. Skutch described the Quizarrá he saw upon his first arrival in 1941 as being little more than a thatched roof shed used for storing maize that overlooked the Peñas Blancas River (Skutch, 1971). Like most of the inhabitants of the El General Valley, the majority of the colonists came from the Central Valley region of the country in the early 1900s. Accounts from both Dr. Skutch and elder members of the community of Quizarrá indicate that early settlers in the community grew crops of tobacco, maize and beans that were transported over a footpath to the Pacific Ocean for shipping to the port of Puntarenas on the Central Pacific coast. Pigs were also raised and were herded over the Cerro de La Muerte for sale in Cartago. These pioneer farms gained their original titles of ownership from the government by the 'improvement' of land from forest to active agriculture, and lands were later partitioned amongst children, resulting in a patchwork arrangement of familial clusters in both communities.

The communities and the surrounding landscape have changed significantly since the arrival of the first settlers. Transportation to and from San Isidro used to be along horse paths through large stretches of forest, most of which has since been removed and replaced with agriculture. Deforestation has affected both the level of water in the main rivers and tributaries, and decreased the occurrence of numerous wild species. Elders of both communities remember wild animals [including Jaguars, Mountain Lions (*Felis concolor*), Collared Peccary and Pacas (*Agouti paca*)] as much more abundant than they are today and streams that are now bare in the dry season as once flowing year round.

Although coffee had been grown throughout the region at least since Dr. Skutch arrived, coffee became more common as a cash crop in the 1960s. Coffee in this region was rarely grown in the rustic manner seen in other Central American countries, but the canopy was taller and denser than what is seen in the communities today. Elder community members remember growing coffee in the 1950s and 1960s under a thick canopy of Guaba (*Inga sp.)* without the use of pesticides or tractors. The crop was harvested by the immediate family, dried in the sun and sold directly to the local *pulperías* (general stores), a practice that was changed upon the construction of *beneficios* when the Pan-American Highway was extended to San Isidro by 1950. In the 1970s, farmers began to remove shade from the coffee farms, leaving the crop under sparse shade (Dr. Skutch, per. comm.).

Today the towns of Quizarrá and the higher elevated Santa Elena have grown and consists of 325 people in 84 occupied homes in Quizarrá, and 734 people in 150 occupied homes in Santa Elena (Ministerio de Salud, 1999). In both communities, homes are spread around a central core marked by a community hall, a school, a soccer field, and a *pulpería*. Added to this common layout are a church in Santa Elena, and a health center in Quizarrá. Each community also had unoccupied dwellings at the time of the Ministry of Health census (26 in Quizarrá, 50 in Santa Elena), some of which may have been the small dwellings provided for the workers that come from Nicaragua or elsewhere outside of the community to pick coffee during the coffee harvesting season. These structures are generally provided by larger landholders who require a large labour force for their harvest.

The houses in the communities are one story, and almost all have electricity and running water, yet telephone lines are restricted to the *pulperías*, and individual houses do not have phones. Instead, homes are connected to the capital by way of the television, which every house has regardless of size. Although many dwellings have an electric stove, every house has a wood-burning oven, located in the open kitchen behind the house. This is often the preferred method of cooking in the community and the use of firewood is an essential part of every household. A half hour bus service to San Isidro serves both communities twice a day along local unpaved dirt roads, riddled with potholes. The nearest paved road is three kilometers away.

4.2. Schedule of fieldwork

The research was carried out in two field seasons. The first season, from January 24 to July 30 1999, included a one-month language instruction course in San Isidro, conduction of informal interviews, and the collection of avian diversity data in the wet season. Accommodation during this period was in a newly built house for rent on a coffee farm approximately 0.7 hectares in size. The farm had a shade canopy composed of citrus trees (sweet orange, sour orange, lemon), mango, a tall hardwood Cedro (*Cedrela odorata*) and had live fences bordering the property. This presented the opportunity to observe activities and biodiversity within a small coffee farm. The second field session occurred from January 16 to March 10, 2000 to collect avian diversity data in the dry season. During this period I resided in the guardhouse at Los Cusingos.

4.3. Informal Interviews

4.3.1. Methods and analysis

To collect site-specific information on the present views and management practices of coffee in the study region between Las Nubes and Los Cusingos, I conducted a total of seventeen farmer interviews, consisting of fifteen homesteads, over the period from April 7 to May 7, 1999 and from June 3 to July 20, 1999. The interviews were informal conversations with the owner of the farm (manager in one farm), and in the majority of cases included a walking tour of the farm. The approach most closely resembled the 'iterative continuous approach' described in Rubin and Rubin (1995), a method designed to "explore the broader implications of a problem and place it in its historical, political or social context". This approach focuses on a relaxed style of interviewing with no preset agendas, and stresses the role of flexibility in constructing how the interview is conducted and how and what questions are asked.

Instead of using a questionnaire, a set of standard questions for each interview was constructed, some of which were designed to elicit open conversation regarding coffee and/or forest conservation in the region (Appendix A). The questions were designed to obtain information on the research questions stated in Chapter 1 (details of the current coffee practice; how the coffee is planted and harvested, schedule of activities, inputs, outputs, etc., the value of trees other than producing shade, and farmers' willingness to alter current practices). The details and objectives of the project were explained to each potential interviewee who was approached, and permission to participate was requested. No informed consent statements were used, as it was believed to hinder the formation of trust and informality necessary for such exchanges[24]. Permission was requested to use the interviewee's name in any future reports for the Tropical Science Center, yet the use of real names was not considered necessary for this report.

In order to be sensitive to time constraints of the farmers, interviews were carried out in conjunction with another FES student, Anna Baggio, who was investigating causes of deforestation, present land-use practices and the role of women in the study region under the Las Nubes Research and Conservation project. The themes of the two sets of questions were similar, and there were few difficulties conducting the interviews to gain answers to both. There was not adequate time under this research project to carry out a preliminary census and then to choose interviews in a random or blocked design manner, nor was there a clear detailed map of households and farming practices in the region already in existence. We therefore approached the selection of landowners to interview in the region through information obtained from local community organizations

[24] Beer (1991) experienced a similar sensation of provoking negative feelings towards the project with the use of official consent forms in on-farm agroforestry interviews on the Atlantic side of Costa Rica.

regarding the types and locations of farms in the study region.

During the first week of our stay in the community, we were invited to a meeting of a group of environmentally concerned farmers called Corvirena, a community oriented group with roots in MINAE. Although only nine people were present (excluding ourselves), we had an opportunity to present the type of research we wished to do, and to inquire as to whether these members would be interested in participating. The response was favorable, and we initiated our interviews with this group of farmers. From these farms and interviews, we began to compile a list of members in the community, and slowly learnt more of their agricultural practices to plan our future interviews. This often led to interviews with farmers who were not currently growing coffee, but relevant information about the region and coffee practices in the past were always obtained regardless.

We focused our time and resources on properties directly adjacent to the Peñas Blancas River. We deemed this the most important area of influence for providing more habitat for fauna to disperse among intact forest regions as there was already a small strip of trees on either side of the river, and numerous animals have been sighted passing through there. Although we could not feasibly interview all members of the community, we managed to interview a subset of farms along the river as well as other houses somewhat scattered throughout the 6 km region.

The initial few interviews were conducted with the assistance of Edén Chinchilla Sanchez, the guard at Los Cusingos and employee of TSC whose family has lived in Quizarrá for over 40 years. Edén is currently enrolled in a teaching degree, and he and his family are well-respected members of the community, owning a small coffee farm on the main road to Quizarrá. We found that having Edén accompany us on our interviews created a relaxed atmosphere of trust with the community members, that enabled the conversations to flow smoothly. Our association with the TSC held no significance with community members because few knew of the organization. Being accepted as a friend by a well-respected member of the community therefore provided us with a means for a more open exchange of information than we could have achieved as two female foreigners alone.

In the majority of cases, notes were taken during the interviews and a full report for the interview was written up as soon as possible afterwards. For seven interviews, however, we asked permission to use a tape-recorder, and recorded the sessions. This was not attempted in all interviews, as it was not always feasible to record depending on the location of the interview. For instance, if the majority of the interview took part walking through the farm, the interference from outside noises would have over-shadowed the conversations. The interviews that were taped were transcribed by a hired assistant in San Isidro.

The information from the interviews was analyzed by examining the material for common themes and ideas. For each person interviewed, a summary sheet was produced with answers to the standard questions asked and responses to open questions. Responses were coded and amalgamated under similar themes for further examination.

4.3.2. Additional unofficial interviews

In addition to the informal interviews described above, numerous unofficial meetings or information gathering sessions were arranged during March to July, 1999 and January to March 2000, with various institutions involved in coffee production, and institutions involved in environmental issues in Costa Rica (Appendix B). Continual conversations, exchange and support occurred with these individuals and organizations throughout the study period. Countless other unofficial conversations and anecdotal information in San José, San Isidro and in the community provided invaluable information on coffee systems and environmental conservation in Costa Rica.

4.4. Biodiversity sampling: avian diversity in coffee farms

The composition of avian diversity was examined in four coffee management systems of the study region, all considered shade coffee in Costa Rica by ICAFE, and comparisons were made between these four systems. The farms varied in the main tree species used as a layer over coffee, and because of management practices used with each species, the farms also differed in the amount of shade provided in the farm, ranging from 40% to negligible shade. The working hypothesis of the study was that a higher bird diversity should be present in the farm type with the tallest canopy and the highest percent of shade. A difference was also expected seasonally, as there is an influx of migrant species in the dry season, and sampling was conducted in both the wet season and the dry season.

The four management practices examined were each dominated by one tree species in the canopy, hereafter used to identify the category, although other species may have been present at a lower density. These four categories were: (1) Poró (*E. poeppigiana)* and coffee, (2) *Musa* species and coffee, (3) Eucalyptus (*Eucalyptus deglupta)* and coffee and (4) Amarillón (*Terminalia amazonia)* and coffee.

The four coffee management categories selected for avian diversity studies were chosen for a variety of reasons. Poró was chosen due to the fact that the majority of farms in the study region used this species alone or in combination on their farms. The *Musa* category was similarly chosen as almost every farm in the region incorporated some banana and plantain plants within the coffee farms, although not as frequently as the only shade over coffee. Eucalyptus was chosen because a number of smallholders in the region have started to incorporate a few individual Eucalyptus trees into their farm, and have expressed interest in planting more. Similarly, with the timber tree Amarillón, numerous members of the community have expressed interest in incorporating more of these trees into their coffee farms.

As the variability of shade trees and coffee management practices in the region is high, it was difficult to locate farms that were standardized across variables such as elevation, size, distance to road, and distance to small forest patches. As such, these data were noted for each point sampled for consideration in the analysis. Once the four farm categories were chosen, it was difficult to locate numerous farms that fit the criteria in each category, therefore only one farm could be sampled for both Eucalyptus and Amarillón. Two farms were surveyed in each of the Poró and *Musa* categories. Each category (shade tree) is described briefly below, with characteristics of the six sample farms summarized in Table 2. Fig. 3 indicates the location of the six sample farms within the study region.

4.3.1. Coffee farm categories

Poró (Erythrina poeppigiana)

A deciduous broad-leaved nitrogen-fixing legume that is easily established vegetatively with stakes. The tree produces orange flowers between the months of January and March. The species is not native to Costa Rica, but is commonly found with coffee throughout the country. Poró can reach heights of up to 35 m, but the common practice in Costa Rican coffee farms is to cut the crown of the growing tree until a three to four metre stump remains with one or two leafed branches, and the tree never reaches the flowering stage. Poró cut in this manner offers negligible shade to the coffee, and is the closest type of coffee farm to sun coffee in the study region. Leaves, however, were present on the stumps during both field seasons. Two farms were sampled, both completely dominated by Poró, with occasional individuals of other tree species scattered through the farms.

Musa species

A wide variety of *Musa* species were used in the farms, including banana, plantain, guineo negro, and bananita rosa. The height of the *Musa* plants ranged from four to five metres in height, and were spaced from one banana plant to four coffee plants, up to one plant for every fifteen coffee plants in different sections of the two farms sampled. Plants were always in different stages of development during both field sessions, and there were always individuals in flowering and fruiting stages seen throughout both farms. The shade produced from the thick overhanging leaves ranged from 20-30%.

Table 2: Characteristics of the six farm sites used for avian point counts in Santa Elena and Quizarrá. (cfh = approximate coffee height; cnh = approximate canopy height; % in canopy = percent of canopy dominated by the shade category species).

SHADE CATEGORY	SITE	SIZE (HA)	ALTITUDE (MASL)	CFH (M)	CNH (M)	SURROUNDING LAND USE	% IN CANOPY
Poró	**P1**	11	690-700	1.5-2.5	2-4	-road borders 2 sides - forest patch - coffee farm	95
	P2	9	630-640	1.5-2.5	2-4	- adjacent to Cusingos on 1 side - forest patch - sugar cane - coffee	95
Banana	**B1**	4	758-770	1.5-2	4-5	- coffee farms on 3 sides - narrow road	80
	B2	8	690-700	1.5-2	3-4	- sugar cane - coffee	60
Eucalyptus	**E**	132	830-910	1-2.5	7-8	- coffee - pasture - road borders one side	99
Amarillón & Cedro	**T**	22	620-635	2-3	8-12	- adjacent to Cusingos - reforestation patch on 2 sides - pig farm	60 20

Eucalyptus (Eucalyptus deglupta)

A fast growing species (up to 5 m per year) native to the Philippines and New Guinea. It has a very straight multi-colored trunk and thin canopy. White flowers in racimes were present in some individuals in both sampling seasons, although there was a greater preponderance in the wet season. The one farm sampled had 377 Eucalyptus trees per hectares in the wet season, producing a shade of approximately 30-40%. In January 2000, however every third tree was being removed as a result of an increase a fungus that affects the coffee, 'ojo de gallo' (*Myecena citricolor)*, reducing the amount of shade.

Amarillón (Terminalia amazonia)

A species known for its high quality timber, that reaches heights of 35-42m, with horizontally arranged whorls of branches. The species flowers from February to March and fruits March to April. In the farm examined, Amarillón dominated the canopy, yet there was another timber tree, the native Cedro (*Cedrela odorata*) also incorporated with the coffee at a frequency of approximately 20%. The canopy in the farm reached heights of over twelve metres, the Amarillón often reaching heights of ten metres and Cedro trees reaching heights of twelve metres or more. Cedro is deciduous and produces oval woody fruits in the dry season. The amount of shade in the farm often reached 40 - 50% when both trees had foliage, yet was reduced somewhat in the dry season.

4.4.2. Point Counts

The diversity of bird species was assessed using 25-m fixed-radius point counts (Hutto et al., 1986). All birds seen (with binoculars) or heard within a 25-m radius of the point were noted during a 15-minute period. Wherever possible the location of the individual (ground, coffee layer, or canopy layer) was noted. The canopy layer was defined as any tree in the layers above coffee. In the Poró farm this consisted mainly of the diminutive stumps scattered throughout the farm. The 15-minute sample time was used to ensure proper identification of all species. Upon arrival at the point, 20 seconds were taken to note down the time, elevation (with a Thommen altimeter), weather code on a scale of 1 to 5 (1-full sun no clouds to 5-cloudy/rain), distance of the point to the forest (dff), distance of the point to the road (dfr), estimated height of coffee and estimated height of the shade trees.

Individuals that flew over a point during the census period without landing or interacting with foliage within the twenty-five metre designated area were not included, hence removing aerial foragers [such as Turkey Vultures (*Cathartes aura*) and swallows (Hirundinidae species)] from the analysis. Points were sampled along set trails chosen through farms, usually based on pre-existing trails, and were at least 150-m apart from one another and 25-m from a road or edge habitat.

The study attempted to reduce all possibilities of bias, although inevitably there is some bias that might produce results varying from the true species composition in the region (Bibby et al., 1992). All points were sampled at a standardized time between 0530 and 1030, automatically excluding the consideration of nocturnal species. Methods and effort of observation were held consistent across all points. The order of farms visited was scattered during the sampling season, and none of the replications for one farm were clustered in one week. Due to the small number of farms in each category, each farm was sampled at least 3 times.

Four assumptions were made for sampling biodiversity with point counts, adapted from Bibby et al. (1992): (1) birds do not approach the observer nor flee from the observer; (2) birds are 100% detectable at the observer's location; (3) birds do not move much between points during the count periods; and (4) birds are fully and correctly identified. To provide support for this last assumption, my identification experience comes from a full year bird taxonomy and ecology course at the University of Toronto, three years mist-netting experience of eastern North American birds with a volunteer migration monitoring project in Toronto, practical experience in Panama (2 weeks), Honduras (2 weeks) and Costa Rica (3 weeks) through courses and travel in 1998, and four months spent living on a coffee farm in the research area conducting interviews and learning the local avifauna before initiating the point counts (February to May, 1999). The assumptions were made with the understanding that some habitats are easier to view birds than others, some birds are easier to view simply by the nature of their activities or calls and that ease of detection varies with the season (Bibby et al., 1992). All attempts were made during sampling time to ensure these assumptions were met.

As this research was meant to build upon existing data that has already provided evidence for the similarity in species richness between shaded coffee and remnant forest sections, bird diversity was not sampled in the surrounding forest patches (e.g. Los

Cusingos). It was assumed, based on the extensive studies of Dr. Skutch, that the avian diversity in the forest remnant habitat was higher than the coffee systems in question. Test point counts conducted at Los Cusingos resulted in low species numbers due to the difficulty in observing species in thick foliage, which would influence any results comparing all five habitats. In addition, there was not adequate time during this research project to do a thorough survey of the forest at Cusingos. Instead, as the bird species composition is well known at Cusingos from the studies of Dr. Alexander Skutch, this information was used to compare which species previously seen at Los Cusingos also occurred in the sample farms, and the focus of the study was put on comparing the different coffee management practices with each other.

A total of 243 point counts were surveyed during two sampling periods in order to assess the diversity of both resident and migratory species; 109 points during the wet season (June and July 1999), and 134 points during the dry season (January and February 2000). For each sample farm, a set number of points were sampled each sampling day and repeated over the sampling session, distributed as follows: E (Eucalyptus) 10 points, T (Amarillón) 8 points, B1 (*Musa)* 4 points, B2 (*Musa*) 4 points, P1 (Poró) 6 points, and P2 (Poró) 6 points in the wet season and 4 points in the dry season. The number of points conducted in each farm, arranged by season, is displayed in Table 3.

TABLE 3: Number of 25-m radius point counts sampled in six coffee farms of four management categories identified by main shade tree species (Quizarrá and Santa Elena, Costa Rica).

FARM	WET SEASON	DRY SEASON	TOTAL POINTS
P1	18	24	42
P2	12	12	24
B1	12	12	24
B2	8	15	23
E	40	40	80
T	19	31	50
TOTAL POINTS	109	134	243

4.4.3. Data analysis

Species richness (number of species) was taken as the cumulative number of bird species noted across all points in each sample farm. Species noted between points (off counts) were included in the value for species richness, yet were not included in the statistical analyses. Species diversity indices that include both number of species and abundance of individuals were also used to compare the six farms. These indices were chosen for a variety of reasons that are stated with each diversity index below.

The Berger-Parker Index (d) was chosen to investigate species diversity because the value has a low sensitivity to sample size and a simple calculation (Magurran, 1988). The index evaluates dominance by one species and is calculated as follows:

$$d = N_{max}/N,$$

where N = total number of individuals, and N_{max} = the number of individuals of the most abundant species. The value commonly examined is inverted (1/d) in order that increasing values signify increasing diversity.

The Simpson's Index was examined because it is less sensitive to species richness (Magurran, 1988) and was calculated as follows:

$$D = S\ [n_i\ (n_i - 1)]\ /[N(N - 1)],$$

where n_i is the number of individuals of the i^{th} species, and N is the total number of individuals. Again the reciprocal of the value is looked at in order that diversity increases as the value of the index increases.

The Shannon Biodiversity Index was also used as this diversity index takes into account both evenness and species richness. It also is commonly used in biodiversity surveys, and therefore allows comparison between other studies. The calculation for the Shannon Index (H) is as follows:

$$H = - \Sigma\ p_i \ln p_i,$$

where p_i= abundance proportion per species. The Shannon Index was compared using t-tests between farms and between seasons on the same farm (see Appendix E for formulas and calculations).

The Shannon Evenness (J), which measures evenness of species distribution specifically, was also calculated as J= H/ln S, where H=the Shannon Index, and S= the total number of species in the category. This value ranges from 0 to 1, with 1 representing a situation where all observed species are equally abundant.

Species richness is highly dependent on sample size making it difficult to form conclusions from the six farms as the number of points sampled in each one varies. To address this difference in sample size, two different methods were used. A Monte Carlo approach was used to recalculate species richness and three biodiversity indices at a standardized sample size. This involved randomly selecting twelve points from one farm in one season, calculating the species richness (S) and the biodiversity indices, and averaging the results over 25 trials. This was conducted for each farm that had a sampling effort greater than 12 points in each season. The second method used to compare the six farms that addressed uneven sampling size was a 2-way analysis of variance (ANOVA) with a Bonferroni post-hoc test using the 1999 SPSS statistical package. In this analysis the mean number of bird species per point and the mean number of individuals per point for each of the six farms were compared.

Pearson's correlation coefficients were calculated for the following variables, pooling data from the wet and dry season: number of species per point, number of individuals per point, elevation, weather, distance to forest (dff), distance to road (dfr), approximate coffee plant height and approximate height of shade trees at each point.

One point of interest in the analysis was the comparative use of the four coffee farm habitats between resident and migratory birds. Dry season data was analyzed again keeping these two groups separate. Migratory versus resident birds were tested for significant differences in number of individuals per point and number of species per point in each coffee farm again using a two-way ANOVA. Pearson's correlations were again performed on migratory and resident groups separately to see if any of the variables affected the two groups differently.

Another reason that mere species richness is not an adequate descriptor of a habitat is that it says little about the diversity of functional ecological links. Edge habitats tend to have a higher species diversity due to the presence of generalists, yet may be significantly lacking in forest or woodland species that are most affected by deforestation. To further examine ecological links, therefore, the bird species observed on the point counts were separated into broad guilds of habitat preference, foraging level and food preference, based on the manner of Greenberg et al. (1997a) and on individual species accounts from Stiles and Skutch (1989). This guild allocation (appendix C) was reviewed by Dr. Skutch before observed species were partitioned for analysis. Bird species generally occur in more than one habitat type and consume a varied diet, yet to ease analysis the habitat used most frequently and the food that makes up the majority of the species' diet was used, as dictated in Stiles and Skutch (1989). For the foraging height levels, a species can occur in more than one category as some species have a wide spectrum of preferences. For each guild, the percent of observed individuals in each category were graphed and compared between the six farms, for both sampling seasons. Table 4 illustrates the categories of each of the five guilds along with a brief qualifier to describe the category.

Proportions of forest dependent species in the coffee farms were also examined. In Stiles (1985), the researcher divided the birds of Costa Rica based on their forest dependence and gave each a score. A score of 1 signifies a species that requires at least

50% forest with large interconnected patches, a score of 2 indicates a species that can persist in less than 50% cover provided there are some high canopy trees remaining in coffee farms and gardens, and sizable patches remain, and a score of 3 signifies birds that can persist in scrub, secondary growth and agricultural lands. The scores were applied directly to the species observed in the four management practices, in order to compare number of forest dependent species within each farm. Percentages of each category were also plotted for the comparison between farms.

The final analysis involved examining avian use of ground, coffee or shade tree levels of the coffee farm. The shade level was taken as the main tree species in the canopy (Poró, *Musa*, Eucalyptus or Amarillón). The percent of observed individuals in each layer in each farm was calculated and compared between the six sample farms.

TABLE 4: Descriptions of the three guild sets used to group observed avian species for the analysis of ecological links in the six coffee farms investigated.

Habitat Guilds		
FE	forest edge	Edge of forest fragments
FI	forest interior	Significantly away from edges and borders
S	secondary forest	Secondary forest and habitats with only a thin dispersion of trees
OS	open scrub	Shrubby low height vegetation
NF	non-forest habitat	Human habitations and other habitats without trees
Foraging Level Preference		
H	High	Upper levels of forest and canopy
M	mid-levels	Between the canopy and the understory
L	low levels	Understory and low levels
G	Ground	Ground levels
T	Trunk	Forages on trunks of trees by whatever method
Food Guilds		
I	Insectivorous	Insects and other arthropods
F	Frugivorous	Fruit or the seeds of fruits
N	Nectarivorous	Mainly consuming nectar from flowers, yet taking occasional insects
G	Granivorous	Seeds and grains
O	Omnivorous	Mixed diet of arthropods, fruit, nectar and/or seeds
C	Carnivorous	Meat and insect eaters (mainly raptors)

CHAPTER 5: RESEARCH RESULTS

5.1. Overview of coffee farming in the communities of Quizarrá and Santa Elena

A generalization of coffee practices in Quizarrá and Santa Elena was compiled from the research interviews and daily observations and conversations during the seven months spent in the communities conducting research. Coffee management practices of the study region are discussed in this section, including the varieties of plants used, pesticide and fertilization procedures, and harvest of the crop.

5.1.1. Distribution of farm size and allocation of land to coffee

The majority of farms in Santa Elena and Quizarrá are less than ten hectares in size, with a high percentage of farms less than five hectares. The farm layout includes an area for the dwelling, surrounding gardens for vegetables or herbs, and an area for the main income-generating crop of coffee. Over half of farms in the study region cultivate both coffee and sugar cane on their land, a strategy that insures continuous returns throughout the year, as sugar cane is harvested in the dry season and coffee is harvested in the wet season.

There are a few farms greater than twenty hectares in the two communities. One farm to note especially is Santa Fe, a 138-hectare farm consisting of only coffee and *E. deglupta* that has been in the region for five years. This farm is part of an extensive complex of land cultivated in coffee in the southern Pacific region of Costa Rica including a *beneficio* in Sarchí, near San José. The caretaker of Santa Fe and his family live on the property, yet the owner lives outside of the community and only visits periodically.

5.1.2. Coffee varieties and regulation of the coffee plant

The prevalent varieties of coffee noted in both Santa Elena and Quizarrá are varieties of short stature including *catuai rojo, catuai amarillo, caturra*, *catimor, Villa Sarchi* and CR95. No other varieties were mentioned in either community (e.g.. *tipica*, *bourbon*) and it is probable that those of shorter stature have since replaced these varieties. The majority of coffee is harvested during the wet season. Some farmers expressed a preference for the dry season variety of coffee, *catimor*, because of the longer and more comfortable harvest day, yet only a few farms have small sections of this variety.

Coffee plants are planted closely together in rows, often at a spacing of one metre between plants and two metres between rows. The plants are pruned initially to produce two principle vertical stalks with protruding horizontal branches that bear the flowers and berries. The principle stalk can live from 15 to over 25 years. The plants are pruned yearly in the dry season when plant growth is at a minimum, to remove dead or dying branches, to take off branches with infirmities, to regulate self-shading, and to modify the 'architecture' of the plant[25]. There are various methods of trimming the coffee plant that affects the shape and arrangement of branches, such as 'rock and roll' and 'candelabro',

[25] Each branch of the coffee plant produces berries for three to four years.

which are further described in Ramírez (1997). Pruned coffee branches are used as firewood in the home.

5.1.3. Pests associated with coffee and their control

Coffee pests and disease are present at some density in the majority of farms in Quizarrá and Santa Elena. A higher density of these diseases increases the damage to the plant and the crop, thereby reducing the yield that can be harvested. Table 5 lists the coffee pests mentioned during the interviews. The most commonly mentioned afflictions were *ojo de gallo* (*Myecena citricolor), roya* or leaf rust (*Hemileia vastatrix)* and *mal de hilacha* (*Pellicularia koleroga*). The majority of diseases noted in the farms visited were fungal infections.

TABLE 5: Common coffee pests and infections stated in on-farm interviews in Santa Elena and Quizarrá.

SCIENTIFIC NAME	COMMON SPANISH NAME	TYPE	LOCATION OF DAMAGE
Cecrospora coefficola	Chasparria	Fungus	leaves, fruit
Corticium salmonicolor	Rosada	Fungus	fruit, stalk, branches
Dysmicocus brevipes	Cochinilla de la raiz	Louse	roots
Hemileia vastatrix	Roya	Fungus	leaves
Mycena citricolor	Ojo de Gallo	Fungus	leaves, fruit
Pellicularia koleroga	Mal de hilacha	Fungus	leaves, fruit, stalk, and branches
Pratylenchus spp; Meloidogyne sp.	Nematoda	Nematode	roots

In general owners of small farms (one to two hectares) refrain from using pesticides unless necessary, due to the high purchasing costs. Larger farms apply pesticides from two to three times a year, usually in March or May and in mid-August, as a preventative measure against the aforesaid mentioned pests. Table 6 lists the pesticides used by the farms interviewed, along with their chemical composition.

TABLE 6: Pesticides most commonly used in coffee farms of Santa Elena and Quizarrá, illustrating their chemical components and uses. (Sources: Pesticide Management Education Program, Cornell University; EXTONET (Extension Toxicology Network), Oregon State University).

TRADE NAME	CHEMICAL NAME	TYPE OF PESTICIDE	TOXICITY	USED FOR:
Atemi (Cyproconazole)	Chlorophenyl-alpha-(1-cyclopropylethy)-1H-1,2,4-triazole-1-ethanol	Fungicide	?	ojo de gallo, roya
Benlate (Benomyl)	Methyl 1-(butylcarbamoyl)-2-benzimidazole carbamate	Fungicide	Mammals,birds-low Fish **- high**	Chasparria
Copper compounds	Various with copper as a component	Fungicide/ Bacteriocide	Birds – low Fish – **high** Soil microfauna: **high**	Chasparria, roya
Counter (Terbufos)	S-tert-Butylthiomethyl O,O-diethylphosphorodithioate	Nematicide/ organo-thiophosphate	Mammals, birds, fish: **highly toxic** (cholinesterase inhibitor)	Nematodes
Ferbam (Carbamate)	Ferric dimethyldithio-carbamate	Fungicide	Nonphytotoxic Not stored in body tissue	Chasparria
Silvacure	?	Fungicide	?	Mal de hilacha

Other pests mentioned in the coffee farms included locusts, which consume only the leaves of Poró (*E. poeppigiana)* and Cedro (*C. odorata)* without affecting the coffee. Armadillos have been known to consume coffee roots, but only when there is no other vegetation present in the farm as an alternative food source. Outbreaks of weedy species do not seem to be a large problem in the study region, probably because farms either have some shade from trees or the self-shading resulting from tightly packed coffee plants, which tends to inhibit the growth of weeds. The application of pruned leaves onto the soil as mulch also halts the growth of vegetative species.

A few members of the community stated the occurrence of pests in coffee is inevitable, and that it is possible to live with them without the use of large amounts of pesticides. One individual commented on how he had used a pesticide to eradicate leaf rust from his farm that caused immediate disappearance of the fungus, yet after a few years the fungus returned along with other diseases, so he prefers now not to use any pesticides at all. There is also one farm in the study region taking part in an organic coffee project that will be certified as organic after three years without pesticide use.

5.1.4. Use of fertilizers

The majority of farms in the region apply store bought 'complete' formulas to fertilize the coffee plants, labelled using a five number code for their varying concentrations of nitrogen, phosphorus, potassium, magnesium and boron. These formulas are bought from either individual fertilizer warehouses, or purchased directly from the Agro-Industrial Cooperative of Pérez Zeledón (known as Coopeagri), which delivers the bags of fertilizer directly to the communities. Again, small farms of one or two hectares tend to apply the store bought chemicals only when the plants appear deficient in a mineral, due to the high costs of fertilizers[26]. Larger farms fertilize their crops two to three times a year, coinciding with flowering, fruiting and post-fruiting, to provide adequate nutrients to the plants. Most farms also apply Calcium Carbonate ($CaCO_3$) to the soils in the farm, to reduce the high soil acidity.

There are a variety of methods used as a supplement or an alternative to the store-bought fertilizers, and the majority of small farms use these more frequently, purchasing chemical formulas only when absolutely necessary. The most common alternative fertilizers used are the leaves of Poró or *Inga* species applied as mulch to the soil beneath the coffee plant whenever the shade tree is pruned. Other sources of fertilizer include chicken and cow manure, kitchen scraps, and an organic fertilizer produced by the Coopeagri *beneficio* made out of the fleshy casings of the coffee fruit.

5.1.5. Harvest

In the southern Pacific region of Costa Rica the majority of coffee is harvested from August to December, significantly earlier and more spread out temporally than the harvest in the Central Valley which occurs in the months of December and January. The longer length of harvest season in the South is due the coffee berries flowering and ripening asynchronously as a result of occasional days of rain during the dry season.

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[26] According to Coopeagri prices (March, 2000) one 60kg bag of fertilizer ranged in price from 3225 colones to 4620 colones, an equivalent price of $10 to $15 U.S (@ U.S.$1 = 300 colones, March 2000). Approximately 25 bags of fertilizer per hectare are used each year (spread out over the year), producing a cost of U.S $1250 – U.S. $1875 per year for an average farm of 5 hectares.

Workers must therefore comb through the same farm multiple times during the harvest season to ensure complete collection of the crop. The small amount of summer coffee (*catimor)* grown in the study region is harvested during January and February.

All members of a family, women and children included, participate in the harvest. School aged children collect coffee for three or four hours before or after attending school, depending on the time of day of their classes. If the harvest is especially large, or more help is required, assistance is usually elicited through extended families or close neighbours in a reciprocal agreement to harvest their farm as well. The exception, Santa Fe, provides lodging for 200-300 migrant workers that arrive by bus from Nicaragua to harvest coffee[27]. After the coffee on the family farm is harvested, family members often work for larger farms in the community to earn money. This is often the only source of income for women in the community during the year, as the harvest of cane in the dry season is very dangerous and hard labour.

The wage for harvesters of the coffee varies from 300 colones to 350 colones per *cajuela*[28], the standard size of baskets tied around the waist and used to collect ripe coffee berries. At an exchange rate of U.S.$1 to 278 colones at the beginning of the 99/00 harvest (July, 1999), this is a wage of a little over one dollar for one *cajuela,* which takes from one to two and a half hours to fill, depending on the speed and experience of the harvester[29]. A few of the larger farms offer equal wages for both male and female

[27] During the coffee harvest a large number of migrant workers from Nicaragua live in the communities of Santa Elena and Quizarrá, inhabiting the small one or two room structures built for coffee harvesters.
[28] 20 *cajuelas* are approximately equal to 1 *fanega*.
[29] The time to harvest is limited to the morning hours before the rain begins, making it difficult to earh more than US$3 a day from harvesting coffee.

harvesters, yet this is not always the case, and many women brought up unequal wages as a concern during a workshop on problems in the community (Baggio, 2000).

The *cajuelas* are taken to coffee receptors (*recibidores*) set out by the *beneficios* to collect and tally the coffee harvested. There were five wet processing *beneficios* in the San Isidro region at the time of study: Coopeagri, la Meseta, El General, Peters and Palmichal. Receptors of all *beneficios* are scattered throughout the communities in Pérez Zeledón, yet Santa Elena and Quizarrá have a higher number of Coopeagri receptors. The amount of coffee deposited is marked and credited for each farm at the receptacle. The percentage of unripe green berries is measured through a sample of each harvest, and by law is not allowed to be over 2% of the total yield. The *beneficios* have the right to refuse a harvest if the amount of green coffee is over this percent. Payment for the harvest often comes in the form of agricultural credits and advances throughout the year, with the remainder of the income (by *fanega* deposited in the *recibidores* during the harvest) paid a few months after the harvest. In the farms interviewed, the harvest for the 98/99 season ranged from 16 to 45 *fanegas* per hectare.

5.1.6. Division of labour

The division of labour between men and women with regard to management of coffee farms is more obvious in large than small coffee farms. Generally men undertake the tasks of cropping the coffee and shade trees, fertilization, pesticide application and other general maintenance activities of the farm. Women undertake the jobs necessary for a smoothly functioning household – cleaning the house daily, preparing meals and taking care of children. However in smaller farms, women cut and collect fuel wood from the farm and harvest vegetables and fruit for the daily meals. During the coffee harvesting period, women's duties are doubled, as they are required to spend the morning in the coffee farms picking berries along with regular household activities [see Baggio (2000) for more information on the role of women in the community].

5.1.7. Coopeagri

A large percentage of smallholders in both Santa Elena and Quizarrá prefer to sell their coffee to the Coopeagri *beneficio*. Some of the reasons given for this choice were that the co-operative offers the best price for their harvest in the region, excess capital is distributed to associates at the end of the year, and the coffee receptacles are conveniently close to farms. The co-operative generally pays a higher price to the producer compared to the other beneficios. In the 98/99 harvest the liquidation price was 22,658 colones[30], equivalent to US $82 per fanega (@ U.S.$1 = 278 colones, February 1999).

Coopeagri is one of the largest beneficios in the canton of Pérez Zeledón, processing 135,000 *fanegas* (35.9% for the region) in the 98/99 harvest (Informes Coopeagri, 2000). Each associate must pay 6% of their crop to the co-operative, with 1% going to a personal savings account, and the other 5% towards capital for the cooperative. With this capital, the co-operative has been able to offer extensive services to members as well as the surrounding community including: a supermarket, the only sugar

[30] The other *beneficios* had prices as follows (stated in colones): Meseta, 20,981; Volcafe, 21,181; Peters, 19,030 and Palmichal, 20,496. (Source: Carlos Calderón, per. comm).

refinery in the region, 173 coffee receptacles in 130 communities, an agricultural supply store, a local milk processing plant, a loan centre for agricultural supplies, homes and vehicles, free agricultural and veterinary consulting, and free medical services. The cooperative also owns experimental farms in sugar and coffee (varying in amounts of fertilizers and pesticides used) and protected forested sections. Any profits are partitioned between the associates at the end of the fiscal year.

The cooperative has undertaken many environmental improvements to the *beneficio* over the past few years, for example reducing the amount of water used in processing per *fanega* of coffee from five or six cubic meters to 0.25 through the recycling of water. Three water purification pools were created to treat wastewater before it is released again to the environment. Coopeagri is also now marketing and selling an organic fertilizer made from the pulp removed from the coffee fruit.

In 1990, an organic coffee program involving twenty-five producers was initiated at the cooperative to take advantage of the higher premiums of organic coffee, but the project was soon terminated because a buyer for the product could no longer be found, and because inadequate assistance in how to manage the organic coffee crop led to spoilage of some of the harvest (Carlos Calderón, per. comm.). When asked about the possibilities of future shade coffee or biodiversity friendly coffee projects, the manager of the *beneficio* expressed that the co-operative would consider another such project, with more organized assistance, if the premiums of the coffee sold overcome the decrease in production brought about from more shade and the cost of pest management (Carlos

Calderón, per. comm.). The co-operative has the capacity to separately process organic or shade coffee.

5.1.8. Cost of production

In 1998, ICAFE produced a document on the cost of production of coffee, based on a 10-hectare farm (Rojas-Cubero, 1998). The study found that the total cost of production per *fanega* of coffee harvested is US$88 with 15.34% attributed to management of the farm (pollarding, application of pesticides, weed control etc.), 30.4% from the harvest and transport costs, and 18.62% from the purchase of agrochemicals. With an average harvest of 26 *fanegas* in Perez Zeledón, the estimated cost of production would be US $2288 per hectare, a price comparable to that calculated by Rice (1993) for technified farms across Central America (between $1600 and $2300 per hectare)[31].

Many smallholders in the interviews stated that the high cost of production and low price of coffee did not make the practice very profitable, while others believed a four hectare farm was enough to have a family of six live comfortably. ICAFE has stated this high cost of production, along with the high cost of living in Costa Rica, as a reason why increasing the percent of shade over coffee is disadvantageous for Costa Rica. Their view is that the costs of production cannot be met if yields decrease with denser shade. A detailed cost-benefit analysis for small coffee producers is needed in the study region to investigate household economies under the current management practices, and the

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[31] The valued in Rice (1993) are stated in *manzanas,* where 1 *manzana* is equivalent to 0.69 hectares. The figures here have been converted to hectares. Cost of production stated for traditional farms was between $290 and $580 per hectare.

effect of an increase in shade and a decrease in technification at the farm level.

5.2.Tree and vegetative species incorporated with coffee farms

The structure of vegetative layers in coffee farms of Quizarrá and Santa Elena did not fit easily into one of the five categories discussed in Chapter 2 (Fig. 1), and instead more closely resemble the continuum displayed in Fig. 4. A common practice in all of Costa Rica, seen in the study region, is coffee grown with heavily pruned Poró, resulting in stumps that offer negligible shade (Fig. 4C). Farms were also seen with two layers in the farms, consisting of either coffee with a layer of bananas and some leguminous trees, or as coffee with a commercial tree species (often Eucalyptus), occasionally incorporating leguminous trees as well (Fig. 4B). The highest structural diversity was seen in farms with three layers reaching a height of up to twelve metres, consisting of coffee as the first layer, banana and fruit trees in the intermediate layer and hardwood timber species making up the canopy (Fig. 4A). This last category occurs mainly in smaller farms of one or two hectares, where a larger variety of tree species tend to be grown with coffee, especially over plants located close to the house. True sun coffee (Fig. 1) is not the practice of choice in the communities of Santa Elena and Quizarrá, and only one farm was seen with no shade layer at.

The tree and vegetative species noted in the farms interviewed fell into four main groups: (1) trees planted with coffee for the purpose of shading and/or firewood; (2) trees and vegetation that provided fruit and other food items; (3) trees planted for future use as timber either in the home or for commercial purposes, and (4) trees used as borders or

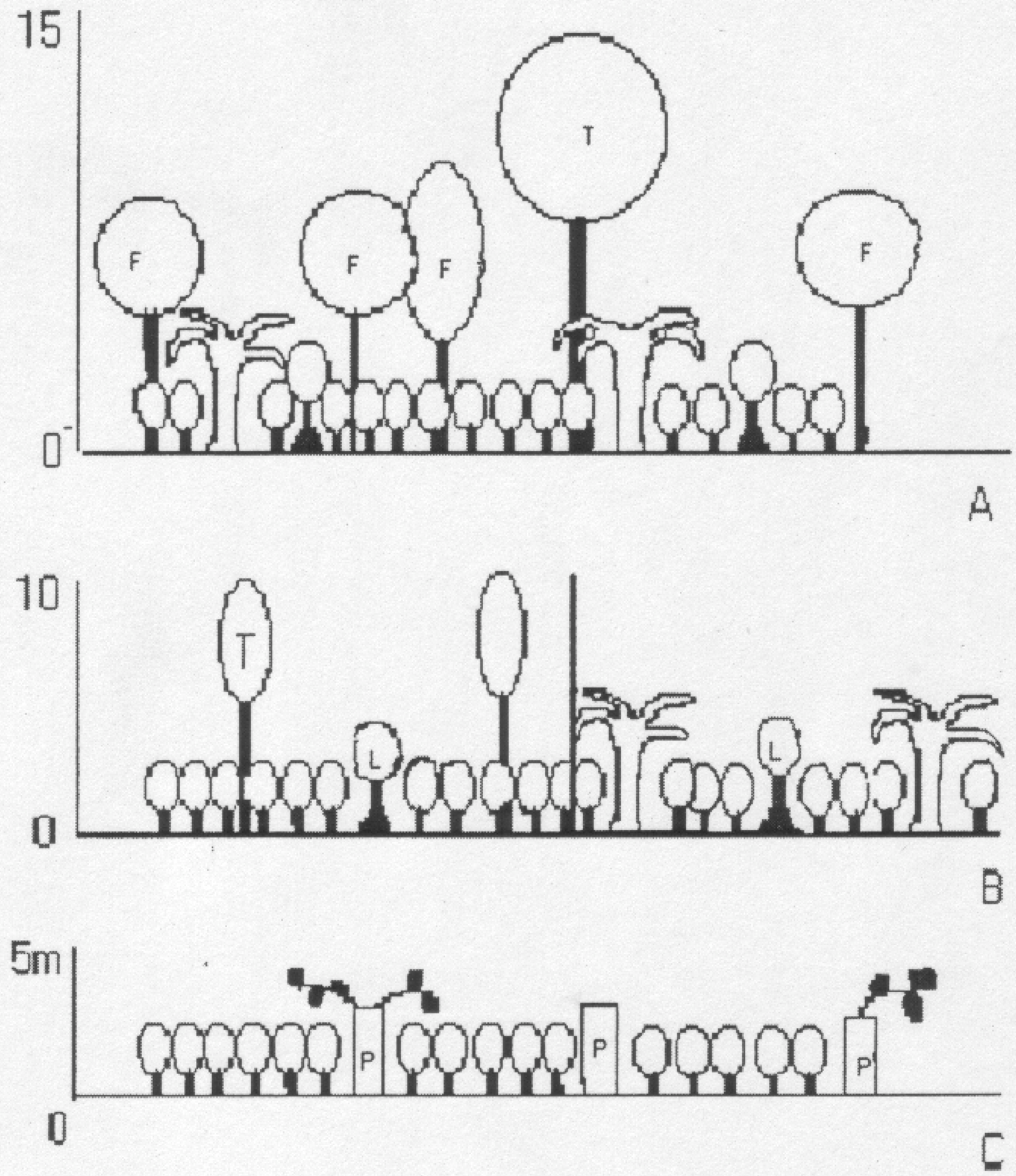

FIGURE 4: Representation of the variety of coffee farms seen in Quizarrá and Santa Elena, Costa Rica. (A) the highest structural diversity seen in the study region, consisting of three layers, and most often in small farms of one or two hectares. (B) an intermediate structural diversity consisting of two layers or strata. The second layer can be bananas with leguminous trees, or a commerciable timber crop such as Eucalyptus (C) Poró (E. poeppigiana) with coffee, heavily pruned for shade regulation, the common practice in farms shaded with only Poró. T= timber; L=legume; F= fruit; P=Poró.

fences around the edges of coffee farms (live fences). Not all farms had representatives of each of these groups, nor did all have more than one species in each group. A total of fifty-two vegetative species were noted in on farm interviews (Table 7), with a range of one to seventeen species observed in one farm.

In the first layer above coffee, the most frequently used species in the two communities is Poró (*E. poeppigiana),* planted at a spacing of 6-m by 6-m or 4-m by4-m, although the layout varies by farm. Leguminous trees in this layer are highly regulated in the amount of shade they provide over the coffee by pruning the crowns regularly. The crown of the growing sapling is cut until a stump of three to four metres in height remains, with only three to four branches emanating from the stump. The trees are pollarded two to three times a year, timed to encourage flowering and then simultaneous ripening of the coffee berries through intense exposure to the sun, and the pruned branches are often used as fuelwood. As a leguminous tree, Poró adds Nitrogen to the farm from leaf fall as well as from leaf mulch. The ease of propagation of Poró may be one reason why although farms vary in the type and number of species in a farm, Poró is always present in come capacity in most farms.

An alternative to Poró as a leguminous tree seen in coffee farms is Guaba (*Inga sp.),* also used as shade and as a natural fertilizer. Guaba is believed to have better quality firewood for cooking and is preferred over the wood of Poró. Despite this quality however, Guaba is not used as frequently as Poró in the two communities. One reason expressed was that Guaba attracts a lot of insect pests, especially termites, which weaken

Table 7: Tree and plant species found associated with coffee farms in Quizarrá and Santa Elena, obtained from on-farm interviews.

SPANISH NAME	USE	LATIN NAME	FAMILY
Aceituno	Timber, live fence	*Simarouba glauca*	Simaroubaceae
Aguacate (avocado)	Fruit	*Persea americana*	Lauraceae
Amarillón	Timber	*Terminalia amazonia*	Combretacea
Arroz (rice)	Food		
Ayote	Food	*Curcurbita pepo*	Curcurbitaceae
Bananito rosa	food for home use and domestic animals	*Musa sp.*	Musaceae
Banano criollo	food for home use and domestic animals	*Musa sp.*	Musaceae
Banana morado	food for home use and domestic animals	*Musa sp.*	Musaceae
Caimito	Food	*Chrysophyllum caimito*	Annonaceae
Caña de Indio	live fence	*Cordyline terminalis*	Agavaceae
Cedro amargo	Timber	*Cedrela odorata*	Meliaceae
Chayote	Food	*Sechium edule*	Curcurbitaceae
Colpachí	shade, leaves as fertilizer live fence, windbreak	*Croton niveus*	Euphorbiaceae
Culantro (cilantro)	Herb		
Eucalypto	Timber	*Eucalyptus deglupta*	Myrtaceae
Frijoles (beans)	Food	*Phaseolus spp.*	
Gallinazo	*shade, fertilizer, timber*	*Schizolobium parahybum*	Leguminosae: Caesalpinoideae
Grapefruit	Fruit	*Citrus paradisi*	Rutaceae
Guaba	shade, food, fertilizer, firewood	*Inga spectabilis*	Leguminosae: Mimosoideae

Guachipelin/Cacique	live fence timber	*Diphysa robinoides*	Leguminosae: Papilionoideae
Guanacaste	Timber	*Enterolobium cyclocarpum*	Leguminosae: Mimosoideae
Guatimol	food for home use and domestic animals	*Musa sp.*	Musaceae
Guayabo	Fruit	*Psidium guajava*	Myrtaceae
Guineo Negro	Food for home use and domestic animals	*Musa sp.*	Musaceae
Guinea rosa	Food for home use and domestic animals	*Musa sp.*	Musaceae
India desnudo	*live fence*	*Bursera simaruba*	Burseraceae
Ira marañon	Timber	*Ocotea tonduzii*	Lauraceae
Itabo	live fence, edible flowers	*Yucca guatemalensis*	Agavaceae
Jobo	live fence, fruit	*Spondias mombin*	Anacardiaceae
Laurel	Timber	*Cordia alliodora*	Boraginaceae
Lengua de vaca	live fence	*Conostegia xalapensis*	Compositae
Limón acido	Fruit	*Citrus aurantifolia*	Rutaceae
Limón dulce	Fruit	*Citrus limetta*	Rutaceae
Madero negro	live fence firewood forage for animals wood for construction leaves as fertilizer edible flowers	*Gliricidia sepium*	Leguminosae: Papilionoideae
Maize	Food	*Zea mays*	Gramineae
Mamón (Chino)	Fruit	*Nephelium mutabile*	Sapindaceae
Mandarina	Fruit	*Citrus reticulata*	Rutaceae
Manglillo	Fruit	*Aspidosperma megalocarpon*	
Mango	Fruit	*Mangifera indica*	Anacardiaceae
Marañon (cashew)	Fruit	*Anacardium occidentale*	Anacardiaceae
María	Timber	*Callophyllum brasiliense*	Guttiferae
Naranja dulce	Fruit	*Citrus sinensis*	Rutaceae

Palo de Leche	Timber	*Brosimum utile*	Moraceae
Pejibaye	fruit, palm heart	*Guilielma utilis*	Palmaceae
Piña (pineapple)	Fruit	*Ananas comosus*	Bromeliaceae
Plátano (plantain)	food for home use and domestic animals	*Musa sp.*	Musaceae
Poró gigante	shade, fertilizer, firewood	*Erythrina poeppigiana*	Leguminosae: Papilionoideae
Rayo	Timber	unknown	Unknown
Tomate	Food	*Lycopersicum sculentum*	Solanaceae
Tiquisque	root crop	*Xanthosoma sagittifolium*	Araceae
Yuca	root crop	*Manihot esculenta*	Euphorbiaceae
Zorrillo	Timber	unknown	Unknown

and degrade the tree rapidly. In addition, Guaba cannot be propagated vegetatively, making it more difficult to establish in a farm.

The incorporation of fruit trees and banana plants in this first layer above coffee occurs most often in the small farms less than five hectares. Almost all farms have some banana and plantain plants, as the fruit is used as an important food source for domesticated animals. The majority of fruit trees incorporated in farms are citrus, and tend to be clustered close to the house, with individual trees scattered widely throughout the farm. Fruits such as avocados, oranges, lemons and grapefruit are consumed in the home, with excess distributed to family and neighbours. A few farms sell their excess fruit crops in the market.

The tallest structural layer, consisting of hardwood timber species, is not found in all farms, and is usually composed of scattered individual trees that do not form a connecting canopy. One reason for this is that the majority of farmers retain any native trees that germinate naturally in the farm and are of a high quality timber source. The most common species fitting these criteria is Cedro (*C. odorata*) and it is a common sight in both communities to see one or two adult Cedro trees in a coffee farm, even if the rest of the farm has negligible shade. Other native trees left to grow naturally in the farm include Aceituno (*Simarouba glauca*), María (*Callophyllum brasiliense*), Ira marañon (*Ocotea tonduzii*), and Palo de Leche (*Brosimum utile*). Farmers pointed out the high quality wood in these species, and expressed that at some time in the future the timber could be either used in the home or sold. Only two main commercial tree species were used in large amounts, planted to create a more continuous canopy: Eucalpytus (*E. deglupta)* and Amarillón (*T. amazonia)*. This continuous layer of timber trees occurs mainly in farms over ten to fifteen hectares.

It is a common practice in the coffee farms of the study region to use live fences to delineate property lines. These are usually species that are easily propagated by stakes, and are spaced evenly around the perimeter of the property, connected with plain or barbed wire fencing. A variety of the species used (Table 7) provide other benefits besides fencing, such as edible fruits or flowers, or nitrogen from leaf fall of leguminous trees. Two of the species commonly used, Lengua de Vaca (*Conostegia xalapensis)* and Guaba (*Inga spp)*, provide a food source for birds either through berries, flowers, or the insects the tree attracts.

Wheelwright et al. (1984) examined tree genera in Monteverde, Costa Rica that were conducive to high bird diversity, due to the provision of fruit as a food source. Key genera that were noted to attract a large number of bird species due to the production of large crops of medium sized fruits were: Cecropia, Ficus, Trema (Ulmaceae), Acnistus (Solanaceae), Sapium (Euphorbiaceae), Cytharexylum (Verbenaceae), Hasseltia (Flacourteaceae), Conostegia (Melastomataceae), and Hampea (Malvaceae). In general the following plant families support a large number of fruit eating birds: Lauraceae, Moraceae, Rubiaceae, Melastomataceae and Solonaceae. Tree species already found incorporated in the coffee farms of Santa Elena and Quizarrá that belong to these families include: Lauraceae: *O. tonduzii* (Ira marañon), *P. americana* (avocado)*;* Moraceae: *B. utile* (Milk tree); Melastomataceae: *Conostegia sp. (*Lengua de vaca).

5.3. Apparent themes from interviews

There were numerous themes that surfaced when examining the information collected from the interviews, yet the three most important and most relevant to the study will be further emphasized here. The first common thread throughout all interviews, and throughout conversations with people in the communities of Quizarrá and Santa Elena, is the general concern that high amounts of shade will increase pests in the coffee crop, this being the main reservation towards adding more trees in a farm. The second topic regards the almost unanimous choice of timber trees by farmers who are interested in incorporating more trees into their farms. The final theme regards the influence of ICAFE and Coopeagri agricultural engineers on coffee management practices.

5.3.1. Reservations to increasing the amount of shade over coffee

The primary reservation expressed towards increasing the amount of shade in coffee farms was that thick shade will increase the humidity in the farm, invariably causing an increase in pests, specifically fungi, and damage to the coffee crop. Although it was believed that a small amount of shade is necessary, maximum amounts were stated at 40%, as both an increase in the amount of pests in the coffee and a reduction in yield occurs with shade beyond this point. Many community members stated that in past harvests when there was denser shade over their crop, most often of the species Guaba, an increase in pest outbreaks (such as *mal de hilacaha* and *ojo de gallo)* convinced them to remove or thin out the shade layer. Although some trees are desired in the farm to reduce erosion, those interviewed noted light regulation to encourage the timing and production of fruit as a priority.

There were additional reservations towards increasing shade in coffee farms mentioned during the interviews. Concern was raised over the reduction in crop yield that would occur with an increase in shade. There was also concern over the amount of damage that could affect the coffee crop through falling branches and leaves from tall shade trees. In addition the cost to purchase the trees themselves was mentioned – one community member trying to plant an additional layer in Amarillón stated a cost of 300 colones per tree (at an exchange rate of $1U.S. to 300 colones, equivalent to 1 $U.S per tree), which can produce high costs for smallholders if planted from 70 trees per hectare [regulations for ECO-O.K. shade coffee in El Salvador (Chris Wille, per. comm.)] up to 370 trees per hectare (the density of *E. deglupta* in Santa Fe).

5.3.2. Preference for timber trees

Of the tree species farmers expressed as desirable to incorporate into coffee farms, timber trees were most commonly suggested. The seven most frequently mentioned tree species are displayed in Table 8. In addition to the income generated from selling the wood in the future, benefits of the majority of these tree species include a tall straight trunk with compact crowns. This lets in ample amounts of sunlight to the coffee crop, meeting the smallholders' preference towards the amount of admitted light. This preference towards timber trees was further supported by the fact that most trees that are left in the farm after natural regeneration are native timber species.

Tavares et al. (1999) also found a preference for timber trees among farmers in Pérez Zeledón, and found that the most frequently used species were *E. deglupta, T. ivorensis,* and *T. amazonia*. Eucalyptus was liked because of its fast growth, ample amount of shade without being too thick, and the lack of provocation of infirmities in the coffee. Farmers in the study believed that the market for *T. amazonia* and *C. odorata* is easily commerciable and that *E. deglupta* has the poorest quality wood of these species.

TABLE 8: Seven most commonly mentioned timber species acceptable by smallholders for incorporation into coffee farms, with characteristics of each species. (Sources: Geilfus, 1994; Allen, 1965).

TREE SPECIES	**CHARACTERISTICS**
Aceituna (*Simarouba glauca*)	Tall tree up to 36 metres, black edible oil rich fruits Wood is white, light and soft
Amarillón (*Terminalia amazonia*)	From 24 – 36 metres in heights, papery winged fruits, flowers in February/March Heartwood is yellowish streaked with red Good for boat framing, flooring, furniture etc.
Cedro (*Cedro amargo*)	Medium sized, 20 –30 metres, flowers June-August Wood is pinkish or reddish brown, soft, light and easy to work with, durable Considered of high value in Santa Elena and Quizarrá
Cristobal (*Platymiscium pinnatum*)	Straight trunk 20 – 30 metres, legume High quality reddish-brown wood Orange flowers from Dec-April
Guanacaste (*Enterolobium cyclocarpum*)	Up to 25 metres with broad crown Small white flowers in December Wood durable, finishes smoothly, good for furniture and inside carpentry
Ira marañon (*Ocotea tonduzii*)	Medium size, 15 – 20 metres Pale yellow flowers in August and September Soft white wood
María (*Callophyllum brasiliense*)	Straight trunk from 20 – 40 metres Wood is pink to red, strong, and easy to work with Good for furniture, canoes and general construction Considered of high value in Santa Elena and Quizarrá

5.3.3. Influences on coffee management practices

The influence of ICAFE was not very strong in the communities, the majority of the smallholders interviewed not having a clear idea of who the organization was and how it affected them. The people who did know of ICAFE had negative responses towards their impact on the economics of coffee, commenting that the national organization “does nothing to help the small producers”. Although members of ICAFE visit the communities occasionally to hold workshops on various management methods such as fumigation and harvesting, the frequency is not very high, and the impact does not seem to be very effective.

The majority of the assistance and outreach on coffee management practices instead comes from the agricultural engineers of Coopeagri. These engineers visit the farms in the region regularly offering help and advice towards management problems in the coffee farms. Recommendations from Coopeagri include planting coffee under the shade of Poró or Guaba and using organic fertilizer, methods that are cheaper and healthier for the farm. Many smallholders respect the years of experience and training the engineers have in their field. The widespread influence of these engineers may offer one manner of distributing information and advice towards changing management practices and behaviour to accommodate more shade in the coffee farms.

Despite the assistance of the Coopeagri engineers, not all information is on hand to smallholders. A few farmers that did say yes to the question on whether they would be interested in incorporating more tree species into their farm, stated they were limited by what trees they knew could be grown with coffee, other than the species commonly seen in farms in Santa Elena and Quizarrá. More information is needed on what trees would not negatively affect yields of the coffee crop.

5.4 Results of data analysis from avian point counts

5.4.1 Examination of species richness and diversity

A total of 87 bird species (and 1907 individuals) were identified on the point counts in the six farms sampled over the two sampling seasons[32], including thirteen Nearctic-breeding migrant species and five tropical migrant species (Table 9; for migratory status and guilds see Appendix C). With the inclusion of species seen in transit between point counts (offcounts), 89 bird species were observed [adding the Bat Falcon (*Falco rufigularis)* and the Gray-necked Woodrail (*Aramides cajanea*)]. On some occasions individual hummingbirds and flycatchers could only be identified down to the family level. These two groups therefore (Hummingbird species and Flycatcher species) were each treated as a separate species during the data analysis so as not to lose the possible information of having a different species in that group[33]. Species area curves plotted combining all six farms and on the Eucalyptus farm separately (Appendix F) show diminishing curves as the number of points increased, indicating that the sampling effort adequately accounted for the majority of species in the region and farm respectively. The following discussion will use the codes designated for each farm (Table 2) for brevity.

Species richness (the total number of species observed in each farm) was highest in farms E and T when data was combined over both seasons (Table 10). The lowest species richness (22 species) was found in B2, yet the richness was also low in the two

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[32] Wet season: June to July 1999; dry season: January and February 2000.
[33] A total of 4 individual flycatchers and 20 individual hummingbirds could only be identified down to the family level.

Poró farms compared to farms E and T. Seven species were found in common across all farms: Rufous-tailed hummingbird (*Amazilia tzacatl),* Bananaquit (*Coereba flaveola),* White-tipped Dove (*Leptotila verreauxi),* House Wren (*Troglodytes aedon),* Clay-colored Robin (*Turdus grayi),* Scarlet-rumped Tanager (*Ramphocelus passerinii)* and Blue-gray Tanager (*Thraupis episcopus)*.

	P1	**P2**	**B1**	**B2**	**E**	**T**
S	22	24	23	19	56	59
% of total species	30	28	26	24	66	66
Number of points	42	24	24	23	80	50

TABLE 10: Avian species richness (S) noted in each of the six coffee farms investigated, combining data from both the wet and dry season. (P=Poró; B=Banana; E=Eucalyptus; T=Amarillón).

To examine possible differences between seasons, species richness was calculated again for each farm, keeping the sampling seasons separate (Table 11; see Appendix D for a species list by farm). Both farms with a higher percentage of shade cover (E and T) showed a higher species richness in each season compared to the farms with a reduced shade layer (farms B and P). Farm T had the highest species richness in the dry season (47 species), and in the wet season the highest value occurred in the Eucalyptus farm (40 species). Comparably, farm B2 had only eight species in the wet season, and farm P2 had thirteen species in the dry season.

All four biodiversity indices suggest that farm T is the most diverse in terms of both number of avian species and evenness of distribution of these species (Table 11a).

FARM	P1	P2	B1	B2	E	T
	WET SEASON					
No. of points	18	12	12	8	40	19
No. of individ. (N)	68	62	65	28	381	181
No. of species (S)	18	18	16	8	41	36
Berger-Parker Index (1/d)	4	2.3	3.8	3.1	5.1	5.3
Simpsons Index (1/D)	9.82	4.86	8	5.91	9.31	15.4
H	2.39	2.14	2.30	1.81	2.68	3.14
J	0.84	0.75	0.83	0.87	0.72	0.87
	DRY SEASON					
No. of points	24	12	12	15	40	31
No. of individ. (N)	99	45	118	92	486	272
No. of species (S)	17	13	16	18	37	47
Berger-Parker Index (1/d)	6.2	2.8	4.4	4	2.9	10.9
Simpsons Index (1/D)	13	6.43	7.3	7.4	4.8	23.67
H	2.62	2.22	2.22	2.25	2.13	3.37
J	0.91	0.87	0.80	0.81	0.60	0.87

TABLE11a: Avian species richness in each of six coffee farms examined differing in the species of shade tree used, in both the wet and dry seasons. Included are the values of the Berger-Parker Index, the Simpson's Index, the Shannon Biodiversity Index (H), and the Shannon Evenness Factor (J) for each farm in both the wet and dry season. (P = Poró; B= Banana; E = Eucalyptus; T = Amarillón).

The Berger-Parker Index (which increases in value with an increase in evenness of distribution, or a decrease in dominance) was largest in farm T in both the wet and dry seasons (5.3 and 10.9 respectively) and lowest in farm P2 (2.3 in wet season, 2.8 in the dry season). The Shannon Evenness Factor J (which shows an increasing evenness as the value approaches J=1) was high for T in both seasons, however high values were also seen in B2 in the wet season and in P1 and P2 in the dry season. The Simpson's Index indicated high diversity in farm T (15.4 in wet season, 23.67 in the dry season) with low values occurring in farm E in the dry season and farm P2 in the wet season. The Shannon Index factor also showed a high diversity in T in both seasons (Table 12). The indices do not show a pattern of gradually increasing diversity along the continuum of increasing tree height and shade (from farms P to T), but generally indicate a low diversity in the Poró farms and a higher diversity as the canopy height increases.

Student t-tests performed on the H values in the wet season between the farms (Appendix E) indicate that the Shannon diversity index for farms T and E were significantly greater than all other farms (including T greater than E) and farm B2 was significantly less diverse than B1 and P1. In the dry season farm T was significantly more diverse than all 5 other farms, and interestingly farm P1 was significantly more diverse than P2, B1, B2 and E, yet only during this season. Comparing diversity values in the wet season versus the dry season for each farm, farm T and B2 were significantly more diverse in the dry season, possibly due to the increase in migrant species, and farm E was significantly less diverse in the dry season, possibly because of the increase in dominance by the Rufous-tailed Hummingbird and Tennessee Warbler or from the reduction of shade seen in the dry season as trees were removed to manage the fungal pest in the coffee.

When the sample sizes are standardized at 12 points with the Monte Carlo approach, the pattern of species richness across the six farms is more conclusive (Table 11b). Farm T has the highest number of species (S) in both seasons. Both Poró farms and both *Musa* farms have a low species richness, and Eucalyptus shows a lower species richness than farm T when sample sizes are accounted for. Farm E also had a higher species richness in the dry season than in the wet season. The patterns seen in the three other biodiversity indices (Table 11b) did not change significantly with the Monte Carlo approach compared to the previous calculations.

Table 12 displays the species accounting for 50% of individuals observed in each farm. The majority of these species are generalist species that do not depend on intact forest, with a forest dependency of 3 or 2-3 (see guild allocations, Appendix C). Farm T shows a more even distribution of species by having a higher number of species contributing to 50% of the individuals observed (six in the wet season, eight in the dry season). It is interesting to note that only farm E and T had migrant species occupying a spot of high abundance during the dry season. Farm P2 had the highest dominance by one species during both seasons (43.5% and 35.6% of individuals observed), whereas farm T had the lowest (9.2% in dry season).

FARM	P1	P2	B1	B2	E	T
	WET SEASON					
No. of points	12	12	12	8	12	12
No. of species (S)	14.00 (± 0.35)	18	16	8	21.96 (± 0.58)	31.32 (± 0.34)
Simpsons Index (1/D)	9.45 (± 0.41)	4.86	8	5.91	9.27 (± 0.26)	15.1 (± 0.6)
H	2.35 (± 0.02)	2.14	2.30	1.81	2.49 (± 0.02)	2.97 (± 0.02)
J	0.89 (± 0.01)	0.75	0.83	0.87	0.76 (± 0.04)	0.84 (± 0.03)
	DRY SEASON					
No. of points	12	12	12	12	12	12
No. of species (S)	13.88 (± 0.29)	13	16	14.6 (± 0.2)	17.96 (± 0.58)	31.04 (± 0.69)
Simpsons Index (1/D)	12.96 (± 0.47)	6.43	7.3	7.46 (± 0.15)	4.72 (± 0.09)	22.89 (± 0.78)
H	2.47 (± 0.02)	2.22	2.22	2.22 (± 0.02)	1.99 (± 0.02)	3.16 (± 0.03)
J	0.94 (± 0.01)	0.87	0.80	0.827 (±0.003)	0.69 (± 0.07)	0.920 (±0.005)

TABLE11b: Values of four biodiversity indices for avian species richness in the wet and the dry season using a Monte Carlo approach (N=25) to account for varying sample sizes. Indices used are species richness (S), Simpson's Index (1/D), Shannon Biodiversity Index (H), and the Shannon Evenness Factor (J).

TABLE 12: Number of species contributing to 50% of the birds observed in each of six farms investigated, separated by season. (Nearctic-breeding migrants are indicated with an *).

	WET SEASON	DRY SEASON
P1	Yellow Tyrannulet (0.250) Scarlet-rumped Tanager (0.13) House Wren (0.103) Variable Seedeater (0.074)	Yellow Tyrannulet (0.162) Scarlet-rumped Tanager (0.11) Blue-gray Tanager (0.101) House Wren (0.081) Tropical Gnatcatcher (0.081)
P2	Scarlet-rumped Tanager (0.435) Rufous-capped Warbler (0.097)	Scarlet-rumped Tanager (0.356) Buff-throated Saltator (0.220)
B1	Blue-Grey Tanager (0.262) Scarlet-rumped Tanager (0.185) Rufous-tailed Hummingbird (0.123)	Blue-grey Tanager (0.229) Scarlet-rumped Tanager (0.212) Rufous-tailed Hummingbird (0.161)
B2	Scarlet-rumped Tanager(0.321) Rufous-tailed Hummingbird (0.214)	Rufous-tailed Hummingbird (0.250) Blue-grey Tanager (0.217) Scarlet-rumped Tanager (0.12)
E	Rufous-tailed Hummingbird (0.197) Snowy-bellied Hummingbird (0.189) Blue Dacnis (0.105) American Swallow-tailed Kite (0.097)	Rufous-tailed Hummingbird (0.348) * Tennessee Warbler (0.270)
T	Scarlet-rumped Tanager (0.188) Clay-colored Robin (0.099) Blue-grey Tanager (0.072) Variable Seedeater (0.072) Streaked Flycatcher (0.05) House Wren (0.05)	* Chestnut-sided Warbler (0.092) Social Flycatcher (0.081) Scarlet-rumped Tanager (0.081) Blue-grey Tanager (0.07) Red-crowned Woodpecker (0.048) Golden-hooded Tanager (0.048) * Tennessee Warbler (0.044) Rufous-tailed Hummingbird (0.04)

5.4.2. Comparison of means between sample farms

The two way ANOVA performed on the average number of species per point and the average number of individuals per point, using both farm and season as independent variables, showed a significant effect for season on average number of species per point

(F=7.138, df=1, P=0.008) and a slight effect for season on average number of individuals per point (F=3.947, df=1, P=0.048). For this reason the two seasons were analyzed separately, to further investigate patterns in each set of data.

Both the average number of species per point and average number of individuals per point were found to be significantly different between the six farms, in both the wet season and the dry season (wet season: average number of species per point F=5.906, P<0.001, df=5; average number of individuals per point F= 8.297, P<0.001, df = 5; dry season: average number of species per point F=8.491, P<0.001, df = 5; average number of individuals per point F=13.821, P<0.001, df = 5). Farm T had the highest average number of species per point in both seasons (Fig. 5), and there is evidence of a trend of increasing number of species per point along the shade continuum from the Poró farms to farm T. Farm B1 however showed a very high value for average number of species per point in the dry season, larger than that seen in the Eucalyptus farm, disrupting the increasing trend. Trends for average number of individuals per point (Fig. 6) are less evident, although both farm T and E tend to have a high amount of individuals per point in both seasons, shared by farm B1 in the dry season. Eucalyptus has the highest average number of individuals per point (10.13) in both seasons.

Using Bonferroni post-hoc tests, significant differences were found between pairs of farms for both the wet and dry season. The resulting P-values for pairs that were significant are displayed in Table 13. In the wet season the average number of species per point was significantly greater in farm T compared to B2 and P1. This was the only significant difference in this variable for the wet season. The average number of

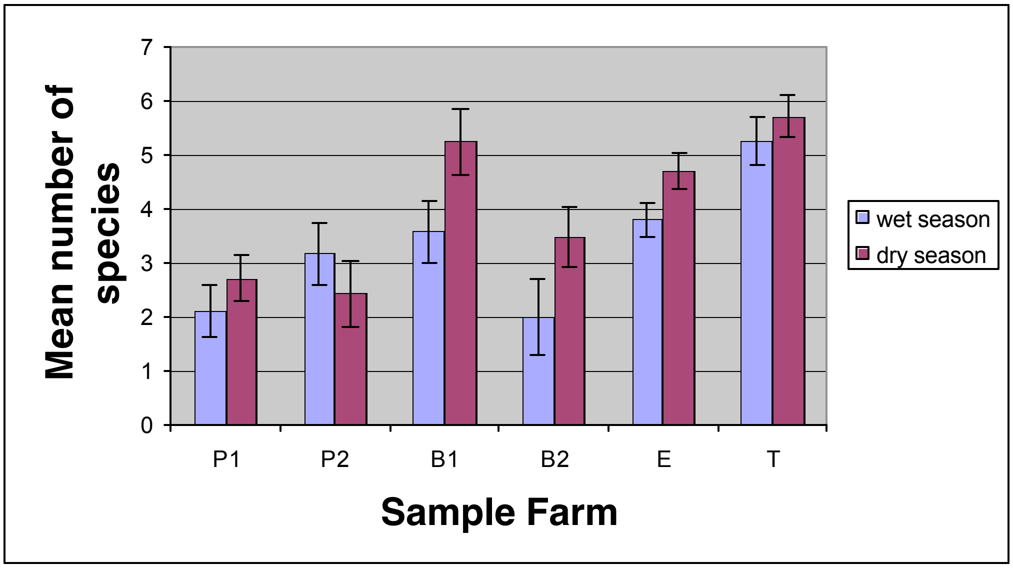


FIGURE 5: Average number of species per point for each of the six coffee farms sampled, in both the wet and dry season. (P= Poró; B= Banana; E= Eucalyptus; T = Amarillón). Error bars signify ± the standard error.

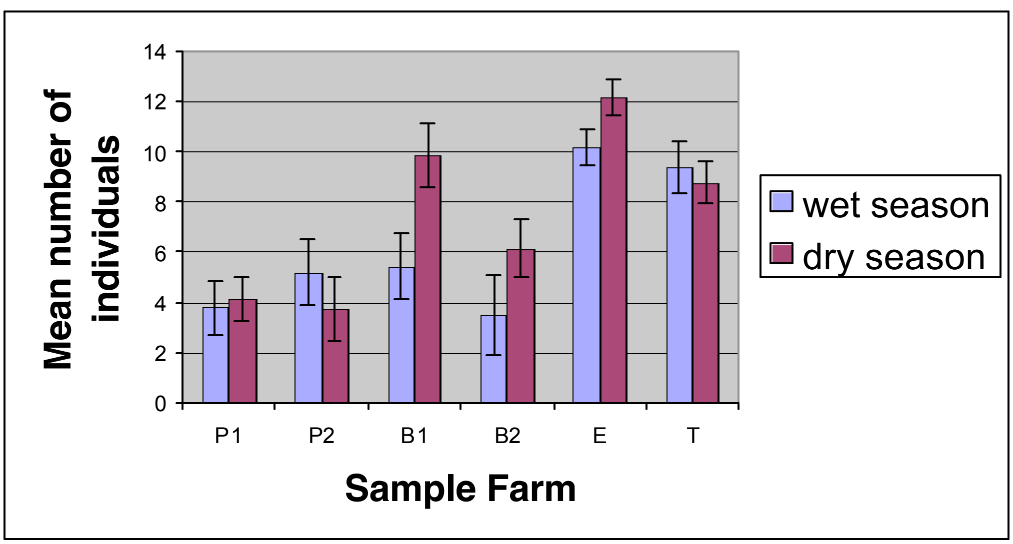


FIGURE 6: Average number of individuals per point for each of the six coffee farms sampled, in both the wet and dry season. (P= Poró; B= Banana; E= Eucalyptus; T = Amarillón). Error bars signify ± the standard error.

AVERAGE NUMBER OF SPECIES PER POINT												
	WET SEASON						DRY SEASON					
	P1	P2	B1	B2	E	T	P1	P2	B1	B2	E	T
P1		*	*	*	*	<.001		*	0.015	*	0.006	<.001
P2	*		*	*	*	*	*		0.022	*	0.022	<.001
B1	*	*		*	*	*	0.015	0.022		*	*	*
B2	*	*	*		*	0.003	*	*	*		*	0.016
E	*	*	*	*		*	0.006	0.022	*	*		*
T	<.001	*	*	0.003	*		<.001	<.001	*	0.016	*	

AVERAGE NUMBER OF INDIVIDUALS PER POINT												
	WET SEASON						DRY SEASON					
	P1	P2	B1	B2	E	T	P1	P2	B1	B2	E	T
P1		*	*	*	<.001	0.004		*	0.006	*	<.001	0.003
P2	*		*	*	0.017	*	*		0.016	*	<.001	0.017
B1	*	*		*	0.029	*	0.006	0.016		*	*	*
B2	*	*	*		0.004	0.037	*	*	*		<.001	*
E	<.001	0.017	0.029	0.004		*	<.001	<.001	*	<.001		0.028
T	0.004	*	*	0.037	*		0.003	0.017	*	*	0.028	

TABLE 13: Results of Bonferroni post-hoc tests on the comparison of means between the six coffee farms sampled differing in the species of tree in the canopy. Displayed are the P values of pairwise comparisons that were significantly different. (P=Poró, B=Banana, E=Eucalyptus, T= Amarillón; * = no significant difference was found when comparing the pair).

individuals per point was significantly greater in the Eucalyptus farm compared to all other farms except for farm T, and farm T was again significantly greater than B2 and P1 in this variable.

The relationships were more complex in the dry season. Although both farm T and E were significantly greater than both Poró farms in terms of number of species per point, farm B1 was as well, and there was no significant difference between farms T, B1 and E. In terms of number of individuals per point, farm E was significantly greater than all other farms, again excepting B1.

5.4.3. Correlations with external variables

The Pearson's correlation coefficients were calculated comparing the following variables: number of species per point, number of individuals per point, weather, altitude, canopy height, coffee height, distance from intact forest patches and distance from the road. Combining data from both seasons, significant correlations at the $P = 0.01$ level occurred between the following: number of species per point and approximate canopy height (0.427); number of individuals per point and number of species per point (0.807); number of individuals per point and altitude (0.32), approximate canopy height (0.42) and approximate coffee height (-0.176). Other significant correlations were between altitude and approximate coffee height (-0.419) and between the approximate canopy height and approximate coffee height (0.179). Within farm variation was minimal, therefore differences observed can be attributed mainly to between farm variation.

5.4.4. Diversity of migrant species

Thirteen Nearctic-breeding migrant species were observed in the dry season. There was considerable variation among the six farms in terms of number of migratory species observed (Table 14). Farms P2 and B2 had only one species of migrant, the lowest out of all six farms, and farm T had the highest number of migrant species, at 10 species. The abundance of migrants compared to residents was low in all six farms, with all farms dominated by resident species in the dry season. Farm E had the highest abundance of migrants, resulting from the high number of Tennessee Warblers attracted to the Eucalyptus flowers.

The ANOVA conducted on the mean number of resident species per point and mean number of migratory species per point found significant differences between all six farms ($F=6.481$, $df=5$, $P<0.001$; $F=8.929$, $df = 5$, $P<0.001$ respectively). Post Hoc tests with the Bonferroni method indicated that in both farm E and farm T, the average number of migratory species per point were significantly larger than farms B2, P1 and P2, but were not significantly different to each other, nor to farm B1. In terms of average number of individual migrants per point, farm E was significantly greater than all five other farms.

Pearson correlations on the number of migratory species per point showed a significant positive correlation at the $P=0.01$ level with number of resident species per point ($r=0.369$) and approximate canopy height ($r=0.481$). Number of resident species per point was positively correlated at the $P=0.01$ level with approximate canopy height

(0.355) and was negatively correlated with the approximate distance from the road ($r = -0.533$).

	P1	P2	B1	B2	E	T
	MIGRATORY SPECIES					
S_m	3	1	3	1	9	10
N_m	13	1	9	3	149	53
Abundance	0.131	0.022	0.076	0.033	0.307	0.195
Mean number of sp. per point	0.42 (±0.15)	0.08 (±0.21)	0.50 (±0.21)	0.13 (±0.19)	1.08 (±0.12)	1.16 (±0.13)
Mean number of individuals	0.54 (±0.42)	0.08 (±0.59)	0.75 (±0.59)	0.20 (±0.53)	3.73 (±0.32)	1.71 (±0.37)
	RESIDENT SPECIES					
S_r	14	12	13	15	25	37
N_r	86	44	109	89	337	219
Abundance	0.87	0.98	0.92	0.97	0.69	0.805
Mean no. of sp. per point	2.29 (±0.37)	2.33 (±0.52)	4.75 (±0.52)	3.33 (±0.47)	3.63 (±0.28)	4.55 (±0.32)
Mean number of individuals	3.58 (±0.74)	3.67 (±1.04)	9.08 (±1.04)	5.93 (±0.93)	8.43 (±0.57)	7.07 (±0.65)

TABLE 14: Avian species richness and abundance for migrant and resident species separately in the dry season for each farm sampled. (P=Poró; B=Banana; E=Eucalyptus; and T=Amarillón; S_m, N_m = species richness and number of individuals for migratory species; S_r , N_r = species richness and number of individuals for resident species). Values in brackets are ± the standard error of the mean.

5.4.5 Comparison of guilds

All six farms were dominated by individuals with a forest dependency of 3 (Fig. 7). The occurrence of forest dependent species (fd = 1) was rare, even in the farms with a high canopy height (farms E and T). Only three species were observed that require intact forest (forest dependency of 1): White-winged Becard (*Pachyramphus polychopterus*) which occurred only in farm T, Blue-crowned Manakin (*Pipra coronata*) which occurred in both farms P2 and E, and White-throated Robin (*Turdus assimillis*) which occurred only in farm E. Seven species between a forest dependency scale of 1 and 2 were observed: Brown Violet Ear (*Colibri delphinae*) and Speckled Tanager (*Tangara guttata*) were observed in farm E, Masked Tityra (*Tityra semifasciata)* was observed in both farms E and T, Grey-headed Tanager (*Eucometis penicillata*) and Ruddy-tailed Flycatcher (*Terenotriccus erythrurus)* were observed only in farm T, the Rufous-and-white Wren (*Thryothorus rufalbus*) was observed in farm B2, and the Orange-billed Sparrow (*Arremon aurantilirostris*) was observed only in farm P2. Although half of the observed highly forest dependent species occurred in the Eucalyptus farm, only four species were found in farm T.

All six farms were dominated by secondary forest species and those of open scrub (Fig. 8) and had a low abundance of forest interior species. This was apparent across all farms, regardless of the height of canopy and amount of shade in the farm. The proportion of forest interior individuals was highest in farm T during the dry season (8%), yet in the wet season farm P2 had a higher proportion of forest interior individuals (7%). Individuals of non-forest species occurred in farms E and T at very low proportions in the dry season, and only slightly larger proportions in the wet season (Fig. 8).

In all six farms, observed individuals were mostly omnivores in both seasons (Fig. 9). Carnivores were rare in all farms, and occurred only in farms E and T. Farm E was dominated by nectarivores in both seasons, attributable to the attraction of species to the Eucalytpus flowers. Insectivores were more or less evenly distributed across all six farms in the wet season, yet were more abundant in farms P1 and T in the dry season. Granivores were more abundant in the dry season.

The number of ground and low level foraging species was higher in both Poró farms, and decreased towards farm T (Fig. 10). The proportions of individuals from canopy foraging species likewise increased across the continuum of farms from negligible shade to higher percentage of shade (farm P to T). Farm B1 stood out by having a low percentage of ground foraging species, and a high percentage of canopy feeding species, similar to farms T and E. Trunk foraging species occurred mainly in farm T, although small proportions were observed in farm B1 in the wet season and farm P1 in the dry season.

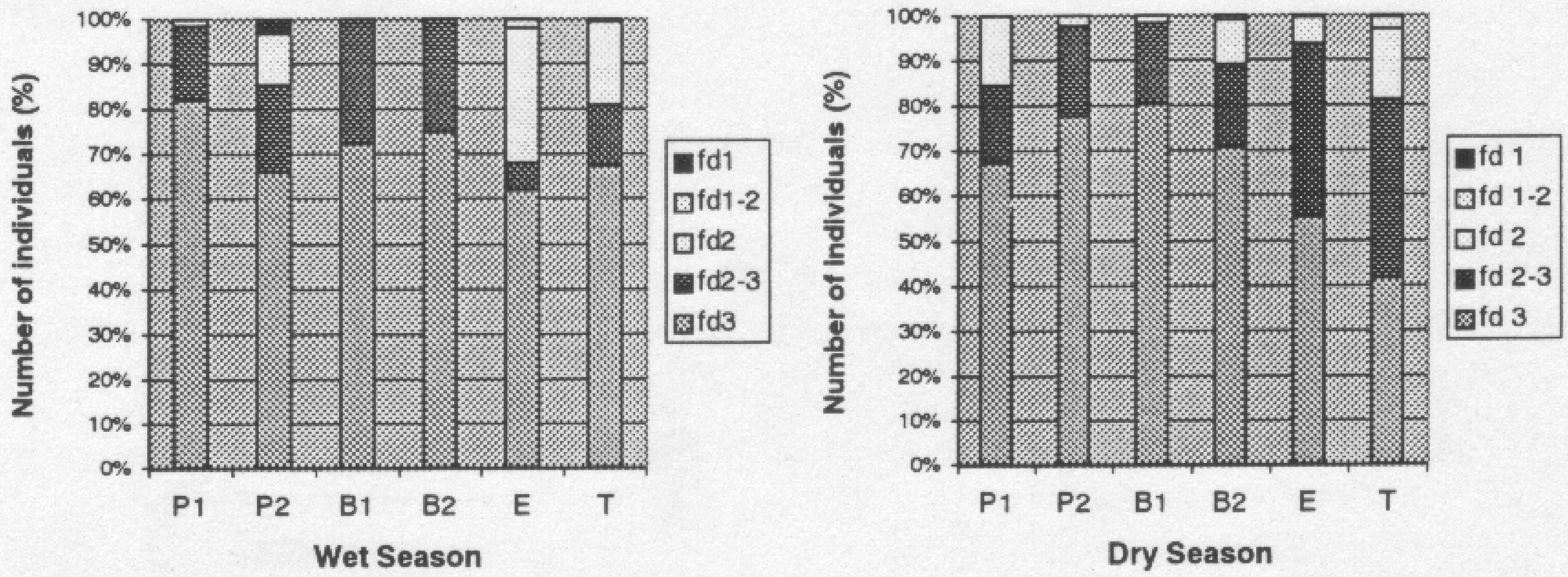


FIGURE 7: Observed avian individuals in each sample farm categorized by forest dependency. Groups are as follows: fd = 1, requires more than 50% forest cover; fd = 2, species that live in less than 50% forest cover as long as some trees are present; fd = 3, species that do notrequire forest patches. (P=Poro; B=Banana; E= Eucalyptus; T= Amarillon).

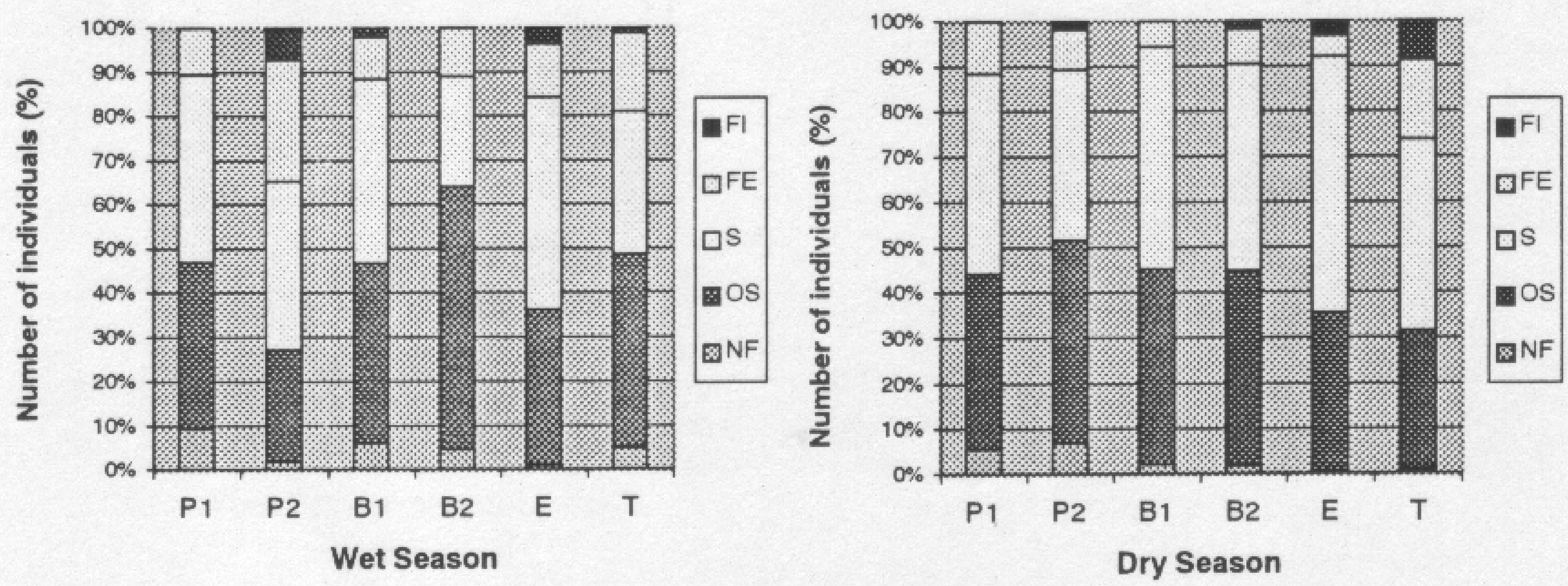


FIGURE 8: Observed avian individuals in each sample farm categorized by habitat preference. FI=forest interior, FE=forest edge, S= secondary forest, OS = open scrub and NF = non forest. (P=Poro; B=Banana; E=Euucalyptus; T=Amarillon).

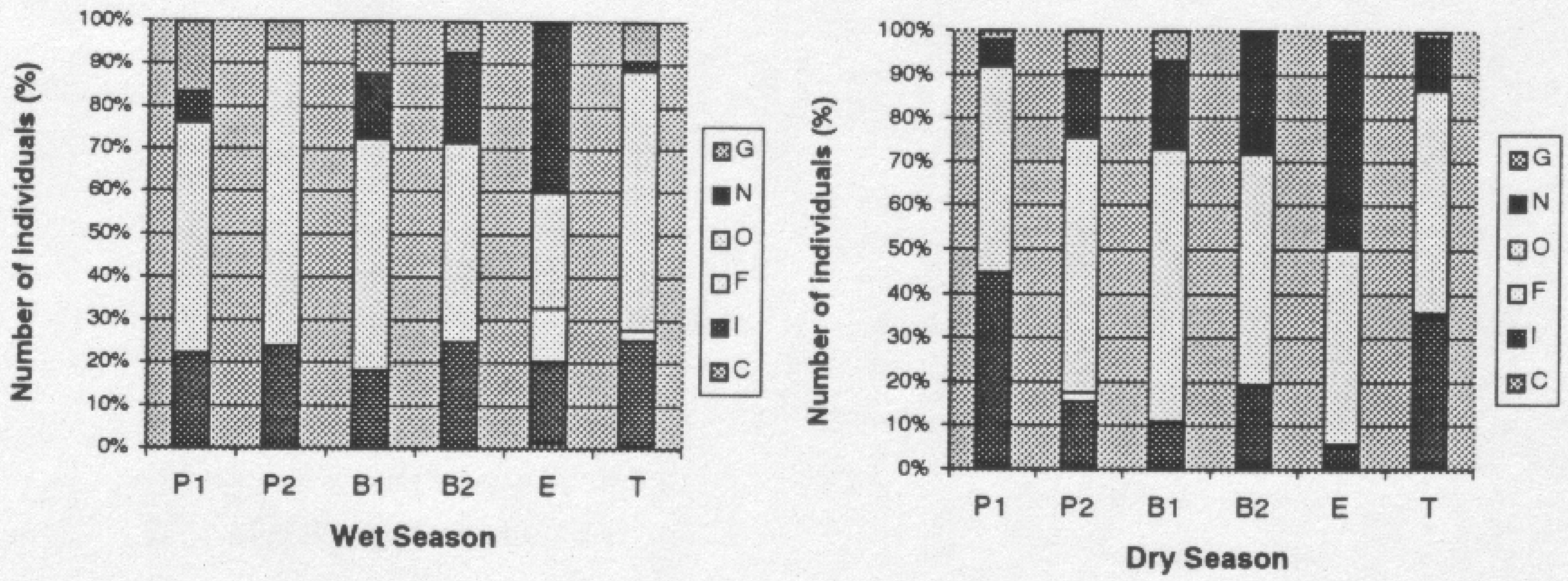


FIGURE 9: Observed avian individuals in each sample farm categorized into feeding guilds. G = granivorous, N=nectarivorous, O= omnivorous, F= frugivorous, I= insectivorous and C= carnivorous. (P=Poro; B=Banana; E=Eucalyptus; T= Amarillon).

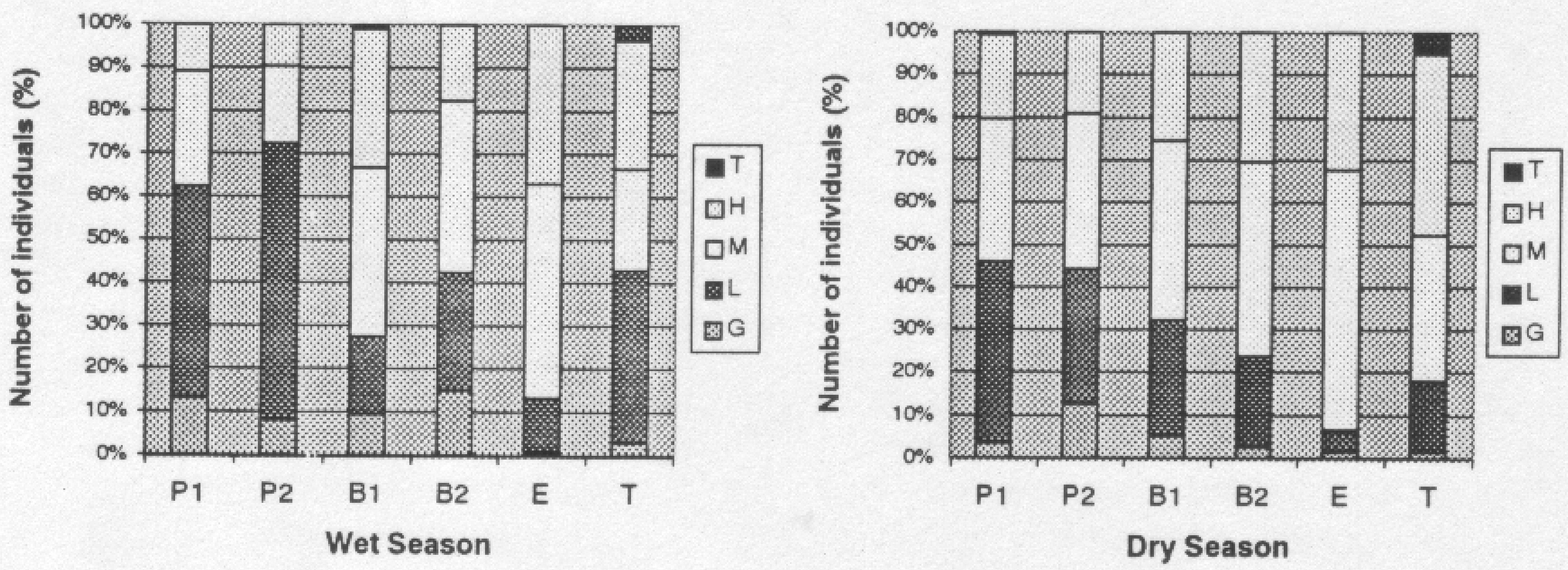


FIGURE 10: Observed avian individuals in each sample farm categorized into foraging level guilds. G = ground, L = low level, M= mid levels, H= high levels, T = trunk. (P= Poro; B=Banana; E = Eucalyptus; T= Amarillon).

5.4.6. Avian use of coffee versus shade layer

In both Poró and *Musa* farms in the wet season, the majority of individuals were observed in the coffee layer (Table 15). In the dry season however, more birds were observed in the canopy layer of farms B1 and B2 (the canopy consisting of the banana plants themselves). In both farms E and T, a low percentage of birds were observed using the coffee layer, and even less using the ground layer. These two farms were dominated by birds foraging in the canopy.

	WET SEASON			DRY SEASON		
	Location Observed					
	ground	Coffe e	canopy	ground	coffee	canopy
P1	10.6	63.6	25.8	1.2	87.2	11.6
P2	3.2	87.1	9.7	7.5	55	37.5
B1	9.4	53.1	37.5	8.2	43.6	48.2
B2	8.3	66.7	25	1.4	35.7	62.9
E	0.3	8.4	91.4	1.8	4.6	93.6
T	2.3	20.3	77.4	1.5	16.5	82

TABLE 15: Strata occupation of birds observed (percent) on point counts in the six sample coffee farms during both sampling seasons. (P=Poró; B= Banana; E=Eucalyptus; T=Amarillón).

5.4.7. Summary

All three biodiversity indices indicated that farm T is the most diverse farm of the six farms sampled in terms of number of species and evenness of abundance of these species. From the results of the ANOVA it is apparent that farms E and T tend to have higher average number of species per point and a higher average number of individuals per point. Farm T also had the highest number of Nearctic-breeding migrant species compared to the other farms, although farm E had the highest abundance of migrants, likely due to the attraction of Tennessee Warblers to the Eucalyptus flowers. Although farm E had a high number of species, it had a less even distribution of these species. Species of forest dependency 1 were rare, but were more likely to occur in farms E and T. These farms were also more likely to have representatives from all food guilds and foraging level guilds. Both farm P1 and P2 were had a low number of species and varied in the evenness of distribution. Farms B1 and B2 varied in diversity, with B1 showing high values of number of species per point and individuals per point, despite the low amount of shade and vertical structures in the coffee farm. It is possible the birds were attracted to a higher density of food source, *Musa* fruit, in this farm compared to B1.

Both the number of species per point and number of individuals per point were positively correlated with the canopy height, indicating an increase in both of these variables as the amount of shade over coffee increases. Individuals were observed using the canopy layer at a higher frequency in farms T and E, and there were few observations of birds using the coffee layer in these farms. In terms of species diversity therefore, it appears there is a low overall diversity in farms P and B, with low amounts of shade, and high diversity in farm T with a higher percentage of shade.

An overall portrait of each of the four farms is possible from point count results. Poró and coffee, with negligible shade, is a poor habitat for avian use and does not provide a high level foraging strata evident in the high proportion of low and ground foraging individuals on the sample farms. These farms have a low species richness of around twenty species, and are strongly dominated by one species. Coffee with Poró also attracts few Nearctic-migrant species in the dry season. The low species richness is likely due to the lack of vegetative strata above the coffee layer to provide foraging habitat.

The *Musa* farms has slightly more structural diversity over the coffee layer than Poró due to the thick leaved *Musa* plants forming the canopy. One *Musa* farm in the study showed low species diversity comparable to the Poró farms, whereas the other Musa farm had a higher level of diversity, at times similar to that of Eucalyptus and Amarillón. This may be attributable to a higher density of banana plants in B1 compared to B2, although this was not empirically tested. Another reason for the slightly higher avian diversity seen in the Musa farms compared to Poró however is the food source provided by the flowers and fruit of the Musa plants, present on the plant in some stage of production throughout the year.

The high avian diversity in Eucalyptus with coffee was unexpected as the tree species is not native to Costa Rica and therefore would not have developed any associations with the feeding habitats of the fauna in the region. The results of the study however do show a high diversity in terms of number of species, presence of species in all food and foraging level guilds, as well as a few forest dependent species. One main attraction to the Eucalyptus tree was the abundance of flowers present during both sampling seasons, a theory supported both through personal observation and the high proportion of nectarivorous species seen on point counts in the farm.

The farm with the native Amarillón had the highest avian diversity, the most even distribution in abundance of these species, and the most Nearctic-breeding migratory species. This is most likely attributed to the higher canopy in this farm providing more levels of foraging habitat. There was no evidence of foraging on flowers during the point counts, seen in the higher percentage of insectivorous and omnivorous individuals in this farm compared to nectarivorous species. Four forest dependent species were observed in this farm, indicating a more suitable habitat for these species than the Poró or *Musa* farms sampled. Of the four coffee farms sampled, the Amarillón farm appears to offer the best habitat for avian species.

6: SYNTHESIS, RECOMMENDATIONS AND CONCLUSIONS

6.1 Avian diversity in four coffee management systems

Results from the study show a low avian diversity in coffee farms with Poró as the main shade tree, and a higher diversity in the coffee farm with Amarillón. The cause of this variation in diversity is most likely due to the height of the shade canopy as both the number of species per point and the number of individuals per point were significantly correlated with this variable, as were both number of migrant and resident species in the dry season. An increase in avian diversity with an increase in tree layer complexity was also seen in Mexico (Garcia et al., 1998) and by Karr and Roth (1971) in a variety of tropical and temperate locations. The current study was by no means exhaustive however, and the number of points sampled was few in comparison to larger projects of avian diversity in other Central American countries. Caution must therefore be taken when interpreting the results, and a long-term more intensive survey of the farms in the region would further support conclusions drawn in this study.

In comparison with avian diversity in coffee farms in other Central American countries, a low total number of avian species was observed in the present study. Studies in Guatemala and Mexico found species richness values of over 100 species (versus 59 species in the Amarillón farm of Santa Elena and Quizarrá). The highest number of species found in the farms of Costa Rica most closely compare to the sun coffee plantations in Guatemala that presented 65 species (Greenberg, 1997b). However, Wunderle and Latta (1996) found only 41 bird species on point counts in sun, shaded coffee and pine forests in the Dominican Republic.

The lower diversity in farms in Costa Rica compared to Mexico and Guatemala is likely due to three factors: (1) the higher structural diversity in coffee farms in Mexico and Guatemala; (2) the use of *Inga* species in the shade canopy; and (3) the status of the habitat surrounding the sample farms. Rustic farms in Mexico were characterized by a canopy of twenty to thirty metres in height, and commercial polyculture at a height of fifteen metres (Moguel and Toledo, 1999). This was significantly higher than the canopies seen in the farms in the study region that ranged from four to twelve metres in height. In the farms in Guatemala, *Inga* species were commonly used in the canopy of planted farms and were noted to attract numerous hummingbird and icterid species. In the farms in Costa Rica, the role of *Inga* was replaced by Poró, which was usually not left to flower because of heavy pruning practices. Additionally, although surrounding habitats of the studied plantations were not described in Greenberg et al. (1997a,b), it is possible that surrounding rustic coffee or forest patches acted as a 'source' for observed birds. In the farms in Costa Rica, the surrounding landscape consisted of coffee farms of varying degrees of shade, sugarcane plantations, and other human managed systems, with only small forest patches, and likely supplied fewer individuals to populate the coffee farms.

The study in Guatemala found 20 – 29 migrant species in the coffee farms, compared to 13 species seen in the farms in Costa Rica. One reason for this discrepancy is that a higher percentage of migrant species spend the non-breeding season in the

Yucatán region of Guatemala and Mexico, whereas fewer species reach the more distant Costa Rica. Although information on the number of migrant species in the coffee farms is an important part of determining avian compositions in coffee farms, this group alone does not provide enough information with which to make conservation management decisions (Hutto, 1992). This is due to the fact that Nearctic-breeding migrants are often found in higher abundance in secondary forests and have a wider habitat breadth than resident species (Hutto, 1992; Blake and Loiselle, 1992). Small amounts of increase in tree cover in farms could provide adequate habitat for migrants (Greenberg, 1992) without assisting resident species. Yet Nearctic-breeding migrants are a group with which the public in North America easily identifies, thereby encouraging the support of shade coffee systems that support a high number of species in this group. It is important to note that in the current study of coffee both resident and migratory species were low in diversity in the farms with Poró and higher in the farm with Amarillón, indicating that the difference in shade tree species among the four types of management systems had an effect on both groups of bird species.

The total diversity of avian species found in the coffee farms of Santa Elena and Quizarrá was a reduced subset of the diversity characteristic of the tropical wet forest of the area. Although 77 of the 89 species observed on point counts have been noted in Los Cusingos, this is a small percentage of the over 300 species censused, including over twenty-five Nearctic-breeding migrant songbirds (TSC, 1993). Noticeably lacking in the coffee farms were representatives of families with strong forest habitat requirements such as antbirds, antwrens and antthrushes (Formicariidae), tinamous (Tinamiformes), trunk foragers such as woodpeckers and woodcreeprs (Picidae and Dendrocolaptidae), and manakins (Pipridae). The coffee farms instead were dominated by non-forest dependent species, with the few forest dependent species occurring in Eucalyptus and Amarillón.

Hypotheses on the impact current coffee systems have on the local avifauna can be made from the present data, although it may be difficult to isolate the effect of coffee systems out of the total effect of land use in the region on bird populations. Past land-use practices, for example, have also had a large effect on bird species, as the entire region has been altered for decades to favour agricultural landscapes, reducing the amount of available forest. The avian species composition of coffee farms before technification in the 1970s is unknown, but informal observations have indicated higher avian richness than that seen today (Dr. Skutch, per. comm.). What is important, however, is how different coffee farms with different management practices in the region currently support avian diversity. It was seen in this study that Poró and coffee offers a poor habitat for bird species, and that the habitat is improved with a taller canopy layer. A much higher diversity was seen in the Amarillón farms, suggesting a beneficial role for increasing the amount of shade with this species while encouraging more sustainable shade coffee practices in the region.

6.2 The potential to increase shade in coffee farms of Santa Elena and Quizarrá.

The amount of technification of coffee in Quizarrá and Santa Elena is high with a wide dispersal of modern short stature varieties of coffee plants. It is unprofitable to transform modern systems directly into traditional practices (Gliessman, 1998) and such a complete transformation was found to be undesirable in the communities. However a more successful goal can be seen in increasing the amount of shade above current levels and incorporating more sustainable practices in existing coffee farms thereby benefiting biodiversity, yet without necessarily reaching the quantity of shade seen in rustic farms. This process of conversion is complex, and requires a gradual transformation in a stepwise fashion. It should include not only an increase of shade, thereby restoring ecological functions in the farms, but should also involve a decrease in external inputs such as agrochemical pesticides and fertilizers, and an increase in the use of organic fertilizer and pest management.

The reservations farmers in the region have towards the increase in amount of shade must first be addressed before shade practices will be widely accepted. A primary reservation noted was the increase in fungal pests with an increase in shade. There is currently a lack of agreement in the literature on the influence of shade on pest species populations (Beer et al., 1998) as there is evidence that both supports an increase and a decrease in pest densities in different locations and situations varying in the percent of shade. Beer et al. (1998) summarized the available information as follows: o*jo de gallo* (*Mycena citricolor)* seems to increase in moist situations, c*hasparria (Cecrospora coeffeicola)* is greater in unshaded plantations, and the correlation between shade levels and leaf rust (*Hemileia vastatrix*) is weak. Although trees can act as an alternative host to coffee pests, there is also evidence that biological control agents can be used to reduce pest populations in coffee farms (Ackerman et al., 1998).

Reservations were also expressed regarding a decrease in yields with more trees in the farm, and the cost of incorporating more trees. A study conducted in Mexico, however, has shown that shade levels up to 40% do not affect yields of the coffee (Soto Pinto et al., 2000). The expense of incorporating saplings into the farm can be alleviated by establishing a tree nursery directly in the community with the species of trees desired by the community members, and run by the members themselves with assistance. These trees could then be distributed to members of a shade coffee project either at zero or low cost. The seeds of some of the trees for the nursery could be obtained from existing native trees in Los Cusingos, and those that do not naturally grow on the property can be obtained from agro-forestry seedbanks at CATIE or other agroforestry organizations.

A pilot farm initiated in the study region that gradually increases shade over time to an acceptable level (40% or more), is one way to address concerns over the increase of pests and decrease of yields in coffee with higher percentage of shade. As this farm progresses it is important to monitor and evaluate the changes by monitoring changes in biodiversity and ecological processes, yields of coffee crop, and changes in labour and profit to the farmers. A continual exchange and investigation with community members should occur, to try different practices that are beneficial both to community members and to biodiversity. Another activity that could address the issue of pests and shade could be to take groups of community members to see first hand successful projects of biodiversity-friendly shade coffee in Costa Rica.

6.3 Modeling a farm with more shade for the region

What is most evident from previous studies on avian diversity in coffee farms, and which is supported with data in this study, is the importance of structural diversity to provide habitat conducive to a high biological diversity. It follows then that the encouragement of additional stratified layers into the coffee farms of Quizarrá and Santa Elena would enhance avian diversity. The goal is to accomplish this with useful species desired by community members themselves that do not produce unacceptable shade levels and that also attract birds through foraging habitat or other methods.

Many small farms in the region have at least part of an intermediate layer consisting of *Musa* spp. and citrus trees. To make this layer more diverse, trees that attract birds with a food source could be added, depending on the preferences of the individual homestead. Included in this layer are the leguminous shade trees such as Poró and *Inga*. Although *Inga* species have been shown to attract a high diversity of hummingbirds and icterid species (Greenberg et al., 1997b), *Inga* is not recommended for this region. Smallholders in the study region expressed displeasure for this genus of tree because of the number of insect pests that attacked the tree and the amount of pests found in the coffee. This middle layer can instead be made denser simply by allowing the Poró to obtain a fuller crown. Allowing the tree to flower would attract species as many bird species (including orioles, honeycreepers, warblers, parakeets, and White-crowned Parrots) are attracted to the flowers and fruit of this species (Skutch, 1992; personal observations). Of interest regarding competition of Poró with the crop, Ramírez (1993) noted that when pollarded, the nodules on the roots of the Poró tree deteriorate rapidly, and that during regrowth of the branches the nodules may compete with the crop for nutrients. This is an additional reason to limit the pruning of Poró trees.

Timber trees offer a promising direction for incorporating more shade into farms, as the majority of farmers interviewed expressed a preference for good timber species. Detailed studies on the avian diversity associated with the timber species desired by farmers, along with their compatibility in coffee agroforestry systems, would determine which are the best for the coffee farms in the region. The incorporation of timber species into the farms would offer a second layer above coffee, increase the structural diversity of the coffee farms, and provide habitat for a higher diversity of avian species. Timber trees that could be incorporated into the coffee farm include Cedro (*Cedrela odorata)*, Amarillón (*Terminalia amazonia*), Cristóbal (*Platymiscium pinnatum)*, and Ira marañon (*Ocotea tonduzii)*.

The use of live fences to delineate coffee farms provides another means for providing important avian habitat. Estrada et al. (1995), conducting research on avian diversity in agricultural landscapes in Mexico, found that live fences could significantly increase the value of an arboreal agricultural landscape in providing connecting habitat for birds. Species that can be included in live fences include Lengua de vaca, *Gliricidia sepium,* and Guachipelin, all of which attract bird species through fruit or other food source. Included in the edge could be Pejibaye (*Guilielma utilis*), *Cecropia* species and Acerola (*Malphigia punicifolia*) which all attract bird species with their fruit.

Management practices in the smaller one to two hectare farms were by default more conducive to biodiversity by using less agrochemical pesticides and fertilizers.

These kinds of management practices should be encouraged in the region, possibly disseminated through workshops in the communities. The information sessions could include topics from tree species that can be grown with coffee, care of shade trees and coffee, pest management options, specifically decreasing pesticide use and increasing integrated pest management strategies, and methods of organic fertilization. The workshops should be structured in a way that involves transfer of information between both parties, as the small farmers have had years of experience with a variety of species on their own farm that will help in plans to establish more shade over coffee. Information could also be disseminated through the Coopeagri engineers if any project regarding increase in shade involves this organization.

6.4 Marketing coffee from the region

Many community members, although very conscious of and concerned about environmental health, were understandably reluctant to drastically change current practices without a guarantee of success or improvement. Most coffee farms in the region rely heavily on income from the coffee farm as a livelihood, and any alterations must be carefully weighed as to the amount of projected risk. Premiums provided from the sale of coffee designated as shade could provide the incentive to sustain shade management practices. Shade coffee co-operatives consisting of small-holders have been formed by communities in countries such as Mexico and El Salvador (Chris Wille, per. comm.), with the help and funding of non-governmental organizations and marketing strategies of companies in coffee consuming nations, and their success will soon be documented. If not marketed as 'shade coffee' specifically, the coffee from the region could be promoted as conducive to biodiversity, or green coffee, on the way to becoming more sustainable with shade practices.

At the level of coffee processing, the possibility of establishing a connection between a shade coffee co-operative and the local Coopeagri *beneficio* should be examined. Coopeagri already has many of the characteristics required of a *beneficio* under the ECO.O.K program (including water treatment, organic fertilizer and ability to process coffee separately) if this method of certification is chosen. An additional challenge in Costa Rica would be convincing ICAFE on the importance of shade coffee for the environment and for the people of Costa Rica. Approaching the organization with arguments of increased economic returns for the country and worldwide acknowledgement of biodiversity friendly sustainable coffee practices could address this issue.

The market opportunity for shade coffee requires as much work in northern countries as in the coffee producing countries however. A study conducted by the Commission for Environmental Conservation (CEC)[34], measuring consumer interest in shade coffee in North America, found that the shade concept is not very well understood and that the majority of people choose their coffee by flavour rather than environmental issues (CEC, 1999). Interestingly Canadian consumers in this study expressed a preference for shade coffee in terms of taste, while U.S. consumers did not distinguish a

[34] An institution established in a side agreement to NAFTA concerned with environmental issues across all three participating countries. It has increasingly supported the investigation of shade coffee in Mexico in recent years.

taste difference between sun and shade coffee. Encouraging the demand for shade coffee in the North therefore would require education campaigns on the issues regarding sun versus shade coffee, stressing the improved flavour of shade coffee (in Canada).

6.4 Future Research needed in the study region

The cultivation of coffee is just one aspect of the communities involved in the research, and the incorporation of more sustainable coffee practices is just one part of improving the environment and quality of life in the communities between Las Nubes and Los Cusingos. Community workshops conducted to provide an opportunity to discuss the most important problems in the communities (Baggio, 2000), raised issues including poor road conditions, lack of community cohesion (Santa Elena), lack of recreational activities and centres for community youths, and concern over water contamination.

Numerous future projects could offer promising results towards the goal of the Las Nubes-Los Cusingos Conservation Project, to both provide more habitat conducive to biodiversity and to improve the quality of life in the communities between the two protected areas. The construction of a research/community centre, complete with computers and means to communicate with other institutions (via internet, fax, or phone) would facilitate future research while providing a location for community meetings on a variety of topics and environmental education programs for children, youths and adults. Signs demarcating the trail in Los Cusingos and in Las Nubes with information regarding different bird species and other animals would encourage more people to explore the existing trail system, attracting more visitors to the two protected areas.

There is still much information that needs to be obtained in the study area before any projects can be planned, much of which could be obtained as research projects from the students at the Faculty of Environmental Studies, York University, and the Tropical Science Center in Costa Rica, as set out as objectives in their partnership. Such research should include the following:

- Economic studies comparing the practice of shade coffee to the current method of coffee production in the area from the perspective of the small farmers themselves, including all externalities and the additional revenues gained from the sale of products such as timber and fruit produced in the coffee farm.
- Ecological studies of how best to inter-relate the variety of shade tree species and shrubs with coffee to produce the most benefits for biodiversity and for the farmer.
- A complete survey classifying the types and locations of the coffee farms in the region (e.g. Poró and coffee, Poró and *Musa* and coffee, Poró and *Musa* and fruit and coffee, etc.).
- Further investigation on additional tree species mentioned in interviews to attract many birds species, to determine if they also provide uses or services for people, and would be acceptable with coffee, including: Tucuico (*Ardisia revoluta*), Pilón (*Hieronyma oblonga*) and others.

- Studies conducted to increase the knowledge of flora and fauna in Las Nubes including insect and plant surveys, census of orchid species, and future bird banding projects of resident and migratory species.
- Comparative studies on both the ecology and household economy of existing coffee management practices in the study region with traditional rustic coffee systems in Costa Rica, and/or other Central American countries.

6.5. Conclusions

In the search for methods of land-use that have less of an impact on biodiversity, coffee with a structurally diverse shade canopy offers one alternative in existing coffee systems that fulfills this goal. In the southern Pacific region of Costa Rica, coffee grown with the heavily pruned Poró offers a very poor habitat for avian diversity, whereas coffee grown with the timber trees Amarillón and Cedro with a high canopy of twelve metres, are much more conducive to avian diversity. The diversity seen in the Amarillón farm was lacking many of the forest dependent species seen in the surrounding lowland rainforest, yet had a much higher diversity than the other three coffee management systems examined in the study region.

It is important that conservation projects include the cooperation and participation of local communities, to successfully reach the desired goal. Although community members in Santa Elena and Quizarrá did not desire a complete reversion to rustic coffee, it is likely that an increase in shade levels in coffee farms could occur above the current levels, using especially timber species such as Amarillón. Encouraging more ecologically-beneficial management practices in addition to an increase structural diversity would provide habitat more conducive to local biodiversity. It could also benefit the farmers through reduced costs of production, provision of additional products for home use and/or sale, and the opportunity for a healthier local environment.

Recommendations on how an increase in the amount of shade could be encouraged in the communities of Santa Elena and Quizarrá were proposed from the synthesis of information collected during the study period. Ways to increase structural complexity in existing farms included:

- Incorporating timber species in the canopy layer including: Cedro (*Cedrela odorata),* Amarillón (*T. amazonia),* Cristóbal (*Platymiscium pinnatum)* and Ira marañon (*Ocotea tonduzii).*
- Allowing Poró trees to attain more foliage, and perhaps to flower.
- Incorporating more fruit trees into the middle layer of the coffee farm, the species dependent on the personal preferences of the smallholder.
- Encouraging the use of live fences to delineate coffee farms, using species that provide a food source for bird species, including *Inga* sp. and *Conostegia* sp.

Recommendations for encouraging an increase in shade in coffee farms in the two communities included:

- Pilot farms in the communities with 40% or more shade over the coffee.
- Arranging group trips from the community to successful shade coffee farms.

- A tree nursery with the desired timber species to distribute free shade tree saplings.
- Workshops on shade and coffee, tree species that can be incorporated with coffee with additional uses, and management methods including a reduction in pesticide use and the encouragement of organic fertilizer.
- Establishment of a shade coffee cooperative in the community.
- Pursuing links with Coopeagri to process and package shade coffee from the community separately before export.
- Certification of coffee in the region either under one of the existing shade coffee labels, or as 'sustainably grown' coffee that is working towards this certification.
- Increasing the awareness of consumers to shade coffee in Canada and elsewhere.

Although structurally diverse agroforestry systems could never replace the value of having sections of untouched forest, they ease the transition between remnant forest and heavy land-use regions, provide connecting links for faunal dispersal, and provide additional foraging and breeding niches. Most importantly they ease the pressure off of existing forest patches if all socio-economic needs can be met with the farm itself. The dispersal of shade coffee practices in the communities of Santa Elena and Quizarrá could provide the method to increase suitable habitat between the two protected areas, thereby providing a link between Los Cusingos Neotropical Bird Sanctuary and Las Nubes Biological Reserve, while simultaneously having a positive effect on the livelihoods of community members.

TABLE 9: Bird species observed on point counts and their abundance in six coffee farms differing in the main tree species in the canopy in the communities of Quizarrá and Santa Elena. Wet season: June and July 1999;dry season: January and February 2000. (P=Poró, B=Banana, E=Eucalyptus, T=Amarillón).

			WET SEASON						DRY SEASON					
SCIENTIFIC NAME	**ENGLISH NAME**	**SPANISH NAME**	**P1**	**P2**	**B1**	**B2**	**E**	**T**	**P1**	**P2**	**B1**	**B2**	**E**	**T**
Falconiformes: Accipitidrae														
Elanoides forficatus	American Swallow-tailed Kite	Tijerilla	0	0	0	0	0.097	0.044	0	0	0	0	0	0
Buteo magnirostris	Roadside Hawk	Gavílan Chapulinero	0	0	0	0	0.013	0.006	0	0	0	0	0	0.004
Columbiformes: Columbidae														
Columba speciosa	Scaled Pigeon	Paloma Morada	0	0	0	0	0	0	0	0	0	0	0	0.004
Columbina talpacoti	Ruddy-Ground Dove	Tortolita	0	0	0	0.071	0	0	0	0	0	0	0	0.004
Leptotila verreauxi	White-tipped Dove	Coliblanca	0.074	0.032	0.077	0	0	0.017	0.02	0	0.068	0.011	0.019	0.007
Psitaciformes: Psitacidae														
Brotogeris jugularis	Orange-chinned Parakeet	Perico	0	0	0	0	0	0.011	0	0	0	0	0	0
Pionus senilis	White-crowned Parrot	Chucuyo	0	0	0	0	0.003	0	0	0	0	0	0.006	0
Cuculiformes: Cuculidae														
Piaya cayana	Squirrel Cuckoo	Bobo Chiso	0	0	0	0	0	0	0	0	0	0	0	0.033
Apodiformes: Trochilidae														
Amazilia decora	Beryl-crowned Hummingbird	Amazilia Corona de Berilo	0	0	0	0	0	0	0	0	0	0.011	0	0.007
Amazilia edward	Snowy-bellied Hummingbird	Amazilia Vientriblanca	0.029	0	0	0	0.189	0.006	0	0.022	0	0	0.107	0.022
Amazilia tzacatl	Rufous-tailed Hummingbird	Amazilia Rabirrufa	0.044	0	0.123	0.214	0.197	0.011	0.061	0.133	0.161	0.25	0.348	0.04
Colibri delphinae	Brown Violet-Ear	Colibrí Orejiviolácedo	0	0	0	0	0.005	0	0	0	0	0	0	0
Chlorostilbon canivetii	Fork-tailed Emerald	Esmeralda Rabihorcada	0	0	0	0	0	0	0	0	0	0.011	0	0
Florisuga mellivora	White-necked Jacobin	Jacobino Nuquiblanco	0	0	0	0	0.003	0	0	0	0	0	0	0
Heliomaster longirostris	Long-billed Starthroat	Colibrí Piquilargo	0	0	0.031	0	0	0	0	0	0.008	0	0	0.004
Hylocharis eliciae	Blue-throated Goldentail	Colibri Colidorado	0	0	0	0	0	0	0	0	0	0	0.002	0.029
Phaeochroa curierii	Scaly-breasted Hummingbird	Colibrí Pechiescamado	0	0	0	0	0	0	0	0	0	0	0.002	0.007
Phaethornis guy	Green Hermit	Ermitaño Verde	0	0	0	0	0	0.011	0	0	0	0	0	0
Hummingbird sp.			0.015	0	0	0	0.013	0.017	0.01	0	0	0	0.016	0.007
Trogoniformes: Trogonidae														
Trogon collaris	Collared Trogon	Trogon Collarejo	0	0	0	0	0.003	0	0	0	0	0	0	0
Piciformes: Ramphastidae														
Pteroglossus frantzii	Fiery-billed Aracari	Cusingo	0	0	0	0	0	0.006	0	0	0	0	0	0
Picidae														
Melanerpes rubricapillus	Red-crowned Woodpecker	Carpintero nuquirrojo	0	0	0.015	0	0	0.028	0.01	0	0	0	0	0.048
Picumnus olivaceus	Olivaceous Piculet	Telegrafista	0	0	0	0	0	0	0	0	0	0	0	0.004

			WET SEASON						DRY SEASON					
SCIENTIFIC NAME	**ENGLISH NAME**	**SPANISH NAME**	**P1**	**P2**	**B1**	**B2**	**E**	**T**	**P1**	**P2**	**B1**	**B2**	**E**	**T**
Passeriformes:														
Dendocolaptidae														
Lepidocolaptes souleyetii	Streaked-headed Woodcreeper	Trepador	0	0	0	0	0	0.017	0	0	0	0	0	0.007
Formicariidae														
Thamnophilus bridgesi	Black Hooded Antshrike	Batará Negruzco	0	0	0	0	0	0.017	0	0	0	0	0	0
Thamnophilus doliatus	Barred Antshrike	Batará Barreteado	0	0	0.015	0	0	0	0	0	0	0	0	0
Tityridae														
Pachyramphus polychopterus	White-winged Becard	Cabezón Aliblanco	0	0	0	0	0	0	0	0	0	0	0	0.004
Tityra semifasciata	Masked Tityra	Pájaro Chancho	0	0	0	0	0.005	0	0	0	0	0	0	0.022
Pipridae														
Manacus aurantiacus	Orange-collared Manakin	Hombrecillo	0	0.016	0	0	0	0	0	0	0	0	0	0
Pipra coronata	Blue-crowned Manakin	Saltarín Coroniceleste	0	0.032	0	0	0	0	0	0	0	0	0.004	0
Tyrannidae														
Capsiempis flaveola	Yellow Tyrannulet	Mosquerito Amarillo	0.25	0.081	0	0	0	0	0.162	0	0	0.011	0	0.015
Elaenia chiriquensis	Lesser Elaenia	Elainia Sabanera	0.015	0	0	0	0	0	0.071	0	0	0	0.008	0
Elaenia flavogaster	Yellow-bellied Elaenia	Bobillo	0	0	0	0	0.003	0.011	0	0	0	0	0.01	0.011
Empidonax flaviventris	Yellow-bellied Flycatcher	MosqueritoVientriamarillo	0	0	0	0	0	0	0	0	0	0	0	0.004
Legatus leucophaius	Piratic Flycatcher	Mosquero Pirata	0	0	0	0	0	0	0	0	0	0	0	0.026
Megarhynchus pitangua	Boat-billed Flycatcher	Mosquerón Picudo	0	0	0.015	0	0.01	0.017	0	0	0	0.022	0.014	0.026
Myiarchus crinitus	Great Crested Flycatcher	Copetón Viajero	0	0	0	0	0	0	0	0	0	0	0.002	0
Myiarchus tuberculifer	Dusky-capped Flycatcher	Copetón Crestioscuro	0	0	0	0	0.005	0.011	0	0	0	0	0.006	0.004
Myiodynastes maculatus	Streaked Flycatcher	Mosquero listado	0	0	0	0	0	0.05	0	0	0	0	0	0
Myiozetetes similes	Social Flycatcher	Pecho amarillo	0	0	0.031	0	0.003	0.028	0	0.044	0.008	0	0	0.081
Pitangus sulphuratus	Great Kiskadee	Cristofué	0	0	0	0	0	0	0	0.022	0	0	0	0
Terenotriccus erythrurus	Ruddy-tailed Flycatcher	Mosquerito Colirrufo	0	0	0	0	0	0	0	0	0	0	0	0.004
Todirostrum cinereum	Common Tody Flycatcher	Espatulilla Común	0.015	0.016	0.015	0	0.008	0.006	0	0	0	0	0	0.018
Todirostrum sylvia	Slate-headed Tody Flycatcher	Espatulilla Cabecigrís	0	0.016	0	0	0	0.011	0	0	0	0	0	0.007
Tyrannulus elatus	Yellow-crowned Tyrannulet	Mosqerito Coroniamarillo	0	0	0	0	0	0.006	0	0	0	0	0	0
Tyrannus melancholicus	Tropical Kingbird	Pecho amarillo	0	0	0	0	0.013	0.017	0	0	0	0	0.002	0.004
Zimmerius vilissimus	Mistletoe Tyrannulet	Mosquerito Cejigris	0	0	0	0	0.003	0	0	0	0	0	0	0
Flycatcher sp.			0	0	0	0	0.003	0.017	0	0	0	0	0	0
Corvidae														
Cyanocorax morio	Brown Jay	Piapia	0	0	0	0	0	0	0	0	0	0	0.012	0

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	WET SEASON P1	WET SEASON P2	WET SEASON B1	WET SEASON B2	WET SEASON E	WET SEASON T	DRY SEASON P1	DRY SEASON P2	DRY SEASON B1	DRY SEASON B2	DRY SEASON E	DRY SEASON T
Troglodytidae														
Thryothorus modestus	Plain Wren	Chinchirigüí	0	0	0	0.036	0.003	0	0	0	0	0	0	0
Thryothorus rufalbus	Rufous-and-white Wren	Soterrey Rufo y Blanco	0	0	0	0	0	0	0	0	0	0.011	0	0
Thryothorus rutilus	Rufous-breasted Wren	Soterrey carimoteado	0.059	0.032	0	0	0.021	0.011	0.04	0	0.017	0	0	0
Troglodytes aedon	House Wren	Soterrey	0.103	0.016	0.062	0.036	0.003	0.05	0.081	0.067	0.034	0.033	0.004	0.004
Turdidae														
Catharus aurantirostris	Orange-billed Nightingale-Thrush	Jilguerillo	0.029	0.032	0	0.071	0.003	0.011	0.01	0.022	0	0	0	0
Turdus assimilis	White-throated Robin	Yigüirro Collarejo	0	0	0	0	0.003	0	0	0	0	0	0	0
Turdus grayi	Clay-colored Robin	Yigüirro	0	0.016	0	0	0.008	0.099	0.01	0	0.102	0.065	0.002	0.022
Sylviidae														
Polioptila plumbea	Tropical Gnatcatcher	Perlita Tropical	0	0	0	0	0.029	0.022	0.081	0	0	0.065	0.023	0.04
Vireonidae														
Hylophilus decurtatus	Lesser Greenlet	Verdillo Menudo	0	0	0	0	0	0	0	0	0	0	0.002	0
Vireo flavifrons	Yellow-throated Vireo	Vireo Pechiamarillo	0	0	0	0	0	0	0	0	0	0	0.008	0.011
Vireo flavoviridis	Yellow-green Vireo	Cazadora	0	0	0	0	0.003	0.017	0	0	0	0	0	0
Vireo philadelphicus	Philadelphia Vireo	Vireo Amarillento	0	0	0	0	0	0	0	0	0	0	0.004	0
Coerebdae														
Coereba flaveola	Bananaquit	Pinchaflor	0.029	0.065	0.077	0.179	0.003	0.022	0.03	0.089	0.042	0.087	0.002	0.037
Parulidae														
Basileuterus rufifrons	Rufous-capped Warbler	Reinita Cabecicastaña	0.015	0.097	0	0	0.024	0.006	0.071	0	0	0	0.004	0
Dendroica pensylvanica	Chestnut-sided Warbler	Reinita de Costillas Castañas	0	0	0	0	0	0	0.071	0	0	0	0.008	0.092
Dendroica petechia	Yellow Warbler	Reinita Amarilla	0	0	0	0	0	0	0.03	0	0.017	0	0.002	0.007
Mniotilta varia	Black-and-white Warbler	Reinita Trepadora	0	0	0	0	0	0	0	0	0	0	0	0.018
Oporornis philadelphia	Mourning Warbler	Reinita Enlutada	0	0	0	0	0	0	0.03	0	0	0	0	0.004
Seiurus noveboracensis	Northern Waterthrush	Tordo de Agua	0	0	0	0	0	0	0	0	0	0	0	0.004
Vermivora perigrina	Tennessee Warbler	Reinita Verdilla	0	0	0	0	0	0	0	0.022	0.025	0.033	0.27	0.044
Wilsonia pusilla	Wilson's Warbler	Reinita Gorrinegra	0	0	0	0	0	0	0	0	0	0	0.002	0.004
Icteridae														
Icterus g. galbula	Baltimore Oriole	Bolsero Norteño	0	0	0	0	0	0	0	0	0.034	0	0.008	0.007
Icterus spurius	Orchard Oriole	Bolsero Castaño	0	0	0	0	0	0	0	0	0	0	0.002	0

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	WET SEASON P1	P2	B1	B2	E	T	DRY SEASON P1	P2	B1	B2	E	T
Thraupidae														
Chlorophanes spiza	Green Honeycreeper	Mielero Verde	0	0	0	0	0.005	0	0	0	0	0	0	0.004
Cyanerpes cyaneus	Red-legged Honeycreeper	Trepador	0	0	0	0	0.016	0.011	0	0	0.017	0.022	0.006	0.04
Dacnis cayana	Blue Dacnis	Mielero Azulejo	0	0	0	0	0.105	0.017	0	0	0	0	0	0
Dacnis venusta	Scarlet-thighed Dacnis	Mielero Celeste y Negro	0	0	0	0	0.003	0	0	0	0	0	0	0
Eucometis penicillata	Grey-headed Tanager	Tangara Cebecigrís	0	0	0	0	0	0.006	0	0	0	0	0	0
Ramphocelus passerinii	Scarlet-rumped Tanager	Sargento	0.132	0.435	0.185	0.321	0.058	0.188	0.111	0.356	0.212	0.12	0	0.081
Tangara guttata	Speckled Tanager	Zebra	0	0	0	0	0.008	0	0	0	0	0	0	0
Tangara gyrola	Bay-headed Tanager	Tangara Cabecicataña	0	0	0	0	0.003	0	0	0	0	0	0	0
Tangara larvata	Golden-hooded Tanager	Siete Colores	0	0.032	0.031	0	0.029	0.006	0	0	0	0.033	0.035	0.048
Thraupis palmarum	Palm Tanager	Tangara Palmera	0	0	0	0	0.005	0	0	0	0.008	0	0.004	0
Thraupus episcopus	Blue-Gray Tanager	Viuda	0.059	0	0.262	0.071	0.087	0.072	0.101	0.089	0.229	0.217	0.049	0.07
Emberizidae														
Arremon aurantiirostris	Orange-billed Sparrow	Pinzón Piquinaranja	0	0	0	0	0	0	0	0.022	0	0	0	0
Arremonops conirostris	Black-striped Sparrow	Pinzón Cabecilistado	0.015	0.016	0	0	0.003	0	0	0	0	0	0	0
Saltator albicollis	Streaked Saltator	Saltator Listado	0	0	0	0	0.003	0	0	0	0	0	0	0
Saltator maximus	Buff-throated Saltator	Sinsonte Verde	0	0.032	0.015	0	0.003	0.039	0	0.22	0.017	0	0.002	0.007
Sporophila aurita	Variable Seedeater	Espiguero Variable	0.074	0.032	0.015	0	0	0.072	0	0.022	0	0	0	0.004
Tiaris olivacea	Yellow-faced Grassquit	Gallito	0.015	0	0.031	0	0.003	0	0	0	0	0	0.002	0

Appendix A: Question set for informal interviews of small farmers in Santa Elena and Quizarrá, Costa Rica.

1) General:

What is the size of the farm? How many *manzanas* are in coffee? How many people live here? Do you have another occupation outside of this farm? When did you buy this farm or when did you come to live here?

2) Vegetation in coffee farm:

What kinds of trees and plants do you have growing with your coffee? Do you leave any trees to grow in your farm naturally?

3) Management of the farm

Can you describe a typical year of coffee production in your farm? (What is your system of cutting the branches of the coffee plants and/or trees? What is your system of fertilization? What is your system to manage pests and weeds? What is the average harvest for coffee in your farm? Who do you sell your coffee to and why?

Do you follow any recommendations on how to manage your farm? Whose recommendations do you follow?

Do you know of ICAFE? What do you think of their recommendations?

Do you have problems with pests in your coffee? What kinds?

Have you seen any wild mammals or wild birds in your farm?

4) Coffee and shade

Have you ever had other types of trees or more trees over the coffee in your farm? How did the harvest and health of the coffee compare between that case and your farm today?

What do you think of the use of many trees over coffee?

Have you seen other coffee farms with many trees over their coffee?

Have you ever thought of planting trees, whose products you could use or sell? What kinds of trees would they be?

Are you interested in planting more trees with your coffee?

Appendix B: Individuals and organizations interviewed in Costa Rica during February to June, 1999 and January to March, 2000.

Los Cusingos
Dr. Alexander Skutch, Tropical Ornithologist
Edén Chincilla Sánchez, Administrator

Tropical Science Center
Dr. Julio C. Calvo, Executive Director
M.Sc. Rafael Bolaño
Ing. Vicente Watson
+ various other key researchers;

MINAE
Lic. Martha Jimenez C., legal assistant
+ various other officials

ICAFE
Ing. Agr. Carlos Fonseca C., Coordinator ICAFE-San Isidro

CATIE
Numerous researchers from CATIE and abroad at the IUFRO conference entitled 'Multistrata Agroforestry Systems With Perennial Crops' from February 23-27, 1999, held at CATIE

COOPEAGRI
Jorge Conejo, Administration at the head office in San Isidro
Ing. Gilbert Ramírez Alfaro, Industrial Admnistrative Director of the sugar mill
Ing. Guillermo Quirós G., Manager of the coffee *beneficio* during 1999
Ing. Carlos Calderón, Manager of the coffee *beneficio* during 2000
Ing. Agr. Mariano Ruiz Albarca, Manager of agricultural operations.

Rainforest Alliance
Chris Wille, Director of the ECO-O.K. Certification Program.
Tom Divney, Program Coordinator for the Forest Agriculture Certification

Appendix C: Guild allocations for each species seen on point counts in the communties of Quizarra and Santa Elena, Costa Rica.

SCIENTIFIC NAME	COMMON ENGLISH NAME	SPANISH NAME	STATUS	FD	Diet	Habitat	Level
Falconiformes: Accipitidrae							
Elanoides forficatus	Swallow-tailed Kite	Tijerilla	M	2	I/C	S-FE	H
Buteo magnirostris	Roadside Hawk	Gavílan Chapulinero	R	3	C	OS-FE	M
Columbiformes: Columbidae							
Columba speciosa	Scaled Pigeon	Paloma Morada	R	2	F	FI-FE	H
Columbina talpacoti	Ruddy-Ground Dove	Tortolita	R	3	D	NF	G
Leptotila verreauxi	White-tipped Dove	Coliblanca	R	2-3	D	S	G
Psitaciformes: Psitacidae							
Brotogeris jugularis	Orange-chinned Parakeet	Perico	R	3	F	OS-S	M-H
Pionus senilis	White-crowned Parrot	Chucuyo	R	2	F	FE	H
Cuculiformes: Cuculidae							
Piaya cayana	Squirrel Cuckoo	Bobo Chiso	R	2-3	I	FE-OS	H
Apodiformes: Trochilidae							
Amazilia decora	Beryl-crowned Hummingbird	Amazilia Corona de Berilo	R	2	N	S	M
Amazilia edward	Snowy-bellied Hummingbird	colibrí	R	3	N	OS-S	M
Amazilia tzacatl	Rufous-tailed Hummingbird	colibrí	R	3	N	OS-S	M
Colibri delphinae	Brown Violet-Ear	Colibrí Orejiviolácedo	R	1-2	N	FI-S	H
Chlorostilbon canivetii	Fork-tailed Emerald	Esmeralda Rabihorcada	R	3	N	OS	L
Florisuga mellivora	White-necked Jacobin	Jacobino Nuquiblanco	R	2	N	S	H
Heliomaster longirostris	Long-billed Starthroat	Colibrí Piquilargo	R	2-3	N	FE-S	H
Hylocharis eliciae	Blue-throated Goldentail	Colibri Colidorado	R	2	N	S	M
Phaeochroa cuvierii	Scaly-breasted Hummingbird	colibrí	R	2-3	N	FE	M-H
Phaethornis guy	Green Hermit	Ermitaño Verde	R	2	N	FE	L-M
Trogoniformes: Trogonidae							
Trogon collaris	Collared Trogon	Trogon Collarejo	R	2	I	FI-S	M
Piciformes: Ramphastidae							
Pteroglossus frantzii	Fiery-billed Aracari	Cusingo	R	2	O	FI-S	H

SCIENTIFIC NAME	COMMON ENGLISH NAME	SPANISH NAME	STATUS	FD	Diet	Habitat	Level
Picidae							
Melanerpes rubricapillus	Red-crowned Woodpecker	Carpintero nuquirrojo	R	2-3	I	FE	T
Picumnus olivaceus	Olivaceous Piculet	Telegrafista	R	2-3	I	FE	L-M
Passeriformes:							
Dendocolaptidae							
Lepidocolaptes souleyetii	Streaked-headed Woodcreeper	Trepador	R	2-3	I	S	T
Formicariidae							
Thamnophilus bridgesi	Black Hooded Antshrike	Batará Negruzco	R	2	I	FE	L-M
Thamnophilus doliatus	Barred Antshrike	Batará Barreteado	R	2-3	I	OS	L
Tityridae							
Pachyramphus polychopterus	White-winged Becard	Cabezón Aliblanco	R	1	O	FI	H
Tityra semifasciata	Masked Tityra	Pájaro Chancho	R	1-2	O	FE-FI	H
Pipridae							
Manacus aurantiacus	Orange-collared Manakin	Hombrecillo	R	2	O	FE	L
Pipra Coronata	Blue-crowned Manakin	Saltarín Coroniceleste	R	1	O	FI	L
Tyrannidae							
Camptostoma obsoletum	Southern Beardless Tyrannulet	Mosquerito Silbador	R	2-3	O	OS-S	M
Capsiempis flaveola	Yellow Tyrannulet	Mosquerito Amarillo	R	3	O	S	L
Elaenia chiriquensis	Lesser Elaenia	Elainia Sabanera	M	3	O	OS	L
Elaenia flavogaster	Yellow-bellied Elaenia	Bobillo	R	3	O	OS	M
Empidonax flaviventris	Yellow-bellied Flycatcher	MosqueritoVientriamarillo	NM	2-3	I	S-FI	L
Legatus leucophaius	Piratic Flycatcher	Mosquero Pirata	M	3	O	OS-S	H
Megarhynchus pitangua	Boat-billed Flycatcher	Mosquerón Picudo	R	2-3	O	FE	H
Myiarchus crinitus	Great Crested Flycatcher	Copetón Viajero	NM	2	O	FI-S	H
Myiarchus tuberculifer	Dusky-capped Flycatcher	Copetón Crestioscuro	R	2-3	O	FE	H
Myiodynastes maculatus	Streaked Flycatcher	Mosquero listado	R-M	2	O	FE	H
Myiozetetes similes	Social Flycatcher	Pecho amarillo	R	3	O	OS	H
Pitangus sulphuratus	Great Kiskadee	Cristofué	R	3	O	NF	H
Terenotriccus erythrurus	Ruddy-tailed Flycatcher	Mosquerito Colirrufo	R	1-2	I	FI-S	L-M
Todirostrum cinereum	Common Tody Flycatcher	Espatulilla Común	R	2-3	I	OS-S	M-H
Todirostrum sylvia	Slate-headed Tody Flycatcher	Espatulilla Cabecigrís	R	3	I	S	L
Tyrannulus elatus	Yellow-crowned Tyrannulet	Mosqerito Coroniamarillo	R	3	F-I	OS	H
Tyrannus melancholicus	Tropical Kingbird	Pecho amarillo	R	3	O	NF-OS	H
Zimmerius vilissimus	Mistletoe Tyrannulet	Mosquerito Cejigris	R	2	O	FI-S	H

SCIENTIFIC NAME	COMMON ENGLISH NAME	SPANISH NAME	STATUS	FD	Diet	Habitat	Level
Corvidae							
Cyanocorax morio	Brown Jay	Piapia	R	2-3	O	OS-FE	L-H
Troglodytidae							
Thryothorus modestus	Plain Wren	Chinchirigüí	R	3	I	OS	L
Thryothorus rufalbus	Rufous-and-white Wren	Soterrey Rufo y Blanco	R	1-2	I	OS	G-L
Thryothorus rutilus	Rufous-Breasted Wren	Soterrey carimoteado	R	3	I	FE	M
Troglodytes aedon	House Wren	Soterrey	R	3	I	NF	L
Turdidae							
Catharus aurantirostris	Orange-billed Nightingale-Thrush	Jilguerillo	R	2-3	O	FE	G
Turdus assimilis	White-throated Robin	Yigüirro Collarejo	R	1	O	FI-S	G-L
Turdus grayi	Clay-colored Robin	Yigüirro	R	3	O	OS-S	G
Sylviidae							
Polioptila plumbea	Tropical Gnatcatcher	Perlita Tropical	R	2	I	S	L-H
Vireonidae							
Hylophilus decurtatus	Lesser Greenlet	Verdillo Menudo	R	2	O	FI-FE	H
Vireo flavifrons	Yellow-throated Vireo	Vireo Pechiamarillo	NM	2	I	FI-FE	H
Vireo flavoviridis	Yellow-green Vireo	Cazadora	M	3	O	S-OS	H
Vireo philadelphicus	Philadelphia Vireo	Vireo Amarillento	NM	2	O	FE	M-H
Coerebidae							
Coereba flaveola	Bananaquit	Pinchaflor	R	2-3	I	FE-S	M-H
Parulidae							
Basileuterus rufifrons	Rufous-crowned Warbler	Reinita Cabecicastaña	R	2	I	FE-S	L
Dendroica pensylvanica	Chestnut-sided Warbler	Reinita de Costillas Castañas	NM	2-3	I	S	M-H
Dendroica petechia	Yellow Warbler	Reinita Amarilla	NM	3	I	OS-S	M
Mniotilta varia	Black-and-white Warbler	Reinita Trepadora	NM	2	I	FI-S	T
Oporornis philadelphia	Mourning Warbler	Reinita Enlutada	NM	2-3	I	OS-S	L
Seiurus noveboracensis	Northern Waterthrush	Tordo de Agua	NM	3	I	FI	G
Vermivora perigrina	Tennessee Warbler	Reinita Verdilla	NM	2-3	O	S	M-H
Wilsonia pusilla	Wilson's Warbler	Reinita Gorrinegra	NM	2-3	I	FE	L-H
Icteridae							
Icterus g. galbula	Baltimore Oriole	Bolsero Norteño	NM	2-3	N(F&I)	S	L-H
Icterus spurius	Orchard Oriole	Bolsero Castaño	NM	3	N(F&I)	OS-S	M

SCIENTIFIC NAME	COMMON ENGLISH NAME	SPANISH NAME	STATUS	FD	Diet	Habitat	Level
Thraupidae							
Chlorophanes spiza	Green Honeycreeper	Mielero Verde	R	2	F	FI-S	H-L
Cyanerpes cyaneus	Red-legged Honeycreeper	Trepador	R	2	O	FE	H-L
Dacnis cayana	Blue Dacnis	Mielero Azulejo	R	2	F	S	H
Dacnis venusta	Scarlet-thighed Dacnis	Mielero Celeste y Negro	R	2	O	FE	H
Eucometis penicillata	Grey-headed Tanager	Tangara Cebecigrís	R	1-2	I	FI-S	L
Ramphocelus passerinii	Scarlet-rumped Tanager	Sargento	R	3	O	OS	L
Tangara guttata	Speckled Tanager	Zebra	R	1-2	F	FI-S	H
Tangara gyrola	Bay-headed Tanager	Tangara Cabecicataña	R	2	F	FI	M-H
Tangara larvata	Golden-hooded Tanager	Siete Colores	R	2-3	O	FI-S	H
Thraupis palmarum	Palm Tanager	Tangara Palmera	R	3	O	OS	H
Thraupus episcopus	Blue-Gray Tanager	Viuda	R	3	O	OS-S	M-H
Emberizidae							
Arremon aurantiirostris	Orange-billed Sparrow	Pinzón Piquinaranja	R	1-2	O	FI-S	L-G
Arremonops conirostris	Black-striped Sparrow	Pinzón Cabecilistado	R	2-3	O	OS	L
Saltator albicollis	Striped Saltator	Saltator Listado	R	3	O	OS-S	L
Saltator maximus	Buff-throated Saltator	Sinsonte Verde	R	3	O	OS-S	M
Sporophila aurita	Variable Seedeater	Espiguero Variable	R	3	G	OS	L
Tiaris olivacea	Yellow-faced Grassquit	Gallito	R	3	G	NF	G

Explanation of codes (see text for further descriptions):

STATUS:
R = breeding resident
NM = nearctic breeding ~~migrant~~
M = tropical migrant

FOREST DEPENDENCY (FD):
1 = requires >50% forest
2 = survives in patchy forest (<50% intact forest)
3 = does not require forest

DIET GUILDS:
C = meat eater
G = granivore
F = frugivore
I = insectivore
N = nectarivore
O = omnivore

HABITAT GUILDS:
FE = forest edge
FI = forest interior
NF = nonforest
OS = open scrub
S = secondary forest

FORAGING LEVEL GUILDS (Level)
G= ground
L= low heights
M= medium heights
H= canopy
T= trunk

Appendix D: Avian species observed in six coffee farms sampled in the southern Pacific region of Costa Rica

Farm P1 (Poro)

Wet Season	freq	Dry Season	freq
Capsiempis flaveola	0.25	*Capsiempis flaveola*	0.162
Ramphocelus passerinii	0.132	*Ramphocelus passerinii*	0.111
Troglodytes aedon	0.103	*Thraupus episcopus*	0.101
Sporophila aurita	0.074	*Troglodytes aedon*	0.081
Leptotila verreauxi	0.074	*Polioptila plumbea*	0.081
Thryothorus rutilus	0.059	*Elaenia chiriquensis*	0.071
Thraupus episcopus	0.059	*Basileuterus rufifrons*	0.071
Amazilia tzacatl	0.044	*Dendroica pensylvanica* **	0.071
Coereba flaveola	0.029	*Amazilia tzacatl*	0.061
Catharus aurantirostris	0.029	*Thryothorus rutilus*	0.04
Amazilia edward	0.029	*Coereba flaveola*	0.03
Todirostrum cinereum	0.015	*Dendroica petechia***	0.03
Tiaris olivacea	0.015	*Oporornis philadelphia***	0.03
Elaenia chiriquensis	0.015	*Leptotila verreauxi*	0.02
Basileuterus rufifrons	0.015	*Melanerpes rubricapillus*	0.01
Arremonops conirostris	0.015	*Catharus aurantirostris*	0.01
Trochilidae sp.	0.015	*Turdus grayi*	0.01
*Polioptila plumbea**		Trochilidae sp.	0.01
*Buteo magnirostris**			

Farm P2 (Poro)

Wet Season	freq	Dry Season	freq
Ramphocelus passerinii	0.435	*Ramphocelus passerinii*	0.356
Basileuterus rufifrons	0.097	*Saltator maximus*	0.22
Capsiempis flaveola	0.081	*Amazilia tzacatl*	0.133
Coereba flaveola	0.065	*Coereba flaveola*	0.089
Leptotila verreauxi	0.032	*Thraupus episcopus*	0.089
Pipra coronata	0.032	*Troglodytes aedon*	0.067
Thryothorus rutilus	0.032	*Myiozetetes similes*	0.044
Catharus aurantirostris	0.032	*Amazilia edward*	0.022
Tangara larvata	0.032	*Pitangus sulphuratus*	0.022
Saltator maximus	0.032	*Catharus aurantirostris*	0.022
Sporophila aurita	0.032	*Vermivora perigrina***	0.022
Manacus aurantiacus	0.016	*Arremon aurantiirostris*	0.022
Todirostrum cinereum	0.016	*Sporophila aurita*	0.022
Todirostrum sylvia	0.016		
Troglodytes aedon	0.016		
Turdus grayi	0.016		
Arremonops conirostris	0.016		
*Pionus senilis**			

* species observed in transit between point counts (offcounts)
** Nearctic-breeding migrant species

Farm B1 (Banana)

Wet season	freq	Dry Season	freq
Thraupus episcopus	0.262	*Thraupus episcopus*	0.229
Ramphocelus passerinii	0.185	*Ramphocelus passerinii*	0.212
Amazilia tzacatl	0.123	*Amazilia tzacatl*	0.161
Leptotila verreauxi	0.077	*Turdus grayi*	0.102
Coereba flaveola	0.077	*Leptotila verreauxi*	0.068
Troglodytes aedon	0.062	*Coereba flaveola*	0.042
Heliomaster longirostris	0.031	*Troglodytes aedon*	0.034
Myiozetetes similes	0.031	*Icterus g. galbula***	0.034
Tangara larvata	0.031	*Vermivora perigrina***	0.025
Tiaris olivacea	0.031	*Thryothorus rutilus*	0.017
Melanerpes rubricapillus	0.015	*Dendroica petechia***	0.017
Thamnophilus doliatus	0.015	*Cyanerpes cyaneus*	0.017
Megarhynchus pitangua	0.015	*Saltator maximus*	0.017
Todirostrum cinereum	0.015	*Heliomaster longirostris*	0.008
Saltator maximus	0.015	*Myiozetetes similes*	0.008
Sporophila aurita	0.015	*Thraupis palmarum*	0.008

Farm B2 (Banana)

Wet Season	freq	Dry Season	freq
Ramphocelus passerinii	0.321	*Amazilia tzacatl*	0.25
Amazilia tzacatl	0.214	*Thraupus episcopus*	0.217
Coereba flaveola	0.179	*Ramphocelus passerinii*	0.12
Columbina talpacoti	0.071	*Coereba flaveola*	0.087
Catharus aurantirostris	0.071	*Turdus grayi*	0.065
Thraupus episcopus	0.071	*Polioptila plumbea*	0.065
Thryothorus modestus	0.036	*Troglodytes aedon*	0.033
Troglodytes aedon	0.036	*Vermivora perigrina***	0.033
		Tangara larvata	0.033
		Megarhynchus pitangua	0.022
		Cyanerpes cyaneus	0.022
		Leptotila verreauxi	0.011
		Amazilia decora	0.011
		Chlorostilbon canivetii	0.011
		Capsiempis flaveola	0.011
		Thryothorus rufalbus	0.011
		*Elanoides forficatus**	
		*Melanerpes rubricapillus**	

Farm E (Eucalyptus)

Wet Season	freq	Dry Season	freq
Amazilia tzacatl	0.19685	*Amazilia tzacatl*	0.34774
Amazilia edward	0.18898	*Vermivora perigrina***	0.26955
Dacnis cayana	0.10499	*Amazilia edward*	0.107
Elanoides forficatus	0.09711	*Thraupus episcopus*	0.04938
Thraupus episcopus	0.08661	*Tangara larvata*	0.03498
Ramphocelus passerinii	0.05774	*Polioptila plumbea*	0.02263
Polioptila plumbea	0.02887	*Leptotila verreauxi*	0.01852
Tangara larvata	0.02887	*Megarhynchus pitangua*	0.0144
Basileuterus rufifrons	0.02362	*Cyanocorax morio*	0.01235
Thryothorus rutilus	0.021	*Elaenia flavogaster*	0.01029
Cyanerpes cyaneus	0.01575	*Elaenia chiriquensis*	0.00823
Buteo magnirostris	0.01312	*Vireo flavifrons***	0.00823
Tyrannus melancholicus	0.01312	*Dendroica pensylvanica***	0.00823
Megarhynchus pitangua	0.0105	*Icterus g. galbula***	0.00823
Todirostrum cinereum	0.00787	*Pionus senilis*	0.00617
Turdus grayi	0.00787	*Myiarchus tuberculifer*	0.00617
Tangara guttata	0.00787	*Cyanerpes cyaneus*	0.00617
Colibri delphinae	0.00525	*Pipra coronata*	0.00412
Tityra semifasciata	0.00525	*Troglodytes aedon*	0.00412
Myiarchus tuberculifer	0.00525	*Vireo philadelphicus***	0.00412
Chlorophanes spiza	0.00525	*Basileuterus rufifrons*	0.00412
Thraupis palmarum	0.00525	*Thraupis palmarum*	0.00412
Pionus senilis	0.00262	*Hylocharis eliciae*	0.00206
Florisuga mellivora	0.00262	*Phaeochroa curierii*	0.00206
Trogon collaris	0.00262	*Myiarchus crinitus***	0.00206
Elaenia flavogaster	0.00262	*Tyrannus melancholicus*	0.00206
Myiozetetes similes	0.00262	*Turdus grayi*	0.00206
Zimmerius vilissimus	0.00262	*Hylophilus decurtatus*	0.00206
Thryothorus modestus	0.00262	*Coereba flaveola*	0.00206
Troglodytes aedon	0.00262	*Dendroica petechia***	0.00206
Catharus aurantirostris	0.00262	*Wilsonia pusilla***	0.00206
Turdus assimilis	0.00262	*Icterus spurius***	0.00206
Vireo flavoviridis	0.00262	*Saltator maximus*	0.00206
Coereba flaveola	0.00262	*Tiaris olivacea*	0.00206
Dacnis venusta	0.00262	Trochilidae sp.	0.01646
Tangara gyrola	0.00262	*Buteo magnirostri**	
Arremonops conirostris	0.00262	*Piaya cayana**	
Saltator albicollis	0.00262	*Aramides cajanea**	
Saltator maximus	0.00262		
Tiaris olivacea	0.00262		
Trochilidae sp.	0.01312		
Tyrannidae sp.	0.00262		
*Falco rufigularis**			

Farm T (Amarillon)

Wet Season	freq	Dry Season	freq
Ramphocelus passerinii	0.18785	*Dendroica pensylvanica***	0.09191
Turdus grayi	0.09945	*Myiozetetes similes*	0.08088
Thraupus episcopus	0.07182	*Ramphocelus passerinii*	0.08088
Sporophila aurita	0.07182	*Thraupus episcopus*	0.06985
Myiodynastes maculatus	0.04972	*Melanerpes rubricapillus*	0.04779
Troglodytes aedon	0.04972	*Tangara larvata*	0.04779
Elanoides forficatus	0.0442	*Vermivora perigrina***	0.04412
Saltator maximus	0.03867	*Amazilia tzacatl*	0.04044
Melanerpes rubricapillus	0.02762	*Polioptila plumbea*	0.04044
Myiozetetes similes	0.02762	*Cyanerpes cyaneus*	0.04044
Polioptila plumbea	0.0221	*Coereba flaveola*	0.03676
Coereba flaveola	0.0221	*Piaya cayana*	0.03309
Leptotila verreauxi	0.01657	*Hylocharis eliciae*	0.02941
Lepidocolaptes souleyetii	0.01657	*Legatus leucophaius*	0.02574
Thamnophilus bridgesi	0.01657	*Megarhynchus pitangua*	0.02574
Megarhynchus pitangua	0.01657	*Amazilia edward*	0.02206
Tyrannus melancholicus	0.01657	*Tityra semifasciata*	0.02206
Vireo flavoviridis	0.01657	*Turdus grayi*	0.02206
Dacnis cayana	0.01657	*Todirostrum cinereum*	0.01838
Brotogeris jugularis	0.01105	*Mniotilta varia***	0.01838
Amazilia tzacatl	0.01105	*Capsiempis flaveola*	0.01471
Phaethornis guy	0.01105	*Elaenia flavogaster*	0.01103
Elaenia flavogaster	0.01105	*Vireo flavifrons***	0.01103
Myiarchus tuberculifer	0.01105	*Leptotila verreauxi*	0.00735
Todirostrum sylvia	0.01105	*Amazilia decora*	0.00735
Thryothorus rutilus	0.01105	*Phaeochroa curierii*	0.00735
Catharus aurantirostris	0.01105	*Lepidocolaptes souleyetii*	0.00735
Cyanerpes cyaneus	0.01105	*Todirostrum sylvia*	0.00735
Buteo magnirostris	0.00552	*Dendroica petechia***	0.00735
Amazilia edward	0.00552	*Icterus g. galbula***	0.00735
Pteroglossus frantzii	0.00552	*Saltator maximus*	0.00735
Todirostrum cinereum	0.00552	*Buteo magnirostris*	0.00368
Tyrannulus elatus	0.00552	*Columba speciosa*	0.00368
Basileuterus rufifrons	0.00552	*Columbina talpacoti*	0.00368
Tangara larvata	0.00552	*Heliomaster longirostris*	0.00368
Trochilidae sp.	0.01657	*Picumnus olivaceus*	0.00368
Tyrannidae sp.	0.01657	*Pachyramphus albogriseus*	0.00368
*Piaya cayana**		*Empidonax flaviventris***	0.00368
		Myiarchus tuberculifer	0.00368
		Terenotriccus erythrurus	0.00368
		Tyrannus melancholicus	0.00368
		Troglodytes aedon	0.00368
		*Oporornis philadelphia***	0.00368
		*Seiurus noveboracensis***	0.00368
		*Wilsonia pusilla***	0.00368
		Chlorophanes spiza	0.00368
		Sporophila aurita	0.00368
		Hummingbird sp.	0.00735

Appendix E: Student t-test calculations and results comparing the Shannon diversity index (H) between the six sample coffee farms

Formulas:

$$H = Sp_i lnp_i$$

$$Var(H) = [Sp_i(lnp_i)^2 - (Sp_i lnp_i)^2] / N + (S-1)/ 2N^2$$

$$t = (H_1 - H_2) / (VarH_1 + VarH_2)^{1/2}$$

$$df = (VarH_1 + VarH_2)^2 / [(VarH_1)^2/N_1 + (VarH_2)^2/N_2]$$

where H = Shannon Diversity Index

p_i = proportion of species i

N = total number of individuals per farm

S = total number of species per farm

(source: Magurran, 1988)

Results:

Wet season:

	P1	P2	B1	B2	E	T
P1		t = 1.22 df = 117 0.1<P<0.15	t = 0.52 df = 133 P>0.25	t = 3.06 df = 68 P<0.0025*	t = -2.10 df = 110 0.01<P<0.02*	t = -5.16 df = 128 P<0.001*
P2	-		t = -0.79 df = 115 P> 0.25	t = 1.51 df = 84 0.01<P<0.05	t = -3.06 df = 82 P<.0025*	t = -5.49 df = 92 P<0.001*
B1	-	-		t = 2.61 df = 66 P<0.01*	t = -2.78 df = 107 P<0.001*	t = -5.85 df = 125 P<0.001*
B2	-	-	-		t = -5.48 df = 40 P<0.001*	t = -8.07 df = 46 P<0.001*
E	-	-	-	-		t = -4.5 df = 418 P<0.001*
T	-	-	-	-	-	

* significant at the P=0.05 level

Dry Season:

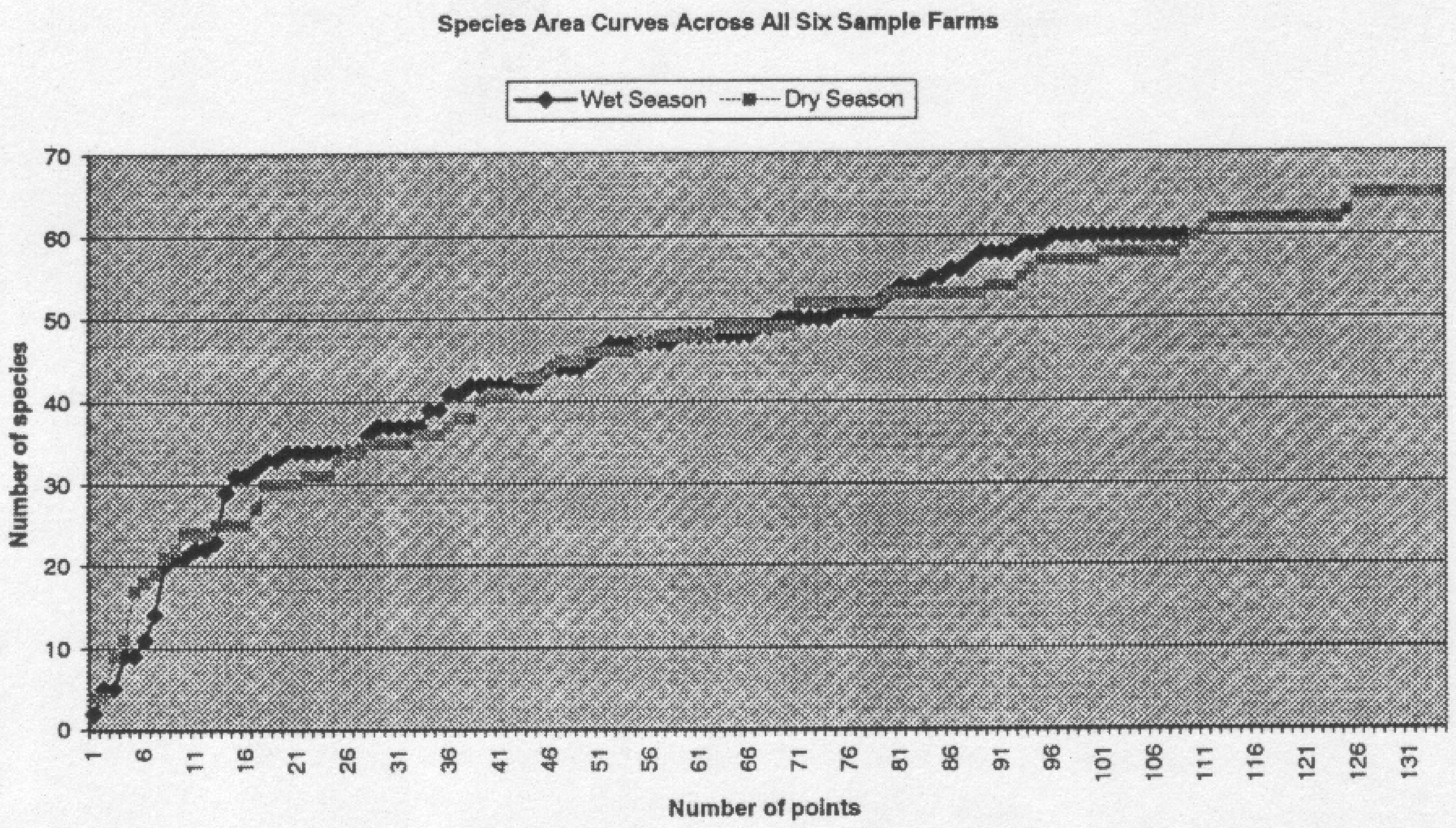
	P1	P2	B1	B2	E	T
P1		t = 3.13 df = 85 P<0.005*	t = 3.54 df = 212 0.01<P<0.02*	t = 3.0 df = 166 P<0.0025*	t = 5.08 df = 306 P<0.001*	t = -8.3 df = 234 P<0.001*
P2	-	-	t = 0 df = 109 P> 0.25	t = 0.204 df = 151 P>0.25	t = 0.37 df = 54 P>0.25	t = 2.3 df = 106 0.01<P<0.02*
B1	-	-		t = 0.06 df = 197 P>0.25	t = 0.81 df = 266 P>0.25	t = 10.9 df = 217 P<0.001*
B2	-	-	-		t = 0.99 df = 181 P>0.25	t = 9.64 df = 153 P<0.001*
E	-	-	-	-		t = 14.22 df = 745 P<0.001*
T	-	-	-	-	-	

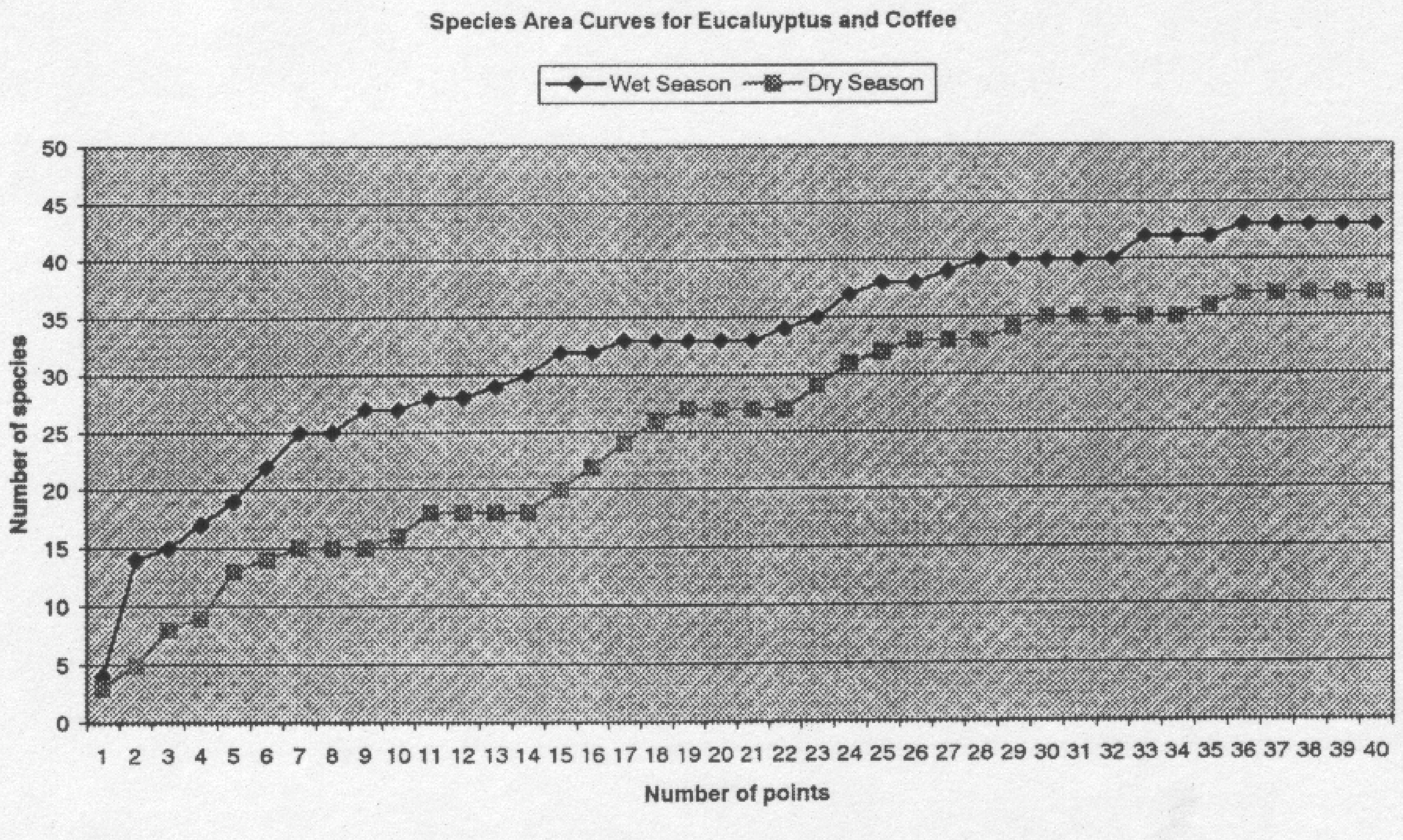
* significant at the P=0.05 level

Wet versus Dry season:

	P1	P2	B1	B2	E	T
t	-1.63	-0.41	0.54	-2.49	5.93	-2.37
df	112	90	134	58	859	353
P	0.05<P<0.1	P>0.25	P>0.25	0.005<P<0.01	P<0.001	0.005<P<0.01
Significant At P=0.05 level	no	no	no	yes	yes	yes

Appendix F: Species Area Curves





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