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Tropical bird assemblages in coffee agroforestry systems: exploring the relationships between landscape context, structural complexity and bird communities in the Turrialba – Jiménez Biological Corridor, Costa Rica

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Por

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To my parents with love always

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BIOGRAPHY

Elena Florian was born in Costa Rica in 1975. She obtained a Bachelor of Science from Tulane University in New Orleans, USA in 1998 with a major in Ecology, Evolution and Organismal Biology and a minor in Environmental Science. In 1997, she participated in a Semester Abroad Program at the University of São Paulo, Brasil where she took courses in tropical ecology. She has traveled quite extensively around Latin America. In 2004, she initiated her Masters studies in Tropical Agroforestry at the Tropical Agronomical Center for Research and Higher Education (CATIE) where she obtained her M.Sc. degree in 2005.

Her undergraduate research work was focused in phytoremediation particularly looking at the effects of lead contamination on the physiology of native species of plants found in wetland areas of Louisiana. She also worked as a research assistant for the Huertos Proyect at La Selva Biological Station in Sarapiquí, Costa Rica, developing field techniques to evaluate nutrient leaching and productivity of native tropical timber species. In addition, Elena has worked for the past five years for the Monteverde Institute, a non-profit organization based in the small rural community of Monteverde, Costa Rica. She developed the curriculum of several international courses in tropical ecology, conservation biology and sustainable development. She also worked as an instructor for the tropical biology and agroecology teaching modules.

She developed her Master's dissertation work with the support of the IGERT-Coffee Project developed by CATIE-University of Idaho and funded by National Science Foundation. The objective of this project was to study various issues related to the sustainability of coffee agroecosystems and the conservation of biodiversity within the Turrialba region. Her main research interests are tropical ecology, conservation biology, and sustainable production systems.

CONTENT

Florian Rivero, E.M. Tropical bird assemblages in coffee agroforestry systems: exploring the relationships between landscape context, structural complexity and bird communities in the Turrialba – Jiménez Biological Corridor, Costa Rica. Thesis Mag. Sc. CATIE, Turrialba, CR. 108 p.

Keywords: avifauna, biodiversity, connectivity, *Cordia alliodora*, *Erythrina poeppigiana*, forest, fragmentation, shade coffee

Abstract

Coffee agroforestry systems are reknown for their high species richness and complex vegetation structure and stand out as a promising tool for conserving biodiversity within agricultural landscapes. Shaded coffee plantations can attract a variety of birds, and have the potential to serve as refuges for birds, however this conservation potential is likely to depend on the structure of the coffee plantation as well as the surrounding landscape composition. The objective of this study was to explore the relationships between the structural complexity and the landscape context (surrounding forest cover) of coffee plantations and bird assemblages present in these systems within the Turrialba - Jiménez Biological Corridor.

To examine the effects of structural complexity and landscape context on bird communities, a total of 20 *Erythrina poeppigina* and 20 *Erythrina poeppigiana – Cordia alliodora* coffee plantations and five forests were selected and georeferenced. For each coffee plantation, two 50 m x 50 m plots and twenty five 10 m x 10 m quadrats were used to characterize the structure and floristic composition. The percent of surrounding forest cover was calculated at a distance radius of 500, 1000 and 1500 m from each coffee plantation. Point counts were used to characterize birds in coffee plantations and forest sites.

A total of 101 species of birds were observed in coffee plantations; the majority being generalist species. A total of 1,064 individuals (85 species) of birds were observed in *Erythrina poeppigiana – Cordia alliodora* coffee plantations and 623 individuals (56 species) of birds observed in *Erythrina poeppigina* coffee plantations indicating that structurally more complex coffee plantations contained more individuals and species of birds. The majority of birds were insectivores and omnivores. Epiphyte cover, canopy height and the number of

Cordia alliodora trees had a positive effect on the abundance, species richness, and diversity of birds within coffee plantations. The presence of surrounding forest cover had a negative effect in the overall abundance, species richness, and diversity of birds but a positive effect on forest specialists.

This study showed that structurally more complex coffee plantations such as *Erythrina poeppigiana – Cordia alliodora* coffee plantations were able to harbor a greater abundance and number of species of birds than *Erythrina poeppigiana* coffee plantations. This study also provided evidence that the presence of forest cover around coffee plantations favored the presence of forest dependent bird species. Therefore, conservation efforts should promote the diversification of coffee plantations and the protection of forests around these plantations in order to increase or restore structural and functional connectivity within the landscape.

Florian Rivero, E.M. Avifauna en sistemas agroforestales cafetaleros: relaciones entre el contexto paisajítico, la complejidad estructural y comunidades de aves dentro del Corredor Biológico Turrialba – Jiménez, Costa Rica. Tesis Mag. Sc. CATIE, Turrialba, CR. 108 p.

Palabras clave: biodiversidad, bosque, café bajo sombra, conectividad, *Cordia alliodora*, *Erythrina poeppigiana*, fragmentación, paisaje

Resumen

Los sistemas agroforestales cafetaleros se destacan por tener la capacidad de albergar una alta riqueza de especies y una mayor complejidad estructural y pueden servir como una herramienta para conservar la biodiversidad en paisajes agrícolas. Las plantaciones de café bajo sombra pueden atraer una gran variedad de aves y potencialmente pueden proveer refugio para estos organismos. El potencial que tienen los cafetales para la conservación puede ser influido por la estructura de la plantación al igual que la composición del paisaje. El objetivo de este estudio fue el de explorar las relaciones que existen entre el contexto paisajístico (cobertura de bosque aledaño), la complejidad estructural y las comunidades de aves presentes dentro de estos sistemas en el Corredor Biológico Turrialba - Jiménez

Para examinar los efectos de la complejidad estructural y el contexto paisajístico en las comunidades de aves, se seleccionaron y se georeferenciaron un total de 20 plantaciones con café – *Erythrina poeppigiana*, 20 plantaciones de café – *Erythrina poeppigiana – Cordia alliodora* y cinco bosques. Dentro de cada plantación se establecieron dos parcelas de 50 m x 50 m y veinticinco cuadrículas de 10 m x 10 m para caracterizar la estructura y composición florística de cada plantación. Adicionalmente, se calculó el porcentaje de cobertura de bosque alrededor de cada plantación a un radio de distancia de 500, 1000 y 1500 m. Se utilizaron puntos de conteo para caracterizar las comunidades de aves presentes en las plantaciones y bosques.

Se observaron un total de 101 especies de aves en cafetales y la mayoría de estas aves fueron especies generalistas. Un total de 1064 individuos (85 especies) de aves fueron registradas en plantaciones de café - *Erythrina poeppigiana – Cordia alliodora* mientras que 623 individuos (56 especies) de aves fueron registradas en las plantaciones de café – *Erythrina poeppigiana*

plantaciones de café - *Erythrina poeppigiana – Cordia alliodora* mientras que 623 individuos (56 especies) de aves fueron registradas en las plantaciones de café – *Erythrina poeppigiana* indicando una mayor riqueza y abundancia de aves dentro de los sistemas con mayor complejidad estructural. La mayoría de las aves presentes fueron insectívoras y omnívoras. La cobertura de epífitas, la altura del dosel, el número de árboles de *Cordia alliodora* tuvieron un efecto positivo en la abundancia, riqueza de especies y diversidad de aves. El contexto paisajístico (cobertura de bosque alrededor) tuvo un efecto negativo en la abundancia, riqueza de especies y diversidad general de aves pero tuvo un efecto positivo para aves especialistas de bosque.

Este estudio mostró que las plantaciones con mayor complejidad estructural como las plantaciones de café – *Erythrina poeppigiana – Cordia alliodora* lograron albergar una mayor abundancia y diversidad de aves que en la plantaciones de café – *Erythrina poeppigiana*. Este estudio también brindó evidencia sobre la importancia de conservar la cobertura de bosque alredor de las plantaciones para las aves dependientes de bosque, por lo tanto, es necesario promover esfuerzos de conservación los cuales contribuyan a la diversificación de sistemas agroforestales cafetaleros y la protección de los bosques para incrementar y restaurar la conectividad estructural y funcional dentro del paisaje del Corredor Biológico Turrialba – Jiménez.

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1 INTRODUCTION

The dynamic process of natural habitat loss and fragmentation has profound implications for the conservation of biodiversity in agricultural landscapes. The major consequences for wildlife include the loss of species from fragments and entire landscapes, changes in the composition of faunal assemblages, and changes in ecological processes involving animal species. Habitat isolation, a fundamental consequence of the process of fragmentation, also influences the status of animal populations and communities in agricultural landscapes (Bennett 1999).

Within agricultural landscapes, coffee agroforestry systems are reknown for their high species richness and complex vegetation structure and stand out as a promising biodiversity conservation tool (Perfecto and Vandermeer 1994; Wunderle and Latta 1996; Perfecto *et al.* 1997; Greenberg 1997 a,b.; Moguel and Toledo 1999). Shaded coffee plantations are agroforestry systems that have the potential to conserve diverse and abundant wildlife (Somarriba *et al.* 2004). These areas can potentially play important functions by serving as biological corridors, increasing buffer zones around key natural reserves of forest fragments and enhancing the conservation value of forest patches (Rice and Ward 1996). When properly managed, coffee agroforestry systems can also provide other fundamental environmental services, such as watershed protection and carbon sequestration (Jiménez *et al.* 2001).

Shaded coffee plantations can attract a variety of birds, and have the potential to serve as a refuge for bird species in deforested landscapes These systems are also critical habitats for large numbers of migratory birds that arrive from the north at the beginning of the dry season and are some of the most important agricultural habitats for migratory birds in the tropics (Wunderle and Latta 1994, 1996; Greenberg *et al.* 1997). According to Greenberg *et al.* (1997), in some cases, the abundance of migratory birds in shade coffee can even be higher than that found in the primary forest.

The ability of coffee plantations to harbor avifauna depends heavily on the floristic and structural complexity of vegetation and the presence of food resources, nesting and foraging sites, shelter, and habitat. Coffee plantations that have low structural complexity and provide few resources for organisms are only of limited habitat value for some species (Perfecto *et* al. 1996). According to Somarriba *et al.* (2004), the diversity of fauna in coffee plantations may be related to the food that is available to them. For example, the presence of flowers in shade species is likely to attract to the plantations nectar feeding birds (Somarriba *et al.* 2004). Coffee plantations with greater structural complexity can also contain high densities of fruit-producing trees that are likely to support high numbers of frugivorous bird species (Greenberg *et al.* 1997 a,b). In addition to the trees themselves, the occasionally diverse communities of epiphytes on tree trunks and branches also provide additional shelter, nest sites and food resources (Cruz- Angon 2004).

Farm management practices such as tree pruning, elimination of epiphytes and agrochemical use may also influence the presence of avifauna in coffee plantations. Prunning of shade trees at different times of the year can affect the seasonal distribution of foliage and flowers in coffee farms (Calvo and Blake 1998). Distribution and abundance of foliage and flowers can influence foraging patterns of birds, abundance and nesting success (Pearson 1975; Martin 1993 cited in Calvo and Blake 1998). The toxicity and the amount of agrochemicals applied in intensively managed systems is likely to negatively affect the populations of organisms present in coffee plantations (Perfecto and Vandermeer 1994; Perfecto *et al.* 1997; Somarriba *et al.* 2004).

The location of coffee agroforestry systems within the landscape may also affect bird assemblages. The size and distribution of forest fragments in the surrounding landscape, the distance from coffee agroforestry systems to forest remnants, the presence of live fences, windbreaks, dispersed trees and remnant vegetation and the degree of connectivity to nearby forests are factors likely to influence the fauna present in coffee agroforestry systems (Somarriba *et al.* 2004). Birds visiting or using coffee plantations probably move across the landscape and this movement and dispersal of species is likely to be influenced by the available resources and habitats present inside and outside coffee plantations. The abundance, distribution and quality of other habitats in the landscape and their proximity to coffee plantations (Somarriba *et al.* 2004) are also important factors determining the survival, reproduction and dispersion of species across the landscape (Bennett 1999).

Most studies of birds in coffee plantations have shown a clear relationship between the diversity and abundance of bird communities and the structural and floristic complexity of coffee plantations (Wunderle and Latta 1998). Those coffee plantations that are more structurally and floristically diverse have a greater avian diversity than less complex plantations (Martinez and Peters 1996; Wunderle and Latta 1998; Moguel and Toledo 1999). However, very few studies have examined the influence of forest cover around the coffee plantation) on the abundance and diversity of avifauna within individual coffee plantations. There are similarly no studies that relate the presence of avifauna to management practices in coffee plantations although it is expected that coffee plantations that are more intensively managed and use greater quantities of agrochemicals would have a lower bird abundance and lower species richness than those that are less intensively managed (Somarriba *et al.* 2004).

1.1 Research objectives

1.1.1 General objective

The general objective was to examine the effect of the structural complexity of coffee agroforestry systems and forest cover around coffee plantations on tropical bird communities present in the Turrialba-Jiménez Biological Corridor, Costa Rica

1.1.2 Specific objectives

1. To characterize the diversity and composition of birds observed in coffee plantations

2. To compare the diversity and composition of birds in coffee farms with different structural complexities

3. To determine how the surrounding forest cover was related to the bird communities observed in coffee plantations.

4. To provide recommendations for the management and conservation of birds present in coffee agrorestry systems within the Turrialba-Jiménez Biological Corridor, Costa Rica

1.2 General hypotheses

- Greater structural complexity of coffee plantations will increase the abundance and diversity of birds present in coffee plantations

- The amount of forest cover surrounding a given coffee plantation will be positively related with species richness and diversity of birds present in coffee plantations

1.3 Justification

The University of Idaho (UI) in collaboration with the Tropical Agricultural Research and Higher Education Center (CATIE), has established an interdisciplinary graduate research and education program in conservation biology and sustainability of agricultural and forest systems. This program is funded by the National Science Foundation Integrative Graduate Education and Research Traineeship (IGERT) program and is based on the urgent need to create interdisciplinary integration for biodiversity conservation and sustainable production in anthropogenically fragmented landscapes in Costa Rica. One area of research interest is to look at the potential compatibility between agricultural production and the conservation of biodiversity of coffee agroecosystems in the Turrialba region. This investigation serves as a pilot project for this program and generates information for the IGERT research coffee team on the implications of structural complexity and forest cover around coffee plantations for the conservation and management of avifauna in fragmented agricultural landscapes.

2 LITERATURE REVIEW

2.1 Fragmentation and landscape transformation

Habitat loss and fragmentation have been recognized throughout the world as key issues threatening the conservation of biological diversity (IUCN 2004). As the global population increases, less and less of the Earth's surface remains free from human interference. Human activities have modified the environment to the extent that the most common landscape patterns are mosaics of human settlements, farmland and scattered fragments of natural ecosystems. Most conservation reserves, even large reserves, are becoming increasingly surrounded by intensively modified environments and in the long term appear destined to function as isolated natural ecosystems (Bennett 1999).

Habitat fragmentation is a dynamic process that results in the reduction of natural habitat through time. According to Bennett (1999), the term "fragmentation" is generally used to describe changes that occur when naturally contiguous habitats are broken into multiple small and scattered remnants that are separated from each other. Fragmentation begins with "a gap formation or perforation of the vegetative matrix. At the beginning, the matrix (the most common habitat type) remains as natural vegetation, and species composition and abundance patterns may be little affected. But when the gaps become bigger and more numerous, these gaps become the predominant land-use type in the matrix and the connectivity to the original vegetation is reduced "(Meffe and Carroll 1994).

The process of fragmentation is characterized by the following processes: a) overall loss of habitat in the landscapes, b) reduction in the size of the habitat, c) isolation of habitat fragments and, d) increased intensification and use of the matrix surrounding the isolated natural habitat fragments (Meffe and Carroll 1994; Bennett 1999). These changes in landscape patterns arising from fragmentation can be readily identified and described by measuring attributes such as the total remaining area of natural habitat, the size-frequency distribution of fragments, the shapes of fragments, the mean distance between fragments, and the level of contrast between habitats and adjacent land uses. Spatial patterns and arrangement of habitat also result in a series of other changes such as the modification of ecological processes in response to the changing habitat geometry (Bennett 1999). Such changes can have far-reaching effects on the flora and fauna, the soil and water resources, and on human ecology (Saunders *et al.* 1991; Forman 1995).

2.2 Ecological consequences of forest fragmentation

Forest fragmentation affects tropical species and ecosystems in many ways. There are a variety of important consequences and interactions of fragmentation that commonly occur in human-dominated landscapes.

2.2.1. Area effects

The primary impact of fragmentation is the loss of species because of habitat loss and reduction in fragment size. Habitat reduction and fragmentation have impacts at different scales for different organisms (Lord and Norton 1990). Large habitat fragments usually contain more species overall (greater species richness), a higher density of species per unit area and a wider range of habitats than smaller fragments (Brown and Hutchings 1997). Therefore, there is a direct relation between the richness and abundance of species and the size of the fragment (Bennett 1999). Connor and McCoy (1979) cited by Bennett (1999) proposed three explanations for this relationship:

1) "Small fragments contain small samples of original habitat; therefore, it is likely that they will contain a lower diversity compared to the larger fragments due to habitat reduction;
2) With a decreasing area there is reduced diversity of habitats for diverse species survival; and
3) Smaller areas support smaller population sizes which can affect the population viability of many species in a fragment."

When a species is confined to a fragment, its persistence will depend on the size of the fragment and the dynamic of the population; therefore smaller populations will be more vulnerable to extinction (Bennet 1999).

2.2.2 Degree of isolation

Habitat isolation is another consequence of habitat fragmentation. Species that are restricted to certain kinds of habitat will depend on a range of habitat patches in relatively close proximity in order to move, if no single patch is large enough to meet the needs of the organisms. Clearings and degraded land might be considered impenetrable barriers of movement for some species since they might be constrained by their morphology, physiology and behaviour.

The viability of metapopulations may depend on movement of individuals between these patches in order to balance species extirpation from the local patches. Many species require a mix of different habitats with distinct resources – for example, food patches, roost sites, and breeding sites- in order to meet their life history requirements. If these critical areas become separated, populations may decline rapidly to extinction (Meffe and Carroll 1994). The consequences of isolation vary with time, distance to the nearest forest fragment or between fragments and the degree of connectivity between the required habitats (Saunders *et al.* 1990) which affect the movement of animals and plant propagules between fragments.

2.2.3 Edge effects

One inevitable consequence of habitat fragmentation is the creation of edges or abrupt transitions between the natural vegetation and the adjacent modified habitat which marks a contrast in the structure and floristic composition of vegetation as a result of changes in the physical and ecological processes that occur in fragments as well as towards the matrix (Mesquita *et al.* 1999; Kattan 2002). As fragmentation occurs, the amount of edge found in the natural vegetation increases, because small pieces of habitat have more edge relative to the entire surface than the larger blocks of natural vegetation. Populations of some forest species have experienced declines in smaller fragments as well as in edges and disturbed areas (Laurance 1994) but these changes may favor other species that are likely to live in edge conditions (Faarborg 2002).

The impact of edge effects can be measured by 1) the intensity or magnitude of the change (for example, changes in microclimatic conditions) and 2) its penetration, which is defined as the maximum distance that the edge effect is detected, measured from the edge towards the "center" of the forest fragment (Kattan 2002). The impact of the edge effect is directly related to the size and shape of the forest fragment, since the relation between total area of the fragment and the perimeter determines the proportion of area that is exposed to the border effects.

The reduction in spatial continuity, together with edge effects, increases the vulnerability of fragmented vegetation to extrinsic disturbances such as windstorms, fire and flooding. The impacts of extrinsic disturbances vary with the nature of fragment dispersion. Finer scales of fragmentation may not only increase the vulnerability of vegetation to disturbance but may also lead to occurrence of disturbance regimes that would not occur in equivalent intact vegetation.

Landscape management should be focused on the development of a matrix of non-hostile habitats for wildlife use in order to increase connectivity between forest fragments and reduce the extinction vulnerability of species. In order to achieve this, it will be necessary to reduce edge effects through land uses that facilitate a gradual transition between forest types across which organisms may readily move.

2.2.4 Matrix effects

The matrix is composed of a mosaic of modified habitats, such as pastures, crops, plantations, and secondary forest that surround forest fragments. Different matrix habitats can have major influences in the ecology of fragmented forests. The matrix is an important component in the evolution of the dynamics of the fragment for various reasons (Gascon *et al.* 1998):

1) "The matrix can act as a selective filter for the movement of organisms across the landscape. The type of vegetation in the matrix will determine the type of species that will be able to move through that filter;
2) The matrix can exert a strong influence over the dynamics of biological communities within the forest fragment; and
3) Different types of matrix can influence forest fragment edge effects. If the vegetation in the matrix is structurally similar to the original habitat the ecological and physical impacts of edge effects can be drastically reduced."

Fragmented landscapes are composed of modified habitats of different qualities for the species. Increased connectivity of forest fragments within the matrix can prevent a reduction in abundance and/or the extinction of local species. In general, generalist species tend to be less affected by larger scales of fragmentation than specialist species. Specialist species often require "interior" habitat to live and reproduce. When this type of habitat is reduced, populations will not be able to be sustained no matter how close the fragments are, and they will be also less likely to utilize areas of fragmented vegetation as corridors between the intact vegetation fragments (Lord and Norton 1990).

2.2.5 Changes in species assemblages

Different species of animals respond to habitat fragmentation in different ways. Differences in home range area, body size, food resources and foraging patterns, nesting and shelter requirements, as well as tolerance to habitat disturbance and sensitivity to altered microclimates, influence the response of each species to fragmentation. The outcome is that after isolation, the composition of faunal assemblages found in fragments differs from that in large intact forest habitats (Bennett 1999).

Edge effect studies show that species composition and abundance change in fragmented landscapes. For example, forest interior bird species may not be able to maintain their populations in landscapes where edge is abundant and will be displaced by species that are adapted to live in edge habitats. Species composition will tend to change as species become more vulnerable to habitat reduction, isolation and edge effects and competition associated with landscape fragmentation (Meffee and Carroll 1994).

The addition of species to fragmented landscapes (due to species invasion) is an important aspect to consider when establishing conservation strategies to reduce the loss of species. Many of the species that invade fragmented landscapes are exotics. Increases in the number of species at a local scale due to the invasions of exotic species are often accompanied by declines in diversity as sensitive native species are progressively lost, even though overall species richness may remain the same or even increase (Meffe and Carroll 1994).

2.3 Habitat configurations to enhance connectivity

According to Noss (1991), "the concept of connectivity implies the connection of habitats, species, communities and ecological processes at multiple spatial and temporal scales". This concept is used to describe how the spatial arrangement and the quality of the elements that compose the landscape affect the movement of organisms between the habitat patches (Bennett 1999). On a landscape scale, connectivity can be defined by "the degree in which the landscape facilitates or prevents the movement of organisms between patches" (Taylor *et al.* 1996, cited by Bennett 1999).

It is important to recognize that the landscape is perceived in different ways by different organisms and the importance and level of connectivity will therefore vary between the different species (Bennett 1999). The movement and dispersion of species is influenced by the structural component of the landscape and the behaviour of the species (Bennett 1999). The structural component is determined by the spatial arrangement of the different types of habitats present in the landscape and is influenced by the continuity of appropriate habitats, distance between habitats and the presence of alternative pathways or networks between suitable habitats. The behavioral component is related to the response behavior of the individuals and species to the physical structure of the landscape and is influenced by factors such as the scale at which the species perceive and move in the environment, habitat requirements and degree of specialization and tolerance to habitat disturbance (Bennett 1999).

Animal species vary in their tolerance to habitat disturbance and change. Some species are tolerant of human disturbance and are able to adapt and move through the mosaic of modified habitats. Such species generally do not require a high degree of habitat connectivity in order to move from one place to the other. Nevertheless, there are also organisms that are sensitive to habitat changes and require connectivity in order to move across a disturbed landscape (Bennett 1999). For example, Newmark (1991) showed that bird species found in forest interior habitats can have limited tolerance to disturbed habitats. He found that for some species cleared land was an impenetrable barrier for bird movement. For these species, the population viability and connectivity in landscapes depend on the availability of suitable habitat.

Landscape connectivity can be achieved by promoting the movement of organisms and ensuring its population continuity through the management of the landscape mosaic or by managing specific habitats in order to maintain the connectivity for species, biological communities and ecological processes (Bennett 1999). Restoring ecological connectivity through private landholdings between protected areas may also be critical to ecoregional conservation efforts. One possible way to mitigate the effects of fragmentation is to create continuous corridors between fragments. Stepping stones (small patches that facilitate the movement of individuals from one fragment to the other through the matrix) that consist of forest fragments or agroforestry parcels provide temporary habitats for species while they move along the heterogeneous landscape. These alternatives contribute to the genetic flux of many species and reduce inbreeding depression and demographic and genetic stochasticity in fragmented populations (Gerlach and Musolf 2000; Somarriba *et al.* 2004).

2.3.1 Landscape management for conservation

Human dominated landscapes can be managed in a manner that benefits conservation. A basic knowledge of the ecology of the species or assemblages for which connectivity is the goal is an important foundation for managing habitats at a landscape level. Knowledge of the dynamic interactions between organisms and the landscape elements as well as the spatial scale of a species movement is of particular value. How far is the home range or territory? How far do animals regularly move? Do they undertake seasonal or nomadic movements? How far do animals regularly move? And which habitats to organisms normally use?

Landscape links such as biological corridors, forest fragments, stepping stones and agroforestry systems are alternatives that may contribute to the provision of year-round resources for feeding, breeding and shelter. Knowing the behavioural and ecological attributes, such as the the level of tolerance for disturbed habitats, the role of dispersal in life-history, the age and sex of the dispersing individuals, and dispersal behaviour of organisms will help to determine the most effective type of linkage in order to facilitate the movement and the ability of species to effectively use such links (Harrison 1992).

Establishing adequate linkages throughout the landscape is critical for maintaining animal populations in reserve areas and evaluating regions surrounding the reserves, all for the purpose of mitigating the threats to biodiversity. A better understanding of the patterns and processes of ecosystems across different landscapes will allow more accurate prediction of impacts of human activity on landscape structure and the possibility of mitigation through implementation of more sustainable land use practices.

2.4 The conservation value of agroecosystems

In most of the tropics, agroecosystems dominate the landscape, but some remnant primary forest is found in patches distributed throughout the agricultural landscape (Pimentel *et al.* 1992; Perfecto and Vandermeer 1994; Estrada *et al.* 1997; Gascon *et al.* 2004). Most species that survive in forest remnants also interact with the surrounding agricultural landscape therefore it is essential to understand the interactions of organisms with the agricultural systems in order to understand how the organisms within these patches function and how these functions shape the ecological processes that occur within preserved and forested areas.

It is undeniable that agricultural practices impact wildlife in several ways, including among others, habitat loss and disturbance, reduced water quality and quantity, and pesticide toxicity. Intensification practices also diminish agroecosystem biodiversity by reducing the space allotted to hedgerows, copses, or wildlife corridors (Alkorta *et al.* 2003). Nevertheless, these systems can be improved in order to increase productivity and biodiversity value through the incorporation of more sustainable agricultural practices such as fallow periods, intercroppings, and agroforestry systems (McNeely and Scherr 2001).

Besides offering some secondary habitat to organisms, agroforestry systems can be used as an indirect conservation tool to protect natural areas from exploitation. Agroforestry systems can be integrated in corridors where they could play a conservation role by producing timber and non timber forest products thereby minimizing the exploitation of protected areas and helping mitigate biodiversity losses (Gascon 2004) and can also reduce edge effects. The incorporation of agroforestry systems in buffer zones around protected natural areas is an attractive alternative for many farmers that can be compatible with conservation interests.

Coffee is a crop that is emerging as one of the agricultural and/or agroforestry systems with the greatest potential to preserve biodiversity since it is often grown in areas of high biodiversity. In the New World, for example, coffee is grown in Mexico, Ecuador, Peru, Brazil, Colombia and Costa Rica, all of which are considered as centres of megadiversity (Mittermeir and Mittermeir cited in Botero and Baker 2001). Colombia is regarded as having the world's richest diversity of birds and amphibians and is second only to Brazil in plant diversity. Equally, although smaller in size, Costa Rica is another coffee producing country noted for its high biodiversity (Botero and Baker 2001). Nevertheless, during the past 20 to 30 years these areas have undergone a substantial transformation due to increased intensification of coffee production involving the use of high-yielding coffee varieties, high agrochemical inputs and the reduction or complete elimination of shade trees (Rice and Ward 1996). This phenomenon has been very profound in Costa Rica, where more than 40% of the coffee farms have experienced a high degree of shade reduction (Perfecto *et al.* 1996). Associated with this transformation from traditional to non-shaded coffee cultivation, has been the dramatic loss of biodiversity.

2.5 Coffee production systems in Costa Rica

Coffee is cultivated under different production systems in Latin America. These systems conform a continuum that range from traditional coffee production systems with higher diversity in the structure and composition of the shade canopy, to those with reduced shade and intense management (Moguel and Toledo 1996; Perfecto *et al.* 1996; Somarriba *et al.* 2004). Based on vegetational structure and management intensity (Somarriba *et al.* 2004), coffee production systems can be classified as:

- "Traditional rustic coffee plantations. These production systems are established in areas of natural forest. This system removes only the lower strata of the forest. As a result the original tree cover is maintained, under which coffee plants are inserted. The canopy is also thinned to regulate the shade.

- Traditional polyculture systems. Coffee is introduced under the cover of the original natural vegetation and is grown with numerous useful plant species.

- Commercial polyculture system. This system involves the total removal of the original forest canopy trees and the introduction of a set of shade trees which are appropriate for coffee cultivation.

- Coffee plantations with two shade strata typically composed by *Erythrina poeppigiana* and *Cordia alliodora* which are commonly found in coffee systems of middle elevation in Costa Rica. The shade of *E. poeppigiana* is regulated by heavy prunning; and *C. alliodora* is mostly managed for timber. Other variations of the system consists replacing *Erythrina poeppigiana* with bananas or other perennial crops.

- Coffee plantations with one shade stratum composed mainly of one shade species. The vertical structure is simple and it is managed intensively.

- Coffee plantations with shade canopy species that are distributed in a linear pattern along field borders and roads.

- Sun grown coffee monocultures with no shade canopy".

The architectural, vegetational, and structural complexity of these systems and their corresponding systematic and ecophysiological features have different ecological consequences, not only on a microenvironmental scale (Jimenez- Avila 1981; Nestel 1995) but also on a regional ecosystemic scale. For instance, the presence or absence of shade in coffee plantations not only has implications in the ecology and economy of coffee agroecosystems but may also play an important role in the maintenance of populations of organisms at a landscape level. Scientific evidence has linked the complete elimination of tree cover with a less stable physical environment because of increased soil and air temperature, lowered soil water content, decreased abundance and diversity of soil microorganisms, and decreased soil fertility. The presence of shade also provides a greater variety of habitats for macrofauna and microfauna (Nestel 1995). Consequently, the different coffee systems, representing different ecological designs and degrees of ecosystem manipulation, affect in different ways and to varying degrees ecological and biological processes such as hydrologic balance, soil quality, forest cover and biological diversity (Moguel and Toledo 1999).

2.6 Coffee and biodiversity

In the last few years, coffee plantation systems have been widely studied for their potential to conserve biodiversity. Studies in traditional shaded coffee plantations have demonstrated that structurally diverse agroecosystem have potential as a refuge for biodiversity (Perfecto *et al.* 1996; Moguel and Toledo 1999). These studies have been carried out independently with a variety of taxa, primarily with birds (Wunderle and Latta 1996; Estrada *et al.* 1997; Greenberg et al. 1997a, 1997b; Wunderle 1999; Johnson 2000) and arthropods (Nestel and Dickschen 1990; Perfecto and Vandermeer 1994, 2002; Perfecto and Snelling 1995; Perfecto et al. 1997; Johnson 2000).

Polyspecific shaded coffee plantations have a high structural complexity and can provide food resources, nesting, mating, and foraging sites, shelter, or habitat to many organisms. In contrast, monospecific shade coffee plantations have low structural complexity therefore, it provides fewer resources to organisms and is of only limited habitat value for a few species (Perfecto *et al.* 1996). In addition to the trees themselves, the occasionally diverse communities of epiphytes on tree trunks and branches may offer a wider variety of microhabitats for both plants and animals.

2.7 Avifauna diversity in tropical coffee agroecosystems

Various studies show that shade coffee plantations provide a valuable refuge for birds and other organisms in heavily deforestated agricultural regions (Perfecto *et al.* 1996; Greenberg *et al.* 1997 a,b; Wunderle and Latta 2000). For example, studies conducted by Botero and Baker (2001), found 170 bird species in shaded coffee plantations which represent an estimated 10% of the avifauna present in Colombia. Shade coffee plantations can also support high densities of species that are dependent on closed canopy forest (Wunderle and Waide 1993; Wunderle and Latta 2000). Greenberg *et al.* (1997) found that forest habitats in Central Guatemala contained the greatest diversity of birds, followed by shaded the coffee plantations and sun coffee plantations. Greenberg also showed that shade coffee plantations can support an even higher number of forest migrants species (generalists and specialists) compared to other modified habitats and often with higher densities than in the natural forests. The diversity of avifauna present in these production systems includes the presence of forest specialists, forest generalists, scrub/second growth species and edge species which belong to the frugivorous, insectivorous, and nectarivorous guilds (Greenberg *et al.* 1997; Moguel and Toledo 1999).

Shaded coffee plantations are also critical habitats for migratory birds that spend their time in the tropics during the winter season. In some cases, the species abundance of migratory birds in shade coffee can be higher than in primary forest (Greenberg *et al.* 1997). The migrant birds appear to be better adapted to live in shaded coffee plantations because they adopt more flexible habitat needs compared to the resident birds that breed in the area (Perfecto *et al.* 1996) Wundele and Latta (1994) also found that migratory species in shade coffee plantations survived the winter at a rate comparable with those birds found in the natural habitats.

However, not all shade coffee plantations may be equivalent in their attractiveness to birds, as variation in canopy structure and composition influence avian abundance and diversity in some plantations (Greenberg *et al.* 1997 a; Johnson 2000). Demonstration of the potential value of shade coffee to birds requires identification of particular habitat characteristics of the plantations with which various bird species are associated. Avian distribution might also be influenced by the area of the plantation in shade coffee plantations, based on other studies of species – area effects on birds. Although most species-area studies have been conducted in the temperate region, few tropical studies indicate that many tropical resident species are sensitive to habitat patch size (Lovejoy *et al.* 1986). Plantation size and degree of isolation might affect the number of bird species. It is assumed that small isolated shade coffee plantations are more likely to support fewer species per unit area of habitat than larger plantations.

2.8 Factors affecting avifauna diversity in coffee plantations

Avifauna diversity in coffee plantations may differ due to differences in vegetation composition and structural complexity, plantation management such the use of agrochemicals and pruning intensity of shade trees, and the composition and structure of the surrounding landscape (Somarriba et al. 2004).

2.8.1 Structural complexity of the plantation

The diversity of avifauna present in shaded coffee plantations is directly related to their structural and floristic complexity (Wunderle and Latta 1998), therefore coffee plantations that are more structurally and floristically diverse have a greater diversity than low diversity coffee plantations. For example, Moguel and Toledo (1999) found up to 184 bird species in shaded coffee plantations compared to 6-12 bird species in sun-grown coffee plantations (Martinez and Peters 1996).

Food availability may be a factor that accounts for the differences in the avifauna present in different types of coffee plantations. The diversity and abundance of nectarivorous, frugivorous and omnivorous bird species in coffee plantations will depend on the species of plant that is flowering or fruiting (Greenberg et al. 1997; Wunderele and Latta 2000; Somarriba *et al.* 2004); in addition, to the wide variety of insects that can be found in these systems which makes them key foraging sites for insectivorous species (Wunderle and Latta 2000).

2.8.2 Plantation management

Agricultural practices such as thinning or pruning shade trees can affect the presence of avifauna. Prunning of shade trees at different times of the year can affect the seasonal distribution of foliage in coffee farms (Calvo and Blake 1998). Distribution and abundance of foliage can influence foraging patterns of birds, abundance and nesting success (Pearson 1975; Martin 1993 cited in Calvo and Blake 1998). Severe pruning of large branches may even affect cavity nesters such as woodpeckers in finding suitable sites for nest construction.

The use of agricultural chemicals can affect the presence of avifauna in coffee plantations. Chemicals potentially harmful to birds include insecticides, herbicides and fertilizers. Agricultural chemicals probably affect birds both directly via toxic effects and indirectly by changes in food availability and habitat. The effects of pesticides, particularly herbicides, are a major concern. Herbicides are of major concern because they simplify the vegetation structure and species composition of the plantation. Intensive use of herbicides can potentially reduce the ground cover of a coffee plantation and change avian community structure or reproductive success through loss of suitable habitat or declines in prey abundance (Gard and Hooper 1995; Rodenhouse *et al.* 1995). It is to be expected that coffee plantations that are more intensively managed or use greater quantities of pesticides would have lower populations and lower species richness (Perfecto and Vandermeer 1994; Perfecto *et al.* 1997) than less intensively managed plantations.

2.8.3 Effects of landscape structure on avifauna diversity

Birds are one of the most studied groups of organisms at a landscape level. Birds are highly mobile organisms and consequently their movements cannot be easily followed. What we know of avian movement is limited primarily to data from recapture birds and movements of birds on discrete study areas (Haas 1995). Between the data that can be collected on distance dispersal on single study areas and large scale movements, there is a gap of knowledge in the frequency and importance of different lengths of dispersal and resource use within the landscape. Behavioural avoidance, rather than physical inability to traverse distances, is probably one of the reasons why many forest-interior birds are inhibited by forest gaps. According to Stouffer and Bierregaard (1995), approximately 20% of tropical forest birds at diverse sites in southern Brazil and eastern Tanzania are reported to be incapable of crossing gaps wider than several hundred meters.

Species richness and abundance of avifauna in coffee agroforestry systems are likely to be influenced by the landscape context such as patch size and frequency of adjacent forest patches, interpatch distance, degree of isolation and connectivity with respect to other similar coffee plantations and nearby forests, the diversity of patch types as well as by the presence of live fences, dispersed trees, and other remnant vegetation (Van Dorp and Opdam 1987; Forman 1995; Somarriba *et al.* 2004).

Several studies have shown that local species richness is reduced in smaller habitat patch size and in habitats located at greater distance from forest fragments (Dorp and Opdam 1987; Boulinier *et al.* 1998; Zannette *et al.* 2000). Martinez and Peters (1996) reported a total of 184 bird species in traditional coffee fields adjacent to a tropical forest when compared to 82 species in coffee plantations isolated from forest remnants; suggesting the importance of forest habitat to the persistence of many bird species in agricultural areas. Habitat patch isolation can also restrict the movement of certain of birds which can in turn lead to higher probabilities of local extinction. For example, Dunning *et al.* 1995 showed that linear landscapes and isolated patches of habitat were less likely to be colonized by Bachman's sparrows (*Aimophila aestivalis*). The amount of matrix relative to habitat fragment and the degree of contrast between edge effects might also influence exposure to brood parasitism and predation. If conditions favor predators and parasites then the reproductive success of some species of birds will decrease. Even in habitats with "natural" conditions nest predation rates often approach 50% but in forest fragments nest predation rates can be greater than 90% (Faaborg 2002).

Adjacent forest patches provide food and nesting resources for birds. Zannette *et al.* (2000) showed that birds experienced greater food shortage during breeding season in smaller fragments than in large fragments. This is influenced by the lower prey biomass present in smaller fragments. Differences in the microclimatic conditions due to edge effects could explain the variation of food abundance.

Kurosawa and Askins (2003) showed that a number of forest-interior species of birds were significantly affected by the density of connecting elements mainly because connecting areas can provide additional feeding habitat for the birds in the adjacent forest patches, both during the breeding season and during winter and facilitates the movement and dispersal of birds.

Structurally more complex diverse coffee plantations near natural forests can serve as buffer zones and thereby can contribute to increase the habitat area for some species. At the same time, the presence of trees in coffee plantations may help increase the overall landscape connectivity, thereby facilitating animal movement to and from isolated forest patches in the coffee farm matrix.

3 METHODS

3.1 Description of the study site

The study was conducted in the Turrialba-Jiménez Biological Corridor (TJBC), Costa Rica. The Biological Corridor is located in the counties of Turrialba and Jiménez in the Province of Cartago, in the eastern part of Costa Rica (9°73' N, 83°43' W), and covers an extension of 71,386 ha (Figure 1).

The TJBC is part of the Central Volcanic Mountain Range Conservation Area. The TJBC borders with a nucleus of protected areas that fall under different management categories. These include the Turrialba Volcano and Irazu Volcano National Parks on the northern side, the Pacuare River Forest Reserve and Cabecar de Chirripo (Duchi) Indigenous Reserve to the east, the Macho River Forest Reserve to the southeast, and the Tuis River Watershed Protected Zone, La Marta Wildlife Refuge and the Tapanti-Macizo de la Muerte National Park to the south. Forty percent of the area within the corridor is covered by forest. This forest cover is made up of a mixture of old-growth fragments, riparian forests and secondary forest or abandoned agricultural land. The largest tracts of forest are located on the southern and eastern side of the corridor (Figure 1).

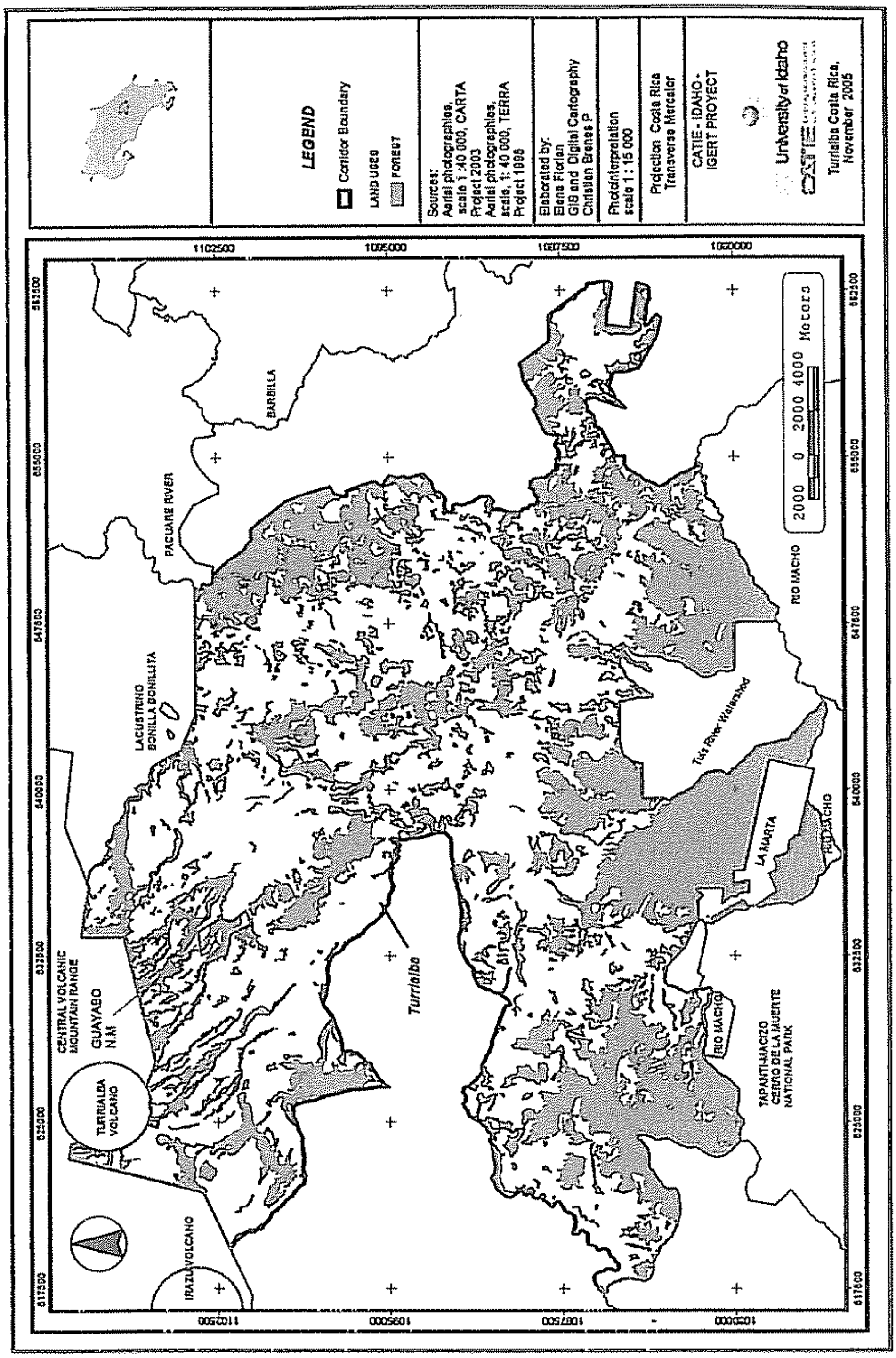


Figure 1. Location of the Turrialba – Jiménez Biological Corridor (TJBC), Costa Rica and the remaining forest cover (in green).

The area is topographically diverse, with elevations ranging from 500 m in river valleys to over 3328 m on ridges. The climatic conditions are influenced by the Northeast trade winds that bring moisture from the Carribean side to the Central Volcanic Mountain Range of Costa Rica.

According to the Holdrige Life Zone classification system (Holdrige 1978), the TJBC represents seven life zones and four transition zones. The most representative life zones are: tropical premontane wet forest (53%), tropical premontane rainforest (22%) and lower montane wet forest (5%) (Canet 2003). The climate and volcanic soil characteristics present in the region permit various agricultural activities primarily cattle pastures (21% of the corridor), coffee (14%) and sugar cane plantations (5.8%), macadamia, fruits and vegetables (2.5%). Land use is diverse and divided among many small landholdings (Appendix 1)m. A number of communities are found in this area, of which the town of Turrialba constitutes the most important urban centre in the region with a population of 32,000 people (Canet 2003).

A total of 10,213 hectares of conventional and organic coffee is produced in the Turrialba region. The majority of it is grown at an altitudinal range from 600 – 1300 meters above sea level (ICAFE 2003). Coffee production currently represents 14% of the total area of the TJBC. Despite this large area, coffee production has experienced a reduction of 14.3% in the past four years, mainly due to the impact of the global coffee crisis (Moya 2005).

There are two main types of coffee production systems in the region: conventional and organic production. Conventional coffee production generally requires high levels of external inputs and has been linked to soil degradation, environmental pollution, and human health problems (Fernandez and Muschler 1999), particularly for small and medium scale producers. These farmers rely on purchased inputs and a single source of income from coffee monocultures can create serious economic risks due to increasing costs and unstable world market prices for coffee.

In contrast, organic coffee production systems, based on diversity, recycling, biological processes, and mimicry of natural habitats (IFOAM 1996; Figueroa - Zevallos *et* al. 1996 cited in Lyngbæk *et al.* 2001), can generate multiple products for the farmers with fewer external impacts compared to conventional coffee systems. Since the 1990's, the Association of Organic Producers of Turrialba (APOT) has produced coffee using more environmentally friendly practices. There are 115 active members in APOT of which a total of 68 members are organically certified coffee producers; 50 of them are located within the TJBC (Hidalgo 2003). Environmentally - friendly practices include the incorporation and diversification of shade tree cover, the use of organic fertilizers, the diversification of crops produced in the farm and reduced pesticide use. The Turrialba region therefore provides a good setting to study the impact of various farm management practices, both conventional and organic, on the biodiversity present in coffee agroforestry systems.

3.2 Coffee farm selection

In order to explore the relationship between the landscape context and structural complexity of coffee agroforestry systems and birds observed, of the 86 APOT's organic farms and a sample of 115 randomly selected conventional coffee farms located within the TJBC were selected and georeferenced with the aid of the APOT and ICAFE data bases. These data bases contained contact information of the property owners and the location of each farm. For each farm, the following information was compiled: dominant shade species, number of strata, altitude and homogeneity in the spatial arrangement of the dominant shade species for each farm. Based on these criteria, the most common coffee plantation types found in the region were identified.

Aproximately 89.1% of the coffee plantations present in the TJBC had a shade canopy and only 10.9% of the coffee area was planted with no shade. The majority of the coffee plantations that were surveyed (including both organic and conventional farms) had one or two canopy layers indicating the predominance of low diversity shade coffee systems in this region. Coffee plantations with a single tree layer were mostly dominated by *Erythrina poeppigiana* although some farmers have also incorporated crops that have commercial value such as *Musa* spp. into these plantations. Plantations with two shade strata were dominated by *Erythrina poeppigiana* and *Cordia alliodora*. Very few multistory coffee polycultures (three canopy layers or more) were found in the region, and most of these farms with this type were organic.

The most common coffee farm types found in the region were *Erythrina poeppigiana* and *Erythrina poeppigiana – Cordia alliodora* coffee plantations. EC plantations were characterized by having a high density and a homogeneous distribution of *Erythrina poeppigiana*. On the other hand, ECC plantations were characterized by having a homogeneous distribution and high density of *Erythrina poeppigiana* and *Cordia alliodora*. In these plantations, *Erythrina poeppigiana* conformed the lower tree canopy layer whereas *Cordia alliodora* was the tree species that conformed the upper canopy layer in this type of coffee plantation.

For this study, the two most common coffee plantation types that showed clear structural differences between them were selected: *Erythrina poepiggiana* (EC) and *Erythrina poepiggiana – Cordia alliodora* (ECC) coffee plantations. A total of 40 farms (20 EC and 20 EC plantations) were selected for this study from which 36 farms were conventional and 6 were organic. Farms were randomly selected based on the following criteria: an altitudinal range of 650-1000 meters above sea level corresponding to the tropical premontane wet forest life zone, homogeneous distribution of the dominant tree shade species and a minimum area of 2.5 hectares of land.

3.3 Distribution of study plantations within the landscape of the Turrialba Jiménez Biological Corridor

The forty selected coffee plantations were distributed along the TJBC in 14 different communities: Santa Teresita (6 farms), Aquiares (2), Santa Rosa (1), Azul (2), Alto Varas (1), Turrialba (1), Atirro (2), La Suiza (11), Tuis (2), Javillos (2), Chitaría (1), Pavones (2) San Pablo de Tres Equis (2), Tayutic (2), Bajo Pacuare (2) and Grano de Oro (1). The sizes of coffee plantations ranged from 2.5 to 40 ha with a mean of 9.2 ha. Additionally five forest sites were selected as reference sites. The size of these forests varied between 120 and 232 ha. The selected forests were Guayabo National Monument with 232 ha, La Isabel (150 ha), Chitaría (150 ha), La Marta Wildlife Refuge (120 ha) and Bajo Pacuare (125 ha). These sites had a mixture of secondary and old-growth forest. Each coffee plantation and forest was georeferenced with Global Positioning System (GPS) and located in the TJBC map (Figure 2).

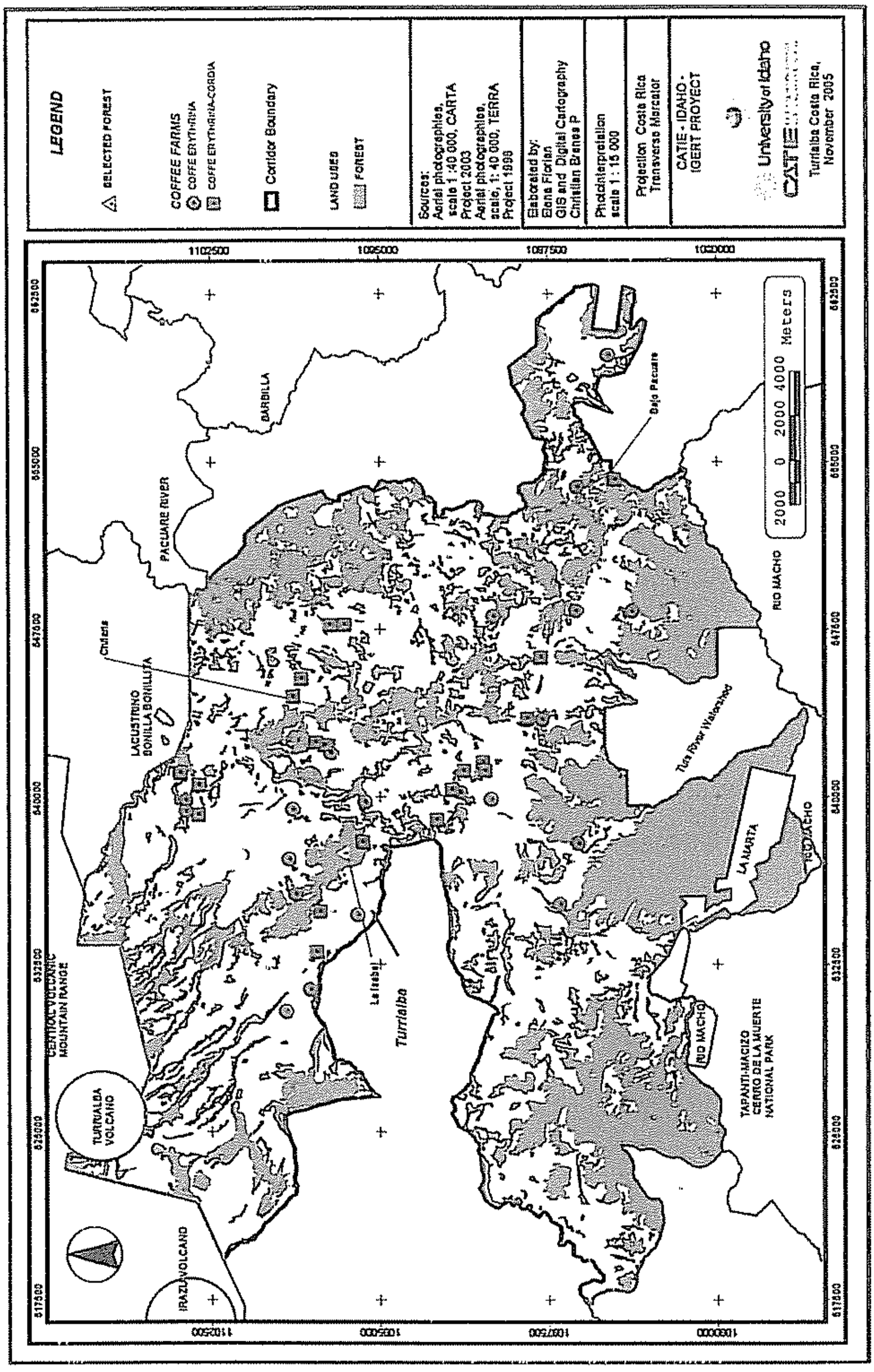


Figure 2. Distribution of the 20 *Erythrina poeppigiana* (EC), 20 *Erythrina poeppigiana-Cordia alliodora* (ECC) coffee plantations and five forest sites within the TJBC, Costa Rica, where bird communities were characterized. Forest cover is represented in green.

3.4 Characterization of bird communities and coffee plantations

3.4.1 Selection of plots for bird characterization and characterization of coffee plantations

For each of the 40 coffee plantations two 25 m fixed-radius circular plots were established for bird counts. The first circular plot was placed 50 m from the center point of each plantation. Each circular plot was located at 100 m from each other and at least 20 m from the edge or farm house. These circular plots were used as point counts (Hutto *et al.* 1986; Ralph *et al.* 1996) for the characterization of the bird communities. In addition, two 50 m x 50 m vegetation plots were established around each point count or bird observation area to determine the structural and floristic composition of each of the coffee plantations.

3.4.2 Structural and floristic composition

Within each 50 m x 50 m vegetation plot, all trees with a diameter at breast height ≥ 10 cm were registered. Additional measurements taken included: the number of trees, the estimated canopy diameter of shade trees, height and epiphyte cover. Plants that produced flowers or fruits at the time of the survey were also recorded. In addition, ten coffee plants were randomly selected for each plot. For each coffee plant, the height was measured and an average height of all the coffee plants per plot was obtained. The number of shade trees with a dbh ≥ 10 cm, and the percent of shade trees and coffee plants that were pruned (partially or completely) at the time of the survey were also quantified.

In order to further characterize coffee management, each vegetation plot was subdivided into 10 m x 10 m quadrats. Within the center of each of the 25 quadrats, structural hetereogeneity of the coffee plantation, the percent of canopy cover, percent of herbaceous cover and weed height were assessed. The values obtained for these variables were averaged for each farm (Figure 3).

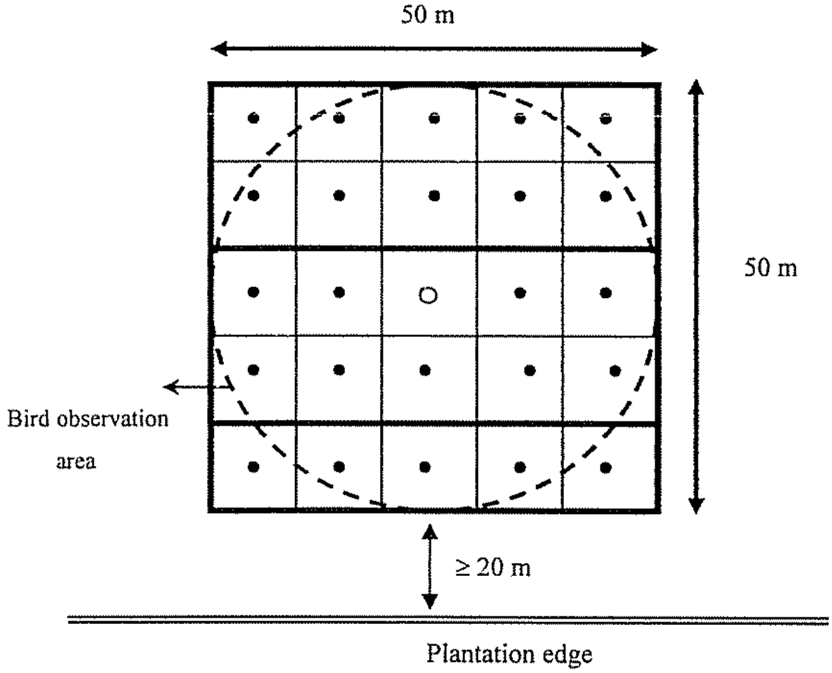


Figure 3. Quadrats used to compile management data in vegetation plots. The white circle represents the center of the point count area and black circles represent the center of the 10 m x 10 m quadrats. The circle dotted circle represents the area in which birds were surveyed.

The structural heterogeneity of each coffee plantation was assessed using Thiollay's (1992) methodology (in the center of each 10 m x 10 m quadrat). The percent of vegetation cover in each of four main strata (0-2, 2-9, 10-20, and > 20 m) was visually estimated by using a simple index of 1 to 3 (1-33, 34 – 66, and 67-100%) at the center of each individual quadrat. Foliage cover scores were obtained for each strata based on visual estimations. The sum of the four indices in each stratum was used as an index of vertical heterogeneity for each coffee farm.

Canopy cover was measured with a spherical densiometer. A total of four densiometer readings were recorded in each of the four cardinal directions at 1 m above ground in the center of each quadrant and an average reading was calculated for each plot. Herbaceous ground cover was estimated by placing a 0.5 m x 0.5 m frame on the ground in the center of each of the 25 quadrats per plot. Herbaceous cover was estimated by visually using an index from 0 to 3 (0 = 0 – 25%, 1 = 25 – 50%, 2 = 50 – 75% and 3 = 75 – 100%). An average value was calculated for each plot. Table 1 presents a summary of the structural, composition and management variables compiled for each coffee plantation.

Table 1. Structural, vegetation and management information compiled from each of the 50 m x 50 m vegetation plots.

Structure	Management	Composition
Height of shade trees (m)	% of pruned shade trees	Species present
Canopy diameter of shade trees (m)	Coffee plant height	# of species of shade trees
% of epiphyte cover	Coffee plant density	# of shade trees per species
# of fruiting trees	% of herbaceous cover	
# of flowering trees	Weed height	
Index of vertical heterogeneity	% of shade	

3.4.3 Landscape context surrounding coffee plantations

The interpretation and digitalization of the forest cover around the coffee plantations was done with ArcView 3.1 (Environmental Systems Research Institute) on a 2003 infra-red photograph provided by the Costa Rican National Center of High Technology (CENAT) at a working scale of 1: 15000. The percent of forest cover surrounding each coffee plantation was calculated by placing each coffee plantation at the center of overlaying concentric circles with a radii of 500, 1000 and 1500 m which corresponded to circular plots with an area of 78.5, 314.2 and 706 ha respectively. The percent of forest cover was calculated separately within each circular plot. Forest cover measurements were considered as co-variables in analysis of Co-variance (ANCOVA).

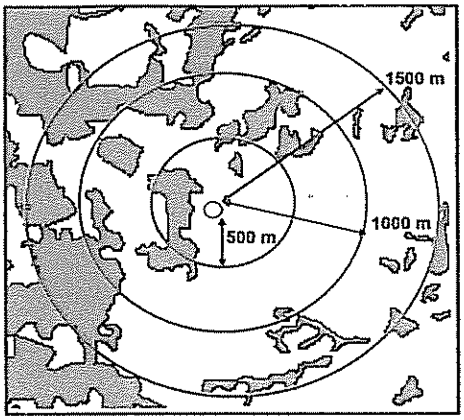


Figure 4. Forest cover surrounding coffee plantations within a radius of 500, 1000 and 1500 m. The yellow circle represents the individual coffee plantation placed at the center of each concentric circle.

3.4.4 Avifauna community assessment

In order to characterize avifauna communities within the coffee plantations, two 25 m fixed-radius point counts were established in each of the 40 coffee plantations (ie. 80 point counts total). This method is a standard technique for bird surveys in tropical habitats and is a fast method that allows sampling in a large number of sites (Hutto *et al.* 1986; Ralph *et al.* 1996). The first point count was placed at the center of each farm. The second point count was located at least 100 m from the other, and at a minimum distance of 20m from the edge or farm house (Figure 5).

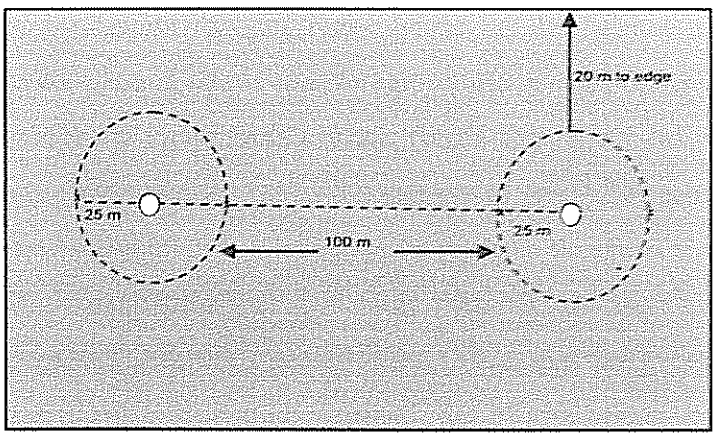


Figure 5. Circular plots used to characterize avifauna communities in coffee plantations

Additionally, two point counts plots were established in each of five forest sites distributed across the TJBC to characterize and compare bird communities present in forest habitats. All of the 80 point count plots in the coffee plantations and the 10 point counts in forest fragments were visited during two periods (April- May 2005 and June-August 2005).

At each point, observations were made for a period of 10 minutes between 06:00 and 08:00 and for another 10 minutes between 15:30 and 17:50. In each time period, each point count was visited once in the morning and and once in the afternoon in order to obtain data from each count station for each type of farm and forest throughout the day. The total observation time per point count site was 40 minutes (10 minutes x 2 times/day x 2 point counts) and the total observation time for each farm was 80 minutes per farm. For each 10 minute point count the following information was collected: species, sex (where possible), location or strata of occurrence, and activity in each of the plots. Only birds observed within the point counts were recorded. Individuals that flew over or flew through the plantations were recorded separately during the observation period and were not included in the analysis. Analyses were restricted to counts of birds detected only within the 25 m radius point counts. No surveys occurred during rainy days since precipitation typically affected bird activity.

To investigate the relationships of birds with the structural complexity of coffee agroforestry systems, species were classified into guilds. The guild classifications were based on observations in the field and information presented in Stiles and Skutch (1985, 1989). Species were categorized into strata of occurrence based on the habitat in which they were most commonly observed: ground (birds that forage on the ground or leaf litter), understory (birds that forage in shrubbery under trees), trunk (birds that occur on trunks or branches at all levels) and canopy (birds that forage in the crowns of trees). Species were also classified by diet using Stiles and Skutch (1989): insectivores (species that feed almost exclusively on small invertebrates), frugivores (birds that feed more than half the time on fruit or on the seeds of fruit while on trees, e.g. parrots), nectarivores (birds that feed more than half the time on nectar), omnivores (birds that feed on a mixed diet of arthropods, fruit, nectar, or seeds) and granivores (birds that feed more than half time on seeds).

Birds were also classified by its degree of forest dependence using Stiles and Skutch (1985) and Sekercioglu *et* al. (2002). Each bird was categorized into a forest dependence class: high (class 1), intermediate (class 2) and low (class 3) which corresponded to forest specialist, forest generalist and non forest species respectively (Table 2). Intermediate class assignations were used for those species that did not fit neatly into a single class (for example, 1.5, 2.5). This information was useful for determining the conservation value of coffee plantations and the sensitivity of individual bird species that were present in coffee plantations to landscape fragmentation.

Table 2. Classification of bird species into three levels or classes of forest dependence (based on Stiles and Skutch 1985; Sekercioglu *et* al. 2002).

Class	Criteria
1 (Forest specialist)	Species requires at least 50 percent cover with large interconnected forest patches.
2 (Forest generalist)	Species can persist in the persistence of forest fragmentation (50% or less forest cover). These are also forest edge species.
3 (Forest independent)	Species requires no forest and can persist in second growth, scrub and agricultural lands.

3.5 Data Analysis

3.5.1 Structural and floristic composition

Data on plantation structure (height of shade trees, canopy diameter, % of epiphyte cover, # of fruits, # of flowers, index of hetereogeneity), management (% of pruned trees, coffee plant height,coffee density, % of herbaceous cover, weed height and % of shade cover) and floristic composition (species present, # of species and # of shade trees) were compiled from each of the two 50 m x 50 m vegetation plots. The data on structural, management and floristic composition variables were combined from each vegetation plot to obtain the information for each farm.

3.5.2 Avifauna composition and diversity within each coffee plantation

A total of 3,200 minutes of observation was completed in coffee plantations and 400 minutes in forest sites (Table 3). Data from bird observations in April – May 2005 and June – August 2005 were combined for all analysis. The information compiled for the two point counts per farm were combined and added to obtain the total number of bird species and individuals for each coffee plantation.

Table 3. Sampling effort measured in observation time (minutes) for a each point count, each coffee plantation, plantation type, each forest and all the forests. Observation time for each point count was measured as 2 times/day x 10 min/period x 2 days

Sampling level	Observation time (min)
Point count	40
One plantation (2 point counts)	80
EC plantations (2 point counts x 20 farms)	1600
ECC plantations (2 point counts x 20 farms)	1600
One forest (2 point counts)	80
All the forests (2 point counts x 5 forests)	400
Total sampling effort	**3600**

For each coffee plantation I calculated species richness (S), evenness (E), Shannon-Wiener Diversity Index (H), Simpson Index (D) and Margaleff Index (D_{mg}). All the values for these indices were calculated by using the program ESTIMATES 6.0 (Colwell 2001). The formulas and explanations of these indices are found in Table 4.

Table 4. Formulas and explanations of diversity indices used to characterize the bird communities in coffee plantations within the TJBC, Costa Rica.

Diversity Index	Formula	Explanation
Shannon – Wiener (H')	**$H' = -\sum p_i \ln p_i$**	Accounts for the abundance and evenness of species present. The proportional abundance of species *i* or the number of individuals of species *i* divided by the total number of individuals in the sample (p_i) is calculated and multiplied by the natural logarithm of this proportion ($\ln p_i$). The values of H' range between 0 and log S.
Evenness (E)	**$E = 1/Sp1$** **$0 \leq E \leq 1$**	Shows the relationship between the abundance of each species and how evenly these individuals were distributed among species. When the value of E is close to zero, it means that one species dominated the same community and when it is close to 1, all the species shared similar abundances.
Simpson Index (D)	**$\lambda = \sum p_i^2$**	Shows the probability that two individuals randomly selected in a sample corresponded to the same species. It takes into account the representativeness of species with a higher importance value without evaluating its contribution to the rest of the species.
Margaleff Index (D_{Mg})	**$D_{Mg} = (S - 1)/ \ln (N)$**	Shows the relationship between the number of species and the number of individuals. The index will varied with the number of individuals. Values closer to zero mean that there are fewer species.

Rank-abundance curves were also generated for each type of coffee plantation in order to have a sense of the composition and dominance of species in each type of coffee plantation.

2.5.3 Comparison of avifauna richness and abundance between coffee plantations

T-tests were used to compare bird abundance, species richness, diversity indices (H', D', D_{Mg} and E'), feeding guilds and forest dependence between EC and ECC plantations. An analysis of co-variance (ANCOVA) was also used to determine if the co-variables (forest cover around each farm at distances of 500m, 1000, 1500 m and the variables for structure, management and composition) affected differences in the bird abundance, species richness and diversity across the different types of coffee plantations. Statistical analysis were conducted using with the statistical program InfoStat/Professional 1.1 (Robledo *et al.* 1998).

Additionally, the Jaccard Index (I) was used to compare the degree of similarity of bird communities between the different types of coffee plantations and the forest fragments. The Jaccard Index is a similarity index that indicates how similar two sites were based on the number of species that these sites share. The similarity coefficient of Jaccard was calculated by using the following formula:

$$I_j = \frac{c}{a + b - c}$$

Where:

a = number of species present in site A

b = number of species present in site B

c = number of species present in both sites A an B

Most similarity indices range from 0 – 1; the closer to 1, the similar the two communities.

Additionally, the Sørensen Index was also calculated with the following formula:

$$I_s = \frac{2c}{a + b}$$

This index relates the number of species found in each site with the number of species found in both sites. The closer to 1 the more similar the communities are with respect to their relative abundances.

A species accumulation curve was generated in order to show differences in species richness between the different types of coffee plantations and determine sampling efficiency for each treatment. The data were generated using ESTIMATES 6.0 (Colwell 2001). Species accumulation curves were done with SigmaPlot (2000). A cluster analysis was conducted to differentiate groups of coffee plantations based on differences found in the composition of bird communities that were present in coffee agroforestry systems. The farms were grouped using the Sorensen (Bray-Curtis) distance measure and flexible beta as the linkage method in order to generate a dendrogam that showed the degree of association between the different groups of farms (Gauch 1982). Once the cluster analysis was done, an Indicator Species Analysis (Dufrene and Legendre 1997) was performed in order to identify indicator species for each cluster group. The method combined information on the species abundance and the probability of occurrence of a species in a particular group. The indicator values for each species were tested for statistical significance using the Monte Carlo technique. Cluster analysis and the Indicator Species Analysis was performed in the program PcOrd (McCune and Mefford 1999).

3.5.4 Relationship between vegetation characteristics, landscape context and bird abundance and species richness in coffee plantations

A simple linear regression was performed between each of the variables of forest cover (500, 1000 and 1500 m) with abundance and species richness of birds per farm in order to explore the relationship between the landscape context and bird communities. A cluster analysis with the variables of structure (height of shade trees, canopy diameter, # of fruits, # of flowers, index of heterogeneity), management (% of pruned shade trees, coffee plant density, % of herbaceous cover index, weed height and % of canopy shade) and composition (# of species of shade trees, # of shade trees with a DBH $\geq$ 10 cm) was performed with the average linkage method and a distance of 1 minus the absolute value of Pearson correlation coefficient to find the degree of correlation between the various variables. Variables that were grouped by more than 0.55 were considered to be correlated (Johnson and Wichern 1998). The variables that were selected were: number of fruits, percent of pruned shade trees, the number of *Cordia alliodora* tress, canopy diameter of shade trees, height of shade trees, percent of surrounding forest cover at a distance of 1000 m, percent of epiphyte cover, herbaceous cover index, number of trees with a dbh $\leq$ 10 cm and the number of shade trees with a dbh $\geq$ 10 cm.

Once the dendrogram was generated, I then proceeded to select only variables that were not correlated for the multiple regression analysis. The multiple regression analysis was used to explore the relationship of the structural and floristic characteristics of the coffee plantations and forest cover around individual plantations with the abundance and species richness of bird communities. A step wise multiple regression analysis was performed to find the variables that had a degree of significance at 0.05. This analysis helped to determine which variables influenced the most in the abundance and species richness of birds that were present in coffee plantations

4. RESULTS

4.1 Characterization of coffee plantations

4.1.1 General structural and floristic composition

A total of 3,202 shade trees (dbh ≥ 10 cm) from 25 species (14 families) were registered in coffee plantations (Appendix 3). The most common species in these agroforestry systems were *Erythrina poeppigiana* with 73% of all the individuals, followed by *Cordia alliodora* (17%). The rest of the species were represented by 10 individuals or less.

An average of 80 individuals of plant species with dbh ≥ 10 cm and a mean of 3.0 species were found in each of the 50 m x 50 m plots in the forty coffee farm plantations (Table 5). The average diameter at breast height (DBH) for shade species was 25.4 cm with an average height of 7.3 m. The average shade cover was 47.3%. The mean number of *Erythrina poeppigiana* was 60.2 individuals, which extrapolates to a average density of 306 trees ha^{-1}. The mean number of *Cordia alliodora* was 13.50 ± 2.88 trees which extrapolates to an average density of 93 trees ha^{-1}. Approximately 22.6% of the shade trees were pruned in coffee plantations. The mean herbaceous cover index was 0.74 and the average height of the herbaceous layer was 16.3 cm.

Table 5. Mean values (± standard of error) of structural, management and floristic characteristics of coffee plantations (n = 40) within the TJBC, Costa Rica. The information was compiled from the two 50 m x 50 m vegetation plots. Data represent means per coffee plantation. The herbaceous cover index was calculated by averaging the index values obtained from the twenty five 10 m x 10 m quadrats. Index values were classified as: 0= 0-25%; 1 = 25 – 50%; 2= 50-75%; 3= 75-100% herbaceous cover.

Structure	Mean ± SE	Management	Mean ± SE	Composition	Mean ± SE
Height (m)	7.27 ± 0.56	% of pruned shade spps.	22.59 ± 4.69	# of trees. ≥10 cm dbh	80.00 ± 5.8
Canopy diameter	1.95 ± 0.15	Density of coffee ha-1	6,313 ± 270	# of spp. ≥ 10 cm dbh	3.03 ± 0.25
dbh ≥ 10 cm	2.15 ± 0.27	Coffee plant height	1.69 ± 0.03	# of *Erythrina spp.*	60.20 ± 4.86
% of epiphyte cover	13.43 ± 2.93	Herbaceous cover index	16.34 ± 2.49	# of *Cordia spp.*	13.50 ± 2.88
# of fruits	0.18 ± 0.11	% of shade cover	47.28 ± 2.68	# of trees ≤ 10 cm dbh	12.45 ± 2.12
# of flowers	0.38 ± 0.26			# of spp. ≤10 cm dbh	2.15 ± 0.27

4.1.2 Structural and floristic composition in coffee plantations

A total of 1,610 individuals of plants with a dbh≥ 10 cm were registered in vegetation plots of EC plantations. These individuals belonged to 18 species (14 plant families). The most common shade species in this type of coffee plantation was *Erythrina poeppigiana* with 1380 individuals, followed by *Musa spp.* (107 individuals). *ECC* plantations registered a greater number of shade trees (1,728) which represented 19 species (12 families) compared to EC plantations. The most common shade species however, were also *Erythrina poeppigiana* (1,043 individuals), followed by *Cordia alliodora* (532 individuals). Trees in ECC plantations had a significantly greater mean height (p = 0.0464), structural heterogeneity index (p = 0.0001) and epiphyte cover (p=0.0165) compared to EC plantations (Figure 12). There were no significant differences in the number of trees (p=0.2756), number of species (p=0.1426), DBH (0.3739) and canopy diameter (p=0.474) between both types of coffee plantations (Table 6).

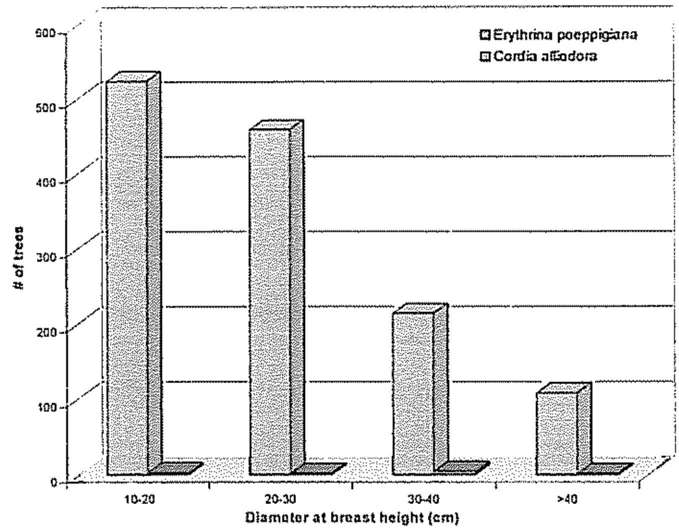
Table 6. Structural and floristic characteristics of *Erythrina poeppigiana* (EC) and *Erythrina poeppigiana - Cordia alliodora* (ECC) coffee plantations. Data include information on mean number of trees, species, diameter at breast height (DBH), percent of epiphyte cover and structural heterogeneity index. Mean canopy diameter was measured with the following index: 0 = 0 – 1 m; 1 = 0 – 3 m; 2 = 0 – 6 m; 3 = 0 – 10 m; 4 = +10 m. Index values were added and averaged for each coffee plantation. Except where specified otherwise, all data are means ± SE.

Vegetation variables	EC ± SE	ECC ± SE	p-value
Total # of trees	1474	1728	
Total # of species	18	17	
# of trees/plot*	73.6 ± 9.01 a	86.4 ± 7.27 a	0.1426
# of species/plot*	2.65 ± 0.39 a	3.4 ± 0.31 a	0.2756
Dbh (cm)	24.46 ± 1.83 a	26.29 ± 0.89 a	0.3739
Height (m)	6.15 ± 0.86 b	8.38 ± 0.66 a	0.0464
Canopy diameter Index	1.84 ± 0.22 a	2.05 ± 0.2 a	0.474
% of epiphyte cover	6.52 ± 3.35 b	20.33 ± 4.37 a	0.0165
Heterogeneity Index	4.44 ± 0.09 b	5.66 ± 0.13 a	0.0001

* Plots = 50 m x 50 m

The two types of coffee plantations had distinct diameter distributions (Figure 6). Most of *Erythrina poeppiggina* in EC plantations had diameters between 10 – 20 cm. Only eight *Cordia alliodora* trees were registered in EC plantations and most of them had diameters between 30-40 cm. In contrast, *Erythrina poeppigiana* in ECC plantations had larger diameters that ranged between 20-30 cm and a mean dbh of 25.51 ± 1.18 cm. Most of the *Cordia allliodora* trees in ECC plantations also had diameters in this range but the mean was 18.31 ± 2.42, a smaller mean dbh than that of the *Erythrina poeppigiana* trees (Figure 6).

a)



b)

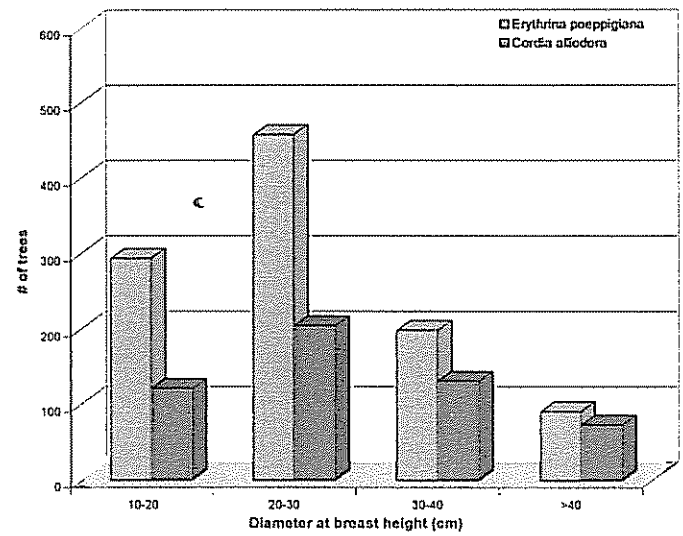


Figure 6. Diameter distributions of *Erythrina poeppigiana and Cordia alliodora* trees in (a) *Erythrina poeppigiana* (EC) and (b) *Erythrina poeppigiana – Cordia alliodora* (ECC) coffee plantations in the TJBC, Costa Rica.

The two types of coffee plantations also varied in tree height (Figure 7). The majority of *Cordia alliodora* trees in ECC plantations had canopies taller than 15 m and the mean height was 10.61 ± 1.49 m. In the EC plantations, the canopy was dominated by *Erythrina poeppigiana* and most of these trees were found in the 0 – 5 m range with a mean height of 5.17 ± 0.52 m. Most of the *Erythrina poeppigiana* trees in ECC plantations were found in the

0-5 m range. Frequent pruning of *Erythrina poeppigiana* for shade regulation might explain the presence of trees with large diameters (Figure 6) yet short heights (Figure 7).

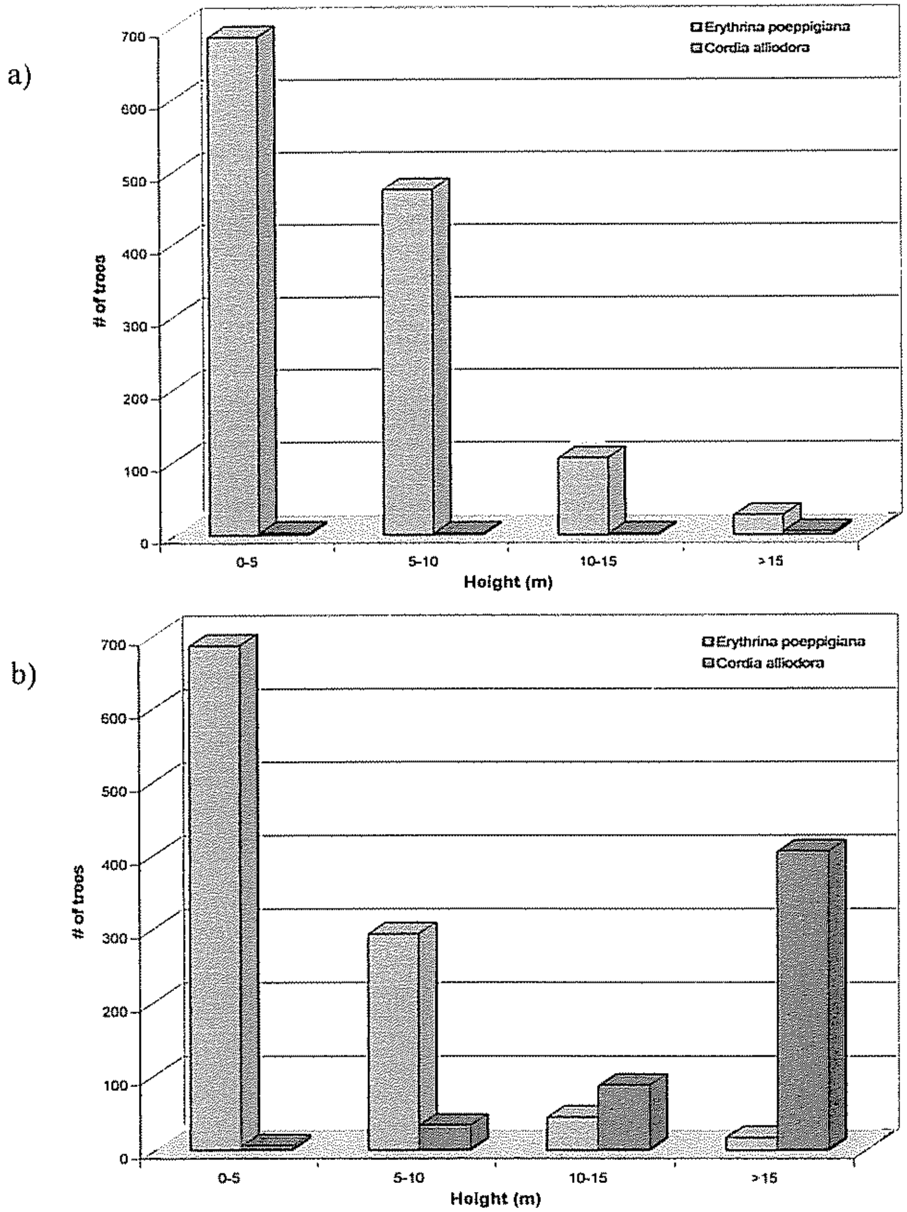


Figure 7. Height distribution of *Erythrina poeppigiana* and *Cordia alliodora* trees in (a) *Erythrina poeppigiana* (EC) and (b) *Erythrina poeppigiana – Cordia alliodora* (ECC) coffee plantations.

EC plantations contained a significantly greater density of *Erythrina poeppigiana* (349 ± 40.85 trees ha^{-1}; p= 0.0523) compared to ECC plantations (264 ± 25.61 trees ha^{-1}). ECC plantations contained significantly greater densities of *Cordia alliodora* (136 ± 20.34 trees ha^{-1}; p=0.0001) compared to EC plantations (2 ± 0.92 trees ha^{-1}). *Cordia alliodora* also had a significantly greater mean canopy diameter index (3.46; p= 0.0001) in ECC plantations than EC plantations. No significant differences were found in coffee density (p=0.6899), herbaceous cover index (p= 0.741), mean height (p = 0.4103) and canopy diameter of *Erythrina poeppigiana* (p=0.4105) between the two types of coffee plantations.

4.1.3 Surrounding landscape context

The mean percent of forest cover around the 40 coffee plantations at a radius of 500 m was 17.7 % ± 2.81 and ranged between 0 and 70 %. The mean percent of forest cover at 1000 m was 21.9 % ± 2.59 ranging from 2.5 to 72.9 % and finally for the 1500 m, the mean forest cover was 17.7 % ranging from 5.9 to 70.6 %. The distribution of forest cover varied across all the coffee plantations (Figure 8). The results also showed that the mean percent of forest cover did not vary significantly between the two types of coffee plantations. At 500 m, the mean percent of forest cover was 17.8 % ± 3.1 in EC and 17.5 % ± 4.79 in ECC plantations. At 1000 m, the mean percent of forest cover was 23.1 % ± 3.42 in EC and 20.6 % ± 3.96 in ECC plantations and at 1500 m, the mean percent of forest cover was 26.3 % ± 3.42 in EC and 22.8 % ± 3.46 in ECC plantations.

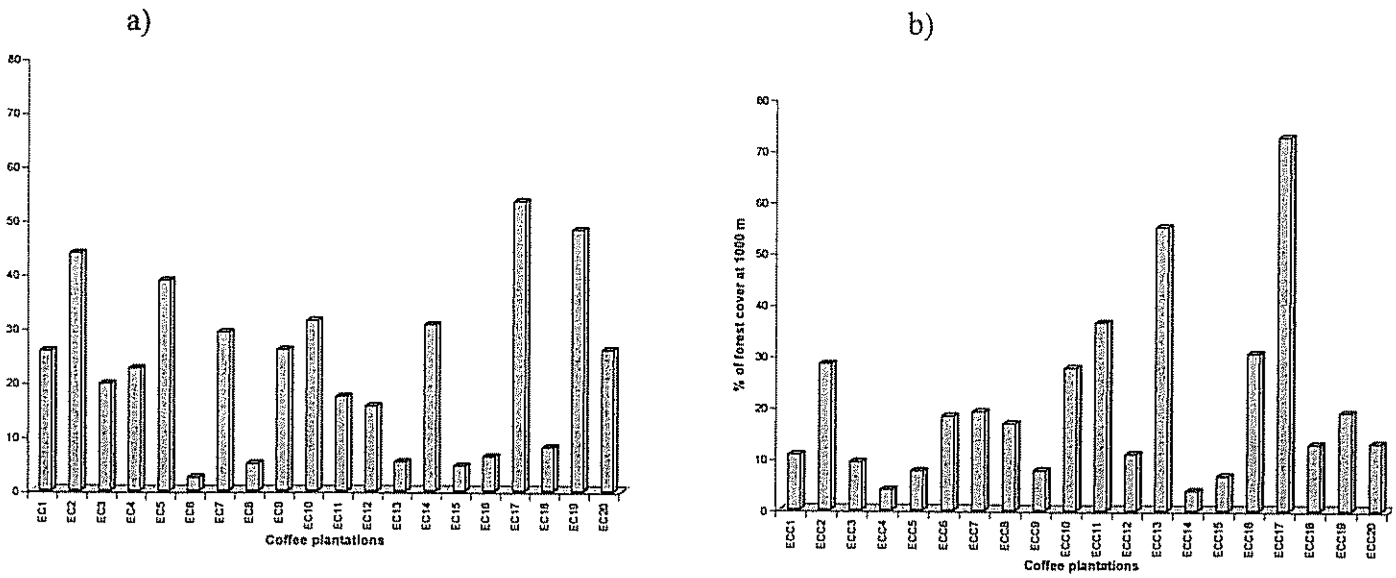


Figure 8. Distribution of forest cover around a) *Erythrina poeppigiana* (EC) and b) *Erythrina poeppigiana – Cordia alliodora* coffee plantations at 1000 m radii within the TJBC, Costa

Rica. Locations of individual coffee plantations and their abbreviations can be found in Appendix 2.

4.2 Characterization of tropical bird communities

4.2.1 General structure and composition of the community

A total of 1780 birds belonging to 35 families and 185 species were registered in coffee plantations and in five forest sites inside the Turrialba – Jiménez Biological Corridor (Appendices 4 and 5). Most of the species that were recorded were resident species, except for 12 species which were long distance migrants. Most of the migrant species were in the Parulidae and Vireonidae families.

Tyrannidae was the family that registered the most species (16 species), followed by Thraupidae (12 species) and Emberizadae (12 species). A total of 25 families were represented by only 5 species or fewer and 11 families were represented only by one species (Figure 9).

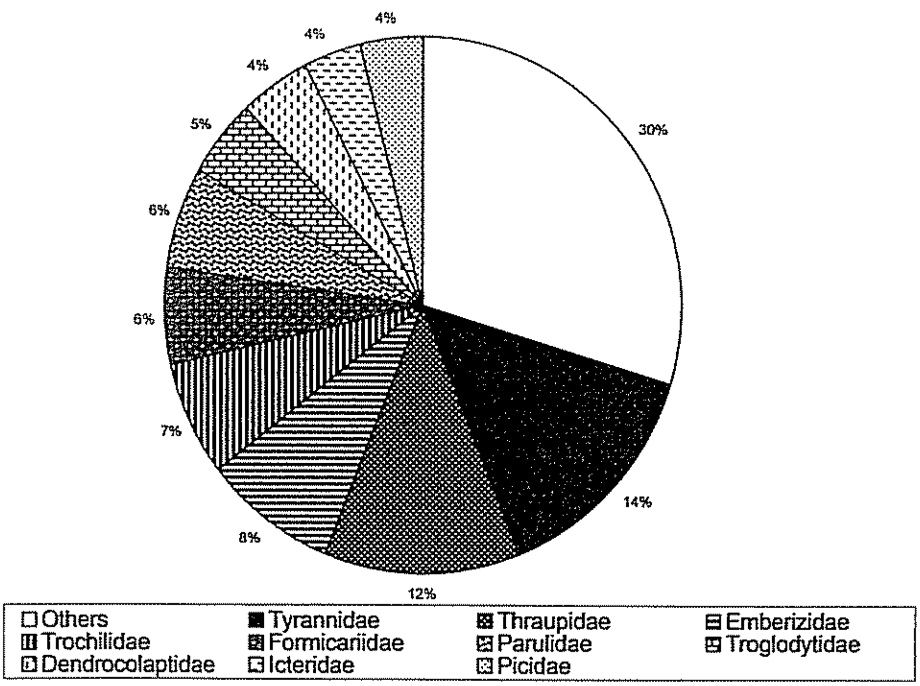


Figure 9. Composition of bird families (N = 35) based on number of species found in coffee plantations and forests in the TJBC, Costa Rica

Bird species with high conservation value that were recorded in coffee plantation point counts were the olive-sided flycatcher (*Contopus borealis)* and the white-crowned parrot (*Pionus senilis)*. The crimson-fronted parakeet (*Aratinga finschi*) and the red-lored parrot (*Amazona autumnalis*) were also observed in coffee plantations but were not registered inside the point counts. The olive- sided flycatcher is a long distant migrant and according to the IUCN Red list (Bird Life International 2004) this species is considered as "near threatened" since its experiencing population declines throughout the range of this species. The white-crowned parrot (*Pionus senilis*), the crimson-fronted parakeet (*Aratinga finschi*) and the red-lored parrot (*Amazona autumnalis*) are listed in CITES and the official list of threatened wildlife species for Costa Rica (UICN 1997) White-crowned parrots *(Pionus senilis)*, crimson fronted parakeets (*Aratinga finschi*) and red-lored parrots (*Amazona autumnalis*) were frequently seen in coffee plantations of this region nevertheless they are experiencing declines mainly because these birds are considered pests for some agricultural crops and people poach them to sell them or keep them as house pets (INBIO 2004).

4.2.2 Avifauna structure in coffee agroforestry systems

A total of 1,687 birds of 101 species (30 families) were registered in the 80 point counts in coffee plantations (Appendix 4). Tyrannidae was the bird family with the greatest species richness (15.8% of species) followed by Emberizadae (11.9% of species) and Thraupidae (11.9% of species). The common-tody flycatcher (*Todirostrum cinereum*) was the most common species in the Tyrannidae family. The Emberizadae family registered the greatest number of birds (19.1%), followed by Thraupidae (18.7%) and Tyrannidae (10.7%) (Table 7). The most abundant species in the Emberizadae family was *Sporophilla aurita.*

Table 7. Abundance and species richness of the 12 most common bird families found in coffee plantations in the TJBC, Costa Rica, organized by descending abundance. Data represent the totals (and %) for 80 point counts; 40 in *Erythrina poeppigiana* (EC) and 40 in *Erythrina poeppigiana – Cordia alliodora* (ECC) coffee plantations.

Family	# of species	% of species	# of individuals	% of individuals
Emberizidae	12	11.9	322	19.1
Thraupidae	12	11.9	316	18.7
Tyrannidae	16	15.8	181	10.7
Turdidae	2	0.02	157	9.3
Troglodytidae	7	6.9	131	7.8
Trochilidae	5	5.0	104	6.2
Sylviidae	0	0.0	101	6.0
Parulidae	5	5.0	60	3.6
Icteridae	6	5.9	51	3.0
Columbidae	3	3.0	49	2.9
Picidae	5	5.0	49	2.9
Dendrocolaptidae	3	3.0	24	1.4
Others	26	25.7	213	12.6

The rank-abundance curve (Figure 10) shows the composition and dominance of the bird species in the 40 coffee plantations. The most abundant species were the variable seedeater (*Sporophila aurita,* 11.6 % of all the birds) followed by the clay-colored robin (*Turdus grayi,* 8.1 %), blue-gray tanager (*Thraupis episcopus,* 6.8 %), tropical gnatcatcher (*Polioptila plumbea,* 5.9 %), rufous-tailed hummingbird (*Amazilia tzacatl,* 5.6 %), golden-hooded tanager (*Tangara larvata,* 4.2 %), common-tody flycatcher (*Todirostrum cinereum,* 3.9 %), yellow-faced grassquit (*Tiaris olivacea,* 3.6 %) and the plain wren (*Thryothorus modestus,* 3.6 %). Each of these species was represented by more than 50 individuals (Figure 10).

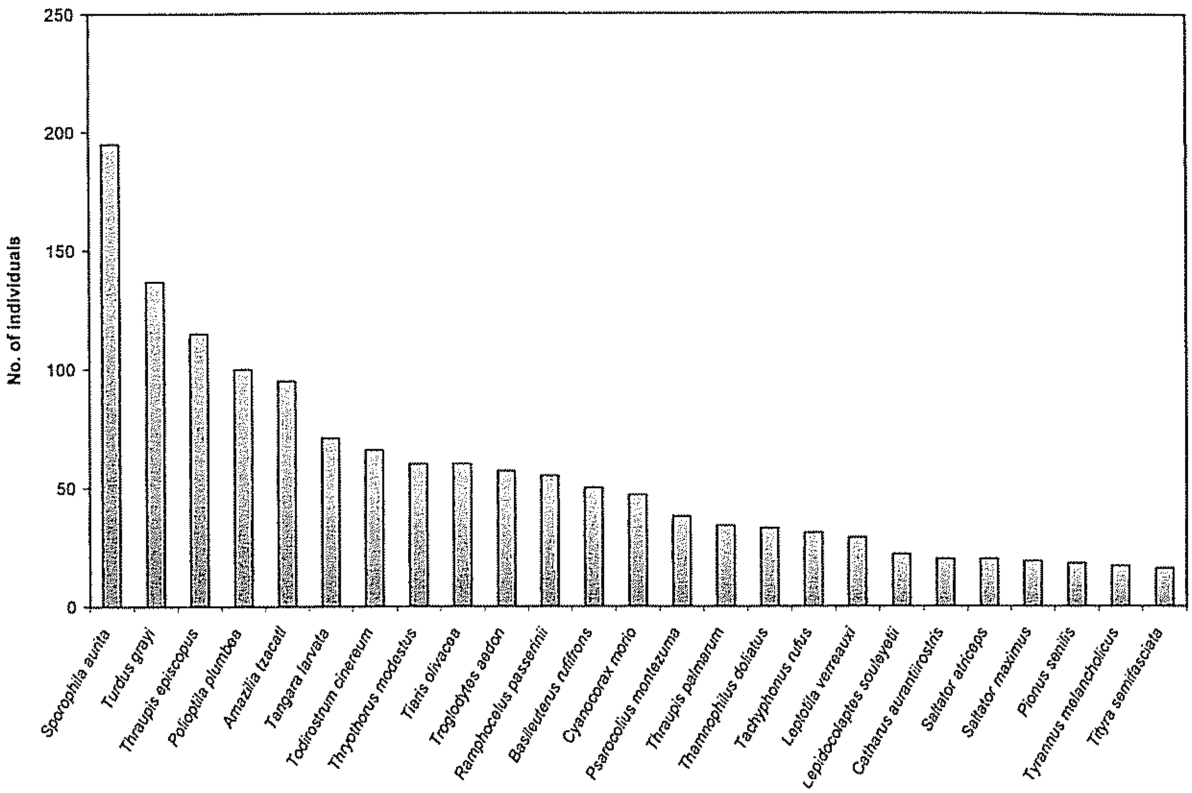


Figure 10. Rank-abundance curve of the 25 most abundant bird species registered in the 80 point count plots in coffee plantations in the TJBC, Costa Rica

Coffee plantations were dominated by the presence of granivorous bird species such as *Sporophila aurita* and omnivorous bird species such as *Turdus grayi* and *Thraupis episcopus*.

The majority of the species were generalist species that showed an affinity for nonforest habitats (Class 3) (Table 8). Some forest generalists that have an affinity to forest edge and nonforest habitats were also observed (Class 2.5) such as *Thraupis episcopus* and *Todirostrum cinereum*. Only seven individuals (of five species) of birds that were observed were forest specialists. These were: *Sclerurus mexicanus*, *Henicorhina leucosticta*, *Tolmomyias assimilis*, *Monasa morphoeus* and *Piculus simplex*.

Table 8. The 10 most abundant bird species present in coffee plantations, in decreasing order of abundance. Feeding guilds (FG), preferred habitat (PH) and forest dependence (FD) classification are from Stiles and Skutch (1985 and 1989) and personal observations: G = Granivorous; I = Insectivorous; N = Nectarivorous; O = Omnivorous; NF = Nonforest; FE = Forest edge; FC = Forest canopy; 1 = Needs almost continous forest; 2 = Needs at least patchy forest; 3 = Does not need forest.

Species	# of individuals	% of individuals	# of coffee farms where found (n = 40)	FG	PH	FD
Sporophila aurita	195	11.6	36	G	NF,FE	3
Turdus grayi	137	8.1	37	O	NF,FE	3
Thraupis episcopus	115	6.8	27	O	NF,FE,FC	2.5
Polioptila plumbea	100	5.9	32	I	FC,FE	2
Amazilia tzacatl	95	5.6	36	N	NF,FE	3
Tangara larvata	71	4.2	19	O	FE,NF,FC	3
Todirostrum cinereum	66	3.9	22	I	FE,NF,FC	2.5
Thryothorus modestus	60	3.6	26	I	NF,FE	3
Tiaris olivacea	60	3.6	25	O	NF	3
Troglodytes aedon	57	3.4	26	I	NF	3

The majority of individuals (85.6 %) and species (66.3 %) observed in the coffee plantations were generalist species and were not dependent on the forest habitat (Table 9). However, 13.7 % of the individuals and 27.7 % of the bird species were forest generalists. Very few species and individuals and species were forest specialists (Table 9). However, when we combined species abundance and species richness for the forest specialist and forest generalists birds, we found that up to 14.4 % of individuals and 33.6 % of the bird species are dependent upon the forest habitat to some degree (Classes 1, 1.5 and 2).

Table 9. Abundance and species richness for forest specialist, forest generalist and generalist birds observed in 40 coffee plantations within the TJBC, Costa Rica. Forest dependency Class 1 and 1.5 were considered as forest specialists, Class 2 as forest generalists and Class 2.5 and 3 as generalist birds.

	Abundance		Species	
Forest dependency	#	%	#	%
Forest specialist	12	0.7	6	5.9
Forest generalist	231	13.7	28	27.7
Generalist	1444	85.6	67	66.3

Generalist birds (Class 3) had the highest mean number of individuals (23.78 ± 1.71) and species (8.38 ± 0.49) per plantation followed by forest generalist bird species (Class 2 and 2.5). Very few forest specialist birds (Class 1 and 1.5) were found in coffee plantations (Table 10).

Table 10. Mean number of individuals and species ± standard of error (SE) of birds of different forest dependencies observed for each coffee plantation (n = 40) in the TJBC, Costa Rica. Dependency classes include: (1) Needs continous forest, (1.5) Needs continous forest and patchy forest, (2) Needs patchy forest, (2.5) Can persist in patchy forest and nonforest areas, (3) Does not need forest to persist.

	Class of forest dependence				
Birds	**1**	**1.5**	**2**	**2.5**	**3**
Individuals	0.08 ± 0.06	0.2 ± 0.1	5.78 ± 0.57	12.43 ± 1.5	23.78 ± 1.71
Species	0.05 ± 0.03	0.15 ± 0.07	2.5 ± 0.21	4.95 ± 0.37	8.38 ± 0.49

In terms of species richness, 51.5% of all the bird species were insectivorous, the majority of which were in the Tyrannidae family. A high proportion of bird species were also omnivorous (24.8%). In terms of the number of individuals the majority of birds were omnivores (38.6%) followed by insectivores (Table 11).

Table 11. Feeding guild composition of birds in coffee plantations within the TJBC, Costa Rica. Mean number of individuals and species of birds ± standard of error (SE) was measured per plantation (n = 40). Feeding guilds were compiled from Stiles and Skutch (1989).

	Individuals			Species		
Feeding guild	**N**	**Mean ± SE**	**%**	**N**	**Mean ± SE**	**%**
Carnivorous	6	0.15 ± 0.09	0.4	1	0.08 ± 0.04	1.0
Frugivorous	49	1.23 ± 0.36	2.9	9	0.63 ± 0.12	8.9
Granivorous	250	6 ± 0.69	14.8	10	1.55 ± 0.14	9.9
Insectivorous	629	15.68 ± 1.39	37.3	54	7.25 ± 0.51	53.5
Nectarivorous	102	2.55 ± 0.38	6.0	5	1.08 ± 0.08	5.0
Omnivorous	651	16.38 ± 1.39	38.6	22	5.68 ± 0.31	21.8

4.2.3 Comparison of bird communities in Erythrina poeppigiana and Erythrina poeppigiana – Cordia alliodora coffee plantations

A total of 623 individuals of 56 species (21 families) of birds were observed in EC plantations farms compared to 1064 individuals from 85 different species (29 families) in ECC plantations. ECC plantations had a significantly greater mean number of birds per farm (t-test, t=4.81; p = 0.0001) and mean species per farm (t-test, t = 4.73; p = 0.0001) than EC plantations (Figure 11).

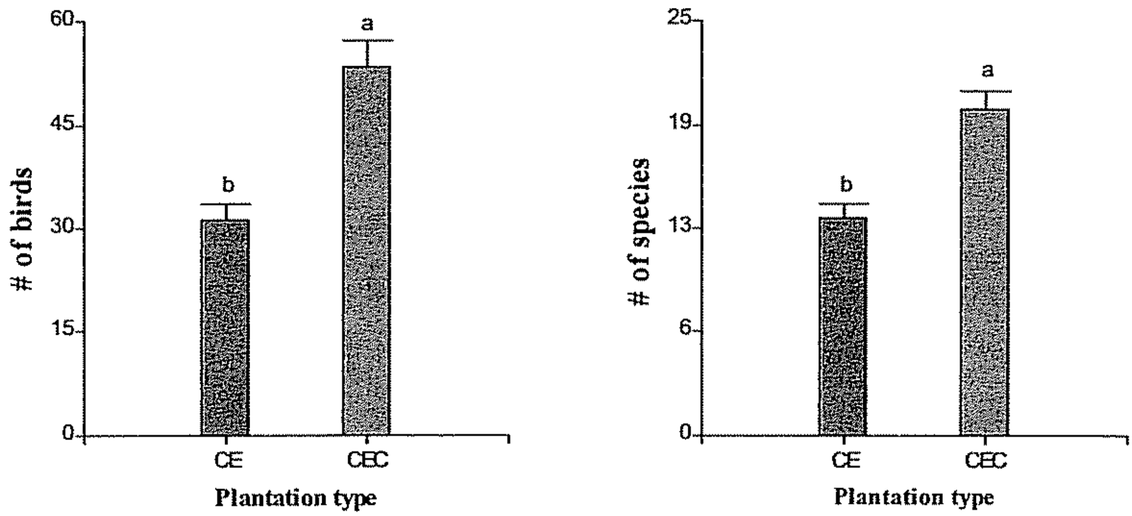


Figure 11. Comparison of the mean number of birds and bird species found per coffee plantation in EC and ECC farms (n=40 point counts/plantation type). Different letters indicate significant differences between coffee plantations ($p<0.05$).

The species accumulation curve of the observed bird species did not reach an asymptote suggesting that more species could be registered with an increased sampling effort. Species accumulation curves also indicated clear differences in bird species richness between EC and ECC plantations (Figure 12), with ECC accumulating bird species more rapidly than EC plantations. Total bird species richness per coffee plantation varied between 12 and 66 bird species for EC plantations and between 20 and 99 bird species for ECC.

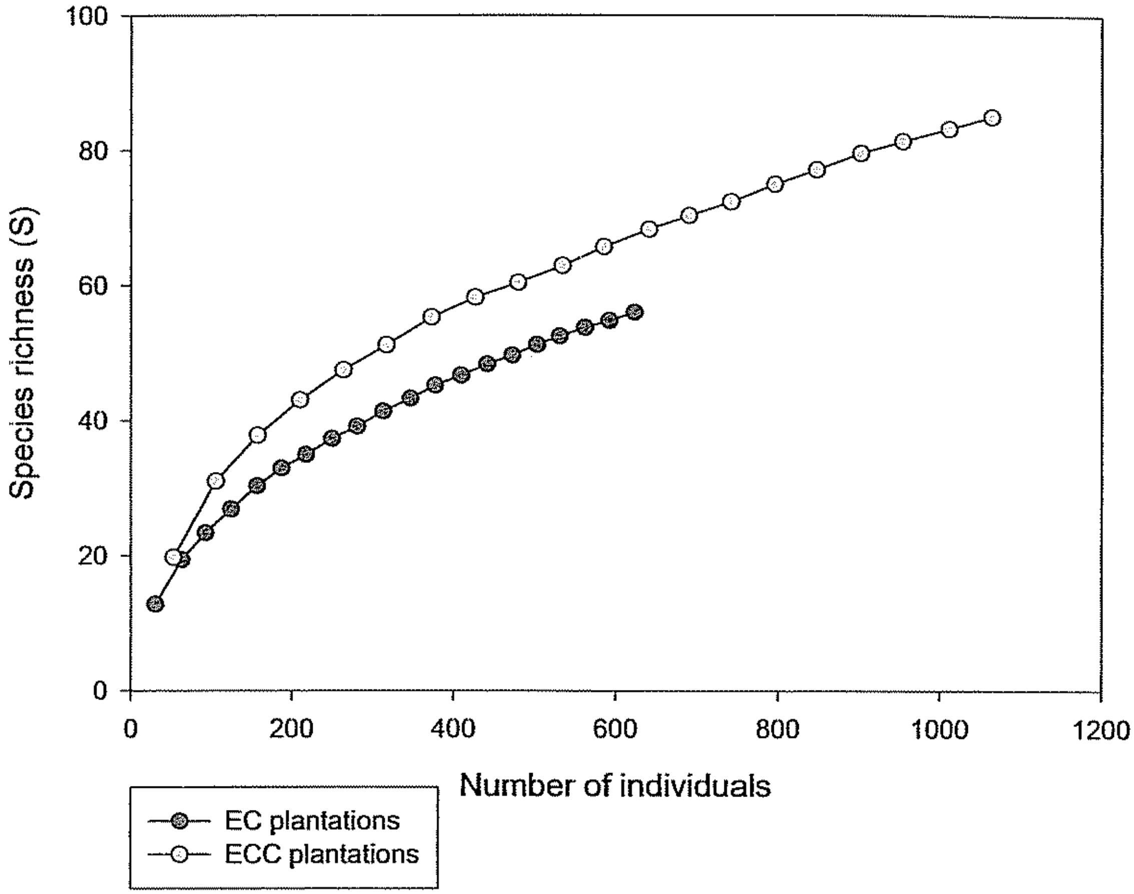


Figure 12. Species accumulation curves for birds in *Erythrina poeppigiana* (EC) and *Eryrthrina poeppigiana – Cordia alliodora* (ECC) coffee plantations in the TJBC, Costa Rica.

Although the species accumulation curve did not level off, the majority of the expected number of species were found in EC and ECC. The sampling efficiency for EC plantations was 61.4 % and 70 % in ECC plantations when observed species and the expected number of species were compared using species richness estimators ACE, ICE and CHAO (Table 12).

Table 12. Parametric and non-parametric estimates of the total species richness present in *Erythrina poeppigiana* (EC) and *Erythrina poeppigiana* – *Cordia alliodora* (ECC) coffee plantations. Percent of sampling efficiency was calculated from the observed number of species and the mean number of expected species.

Coffee plantation	Observed species	Expected species richness			Mean # of expected species	% Sampling efficiency
		ACE	ICE	CHAO1		
EC	56	77.58	106.01	92.1	91.2	61.4
ECC	85	116.08	113.41	135.06	121.5	70

ECC plantations had a significantly greater Shannon-Wiener ($p=0.0001$) and Margaleff ($p=0.0001$) indices than in EC coffee plantations. The Simpson Index (D) was significantly greater ($p=0.0094$) in EC plantations than in ECC plantations. There were no significant differences ($p= 0.2953$) in eveness (E) between both types of plantations (Table 13).

Table 13. Abundance, species richness, mean values (± SE) of Shannon-Wiener, Simpson, Eveness and Margaleff indices for bird communities present in *Erythrina poeppigiana* (EC) and *Erythrina poeppigiana* – *Cordia alliodora* (ECC) coffee plantations. Letters indicate significant differences across EC and ECC plantations ($p<0.05$)

Diversity Index	EC (n=20 farms)	ECC (n=20 farms)	T-value	P-value
Abundance	31.15 ± 2.43 b	53.20 ± 3.89 a	4.81	0.0001
Species richness	13.15 ± 0.78 b	19.65 ± 1.13 a	4.73	0.0001
Shannon- Wiener (H)	2.28 ± 0.06 b	2.68 ± 0.06 a	-4.36	0.0001
Simpson (D)	0.12 ± 0.01 a	0.09 ± 0.01 b	2.77	0.0094
Evenness (E)	0.9 ± 0.01 a	0.91 ± 0.01 a	-1.06	0.2953
Margalef (D_{Mg})	3.54 ± 0.17 b	4.71 ± 0.21 a	-4.37	0.0001

The composition of bird families present in the two types of coffee plantations were very similar. In both cases, most of the species (17.9% in EC plantations and 15.9% in ECC plantations) belonged to the Tyrannidae family. Other common families in the plantation were

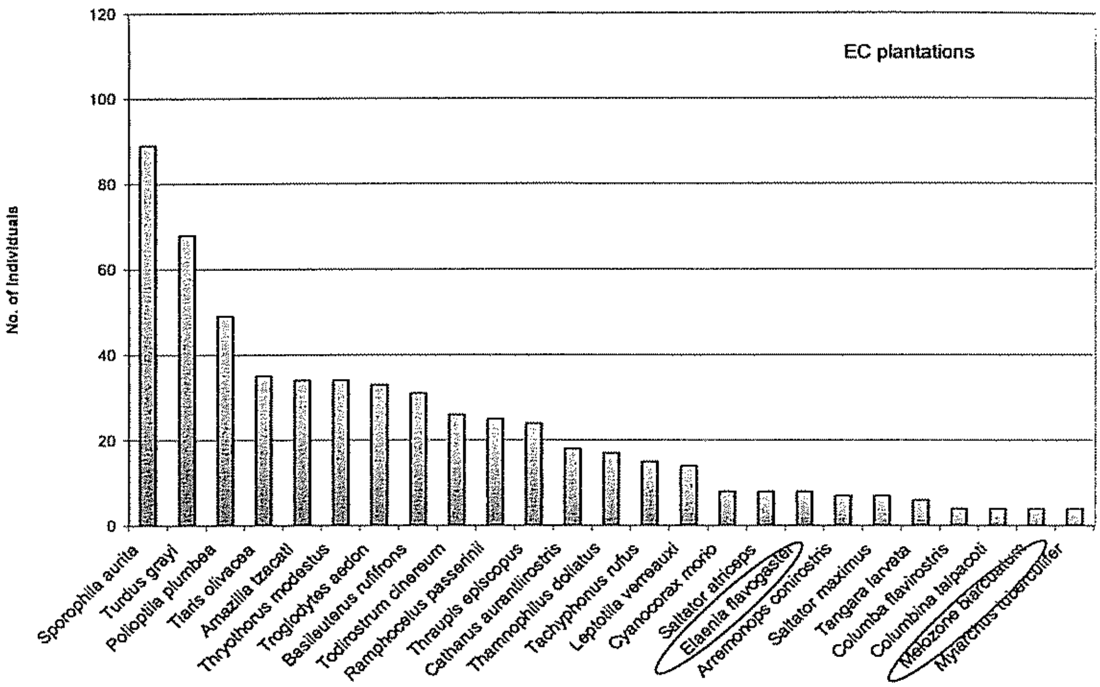
Emberizadae (14.3 % in EC, 11.8 % in ECC plantations) and Thraupidae (12.5 % in EC an 14.1 % in ECC plantations). Two forest generalist families that were present in ECC plantations but not in EC plantations were the Dedrocolaptidae (woodcreepers) and Picidae (woodpeckers) families (Table 14).

Table 14. Composition of bird families based on the number (n) and percent of species and individuals of birds observed in *Erythrina poeppigiana* (EC) and Erythrina poeppigina – Cordia alliodora (ECC) coffee plantations within the TJBC, Costa Rica. Data present the total number of species and individuals observed in 40 point counts per coffee plantation type.

	CE				CEC			
Family	**Species**		**Individuals**		**Species**		**Individuals**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Columbidae	3	5.4	22	3.5	3	3.5	27	2.5
Dendrocolaptidae	0	0.0	0	0.0	3	3.5	22	2.1
Emberizidae	8	14.3	154	24.7	10	11.8	169	15.9
Icteridae	3	5.4	9	1.4	5	5.9	42	3.9
Parulidae	3	5.4	34	5.5	3	3.5	25	2.3
Picidae	0	0.0	0	0.0	5	5.9	28	2.6
Sylviidae	2	3.6	50	8.0	0	0.0	51	4.8
Thraupidae	7	12.5	74	11.9	12	14.1	242	22.7
Trochilidae	0	0.0	34	5.5	5	5.9	70	6.6
Troglodytidae	5	8.9	71	11.4	4	4.7	62	5.8
Turdidae	2	3.6	86	13.8	0	0.0	71	6.7
Tyrannidae	10	17.9	52	8.3	13	15.3	108	10.2
Others	13	23.0	38	6.0	22	25.9	147	13.9
TOTAL	**56**	**100**	**624**	**100**	**85**	**100**	**1,064**	**100**

Both types of coffee plantations shared the same dominant species: *Sporophila aurita*. Other abundant species observed in EC plantations included *Turdus grayi* (68 individuals) and *Polioptila plumbea* (49 individuals) while in ECC plantations *Thraupis episcopus* (91 individuals) and *Turdus grayi* (69 individuals) were also common. Of the 25 most common species, *Elaenia flavogaster* and *Melozone biarcuatum* were the only two species present in EC and not ECC plantations whereas *Pionus senilis* and *Myiodynastes luteiventris* were two abundant species present in ECC and not EC plantations.

a)



b)

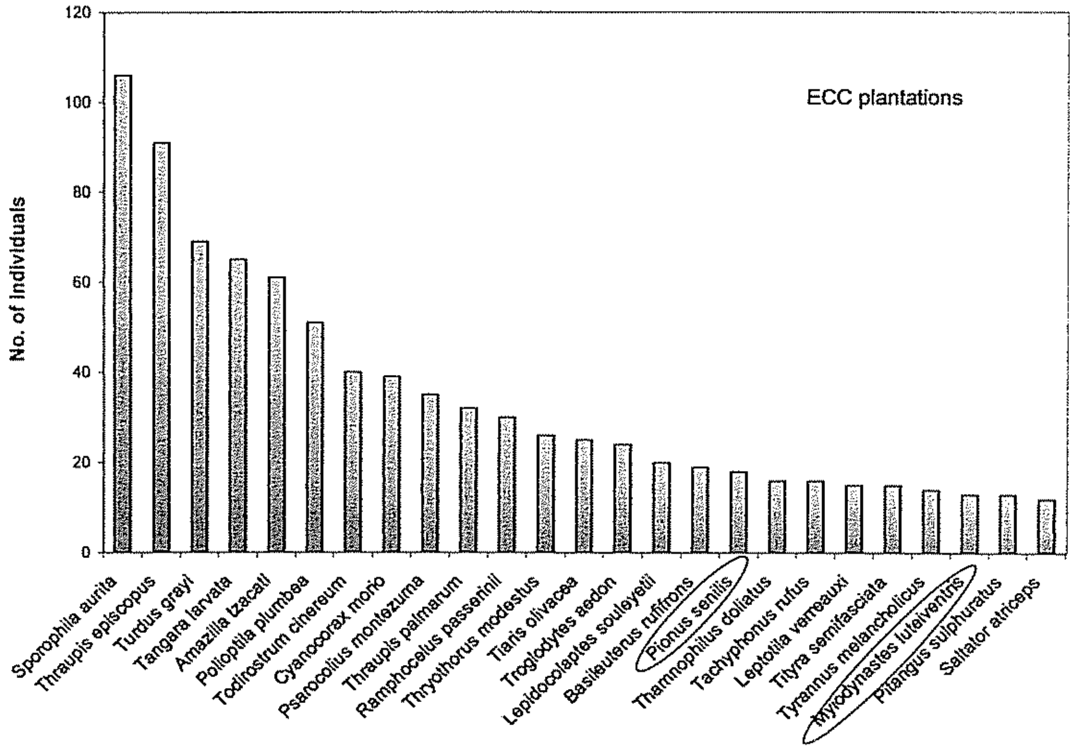


Figure 13. Rank – abundance curves of the most abundant species (N=25) and number of individuals observed in a) *Erythrina poepp*igiana coffee (EC) plantations and b) *Erythrina poeppigiana – Cordia alliodora* (ECC) coffee plantations. Data represent the total number of individuals from 40 point

counts in 20 farms for each coffee farm type. Common species that were observed only in one type of coffee plantation are circled in red.

There were some differences in the composition of bird feeding guilds in the two types of plantations. Both EC and ECC plantations were dominated by insectivorous and omnivorous bird species. There was a significant greater abundance of frugivorous (p = 0.0145), insectivorous (p= 0.0064) and nectivorous (p=0.0328) birds in ECC plantations than in EC plantations. No significant differences were found in granivorous bird abundance (p = 0.7231) between both types of coffee plantations (Table 15).

The t-tests also showed greater species richness of frugivorous (p=0.0038), insectivorous (p=0.0006) and omnivorous (p= 0.0006) birds in ECC compared to EC plantations. No significant differences were found with granivorous (p=0.3002) and nectarivorous (p=0.1344) birds between both types of coffee plantations.

Table 15. Feeding guild composition in terms of (a) mean number of individuals and (b) mean species richness per farm observed in *Erythrina poeppigiana* coffee (EC) plantations and *Erythrina poeppigiana – Cordia alliodora* coffee (ECC) plantations coffee plantations. Feeding guilds was compiled from Stiles and Skutch (1982) Different letters represent significant differences across the two types of coffee plantations ($p<0.05$).

a) Abundance of individuals

	EC plantation			**ECC plantation**		
Feeding guild	**N**	**Mean ± SE**	**%**	**N**	**Mean ± SE**	**%**
Canivores	0	0a	0	6	0.30 ± 0.18 a	0.6
Frugivores	7	0.35 ± 0.21 a	1.1	42	2.10 ± 0.63 b	3.9
Granivores	115	5.75 ± 1.02 a	18.5	127	6.25 ± 0.96 a	11.9
Insectivores	239	11.95 ± 1.17 a	38.4	390	19.4 ± 2.25 b	36.7
Nectarivores	36	1.75 ± 0.34 a	5.8	70	3.35 ± 0.63 b	6.7
Omnivores	225	11.30 ± 1.15 a	36.1	429	21.45 ± 1.99 b	40.3

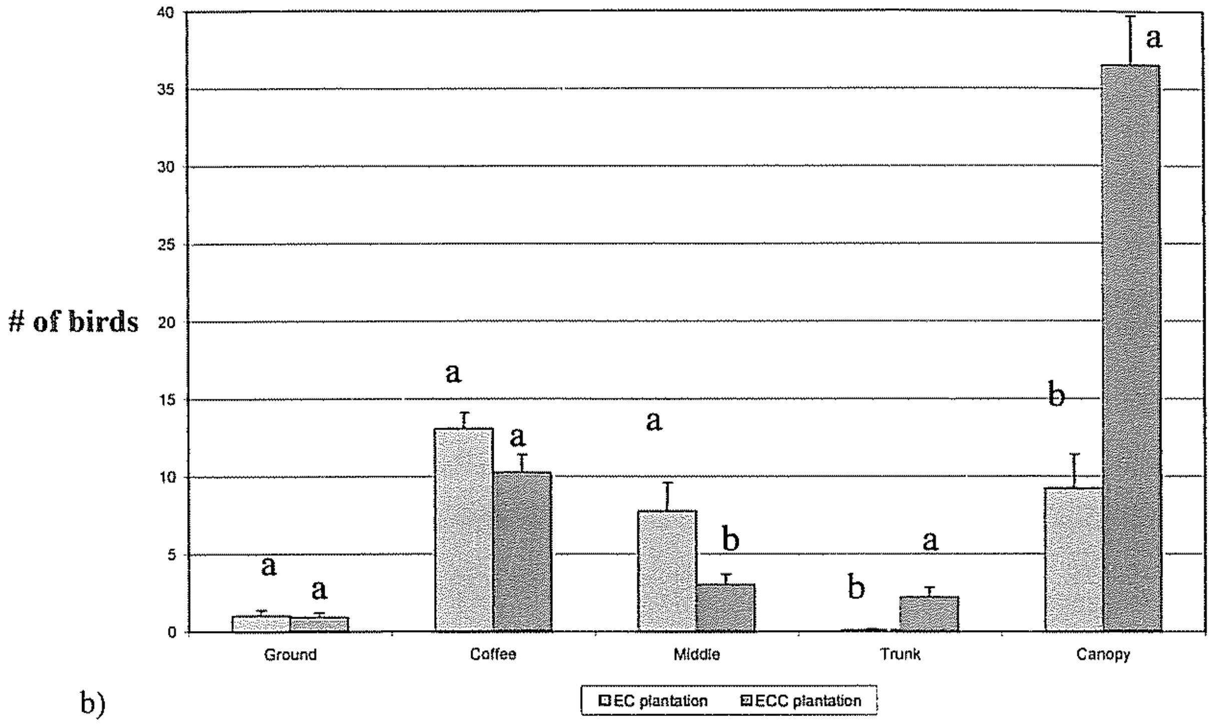
b) Species richness

	EC plantation			ECC plantation		
Feeding guild	**N**	**Mean ± SE**	**%**	**N**	**Mean ± SE**	**%**
Carnivores	0	0 a	0	1	0.13 ± 0.08 a	1.1
Frugivores	4	0.2 ± 0.09 a	7.1	9	1.05 ± 0.18 b	10.6
Granivores	6	1.7 ± 0.19 a	10.7	6	1.4 ± 0.21 a	7.1
Insectivores	28	5.55 ± 0.39 a	50.0	41	8.95 ± 0.79 b	48.2
Nectarivores	2	0.95 ± 0.09 a	3.6	5	1.2 ± 0.14 b	5.9
Omnivores	16	4.65 ± 0.36 a	28.6	23	6.7 ± 0.41 b	27.1

Strata use by birds differed between the coffee plantations (Figure 14). In EC plantations the majority of individuals (13.1 ± 1 per farm) and species (6.45± 0.41 per farm) of birds used the coffee strata where in ECC plantations the majority of individuals (36.55 ± 14.24 per farm) and species (13.65 ± 4.42 per farm) used the upper canopy strata of *Cordia alliodora* (≥ 15 m). A significantly greater mean number of individuals and species used the middle (p=0.019 for individuals, p= 0.0024 for species), trunk (p = 0.0021 for individuals, p=0.0001 for species) and canopy strata (p =0.0001 for individuals, p=0.0001 for species) in ECC plantations compared to EC plantations (Figure 14).

No significant differences were found in terms of mean number of individuals and species for birds found in ground (p=0.8169 for individuals, p = 0.9999 for species) and coffee strata (p=0.0681 for individuals, p= 0.3165 for species) between both types of plantations.

a)



b)

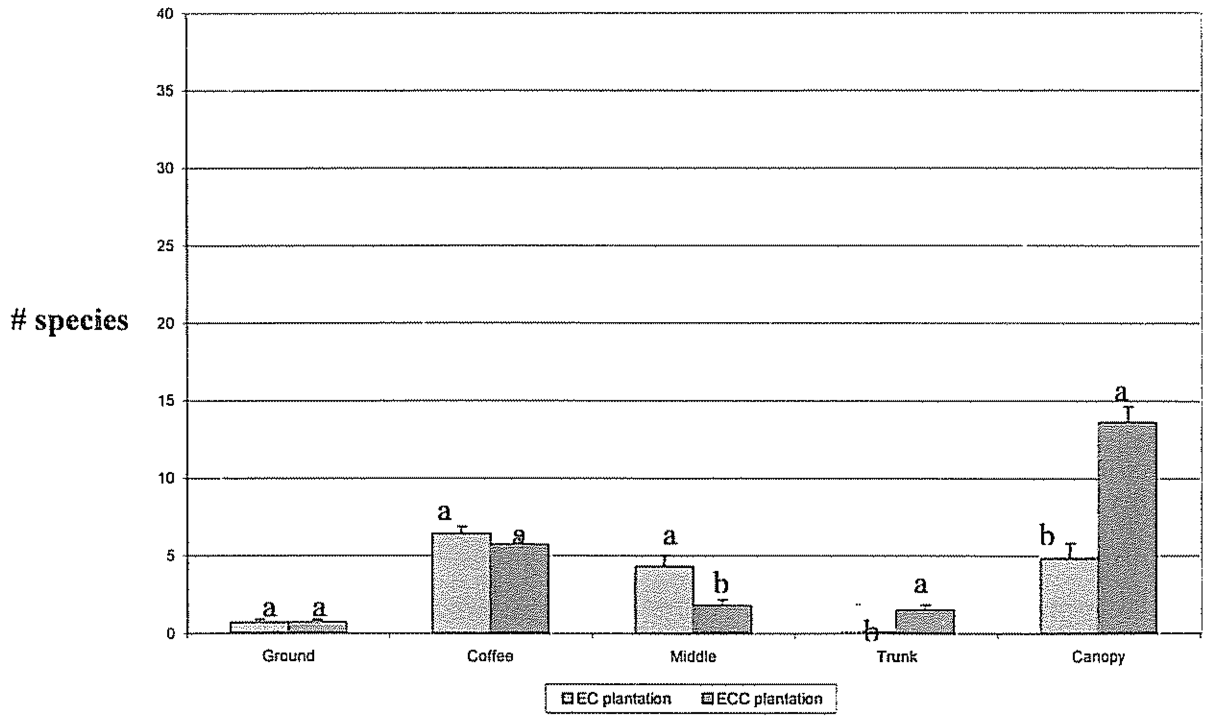


Figure 14. Mean number of individuals (a) and (b) species of birds per farm observed at different strata levels: ground, coffee, middle, trunk and canopy in *Erythrina poeppigiana* (EC) and *Erythrina poeppigiana – Cordia alliodora* (ECC) coffee plantations. Different letters represent significant differences between EC and ECC plantations with a given strata ($p<0.05$).

The most common bird activity was perching (47.6% of all the individuals) followed by singing (45.5% of all the birds observed) (Table 16). The black-cheeked woodpecker (*Melanerpes pucherani)* was the only bird species that was observed copulating and the black-striped sparrow (*Arremonops conirostris*), yellow-faced grassquit (*Tiaris olivacea*), blue-gray tanager (*Thraupis episcopus*), rufous-tailed hummingbird (*Amazilia tzacatl*), clay-colored robin (*Turdus grayi*) and the common pauraque (*Nyctidromus albicollis*) were the only species observed nesting in coffee plantations.

Table 16. Main bird activities that were registered in coffee plantations within the TJBC, Costa Rica (n = 1687 birds).

Activity	**# of birds**	**%**
Copulating	4	0.2
Nesting	9	0.5
Feeding	75	4.4
Singing	768	45.5
Perching	803	47.6

ECC plantations registered a significantly greater mean number of individuals ($p=0.0027$) and species ($p=0.0023$) that were singing than in EC plantations. A greater number of individuals ($p=0.0001$) and species ($p=0.0001$) that perched were also found in ECC coffee plantations. However, there were no significant differences in the number of individuals ($p=0.4180$) and species ($p=0.2957$) that were feeding and birds that were nesting ($p= 0.32$ mean number of individuals, $p=0.2678$ mean number of species).

There were significant differences in bird forest dependency between the two types of coffee plantations (Table 17). Most of the birds observed in coffee plantations were generalist birds

(Class 3). ECC plantations had a significantly greater number of individuals and species richness of generalist (Class 3) and forest generalist (Class 2) birds than EC plantations (Table 15). They also had a high species richness (p=0.0085) of forest specialist birds (Class 1), however, no significant differences were found in the abundance of forest specialists individuals (p=0.7011).

Table 17. Mean number of a) individuals and b) species (±SE) of birds of different forest dependencies observed in each *Erythrina poeppigiana* (EC) and *Erythrina poeppigiana – Cordia alliodora* (ECC) coffee plantation in the TJBC, Costa Rica. Dependency classes include: (1) Needs continous forest and forest specialist, (2) Needs patchy forest and forest generalist, (3) Does not need forest to persist and generalist. Different letters represent significant differences (p ≤ 0.05).

a) Abundance

	EC plantations n = 20	**ECC plantations n = 20**
Forest dependency	**Mean ± SE**	**Mean ± SE**
Class 1	0.15 ± 0.08 a	0.10 ± 0.1 a
Class 2	4.50 ± 0.69 b	7.00 ± 0.84 a
Class 3	19.45 ± 1.82 b	28.00 ± 2.61 a

b) Species richness

	EC plantations n = 20	**ECC plantations n = 20**
Forest dependency	**Mean ± SE**	**Mean ± SE**
Class 1	0.05 ± 0.05 b	0.4 ± 0.11 a
Class 2	1.70 ± 0.21 b	3.50 ± 0.34 a
Class 3	7.45 ± 0.51 b	9.60 ± 0.78 a

A hierarchical cluster analysis was performed to define groups of farms based on the composition and relative abundance of bird species in the coffee plantations. The analysis was done by using Sorensen (Bray-Curtis) distance measure and Flexible beta as the linkage method. Farms were separated in two distinct groups. Most of the birds in in EC plantations were associated with group 1, while most of the birds in ECC plantations were associated with group 2. A few EC and ECC plantations were associated together in group 1 which shows that variables other than structural complexity of coffee agroforestry systems might also play a role in defining the structure of bird communities (Figure 15).

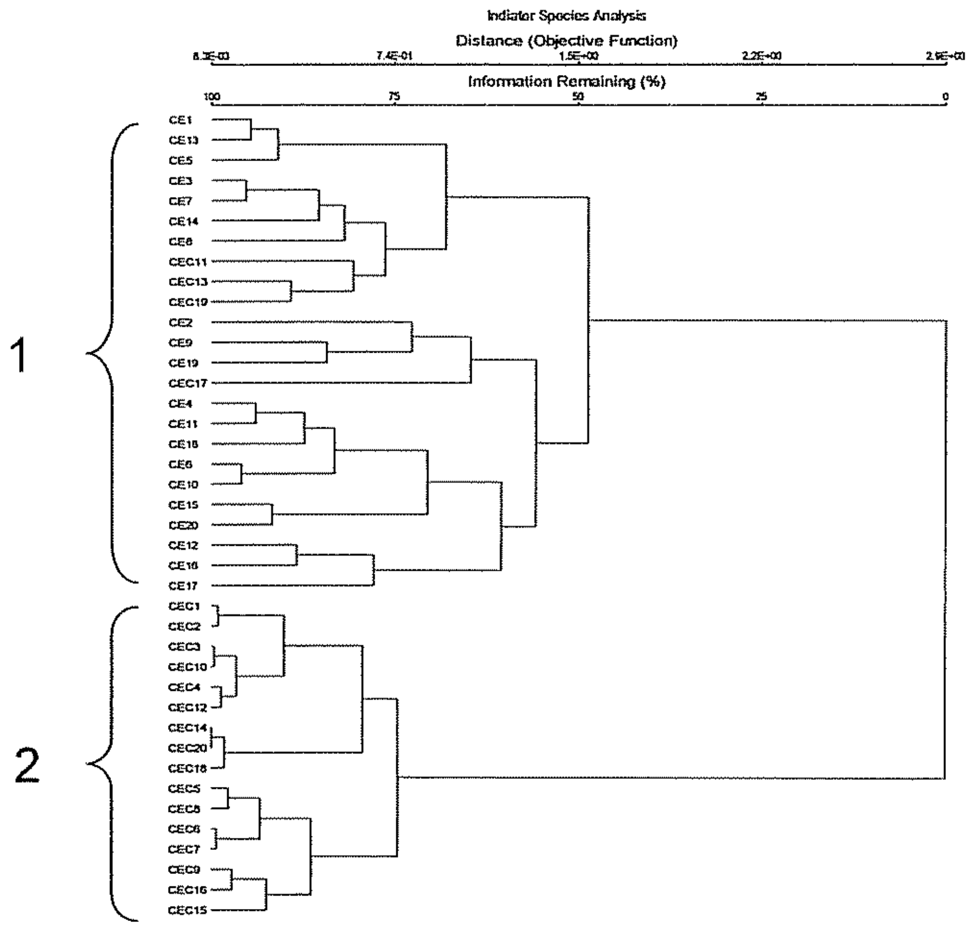


Figure 15. Hierarchical cluster analysis performed to define groups of farms based on composition and relative abundance of bird species that were observed in *Erythrina poeppigiana* (CE) and *Erythrina poeppigiana – Cordia alliodora* (CEC) coffee plantations. Cluster analysis was performed with the program PC Ord (McCune *et* al. 1999). Codes refer to individual coffee farms. A list of the farms is found in Appendix 2.

The Indicator Species Analysis by Dufrene and Legendre's method was used to identify the most characteristic species present for each of the farm clusters. Species with the highest indicator values (IV) and p<0.05 were considered the most representative species for each of the groups. The results of this analysis showed that the most characteristic species found in EC coffee plantations (Group 1) was *Basileuterus rufifons*. A total of twelve indicator species were found for group 2 (ECC coffee plantations). These included: *Thraupis episcopus, Lepidocolaptes souleyetii, Cyanocorax morio, Contopus cinereus, Tangara larvata, Psarocolius Montezuma,* (Table 18). *Thraupis episcopus* was considered as the most characteristic species for this group and had the highest IV value (IV = 53.3; p = 0.003).

Table 18. Indicator species associated with different clusters of coffee farms. Higher indicator values (IV) indicates most characteristic species found in a single cluster or group.

Species	Common name	Group	IV	p-value
Basileuterus rufifons	Rufous-capped warbler	1	55.7	0.01
Thraupis episcopus	Blue-gray tanager	2	65.3	0.002
Lepidocolaptes souleyetii	Streak-headed woodcreeper	2	57.2	0.001
Cyanocorax morio	Brown jay	2	52.2	0.003
Contopus cinereus	Tropical pewee	2	51.7	0.02
Tangara larvata	Golden-hooded tanager	2	50.9	0.011
Psarocolius montezuma	Montezuma oropendola	2	49.4	0.003
Pionus senilis	White-fronted parrot	2	35.4	0.012
Thraupis palmarum	Palm tanager	2	34.9	0.032
Tityra semifasciata	Masked tityra	2	31.6	0.033
Melanerpes hoffmani	Hoffmann's woodpecker	2	31.2	0.007
Tyrannus melancholicus	Tropical kingbird	2	29.4	0.034
Melanerpes pucherani	Black-cheeked woodpecker	2	25	0.027

4.2.4. Comparison of bird communities in coffee plantations and forest fragments

A total of 93 individuals and of 40 different species (17 families) were registered in the 10 points that were located in the forests of Guayabo National Monument, La Isabel, Chitaría, La Marta and Pejibaye. This list was complemented with additional bird species that were observed outside of the point counts, for a total of 143 species (Appendix 5). The mean number of bird species in each forest sites was lower (12 ± 0.55) compared to ECC (20 ± 1.13) and EC (13 ± 0.78) coffee plantations (Figure 16).

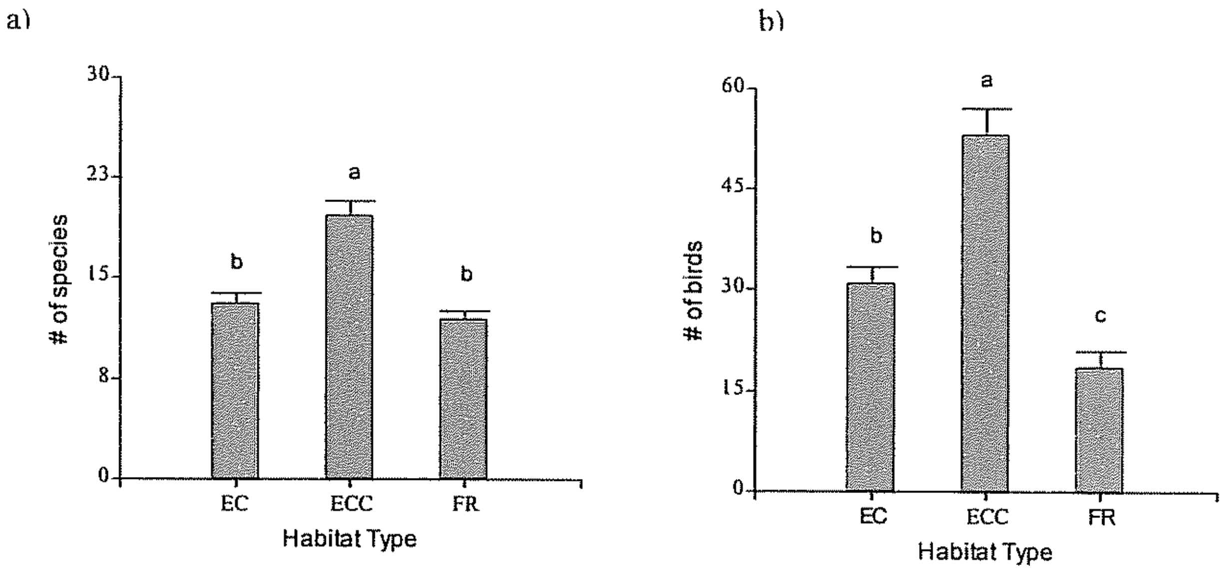


Figure 16. a) Mean number of bird species and b) bird abundance observed in *Erythrina poeppigina* (EC), *Erythrina poeppigiana – Cordia alliodora* (ECC) coffee plantations and forest sites (FR).

The species accumulation curve showed differences in bird species richness between the forest sites and the two types of coffee plantations. A much lower sampling efficiency was obtained for the forests (56%) compared to EC (61.4%) and ECC (70%) coffee plantations due to a lower sampling effort in forests. However, it is clear that the rate of species accumulation in forests is greater than that in EC and ECC plantations. There is a need to increase sampling much more than for each of the two types of coffee plantations to reach the stabilization point (Figure 17).

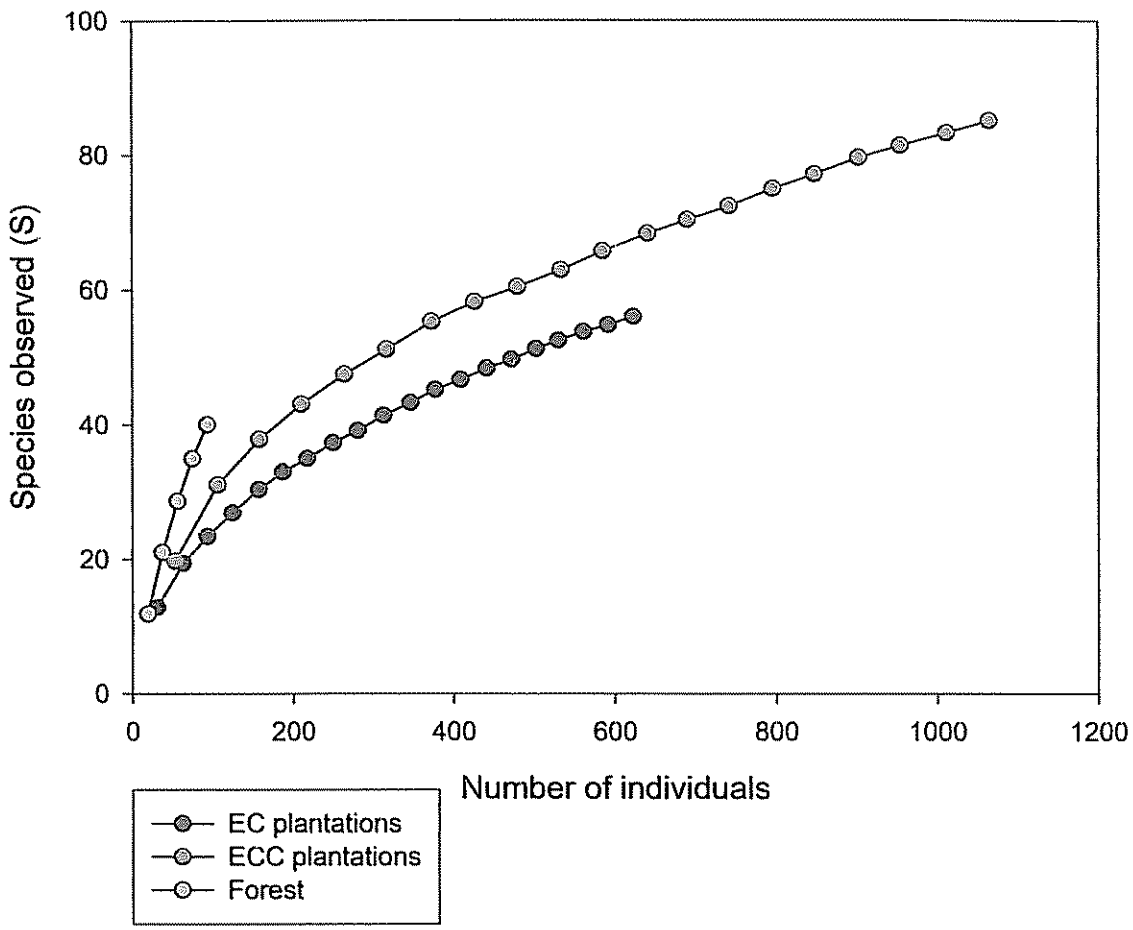


Figure 17. Species accumulation curves for birds in *Erythrina poeppigiana* (EC) and *Eryrthrina poeppigiana – Cordia alliodora* (ECC) coffee plantations and forest sites.

Of the 184 species of birds observed in coffee plantations and forest sites, 20 species were observed only in ECC plantations, 12 of them only in EC plantations and 83 species only in forest sites. A total of 29 species were shared between all the three sites and 10 of them were shared between EC and ECC coffee plantations (Figure 18). ECC plantations shared more species (26 species) with forest than EC plantations (5).

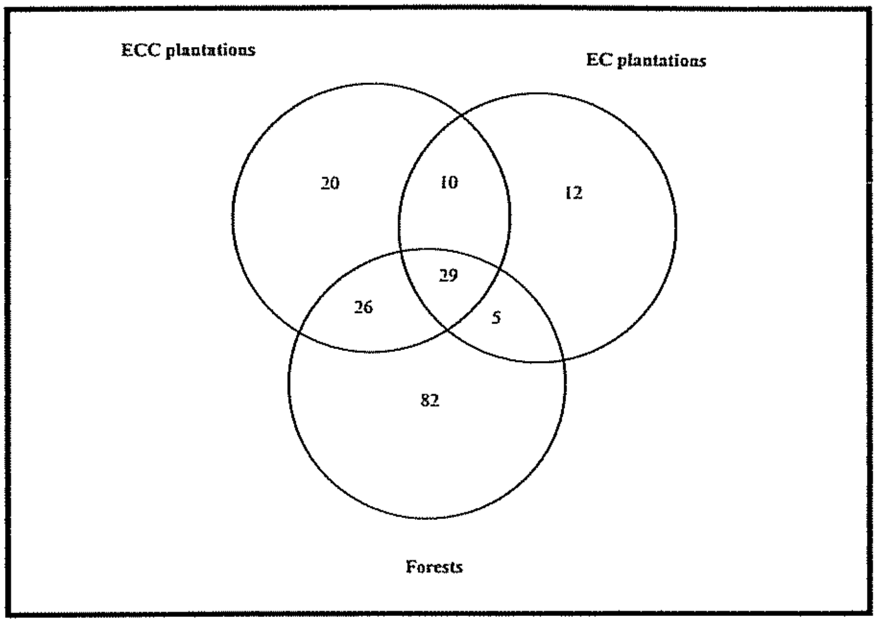


Figure 18. Venn diagram showing the number of shared species between *Erythrina poeppigiana* (EC), *Erythrina poeppigiana – Cordia alliodora* (ECC) coffee plantations and forest sites. Data represent the total number of bird species observed in each habitat and include data from point counts and observations outside point counts.

Forest sites were also dominated by insectivorous and omnivorous birds, nevertheless, the abundance and species richness of frugivorous and nectarivorous birds were greater in forest sites than in EC and ECC plantations (Table 19).

Table 19. (a) Abundance and (b) species richness of bird feeding guilds observed in Erythrina poeppigiana coffee (EC) plantations, Erythrina poeppigiana – Cordia alliodora coffee (ECC) plantations and forest sites. Feeding guilds were compiled from Stiles and Skutch (1982).

a) Abundance of individuals

	EC plantation		ECC plantation		Forest sites	
Feeding guild	**N**	**%**	**N**	**%**	**N**	**%**
Carnivores	0	0	6	0.6	0	0
Frugivores	7	1.1	42	3.9	11	11.8
Granivores	115	18.5	127	11.9	0	0
Insectivores	239	38.4	390	36.7	43	46.2
Nectarivores	36	5.8	70	6.7	18	19.4
Omnivores	225	36.1	429	40.3	21	22.6

b) Species richness

	EC plantation		ECC plantation		Forest sites	
Feeding guild	**N**	**%**	**N**	**%**	**N**	**%**
Carnivores	0	0	1	1.1	0	0
Frugivores	4	7.1	9	10.6	6	15
Granivores	6	10.7	6	7.1	0	0
Insectivores	28	50	41	48.2	18	45
Nectarivores	2	3.6	5	5.9	6	15
Omnivores	16	28.6	23	27.1	10	25

The most common bird species observed in forest fragments were the white-breasted woodwren (*Henicorhina leucosticta*), the green hermit (*Phaethornis guy*) and the black-faced anththrush (*Formicarius analis*). Of the 143 species observed in forest fragments, seven of them are currently classified as threatened species because their populations have been reduced by habitat reduction, poaching and hunting (IUCN 1997; INBIO 2004). These threatened species were: the semiplumbeous hawk (*Leucopternis semiplumbea*), the crested guan (*Penelope purpurascens*), the sunbittern (*Eurypyga helias*), the orange-bellied trogon (*Trogon aurantiventris*), the crimson-fronted parakeet (*Aratinga finschi*), the white-crowned parrot (*Pionus senilis*) and the gray-headed manakin (*Piprites griseips*). Of these species, the crimson-fronted parakeet (*Aratinga finschi*) and the white-crowned parrot (*Pionus senilis*) were also found in coffee plantations.

The composition of bird communities that were present in forest fragments and coffee plantations was very different. The Jaccard similiarity coefficient for coffee plantations and forests was only 0.11. When comparing each type of coffee plantation with forests, the Jaccard similiarity coefficient was higher in ECC plantation (0.23) compared to EC plantations (0.02). Low Jaccard similiarity coefficients indicated that relatively few species were shared with the forest fragments. A similar pattern was shown with the results of the Sorensen similiarity coefficient. The Sorensen similiarity coefficient for coffee plantations and forest was 0.23; for

ECC coffee plantations and forest was 0.22 and for EC coffee plantations the Sorensen similiarity coefficient was 0.05.

4.3 Relationship between the surrounding landscape and species diversity and abundance in coffee plantations

A Pearson correlation analysis was performed to examine relationships between the spatial co-variables of 500, 1000 and 1500 m with species richness and abundance. Significant correlations were found between percent of forest cover at 500 and 1000 m (p=0.90), 500 and 1000 m (p=0.78) and 1000 and 1500 (p =0.95). Since correlations were significant, each co-variable was analyzed separately for the analysis of co-variance (ANCOVA) and multiple linear regressions.

The analysis of co-variance (ANCOVA) showed that the plantation type (factor) had a significant effect in overall bird abundance and species richness at 500, 1000 and 1500 m. The % of surrounding forest cover at 500 m significantly affected bird abundance (F=7.46; p = 0.0096) and the Shannon Diversity Index (F = 4.51; p = 0.0405) and differences for species richness were close to significance (F = 3.71; p = 0.0619). Forest cover at 1000 m also affected bird abundance (F = 5.32; p = 0.0268), species richness F = 4.47; p = 0.0412) and in the Shannon Diversity Index (F = 7.07; p = 0.0115). However, the % of forest cover at 1500 m did not significantly affected bird abundance (F = 2.91; p = 0.0964) There were also significant differences in species richness (F = 4.35; p = 0.044) and Shannon diversity Index (F = 7.81; p = 0.0082) (Table 20).

Table 20. Analysis of co-variance (ANCOVA) between overall bird abundance, species richness and Shannon Diversity Index with surrounding forest cover at a distance of a) 500, b) 1000 and c)1500 m.

a) Forest cover at 500 m

	Bird abundance	**Species richness**	**Shannon**
Model	0.0001*	0.0001*	0.0001*
Plantation type (factor)	0.0001*	0.0001*	0.0001*
% forest cover (co-variable)	0.0096*	0.0619	0.0405*
Slope	-0.33	-0.07	-0.01

* Significant differences (p≤ 0.05)

b) Forest cover at 1000 m

	Bird abundance	Species richness	Shannon
Model	0.0001*	0.0001*	0.0001*
Plantation type (factor)	0.0001*	0.0001*	0.0001*
% forest cover (co-variable)	0.0268*	0.0412*	0.0115*
Slope	-0.31	-0.09	0.0115

* Significant differences ($p \leq 0.05$)

c) Forest cover at 1500 m

	Bird abundance	Species richness	Shannon
Model	0.0001*	0.0001*	0.0001*
Plantation type (factor)	0.0001*	0.0001*	0.0001*
% forest cover (co-variable)	0.0964	0.044*	0.0082*
Slope	-0.25	-0.09	-0.01

* Significant differences ($p \leq 0.05$)

Bird abundance and species richness for the different bird forest dependency classes were also compared with surrounding forest cover at distances of 500, 1000 and 1500 m.

The results of the ANCOVA showed that for forest specialist birds the type of plantation did not have a significant effect in bird abundance and species richness but the % of forest cover had a significant effect in bird abundance and species richness. Bird abundance increased significantly with increasing surrounding forest cover at 500 m ($F = 13.59$; $p=0.007$), 1000 m ($F=9.62$; $p=0.0037$) and at 1500 m ($F = 8.9$; $p=0.005$). Species richness also increased with increasing surrounding forest cover at 500 m ($F = 12.11$; $p =0.0013$), 1000 m ($F = 9.25$; $p =0.0043$) and 1500 m ($F = 9.78$; $p =0.0034$) (Table 21).

Table 21. Analysis of co-variance (ANCOVA) of forest specialist birds between bird abundance and species richness with surrounding forest cover at a distances of 500, 1000 and 1500 m.

	% of forest cover at 500 m		% of forest cover at 1000 m		% of forest cover at 1500 m	
	Abundance	Species richness	Abundance	Species richness	Abundance	Species richness
Model	0.0028*	0.0053*	0.0126*	0.0161*	0.0168*	0.0131*
Plantation type (factor)	0.6089	0.9999	0.6233	0.9999	0.626	0.9999
% forest cover (co-variable)	0.0007*	0.0013*	0.0037*	0.0043*	0.005*	0.0034*
Slope	0.01	0.01	0.01	0.01	0.01	0.01

* Significant differences (p≤ 0.05)

In the case of forest generalist birds (Table 22) the plantation type had a positive effect only for species richness with surrounding forest cover at 500, 1000 and 1500 m. There were also no significant differences in bird abundance with surrounding forest cover at 500 m (F = 0.14; p =0.7056), at 1000 m (F = 0.06; p =0.8064) and at 1500 m (F = 0.06; p =0.8031). Species richness was also not significant with forest cover at 500 m (F = 0.01; p =0.9247), at 1000 m (F = 0.45; p =0.5062) and at 1500 m (F= 0.54; p =0.4664).

Table 22. Analysis of co-variance (ANCOVA) of forest generalist birds between bird abundance and species richness with surrounding forest cover at a distances of 500, 1000 and 1500 m.

	Forest cover at 500 m		Forest cover at 1000 m		Forest cover at 1500m	
	Abundance	Species richness	Abundance	Species richness	Abundance	Species richness
Model	0.2566	0.006*	0.2676	0.0048*	0.2682	0.0046*
Plantation type (factor)	0.1102	0.0015*	0.1106	0.0014*	0.1106	0.0014*
% forest cover (co-variable)	0.7056	0.9247	0.8064	0.5062	0.8131	0.4664
Slope	0.01	-0.0009	-0.01	-0.01	-0.01	-0.01

* Significant differences (p≤ 0.05)

Finally for generalist bird species (Table 23) the plantation type had a negative effect in the bird abundance and species richness. Bird abundance also decreased with increasing surrounding forest cover at 500 m (F = 7.72; p =0.0085) and at 1000 m (F = 4.9; p =0.0331) but there were no significant differences at 1500 m (F = 3.44; p =0.0715). Species richness also significantly decreased with increasing surrounding forest cover at 500 m ($F = 7.41$; $p=0.0154$) and at 1000 m ($F = 3.93$; $p = 0.0538$) but no significant differences were found with surrounding forest cover at 1500 m ($F = 2.92$; $p = 0.0957$).

Table 23. Analysis of co-variance (ANCOVA) of generalist birds between bird abundance and species richness with surrounding forest cover at a distances of 500, 1000 and 1500 m.

	Forest cover at 500 m		**Forest cover at 1000 m**		**Forest cover at 1500 m**	
	Abundance	**Species richness**	**Abundance**	**Species richness**	**Abundance**	**Species richness**
Model	0.001	0.0027	0.0034	0.0083	0.0065	0.0131
Plantation type (factor)	0.0048	0.0097	0.0062	0.0118	0.0071	0.0128
% forest cover (co-variable)	0.0085	0.0154	0.0331	0.0548	0.0715	0.0957
Slope	-0.22	-0.06	-0.2	-0.05	-0.18	-0.05

* Significant differences ($p \leq 0.05$)

Simple linear regressions was performed on bird abundance and species richness with percent of forest to compare differences between the overall bird community and forest birds (forest specialists) that were present in coffee plantations. The results showed a significant negative relationship between surrounding forest cover at 500 m and bird abundance for all birds ($r^2=0.15$; $p=0.0136$) and a positive relationship with forest specialist birds ($r^2=0.26$; $p=0.0007$). Species richness of all birds also decreased significantly with surrounding forest cover at 500 m ($r^2=0.09$, $p=0.0630$) but increased significantly for forest specialists ($r^2=0.25$; $p= 0.00011$) (Figure 19).

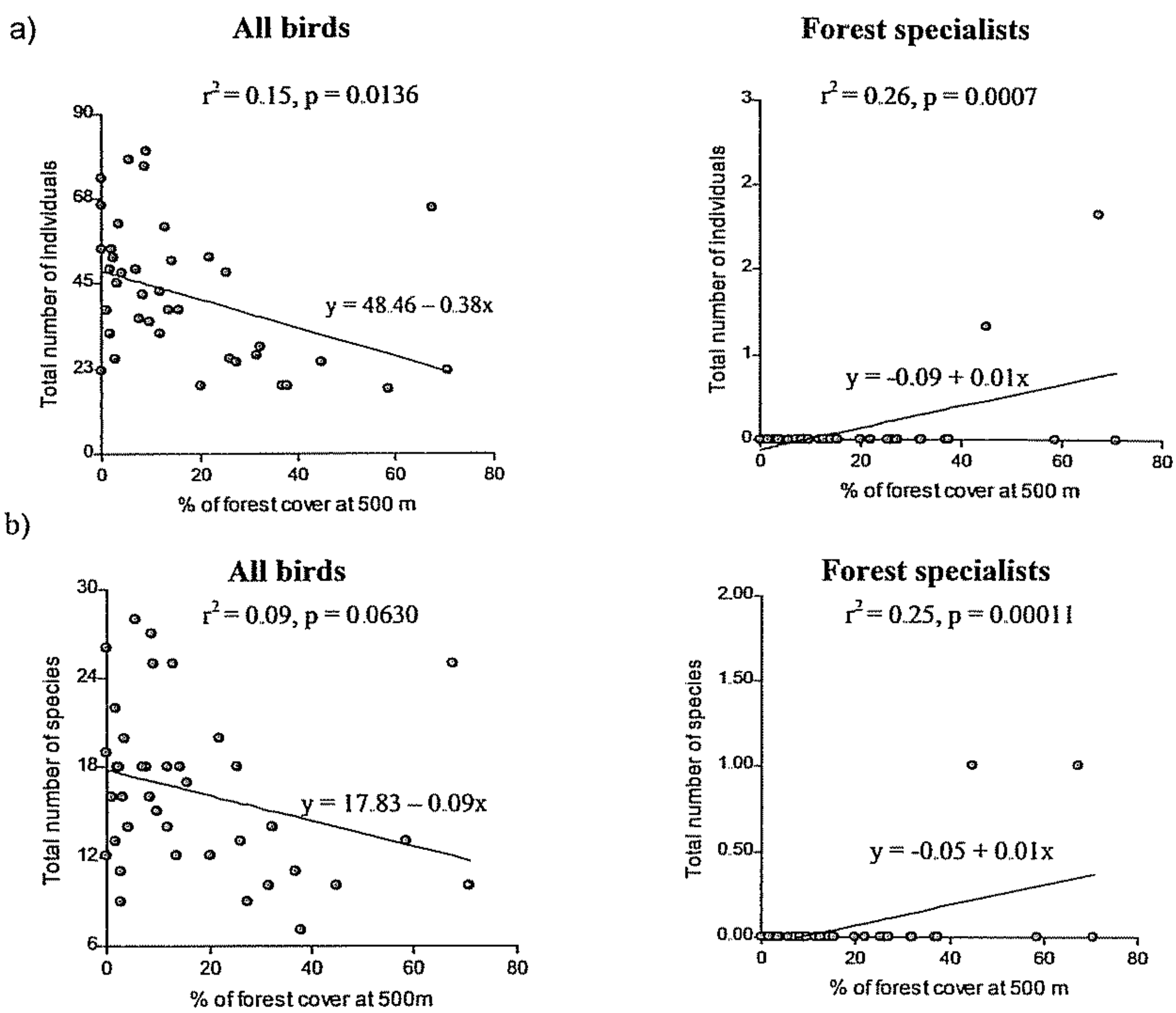


Figure 19. Simple linear regressions showing the distribution in a) the number of birds and b) species richness observed for all the birds and forest specialist birds in *Erythrina poeppigiana* (EC) and *Erythrina poeppigiana – Cordia alliodora* (ECC) coffee plantations with percent of surrounding forest cover at 500 m.

A significant negative relationship was also present between surrounding forest cover at 1000 m and overall bird abundance (r^2=0.15; p=0.0126) and a positive relationship with forest specialist birds (r^2=0.19; p=0.0045). Species richness of all birds also decreased significantly with surrounding forest cover at 1000 m (r^2=0.11, p=0.0367) but increased significantly for forest specialists (r^2=0.20; p= 0.0042) (Figure 20).

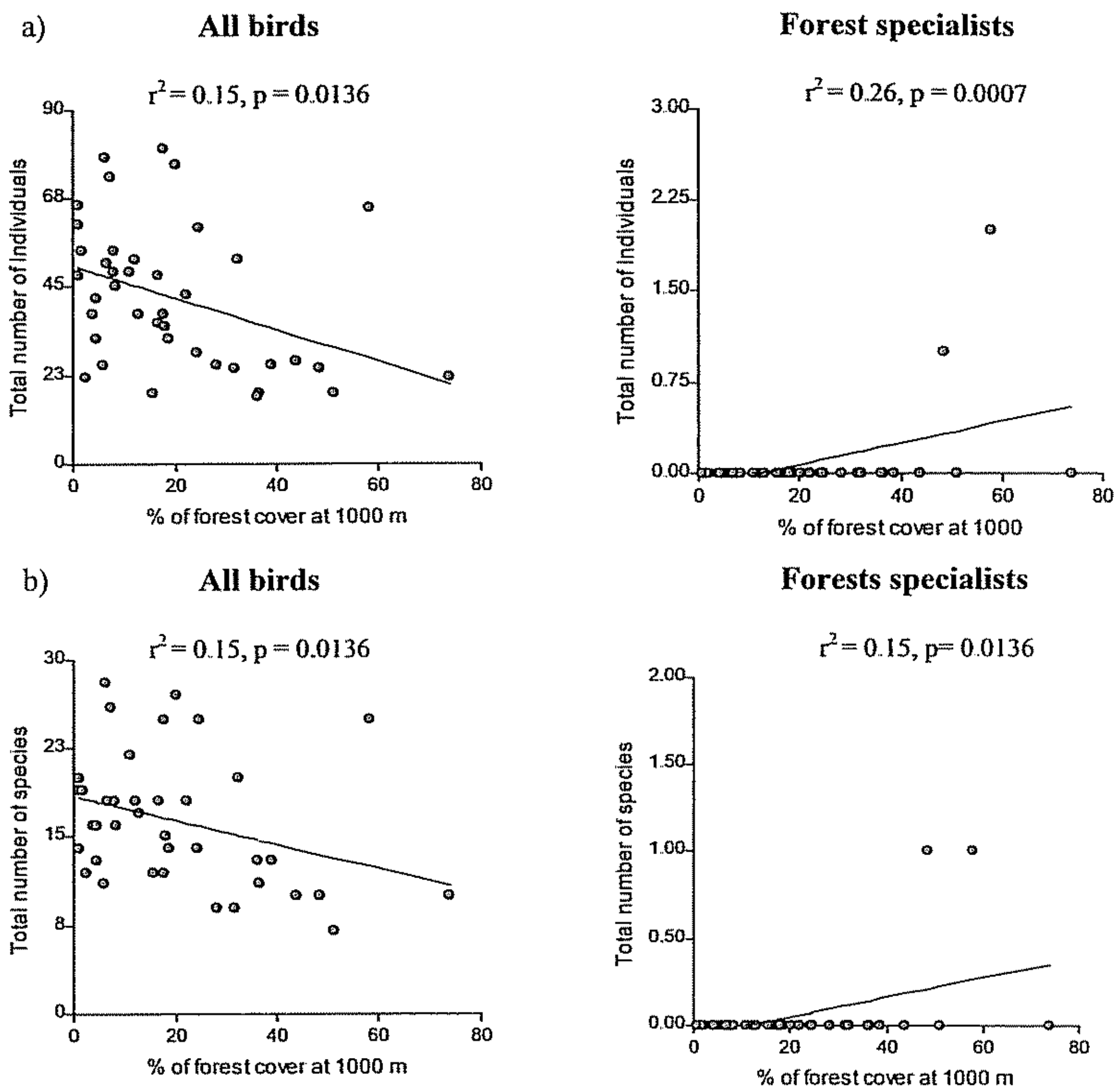


Figure 20. Simple linear regressions showing the distribution in a) the number of birds and b) species richness observed for all the birds and forest specialist birds in *Erythrina poeppigiana* (EC) and *Erythrina poeppigiana* – *Cordia alliodora* (ECC) coffee plantations with percent of surrounding forest cover at 1000 m.

The same negative association was also present between surrounding forest cover at 1500 m and overall bird abundance (r^2=0.14; p=0.0182) as well as a positive association with forest specialist birds (r^2=0.17; p=0.0076). Species richness of all the birds also decreased significantly with surrounding forest cover at 1500 m (r^2=0.12, p=0.0312) but increased significantly for forest specialists (r^2=0.20; p= 0.0037) (Figure 21).

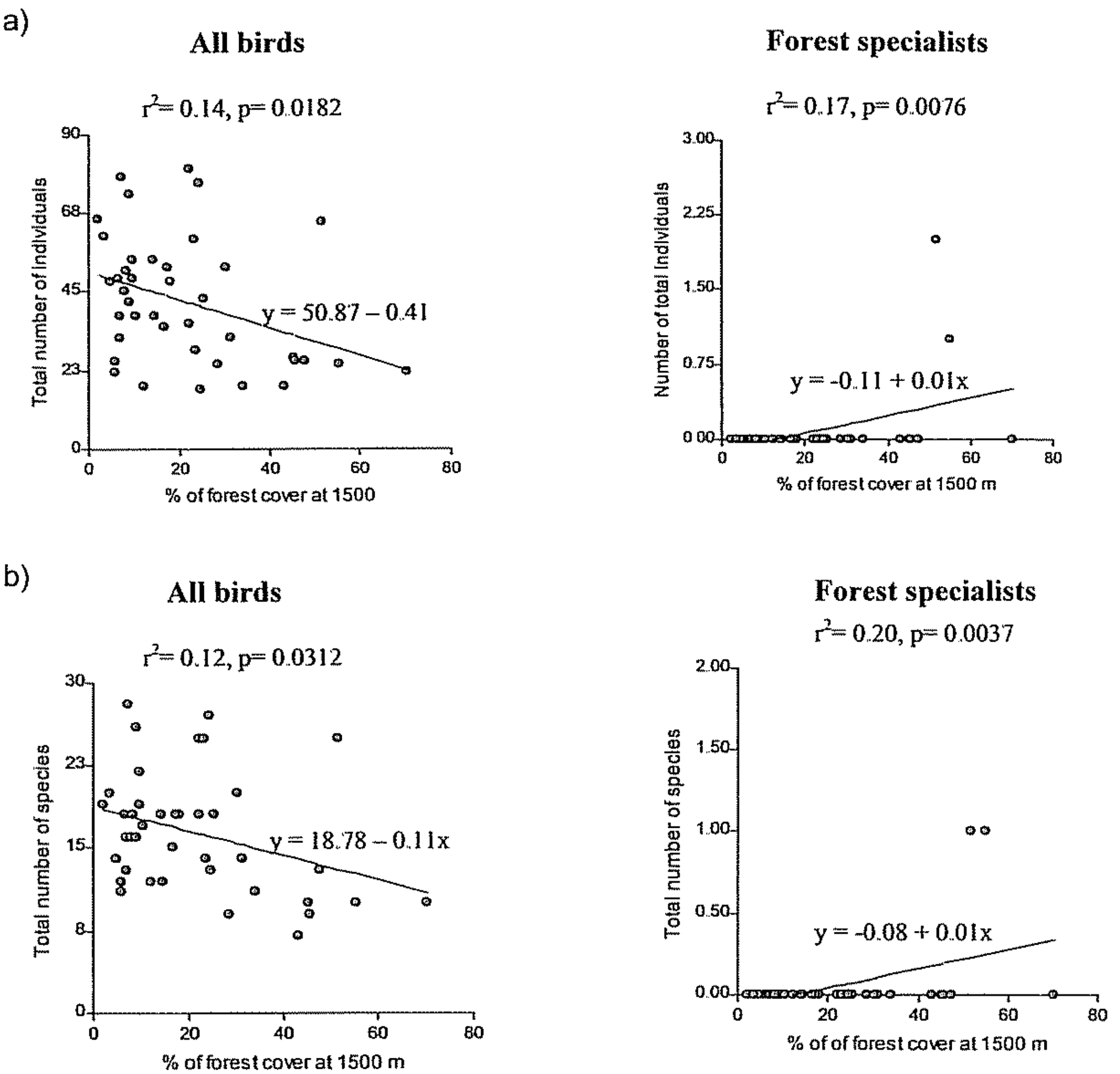


Figure 21. Simple linear regressions showing the distribution in a) the number of birds and b) species richness observed for all the birds and forest specialist birds in *Erythrina poeppigiana* (EC) and *Erythrina poeppigiana – Cordia alliodora* (ECC) coffee plantations with percent of surrounding forest cover at 1500 m.

4.4 Relationship between bird communities and structural and floristic composition of coffee plantations

The cluster analysis showed a high degree of correlation between some of the variables of structure, management and composition. A total of 12 from the 26 different variables were selected for the multiple regression analysis. The variables that were selected to perform the multiple linear regressions were: number of fruits, % of pruned shade trees, number of *Cordia* *alliodora* (CA) trees, canopy diameter for shade trees ≥ 10 cm DBH, mean height of shade trees, % of surrounding forest cover at a distance of 1000 m, % of epiphyte cover, herbaceous cover index, number of trees with a DBH≤ 10 cm and number of trees with a DBH ≥ 10 cm (Figure 22).

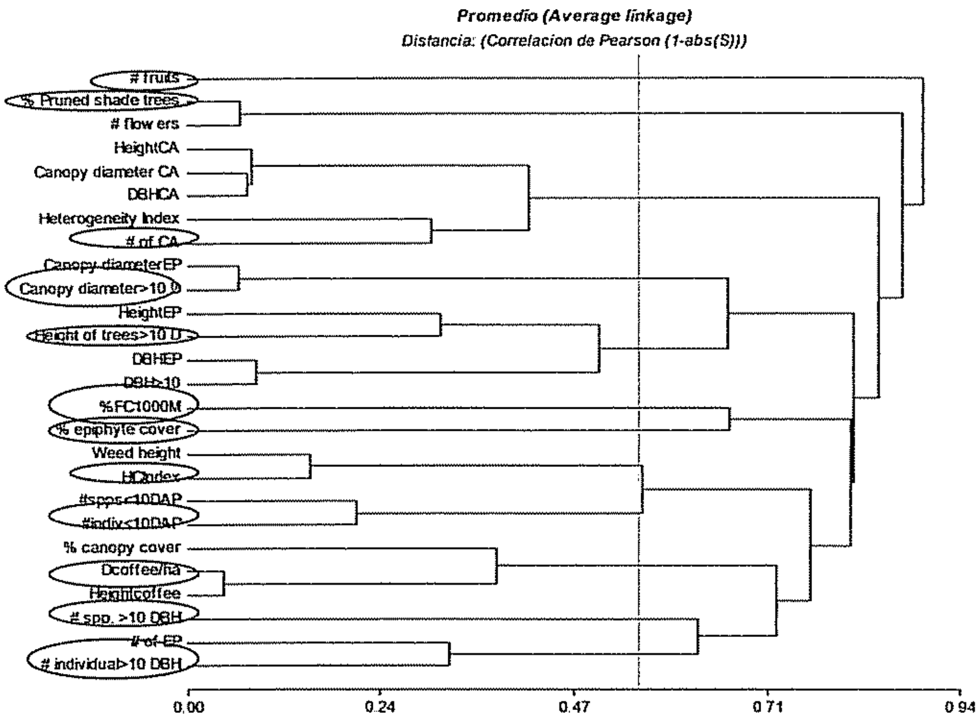


Figure 22. Cluster analysis with all the variables of structure, management and composition measured in the vegetation plots of coffee plantations. Variables selected for multiple linear regressions are circled in red.

Variables that showed a positive significant effect on overall bird abundance were epiphyte cover ($p = 0.0457$) and the height of shade trees with a DBH ≥ 10 cm. There were no significant effects of the number of *Cordia alliodora* ($p = 0.1862$), # of trees with a DBH ≥ 10 cm and the number of fruits present in the shade trees on bird abundance (Table 24).

Table 24. Multiple linear regressions of vegetation charactereristics with the number of individuals of birds observed in coffee plantations within the TJBC, Costa Rica.

Variable	Estimator	T	p-value	r^2
% epiphyte cover	0.45	2.8	0.0457*	0.58
# of *Cordia alliodora*	0.20	1.35	0.1862	
Height of trees with dbh ≥ 10 cm	1.57	2.19	0.0358*	
# of trees with dbh ≥ 10 cm	0.11	1.58	0.1230	
# of fruits	4.68	1.44	0.1589	

* Significant differences (p≤ 0.05)

Variables that showed a positive effect on species richness were epiphyte cover (p=0.0207), the number of *Cordia alliodora* present in coffee plantations (p=0.0104) and the height of shade trees that had a DBH ≥ 10 cm (Table 25). Coffee density (p=0.1799) had no impact on bird species richness.

Table 25. Multiple linear regressions of vegetation characteristics with bird species richness in coffee plantations present within the TJBC, Costa Rica.

Variable	Estimator	T	p-value	r^2
Epiphyte cover	0.10	2.42	0.0207*	0.51
# of *Cordia alliodora*	0.11	2.71	0.0104*	
Height of trees ≥10 cm DBH	0.54	2.43	0.0205*	
Coffee density ha^{-1}	-0.92	-1.37	0.1799	

*Significant differences (p≤ 0.05)

The number of *Cordia alliodora* and the height of shade trees with a DBH ≥ 10 cm had a significant positive effect whereas coffee density had a significant negative effect on the bird diversity. Epiphyte cover and the % of pruned trees had no effect on bird diversity (Table 26).

Table 26. Multiple linear regressions of vegetation characteristics with Shannon Diversity Index in coffee plantations present in the TJBC, Costa Rica.

Variable	Estimator	T	p-value	r^2
Epiphyte cover	0.0047	1.83	0.0756	0.51
# of *Cordia alliodora*	0.012	2.23	0.0327*	
Height of trees ≥ 10 cm DBH	0.04	2.46	0.0190*	
Coffee density ha^{-1}	-0.09	-2.13	0.0406*	
% of pruned shade trees	-0.02	-0.98	0.3317	

* Significant differences ($p \leq 0.05$)

5. DISCUSSION

Coffee plantations in the Turrialba – Jiménez Biological Corridor have diverse bird communities and contribute to the conservation of avifauna present in the Corridor. The study registered 101 species of birds within coffee systems, roughly representing 12% of the overall avifauna diversity found Costa Rica, and it is estimated that as many as 135 species can be found in these systems. However, most of the species that were present in these systems were generalist species and only five species were forest interior species. A total of 83 species were observed in forest sites and the majority of these species found in these sites were not observed in coffee plantations.

5.1 Comparison of floristic, structural and landscape characteristics between plantation types

Erythrina poeppigiana (EC) and *Erythrina poeppigiana – Cordia alliodora* (ECC) coffee plantations were the two types of plantations commonly found in the region. Both types of coffee plantations showed differences in structure and composition of dominant shade tree species but both were managed in similar ways.

EC plantations contained only one canopy layer dominated by *Erythrina poeppigiana*. Shade trees in EC plantations had smaller diameters, shorter mean canopy heights, fewer epiphytes, lower floristic diversity and a greater density of planted *Erythrina poeppigiana* than ECC plantations. The overall structural complexity for this type of coffee plantation was also low. The dominant shade species was the leguminous tree *Erythrina poeppigiana* which is used mainly as a service tree that fixes nitrogen and is a species easy to propagate and manage for shade regulation (Beer et al. 1998; Muscler 2000; Somarriba *et. al.* 2004).

ECC plantations, on the other hand, contained two canopy layers: an overstory canopy layer dominated by *Cordia alliodora* and a lowere canopy layer dominated by *Erythrina poeppigiana*. ECC plantations presented greater canopy diameters, heights and epiphyte cover than EC plantations. The density of planted *Erythrina poeppigiana* was lower in ECC plantations compared to EC plantations due to the presence of *Cordia alliodora* trees. However, the shade of the *Erythrina poeppigiana* seemed to be managed more intensively than in EC plantations in order to maintain an acceptable level of shade (approximately 50%) for coffee production (Muschler 1995; Somarriba *et.* al. 2004). *Cordia alliodora* is chosen by farmers because it is a fast growing species which naturally regenerates quickly, has a narrow and open canopy and has a high commercial value which may be important for supplementing farmer's income when coffee prices are low (Beer *et al.* 1998; Muschler 2000).

The majority of the EC and ECC plantations were managed intensively. Both types of plantations presented a low tree species richness, coffee was planted in very high densities (4000 – 6000 plants per hectare) and agrochemicals were used intensively. The low mean herbaceous cover observed in these plantations also indicated intensive use of herbicides.

EC and ECC coffee plantations were located in a highly fragmented landscape dominated by a matrix of pastures and coffee plantations. The forests patches retained within this matrix represent 40 % of the total area within the TJBC. Forest cover around the plantations ranged from 0 – 68% at a distance radius of 500 m, 3 – 75% at 1000 m and 6 – 70% at 1500 m, but did not vary significantly between the two types of coffee plantations. Despite the wide range of percent of surrounding forest cover, the mean percent of forest cover around coffee plantations was only 18 – 21% indicating the high fragmentation in the forest landscape around coffee plantations within the TJBC. The reduction of forest cover in the landscape can lead to the reduction and loss of habitat particularly for forest dependent bird species, increased isolation of habitat fragments and a reduction in bird movement and dispersal across the landscape. The type of matrix can also influence in the composition (Meffee and Carroll 1994; Bennett 1999) and dynamics of bird communities either inside and/or outside forest fragments.

5.2 Bird communities in coffee plantations

A total of 101 bird species were observed in coffee plantations of which 56 bird species were observed in EC plantations and 85 in ECC plantations. On the basis of species accumulation curves, it is estimated that that as many as 92 bird species can be found in EC plantations and 135 bird species in ECC plantations. Most of the species that were found in coffee plantations were insectivorous and omnivorous, probably because very few fruits and flowers were found in coffee plantations.

Most of the birds observed in coffee plantations were generalist species that are adapted to live in open habitats and do not require forest. Forest specialists, on the other hand, are bird species that require at least 50 % forest cover with large interconnected forest patches (Stiles and Skutch 1985). Only 4.9 % of all the species observed in coffee plantations were forest specialists. Many species (83 of them) observed in forests were not observed in coffee plantations, indicating that the coffee plantations selected for this study did not provide sufficient resources to attract forest species.

5.3 Effects of plantation structure on birds

There were significant differences in the bird communities present in EC and ECC plantations. A total of 56 species of birds were registered in EC plantations. This relatively low bird diversity has also been documented in other coffee plantations with a single canopy layer dominated by either *Inga* or *Gliricida* shade species in Guatemala (Greenberg *et al.* 1997a). Together these results suggest that coffee plantations with one canopy layer particularly dominated by *Erytrhina poeppigiana* provide a poor habitat for birds. This may be due to the frequent pruning of *Erythrina poeppigiana* for shade regulation can affect the distribution of foliage, flowers and fruits and therefore influence the foraging patterns, abundance and nesting success of birds (Calvo and Blake 1998)

In contrast, ECC plantations had a greater abundance and number of bird species (with 85 species total). The presence of additional shade tree species such as *Cordia alliodora* in ECC plantations provided additional structural complexity to the coffee plantation which in turn appears to provide habitat and additional resources to birds for feeding, nesting and mating (Greenberg *et al.* 1997a,b; Somarriba *et al.* 2004). Epiphyte cover present in *Cordia alliodora* had a strong positive influence on the abundance, species richness and diversity of birds. Epiphytes create a variety of microhabitats, add considerable biomass and surface area to the tree crown (Nadkarni *et al.* 1989; Sillet 1996) and provide nest sites, refuge, nest materials and food in the form of flowers, nectar, fruits, water, small vertebrates and invertebrates (Somarriba *et al.* 2004; Cruz-Angon and Greenberg 2005). Epiphytes can also be a critical food source in coffee plantations when host trees like *Cordia alliodora* and *Eryrthrina poeppigiana* are not flowering or fruiting (Williams *et al.* 2002).

The feeding guild composition of bird communities was very similar between the two types of coffee plantations. The majority of bird species found in coffee plantations were insectivores and omnivores. The dominance of these two guilds has similarly been reported in shade coffee plantations elsewhere (Wunderle and Latta 1996; Greenberg et al. 1997b). Food availability in coffee plantations influences bird feeding guild composition in coffee plantations. For example, the presence of flowers and fruits in coffee plantations influences the abundance and diversity of nectarivorous, frugivorous and omnivorous bird species (Greenberg et al. 1997a.; Wuderle and Latta 2000; Somarriba *et al.* 2004). In the case of EC plantations, very few flowers and fruits were observed in the field and this lack of forest resources limited the presence of nectarivorous and frugivorous birds.

The presence of insectivorous birds in EC and ECC plantations might be related to the availability of arthopods in coffee plantations. Monterrey *et al.* (2001) showed that the incidence of certain insect pests such as leaf miners (*Leucoptera coffeella L.*) is influenced by the intensity of the shade management. Coffee plantations that have a very intensive shade management might influence the populations of certain arthropods that are important food sources for certain species of birds. Johnson (2000) also observed a predominance of insectivorous birds in monospecific shade coffee plantations and also found that dense areas of the coffee plantation particularly such as unpruned coffee plants and the upper canopy layers can also contain disproportionaly high abundances of flying arthropods. A wide variety of insects can be found in these systems which makes them key foraging sites for insectivorous bird species.

Several studies show that omnivorous and frugivorous birds have been frequently seen in coffee plantations that have greater structural complexity (Perfecto et al. 1996; Greenberg et al. 1997 a) which tends to support the high abundance of these species observed in EC and ECC plantations. The presence of omnivorous birds might be influenced by the presence of fruits and insects available in the upper canopy of the *Cordia alliodora* trees. In EC and ECC plantations fruits were found in some vines that grew around the coffee plants.

The findings of this study also showed that the variable seedeater (*Sporophila aurita*), granivorous species, was one of the most abundant bird species observed in both types of coffee plantations probably because of the presence of high herbaceous cover in some coffee plantations and the presence of other surrounding landuses provided adequate habitat for this particular species (e.g. sugar cane plantations and early forest regeneration areas among others).

Most of the bird species observed in coffee plantations included species characteristic of open agricultural habitats (generalists) or forest generalists; on the other hand, there were few forest specialists. These results are consistent with other studies that demonstrated the same pattern (Greenberg et al. 1997a,b; Moguel and Toledo 1999), however very few studies have reported the presence of specialist forest bird species in coffee plantations (Wunderle and Latta 1996; Greenberg et. al. 1997a.). Most of the forest generalist and forest specialist bird species were observed in the structurally more complex ECC plantations indicating the importance of more structurally complex plantations for these species.

5.4 Relationship between bird abundance and diversity and landscape context

The landscape context is considered an important factor that can affect bird species composition and abundance (Askins 1995; McGarigal and McComb 1995). In this study, bird abundance, species richness and diversity in coffee plantations were influenced by the amount of surrounding forest cover. The overall diversity of birds decreased with increased surrounding forest cover at a radius of 500, 1000 and 1500 m. Overall bird abundance also decreased at distances of 500 and 1000 m and species richness decreased at distances of 1000 and 1500 m. These findings appears to contradict previous studies that have shown that surrounding forests can exert a positive influence in species richness in coffee (Aguilar- Ortiz 1982; Martinez and Peters 1996). Increased species richnesss has been shown in other agricultural systems close to forest remnants partly because there is an increased level of connectivity and proximity that allows species to move from forest remnants and also because certain agricultural systems have the ability to provide additional resources that can attract open and forest habitat species in a highly deforestated matrix (Luck and Daily 2003).

The unexpected negative relationship between the percent of forest cover and species richness and abundance might be due to the fact that most of the species observed in the coffee plantations were composed of generalist species. Generalist species do not require forest to survive, therefore the presence of open agricultural habitats around these coffee plantations would probably be a better habitat than forest for these bird species. Species abundance and richness of generalist species might also be influenced by the overall landscape patchiness, measured most directly as the number of patches in the landscape (Forman 1995). It would also be expected that habitat generalists are better suited to exist in patchy landscapes where the amount of edge and number of patches are high compared to forest species that generally uses fewer types of habitats (Forman 1995; Gutzwiller 2005).

On the other hand, species richness, abundance and diversity of forest birds observed in coffee plantations increased with increased surrounding forest cover at distances of 500, 1000 and 1500 m, though this relationship was weak. These results are consistent with the previous studies which shows that forest interior species in particularly have a positive association with the density of forest surrounding agricultural matrices (Van Dorp and Opdam 1987, Forman 1995). Birds that are forest specialist species often require "forest interior" habitat to live and reproduce and often are sensitive to landscape fragmentation (Lord and Norton 1990). They also require large extension of continous forest or large interconnected forest patches to survive. Structurally more complex coffee plantations near natural forests can serve as buffer zones by creating an environment adjacent to forest fragments that is structurally more similar to forest habitats and appopiate as habitat for some of the forest dependent species. The presence of trees in coffee plantations may also help increase landscape connectivity by facilitating the movement of birds between forest patches across the agricultural landscape.

6. CONCLUSIONS

A total of 101 species of birds were found in the agricultural landscape of the Turrialba-Jiménez Biological Corridor, indicating that coffee plantations have a potential to harbor and conserve the diversity of birds. However, most of the bird species found were generalist species belonging mostly to the insectivorous and omnivorous feeding guilds. The more structurally complex coffee plantations (ECC) harbored a greater abundance and diversity of birds and more forest dependent birds than EC plantations. Conservation efforts should therefore promote the diversification or conversion of EC plantations to more structurally diverse plantations. Improving the structural quality of the coffee plantations will play an important role in providing additional resources, habitat and connectivity to different organisms (Perfecto and Vandermeer 2002) including birds.

The abundance and diversity of bird communities were influenced by a variety of factors that operate at different spatial scales. Broad-scale factors such as the landscape context also played an important role in the defining the abundance and diversity of bird communities that were present in coffee plantations. Coffee plantations with little surrounding forest cover tended to be dominated by generalist species that live in open agricultural habitats where as plantations with high surrounding forest cover tended to favor more the presence of forest dependent bird species.

However, additional research is needed to examine in greater detail the effect of landscape structure and composition in the abundance and diversity of birds present in coffee plantations. Further research should be aimed at evaluating the influence of coffee patch size distribution, density, landscape patchiness and connectivity to forest fragments in bird communities. This information would help to identify key areas within the Turrialba- Jimenez Biological Corridor that are critical for the conservation and management of birds in coffee production systems.

7. RECOMMENDATIONS FOR THE CONSERVATION AND MANAGEMENT OF BIRDS IN COFFEE PLANTATIONS WITHIN THE TJBC, COSTA RICA

Structural more complex coffee plantations have the potential to maintain a high abundance and species richness of birds within the Turrialba-Jiménez Biological Corridor therefore it is important to find alternative ways to incorporate additional species of trees to improve the structural quality of coffee plantations and attract other species of birds. Very few frugivorous and nectarivorous birds were found in these systems therefore the incorporation of fruit trees such as *Psidium guajava, Persea americana, Citrus spp., Bactris gasipaes, Musa spp. Cecropia spp.* and trees with nectar producing flowers such as *Gliricidia sepium, Inga spp.* among others, might attract some of these bird species.

Forest cover around coffee plantations favors the presence of forest dependent bird species suggesting the importance of forest habitat of the persistence of these species in a landscape that is dominated by an agricultural matrix. Structural more complex coffee plantations can provide habitat and resources for some of these bird species. In addition, these systems can also increase the overall connectivity, by facilitating the dispersal of birds to and from isolated forest patches across the coffee farm matrix.

It would be useful to explore the possibility of using payments for environmental services (PES) and/or other incentives that help promote more complex structure of coffee agroforestry systems the favors the presence of birds. The National Fund for Forestry Finance (FONAFIFO) is a Costa Rican government organization that provides economic incentives for

PES to small and medium scale farmers for forests and agroforestry systems. Payments for agroforestry systems should contemplate spatial and temporal configurations of shade trees and their location relative to landscape features (such as water bodies or forest fragments), species selection (preferably native species), density and management. These incentives should also take into account the protection and proper management of forests present around these coffee plantations.

Coffee plantations, in general, should have the greatest structural and floristic diversity and at the same time provide economically viable returns to the coffee farmers. It is important these trees have a commercial value and identify the markets for the commercialization of these alternative products e.g. fruits and timber products. The promotion of these multi-strata coffee production systems will lessen the dependence of small farmers on a single cash crop and have the secondary effect of improving coffee farms as habitat for birds and other organisms. The adoption of these types of agroforestry systems could present a viable economic solution particularly to small-scale coffee farmers are suffering the most the impact of the global coffee crisis. The Association of Organic Producers of Turrialba (APOT) should encourage their members to diversify the coffee production by incorporating native species of timber and fruit trees that have high commercial and wildlife value as well as finding alternative markets to commercialize these value added products and contribute to improve the livelihoods of coffee farmers in the region.

It will be important to explore alternatives of biodiversity – friendly coffee certification programs as a market-based strategy to promote the conservation of diverse coffee agroforestry systems or the restoration of sun grown coffee plantations to shade plantations. Some example of coffee certification schemes that could be implemented are: organic coffee, fair trade, shade coffee, Smithsonian Bird Friendly label, rainforest alliance Eco-OK label. Many of these certification schemes favors the incorporation of additional species which in turn contribute to increase the structural complexity of these coffee plantations This study showed that the structural complexity of coffee plantations is a key factor in certification schemes, many of their principles are valid and can have a positive impact in the biodiversity present within these coffee agroforestry systems.

In the case of the SMBC Bird Friendly Coffee program, planted-shade plantations generally consist of a backbone of trees which are the predominant species planted to provide the optimal shade environment for the coffee plant. These species cannot comprise more than 60 % canopy cover. The remaining 40 % of shade trees should comprised of 10 or more species. It is common to find in coffee systems common backbone trees such as *Inga* spp. and, at lower elevations and latitude sites *Erythrina* spp. and *Gliricidia sepium*. From the consideration of biodiversity conservation, *Erythrina* and *Gliricidia* are considered under this scheme as unacceptable backbone species because they are deciduous during the dry season leaving the "shade" plantation shadeless during a time of the year when canopy cover for both migrant and resident birds may be most critical. It is recommended that farmers incorporate species that are not decidous, are native to the region and can reach a minimum height of 12 meters (SMBC 1998). The incorporation of species like *Cordia alliodora* in coffee systems contributes to increasing the structural complexity of coffee plantations and therefore attract a wide variety of birds. It is also a native fast growing timber species widely used in the TJBC therefore it could be used as a potential backbone shade tree in many coffee plantations.

This study also provided new evidence about the importance of retaining the forest cover around coffee plantations for the conservation and management of forest dependent bird species. Certification schemes should include criteria that favor the restoration and protection of forests in order to ensure the survival and facilitate the movement of birds across the TJBC landscape.

8. LITERATURE CITED

Askins, RA. 1995. Hostile landscapes and the decline of migratory birds. Science 267: 1956-1957

Beer, J. 1987. Advantages, disadvantages and desirable characteristics of shade trees for coffee, cacao and tea. Agroforestry Systems 7:103-104.

Beer, J; Muschler, R; Kaas, D; Somarriba, E. 1998. Shade management in coffee and cacao plantations. Agroforestry Systems 38: 139-164.

Bennett, A. 1999. Linkages in the landscape: the role of corridors and connectivity in wildlife conservation. UICN. UK. 254 p.

Bierregaard, R.O., Jr. 1992. The biological dynamics of tropical rainforest fragments. BioScience 42:859-866.

Bird Life International. 2004. Threatened birds of the world. CD.

Colwell, R.K. 1997. Estimate S: estimation of species richness and shared species from samples. Computer program. University of Conneticut, U.S.

Cruz-Angon, A. 2004. Epiphytes, birds and coffee: more tropical connections. Smithsonian Bird Center. USA. Consulted on Dec. 2004. Available at: http://nationalzooo.si.edu/ConservationandScience/MigratoryBirds/Science_Articles/default.cfm?id=14

Cruz-Angón, A; Greenberg, R. 2005. Are epiphytes important for birds in coffee plantations? An experimental assessment. Journal of Applied Ecology 42:150-159

Dufrene, M; Legendre, P. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67:345-366

Forman, RTT. 1995. Land mosaics: the ecology of landscapes and regions. Cambridge University Press. UK. 632 p.

Gauch, HG. 1982. Multivariate analysis in community ecology. Cambridge University Press. UK. 250 p.

Greenberg, R; Bichier, P; Cruz Angon, A; Reitsma, R. 1997a. Bird populations in shade and sun coffee plantations in Central Guatemala. Conservation Biology 11: 448–459.

Greenberg, R; Bichier, P; Sterling, J. 1997b. Bird populations in rustic and planted shade coffee plantations of Eastern Chiapas, Mexico. Biotropica 29: 501–514.

Gutzwiller,KJ; Barrow,WC. 2002. Does bird community structure vary with landscape patchiness? A Chihuahuan desert perspective. OIKOS 98: 284-298

Holdridge, LR. 1978. Ecología basada en zonas de vida. Serie libros y materials educativos No. 34. Instituto Interamericano de ciencias agrícolas (IICA). San José, CR. 159 p.

Hidalgo, M. Estratificación de las áreas de café Regional Turrialba. ICAFE. Turrialba, CR. 1p.

Hutto, RL; Pletschet, SM; Hendricks, P. 1986. A fixed-radius point count method for non-breeding season use. The Auk 103: 593-602.

Instituto Nacional de Biodiversidad (INBIO). 2004. Base de datos: especies de Costa Rica. Consulted on June 2005. Available at: http://www.inbio.ac.cr.

International Federation of Organic Agriculture Movements (IFOAM). 1996. Basic standards for organic agriculture and processing, and guidelines for coffee, cocoa and tea: evaluation of inputs. International Federation of Organic Agriculture Movements. Tholey-Theley. DE. 44 p.

Instituto del Café de Costa Rica (ICAFE). 2003. Informe sobre la actividad cafetalera de Costa Rica. ICAFE. San José, CR. 86 p.

Jiménez, F; Muschler, R; Kopsell, E. 2001. Funciones y aplicaciones de sistemas agroforestales. Colección de módulos de enseñanza agroforestal. No.6. Centro Agronómico Tropical de Investigación y Enseñanza (CATIE). Turrialba, Costa Rica. 187 pp.

Johnson, RA; Wichern, DW. 1998. Applied multivariate statistical analysis. 4th Ed. Prentice Hall, Upper Saddle River, NJ. US.

Lyngbæk, AE; Muschler, RG; Sinclair, FL. 2001. Productivity and profitability of multistrata organic versus conventional coffee farms in Costa Rica. Agroforestry Systems 53: 205–213.

Martinez, E; Peters W. 1996. La cafeticultura biologica:la finca Irlanda como estudio de caso de un diseño agroecológico. *In:* Trujillo, J; León-González, F; Calderon, R; Torres-Lima, P. eds. Ecología aplicada a la agricultura:temas selectos de México. Universidad Autónoma Metropolitana. Ciudad de México, MX. p. 159 – 183

McCune, B; Mefford, MJ. PC-ORD. 1999. Multivariate analysis of ecological data. Version 4. MjM Software Design, Gleneden Beach, Oregon, US.

McGarigal,K; McComb,WC. 1995. Relationships between landscape structure and breeding birds in Oregon Coast Range. Ecological Monographs 65:235-260

McNeely, J; Scherr,S. 2003. Ecoagriculture:strategies to feed the World and Save Biodiversity.

Island Press, Washington, DC. US. 247p.

Moguel, P; Toledo, VM. 1999. Biodiversity conservation in traditional coffee systems in Mexico. Conservation Biology 12: 1–11.

Moya, JB. 2005. Situación internacional y nacional del mercado de café. Presentación de PP. ICAFE. Unpublished.

Muscheler, RG. 1995. Efectos de diferentes niveles de sombra de *Erythrina poeppigiana* sobre *Coffea Arabica* vars. Caturra y Catimor. In: II Semana Científica del Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), pp 158-160. CATIE, Turrialba, CR.

Muschler, RG. 2000. Arboles en cafetales. Modulo de Ensenanza Agroforestal No. 5. CATIE/GTZ. CR. 139 pp.

Muschler, RG. 2001. Shade improves coffee quality in a sub-optimal coffee-zone of Costa Rica. Agroforestry Systems 51:131-139.

Nadkarni,NM; Matelson, TJ.1989. Bird use of epiphyte resources in neotropical trees. Condor 91:891-907

Perfecto, I.; Vandermeer, J. 1994. Understanding biodiversity loss in agroecosystems: reduction of ant diversity resulting from transformation of the coffee agroecosystem in Costa Rica. Entomology (Trends in Agricultural Sciences) 2:7-13.

________; R. A. Rice; Greenberg,R; Van der Voort , ME. 1996. Shade coffee: a disappearing refuge for biodiversity. BioScience 46(8): 598-608.

________; Vandermeer, J; Hanson, P; Cartin, V. 1997. Arthropod diversity loss and transformation of a tropical agroecosystem. Biodiversity and Conservation 6:935-945.

Ralph, CJ; Geupel, GR; Puly, P; Martin, TE; De Sante, DF; Milla, B. 1996. Manual de métodos de campos para el monitoreo de aves terrestres. General Technical Report. Albany, CA: Pacific Southwest Station, Forest Service, U.S. Department of Agriculture. US. 59 p.

Rice, R. A., J. Ward 1996. Coffee, Conservation, and Commerce in the Western Hemisphere. Natural Resources Defense Council. Consulted on Dec. 2004. Available in: http://www.nrdc.org/health/farming/ccc/cptinx.asp

Robledo, CW; Di Rienzo, JA; Balzarini, MG; González, LA; Tablada, EM; Casanoves, F. 2004. InfoStat. Universidad Nacional de Argentina, AR.

SMBC (Smithsonian Migratory Bird Center). 1998. Shade management criteria for "Bird-Friendly" coffee. Smithsonian Migratory Bird Center, Smithsonian Institution, Washington, DC. US. 63p.

Sillett, TS. 1996. Foraging ecology of epiphyte-searching insectivorous birds in Costa Rica. Condor:96:866-877

Somarriba, E; Harvey, CA; Samper, FA; González, J; Staver, C; Rice, RA. 2004. Biodiversity conservation in neotropical (*coffea arabica*) plantations. *In:* Gotz, S; da Fonseca, AB; Harvey, CA; Vasconcelos, HL; Izac, ANM. Agroforestry and biodiversity conservation in tropical landscapes. Island Press. US. p. 198- 226.

Stiles, FG. 1985. Conservation of forest birds in Costa Rica: problems and perspectives. In: Conservation of Tropical Birds. Eds. Diamond, AW; Lovejoy, TE. International Council of Bird Preservation. Technical Publication No. 4. pp. 142-169

Stiles, FG; Skutch, AF. 1989. A guide to birds of Costa Rica. Comstock Publishing Associates, a division of Cornell University Press. Ithaca, New York. 511 p.

Unión Mundial para la Naturaleza (UICN). 1997. Listas de fauna de importancia para la conservación en Centroamérica y México. CCAD. México. P.223.

Vandeer, J; Perfecto,I. 1997. The agroecosystem: a need for the conservation biologist's lens. Conservation Biology 11:1-3

Van Dorp, D; Opdam, PFM.1987. Effects of patch size, isolation and regional abundance of forest bird communities Landscape Ecology 1:59-73.

Williams-Linera, M; RH, Isunza, EV. 2002. La fragmentacion del bosque mesofilo de montaña y patrones de uso del suelo en la region oesta de Xalapa, Veracruz, Mexico. Madera y Bosques 8:73-89.

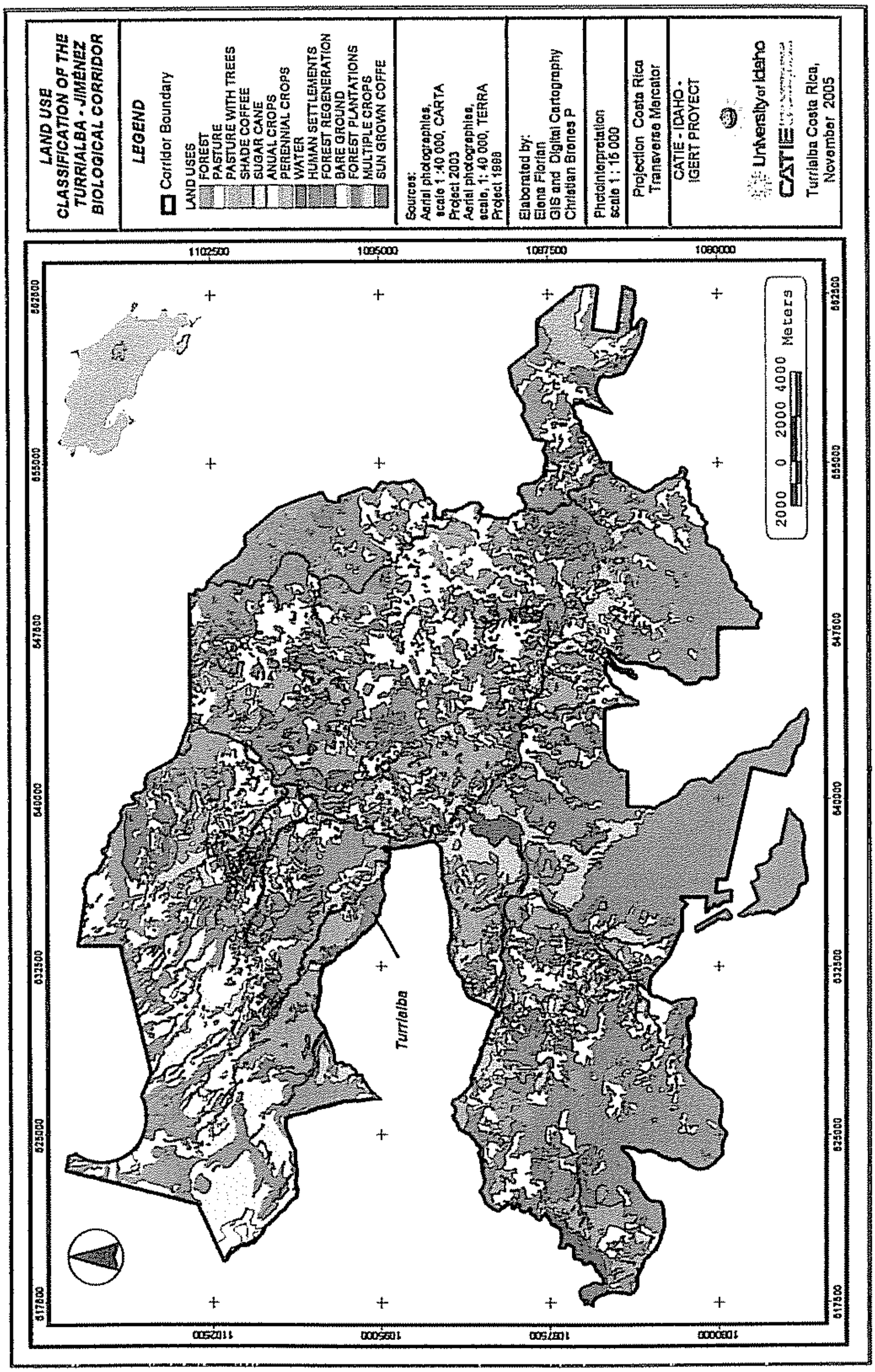
Wunderle, J; Latta S.C. 1996. Avian abundance in sun and shade coffee plantations and remnant pine forest in the Cordillera Central, Dominican Republic. Ornitologia. Neotropica 7:19-34.

__________; Latta, S. 1998. Avian resource use in Dominican shade coffee plantations. Wilson Bulletin 110: 271-281.

Zanetta, C. 2001. The evolution of the World Bank's urban lending in Latin America: from sites and services to municipal reform and beyond. Habitat International 25:513-533.

Znajda, SK. 2000. Conservación de Habitat, Diversidad de Aves y Agroecosistemas de café en Costa Rica. Coloquio Internacional: Desarrollo sustentable, participación comunitaria y conservación de la biodiversidad en México y América Latina. San Luis Potosí, México. 25 p.

Appendix 1. Land use classification of the Turrialba – Jiménez Biological Corridor, Costa Rica. Forest cover is represented in dark green.



APPENDIX 2. List of the selected *Erythrina poeppigiana* (EC) and *Erythrina poeppigiana – Cordia alliodora* coffee farms, location, property owner and GPS position within the Turrialba – Jiménez Biological Corridor, Costa Rica

Erythrina poeppigiana (EC) coffee plantations

Farm Code	District	Community	Property owner	Coordinate X	Coordinate Y
CE1	Tayutic	Tayutic	Jorge Fallas	548332	1086298
CE2	Tayutic-Platanillo	San Antonio	Gerardo Mata	548329	1083787
CE3	La Suiza	Eslabon	Tomás Guardia	540216	1091439
CE4	La Suiza	Juray-Atirro	Zonex Inter.	535194	1087004
CE5	La Suiza	Atirro-Centro	Marcos Quirós	537932	1086190
CE6	La Suiza	Atirro	Zonex Inter.	539893	1090062
CE7	Pavones	Centro	FRANCOSTA	539770	1095650
CE8	Pavones	Celulosa	Scott Paper S.A.	541967	1097171
CE9	La Suiza	La Cristina	Finca Belgravia	543474	1087784
CE10	Tuis	Cien Manzanas	Ricardo Fallas	548104	1089952
CE11	Santa Teresita	Colima	Volcafé	539906	1103627
CE12	Santa Teresita	Colima	Volcafé	539406	1103617
CE13	Santa Teresita	Guayabo Abajo	Fernando Paéz	539441	1098890
CE14	Turrialba	Centro - Azul	Carlos Mora	534720	1096013
CE15	Santa Rosa	Aquiares	Cafetalera Aquiares	530413	1099187
CE16	Santa Rosa	Aquiares	Cafetalera Aquiares	531411	1098096
CE17	Turrialba	La Isabel	Rolando Picado	535644	1098746
CE18	Turrialba	Alto Varas	Arnoldo Gonzalez	537217	1099044
CE19	Chirripo	Bajo Pacuare	Victor Hugo	553896	1086243
CE20	Chirripó	Grano de Oro	Alvaro Rojas	559765	1084829

Erythrina poeppigiana – Cordia alliodora (ECC) coffee plantations

Farm code	District	Community	Property owner	Coordinate X	Coordinate Y
CEC1	Pavones	Javillos	Alexander Quirós	542313	1097422
CEC2	Pavones	Javillos	Carlos Cortés	542449	1097820
CEC3	Tres Equis	San Pablo	Volcafé	547716	1096559
CEC4	Tres Equis	San Pablo	Volcafé	547689	1097203
CEC5	Tres Equis	Chitaría	Evangelista González	545285	1098469
CEC6	La Suiza	Eslabon	Volcafé	538983	1092461
CEC7	La Suiza	La Cristina	Rodrigo Guevara	543513	1088435
CEC8	Tuis	Tuis-Centro	Felipe Falla	546238	1087824
CEC9	La Suiza	El Carmen	Sergio Salas	541536	1090405
CEC10	Santa Teresita	Colima	Volcafé	540543	1103039
CEC11	Santa Teresita	Colima	Volcafé	541109	1103857
CEC12	Santa Teresita	Corralon	Volcafé	539222	1103058
CEC13	Turrialba	Azul	Jorge Mora	537986	1095763
CEC14	Santa Rosa	Centro	Beneficio Santa Rosa	533040	1097800
CEC15	La Suiza	El Carmen	Pekín Fernández	541171	1090319
CEC16	Turrialba	La Isabel	Rolando Picado	534881	1097654
CEC17	Tayutic	Bajo Pacuare	Bonifacio Acuña	554228	1084542
CEC18	La Suiza	La cruzada	José Joaquín Moya	541181	1091261
CEC19	La Suiza	Eslabon	Mario Aguilar	540325	1091774
CEC20	Pavones	Chitaria	Claudino Camacho	544501	1098856

APPENDIX 3. Species of shade trees registered in *Erythrina poeppginana* (EC) and *Erythrina poeppigiana – Cordia alliodora* (ECC) coffee plantations.

SCIENTIFIC NAME	SPANISH NAME	EC	ECC
Bombacaceae			
Ochroma lagopus	Balsa	X	
Boraginaceae			
Cordia alliodora	Laurel	X	X
Cecropiacea			
Cecropia pittieri	Guarumo	X	X
Fabaceae			
Erythrina poepigiana	Poró	X	X
Gliricidia sepium	Madero negro		X
Inga edulis	Inga	X	
Lauraceae			
Persea americana	Aguacate		X
Ocotea spp-	Quizarra	X	
Liliacea			
Dracaena masagiana	Caña India		
Yucca elephantipes	Itabo	X	X
Meliaceae			
Cedrela odorata	Cedro amargo	X	X
Melastomataceae			
Conostegia spp	Lengua de vaca	X	
Mimosaceae			
Samanea saman	Cenízaro		X
Moraceae			
Artocalpus artilis	Fruta de pan		X
Ficus spp.	Matapalo	X	X
Musaseae			
Musa spp.	Banano	X	X
Myrtaceae			
Eucaliptus deglupta	Eucalipto	X	
Psidium friedrichthalianum	Cas	X	X
Psidium guayava	Guayaba		X

SCIENTIFIC NAME	SPANISH NAME	EC	ECC
Palmae			
Bactris gasipaes	Pejibaye	X	
Rutacea			
Citrus aurantifolia	Limón ácido	X	X
Citrus reticulata	Mandarina		X
Citrus sinencis	Naranja	X	X
Sterculiaceae			
Theobroma cacao	Cacao	X	

APPENDIX 4. Bird species observed in point counts and their abundance in coffee – *Erythrina poepiggiana* (CE) and coffee – *Erythrina poepiggiana* – *Cordia alliodora* (CEC) agroforestry systems present in the Turrialba-Jimenez Biological Corridor, Costa Rica. Feeding guilds (FG), preferred habitat and forest dependence (FD) information was compiled from Stiles and Skutch (1982) and personal observations (C = Carnivorous; G= Granivorous; I = Insectivorous; N = Nectarivorous; O= Omnivorous; FI = Forest interior; FC = Forest canopy; FE = Forest edge; NF = Nonforest; %TAF = % of individuals of a given species from all the especies present in coffee agroforestry systems).Data represent 3200 minutes of observations.

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	CODE	HABITAT	FG	FD	CE	CEC	% TAF
Apodiformes:Trochilidae									
Amazilia tzacatl	Rufous-tailed hummingbird	Amazilia rabirrufa	AMATZA	NF,FE	N	3	34	61	5.60
Anthracothrorax prevostii	Green-breasted mango	Manguito pechiverde	ANTPRE	FE,NF	N	3	0	4	0.24
Florisuga mellivora	White-necked jacobin	Jacobino nuquiblanco	FLOMEL	FC,FE,NF	N	2	0	3	0.18
Lophornis adorabilis	White-crested coquette	Coqueta crestiblanca	LOPADO	FC,FE	N	2	0	1	0.06
Phaethornis superciliosus	Long-tailed hermit	Ermitaño colilargo	PHASUP	FI,FE	N	2	0	1	0.06
Caprimulgiformes: Caprimulgidae									
Nyctidromus albicollis	Common pauraque	Cuyeo	NYCALB	FE,NF	I	2.5	0	3	0.18
Columbiformes: Columbidae									
Columba flavirostris	Red-billed pigeon	Paloma morada	COLFLA	NF,FE,FC	F	3	4	10	0.83
Columbina talpacoti	Ruddy.ground dove	Tortolita	COLTAL	NF	G	3	4	2	0.36
Leptotila verreauxi	White-tipped dove	Paloma coliblanca	LEPVER	FE,FI,NF	G	2.5	14	15	1.72
Coraciformes: Momotidae									
Momotus momota	Blue-crowned motmot	Pájaro bobo	MOMMOM	FE,NF,FI	I	2.5	0	1	0.06
Cuculiformes: Cuculidae									
Crotophaga sulcirostris	Groove-billed ani	Tijo	CROSUL	NF	I	3	1	0	0.06
Piaya cayana	Squirrel cuckoo	Pájaro ardilla, bobo chizo	PIACAY	FE,FC	I	2.5	0	1	0.06

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	CODE	HABITAT	FG	FD	CE	CEC	% TAF
Falconiformes: Accipitridae									
Buteo magnirostris	Road-side hawk	Gavilán pollero	BUTMAG	FE,NF	C	2	0	6	0.36
Cathartidae									
Coragyps atratus	Black vulture	Zopilote	CORATR	A	O	3	0	3	0.18
Galliformes: Cracidae									
Ortalis cinereiceps	Gray-headed chachalaca	Chachalaca	ORTCIN	FE,NF	F	2.5	1	5	0.36
Passeriformes: Coerebidae									
Coereba flaveola	Bananaquit	Reinita mielera, Sta. Marta	COEFLA	FC,FE,NF	N	2.5	2	0	0.12
Corvidae									
Cyanocorax morio	Brown jay	Piapia	CYAMOR	FE,NF	O	2.5	8	39	2.78
Dendrocolaptidae									
Dendrocolaptes certhia	Barred woodcreeper	Trepador barreteado	DENCER	FC,FI,FE	I	2	0	1	0.06
Lepidocolaptes souleyetii	Streak-headed woodcreeper	Trepador cabecirrayado	LEPSOU	FE,NF,FC	I	2.5	2	20	1.30
Xiphorhynchus guttatus	Buff-throated woodcreeper	Trepador gorgianteado	XIPGUT	FC,FE	I	2	0	1	0.06
Emberizidae									
Amaurospiza concolor	Blue seedeater	Semillero azulado	AMACON	FE	G	2.5	0	1	0.06
Arremonops conirostris	Black-striped sparrow	Pinzón cabecilistado	ARRCON	NF,FE	I	2.5	7	7	0.83
Cyanocompsa cyanoides	Blue-black grosbeak	Picogrueso negro azulado	CYACYA	FE,FI,NF	O	2	0	1	0.06
Guiraca caerulea	Blue grosbeak	Picogrueso azul	GUICAE	NF,FE	I	2.5	0	1	0.06
Melozone biarcuatum	Prevost's ground sparrow	Pinzón cafetalero	MELBIA	NF,FE	G	2.5	4	0	0.24
Oryzoborus funereus	Thick-billed seed finch	Semillero picogrueso	ORYFUN	NF,FE	G	2.5	1	0	0.06
Saltator atriceps	Black-headed saltator	Saltador cabecinegro	SALATR	FE,NF	O	3	8	12	1.18
Saltator maximus	Buff-throated saltator	Sinsonte verde	SALMAX	FE,NF	O	3	7	12	1.12
Sporophila aurita	Variable seedeater	Espiguero	SPOAUR	NF,FE	G	3	89	106	11.55
Tiaris olivacea	Yellow-face grassquit	Gallito	TIAOLI	NF	O	3	35	25	3.55
Volatinia jacarina	Blue-black grassquit	Semillerito negro azulado	VOLJAC	NF	G	3	3	1	0.24

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	CODE	HABITAT	FG	FD	CE	CEC	% TAF
Zonotrichia capensis	Rufous-collard sparrow	Comemaiz	ZONCAP	NF	G	3	0	2	0.12
Formicariidae									
Thamnophilus doliatus	Barred antshrike	Batará barreteado	THADOL	FI,FE,NF	I	2.5	17	16	1.95
Furnariidae									
Sclerurus mexicanus	Tawney-throated leaftosser	Tirahojas pechirrufo	SCLMEX	FI	I	1	0	2	0.12
Synallaxis brachyura	Slaty spinetail	Arquitecto plomizo	SYNBRA	FE,NF	I	2	1	0	0.06
Hirundinidae									
Stelgidopteryx serripennis	Northern-rough winged swallow	Golondrina alirrasposa norteña	STESER	NF	I	3	1	1	0.12
Icteridae									
Dives dives	Melodious blackbird	Tordo cantor	DIVDIV	NF,FE	O	2.5	3	2	0.30
Icterus dominicensis	Black-cowled oriole	Bolsero capuchinegro	ICTDOM	FE,NF	O	3	0	1	0.06
Molothrus aeneus	Bronzed cowbird	Vaquero ojirrojo	MOLAEN	NF	I	3	0	2	0.12
Psarocolius montezuma	Montezuma oropendola	Oropendola de Montezuma	PSAMON	FE,NF,FC	O	2.5	3	35	2.25
Psarocolius wagleri	Chestnut-headed oropendola	Oropendola cabecicastaña	PSAWAG	FE,FC,NF	O	2	0	2	0.12
Quiscalus mexicanus	Great-tailed grackle	Zanate	QUIMEX	NF,FE	O	3	3	0	0.18
Parulidae									
Basileuterus rufifrons	Rufous-capped warbler	Reinita cabecicastaña	BASRUF	FI,FE,NF	I	2	31	19	2.96
Dendroica pensylvanica	Chestnut-sided warbler	Reinita de costillas castañas	DENPEN	FC,FE,NF	I	2.5	1	0	0.06
Dendroica petechia	Yellow-warbler	Reinita amarilla	DENPET	NF,FE	I	3	0	1	0.06
Geothlypis semiflava	Olive-crowned yellowthroat	Antifacito coroniolivo	GEOSEM	NF,FE	I	2.5	0	5	0.30
Oporornis philadelphia	Mourning warbler	Reinita enlutada	OPOPHI	FE,NF	I	2	2	0	0.12
Sylviidae									
Polioptila plumbea	Tropical gnatcatcher	Perlita tropical	POLPLU	FC,FE	I	2	49	51	5.92
Ramphocaenus melanurus	Long-billed gnatwren	Soterillo picudo	RAMMEL	FE,NF,FI	I	2.5	1	0	0.06

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	CODE	HABITAT	FG	FD	CE	CEC	% TAF
Thraupidae									
Chlorospingus canigularis	Ashy-throated bush-tanager	Tangara de monte	CHLCAN	FC,FE	O	2	0	1	0.06
Cyanerpes lucidus	Red-legged honeycreeper	Mielero patirrojo	CYALUC	FC,FE	O	2	0	1	0.06
Dacnis venusta	Scarlet-thighed dacnis	Mielero celeste y negro	DACVEN	FC,FE	F	2	1	2	0.18
Euphonia gouldi	Olive-backed euphonia	Eufonia olivacea	EUPGOU	FC,FE	F	2	0	1	0.06
Euphonia luteicapilla	Yellow-crowned euphonia	Monjita	EUPLUT	FE,NF	F	2.5	0	1	0.06
Habia fuscicauda	Red-throated ant tanager	Tangara hormiguera gorgirroja	HABFUS	FI,FE	O	2	0	1	0.06
Phlogothraupis sanguinolenta	Crimson-collard tanager	Sangre de toro	PHLSAN	FE,NF	O	3	1	1	0.12
Ramphocelus passerinii	Scarlet-rumped tanager	Sargento	RAMPAS	NF	O	3	25	30	3.26
Tachyphonus rufus	White-lined tanager	Fraile	TACRUF	NF,FE	O	3	15	16	1.84
Tangara larvata	Golden-hooded tanager	Siete colores	TANLAR	FE,NF,FC	O	3	6	65	4.20
Thraupis episcopus	Blue-gray tanager	Viuda	THREPI	NF,FE,FC	O	2.5	24	91	6.81
Thraupis palmarum	Palm tanager	Tangara palmera	THRPAL	NF	I	3	2	32	2.01
Tityridae									
Pachyramphus cinnamomeus	Cinnamon becard	Cabezón canelo	PACCIN	FE	I	2.5	0	4	0.24
Tityra semifasciata	Masked tityra	Pájaro chancho	TITSEM	FC,FE	O	2.5	1	15	0.95
Troglodytidae									
Campylorhynchus zonatus	Banded-backed wren	Sotorrey matraquero	CAMZON	FE,NF	I	2.5	0	11	0.65
Henicorhina leucophrys	Gray-breasted woodwren	Sotorrey de selva pechigris	HENLEUP	FI,FE	I	1	1	0	0.06
Henicorhina leucosticta	White-breasted woodwren	Sotorrey de selva pechiblanco	HENLEUC	FI,FE	I	1.5	2	0	0.12
Thryothorus atrogularis	Black-throated wren	Sotorrey gorginegro	THRATR	FE,NF	I	3	0	1	0.06
Thryothorus modestus	Plain wren	Chinchirigui	THRMOD	NF,FE	I	3	34	26	3.55
Thryothorus nigricapillus	Bay wren	Sotorrey castaño	THRNIG	FE,NF	I	2	2	0	0.12
Troglodytes aedon	House wren	Cucarachero	TROAED	NF	I	3	33	24	3.37
Turdidae									
Catharus aurantiirostris	Orange-billed nightingale thrush	Zorzal piquianaranjado, jilguerillo	CATAUR	FE,NF	O	2.5	18	2	1.18
Turdus grayi	Clay-colored robin	Yiguirro	TURGRA	NF,FE	O	3	68	69	8.11

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	CODE	HABITAT	FG	FD	CE	CEC	% TAF
Tyrannidae									
Contopus cinereus	Tropical pewee	Pibi tropical	CONCIN	NF	I	3	1	12	0.77
Coryphotriccus albovittatus	White-ringed flycatcher	Mosquero cabecianillado	CORALB	FE,NF	I	2.5	0	1	0.06
Elaenia flavogaster	Yellow-bellied elaenia	Copentoncillo	ELAFLA	NF,FE	I	3	8	0	0.47
Empidonax flavescens	Yellowish-flycatcher	Mosquerito amarillento	EMPFLA	FC,FE	I	2	1	0	0.06
Legatus leucophaius	Piratic flycatcher	Mosquero pirata	LEGLEU	FE,NF	I	3	0	3	0.18
Megarhynchus pitanga	Boat-billed flycatcher	Mosquerón picudo	MEGPIT	FC,FE,NF	I	2.5	0	4	0.24
Mitrephanes phaeocercus	Tufted flycatcher	Mosquerito moñudo	MITPHA	FC,FE	I	2	0	2	0.12
Myiarchus tuberculifer	Dusky-capped flycatcher	Copetón crestioscuro	MYITUB	FC,FE,NF	I	2.5	4	8	0.71
Myiodynastes luteiventris	Sulphur-bellied flycatcher	Mosquero ventiazufrado	MYILUT	FC,FE	I	2.5	0	13	0.77
Myiozetetes similis	Social flycatcher	Pecho amarillo	MYISIM	FE,NF	I	3	3	8	0.65
Ornithion semiflavum	Yellow-bellied tyrannulet	Mosquerito cejiblanco	ORNSEM	FE,FC	I	2	4	0	0.24
Pitangus sulphuratus	Great kiskadee	Pecho amarillo	PITSUL	NF	I	3	1	13	0.83
Todirostrum cinereum	Common-tody flycatcher	Espatulilla común	TODCIN	FE,NF,FC	I	2.5	26	40	3.91
Tolmomyias assimilis	Yellow-margined flycatcher	Piquiplano amarillo	TOLASS	FC,FE	I	1.5	1	3	0.24
Tyrannus melancholicus	Tropical kingbird	Pecho amarillo	TYRMEL	NF	I	3	3	14	1.01
Zimmerius vilissimus	Mistletoe tyrannulet	Mosquerito cejigris	ZIMVIL	FC,FE,NF	I	2	0	9	0.53
Vireonidae									
Vireo flavoviridis	Yellow-green vireo	Vireo cabecigris	VIRFLA	FE,NF,FC	O	3	0	3	0.18
Vireo philadelphicus	Philadelphia vireo	Vireo amarillento	VIRPHI	FE	O	2.5	1	0	0.06
Piciformes: Bucconidae									
Monasa morphoeus	White-fronted nunbird	Monja frentiblanca	MONMOR	FC,FE	I	1.5	0	1	0.06
Picidae									
Dryocopus lineatus	Lineated woodpecker	Carpintero lineado	DRYLIN	FE,NF	I	2.5	0	2	0.12
Melanerpes hoffmannii	Hoffmann's woodpecker	Carpintero de Hoffmann	MELHOF	FE,NF	I	2.5	0	12	0.71
Melanerpes pucherani	Black-cheeked woodpecker	Carpintero carinegro	MELPUC	FC,FE	I	2	0	8	0.47
Piculus rubiginosus	Golden-olive woodpecker	Carpintero Verde Dorado	PICRUB	FC,FE	I	2	1	6	0.41
Piculus simplex	Rufous-winged woodpecker	Carpintero alirrufo	PICSIM	FC,FE	I	1.5	0	2	0.12

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	CODE	HABITAT	FG	FD	CE	CEC	% TAF
Rasphastidae									
Pteroglossus torquatus	Collard aracari	Tucancillo collarejo, curre	PTETOR	FC,FE,NF	F	2	1	3	0.24
Ramphastos sulfuratus	Keel-billed toucan	Tucàn picoiris	RAMSUL	FC,FE	F	2	0	1	0.06
Psittaciformes:Psittacidae									
Pionus senilis	White-crowned parrot	Chucuyo	PIOSEN	FE,FC	F	2	0	18	1.07
Tinaformes:Tinamidae									
Crypturellus soui	Little tinamou	Gongolona	CRYSOU	FE,NF	O	3	0	2	0.12
Trogoniformes:Trogonidae									
Trogon violaceus	Violaceous trogon	Trogon violaceo	TROVIO	FE	F	2.5	0	1	0.06

APPENDIX 5. Bird species observed in point counts in Guayabo National Monument (GUA), La Isabel (ISA), Chitaria (CHI), La Marta (MAR) and Pejibaye (PEJ) forest fragments with the Turrialba – Jimenez Biological Corridor, Costa Rica. Feeding guilds (FG), preferred habitat, d forest dependence (FD) information was compiled from Stiles and Skutch (1982) and personal observations(C=carnivorous; G=Granivorous; I=Insectivorous; N=Nectarivorous; O=Omnivorous; FI=Forest Interior; FC=Forest canopy; FE=Forest Edge; N=Nonforest). Species observed outside of point counts are marked with an *.

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	HABITAT	FG	FD	GUA	ISA	CHI	MAR	PEJ
Apodiformes: Apodidae										
Streptoprocne zonaris	White-collard swift	Golondron	FI, FE	I	2				X*	X*
Trochilidae										
Amazilia tzacatl	Rufous-tailed hummingbird	Amazilia rabirrufa	NF, FE	N	3	X*	X	X*		
Archilochus colubris	Ruby-throated hummingbird	Colibri garganta rubi	FE,NF	N	3		X*			
Campylopterus hemileucurus	Violet sabrewing	Ala de Sable violaceo	FI,FE	N	2	X*				
Eupherusa nigriventris	Black-bellied hummingbird	Colibri pechinegro	FC,FE	N	1.5				X*	X*
Florisuga mellivora	White-necked jacobin	Jacobino nuquiblanco	FC, FE (NF)	N	2			X		
Heliothryx baroti	Purple-crowned fairy	Colibri picopinzon	FC,FE	N	2	X*			X*	
Lampornis castaneoventris calolaema	Purple throated mountain gem	Colibri montañés gorgimorado	FI,FE	N	2	X*				
Lophornis adoralis	White-crested coquette	Coqueta crestiblanca	FC,FE	N	2			X*		
Phaethornis guy	Green hermit	Ermitaño verde	FI,FE	N	2	X	X	X	X	X
Phaethornis longuemareus	Little hermit	Ermitaño enano	FI,FE	N	2.5	X	X*	X*		
Phaethornis superciliosus	Long-tailed hermit	Ermitaño colilargo	FI, FE	N	2	X			X*	
Thalurania colombica	Crowned woodnymph	Ninfa violeta y verde	FI,FE,NF	N	2.5	X*	X		X	
Caprimulgiformes: Caprimulgidae										
Nyctidromus albicollis	Common pauraque	Cuyeo	FE, NF	I	3	X*			X*	

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	HABITAT	FG	FD	GUA	ISA	CHI	MAR	PEJ
Columbiformes:Columbidae										
Columba flavirostris	Red-billed pigeon	Paloma morada	NF, FE, FC	F	3	X*				
Columba nigrirostris	Short-billed pigeon	Dos-tontos-son	FC,FE,NF	I	2	X*				X*
Leptotila cassinii	Gray-chested dove	Paloma pechigris	FE,NF	G	2.5					X*
Leptotila verreauxi	White-tipped dove	Paloma coliblanca	FE,FI,NF	G	2.5		X*		X*	
Coraciformes: Momotidae										
Baryphthengus martii	Rufous motmot	Pajaro bobo	FC,FE	O	2				X*	
Electron platyrhynchum	Broad-billed motmot	Momoto piquiancho	FC,FE	I	2					
Momotus momota	Blue-crowned motmot	Pájaro bobo	FE, NF (FI)	I	2.5	X*	X*	X*		
Cuculiformes:Cuculidae										
Piaya cayana	Squirrel cuckoo	Pájaro ardilla, bobo chizo	FE,FC	I	2/jan	X*		X		X
Falconiformes: Accipitridae										
Buteo platypterus	Broad-winged hawk	Gavilán pollero	FE,NF	C	3					
Elanoides fortificatus	American swallo-tailed kite	Tijereta	FC	C	2					X*
Leucopternis semiplumbea	Semiplumbeous hawk	Gavilán dorsiplomizo	FI	C	1					
Galliformes: Cracidae										
Ortalis cinereiceps	Gray-headed chachalaca	Chachalaca	FE,NF	F	2/jan			X*		
Penelope pupurascens	Crested guam	Pava crestada	FC,FI,FE	F	2			X*		
Gruiformes: Eurypygidae										
Eurypyga helias	Sunbittern	Garza del sol	FI	P	1					
Passeriformes: Coerebidae										

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	HABITAT	FG	FD	GUA	ISA	CHI	MAR	PEJ
Coereba flaveola	Bananaquit	Reinita mielera, Sta. Marta	FC,FE,NF	N	2/jan	X*		X*	X*	X*
Corvidae										
Cyanocorax morio	Brown jay	Piapia	FE,NF	O	2.5	X	X*	X	X*	X*
Cotingidae										
Lipaugus unirufus	Rufous piha	Piha rojiza	FC,FE	I	1			X*		
Dendrocolaptidae										
Dendrocincla homochroa	Ruddy woodcreeper	Trepador rojizo	FI,FE	I	1.5		X			
Dendrocolaptes certhia	Barred woodcreeper	Trepador barreteado	FC,FI,FE	I	2			X*		X
Glyphorhynchus spirurus	Wedge-billed woodcreeper	Trepadorcito pico de cuña	FC,FE,FI	I	2			X*	X*	
Lepidocolaptes souleyetii	Streak-headed woodcreeper	Trepador cabecirrayado	FE,NF,FC	I	2.5	X*				X*
Premnoplex brunnescens	Spotted barbtail	Subepalo moteado	FI,	I	1	X*				
Sittasomus griseicapillus	Olivaceous woodcreeper	Trepadorcito aceitunado	FI,FE,FC	I	2	X*				
Xiphorhynchus erythropygius	Spotted woodcreeper	Trepador manchado	FC,FE	I	1.5		X	X*	X*	
Xiphorhynchus guttatus	Buff-throated woodcreeper	Trepador gorgianteado	FC,FE	I	2			X		
Emberizidae										
Arremon aurantiirostris	Orange-billed sparrow	Pinzón piquinaranja	FI,FE	I	1.5	X*		X	X	
Caryothraustes poliogaster	Black-faced grosbeak	Picogrueso carinegro	FE,FC	O	2				X*	
Pheucticus tibialis	Black-thighed grosbeak	Picogrueso vientriamarillo	FC,FE	O	2			X		
Saltator atriceps	Black-headed saltator	Saltador cabecinegro	FE,NF	O	3	X*		X		X*
Saltator maximus	Buff-throated saltator	Sinsonte verde	FE,NF	O	3	X*		X*	X*	X
Formicariidae										
Cercomacra tyrannina	Dusky antbird	Hormiguero negruzco	FE,NF	I	2.5	X*		X*	X*	X*
Dysithamnus mentalis	Plain antvireo	Batarito cabecigris	FI	I	1		X*			
Formicarius analis	Black-faced antthrush	Gallito hormiguero carinegro	FI	I	1	X	X			
Hylopezus fulviventris	Fulvous-bellied antpitta	Tororoi pechicanelo	FE	I	2.5					X*
Hylophylax naevioides	Spotted antbird	Hormiguero moteado	FI,FE	I	2		X*	X*		
Myrmeciza exsul	Chestnut-backed antbird	Hormiguero dorsicastaño	FE,FI	I	2					

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	HABITAT	FG	FD	GUA	ISA	CHI	MAR	PEJ
Myrmeciza inmaculata	Inmaculate antbird	Hormiguero inmaculado	FI	I	1	X*		X*	X*	
Myrmotherula schisticolor	Slaty antwren	Hormiguerito pizarroso	FI,FE	I	1.5	X*	X		X*	
Thamnistes anabatinus	Russet antshrike	Batará café	FC,FE	I	1.5			X*	X*	
Thamnophilus punctatus	Slaty antshrike	Batará plomizo	FI,FE	I	2					
Furnariidae										
Anabacerthia variegaticeps	Spectacled foliage gleaner	Trepamusgo de anteojos	FI,FC	I	1.5	X*				
Xenops minutus	Plain xenops	Xenops común	FC,FE	I	1.5	X*		X*		
Icteridae										
Cacicus uropygialis	Scarlet-rumped cacique	Plío	FC,FE	O	2			X	X	
Psarocolius montezuma	Montezuma oropendola	Oropendola de Montezuma	FE,NF,FC	O	2.5	X*	X*	X	X*	X*
Psarocolius wagleri	Chestnut-headed oropendola	Oropendola cabecicastaña	FE, FC, NF	O	2	X*		X*		
Parulidae										
Basileuterus culicivorus	Golden-crowned warbler	Reinita coronidorada	FI,FE	I	1.5	X	X	X*	X*	X*
Basileuterus rufifrons	Rufous-capped warbler	Reinita cabecicastaña	FI,FE,NF	I	2					X*
Dendroica pensylvanica	Chestnut-sided warbler	Reinita de costillas castañas	FC,FE,NF	I	2.5			X		
Mniotilta varia	Black and white warbler	Reinita trepadora	FC,FE	I	2			X*		X*
Myioborus miniatus	Slate-throated redstart	Candelita pechinegra	FC,FE	I	2					X*
Phaeothlypis fulvicauda	Buff-rumped warbler	Reinita guardaribera	FE	I	2.5	X*			X*	
Setophaga ruticilla	American redstart	Candelita nortena	FC,FE,NF	I	2.5			X*		X*
Wilsonia pusilla	Wilson's warbler	Reinita gorrinegra	FC,FE,NF	I	2.5			X*		
Sylviidae										
Polioptila plumbea	Tropical gnatcatcher	Perlita tropical	FC,FE	I	2	X*		X*		
Ramphocaenus melanurus	Long-billed gnatwren	Soterillo picudo	FE,NF,FI	I	2.5		X*	X*		X*
Thraupidae										
Chlorophanes spiza	Green honeycreeper	Mielero verde	FC, FE	F	2				X	
Chlorospingus canigularis	Ashy-throated tanager	Tangara de monte gargantigris	FC,FE	O	2				X*	

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	HABITAT	FG	FD	GUA	ISA	CHI	MAR	PEJ
Chlorospingus ophthalmicus	Common bush tanager	Tangara de monte ojeruda	FC,FE,NF	F	2				X*	
Chlorothraupis carmioli	Olive tanager	Tangara aceitunada	FI,FE	O	1.5			X*	X*	
Chrysothlypis chrysomelas	Black and yellow tanager	Tangara negro y dorado	FC,FE	O	1.5				X*	
Dacnis venusta	Scarlet-thighed dacnis	Mielero celeste y negro	FC,FE	F	2				X*	
Euphonia anneae	Tawny-capped euphonia	Barranquilla	FC,FE	F	2		X*		X	
Euphonia gouldi	Olive-backed euphonia	Eufonia olivacea	FC,FE	F	2			X*		
Euphonia hirundinacea	Yellow-throated euphonia	Caciquita	FC,FE, NF	F	2.5	X*	X*			X*
Habia fuscicauda	Red-throated ant tanager	Tangara hormiguera gorgirroja	FI,FE	O	2	X*	X*	X		X
Phlogothraupis sanguinolenta	Crimson-collard tanager	Sangre de toro	FE,NF	O	3	X*			X*	
Piranga flava	Hepatic tanager	Tangara bermeja	FC (FE)	O	2				X*	
Ramphocelus passerinii	Scarlet-rumped tanager	Sargento	NF	O	3			X*	X*	X*
Tachyphonus delattrii	Tawney-crested tanager	Tangara coronidorada	FI,FE	O	2				X*	
Tachyphonus rufus	White-lined tanager	Fraile	NF,FE	O	3					X*
Tangara florida	Emerald tanager	Tangara orejinegra	FC,FE	O	1				X*	
Tangara gyrola	Bay-headed tanager	Tangara cabecicastaña	FC,FE	O	2	X*		X	X	X*
Tangara icterocephala	Silver-throated tanager	Tangara dorada	FC,FE	O	2	X*			X*	
Tangara larvata	Golden-hooded tanager	Siete colores	FE,NF (FC)	O	3	X*		X	X*	
Thraupis episcopus	Blue-gray tanager	Viuda	NF,FE,FC	O	2.5	X*		X		
Thraupis palmarum	Palm tanager	Tangara palmera	NF	I	3	X*		X*		
Tityridae										
Pachyramphus cinnamomeus	Cinnamon becard	Cabezón canelo	FE	I	2.5	X*		X*	X*	
Tityra semifasciata	Masked tityra	Pájaro chancho	FC,FE	O	2.5	X*		X*	X*	X*
Troglodytidae										
Camphylorhynchus zonatus	Banded-backed wren	Sotorrey matraquero	FE,NF	I	2.5	X*		X		X*
Henicorhina leucosticta	White-breasted woodwren	Sotorrey de selva pechiblanco	FI,FE	I	1.5	X	X		X*	X
Thryothorus atrogularis	Black-throated wren	Sotorrey gorginegro	FE,NF	I	3	X*		X*		X*
Thryothorus modestus	Plain wren	Chinchiriguí	NF,FE	I	3	X*		X*		
Thryothorus thoracicus	Striped-breasted wren	Sotorrey pechirayado	FE,NF	I	1.5	X	X*	X*	X*	X*

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	HABITAT	FG	FD	GUA	ISA	CHI	MAR	
Turdidae										
Catharus fuscater	Slaty-backed nightingale thrush	Jilguerillo	FI	O	1				X*	
Catharus mexicanus	Black-headed nightingale thrush	Zorzal cabecinegro	FI	O	1				X*	
Catharus ustulatus	Swaison's thrush	Zorzal de Swaison	FE,FI,FC	I	2			X		
Turdus grayi	Clay-colored robin	Yiguirro	NF, FE	O	3	X*		X*	X*	
Tyrannidae										
Attila spadiceus	Bright-rumped attila	Atila lomiamarilla	FC,FE	I	2				X	
Contopus borealis	Olive-sided flycatcher	Pibi boreal	FE,FC,NF	I	2.5	X*	X*	X	X*	X*
Contopus cinereus	Tropical pewee	Pibi tropical	NF	I	3			X*		
Elaenia flavogaster	Yellow-bellied elaenia	Copentoncillo	NF,FE	I	3			X*		
Empidonax minimus	Least flycatcher	Mosquerito Chebec	NF,FE	I	2.5			X		
Legatus leucophaius	Piratic flycatcher	Mosquero pirata	FE,NF	I	3	X*				
Leptopogon superciliaris	Slaty-capped flycatcher	Mosquerito orejinegro	FI,FE	I	2				X*	
Lophotriccus pileatus	Scale crested pygmy tyrant	Mosquerito de Yelmo	FI,FE	I	2	X	X*		X*	X*
Megarhynchus pitanga	Boat-billed flycatcher	Mosqueron picudo	FC, FE (NF)	I	2.5	X*		X*		
Myiarchus tuberculifer	Dusky-capped flycatcher	Copetón garganticeniza	FC,FE(NF)	I	2.5	X*		X*		
Myiodynastes luteiventris	Sulphur-bellied flycatcher	Pecho amarillo	FC,FE	I	2.5	X*				
Myiozetes similis	Social flycatcher	Pecho amarillo	FE,NF	I	3	X*				
Pitangus sulphuratus	Great kiskadee	Pecho amarillo	NF	I	3	X*		X*		
Platyrinchus mystaceus	White-throated spadebill	Piquichato gargantiblanco	FI	I	1		X			X
Rhytipterna holerythra	Rufous mourner	Plañidera rojiza	FC, FE	O	1.5			X*		
Serpophaga cinerea	Torrent tyrannulet	Mosquerito guardarrios	FE,NF	I	3					
Terenotriccus erythrurus	Ruddy-tailed flycatcher	Mosquerito colirrufo	FE,FI	I	2				X*	
Todirostrum cinereum	Common-tody flycatcher	Espatulilla comun	FE, NF (FC)	I	2.5	X*		X*	X*	
Tolmomyias sulphurescens	Yellow-olive flycatcher	Piquiplano azufrado	FE,NF,FC	I	3	X*		X*		X*
Tyrannus melancholicus	Tropical Kingbird	Pecho amarillo	NF	I	3	X*				
Zimmerius vilissimus	Mistletoe tyrannulet	Mosquerito cejigris	FC,FE (NF)	I	2	X*	X*	X	X*	X*
Vireonidae										
Hylophilus decurtatus	Lesser greenlet	Verdillo menudo	FC,FE,NF	O	2.5	X*		X*	X*	
Vireo flavoviridis	Yellow-green vireo	Vireo cabecigris	FE,NF,FC	O	3					

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	CODE	HABITAT	FG	FD	CE	CEC	MAR	PEJ
Vireo olivaceus	Red-eyed vireo	Vireo ojirrojo	FE,NF	I	3			X*	X*	
Piciformes: Capitonidae										
Eubucco bourcierii	Red-headed barbet	Barbudo cabecirrojo	FC,FE	I	1				X*	
Galbulidae										
Galbula ruficauda	Rufous-tailed jacamar	Gorrión de montaña	FE	I	2				X*	
Picidae										
Campephilus guatemalensis	Pale-billed woodpecker	Carpintero chiricano	FC,FE	I	2	X*				
Melanerpes hoffmannii	Hoffmann's woodpecker	Carpintero de Hoffmann	FE, NF	I	2.5	X		X		
Melanerpes pucherani	Black-cheeked woodpecker	Carpintero carinegro	FC, FE	I	2	X*				X*
Piculus rubiginous	Golden-olive woodpecker	Carpintero verde dorado	FC,FE	I	2	X*		X*		
Verniliornis fumigatus	Smoky-brown woodpecker	Carpintero pardo	FC,FE	I	2	X*		X		
Pipridae										
Corapipo leucorrhoa	White-ruffed manakin	Saltarín gorgiblanco	FI,FE	O	2		X*		X	
Manacus candei	White-collard manakin	Bailarín	FI,FE	F	2	X	X	X*	X	X
Piprites griseiceps	Gray-headed manakin	Saltarín cabecigris	FI,FC	O	1			X*		
Rasphastidae										
Pteroglossus torquatus	Collard aracari	Tucancillo collarejo, curre	FC,FE (NF?)	F	2		X*	X*	X*	X*
Ramphastos sulfuratus	Keel-billed toucan	Tucán picoiris	FC, FE	F	2	X*	X*	X*	X*	X*
Psittaciformes:Psittacidae										
Aratinga finschi	Crimson-fronted parakeet	Cotorra	FE,NF	O	3	X*		X*	X*	
Pionus senilis	White-crowned parrot	Chucuyo	FE, FC	O	2		X*		X*	
Tinaformes:Tinamidae										
Crypturellus soui	Little tinamou	Gongolona	FE, NF	O	3	X*		X*		X*

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	CODE	HABITAT	FG	FD	CE	CEC	MAR	PEJ
Trogoniformes: Trogonidae										
Trogon aurantiiventris	Orange-bellied trogon	Trogon ventrianaranjado	FC,FE	F	2					
Trogon collaris	Collard trogon	Trogon collarejo	FC,FE	I	2	X			X	
Trogon rufus	Black-throated trogon	Trogon cabeciverde	FI,FE	O	1			X		
Trogon violaceus	Violaceous trogon	Trogon violaceo	FE	F	2.5		X			X*

APPENDIX 6. Birds observed in the Turrialba – Jiménez Biological Corridor, Costa Rica. Bird list was compiled by Elena Florian (GL), George LaBar (GL), José Manuel Torres (JT), Philippe Tanimoto (PT) and Rancho Naturalista. A total of 489 species have been registered for the TJBC. * indicates species that have reduced populations or are endangered of becoming extinct (IUCN 1998; INBio 2004)

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	EF	GL	JT	PT	RN
Anseriformes: Anatidae							
Anas acuta	Northern pintail	Pato rabudo		X			
Anas americana	American wigeon	Pato calvo		X			
Anas clypeata	Northern shoveler	Pato cuchara		X			
Anas discors	Blue-winged teal	Pato canadiense		X			
Anas platyrhynchos	Mallard	Pato cabeciverde		X			
Aythya affinis	Lesser scaup	Porrón menor		X			
Aythya collaris	Ring-necked duck	Porrón collarejo		X			
*Cairina moschata**	Muscovy duck	Pato real	X	X			
Dendrocygna autumnalis	Black-bellied whistling-duck	Pijije común	X	X	X		
Oxyura dominica	Masked duck	Pato enmascarado		X			
Apodiformes:Apodidae							
Cypseloides niger	Black swift	Vencejo negro		X			X
Cypseloides rutilus	Chestnut-collard swift	Cencejo cuellicastaño		X			X
Chaetura cinereiventris	Gray-rumped swift	Vencejo lomigris		X			
Chaetura vauxi	Vaux's swift	Vencejo común		X			X
Panyptila cayennensis	Lesser swallow-tailed swift	Vencejo tijereta mayor		X			X
Streptoprocne zonaris	White-collard swift	Golondrón	X	X	X	X	X
Trochilidae							
Amazilia amabilis	Blue-chested hummingbird	Amazilia pechiazul					X
Amazilia saucerrottei	Steely-vented hummingbird	Amazilia culiazul					X
Amazilia tzacatl	Rufous-tailed hummingbird	Amazilia rabirrufa	X	X	X		X
Anthracothrorax prevostii	Green-breasted mango	Manguito pechiverde	X	X	X	X	X
Archilochus colubris	Ruby-throated hummingbird	Colibrí garganta rubí					X
Campylopterus hemileucurus	Violet sabrewing	Ala de Sable violaceo	X	X	X		X

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	EF	GL	JT	PT	RN
Chalybura urochrysia	Fed-footed plumeleteer	Colibri patirrojo		X			X
Cholorostilbon canivetii	Fork-tailed emerald	Esmeralda rabihorcada		X			
Colibri delphinae	Brown violet-ear	Colibri orejivioláceo pardo		X			X
Colibri thalassinus	Green violet-ear	Colibri orejiviolaceo verde					X
Discosura conversii	Green thorntail	Colicerda verde					X
Doryfera ludovicidae	Green-fronted lancebill	Pico de lanza frentiverde					X
Elvira cupreiceps	Coppery-headed emerald	Esmeralda de coronilla cobriza					X
Eupherusa eximia	Striped-tailed hummingbird	Colobri colirrayado					X
Eupherusa nigriventris	Black-bellied hummingbird	Colibri pechinegro	X		X	X	X
Eutoxeres aquila	White-tipped sicklebill	Pico de hoz		X			X
Florisuga mellivora	White-necked jacobin	Jacobino nuquiblanco	X	X	X	X	X
Glaucis aenea	Bronzy hermit	Ermitaño bronceado					X
Heliomaster longirostris	Long-billed starthroat	Colibri piquilargo		X			
Heliodoxa jacula	Green-crowned brilliant	Brillante frentiverde					X
Heliomaster longirostris	Long-billed starthroat	Colibri piquilargo					X
Heliothryx baroti	Purple-crowned fairy	Colibri picopinzon	X	X	X		X
Hylocharis eliciae	Blue-throated goldentail	Colibri colidorado		X			X
Klais guimeti	Violet-headed humminbird	Colibri cabeciazul		X			X
Lampornis castaneoventris calolaema	Purple throated mountain gem	Colibri montañés gorgimorado					X
Lampornis hemileucus	White-bellied mountain gem	Colibri montañés vientriblanco					X
Lophornis adorabilis	White-crested coquette	Coqueta crestiblanca	X		X	X	X
*Lophornis helenae**	Black-crested coquette	Coqueta crestinegra		X			X
Microchera albocoronata	Snowcap	Copete de nieve		X	X		X
Panterpe insignis	Fiery-throated hummingbird	Colibri garganta de fuego				X	X
Phaethornis guy	Green hermit	Ermitaño verde	X	X	X	X	X
Phaethornis longuemareus	Little hermit	Ermitaño enano	X	X	X	X	
Phaethornis superciliosus	Long-tailed hermit	Ermitaño colilargo	X	X	X		X
Selasphorus scintilla	Scintillant hummingbird	Chispitas					X
Thalurania colombica	Crowned woodnymph	Ninfa violeta y verde	X	X	X		
Threnetes ruckeri	Band-tailed barbthroat	Ermitaño barbudo					X

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	EF	GL	JT	PT	RN
Caprimulgiformes: Caprimulgidae							
Caprimulgus cayennenis	White-tailed nightjar	Chotacabras coliblanco		X			
Caprimulgus carolinensis	Chuck-will's -widow	Chotacabras de paso					X
Caprimulgus saturatus	Dusky nightjar	Chotacabras sombrio		X			
Chordeiles minor	Common nighthawk	Añapero Zumbón		X			X
Lurocalis semitorquatus	Short-tailed nighthawk	Añapero colicorto					X
Nyctidromus albicollis	Common pauraque	Cuyeo	X	X	X	X	X
Nyctibiidae							
Nyctibius griseus	Common potoo	Pájaro estaca					X
Ciconiiformes: Ardeidae							
Ardea herodias	Great blue heron	Garzon	X	X	X		
*Botaurus pinnatus**	Pinnated bittern	Avetoro neotropical		X			
Bubulcus ibis	Cattle egret	Garza bueyera	X	X	X	X	X
Butorides striatus	Green-backed heron	Garcilla verde	X	X			
Casmerodius albus	Great egret	Garza real	X	X		X	X
Cochlearius cochlearius	Boat-billed heron	Chocuaco	X	X	X	X	
Egretta caerulea	Little blue heron	Garceta azul	X	X	X	X	X
Egretta tricolor	Tricolored heron	Garceta tricolor		X			
Egretta thula	Snowy egret	Garceta nivosa				X	
*Ixobrychus exilis**	Least bittern	Mirasol		X			
Nyctanassa violacea	Yellow-crowned night-heron	Martinete cabecipinto		X		X	
Nycticorax nycticorax	Black-crowned night heron	Chocuaca	X	X	X	X	
Tigrisoma fasciatum	Fasciated tiger-heron	Garza tigre de rio					X
Ciconiidae							
Mycteria americana	Wood stork	Cigueñon		X			
Threskiornithidae							
Ajaia ajaja	Roseate spoonbill	Espátula rosada		X			
*Mesembrinibis cayennensis**	Green Ibis	Ibis verde		X		X	

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	EF	GL	JT	PT	RN
Columbiformes: Columbidae							
Claravis pretiosa	Blue ground dove	Tortolita azulada		X			X
Columba fasciata	Band-tailed pigeon	Paloma collareja					X
Columba flavirostris	Red-billed pigeon	Paloma morada	X	X	X	X	X
Columba nigrirostris	Short-billed pigeon	Dos-tontos-son	X	X	X		X
Columba subvinacea	Ruddy pigeon	Paloma rojiza					X
Columbina minuta	Plain-breasted ground-dove	Tortolita menuda		X			
Columbina talpacoti	Ruddy-ground dove	Tortolita	X	X	X	X	X
Geotrygon chiriquensis	Chiriqui quail dove	Paloma-perdiz pechicanela					X
Geotrygon costaricensis	Buff-fronted quail dove	Paloma-perdiz costarriqueña					X
Geotrygon lawrencii	Purplish-backed quail dove	Paloma-perdiz sombría					X
Geotrygon montana	Ruddy quail-dove	Paloma-perdiz rojiza		X			X
Leptotila cassinii	Gray-chested dove	Paloma pechigris	X	X	X		X
Leptotila verreauxi	White-tipped dove	Paloma coliblanca	X	X	X		X
Coraciiformes: Momotidae							
Baryphthengus martii	Rufous motmot	Pájaro bobo	X	X	X		X
Electron platyrhynchum	Broad-billed motmot	Momoto piquiancho	X	X	X		X
Momotus momota	Blue-crowned motmot	Pájaro bobo	X	X	X	X	X
Alcedinidae							
Ceryle alcyon	Belted kingfisher	Martin pescador norteño		X			
Ceryle torquata	Ringed kingfisher	Martín pescador collarejo		X			X
Chloroceryle amazona	Amazon kingfisher	Martín pescador amazónico		X		X	X
Chloroceryle americana	Green kingfisher	Martín pescador verde		X		X	x
Cuculiformes: Cuculidae							
Coccyzus americanus	Yellow-billed cuckoo	Cuclillo piquigualdo		X			X
Coccyzus erythropthalmus	Black-billed cuckoo	Cuclillo piquinegro		X			X
Crotophaga sulcirostris	Groove-billed ani	Tijo	X	X	X		X
Neomorphus geoffroyi	Rufous-vented cuckoo	Cucu hormiguero		X			
Piaya cayana	Squirrel cuckoo	Pájaro ardilla, bobo chizo	X	X	X	X	X

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	EF	GL	JT	PT	RN
Tapera naevia	Striped-cuckoo	Tres pesos	X		X		X
Falconiformes: Accipitridae							
*Accipiter superciliosus**	Tiny hawk	Gavilán enano		X			X
Accipiter striatus	Sharp-shinned hawk	Gavilán pajarero		X			X
Accipiter cooperii	Cooper's hawk	Gavilán de Cooper					X
Accipiter bicolor	Bicolor hawk	Gavilán bicolor					X
Buteo albonotatus	Zone-tailed hawk	Gavilán colifajeado					X
Buteo brachyurus	Short-tailed hawk	Gavilán colicorto					X
Buteo jamaicensis	Red-tailed hawk	Gavilán colirrojo				X	X
Buteo magnirostris	Road-side hawk	Gavilán pollero	X	X	X	X	X
Buteo platypterus	Broad-winged hawk	Gavilán aludo	X	X	X	X	X
Buteo swainsoni	Swainson's hawk	Gavilán de Swainson		X			X
Buteogallus anthracinus	Common-black hawk	Gavilán cangrejero		X			
Buteogallus urubitinga	Great black-hawk	Gavilán negro mayor					X
*Chondrohierax uncinatus**	Hook-billed kite	Gavilán piquianchudo		X			X
Circus cyaneus	Northern harrier	Aguilucho Norteño		X			
Elanoides fortificatus	American swallow-tailed kite	Tijereta	X	X	X		X
Elanus caeruleus	Black-shouldered kite	Gavilán bailarín		X			
Harpagus bidentatus	Double-toothed kite	Gavilán gorgirrayado		X			X
*Harpyhaliaetus solitarius**	Solitary eagle	Aguila solitaria					X
Ictinia mississippiensis	Mississppi kite	Elanio colinegro					X
Leptodon cayanensis	Gray-headed kite	Gavilán cabecigris					X
Leucopternis albicollis	White-hawk	Gavilán blanco		X			X
Leucopternis princeps	Black-chested hawk	Gavilán pechinegro		X			X
*Leucopternis semiplumbea**	Semiplumbeous hawk	Gavilán dorsiplomizo					
*Spizaetus tyrannus**	Black hawk-eagle	Aguilillo negro		X			X
*Spizaetus ornatus**	Ornate hawk-eagle	Aguilillo penachudo	X	X	X		X
*Spizastur melanoleucus**	Black and white hawk-eagle	Aguilillo blanco y negro		X			

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	EF	GL	JT	PT	RN
Falconidae							
Falco columbarius	Merlin	Esmerejón		X			X
*Falco peregrinus**	Peregrine falcon	Halcón peregrino		X			X
Falco sparverius	American kestrel	Cernícalo americano		X			
*Falco rufigularis**	Bat falcon	Halcón cuelliblanco		X			X
Falco sparverius	American kestrel	Cernícalo americano					X
Herpetotheres cachinnans	Laughing falcon	Guaco					
Micrastur ruficollis	Barred forest-falcon	Halcón de monte barreteado					X
Polyborus plancus	Crested caracara	Caracara cargahuesos		X			
Cathartidae							
Cathartes aura	Turkey vulture	Zopilote cabecirrojo	X	X	X		
Coragyps atratus	Black vulture	Zopilote	X	X	X		X
*Sarcoramphus papa**	King vulture	Zopilote rey		X			X
Pandionidae							
Pandion haliaetus	Osprey	Aguila pescadora		X		X	X
Galliformes: Cracidae							
*Chamaepetes unicolor**	Black guan	Pava negra					X
Ortalis cinereiceps	Gray-headed chachalaca	Chachalaca	X	X	X	X	X
*Penelope purpurascens**	Crested guan	Pava crestada	X		X		X
Gruiformes: Rallidae							
Amaurolimnas concolor	Uniform crake	Rascón café		X			
Aramides cajanea	Gray-necked woodrail	Chirinoco	X	X	X		
Fulica americana	American coot	Focha americana		X			
Gallinula chloropus	Common gallinule	Gallareta frentirroja		X			
Laterallus albigularis	White-throated crake	Polluela gargantiblanca	X	X	X		X
Odontophorus guttatus	Spotted wood-quail	Codorniz moteada				X	
Odontophorus leucolaemus	Black breasted wood-quail	Codorniz pechinegra					X
Pardirallus maculatus	Spotted rail	Rascón moteado		X			

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	EF	GL	JT	PT	RN
Porphyrula martinica	Purple gallinule	Gallina de agua	X		X	X	
Porzana carolina	Sora	Pollueia sora		X			
Eurypygidae							
*Eurypyga helias**	Sunbittern	Garza del sol	X	X	X		X
Charadriiformes:Charadriidae							
Charadrius vociferus	Killdeer	Tildío		X			
Scolopacidae							
Actitis macularia	Spotted sandpiper	Andarríos maculado				X	X
Calidris melanotos	Pectoral sandpiper	Correlimos pechirrayado		X			
Calidris minutilla	Least sandpiper	Correlimos menudo		X			
Gallinago gallinago	Common snipe	Becada		X			
Tringa flavipes	Lesser yellowlegs	Zarceta		X			
Tringa solitaria	Solitary sandiper	Andarríos solitario		X		X	X
Jacanidae							
Jacana spinosa	Northern jacana	Jacana centroamericana	X	X	X	X	
Passeriformes: Coerebidae							
Coereba flaveola	Bananaquit	Reinita mielera, Sta. Marta	X	X	X		X
Corvidae							
Cyanocorax morio	Brown jay	Piapia	X	X	X	X	X
Cyanolyca cucullata	Azure-hooded jay	Piapia de montaña					X
Cotingidae							
*Cotinga amabilis**	Lovely cotinga	Cotinga linda					X
Lipaugus unirufus	Rufous piha	Piha rojiza					X
Querula purpurata	Purple throated-fruit crow	Querula gorgimorada				X	
Oxyruncus cristatus	Sharpbill	Picoagudo					X

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	EF	GL	JT	PT	RN
Dendrocolaptidae							
*Campylorhamphus pusillus**	Brown-billed scythebill	Trepador de pico de hoz					X
Dendrocincla fuliginosa	Plain-brown woodcreeper	Trepador pardo		X			X
Dendrocincla homochroa	Ruddy woodcreeper	Trepador rojizo					X
Dendrocolaptes certhia	Barred woodcreeper	Trepador barreteado	X	X	X		X
Dendrocolaptes picumnus	Black-banded woodcreeper	Trepador vientribarreteado					X
Glyphorhynchus spirurus	Wedge-billed woodcreeper	Trepadorcito pico de cuña	X		X		X
Lepidocolaptes souleyetii	Streak-headed woodcreeper	Trepador cabecirrayado	X	X	X	X	X
Premnoplex brunnescens	Spotted barbtail	Subepalo moteado					
Sittasomus griseicapillus	Olivaceous woodcreeper	Trepadorcito aceitunado	X	X	X		X
*Xiphocolaptes promeropirhynchus**	Strong-billed woodcreeper	Trepador gigante					X
Xiphorhynchus erythropygius	Spotted woodcreeper	Trepador manchado				X	X
Xiphorhynchus guttatus	Buff-throated woodcreeper	Trepador gorgianteado	X	X	X	X	
Emberizidae							
Amaurospiza concolor	Blue seedeater	Semillero azulado	X		X		X
Arremon aurantiirostris	Orange-billed sparrow	Pinzón piquinaranja	X		X		X
Arremonops conirostris	Black-striped sparrow	Pinzón cabecilistado	X	X	X		X
Atlapetes brunneinucha	Chestnut-capped brush-finch	Saltón cabecicastaño					X
Atlapetes gutturalis	Yellow-throated brush finch	Saltón gargantiamarilla		X			
Caryothraustes poliogaster	Black-faced grosbeak	Picogrueso carinegro	X	X	X		
Cyanocompsa cyanoides	Blue-black grosbeak	Picogrueso negro azulado	X	X	X		X
Diglossa plumbea	Slaty flowerpiercer	Pinchaflor plomizo				X	
Guiraca caerulea	Blue grosbeak	Picogrueso azul	X	X	X		
Lysurus crassirostris	Sooty-faced finch	Pinzón barranquero					X
Melospiza lincolnii	Lincoln's sparrow	Sabanero de Lincoln		X			
Melozone biarcuatum	Prevost's ground sparrow	Pinzón cafetalero	X	X	X		X
Oryzoborus funereus	Thick-billed seed finch	Semillero picogrueso	X	X	X		X
Oryzoborus nuttingi	Pink-billed seed finch	Semillero piquirosado	X				
Passerina cyanea	Indigo bunting	Azulillo Norteño		X			X
Pheucticus ludovicianus	Rose-breasted grosbeak	Picogrueso pechirrosado	X	X	X		X
Pheucticus tibialis	Black-thighed grosbeak	Picogrueso vientriamarillo	X		X		X

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	EF	GL	JT	PT	RN
Pitylus grossus	Slate-colored grosbeak	Picogrueso piquirrojo		X			
Saltator atriceps	Black-headed saltator	Saltador cabecinegro	X	X	X		
Saltator coerulescens	Grayish saltator	Sinsonte	X		X		X
Saltator maximus	Buff-throated saltator	Sinsonte verde	X		X		X
Sporophila aurita	Variable seedeater	Espiguero	X	X	X		X
Sporophila torqueola	White-collard seedeater	Espiguero collarejo		X	X		
Tiaris olivacea	Yellow-face grassquit	Gallito	X	X	X		X
Volatinia jacarina	Blue-black grassquit	Semillerito negro azulado	X	X	X	X	X
Zonotrichia capensis	Rufous-collard sparrow	Comemaiz	X	X	X		X
Formicariidae							
Cercomacra tyrannina	Dusky antbird	Hormiguero negruzco				X	X
Cymbilaimus lineatus	Fasciated antshrike	Batará lineado					X
Dysithamnus mentalis	Plain antvireo	Batarito cabecigris	X	X			X
Dysithamnus striaticeps	Streaked-crowned antvireo	Batarito pechirrayado					X
Formicarius analis	Black-faced antthrush	Gallito hormiguero carinegro	X	X	X		X
Formicarius nigricapillus	Black-headed antthrush	Gallito hormiguero cabecinegro					X
Formicarius rufipectus	Gallito hormiguero pechicastaño	Rufous-breasted antthrush					X
Grallaria flavirostris	Ochre-breasted antpitta	Tororoi piquigualdo					X
Grallaria guatimalensis	Scaled antpitta	Tororoi dorsiescamado					X
Gymnopithys leucaspis	Bicolored antbird	Hormiguero bicolor				X	X
Hylopezus fulviventris	Fulvous-bellied antpitta	Tororoi pechicanelo	X	X			
Hylophylax naevioides	Spotted antbird	Hormiguero moteado		X			X
Microrhopias quixensis	Dotted-winged antwren	Hormiguerito alipunteado		X			X
Myrmeciza exsul	Chestnut-backed antbird	Hormiguero dorsicastaño	X	X			X
Myrmeciza inmaculata	Inmaculate antbird	Hormiguero inmaculado	X	X			X
Myrmeciza laemosticta	Dull-mantled antbird	Hormiguero alinaculado					X
Myrmotherula fulviventris	Checker-throated antwren	Hormiguerito café		X			X
Myrmotherula schisticolor	Slaty antwren	Hormiguerito pizarroso					
Taraba major	Great antshrike	Batará grande		X			X
Terenura callinota	Rufous-rumped antwren	Hormiguerito lomirrufo					X

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	EF	GL	JT	PT	RN
Thamnistes anabatinus	Russet antshrike	Batará café					X
Thamnophilus doliatus	Barred antshrike	Batará barreteado	X	X	X		X
Thamnophilus punctatus	Slaty antshrike	Batará plomizo		X			X
Fringillidae							
Carduelis xanthogastra	Yellow-bellied siskin	Jilguero vientriamarillo					X
Rhinocryptidae							
Scytalopus argentifrons	Silvery-fronted tapaculo	Tapaculo frentiplateado			X		X
Furnariidae							
Anabacerthia variegaticeps	Spectacled foliage gleaner	Trepamusgo de anteojos	X				
Automolus ochrolaemus	Buff-throated foliage gleaner	Hojarrasquero gorgianteado		X			X
Cranioleuca erythrops	Red-faced spinetail	Colaespina carirroja					X
Margarornis rubiginosus	Rudy treerunner	Subepalo rojizo			X		X
Phylydor rufus	Buff-fronted foliage gleaner	Trepamusgo rojizo					X
Premnoplex brunnescens	Spotted barbtail	Subepalo moteado	X		X		X
Progne chalybea	Gray-breasted martin	Martín pechigris		X		X	X
Pseudocolaptes lawrencii	Buffy tuftedcheek	Trepamusgo cachetón					X
Sclerurus albigularis	Gray-throated leaftosser	Tirahojas gargantigris					X
Sclerus guatemalensis	Scaly-throated leaftosser	Tirahojas barbiescamado					X
Sclerurus mexicanus	Tawney-throated leaftosser	Tirahojas pechirrufo					X
Synallaxis brachyura	Slaty spinetail	Arquitecto plomizo	X	X	X		X
Syndactyla subalaris	Lineated foliage-gleaner	Trepamusgo lineado					X
Xenops minutus	Plain xenops	Xenops común	X	X	X		X
Xenops rutilans	Streaked-xenops	Xenops rayado			X		X
Hirundinidae							
Hirundo pyrrhonota	Cliff swallow	Golondrina risquera		X			X
Hirundo rustca	Barn swallow	Golondrina tijereta	X	X	X	X	
Notiochelidon cyanoleuca	Blue and white swallow	Golondrina azul y blanca	X	X	X		X
Riparia riparia	Bank swallow	Golondrina rebereña		X			X

SCIENTIFIC NAME	ENGLISH NAME	SPANISH NAME	EF	GL	JT	PT	RN
Stelgidopteryx serripennis	Northern-rough winged swallow	Golondrina alirrasposa norteña	X	X	X		X
Stelgidopteryx ruficollis	Southern-rough winged swallow	Golondrina alirrasposa sureña	X	X	X	X	X
Tachycineta albilinea	Mangrove swallow	Golondrina lomiblanca		X			
Tachycineta bicolor	Tree swallow	Golondrina bicolor		X	X	X	
Icteridae							
Amblycercus holosericeus	Yellow-billed cacique	Pico de plata		X			X
Cacicus uropygialis	Scarlet-rumped cacique	Pllo	X	X	X		X
Dives dives	Melodious blackbird	Tordo cantor	X		X		X
Icterus dominicensis	Black-cowled oriole	Bolsero capuchinegro	X	X	X	X	X
Icterus g. galbula	Northern baltimore oriole	Bolsero norteño	X	X	X	X	X
Icterus spurius	Orchard oriole	Bolsero castaño		X	X		X
Molothrus aeneus	Bronzed cowbird	Vaquero ojirrojo	X	X	X	X	X
Psarocolius montezuma	Montezuma oropendola	Oropendola de Montezuma	X	X	X		X
Psarocolius wagleri	Chestnut-headed oropendola	Oropendola cabecicastaña	X	X	X		X
Quiscalus mexicanus	Great-tailed grackle	Zanate	X	X	X	X	X
Scaphidura oryzivora	Giant cowbird	Vaquero grande		X			X
Spiza americana	Dickcissel	Sabanero arrocero		X			
Sturnella magna	Eastern meadowlark	Zacatero común					X
Mimidae							
Dumetella carolinensis	Gray catbird	Pájaro-gato gris		X		X	X
Parulidae							
Basileuterus culicivorus	Golden-crowned warbler	Reinita coronidorada					X
Basileuterus rufifrons	Rufous-capped warbler	Reinita cabecicastaña	X		X		
Basileuterus tristriatus	Three-striped warbler	Reinita cabecilistada					X
Dendroica castanea	Bay-breasted warbler	Reinita castaña		X			X
Dendroica cerulea	Cerulean warbler	Reinita cerulea		X			X
Dendroica coronata	Yellow-rumped warbler	Reinita lomiamarilla		X			X
Dendroica dominica	Yellow-throated warbler	Reinita gorgiamarilla		X			
Dendroica fusca	Blackburnian warbler	Reinita gorginaranja		X			X

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Dendroica magnolia	Magnolia warbler	Reinita colifajeada		X			X
Dendroica pensylvanica	Chestnut-sided warbler	Reinita de costillas castañas	X	X	X	X	X
Dendroica petechia	Yellow-warbler	Reinita amarilla	X	X	X	X	X
Dendroica tigrina	Cape may warbler	Reinita tigrina		X			
Dendroica virens	Black-throated green warbler	Reinita cariamarilla		X			X
Geothlypis poliocephala	Gray-crowned yellowthroat	Antifacito coronigris					X
Geothlypis semiflava	Olive-crowned yellowthroat	Antifacito coronaolivo	X	X	X		X
Geothlypis trichas	Common yellowthroat	Antifacito norteño		X			
Helmitheros vermivorus	Worm-eating warbler	Reinita gusanera			X		X
Icteria virens	Yellow-breasted chat	Reinita grande		X			
Mniotilta varia	Black and white warbler	Reinita trepadora	X	X	X	X	X
Myioborus miniatus	Slate-throated redstart	Candelita pechinegra					X
Oporornis formosus	Kentucky warbler	Reinita cachetinegra		X			X
Oporornis philadelphia	Mourning warbler	Reinita enlutada	X	X	X		X
Oporornis tolmiei	Macgillivray's warbler	Reinita de tupidero		X			
Parula pitiayumi	Tropical parula	Parula tropical		X	X		
Phaeothlypis fulvicauda	Buff-rumped warbler	Reinita guardaribera	X	X	X		X
Seiurus aurocapillus	Ovenbird	Reinita hornera		X			X
Seiurus motacilla	Louisiana waterthrush	Reinita acuática piquigrande		X	X		X
Seiurus noveboracensis	Northern waterthrush	Reinita acuatica norteña		X			
Setophaga ruticilla	American redstart	Candelita norteña	X	X	X	X	X
Vermivora chrysoptera	Golden-winged warbler	Reinita alidorada		X	X		X
Vermivora peregrina	Tenesee warbler	Reinita verdilla	X	X	X		X
Vermivora pinus	Blue-winged warbler	Reinita aliazul		X	X		X
Vermivora ruficapilla	Nashville warbler	Reinita cachetigris					X
Wilsonia canadensis	Canada warbler	Reinita pechirrayada		X			X
Wilsonia citrina	Hooded warbler	Reinita encapuchada		X			X
Wilsonia pusilla	Wilson's warbler	Reinita gorrinegra	X	X	X	X	X
Sylviidae							
Microbates cinereiventris	Tawney-faced gnatwren	Soterillo caricafé					X
Polioptila albiloris	White-lored gnatcatcher	Perlita cabecinegra		X			

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Polioptila plumbea	Tropical gnatcatcher	Perlita tropical	X	X	X	X	X
Ramphocaenus melanurus	Long-billed gnatwren	Soterillo picudo	X	X	X		X
Bombycillidae							
Bombycilla cedrorum	Cedar waxwing	Ampelis americano					X
Thraupidae							
Chlorophanes spiza	Green honeycreeper	Mielero verde	X	X	X		X
Chlorophonia callophrys	Golden-browed chlorophonia	Rualdo					X
Chlorospingus canigularis	Ashy-throated bush-tanager	Tangara de monte gargantigris					
Chlorospingus ophthalmicus	Common bush tanager	Tangara de monte ojeruda	X				X
Chlorospingus pileatus	Sooty-capped bush tanager	Tangara de monte cejiblanca	X				
Chlorothraupis carmioli	Olive tanager	Tangara aceitunada	X	X	X		X
Chrysothlypis chrysomelas	Black and yellow tanager	Tangara negro y dorado	X		X		X
Cyanerpes cyaneus	Red-legged honeycreeper	Mielero patirrojo	X	X	X		
Cyanerpes lucidus	Shining honeycreeper	Mielero patirrojo	X	X	X		X
Dacnis venusta	Scarlet-thighed dacnis	Mielero celeste y negro	X	X	X		X
Euphonia anneae	Tawny-capped euphonia	Barranquilla					X
Euphonia gouldi	Olive-backed euphonia	Eufonia olivacea	X	X	X		
Euphonia hirundinacea	Yellow-throated euphonia	Caciquita	X	X	X		X
Euphonia luteicapilla	Yellow-crowned euphonia	Monjita					X
Euphonia minuta	White-vented euphonia	Eufonia menuda		X			
Habia fuscicauda	Red-throated ant tanager	Tangara hormiguera gorgirroja					X
Mitrospingus cassinii	Dusky-faced tanager	Tangara carinegruzca					X
Phlogothraupis sanguinolenta	Crimson-collard tanager	Sangre de toro	X	X	X		X
Piranga flava	Hepatic tanager	Tangara bermeja	X	X	X		X
Piranga ludoviciana	Western tanager	Tangara carirroja					X
Piranga leucoptera	White-winged tanager	Tangara aliblanca				X	X
Piranga olivacea	Scarlet tanager	Tangara escarlata					X
Piranga rubra	Summer tanager	Tangara veranera		X	X	X	
Ramphocelus passerinii	Scarlet-rumped tanager	Sargento	X	X	X		X

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Tachyphonus delattrii	Tawney-crested tanager	Tangara coronidorada					
Tachyphonus luctuosus	White-shouldered tanager	Tangara caponiblanca	X	X	X		
Tachyphonus rufus	White-lined tanager	Fraile	X	X	X	X	X
Tangara florida	Emerald tanager	Tangara orejinegra	X		X		X
Tangara dowii	Spangled-cheeked tanager	Tangara vientricastaña	X		X	X	X
Tangara gittata	Speckled tanager	Tangara moteada					X
Tangara gyrola	Bay-headed tanager	Tangara cabecicastaña	X		X		X
Tangara icterocephala	Silver-throated tanager	Tangara dorada				X	X
Tangara larvata	Golden-hooded tanager	Siete colores	X	X	X	X	X
Thraupis episcopus	Blue-gray tanager	Viuda	X	X	X	X	X
Thraupis palmarum	Palm tanager	Tangara palmera	X	X	X	X	X
Tityridae							
Pachyramphus albogriseus	Black and white beccard	Cabezón cejiblanco					X
Pachyramphus cinnamomeus	Cinnamon becard	Cabezón canelo	X	X	X		X
Pachyramphus polychopterus	White-winged beccard	Cabezón aiblanco	X	X	X	X	X
Pachyramphus versicolor	Barred becard	Cabezón ondeado				X	X
Tityra inquisitor	Black-crowned tityra	Tityra coroninegra	X	X	X	X	X
Tityra semifasciata	Masked tityra	Pájaro chancho	X	X	X		X
Troglodytidae							
Camphylorhynchus zonatus	Banded-backed wren	Sotorrey matraquero	X	X	X		X
Cyphorhinus phaeocephalus	Song wren	Sotorrey canoro		X			
Henicorhina leucophrys	Gray-breasted woodwren	Sotorrey de selva pechigris	X				X
Henicorhina leucosticta	White-breasted woodwren	Sotorrey de selva pechiblanco	X	X	X		X
Microcerculus luscinia	Whistling wren	Sotorrey silbador					X
Microcerculus philomela	Nightingale wren	Sotorrey ruiseñor		X			
Thryothorus atrogularis	Black-throated wren	Sotorrey gorginegro	X	X	X		X
Thryothorus fasciatoventris	Black-bellied wren	Sotorrey vientrinegro			X		
Thryothorus modestus	Plain wren	Chinchirigui	X	X	X		X
Thryothorus nigricapillus	Bay wren	Sotorrey castaño	X	X	X		X

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Thryothorus rufalbus	Rufous and white wren	Sotorrey rufo y blanco			X		
Thryothorus thoracicus	Striped-breasted wren	Sotorrey pechirayado	X	X	X		X
Troglodytes aedon	House wren	Cucarachero	X	X	X	X	X
Throglodytes ochraceus	Ochraceous wren	Sotorrey ocroso					X
Turdidae							
Catharus aurantiirostris	Orange-billed nightingale thrush	Zorzal piquianaranjado, jilguerillo	X		X		X
Catharus fuscater	Slaty-backed nightingale thrush	Jilguerillo	X		X		X
Catharus fuscescens	Veery	Zorzal dorsirrojizo					X
Catharus gracilirostris	Black-billed nightingale-thrush	Zorzal piquinegro			X		X
Catharus mexicanus	Black-headed nightingale thrush	Zorzal cabecinegro					
Catharus minimus	Gray-cheeked thrush	Zorzal carigris					X
Catharus ustulatus	Swaison's thrush	Zorzal de Swaison	X	X	X		X
Hylocichla mustelina	Wood thrush	Zorzal de bosque					X
Myadestes melanops	Black-face solitaire	Jilguero	X				X
Turdus assimilis	White-throated robin	Mirlo gorgiblanco					X
Turdus grayi	Clay-colored robin	Yiguirro	X	X	X		X
Turdus plebejus	Mountain robin	Yiguirro de montaña		X			X
Tyrannidae							
*Aphanotriccus capitalis**	Tawney-chested flycatcher	Mosquerito pechileonado					X
Attila spadiceus	Bright-rumped attila	Atila lomiamarilla	X	X	X		X
Colonia colonus	Long-tailed tyrant	Mosquro coludo	X	X	X	X	X
*Contopus borealis**	Olive-sided flycatcher	Pibi boreal	X	X	X		X
Contopus cinereus	Tropical pewee	Pibi tropical	X	X	X		X
Contopus lugubris	Dark pewee	Pibi sombrio	X	X	X		X
Contopus sordidulus	Western wood-pewee	Pibí occidental		X			X
Contopus virens	Eastern wood-pewee	Pibi oriental		X			X
Coryphotriccus albovittatus	White-ringed flycatcher	Mosquero cabecianillado	X	X	X	X	
Elaenia chiriquensis	Lesser elaenia	Elainia sabanera					X
Elaenia flavogaster	Yellow-bellied elaenia	Copentoncillo	X	X	X	X	X
Elaenia frantzii	Mountain elaenia	Elainia montañera					X

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Empidonax albigularis	White-throated flycatcher	Mosquerito gargantiblanco					X
Empidonax alnorum	Alder flycatcher	Mosquerito de charral					X
Empidonax flavescens	Yellowish-flycatcher	Mosquerito amarillento	X		X	X	
Empidonax flaviventris	Yellow-bellied flycatcher	Mosquerito ventriamarillo		X			X
Empidonax minimus	Least flycatcher	Mosquerito Chebec	X		X		X
Empidonax traillii	Willow flycatcher	Mosquerito de Traill					X
Empidonax virescens	Acadian flycatcher	Mosquerito verdoso		X			X
Legatus leucophaius	Piratic flycatcher	Mosquero pirata	X	X	X		X
Leptopogon amaurocephalus	Sepia-capped flycatcher	Mosquerito cabecipardo					X
Leptopogon superciliaris	Slaty-capped flycatcher	Mosquerito orejinegro	X	X	X		
Lophotriccus pileatus	Scale crested pygmy tyrant	Mosquerito de Yelmo	X	X	X		X
Megarhynchus pitanga	Boat-billed flycatcher	Mosquerón picudo	X	X	X	X	X
Mionectes olivaceous	Olive-striped flycatcher	Mosquerito ojimanchado					X
Mionectes oleagineus	Ochre-bellied flycatcher	Mosquerito aceitunado		X			X
Mitrephanes phaeocercus	Tufted flycatcher	Mosquerito moñudo	X		X		X
Myiarchus crinitus	Great crested flycatcher	Copetón viajero		X			X
Myiarchus tuberculifer	Dusky-capped flycatcher	Copetón garganticeniza	X		X	X	X
Myiobius sulphureipygius	Sulphur-rumped flycatcher	Mosquerito lomiamarillo					X
Myiodynastes hemichrysus	Golden-bellied flycatcher	Mosquero vientridorado					X
Myiodynastes luteiventris	Sulphur-bellied flycatcher	Pecho amarillo	X	X	X	X	X
Myiopagis viridicata	Greenish elaenia	Elainia verdosa		X			X
Myiozetes similis	Social flycatcher	Pecho amarillo	X	X	X	X	X
Myiozetes granadensis	Gray-capped flycatcher	Pecho amarillo	X	X	X	X	X
Oncostoma cinereigulare	Northern bentbill	Piquitorcillo norteño		X			
Ornithion semiflavum	Yellow-bellied tyrannulet	Mosquerito cejiblanco					
Phainoptila melanoxantha	Black and yellow silky flycatcher	Capulinero negro y amarillo					X
Phyllomyias zeledoni	Zeledon's tyrannulet	Mosquerito frentiblanco					X
Phylloscartes superciaris	Rufous-browed tyrannulet	Mosquerito cejirrufo					X
Pitangus sulphuratus	Great kiskadee	Pecho amarillo	X	X	X		X
Platyrinchus mystaceus	White-throated spadebill	Piquichato gargantiblanco	X		X		X
Rhynchocyclus brevirostric	Eye-ringed flatbill	Piquiplano de anteojos					X
Rhytipterna holerythra	Rufous mourner	Plañidera rojiza	X	X	X		X

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Sayornis nigricans	Black phoebe	Mosquero de agua	X		X	X	
Serpophaga cinerea	Torrent tyrannulet	Mosquerito guardarríos	X	X	X		X
Terenotriccus erythrurus	Ruddy-tailed flycatcher	Mosquerito colirrufo					X
Todirostrum cinereum	Common-tody flycatcher	Espatulilla común	X	X	X		X
Todirostrum nigreceps	Black-headed tody flycatcher	Espatulilla cabecinegra		X			X
Tolmomyias assimilis	Yellow-margined flycatcher	Piquiplano amarillo	X		X		X
Tolmomyias sulphurescens	Yellow-olive flycatcher	Piquiplano azufrado	X	X	X		X
Tyrannus forticatus	Scissor-tailed flycatcher	Tijerillo		X			
Tyrannus melancholicus	Tropical Kingbird	Pecho amarillo	X	X	X	X	X
Tyrannus tyrannus	Eastern kingbird	Tirano norteño		X			X
Tyrannus verticalis	Western kingbird	Tirano occidental		X			
Zimmerius vilissimus	Mistletoe tyrannulet	Mosquerito cejigris	X	X	X		X
Vireonidae							
Cyclarhis gujanensis	Rufous-browed peppershrike	Vireón cejirrufo					X
Hylophilus decurtatus	Lesser greenlet	Verdillo menudo	X	X	X		X
Hylophilus ochraceiceps	Tawney-crowned greenlet	Verdillo leonado		X			X
Vireo flavifrons	Yellow-throated vireo	Vireo pechiamarillo		X	X	X	X
Vireo flavoviridis	Yellow-green vireo	Vireo cabecigris	X	X	X	X	X
Vireo olivaceus	Red-eyed vireo	Vireo ojirrojo	X	X	X		X
Vireo philadelphicus	Philadelphia vireo	Vireo amarillento	X	X	X		X
Vireolanius pulchellus	Green shrike-vireo	Vireón esmeraldino		X			X
Pelecaniformes: Phalacrocoracidae							
Phalacrocorax olivaceus	Olivaceous cormorant	Cormorán neotropical		X	X		X
Piciformes: Capitonidae							
Eubucco bourcierii	Red-headed barbet	Barbudo cabecirrojo	X		X		X
Semnornis frantzii	Prong-billed barbet	Cocora	X			X	X

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Bucconidae							
Malacoptila panamensis	White-whiskered puffbird	Buco barbón		X			
*Micromonacha lanceolata**	Lanceolated monklet	Monjito rayado			X		X
Monasa morphoeus	White-fronted nunbird	Monja frentiblanca	X		X		X
Galbulidae							
Galbula ruficauda	Rufous-tailed jacamar	Gorrión de montaña	X	X	X		X
*Jacamerops aurea**	Great jacamar	Jacamar grande	X				
Picidae							
Campephilus guatemalensis	Pale-billed woodpecker	Carpintero chiricano	X	X	X	X	X
Dryocopus lineatus	Lineated woodpecker	Carpintero lineado	X	X	X	X	X
Melanerpes formicivorus	Acorn woodpecker	Carpintero careto					X
Melanerpes hoffmannii	Hoffmann's woodpecker	Carpintero de Hoffmann	X	X	X	X	X
Melanerpes pucherani	Black-cheeked woodpecker	Carpintero carinegro	X	X	X	X	X
Piculus rubiginosus	Golden-olive woodpecker	Carpintero Verde Dorado	X	X	X		X
Piculus simplex	Rufous-winged woodpecker	Carpintero alirrufo	X	X	X		X
Sphyrapicus varius	Yellow-bellied sapsucker	Carpintero bebedor					X
Veniliornis fumigatus	Smoky-brown woodpecker	Carpintero pardo	X		X		X
Pipridae							
Chiroxiphia linearis	Long-tailed manakin	Toledo				X	
Corapipo leucorrhoa	White-ruffed manakin	Saltarín gorgiblanco	X	X	X		X
Manacus candei	White-collard manakin	Bailarín	X	X	X		X
Pipra pipra	White-crowned manakin	Saltarín coroniblanco			X		X
*Piprites griseiceps**	Gray-headed manakin	Saltarín cabecigris	X		X		X
Rasphastidae							
Aulacorhynchus prasinus	Emerald toucanet	Tucancillo verde		X			
Pteroglossus frantzii	Fiery-billed aracari	Cusingo	X				

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Pteroglossus torquatus	Collard aracari	Tucancillo collarejo, curre	X	X	X	X	X
Ramphastos sulfuratus	Keel-billed toucan	Tucán picoiris	X	X	X	X	X
Ramphastos swainsonii	Chestnut-mandibled toucan	Tucán de Swainson		X	X		
Selenidera spectabilis	Yellow-eared toucanet	Tucancillo orejiamarillo					X
Podicipediformes: Podicipedidae							
Podilymbus podiceps	Pied-billed grebe	Pato de agua		X			
Tachybaptus dominicus	Least grebe	Patillo		X			
Psittaciformes:Psittacidae							
*Amazona albifrons**	White-fronted parrot	Loro frentoblanco		X			
*Amazona autumnalis**	Red-lored parrot	Lora		X		X	
*Aratinga finschi**	Crimson-fronted parakeet	Cotorra	X	X	X	X	X
*Pionopsitta haematotis**	Brown-hooded parrot	Loro cabecipardo				X	X
*Pionus senilis**	White-crowned parrot	Chucuyo	X	X	X	X	X
*Pyrrhura hoffmanni**	Sulphur-winged parakeet	Perico aliazufrado		X		X	
*Touit costaricensis**	Red-fronted parrotlet	Periquito alirojo					X
Strigiformes: Strigidae							
Asio clamator	Striped owl	Buho listado					X
Ciccaba nigrolineata	Black and white owl	Lechuza banco y negro			X		
Ciccaba virgata	Mottled owl	Lechuza café					X
Glaucidium brasilianum	Ferruginous pygmy-owl	Mochuelo común		X			
*Lophostrix cristata**	Crested owl	Buho penachudo					X
Otus choliba	Tropical Screech owl	Sorococa		X	X		
Otus clarkia	Bare-shanked screech owl	Luchucita serranera	X				
Tyto alba	Barn owl	Lechuza ratonera					X
Tinaformes:Tinamidae							
*Crypturellus boucardi**	Slaty-breasted tinamou	Tinamú pizarroso	X		X		
Crypturellus soui	Little tinamou	Gongolona	X		X		X
*Tinamus major**	Great tinamou	Gallina de monte		X			X

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Trogoniformes:Trogonidae							
*Pharomachrus mocinno**	Resplendent quetzal	Quetzal			X	X	
*Trogon aurantiiventris**	Orange-bellied trogon	Trogon ventrianaranjado	X		X		
Trogon collaris	Collard trogon	Trogon collarejo	X		X		X
Trogon massena	Slaty-tailed trogon	Trogon coliplomizo		X			
Trogon melanocephalus	Black-headed trogon	Trogón cabecinegro		X			
Trogon rufus	Black-throated trogon	Trogon cabeciverde	X	X	X		X
Trogon violaceus	Violaceous trogon	Trogon violaceo	X	X	X	X	X